AIR FORCE
SMALL BUSINESS INNOVATION RESEARCH
PROPOSAL PREPARATION INSTRUCTIONS

The Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio, is responsible for the implementation and management of the Air Force SBIR Program. The Air Force SBIR Program Manager is Mr. Steve Guilfoos, 1-800-222-0336. Do not submit SBIR proposals to the AF SBIR Program Manager under any circumstances. Addresses for proposal submission and numbers for administrative and contracting questions are listed on the following pages, AF-4 through AF-5.

Technical questions may be requested using the DTIC SBIR Interactive Technical Information System (SITIS). For a full description of this and other technical information assistance systems from DTIC, please refer to section 7.1 of this solicitation.

Air Force Nine-Month Phase I Contract

For the Air Force, the contractual period of performance for Phase I shall be nine (9) months, and the price shall not exceed $100,000. The Air Force will consider only one cost proposal with a nine-month contractual period of performance.

The Phase I award winners must accomplish their primary research during the first six months of the contract. This primary research effort, alone, is used to determine whether the AF will request a Phase II proposal. We anticipate no more than 80% of the total cost will be expended within the first six months. After the first six months, additional related research should further the Phase I effort and put the small business in a better position to start Phase II, If awarded.

The last three months of the nine-month Phase I contract will provide project continuity for all Air Force Phase II award winners so that no modification to the Phase I contract should be necessary. The Air Force will accept proposals for modifications to maintain project continuity under special circumstances such as Fast Track.

Our evaluation of the primary research effort and the proposal will be based on the factors listed in Section 4 of the solicitation, in the following descending order of importance: a) the soundness, technical merit, and innovation of the proposed approach and its incremental progress toward topic or subtopic solution; b) the qualifications of the proposed principal/key investigators, supporting staff, and consultants (qualifications include not only the ability to perform the research and development but also the ability to commercialize the results) and c) the potential for commercial (government or private sector) application and the benefits expected to accrue from this commercialization. (The only exception is Fast Track Phase II proposals, which will be selected for Phase II award provided they meet the "technically sufficient" standard in Section 4.3.) The actual assigned weightings will not be disclosed outside of the DoD. Please note that where technical evaluations are essentially equal in merit, and as cost and/or price is a substantial factor, cost to the government will be considered in determining the successful offeror.

You must receive a written invitation before submitting a Phase II proposal (all Fast Track applicants will be invited). The Air Force will select Phase II winners based solely upon the proposal submitted, including Fast Track applicants.

Air Force Cost Proposal

Phase I cost proposals shall reflect a nine month effort not to exceed $100,000. Remember, the first six months constitutes the primary research effort and will be used to evaluate whether a Phase II proposal will be requested.

The Air Force anticipates that pricing will be based on adequate price competition. Proposals, including costs, are limited to 25 pages. However, if the Air Force selects your company to receive an award, be prepared to submit further documentation to substantiate costs. This further information is necessary to facilitate the contracting process.

Air Force Fast Track

Detailed instructions on the Air Force Fast Track and Phase II proposals consistent with this solicitation will be made available by the awarding Air Force activity at the time of Phase I contract award. The Air Force encourages businesses to consider a Fast Track applications when they can attract outside funding and the technology is mature enough to be ready for application following successful completion of the Phase II contract.

Air Force Phase II Enhancement Program

On selected Phase II awards, the Air Force will invite Phase II awardees to apply for a Phase II Enhancement. This program will extend the existing Phase II contract award for up to one year. The Air Force will match dollar for dollar up to $250,000 of outside (non-SBIR) matching funds. Because of the limited amount of available funds, the Air Force will competitively select applications for funding. The main purpose of the program is to address new unforeseen technology barriers that cropped up during the Phase II work. Applications will require written commitment by an Air Force program office that they will acquire and/or use the SBIR technology at the completion of the enhancement program.

Commercial Potential Evidence

An offeror needs to document their Phase I or II proposal's commercial potential as follows: 1) the small business concern's record of commercializing SBIR or other research, particularly as reflected in its Company Commercialization Report (www.dodsbir.net/submission); 2) the existence of second phase funding commitments from private sector or non-SBIR funding sources; 3) the existence of third phase follow-on commitments for the subject of the research and 4) the presence of other indicators of commercial potential of the idea, including the small business' commercialization strategy.

Submission of Final Reports

All final reports will be submitted to the sponsoring agency. **Companies will not** submit final reports directly to DTIC.

Proposal Submission Instructions

Your proposal will be REJECTED if you do not meet all of the following criteria.

1. The Air Force Phase I proposal shall be a nine month effort.

2. You must use the electronic format described in the Electronic Submission described below. The Air Force will not accept any proposals that do not have electronic forms of the Proposal Cover Sheet (formerly, "Appendix A and B"). The electronic forms submitted must match the paper copies submitted via mail/express delivery.

3. A copy of the Company Commercialization Report with summary page must be submitted with all proposals. (See Section 3.4n. of the solicitation.) Even if you have no Phase I or Phase II information to report, you must submit a Company Commercialization Report. Your proposal will not be penalized in the evaluation process if your company never had any SBIR Phase I's or II's in the past.

4. Both the electronic submission of the Proposal Cover Sheet and the paper copies of your proposal must be received on or before the deadline. The Air Force will not accept late proposals, or incomplete proposals. If you have any questions or problems with submission of your proposal allow yourself time to contact the Air Force and get an answer to your question. Submit the electronic Proposal Cover Sheet and Company Commercialization Report early, as computer traffic increases, computer speed slows down. Do not wait until the last minute. The Air Force will not be responsible for late proposals caused by computer systems or servers being "down" or inaccessible**.**

Electronic Submission of the Proposal Cover Sheet:

Prepare your SBIR proposal to the Air Force using the DoD Electronic Submission Web Site at http://**www.dodsbir.net/submission**. This site allows your company to come in at any time (prior to the closing of the solicitation) to add, edit or print out your Proposal Cover Sheet. The Air Force will not accept any Proposal Cover Sheet except those from the Electronic Submission Web Site as valid proposal submission forms.

Note: The Air Force period of performance for Phase I is nine months.

Once you have prepared, printed, and signed the Proposal Cover Sheet, mail it along with one original and four copies of your entire proposal (the copies should include four copies of the signed Cover Sheet) to the appropriate Air Force offices at the addresses listed below.

PROPOSAL SUBMISSION INSTRUCTIONS

For each Phase I proposal, both the electronic submission of the Proposal Cover Sheet and the paper copies (original and 4 copies) of your proposal must be sent to the office designated below. Be advised that any overnight delivery may not reach the appropriate desk within one day. Be sure to read the Air Force instructions on the previous page for the nine-month Phase I contract to avoid the rejection of your proposal. To request notification of proposal receipt, send request (Ref A on page Ref 1) with a self-addressed stamped envelope. Do not call to ask whether your proposal has been received; due to time constraints, we will not be able to answer such telephone calls.

TOPIC NUMBER	ACTIVITY/MAILING ADDRESS	CONTRACTING AUTHORITY
	(Name and number for mailing proposals and for administrative questions)	(For contract questions only)
AF00-001 thru AF00-017 AF00-021 thru AF00-024	Directed Energy Directorate AFRL/DE 3600 Hamilton Avenue SE Kirtland AFB NM 87117-5776 (Robert Hancock, (505) 846-4418)	Dave Tuttle (505) 846-8133
AF00-031 thru AF00-033 AF00-035 thru AF00-042 AF00-044 AF00-047 thru AF00-069	Space Vehicles Directorate AFRL/VS 3600 Hamilton Avenue SE Kirtland AFB NM 87117-5776 (Robert Hancock, (505) 846-4418)	Francisco Tapia (505) 846-5021
AF00-070 thru AF00-074	Space Vehicles Directorate AFRL/VSOT 29 Randolph Road, Bldg 1107, Rm 235 Hanscom AFB MA 01731-3010 (Noreen Dimond, (781) 377-3608)	John Flaherty (781) 377-2529
AF00-075 thru AF00-076 AF00-078 thru AF00-095 AF00-097 thru AF00-100	Human Effectiveness Directorate AFRL/HEOP 2610 Seventh Street Wright-Patterson AFB OH 45433-7901 (Sabrina Davis, (937) 255-2423 x226)	Mary Jones (937) 656-6273
AF00-104 thru AF00-113 AF00-115 thru AF00-128 AF00-130 thru AF00-133	Information Directorate AFRL/IFB 26 Electronic Parkway Rome NY 13441-4514 (Jan Norelli, (315) 330-3311)	Joetta Bernhard (315) 330-2308
AF00-139 AF00-141 thru AF00-151 AF00-153 thru AF00-163 AF00-165 thru AF00-168 AF00-172	Materials & Manufacturing Directorate AFRL/MLOP 2977 P Street, Rm 419, Bldg 653 Wright-Patterson AFB OH 45433-7746 (Marvin Gale, (937) 656-9221)	Terry Rogers (937) 255-5830 Bruce Miller (937) 255-7143
AF00-173 thru AF00-181 AF00-183 thru AF00-190	Munitions Directorate AFRL/MNOB 101 W Eglin Blvd, Suite 140 Eglin AFB FL 32542-6810 (Richard Bixby, (850) 882-8591 x1281)	Stacey Darhower (850) 882-4294 x3411

AF00-195 thru AF00-215	Propulsion Directorate AFRL/PROB 1950 Fifth Street, Bldg 18 Wright-Patterson AFB OH 45433-7251 (Dottie Zobrist, (937) 255-6024)	Susan L. Day (937) 255-5310 Anthony Everidge (937) 255-4818
AF00-219 thru AF00-233	Propulsion Directorate AFRL/PROI 5 Pollux Drive Edwards AFB CA 93524-7033 (Sandi Borowiak, (661) 275-5617)	Donna L. Thomason (661) 277-8596
AF00-235 AF00-237 thru AF00-246 AF00-248 thru AF00-253 AF00-255 thru AF00-263 AF00-265 thru AF00-266	Sensors Directorate AFRL/SNOX 2241 Avionics Circle, Rm N2S24, Bldg 620 Wright-Patterson AFB OH 45433-7320 (Marleen Fannin, (937) 255-5285 x4117)	Kenneth P. Smith (937) 255-5201
AF00-268 thru AF00-285	Air Vehicles Directorate AFRL/VAOP 2130 Eighth Street, Bldg 45 Wright-Patterson AFB OH 45433-7542 (Madie Tillman, (937) 255-5066)	Douglas Harris (937) 255-4427
AF00-292 thru AF00-295	Air Force Flight Test Center AFFTC / XPST 195 East Popson Avenue Bldg 2750, Rm 218 Edwards AFB CA 93524-6843 (Abe Atachbarian, (661) 275-7135)	Donna Thomason (661) 277-8596
AF00-297 thru AF00-300	Arnold Engineering Development Center AEDC/DOT 1099 Avenue C Arnold AFB TN 37389-9011 (Ron Bishel, (931) 454-7734)	Gloria Fairchild (931) 454-7843
AF00-302 thru AF00-303	Warner Robins ALC WR-ALC / TIECT 420 Second Street, Suite 100 Robins AFB GA 31098-1640 (LT, Andrew J. Lofthouse, (912) 926-6617)	Brenda Hopson (912) 926-3985
AF00-305 thru AF00-306	Ogden ALC OO-ALC / TIEH 5851 F Avenue, Bldg 849, Rm A-15 Hill AFB UT 84056-5713 (Bill Wassink, (801) 777-2977)	Martha Scott (801) 777-0199
AF00-308 thru AF00-309	Oklahoma City ALC OC-ALC / TIET 3001 Staff Drive Suite 2AG70A Tinker AFB OK 73145-3040 (Don Boedeker, (405) 736-5364)	David Cricklin (405) 739-4468
AF00-310 thru AF00-312 AF00-314	Air Armament Center AAC/XPP 101 W. D Avenue, Suite 129 Eglin AFB FL 32542-5495 (Dave Uhrig, (850) 882-8096)	Capt. Rich Ward (850) 882-4141 x4551

AIR FORCE 00.1 TOPIC INDEX

AF00-066	Inflatable Structures for Lightweight Solar Arrays
AF00-067	Integrated Payload Dispenser for Multi Micro-Satellite Missions
AF00-068	Miniaturized Vibration Isolation System (MVIS)
AF00-069	High Power, High Rate Launch Vehicle Batteries
AF00-070	Advanced Space Particle Detectors for Microsatellites
AF00-071	Spacecraft Charge Control Technology
AF00-072	Advanced Algorithms for Exploitation of Space-Based Imagery
AF00-073	Surface Luminescent Dust Sensors
AF00-074	Innovative Techniques for Remote Sensing, Threat Detection and Typing

HUMAN EFFECTIVENESS DIRECTORATE, WRIGHT-PATTERSON AFB OH

AF00-075	Behavioral Toxicology – Integration of Chemical Exposure Threats into Command Decision Processes
AF00-076	High Resolution Visual System Development
AF00-078	Automated Material Classification Toolset
AF00-079	Information Warfare Training Models
AF00-080	Agent-Based Measurement System for Advanced Distributed Learning Technologies
AF00-081	Distributed Human Performance Management with Emphasis on Team Performance
AF00-082	Psychological Warfare Training via Advanced Distributed Learning Technology
AF00-083	Graphical User Interface Techniques for Assessing Autonomous Vehicle "Behavior"
AF00-084	Integrated, Hands-Free Control Suite for Maintenance Wearable Computers
AF00-085	Novel Situational Awareness Concepts for Command & Control of Space Assets
AF00-086	Auditory Devices for Remote Threat Detection
AF00-087	Sensor Fusion and Information Warfare
AF00-088	Advanced User-System Interface Technologies for Untethered Computer and Visual Display Interactions
AF00-089	Human-Centered Technologies for Information Superiority
AF00-090	Breakaway Helmet Mount for Night Vision and Targeting Displays
AF00-091	Laser Aircrew Safety and Education Demonstrator-Flight (LASED-F)
AF00-092	Software to Manipulate Large 3-D Voxel-Based Computer Model
AF00-093	Universal Biological Sensor
AF00-094	Vision Corrective Wraparound Spectacles for Laser Eye Protection (LEP)
AF00-095	Remote Thermographer
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AF00-098	Enhancing the Usability of Computer Generated Forces
AF00-099	Aircraft Prognostics: Identifying Imminent Failures in Aircraft and System Components
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AF00-104	Real Time Integrated Planner/Player (RIPP)
AF00-105	Domain-Portable Shallow Ontology Builder
AF00-106	Operational Level Inter-Model Lift Planner
AF00-107	Automated Multi-Level Security Digital Information Transfer using Watermarking Technologies
AF00-108	Security Management and Protection for Large-Scale Information Systems
AF00-109	DoD Information Exchange Using XML
AF00-110	Component-Based Data Fusion Architectures
AF00-111	Rapid Knowledge Base Development using Intelligent Agents
AF00-112	Improved Command and Control Modeling and Simulation
AF00-113	A Robust Integrated Framework for Plan Generation and Execution
AF00-115	Satellite Communications Systems Simulation
AF00-116	Advanced C2 Process Modeling and Requirements Analysis Technology
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AF00-118	Operational Impact Estimation Toolkit
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AF00-120	Wavelet Modulation Techniques for Digital Communications
AF00-121	Voice Authenticated Wireless Communication
AF00-122	Hyper-Spectral Sensor Resolution Enhancement Techniques (RET)
AF00-123	Smart Data Processing for Radar, Multispectral, and Hyperspectral Sensors
AF00-124	Dynamic Architecture Signal Processor Technology
AF00-125	Airborne JTIDS Net Controller
AF00-126	Innovative Information Technologies

AF00-127 Intermediate-Level Event Extraction for Temporal and Spatial Analysis and Visualization
AF00-128 Attack Assessment Tools for Information Warfare
AF00-130 Dynamic Effects Based Command and Control
AF00-131 Distributed Collaborative Environment Technology
AF00-132 Database Accelerating Reconfigurable Computer
AF00-133 Data Intensive System Implementation for Battlespace Awareness

MATERIALS & MANUFACTURING DIRECTORATE, WRIGHT-PATTERSON AFB OH

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AF00-141 Processing of Inflatable Parabolic Reflectors from Polymeric Thin Films
AF00-142 Durability of Bonded Joints for Low Cost & Lo Repair of High Performance Composite Structures
AF00-143 Novel Durable Polymer-Based Lo Hardcoats for Canopy Exteriors Using Benign Processing Techniques
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AF00-145 NDI for Diffusion Bonded Components
AF00-146 Turbine Engine Airfoil Thermal Barrier Coating Reliability Enhancement
AF00-147 Boron Based Ceramic Matrix Composites for Aircraft Brake Friction Materials
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AF00-155 Guided-Wave Electro-Optic Materials
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AF00-157 Growth of Semi-Insulating Silicon Carbide (SIC)
AF00-158 Development of Liquid Crystal Materials for Directed Energy Control
AF00-159 Bulk Growth of Aluminum Nitride for Space and Propulsion Applications
AF00-160 Qualifying Light, High-Performance Materials for Airborne and Space-Based Laser Systems
AF00-161 Fuel Processor for Air Expeditionary Force Deployable Fuel Cells Power Generator
AF00-162 Nondestructive Characterization of Titanium Castings and Weldments
AF00-163 Aircraft Battle Damage Repair (ABDR) of Substructural Core Repair
AF00-165 Directed Electromagnetic Radiation Energy Curing of High Temperature Repair Adhesives
AF00-166 Low Observable Maintainability
AF00-167 Protective Hard Film Coatings and Solid Lubricants
AF00-168 Computational Fluid Mechanics Models for the Processing of Superalloys and Aerospace Titanium Alloys
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AF00-200	Stochastic Modeling of Gas Turbine Engine Blade HCF Capacity
AF00-201	Innovative Damping Concepts for Extreme Environmental Capacity
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AF00-209	Space Based Radar Thermal Control
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AF00-213	Power Systems for MEMS and UAV Applications
AF00-214	High Speed Power Generation Technology for Aerospace Vehicles
AF00-215	Propulsion and Power Systems Commercial Design Philosophies and Practices
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AF00-222	Lightweight, High Temperature Thermoplastic Case & Motor Insulation for Solid Rocket Motor
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AF00-225	Advanced Materials and Cooling Schemes for Rocket Engine Combustion Chambers
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AF00-228	Low Cost, High Performance Rocket Motor Technology
AF00-229	Micro Propulsion Technology Development
AF00-230	Health Monitoring of Rocket Motors Using Embedded Miniature Sensor Technology
AF00-231	High Maneuverability, Small Chemical Propulsion Systems
AF00-232	Lightweight Low Cost Nozzle for Boost Engines
AF00-233	High Purity Solvent Processing for Nonvolatile Residue Testing

SENSORS DIRECTORATE, WRIGHT-PATTERSON AFB OH

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AF00-237	Ultraminiature Laser-Based Atomic Clocks (ULAC)
AF00-238	Automatic Cartographic Data Translation and Registration
AF00-239	High Sensitivity LWIR and MMW Sensor Fusion on One Chip
AF00-240	Analog-to-Digital Converter Development
AF00-241	Improved Spacecraft Telemetry, Data Acquisition Systems
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AF00-243	Antenna Control Computer for TT & C Phased Array Antenna
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AF00-257	Global Reference Information Management

AF00-258	Hybrid Multi-Function FLIR / MWIR Ladar
AF00-259	Synthetic Prediction Technologies for Multiple Target Scenario Modeling
AF00-260	ATR / Fusion Virtual Development and Evaluation Testbed
AF00-261	Integrated Aperture for Passive and Active Electro-Optical Systems
AF00-262	Registration of Images for Polarimetric Dual-Band FOPEN Radar
AF00-263	Real-Time High Fidelity Dense RF Environment Simulation Technology
AF00-265	Distributed Control Evaluation System for Multi-Platform Applications
AF00-266	Space Based Sensors

AIR VEHICLES DIRECTORATE, WRIGHT-PATTERSON AFB OH

AF00-268	Affordable Bonded Textile Reinforced Composite Double-Lap Clevis Joints
AF00-269	Repair of Ceramic Matrix Composite Structures
AF00-270	Design for Limited Life Airframes
AF00-271	Development of Advanced Structural Life Analysis / Enhancement Methodology
AF00-272	Verification and Validation of Integrated and Adaptive Control Systems
AF00-273	Plasma Flow Control Technology
AF00-274	Simulation Techniques to Coordinate Large Numbers of Air Vehicles
AF00-275	Flow Control for Weapons Integration / Vehicle Propulsion / Wing Performance
AF00-276	Network Centric Distributed Vehicle Management Systems
AF00-277	Simulation Based R & D for Space Vehicle Concepts
AF00-278	Evaluation of Vehicle Wiring System
AF00-279	Guidance and Control Techniques for Hypersonic Vehicles
AF00-280	Enhanced Boundary Layer Transition Prediction
AF00-281	Innovative Structural Concept Modeling for Affordable Vehicles
AF00-282	Aeronautical Sciences and Flight Control Technology for Military Aerospace Vehicles
AF00-283	Innovative Weight Efficient Combined Structure / TPS Concepts
AF00-284	Multifunctional Structures
AF00-285	Low Speed Test Techniques for Powered Lift Configurations

AIR FORCE FLIGHT TEST CENTER, EDWARDS AFB CA

AF00-292	Jet Engine Test Cell Air Pollution Control
AF00-293	Embedded Global Positioning System (GPS) / Inertial Navigation System (INS) – Encoded Radar Transponder
AF00-294	Directional Airborne Telemetry Antennas
AF00-295	Low Cost Global Positioning System (GPS)-based Collision Avoidance System

ARNOLD ENGINEERING DEVELOPMENT CENTER, ARNOLD AFS TN

AF00-297	Motion Enabling Device for Virtual Flight Test Application
AF00-298	Turbine Engine Augmentor Rumble and Screech Indicator
AF00-299	Thin High Z Converter Foils
AF00-300	Miniaturized Robust Multichannel Telemetry System

WARNER ROBINS ALC, ROBINS AFB FL

AF00-302	Intelligent Near Net-shape Manufacturing Cell
AF00-303	Reduction of EMI from Hybrid Electric Drivetrains

OGDEN ALC, HILL AFB UT

AF00-305	Portable, Field-Functionalized, Multi-component Vapor Detector
AF00-306	Conversion of Static Models and Stinulus Files to Digital Test Interface Format (DTIF)

OKLAHOMA CITY ALC, TINKER AFB OK

AF00-308	Model Characterizing Electromagnetic Pulse Response from Continuous Wave Electromagnetic Data
AF00-309	Virtual Office Application for Next Generation Internet (NGI)

AIR ARMAMENT CENTER, EGLIN AFB FL

AF00-310	Micro-Miniature, Wireless, Telemetry Sensors
AF00-311	Advanced Global Positioning System Hybrid Simulator
AF00-312	Directed Energy Weapons (DEW) Vulnerability and Lethality Analysis
AF00-314	Electro-Optical Scene Simulation Projector (EOSSP)

AIR FORCE 00.1 TOPICS

AF00-001 TITLE: Opto-Integration of Nonlinear Optical Wavelength Converters

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop highly opto-integrated nonlinear optical (NLO) wavelength converters for high-power, highly efficient, compact, electrically driven fiber lasers for adjunct Space Based Laser (SBL), Airborne Laser (ABL), and other Directed Energy (DE) AF missions.

DESCRIPTION: Fiber lasers have demonstrated efficient optical-to-optical power conversion into a diffraction-limited laser beam. Air Force DE missions require electrically efficient, compact, scaleable architectures leading to tens of kilowatts of continuous-wave power in a diffraction-limited beam. Because alternative wavelength operations are required by some missions, it is desired to implement a similar philosophy of ultracompactness as that being applied to the development of these new Yb-doped (1.1-micron) fiber laser devices. The ultracompactness of components may benefit from the manufacturing techniques and lessons learned from such industries as those in integrated electronics and fiber communications. This solicitation is for the development of highly opto-integrated NLO devices such as second harmonic generators, optical parametric oscillators, and sum frequency mixers or difference frequency mixers. Optically integrated devices might consist of all-fiber or waveguide construction with the pump coupling and signal/idler resonance/extraction being accomplished via fiber couplers. It is expected that micro-optics, fiber or waveguide gratings, or other wavelength division multiplexing technology may be useful. It is imperative that ultracompact packaging conducive to machine-vision assembly and mass-producible manufacturing methods be utilized and that the device be robust. Such an envisioned device may simply be attached to a fiber laser via a simple fiber coupler by the end user. Successful proposals will be keen on power scaleable, mass-producible (x20 long-term cost reduction) architectures or technologies demonstrating high-power density packaging (approaching 10W/cm3).

PHASE I: Design, model, and perform adequate proof-of-principle demonstrations to give confidence for the success of a Phase II program.

PHASE II: Based on Phase I designs, models, and proof-of-principle demonstrations, conduct in-depth testing and refinement of prototype hardware to show a maturity of technology toward potential commercial and military applications.

PHASE III DUAL USE APPLICATIONS: Air Force directed energy applications for this technology (weapons, illuminators, counter-measures) have important commercial parallels in such areas as in communications (e.g. pump sources, WDM systems), medical, printing, and materials processing (e.g. welding, marking, cutting) markets.

REFERENCES:

1. "35-Watt CW Single-mode Ytterbium Fiber Laser at 1.1-microns", M. Muendel, B. Engstrom, D. Kea, et al., Conference on Lasers and Electro-Optics, CPD-28, May 1997.
2. "High-power Fiber Lasers", Sandra G. Kosinski, Daryl Inniss, Conference on Lasers and Electro-Optics, CTuE3, May 1998.
3. "Fiber Laser Oscillators and Amplifiers", Elias Snitzer, Conference on Lasers and Electro-Optics, CWE1, May 1998.
4. "Optical parametric oscillation excited by an incoherent conical beam," A. Piskarskas, V. Smilgevicius, and A. Stabinis, Opt. Commun. 143, 72--74 (1997).

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-002 TITLE: Phase-locked Fiber Laser Array

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop phase-locked fiber laser array technology leading to high-power, high-brightness lasers operating in the 1100 nm portion of the IR spectrum.

DESCRIPTION: Fiber lasers have demonstrated efficient optical-to-optical power conversion into a diffraction-limited laser beam. Air Force DE missions require electrically efficient, compact, scaleable architectures leading to tens of kilowatts of continuous-wave power in a diffraction-limited beam. The power output of an individual diode-pumped fiber laser will ultimately be limited by the damage threshold of the fiber core and cladding materials.

Currently, the state-of-the-art for such a laser in the laboratory is on the order of 100 Watts and about half this for commercially available lasers. A coherent array of such lasers, however, may be capable of scaling to the multi-kilowatt level. In such an array comprising N individual fiber lasers, the peak intensity delivered to a target can be increased by as much as N squared if the lasers are phase locked over the case where all the lasers are independent. This solicitation is for the development of techniques to accomplish the goal of phase-locking an array of fiber lasers to deliver a high-brightness beam. The proposed technique(s) may, for example, be all optical in nature, such as injection locking via evanescent coupling in a multi-core fiber. Alternatively, a hybrid approach employing optical and electronic elements could be used, implementing phase control in a master-slave configuration via opto-electronic devices such as acousto-optic modulators or phase modulators employing the electro-optic effect in solid-state media. Optical coupling between fibers via intra-fiber gratings, Talbot imaging, or phase-conjugate mirrors might also be of use.

PHASE I: Design, model, and perform adequate proof-of-principle demonstrations of phase-locking technology to give confidence for the success of a Phase II program.

PHASE II: Based on Phase I designs, models, and proof-of-principle demonstrations, conduct in-depth development and refinement of prototype hardware to show a maturity of technology toward potential commercial and military applications.

PHASE III DUAL USE APPLICATIONS: Military applications for high-power compact fiber lasers such as those resulting from this proposal are principally weapons-related. Examples of commercial applications for a high-brightness, high-power phased array include laser cutting and welding, laser machining and materials processing, possible medical applications and any other area where a compact, efficient and mechanically robust source of intense infrared radiation is required.

REFERENCES:
1. "High-power Fiber Lasers", Sandra G. Kosinski, Daryl Inniss, Conference on Lasers and Electro-Optics, CTuE3, May 1998.
2. "A CW Diode-pumped Single-silica Fiber Comprising 40 Cores used as Active Elements for a High-power Fiber Laser at 1050nm", P. Glas, M. Naumann, A. Schirrmacher, Th. Pertsch, Conference on Lasers and Electro-Optics, CTuK5, May 1998.
3. "The Talbot Effect", Mansur Mansuripur, Optics and Photonics News, April 1997, pp.42-47.
4. "Self-pumped, continuous-wave phase-conjugator using internal reflection", J. Feinberg, Optics Letters, 7, pp. 486-488 (1981).

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-003 TITLE: High-Brightness Fiber-Coupled Laser Diodes

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop high-brightness, high-power, fiber-coupled diode laser sources to pump high-power fiber lasers for adjunct Space Based Laser (SBL), Airborne Laser (ABL), and other Directed Energy (DE) AF missions.

DESCRIPTION: Fiber lasers have shown efficient optical-to-optical power conversion into a diffraction-limited laser beams. Air Force DE missions require electrically efficient, compact, scaleable laser architectures, for which fiber lasers show great promise. The drivers for such systems will likely consist of banks of fiber-coupled diode lasers. The diode banks could be constructed using an array of diode bars, single emitters, or other possible building blocks. The fiber coupled outputs will then be combined to produce high-brightness, high-power modules suitable for pumping a fiber laser. The details of the design will ultimately depend on factors such as cost, compactness, heat sinking, wavelength control, power supply design, robustness, and serviceability. The primary challenge is to optimally preserve the inherent brightness of the laser diode emission in the fiber coupling and fiber combining processes. Possible approaches might employ technologies such as: bonded and/or shaped waveguides (glass or epitaxial), fiber tapers, fiber end lensing, fiber fusing, or WDMs. Emphasis should be placed on coupling efficiency, simplicity, cost, compactness and robustness. The baseline diode wavelength should be in the 915 nm region for pumping dual-clad Yb doped fiber lasers. A target fiber coupled pump module should provide ~100 W in a single fiber or bundle of fibers with a brightness approaching 1 MW cm-2 sr-1. The target physical dimensions (without driver electronics, but with heat dissipation) are better than 50 W/kg and 0.1 W/ cm-3. The candidate system should be constructed in a way that leads to a significant reduction in unit cost for near-term commercial systems.

PHASE I: Develop a conceptual design based on research, modeling, and producibility. Consider issues associated with manufacturing and assembling the key optical elements. Perform proof-of-principle tests to give confidence for the success of a Phase II program.

PHASE II: Based on Phase I designs, models, and proof-of-principle demonstrations, conduct in-depth testing and refinement of prototype hardware. Build 100 W prototype fiber coupled arrays of diode with a brightness (bundle or single-fiber) significantly exceeding that of currently available technologies. Packaging, heat sinking, original equipment manufactured parts, manufacturing, and commercialization issues should also be considered in the final prototypes to show a maturity of technology toward potential commercial and military applications.

PHASE III DUAL USE APPLICATIONS: Many Air Force directed energy systems and concepts could benefit from this technology. Markets such as those associated with medical lasers, materials processing systems, and laser pump sources could be explored.

REFERENCES:
1. High-Power Diode-Laser Arrays, Endriz Jg, Vakili M, Browder Gs, Devito M, Haden Jm, Harnagel Gl, Plano We, Sakamoto M, Welch Df, Willing S, Worland Dp, Yao Hc, Ieee Journal Of Quantum Electronics V. 28(#4) Pp. 952-965 Apr 1992.
2. Near-Diffraction-Limited Single-Lobe Emission From A High-Power Diode-Laser Array Coupled To A Photorefractive Self-Pumped Phase-Conjugate Mirror, Maccormack S, Eason Rw, Optics Letters V. 16(#10) Pp. 705-707 1991
3. Modal Properties Of An External Diode-Laser-Array Cavity With Diffractive Mode-Selecting Mirrors, Leger Jr, Mowry G, Li X ,Applied Optics V. 34(#21) Pp. 4302-4311 Jul 20, 1995
4. Individual Holographic Optical-Element For Output-Emission Improvement Of A Diode-Laser Array, Spring R, Luthy W, Weber Hp, Helvetica Physica Acta, V. 67(#2) Pp. 221-222 May 1994
5. Numerical-Analysis Of Flared Semiconductor-Laser Amplifiers, Lang Rj, Hardy A, Parke R, Mehuys D, Obrien S, Major J, Welch D, Ieee Journal Of Quantum Electronics, V. 29(#6) Pp. 2044-2051 Jun 1993
6. High-Intensity Rectangular Fiber-Coupled Diode-Laser Array For Solid-State Laser Pumping, Morris Pj, Luthy W, Weber Hp, Applied Optics, V. 32(#27) Pp. 5274-5279 Sep 20, 1993
7. Iii-V Semiconductor Wave-Guiding Devices Using Adiabatic Tapers, Moerman I, Vermeire G, Dhondt M, Vanderbauwhede W, Blondelle J, Coudenys G, Vandaele P, Demeester P, Microelectronics Journal, V. 25(#8) Pp. 675-690 Nov 1994
8. The Shape Of Fiber Tapers, Birks Ta, Li Yw, Journal Of Lightwave Technology, V. 10(#4) Pp. 432-438 Apr 1992
9. Design Approaches For Laser-Diode Material-Processing Systems Using Fibers And Microoptics, Chen Wq, Roychoudhuri Cs, Banas Cm, Optical Engineering, V. 33(#11) Pp. 3662-3669 Nov 1994

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-004 TITLE: Polarization-Maintaining Dual-Clad Yb-doped Fiber

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop polarization-maintaining (PM), dual-clad Yb-doped fiber to enable high-power, linearly polarized, fiber lasers for adjunct Space Based Laser (SBL), Airborne Laser (ABL), and other Directed Energy (DE) AF missions.

DESCRIPTION: Fiber lasers have demonstrated efficient optical-to-optical power conversion into a diffraction-limited laser beam. Air Force DE missions require electrically efficient, compact, scaleable architectures leading to tens of kilowatts of continuous-wave power in a diffraction-limited beam. This solicitation is for the development of polarization-maintaining (PM), dual-clad Yb-doped fibers for linearly polarized (1.1-micron) fiber lasers. Linearly polarized fiber lasers are necessary for non-linear wavelength conversion and may enable coherent beam combining for kilowatt-class fiber laser arrays. Innovative fibers specifically designed for high power (>35W) fiber lasers must meet a number of critical requirements for success. Among these are cladding geometry to efficiently couple the pump-cladding modes to the lasing core, all-glass fibers to eliminate outer-clad burning, and integration of possible diode-pump schemes into the design of the fiber. Successful proposals will offer innovative solutions for a linearly-polarized fiber laser with focus on PM fiber designs that enable single fiber power scaling to a kilowatt (100W near-term goal), enhance or enable new methods for diode-pump coupling, PM mode control, or other laser design constraints that require a reengineered fiber. Successful proposals will be keen on scaleable, mass-producible (x20 long-term cost reduction goal) fiber laser architectures or technologies leading to high electrical efficiency (approaching 30-40%) and high-power density packaging (approaching 10W/cm3).

PHASE I: Design, model, and perform adequate proof-of-principle demonstrations to give confidence for the success of a Phase II program.

PHASE II: Based on Phase I designs, models, and proof-of-principle demonstrations, conduct in-depth testing and refinement of prototype hardware to show a maturity of technology toward potential commercial and military applications.

PHASE III DUAL USE APPLICATIONS: Air Force directed energy applications for this technology may have important commercial parallels such as communications, printing, and materials processing lasers.

REFERENCES:
1. "35-Watt CW Single-mode Ytterbium Fiber Laser at 1.1-microns", M. Muendel, B. Engstrom, D. Kea, et al., Conference on Lasers and Electro-Optics, CPD-28, May 1997.
2. "High-power Fiber Lasers", Sandra G. Kosinski, Daryl Inniss, Conference on Lasers and Electro-Optics, CTuE3, May 1998.
3. "A CW Diode-pumped Single-silica Fiber Comprising 40 Cores used as Active Elements for a High-power Fiber Laser at 1050nm", P. Glas, M. Naumann, A. Schirrmacher, Th. Pertsch, Conference on Lasers and Electro-Optics, CTuK5, May 1998.
4. "Single-mode Photonic Crystal Fiber with an Indefinitely Large Core", T.A. Birks, J.C. Knight, R.F. Creagan, P.St.J. Russell, Conference on Lasers and Electro-Optics, CWE4, May 1998.

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-005 TITLE: Pseudo Anechoic Chamber for Electromagnetic Measurements

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

OBJECTIVE: Research the possibility of performing low-level electromagnetic characterization of antennas and systems without using anechoic chambers or open-air test facilities.

DESCRIPTION: Currently, the measurement of antenna patterns, coupling transfer functions (both time and frequency domain), and electromagnetic scattering can only be done in an anechoic chamber or at a large open-air test site because of the isolation required. Such facilities are expensive to build and operate, and quite often, they are not the right size or are not located where they are needed; however, recent improvements in electronic measurement systems and data processing techniques open up new possibilities for improving such characterization systems and reducing or eliminating the need for special chambers or facilities. Ultra-wideband/short pulse and spread-spectrum electromagnetics are two examples of emerging technologies that may provide this capability. There are also other concepts that may prove worthy of investigation. The offeror is free to investigate any and all and select the approach with the lowest perceived risk or greatest improvement over current technology. Concepts considered under this effort must also address potential interference with others and FCC frequency authorization issues that will affect the application of the technology.

PHASE I: Demonstrate the basic feasibility of the proposed technology and characterize the developmental risk associated with the technology. Specific approaches will be investigated and critical development requirements will be identified for the Phase II effort. The final report shall also include possible Phase II partners and an approach for commercialization in a Phase III effort.

PHASE II: Develop and fabricate a prototype measurement system for performing electromagnetic characterization of antennas and other systems without the use of an anechoic chamber or open-air test facility. Conduct laboratory and other tests that will demonstrate a capability with clear commercial potential. Develop commercial partnership interests for a Phase III production and marketing program.

PHASE III DUAL USE APPLICATIONS: The pseudo anechoic chamber approach should be applicable to both military and commercial needs for characterizing antennas, communications systems, shielded systems, and for the measurement of broadband radar signatures of aircraft, camouflaged systems, and buried objects.

REFERENCES: C.E. Baum, ed., Ultra-Wideband, Short-Pulse Electromagnetics 3, Plenum Press, 1997.

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-006 TITLE: Direct Frequency Doubled Diode Laser

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop an efficient, low cost, and compact laser that operates at a wavelength between 460-550 nm by taking light directly from a diode laser operating at a wavelength between 920-1100 nm and frequency doubling it.

DESCRIPTION: The current method of obtaining laser light at wavelengths between 460-550 nm using a diode laser is to use the diode to pump a Nd laser that is then frequency doubled through a nonlinear crystal such as KTP. The goal is to eliminate the requirement to pump a Nd:Yag laser and instead double the diode output directly. Because the current maximum efficiency of Nd lasers is near 50%, this technique could yield lasers in the wavelength regions of interest that are more efficient. In addition, by eliminating the requirement of having a solid-state laser cavity, it may be possible to shrink the size of the laser considerably. It may even be possible to obtain a green laser-on-a-chip; however, this may be difficult due to the beam quality of diode lasers.

PHASE I: Design and fabricate a deliverable breadboard demonstrator of a direct frequency doubled diode laser system that operates in the wavelength region of 460-550 nm. The focus of this phase should be on finding a nonlinear crystal that can efficiently frequency double the diode output. Considerations during this phase include the beam quality required, spectral bandwidth required, and the temperature tolerance of the nonlinear crystal.

PHASE II: Optimize the design from Phase I with an emphasis on output power and compactness while maintaining high efficiency. The ideal goal should be to arrive at a design that will allow a blue to green laser-on-a-chip to be produced with output powers greater than 100 mW.

PHASE III DUAL USE APPLICATIONS: Military applications envisioned include handheld and vehicle-mounted visible laser illuminators. Many commercial applications are known such as video displays, video laser projection systems, laser pointers, and mass storage devices.

REFERENCES: 1. Casey H.C., and Panish M.B., Heterostructure Lasers, Academic Press, NY, 1978.
2. Dmitriev V.G., G.G. Gurzadyan and D.N. Mikogosyan, Handbook of Nonlinear Optical Cyrstals, 2nd Ed., Springer-Verlag, Berlin, 1997.
3. Verdeyen, Joseph T., Laser Electronics, Prentice-Hall Inc., NJ, 1989.

KEYWORDS: Nd lasers, PPLN, frequency doubling, green and blue lasers, laser diodes, nonlinear optics

AF00-007 TITLE: Electro-Optic Devices for Search and Rescue

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop an accurate, reliable, and low-cost electro-optical search and rescue (SAR) system for locating and tracking downed combat personnel.

DESCRIPTION: A number of organizations and countries, including the USA, are developing and/or expanding their combat search and rescue capability (CSAR). Due to the ever-increasing NATO role and peacekeeping involvement, US military personnel are at risk of being lost in unfamiliar terrain or being downed in enemy territory or unfriendly waters. Technological advances have been made on many SAR fronts, but they either have not been fully integrated, are not available to all SAR units, or suffer from technical deficiencies. As an example, the SARSAT (Search and Rescue Satellite) can locate RF beacons to within 20 km, then SAR personnel must use other means (e.g. electro-optics and handheld beacons) to pinpoint the exact location of downed personnel. To facilitate local area search, electro-optical systems like FLIRs are being used to locate the thermal signature of downed personnel. However, due to the high cost (>$100K) per copy, only a limited number of FLIRs are used in SAR missions. Since FLIRs detect temperature differences, they have limited use when the body temperature of the downed individual is close to that of the surroundings (e.g. in water or in the desert on a hot day). Other systems are being developed to compensate for the FLIR deficiencies and/or augment the FLIR's benefits. These systems use low light level (LLL) sensors (LLL television and night vision goggles [NVG]) for SAR missions, with and without the aid of laser illuminators. However, these systems have their limitations as well. LLL systems, without augmented illumination, have limited utility under cloud-covered and moonless sky conditions. When continuous-wave (CW) lasers are used as illuminators, NVG vision can be hampered by cloud or aerosol backscatter that is close to the rescue vehicles. To compensate for the backscatter problems, research is being conducted using pulsed lasers and range-gated, image-intensified cameras. However, pulsed systems may not be eye-safe at all operating ranges. Laser illumination has two benefits--it aids in better scene illumination, and it can be used with retroreflective tape, paint or corner cubes to precisely pinpoint the location of the downed individual. Use of retroreflectors is inherently advantageous since the laser beam returns in the direction of the interrogator, thereby adding covertness to the search and tracking part of the mission. Modulation of the retroreflected signal can facilitate false target discrimination and confirm the identification of the downed individual. Another electro-optic technology being investigated is the use of laser-induced fluorescent (LIF) paint. LIF paint, when applied on an aircraft, uniforms, or a person's skin, could be detected by SAR vehicles equipped with laser illuminators and LIF-sensitive receivers. However, for long standoff distances, extremely sensitive LIF receivers are necessary and high power laser illuminators may make the system not eye-safe.

Research is needed in wide-area electro-optical SAR technology to speed up the search time while maintaining accuracy and tracking capability. The CSAR should be capable of tracking a downed individual once he/she is detected, either while the SAR vehicle is in motion, or the downed person is on the move. The system should be able to interface with any SAR vehicle, operate in all weather conditions, at any time of the day or night, and provide real time information. The system must locate downed combat personnel in any number of environments ranging from maritime, mountainous regions, desert, jungle, densely wooded areas, arctic, and farm clearings to urban terrain.

Innovative proposals are sought that address existing technical CSAR deficiencies, speed up detection times, and improve the accuracy of detecting and tracking downed personnel. AFRL is interested in receiving proposals in any of the following technology areas: a) wide-area, high-power (multi-watt), semiconductor laser illuminators (pulsed or CW); b) high through-put beam-combining optics to produce lasers identified in "a"; adjustable beam divergence, low-loss transmission telescopes to produce the wide-area illumination beam and handle the lasers identified in "a"; c) matching sensor to operate with laser identified in "a"; d) use of optical augmentation or retro-reflectors for pinpointing personnel location; or e) LIF paints and sensors.

PHASE I: Identify the technology and approach that is being proposed. Demonstrate through analysis the benefits and performance of the proposed system. Design and develop a working electro-optical wide-area SAR system for a proof-of-principle demonstration. Hardware deliverables are highly desired for future government field testing. The government will conduct tests and vehicle integration at no cost to the contractor. Design the SAR system to be platform independent. The deliverable items will include a final report, test results, and hardware. The final report will include a system design, operating and maintenance instructions, parts list, drawings, schematics, block diagrams and vendor literature. Proposals for a subset of a

SAR system will be accepted if it can be shown that the subset is a major element of a SAR system that can be integrated and demonstrated in Phase II.

PHASE II: Capitalize on the work performed in Phase I and the lessons learned from the field trials, and incorporate feedback from the SAR community to optimize the system design, and to deliver a prototype CSAR system that can be integrated with a combat SAR vehicle. The goal will be to have a wide-area, electro-optical CSAR system that exceeds existing field-of-view and/or illumination diameters by at least a factor of three; this will increase the area of the search by nearly an order of magnitude over existing SAR systems. Show by analysis how this goal can be achieved and the impact on the laser, sensor and optical design. The system should include provisions to provide the location of the downed individual, as well as tracking information should the individual be on the move.

PHASE III DUAL USE APPLICATIONS: During Phase III the emphasis will be to transition this technology from the Air Force to DoD-wide CSAR units and the Coast Guard SAR. Other applications include local law enforcement SAR, commercial (e.g. oil rig) SAR, foreign commercial SAR, and NATO and coalition partners CSAR. Other non-SAR applications include non-lethal illuminators for crowd control; covert tracking of personnel, vehicles, and vessels; looking through heavily tinted windows; IFF; target location and tracking.

REFERENCES:
1. Beal, C and Hewish, M., Air Search and Rescue Capability Up, Budgets Down, International Defense Review (IDR), 1 February 1993, p. 117 v.26 no. 02.
2. Rabin, J. Forward-Looking Infrared: Capabilities for Search and Rescue,
3. Miller J.L. and Kelly J. Flight Testing of a Gimballed Active Television Using A Fiber-Optic Coupled Laser Spotlight, Laser Radar Technology and Applications, G. Kamerman, ed., SPIE Proceedings #3380, 1998.

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-008 TITLE: <u>High-Efficiency Mid-Infrared Solid-State Lasers</u>

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop a mid-infrared solid-state laser producing greater than 5J/pulse with limited duty cycle operation and minimal thermal control.

DESCRIPTION: Many applications require lasers which can produce high pulse energies in the mid-infrared region with high beam quality. Additionally, these applications frequently require small, robust lasers which are highly efficient. Unfortunately, the requirements often are conflicting-the engineering tradeoffs made to make a small, highly efficient laser often conflict with those necessary for high beam quality and high pulse energy. However, by relaxing other performance parameters, it may be possible to simultaneously satisfy these primary requirements. For instance, by relaxing the operational requirement from continuously available laser operation to limited duty cycle operation, it may be possible to dramatically reduce the thermal problems which often prove a barrier to laser performance. The goal of this project is to produce a laser-producing pulsed output at a wavelength in the 2 to 5 micron band. The laser should produce pulsed output at a pulse repetition rate of 10 Hz or greater for a minimum of 0.5 s; this "on time" can be followed by a short recovery time where the laser cannot be operated. During this recovery time, the laser can continue to draw power from the main power supply system and "recharge". The amount of recovery time will vary depending on the device design tradeoffs, and any proposal should address the potential tradeoff between size (weight, volume, and thermal mass), recovery time, and output power. The desired output power levels for this device depend on the output wavelength--at 2 microns, the desired pulse energy is 5 J/pulse, while at 4 microns the desired pulse energy is 1.5 J/pulse. The laser must operate without any consumables (such as liquid nitrogen) and has an overall wall-plug efficiency goal of 5%. While it may not be able to simultaneously satisfy all these requirements, any proposal must clearly identify the potential design tradeoffs.

PHASE I: Design a laser capable of satisfying performance goals based on analysis of the engineering tradeoff-offs between duty cycle, efficiency, and device size. Laboratory assessment of the crucial technical concepts and risk areas is desirable and will be a factor in topic selection.

PHASE II: Verify engineering tradeoffs by laboratory demonstration. Refine and produce the laser design; the laser must be rugged enough for field test in a minimal maintenance environment.

PHASE III DUAL USE APPLICATIONS: The technology produced by this SBIR would be useful in applications which require high output energies, but which are severely power- and space-constrained and only require limited-duty cycle operation. Candidate platforms for this technology are unmanned air vehicles, man-portable systems, certain space systems, and others. Candidate military application areas are remote sensing, active imaging, target designation, and others. Candidate commercial applications are those which required limited duty cycle mid-infrared radiation; examples of these areas are remote sensing for environmental monitoring and some medical applications.

REFERENCES:
1. J. Williams-Byrd, U. Singh, N. Barnes, G. Lockard, E. Modlin, and J. Yu, "Room-Temperature, Diode-Pumped Ho:Tm:YLF Laser Amplifiers Generating 700 mJ at 2 micron", Proc.of the ASSL Conf., TOPS V10, Coeur D'Alene, 1997, P199.
2. T. Chuang and R. Burnham, "All Solid-State Mid Infrared Laser Source", Proc.of the ASSL Conf., TOPS V10, Coeur D'Alene, 1997, P262.

KEYWORDS: 2 to 5 micron, duty cycle operation, high beam quality, high pulse energy, mid-infrared, pulsed output, recovery time, solid-state lasers, wall plug efficiency

AF00-009 TITLE: High-Power, High-Brightness Beam Combination of Semiconductor Lasers

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop a new generation high-power, high-brightness semiconductor arrays for industrial and military applications.

DESCRIPTION: Over the past several years, the Air Force has concentrated on developing high-power laser systems for a variety of ranged applications. Semiconductor lasers offer the advantages of compact size, high efficiency, robustness, and electrical pumping.

Numerous methods have been used to achieve near-diffraction-limited diode arrays with relative success. In the past, many different coherent combination techniques (e.g. master-oscillator power-amplifiers, nonlinear beam combination, locked oscillators) have been used to produce phased arrays. More recently, efforts using incoherent beam combination (e.g. polarization combining, spectral combining/wavelength-division multiplexing) are being attempted.

Recently, high-power semiconductor and fiber laser technology has focused on wavelengths in the 980-1100 nm range. Current requirements for applications also require novel wavelengths, especially wavelengths longer than 1500 nm.

The main goal of this topic is to develop a spatially-coherent (i.e. diffraction-limited) beam by combining multiple semiconductor lasers into a single aperture. Both coherent and incoherent combination techniques are acceptable, provided the output beam is diffraction-limited and carries an output power of 10-100 W cw and has a nominal operating wavelength near either 980 nm or 1.5 microns.

PHASE I: Propose, demonstrate, and characterize performance of small-scale, multi-element, beam combination technique with near-diffraction-limited performance. Demonstrate system scalability to larger and/or multiple apertures for higher power levels for Phase II effort.

PHASE II: Develop, characterize, and deliver a prototype array system with state-of-the-art operating levels for brightness and power (10-100 W cw) operating near 980 nm or 1.5 microns.

PHASE III DUAL USE APPLICATIONS: The technology developed in this program has many commercial and military applications. Typical high-brightness applications include laser communications, infrared illumination, remote sensing and environmental testing, laser surgery, optical data recording, wavelength conversion, and industrial cutting and welding.

REFERENCES:
1. Diode Laser Arrays, ed. by D. Botez and D. R. Scifres. Cambridge: Cambridge University Press, 1994.
2. S. MacCormick, et al., Optics Letters, vol. 22, pp. 227-229, 1997.
3. Fiber-Optic Communication Systems, G. P. Agrawal. New York: John Wiley & Sons, Inc., 1992.

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-010 TITLE: Portable Microwave Refractometer System for Sensing Refractive Index and Humidity Fluctuations

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/TM)--Airborne Laser (ABL)

OBJECTIVE: Develop a portable microwave refractometer system for sensing refractive index and humidity fluctuations.

DESCRIPTION: There is a need in the atmospheric sciences community for a portable microwave refractometer that can be used for sensing the atmospheric refractive index and humidity fluctuations at high speed. The system is needed for fine-scale research measurements and for examining the performance of clear-air radars over time. Refractometers have been used to interpret radar returns (Lane and Meadows), and an early description of their designs and operation can be found in Bean and Dutton's Radio Meteorology. The system should be capable of being used with an aircraft platform, being mounted on a tower, or carried aloft by a tethered balloon or kite. State-of-the-art sensors and electronics (COTS when available) must be incorporated into the new system with a wide range of sampling capability (sampling rates, gains, etc.). Displays and software must be "user friendly" and be maintained easily. A calibration method for the system is required. The system should be of moderate size so that it can be mounted on aircraft, carried by balloons/kites, etc., and be operated reliably. The system should be designed to operate in conditions of strong acoustic fields due to jet noise. High subsonic conditions must be considered for mach numbers up to 0.85.

PHASE I: Produce a conceptual design and prototype for the microwave refractometer system, including associated required sensors and software needed to extract humidity and refractive index fluctuations as well as calculate the refractive index structure parameter. Produce and demonstrate a detailed analysis of the predicted performance (range of parameters sensed, accuracies, electronics specifications, etc.). Perform preliminary field tests.

PHASE II: Finalize the design and fabricate a microwave refractometer system using the design. Produce complete documentation. Extensively field test and evaluate the system under various conditions.

PHASE III DUAL USE APPLICATIONS: Although several DoD programs such as the ABL and ground-based laser programs would greatly benefit from a microwave refractometer system using state-of-the-art electronics and sensors, the atmospheric research and radar communities also have shown great interest in such a system. Several measurement campaigns would benefit with information from such a system, and the system would provide needed in situ measurements for calibration of clear-air radars. The system would provide long-term checks of the calibrations. Inquiries as to availability, possible costs, etc. of such a system often arise from researchers. A commercially available system would be very beneficial, particularly since there are networks of clear-air radars in operation.

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1. Lane, J. A., and R. W. Meadows, 1963: Simultaneous radar and refractometer soundings of the troposphere, Nature, Vol. 197, 35-36.

2. Bean, B. R., and E. J. Dutton, 1966: Radio Meteorology, U. S. Govt. Printing Office, Washington, D. C., 431 pp.

KEYWORDS: electromagnetic propagation, humidity fluctuations, radar calibration, refractive index, site characterization, turbulence

AF00-011 TITLE: Advanced Chemical Iodine Lasers for the ABL

TECHNOLOGY AREAS: Weapons

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/TM)--Airborne Laser (ABL)

OBJECTIVE: Demonstrate innovative concepts that will impact an alternative chemical iodine laser.

DESCRIPTION: The AF Space and Missile Center (SMC) is interested in conducting research and development on various aspects of advanced iodine chemical laser concepts in support of the Airborne Laser (ABL) program. The current weapon device concept is based on the chemical oxygen iodine laser (COIL) system. The iodine atom lasant operates at a wavelength of 1.3 um, which is nearly ideal; however, the current two-phase oxygen generation technique presents a number of issues that increase program risk. Alternative chemical concepts for transferring energy efficiently to the iodine atom are of interest. The ABL Program Office would like to pursue a variety of R&D topics in this area. The most important issues to be addressed are included in the phase descriptions below.

PHASE I: 1) Define and model a promising all-gas-phase chemical iodine laser concept, including the key chemical and kinetic reactions, and arrive at a laser design concept. Or 2) investigate the issue of safe storage and handling of hydrazoic acid in the gas phase. Conduct small-scale experiments to demonstrate the concept. Or 3) investigate high-density flow rates of relevant atomic species such as fluorine and chlorine atoms. Define concepts and carry out small-scale verification experiments.

PHASE II: Continue the effort initiated in Phase I. Design, construct and carry out the key experiment(s) identified in Phase I. Construct a kinetic model, exercise the model to predict system behavior, and compare with experimental results. Generate an engineering design for a full-scale device and predict its performance using the model.

PHASE III DUAL USE APPLICATIONS: This phase would involve the generation and implementation of a marketing plan for the technology developed during the first two phases. These technologies are expected to have applications in a variety of manufacturing industries and elsewhere. Possible applications are nuclear reactor decommissioning via robotic fiber-delivered high-power laser output and robotic (aluminum) welding for the auto industry.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-012 TITLE: Wave Optics Simulation

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/TM)--Airborne Laser (ABL)

OBJECTIVE: Design, code, and document a user-friendly simulation environment for the study of control and tracking systems for laser propagation and imaging through the atmosphere.

DESCRIPTION: There is increasing military and commercial interest in laser and imaging systems that operate in the atmosphere, at least over part of the propagation path. Increasing performance requirements make it necessary to optimize control and tracking algorithms for such systems. This necessitates the integration of wave optics propagation codes, control and tracking codes, and data analysis environments. To date this has proved difficult, since the expertise for tracking and control algorithm design and for propagation studies rarely resides in one individual. Further, simulation paradigms for the respective areas are not compatible. The challenge of this effort is to provide an integrated, user-friendly, software environment that accesses wave optics propagation tools, control design tools, and data analysis tools.

It is expected that the successful offerer will integrate existing code, rather than develop it under this effort. In particular, offerers should be familiar with wave optics propagation codes, optical sensor modeling and standard control techniques usually associated with adaptive optics and tracking systems. The offerer should also be familiar with the MATLAB* software environment since it is this data analysis and control paradigm that we suggest be integrated into the software paradigm..

Generally we seek packaging of existing code in a user-friendly way, rather than code development that starts from scratch. Many companies have there own internal wave optics modeling capability. It is this capability we wish to capture in a user-friendly way. Two examples of code that goes part way are the Adaptive Optics Toolbox and ABLSim. The former is a commercial product that is marketed as a MATLAB Toolbox. Information on this product can be viewed at http://www.mathworks.com/products. The latter is not a commercial product but some information on this code and its interfaces can be viewed at http://www.MZA.com/ABLSim. These references are provided to give the offeror an idea of the type of code we are interested in and a concept of two types of interfaces that might be useful.

PHASE I: Design, code and document a prototype software environment that integrates propagation code with the MATLAB control design and data analysis software in a user-friendly, integrated software environment. The environment should contain interfaces for creating and modifying adaptive optics geometry, building wind and turbulence profiles, specifying sensors, and incorporating target and receiver characteristics. It should further allow easy incorporation of track and control algorithms. A block diagram interface for creating both the optical and control systems is envisioned. The code should also allow for easy integration with MATLAB in order to incorporate control and tracking algorithms and for data analysis. The final product should be capable of running under Windows NT and Unix operating systems. Phase I will not necessarily provide robust code, but rather a conceptual design and enough software to clearly demonstrate feasibility of the approach.

PHASE II: Design, code, debug, document, alpha and beta test the above-described software package, so that the Air Force research community has ready access to the tool. The tool must be robust and well documented so that a generally knowledgeable person in either the control design community or the propagation community will find it an effective tool for integrated studies. The code and the documentation should be such that the user can extend the code to study a variety of systems, e.g. Airborne Laser, Space Laser, Relay Mirror and imaging systems. We seek incorporation of as many useful sensor, mirror, camera, and target models as resources allow. Offerors who don't already have many of the standard models used in the laser propagation and imaging community will be at a disadvantage.

PHASE III DUAL USE APPLICATIONS: The final product of Phase II will be a robust flexible code for the study of laser propagation and imaging through the atmosphere. Government programs such as the Airborne Laser, Ground Based Laser and Relay Mirror are highly likely customers. The astronomical community is also a potential customer. Commercial applications include analysis at firms building imaging systems for TV news helicopters, those providing visual information for Geographical Information Systems, and helicopter imaging systems for power line insulator damage detection.

* MATLAB, a registered trademark of MathWorks, is an integrated technical computing environment that combines numeric computation, advanced graphics and visualization, and a high-level programming language. Further information can be found at www.mathworks.com.

REFERENCES:
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2. Coy, Steve C., et. al;., "Extending the Hierarchical Block Diagram Paradigm for Modeling and Development of Large Scale Systems". Proceedings 1997 Summer

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-013 TITLE: Multi-conjugate Optics

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/TM)--Airborne Laser (ABL)

OBJECTIVE: Develop a hardware and software architecture for adaptive optics systems utilizing multiple deformable mirrors and wavefront sensors that would enhance the performance, over that of conventional systems, of directed energy, or imaging, systems propagating or imaging over long horizontal atmospheric paths.

DESCRIPTION: Due to atmospheric scintillation, adaptive optics systems that operate over long horizontal paths are limited by current technology in compensating the entire path. An adaptive optics system with two or more deformable mirrors and/or wavefront sensors theoretically could better compensate for the atmosphere by having part of the atmospheric path compensated by one deformable mirror and another part of the path compensated by another deformable mirror, thereby providing a modicum of amplitude compensation in addition to phase compensation.. The resulting system could avoid some of the limitations imposed by phase-only (one-mirror) adaptive optics systems. Solutions utilizing a multiple mirror concept have not progressed because the location of the optimal conjugate planes has been elusive. In addition, the apparent need for a real focus in a high energy laser train has made the multimirror approach challenging. Creative and innovative approaches are clearly required to address these limitations. This topic permits the design and testing of a multiconjugate adaptive optics system for use over long horizontal paths to ameliorate the effects of atmospheric scintillation. Non-linear optical system approaches are not covered under this topic.

PHASE I: Using a multi-conjugate adaptive optics system approach, develop an optical system design, and test the design using wave optics simulations and a control system model.. As a starting point the offeror's design should anticipate that the ultimate applications are for 1-4 meter class optical optical systems and evaluate the performance, as well as the limitations, of the proposed concept. Accordingly, the study should encompass a parameter trade space that reflects the intended range (for ABL) or elevation angle (GBL, imaging, power beaming, etc.), turbulence condition, optic size, and adaptive optic system prescription (number and location of mirrors, actuator requirements, and wavefront sensor). The breadboard design, whatever the intended application(s) and method of testing, should be scaled accordingly

PHASE II: The multiconjugate adaptive optics system is to be implemented on a breadboard scale and tested over a real, or laboratory-simulated, horizontal path. The offeror may: (1) test the laboratory breadboard at his own or other facility, if such suitable facilities are available, or (2) at the offeror's request, the AFRL may arrange to conduct test, evaluation and analysis of the prototype's performance at the ABL Advanced Concepts Laboratory operated by MIT Lincoln Laboratory or at the Air Force Research Laboratory's North Oscura Peak Facility. The results of the latter evaluation, if chosen, and analysis will be provided to the contractor at no cost to the contractor or the SBIR Program.

PHASE III DUAL USE APPLICATIONS: It is anticipated that a multiconjugate adaptive optics system successfully demonstrated under this research, with economical considerations folded in, would have both commercial and military applications. The military applications include the ABL and follow-on systems, the Starfire Optical Range, and any DOD program utilizing adaptive optics for directed energy systems. The system would also have airborne imaging applications (military as well as commercial), especially for reconnaissance and surveillance systems that must image through turbulent boundary layers. The commercial market includes such areas as astronomy (retrofitting astronomical sites), laser communications systems, power beaming, as well as other potential applications. It is expected that the contractor will focus on flexible Phase I designs which would maximize both the commercial potential and the military potential.

REFERENCES:
1. Michael C. Roggerman and Byron Welsh, Imaging through Turbulence, CRC Press, Boca Raton, 1996.
2. Robert K. Tyson and Peter B. Ulrich, "Adaptive Optics", in The Infrared and Electro-Optical Systems Handbook, Volume 8, SPIE Optical Engineering Press, Bellingham WA, 1993, pp 167-240.
3. Todd D. Steiner and Paul H. Merritt, editors, Airborne Laser Advanced Technology, Proceedings of SPIE, Vol 3381

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-014 TITLE: Novel Wavefront Sensing Techniques

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/TM)--Airborne Laser (ABL)

OBJECTIVE: Develop a wavefront sensor with improved performance over wavefront sensors currently in use in closed-loop adaptive optics systems.

DESCRIPTION: Closed-loop adaptive optics systems use wavefront sensors to measure the incoming phase from a beacon so that the appropriate conjugate phase can be put on a deformable mirror, thereby improving performance. The current Hartmann sensors are limited by camera frame rate, inability to sense waffle mode, sensitivity of alignment to registration errors, and a general incompatibility with branch point reconstructors. These limitations result in overall closed-loop performance considerably below the theoretical limit, and suggest that improved wavefront sensors could dramatically improve the overall system performance.

PHASE I: Using the proposed wavefront sensor concept, bring it to a conceptual design and test the design using wave optics simulations and other design tools.

PHASE II: Build the wavefront sensor prototype and demonstrate its performance on a laboratory breadboard system. The offeror may: 1) test the laboratory breadboard at his own or other facility, if such suitable facilities are available; or 2) at the offeror's request, the AFRL may arrange to conduct test, evaluation and analysis of the prototype's performance at the ABL Advanced Concepts Laboratory operated by MIT Lincoln Laboratory. The results of the latter evaluation, if chosen, and analysis will be provided to the contractor at no cost to the contractor or the SBIR Program.

PHASE III DUAL USE APPLICATIONS: It is anticipated that a wavefront sensor approach successfully demonstrated under this research, with economical considerations folded in, would have both commercial and military applications. The military applications include the ABL and follow-on systems, the Starfire Optical Range, and any DoD program that utilizes adaptive optics for directed energy systems. The system would also have airborne imaging applications (military as well as commercial), especially for reconnaissance and surveillance systems that must image through turbulent boundary layers. The commercial market includes such areas as astronomy (retrofitting astronomical sites), laser communications systems, and power beaming, as well as other potential applications. It is expected that the contractor will focus on flexible Phase I designs which will maximize both the commercial potential and the military potential.

REFERENCES:
1. Michael C. Roggerman and Byron Welsh, Imaging through Turbulence, CRC Press, Boca Raton, 1996.

2. Robert K. Tyson and Peter B. Ulrich, "Adaptive Optics", in The Infrared and Electro-Optical Systems Handbook, Volume 8, SPIE Optical Engineering Press, Bellingham WA, 1993, pp. 167-240.
3. Todd D. Steiner and Paul H. Merritt, editors, Airborne Laser Advanced Technology, Proceedings of SPIE, Vol. 3381.

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-015 TITLE: Advanced High Bandwidth, Large Dynamic Range, Large Size, Fast Steering Mirror

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/TM)--Airborne Laser (ABL)

OBJECTIVE: Develop a large fast steering mirror capable of high bandwidth, large through closed-loop operations

DESCRIPTION: Commercial Off the Shelf (COTS) Fast Steering Mirrors (FSMs) greater than 8 inches in diameter are currently not capable of high bandwidth (>500 Hz), accurate control operations for error rejection tilt errors greater than 1 mrad. Piezo-ceramic actuators have shown great promise for high bandwidth accurate control applications, but are limited to small tilt error rejection due to the low shear strength of ceramics. Voice coil-based actuators, on the other hand, are limited by the accuracy and bandwidth restrictions associated with control of the coil. Recent strides in voice coil control by Schrader suggest a control architecture that could accommodate large size mirrors capable of large, accurate tilt error rejection at high bandwidth.

PHASE I: Perform initial analysis and modeling in order to establish concept feasibility. Develop preliminary design for a large size (>8 in dia.) fast steering mirror capable of >1KHz error rejection for tilt errors greater than 1 mrad.

PHASE II: Finalize Phase I design. Develop, test and deliver prototype mirror with performance characteristics described above.

PHASE III DUAL USE APPLICATIONS: A new FSM with the above listed capabilities would be useful for a number of space and airborne systems including ABL, SBL, and other imaging systems. The potential commercial applications for this technology include real-time mirror coating growth monitoring for high definition TV systems and power line insulator damage detection.

REFERENCES: Schrader, Karl N., "A Modulated White Light Interferometer for Sensing Sub-Wavelength Structural Disturbances," Ph.D. Thesis, University of New Mexico, May 1998.

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-016 TITLE: Tracking in High Scintillation Environments Using a-Priori Information

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/TM)--Airborne Laser (ABL)

OBJECTIVE: Demonstrate the use of maximum a-priori information for tracking in high scintillation environments.

DESCRIPTION: The Air Force is interested in tracking in high scintillation environments for laser propagation and imaging systems. A primary application is the Airborne laser. Conventional and time-tested tracking paradigms do not provide maximum tracking accuracy for these cases. We seek an investigation of algorithms that make optimal use of a-priori information--information such as knowledge of target shape and use of noise statistics--in a unified statistical framework (Bayesian, Max Likelihood, etc.). To date, various modifications of conventional algorithms have been tested and have failed to provide improvement over simple centroid tracking techniques. Most of these investigations have been ad-hoc. While this approach may well result in the sought-for improvements, this solicitation seeks to carry out tracking algorithm investigations in an integrated theoretical framework that sheds light on the failure of recent investigations and leads to new theoretically sound approaches.

PHASE I: Provide a sound paradigm for the general investigation of tracking algorithms in high scintillation environments. Use the paradigm to investigate performance of existing algorithms (e.g. matched filter approaches such as correlation track, various centroiding concepts such as binary, weighted and biased centroid) and to develop new algorithms which make maximum use of a-priori target and noise information. Consideration should also be given to optimally deriving such information on-line. Simulation and analysis will be performed to determine viable candidates for implementation. Select one or more candidates for implementation in Phase II.

PHASE II: Perform final high-resolution simulation of tracker algorithms developed in Phase I and down select to an algorithm(s) that promises considerable tracking enhancement in the high scintillation regime. Develop and test a prototype tracker that incorporates the favored algorithm(s). Possible test sites include the ABL ACT test site at North Oscura Peak, NM and the Advanced Concepts lab at MIT.

PHASE III DUAL USE APPLICATIONS: A tracker which is capable of performing accurate track in a high scintillation environment will have wide application in the DoD community, where long-range tracking through extended atmospheric paths is required. A primary application is for the Airborne Laser System. Other applications include Airborne imaging and shipboard tracking of long-range targets through extended atmospheres. Strictly commercial applications include tracking for imaging systems for TV news helicopters and helicopter imaging systems for power line insulator damage detection.

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1. Brown, W.P., "Simulation of Laser Propagation on Long Stratospheric Paths" Proceedings of SPIE, Aerosense, 3065, Orlando, FL, 23-25 April, 1997.
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4. Ulick, B.L., "Overview of Acquisition, Tracking, and Pointing System Technologies", Proceedings of SPIE, Acquisition, Tracking, and Pointing, 887, 1988.

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-017 TITLE: Development of 1.8 to 3.5 Micron Semiconductor Lasers for IRCM Applications

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop mid-infrared semiconductor lasers emitting in the 1.8 to 3.5 micron range for Band I and II infrared countermeasure applications.

DESCRIPTION: Recent improvements in semiconductor lasers have made them sources practical for use in compact systems for countermeasure applications. Their small size and high efficiency, along with significant improvements in beam quality, mode control, frequency and thermal stability, and output power point to a future in which diode lasers will play a significant role in countermeasure applications. New mid-infrared semiconductor laser material systems are showing tremendous potential and are improving steadily. For example, devices incorporating such designs as the broadened waveguide and tapered amplifier have enabled semiconductor lasers to operate at beam quality and power levels sufficient for infrared countermeasure applications.

PHASE I: Determine laser specifications for infrared countermeasure applications and demonstrate proof of concept. At the end of Phase I, conduct a demonstration of a semiconductor laser capable of operating at 100's of milliwatts peak power (25% duty cycle) with scalability to higher power levels at a wavelength in the range of 1.8 to 3.5 microns

PHASE II: Build and optimize a semiconductor laser meeting infrared countermeasure specifications including 1 watt peak power (25% duty cycle) at a wavelength in the range of 1.8 to 3.5 microns. Deliver a prototype by the end of Phase II.

PHASE III DUAL USE APPLICATIONS: Lasers emitting in the range of 1.8 to 3.5 microns have tremendous potential in many commercial and military applications. Not only can these devices be used in infrared countermeasure applications, but also for environmental monitoring applications. Both of these areas are of great interest in the commercial sector as well as for military applications. In particular, these semiconductor laser devices are needed to replace current inefficient, bulky flash lamps in the Band I and II frequency range for countermeasures.

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1. H. K. Choi, "Current Status of Mid-Infrared Semiconductor Lasers," Annual OSA Meeting, Baltimore MD, October, 1998.
2. H. Q. Le et al, "High Power, High Efficiency, Quasi-CW 4mm Sb-Based Laser," MRS Fall Meeting, Boston MA, December, 1998.
3. H. K. Choi and S. J. Eglash, "High Power Multiple Quantum Well GaInAsSb/AlGaAsSB Diode Lasers Emitting at 2.1 mm with Low Threshold Current Density," Appl. Phys. Lett., Vol 61, pp.1154-1156, 1992.
4. D. Garbuzov, et al, "1.5 mm Wavelength, SCH-MQW InGaAsP/InP Broadened Waveguide Laser Diodes with Low Output Power," Electron. Lett., Vol. 32, pp. 1717-1719, (1996).
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KEYWORDS: diode lasers, environmental monitoring, infrared countermeasures, mid-infrared lasers, mode control, semiconductor lasers, thermal stability

AF00-021 TITLE: Compact Semiconductor Laser-Based Environmental Monitoring System Development

TECHNOLOGY AREAS: Chemical/Biological Defense, Sensors/Electronics/Battlespace

OBJECTIVE: Develop mid-infrared semiconductor lasers for in situ and remote environmental monitoring and detection of chemicals.

DESCRIPTION: Recent improvements in semiconductor lasers have made them sources practical for use in environmental monitoring/analysis. Their small size and high efficiency, along with significant improvements in beam quality, mode control, frequency and thermal stability, and output power, point to a future in which diode lasers will play a significant and dominant role in environmental sensing. Advances in semiconductor "quantum-well" lasers have enabled engineers to "dial-in" the laser emission wavelength. Of particular interest are wavelengths from 2 to 10 microns. In the 2 to 5 micron wavelength region, small molecules found in industrial environments, such as CO2 and CH4, could be monitored. Also in that range, detection of molecules such as tributyl phosphate, known to be important in the production of weapons of mass destruction, is possible. Organic molecules associated with chemical warfare could be detected using semiconductor lasers at longer wavelengths. For example, mustard gas has a strong absorption line at 8.2 microns. Given the advances noted above and the co-technology advances in monitoring methodologies, it is desirable to research and develop fieldable, rugged, and sensitive diode laser-based environmental monitoring systems. It is important to demonstrate that the proposed semiconductor laser-based system has a clear advantage over conventional systems.

PHASE I: Demonstrate proof of concept. Select a promising application using semiconductor lasers, and perform a preliminary investigation to determine laser specifications for the chosen application and required system design parameters. Carry out experiments to prove concept potential. Deliver a preliminary design at the end of Phase I.

PHASE II: Develop demonstrate, and deliver a semiconductor laser prototype device. Ideally, demonstration of the device should be conducted in the operational area in which it will be used.

PHASE III DUAL USE APPLICATIONS: With the increasing pressure for industry to monitor its environmental impact the commercial market for environmental monitoring is tremendous. Military applications include the need to detect manufacturing plants for chemical weapons, testing and detonation of chemical weapons, and even detecting vehicle fumes to monitor convoy activity. A specific example of a military application is a hand-held chemical detection system capable of detecting, identifying, quantifying, and warning personnel of the presence of chemical weapons.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-022 TITLE: Gratings for High-Power Yb-doped Fiber Lasers

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop gratings for use with high-power Yb-doped fiber laser systems.

DESCRIPTION: The Yb-doped dual-clad fiber laser is a leading candidate for use as a compact high-power continuous wave laser system. There are efforts to scale the power of individual fiber lasers to the limits of the dual-clad fiber. Arrays of fibers are envisioned to allow power scaling even further towards kilowatt class lasers. An enabling technology for power scaling of individual fibers and fiber arrays is the use of gratings; among others, the gratings may include Bragg gratings, holographic gratings, and conventional gratings. Bragg grating applications include single wavelength operation (for potential phasing of fiber arrays), enhancement of coupling waveguided pump light to the lasing core, mitigation of nonlinear optical effects, etc. Gratings may be applied in alternative methods for coupling laser diode pump light to the fiber laser. Improved gratings can be useful for beam combination of laser diodes or fiber lasers. The grating implementation should be capable of handling high powers commensurate with scaling goals: ~ 100 W for individual lasers, ~ 1 kW for fiber arrays. Successful proposals will provide an innovation or improvement in grating application or grating technology that will benefit the power scaling of individual fiber lasers or fiber arrays.

PHASE I: Design, model and perform adequate proof-of-principle demonstrations of improved gratings or grating applications to give confidence for the success of a Phase II program.

PHASE II: Based on Phase I designs, models, and proof-of-principle demonstrations, conduct in-depth testing and refinement of prototype hardware to show a maturity of technology toward potential commercial and military applications.

PHASE III DUAL USE APPLICATIONS: Air Force directed energy applications for this technology may have important commercial parallels such as communications, printing, and materials processing lasers.

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6. "Power scaling of fiber lasers", C.L. Balestra et al, DLTR Conference, Albuquerque, June 1997.

KEYWORDS: Bragg gratings, beam combination, diode coupling, gratings, high power fiber laser, holographic gratings

AF00-023 TITLE: Cost-Effective, Scalable, High-Power, Mid-IR Optically (laser) Pumped Molecular Laser Source

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Conduct R&D on novel concepts for cost-effective, scalable, high-power mid-IR laser-pumped molecular gas lasers.

DESCRIPTION: The Air Force Research Laboratory (AFRL) is interested in conducting research and development in cost-effective, high-power, scalable, laser-pumped, mid-infrared (mid-IR) molecular laser sources. Future AF missions will require high-power lasers with output in the mid-IR spectral region. Current gas phase system concepts for high-power lasers utilize gas and chemical laser technology to exploit the inherently scalable nature of these media. However, these sources of high-power radiation are typically large, can be expensive to operate, and may require significant logistical support to enable long-term operation.

Alternative techniques for the efficient production of high-power mid-IR light using optically pumped, laser-pumped molecular gas lasers are sought. These devices are envisioned to be cells that are filled with a molecular gas. The gas is then optically pumped at short wavelengths with a solid state laser source, laser diodes, or fiber lasers, to a high-lying vibrational level. This produces a population inversion and lasing between the pumped level and lower adjacent vibrational levels at longer wavelengths.

This is fundamentally a different concept than direct lasing from a solid state material in the 2 - 5 micron range. Instead laser photons are resonantly absorbed by a gas at short wavelengths on a high vibrational level, for example, V = 2,3, or 4. Cascade lasing in the molecular gas can then occur sequentially on DV = 1 transitions. AFRL/DELC has demonstrated 25% (theoretical) conversion efficiency on a number of hydrogen and deuterim halides with pumping from V=0 to V=2 and lasing from V=2 to V=1. The DV = 1 vibrational frequencies of the hydrogen and deuterim halides lie between 2.7 and 5 microns. Potential advantages of this approach are the following: (1) The pump laser does not need good beam quality although it does need narrow bandwidth to match the line width of the molecular absorption. (2) Arrays of unphased pump lasers can be used to excite the gas. (3) Phasing of the pump radiation can then occur on the down converted radiation with the gas cell resonator. (4) It may be possible to use highly developed pump lasers between 1 and 2 microns such as neodymium in different hosts, arrays of diodes, or arrays of diode pumped fiber lasers. The key technical issues that must be addressed are: (1) narrow banding the pump source and; (2) developing multipass optical designs that will maximize the absorption of the pump radiation. Concepts that can show significant cost reduction benefits through leveraging from technologies currently developed for, and employed in, high volume industrial applications are especially of interest. Continuous wave or pulsed pumping techniques employing direct or resonant pumping schemes should be evaluated.

PHASE I: Evaluate the laser pumped molecular laser concepts using a solid state pump between 1 -2 microns and select the optimum configuration. An optimum wavelength is 4.0 microns and the HBr Laser is a good candidate. Perform a proof-of-principle demonstration showing the feasibility of the optical pumping architecture. This verification experiment, along with applicable modeling and analysis, will lead to a scalable laser design concept.

PHASE II: Assemble and test an appropriately scaled version of the laser design developed in Phase I. The performance of this device if pulsed will produce 5 J/pulse at 10 Hz and if CW will produce 50 watts. Address key issues and experiments identified in the Phase I analysis. Demonstrate scaling concepts using the chosen pump source. Generate an engineering design for a scaled device by mutual agreement with AF representatives and predict its performance using appropriated modeling.

PHASE III DUAL USE APPLICATIONS: This phase will involve the generation and implementation of marketing plans for the technology developed during the first two phases. These technologies are expected to have applications in a variety of high volume commercial applications in the medical, materials processing and other industries.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-024 TITLE: High-Power Fiber Laser

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop High-Power, Highly Efficient, Compact, Electrically Driven Fiber Lasers for Adjunct Space Based Laser (SBL), Airborne Laser, and other Directed Energy (DE) AF missions.

DESCRIPTION: Fiber lasers have demonstrated efficient optical-to-optical power conversion into a diffraction-limited laser beam. Air Force DE missions require electrically efficient, compact, scaleable architectures leading to tens of kilowatts of continuous-wave power in a diffraction-limited beam. This solicitation is for the development of enabling technologies that make possible kilowatt-class, Yb-doped, (1.1-micron) fiber lasers. These new technologies may benefit from the manufacturing techniques and lessons learned from such industries as those in integrated electronics and fiber communications. New enabling technologies may include: 1) all-glass fibers, photonic crystals, polarization-preserving and other innovative fibers specifically designed for high-power fiber lasers; 2) efficient micro-optic, waveguide, or other novel optic systems for coupling of diode-laser emission into fibers; 3) ultra-compact packaging conducive to machine-vision assembly and mass-producible manufacturing methods; 4) novel uses of Bragg gratings for fiber laser performance enhancement, nonlinear optical effects mitigation, or pump-coupling; 5) multi-core fibers, fiber bundles, and novel techniques for coherent and incoherent beam-combining arrays. Successful proposals will be keen on scaleable (kilowatt-class), mass-producible (x20 long-term cost reduction goal) fiber laser architectures or technologies leading to high-electrical efficiency (approaching 30-40%) and high-power density packaging (approaching 10W/cm3).

PHASE I: Design, model, and perform adequate proof-of-principle demonstrations to give confidence for the success of a Phase II program.

PHASE II: Based on Phase I designs, models, and proof-of-principle demonstrations, conduct in-depth testing and refinement of prototype hardware to show a maturity of technology toward potential commercial and military applications.

PHASE III DUAL USE APPLICATIONS: Air Force directed energy applications for this technology may have important commercial parallels, such as communications, medical, printing, and materials processing lasers.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-031 TITLE: Very High Speed, Low Power, Radiation Hard, CMOS and BiCMOS Circuits for Space Applications

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: Develop process(es) for dramatically faster p-channel devices compatible with standard silicon-based, radiation hardened CMOS technology for use in very high-speed circuits for space-based applications.

DESCRIPTION: Silicon-based circuits have enjoyed a sustained, incremental improvement in performance through reduction in the size of device lithographic features. However, currently the highest speeds are 1-10GHz. One of the important fundamental limiting factors is the significantly lower hole-mobility relative to electron mobility in silicon. One possible avenue to increasing the speed of silicon circuits is the use of silicon-germanium alloys. Silicon-germanium HBT technology has matured dramatically. Silicon-germanium has been integrated into a silicon-based process by IBM and has found application in RF-circuits. Another promising application of the silicon-germanium system is the p-MOSFET. Because the hole-mobility in germanium is almost five times as large as that in silicon, insertion of silicon-germanium p-MOSFETs into a CMOS technology has the promise of considerably increasing the overall circuit speed. To date, however, only modest improvements in bulk hole mobility (50%) and in effective channel mobility (90%) have been realized. Recently, it has been found that silicon-germanium-carbon holds even greater promise as a channel material. For space applications, either of these material systems would have to exhibit tolerance to high-energy radiation. It has been previously demonstrated that silicon-germanium HBTs are remarkably tolerant to radiation; however, to date there is no literature on the behavior of the silicon-germanium p-MOSFET. There is also no data at all on the radiation behavior of devices based on silicon-germanium-carbon. The goals of this SBIR are threefold: First, we want a optimized growth process for p-channel devices that demonstrates significant (at least a factor of three) improvement in the hole mobility over conventional silicon in a fully fabricated p-MOSFET. Second, we want an evaluation and, eventually, an optimization of the radiation response of these optimized devices. Third, we want these devices integrated into a silicon-based CMOS process. Proposals for materials systems other than Si-Ge or Si-Ge-C are welcomed, but the proposal must show how these systems are compatible with silicon processing, and how they are economically competitive.

PHASE I: Develop a conceptual process or processes for layer growth that will lead to bulk and channel mobilities for p-channel MOSFETs that are increased by a factor of 2-3. Demonstrate proof of concept and that these processes can be integrated into silicon CMOS processing. Provide a process plan for prototype devices that uses 0.8 micrometer design rules.

PHASE II: Deliver prototype integrated circuits that include the high-performance p-MOSFETs. Fabricate the circuits with 0.8 micrometer design rules. Optimize the channel characteristics and evaluate the radiation tolerance of the prototype ICs. We expect a proof of concept that these are scaleable to at least 0.2 micrometer design rules.

PHASE III DUAL USE APPLICATIONS: Integrate the process and, if necessary, optimize the process for radiation tolerance. Deliver a CMOS circuit with high-speed p-channel devices with identical, or nearly identical geometry to the n-channel devices.

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2. A. C. Mocuta, D. W. Greve, R. M. Strong, Improved Process Window Using Low-Carbon Si1-x-yGex Cy Epitaxial Layers, Presented at the Fall 1998 Materials Research Society Meeting, Boston, MA.
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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-032 TITLE: <u>Advanced Micro-Mechanisms for Small Satellites</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Demonstrate low cost, ultra-lightweight, miniaturized spacecraft mechanisms for deployment and precision pointing that can meet future DoD small spacecraft requirements.

DESCRIPTION: The new paradigm for spacecraft calls for performing missions at lower cost with satellites weighing approximately 100 kilograms rather than the 1000-kg satellites currently used. Current spacecraft mechanisms for release, deployment, and precision pointing are far too large and expensive to be considered, and scaling down may be impractical for microsat (<100kg) and nanosat (<10kg) applications. In recent years, a number of new technologies have emerged which make it feasible to construct extremely small, lightweight, and inexpensive mechanisms for use on small satellites. The primary goal is to reduce both the weight and the cost of mechanisms for deployment and precision pointing by a factor of 10 over what is available in Commercial Off-The-Shelf (COTS) technology. A key component of the program will be to take advantage of the multi-functionality. Emphasis will be placed on hardware demonstration.

PHASE I: Develop conceptual designs of the mechanism based on preliminary analysis. Perform sufficient hardware development and testing to insure that the system requirements can be met. Conduct proof-of-concept demonstrations to indicate the practicality of the design in meeting operational requirements and objectives. Perform a comprehensive review of small sat requirements.

PHASE II: Finalize the mechanism design and validate its performance by meeting Air Force requirements. Develop and demonstrate full-scale operational flight hardware for a specific satellite. Demonstrate scalability of the hardware for satellites of different size (10-100 kg) and function.

PHASE III DUAL USE APPLICATIONS: Commercial and military applications exist for the development of miniaturization spacecraft mechanisms to support the future DoD small satellite requirements. Military applications include programs such as TechSat 21, the AFRL's XSS technology demonstration series, and the Air Force Space Test Program payloads. Commercial applications include the small university payloads and experiments that are now being launched on small/micro satellites.

REFERENCES:
1. K. Marino, New Millennium Represents a Revolution in Spacecraft Design, JPL Universe, 10 February 1995.
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KEYWORDS: deployment, low-cost, mechanisms, multi-functional, precision pointing, separation, spacecraft

AF00-033 TITLE: Advanced Integrated Spacecraft and Launch Vehicle Technologies

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop advanced technologies for launch vehicles and that will reduce the spacecraft life-cycle-costs.

DESCRIPTION: Existing technologies may not be able to meet requirements for future DoD satellite programs. The use of pyrotechnics, for example, will expose fragile sensors and electronics to high shock levels, and sensitive optics might be subject to contamination. In the past ten years, several new technologies have been developed that are having or could have an impact on the aerospace industry; these technologies include isolation, integral damping, composite structures, integral thermal protection, low shock separation, acoustics, etc. Some examples of new structural concepts that have been recently developed are Grid stiffened structures, Chambercore structures, Wavy Fiber Composites, and Multifunctional structures. We are looking for innovative ways to integrate these newly developed technologies into a new system (shrouds, adapters, etc.) that can result in significant cost, reliability, and weight savings for expendable launch vehicles and their satellites. The integration of key technologies could have significant weight reductions that will result in more payload capability for that launch vehicle going to orbit. Each of these new technologies, while promising, currently has significant risks that must be addressed through development, demonstration, and integration. The technologies that are to be developed need to address issues such as reliability, safety, weight, low cost manufacturability and integration, reduced part count, and the ability to meet requirements of that spacecraft/launch vehicle. It is desired that one or a combination of these advanced technologies be integrated.

PHASE I: Formalize and provide supporting analysis for an innovative concept for incorporating the advanced technologies for space systems. Proposers need to define the problem, including specifications and any potential restrictions or limitations faced in the implementation of the technology or technologies with the launch vehicle and satellite manufacturers. Identify the main parameters that influence the integration. State system-level performance goals and develop system component/system level conceptual designs. Present analytical and simulation results to demonstrate performance of the system.

PHASE II: Perform component and ground tests to demonstrate and validate the concept developed in Phase I. Design, fabricate, and test a full-scale demonstration for evaluation.

PHASE III DUAL USE APPLICATIONS: DoD, NASA, and commercial launch vehicle and satellite manufacturers are interested in developing innovative technology that will save weight, cost, and time. This technology will reduce the environment that the spacecraft will need to be designed against, which consequently will reduce the number of satellite failures that occur. This technology will allow the use of instrumentation, sensors, and equipment that currently survive the existing environments. Potential military applications of this technology include Space Based Radar, Space Based laser, SBIRS Low and High, and the Air Force Launch Vehicle Offices. Potential commercial users include Orbital Sciences and Lockheed Martin who are already using isolation technology for their small launch vehicles.

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2. Dr. Bernie F. Carpenter "Shape Memory Release Device Experiment". 11th ASCE Engineering Mechanics Conference, Fort Lauderdale, FL, May, 1996.

KEYWORDS: acoustics, composites, isolation, low cost, low-shock separation, multifunctional structures, spacecraft expendables launch vehicles

AF00-035 TITLE: Composite Flywheel Structure

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a methodology for the design and manufacture of composite flywheels for spacecraft using novel concepts and with an emphasis on high fiber volume fraction.

DESCRIPTION: Spacecraft flywheels show great promise to reduce spacecraft mass through the integration of energy storage and attitude control functions. Additionally, flywheels have the ability to charge and discharge very rapidly and repeatedly to depths much greater than batteries. Composites have been proven to be an ideal material for flywheel applications, and AFRL and NASA are developing prototype systems based on state-of-the-art unidirectional winding techniques. Past AFRL/NASA efforts have focused and continue to focus on exploring the limits of this rotor technology. These traditional rotors have been limited by their strength in the radial direction. Typical high-fiber volume fraction composite manufacturing techniques provide for high strength inplane to the fibers but low strength through the laminate thickness. Therefore, the radial stresses developed during the high rotation speeds of flywheels tend to limit the flywheel's top speed. Alternative manufacturing techniques that include radial-direction fibers tend to lower the fiber volume fraction, and therefore the strength/weight ratio of the flywheel.

PHASE I: Show by analysis & testing an approach to building composite flywheels with high fiber volume fraction and/or reduced susceptibility to radial stresses.

PHASE II: Fabricate a full-scale flywheel using the developed technique and demonstrate by testing its improved characteristics.

PHASE III DUAL USE APPLICATIONS: Potential commercial applications for this technology include all future commercial space vehicle systems. Effective flywheels mechanisms will lead to lighter and cheaper commercial satellites of all kinds, including telecommunication, weather, monitoring and entertainment applications. Potential DoD applications include all future DoD space vehicle systems. This technology will result in lighter, cheaper and more reliable DoD satellites and spacecraft. Additionally, this technology can be considered enabling for DoD systems with high power surge requirements such as Space-Based-Radar and Space-Based-Laser. Potential NASA applications include International Space Station and future earth observing satellites.

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3. "Flywheel Technology for Aerospace Applications," D. A. Christopher, Lt. C. Donet, Proceedings IEEE Aerospace Conference, Mar, 1998.

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-036 TITLE: Threat Warning/Attack Reporting Laser Sensor

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: Develop cost-effective technologies to detect, identify, locate, characterize, and report laser attacks or interference against U.S., and Allied and Commercial satellites.

DESCRIPTION: The program will focus on the demonstration of a threat warning and attack reporting laser sensor. The objective is to miniaturize the sensor package to reduce the weight and power requirements from current capabilities. The laser technology program will demonstrate the laser sensor on the ground with eventual demonstration in space. A visible and infrared subassembly should be used to cover the required wavelengths while maintaining the needed sensitivity and false alarm rejection. The laser sensor should provide two types of information--incident information, and threat information. Incident information is an alert that a threatening event has taken place, and includes where and when the sensor perceived the event. Threat information is used to determine what type of system delivered the attack and where it is based. There are several design issues involved with this effort, including determining performance threshold and goals, evaluating the laser sensor concept for maximum optimal performance, evaluating the candidate detector, modeling the performance of the optical and electronic elements, formulating efficient detection and signal characterization algorithms, and evaluating the sensor packaging technique. Since the laser sensor is intended for nearly universal deployment, the design goals place emphasis not only on sensor performance, but on miniaturization, low mass, and low power consumption. A laser sensor must be sensitive to energy levels many orders of magnitude lower than those which can damage; however, this same sensor ideally must be able to survive any damage. In order to conserve mass and power usage, it is hoped that a single, uncooled detector will suffice for the entire waveband of interest; however, while a cooled detector could greatly enhance infrared detection performance, the cost in both power and weight would be unacceptable. The sensitivities of available uncooled detector arrays, as well as the need for increased sensitivity at visible wavelengths, requires the use of a dual band system.

PHASE I: Design and characterize the laser sensor concept.

PHASE II: Develop a prototype of the laser sensor and test it under appropriate conditions for space and other high performance commercial and military applications.

PHASE III DUAL USE APPLICATIONS: The laser sensor technology developed in Phases I and II will be transitioned to the production of sensor systems suitable for both military threat warning/attack reporting systems and similar systems for laser-sensitive commercial spacecraft. A sensor that could detect and warn of laser emissions would add another safety factor for people involved in the use and study of lasers.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-037 TITLE: Advanced Satellite Docking Mechanisms and Ports

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a satellite docking port that provides mechanical, power, data, fluid, and thermal connections, suitable for attaching an orbital replacement unit (ORU).

DESCRIPTION: Cost effective, on-orbit, satellite servicing (assembly, maintenance, supply, etc) requires that servicing activities be automated. In the near term, this requires reducing the complexity of servicing activities to a level compatible with current intelligent machines. One way to simplify operations is to provide docking ports, on satellites, to which servicing micro-satellites can mechanically dock, connect an ORU, and leave. Such a port would also allow the micro-satellite to connect directly, acting as a temporary ORU. It is therefore necessary to design these docking ports--both satellite and servicer sides--including mechanical docking hardware and connections for data, power, heat, and fluid transfer. Ideal designs would be mechanically simple, low cost, low power, and self-aligning and/or impact absorbing, allowing error in service craft position, orientation, and velocity during docking. They would provide all required connections, and have a low likelihood to fail, leak, or leave fluid behind when disconnected. Mechanisms should be consistent with automated, camera guided rendezvous by the servicing micro-satellite.

PHASE I: Identify components that could become ORUs. Determine required connections for these components. Evaluate existing and/or new designs for suitable connectors. Determine the optimal set of connectors to support a variety of ORUs while minimizing weight and complexity. Produce one or more designs for ORUs and ports, including ports with all connections, and ports with reduced sets. Provide notional designs of docking mechanisms required to attach the ORUs to the ports.

PHASE II: Downselect to one design for each type of port (communication only, fluid transfer, hardware attachment, etc.), and build one or more prototype ports. Also build prototype docking mechanism(s) and ORUs compatible with the ports. Demonstrate manual docking, connection, and transfer of fluid, heat, data and power across the interface. Identify and/or implement improvements that would be necessary to upgrade the system to work in space.

PHASE III DUAL USE APPLICATIONS: PHASE III DUAL USE APPLICATIONS: Military and commercial potential exists for maintaining and refueling new GEO satellites, and any new, large/expensive LEO satellites. In addition, the technology could decrease production costs for satellites mass produced for constellations by facilitating post-production customization and allowing simple retrofits to repair defects discovered during a production run or during ground testing. Potential DoD, NASA, and commercial applications include on-orbit maintenance/refueling for the Air Force SBIRS Low and High programs, Space Based Radar, Space Based Laser, and Iridium, Teledesic, etc.

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KEYWORDS: connectors, couplings, docking, docking power, on-orbit servicing, orbital replacement unit (ORU), refueling

AF00-038 TITLE: Expert System for Predicting Vibroacoustic Environments

TECHNOLOGY AREAS: Information Systems, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/CL)--Launch Programs

OBJECTIVE: Develop an expert system of software to perform vibration, acoustic and shock environmental predictions based on previous vibroacoustic spacecraft launch data and recent advances in mid-frequency acoustic prediction tools.

DESCRIPTION: Prediction of vibroacoustic and shock environments for both DoD and commercial launch vehicles, as well as spacecraft, has become a costly, labor-intensive process, yet such analysis is essential to assure reliability of vehicle structure and airborne equipment. The objective of this topic is to develop an analytical tool that will use a combination of theoretical and empirical methods to provide--in an automated sequence--a more accurate prediction of the vibroacoustic and shock environments. The theoretical methods should explore increased accuracy in the prediction of vibroacoustic environments in spacecraft launch vehicles. In particular, finite element methods and boundary element methods have been shown to have sufficient accuracy at relatively low frequencies, but are computationally expensive and loose accuracy at higher frequencies. Statistical energy methods, on the other hand, have been shown to be accurate at relatively high frequencies but lose accuracy at lower frequencies. Recent advances in mid-frequency prediction have the potential to greatly improve the accuracy of vibroacoustic prediction methods in spacecraft launch vehicles across the entire frequency band. Improved accuracy in prediction should result in fewer spacecraft failures and possibly reduced testing requirements. In addition, improved accuracy would greatly facilitate current efforts at AFRL/VSDV investigating innovative methods of vibroacoustic control in launch vehicles. The analytical tool to be developed will allow the user to perform analyses at the spacecraft/launch vehicle location of interest.

PHASE I: Develop software prototype program with analysis and database capability. Provide a proof-of-concept demonstration.

PHASE II: Refine, debug and simplify the software, and generalize input and processing in a manner to make the final product usable by a wide variety of potential customers in aerospace applications. Provide demonstration of software prototype and compare to experimental results on representative mutually agreed vibroacoustic testbed.

PHASE III DUAL USE APPLICATIONS: Provide full-scale demonstration to (Air Force/Contractor) specifications on mutually agreed launch vehicle and compare to test data. The final software product should be usable for many types of military and commercial structural applications--it should be applicable not just to space vehicles, but also in the civil engineering, aircraft design, automotive design and other similar structural fields.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-039 TITLE: Thermally Conductive Hinge Materials for Deployable Radiators

TECHNOLOGY AREAS: Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop deployable radiator hinge configurations to facilitate heat rejection in future satellites.

DESCRIPTION: At today's level of technology, conventional spacecraft have surface areas capable of rejecting internal waste heat using structural panel radiators or body mounted radiators. Present (commercial and military) trends are that satellite power will increase and satellite size will decrease (with the use of high-density electronic packaging techniques). At some point, there will not be adequate area on the satellite to reject the internally generated heat, and advanced radiators will be necessary. Within the next five years, the need for deployable radiators will be obvious. However, the critical design feature for high heat rejection on a deployable radiator is transporting the waste heat across the hinge. Thermal straps and high conductivity composite hinge materials, although they have an advantage in their simplicity, are not feasible because of high interface resistance which limits the heat transfer capability and reduces the heat rejection potential. Other methods of transporting heat across the hinge (e.g., heat pipe, flexible bellows, and coiled tubes) have been investigated in the past. Among the key technologies for future deployable radiators is the development of reliable lightweight hinge materials and systems. Considering the severe weight constraints of future spacecraft, the technological challenge is high. Some combination research should be focused on the above-mentioned technologies with fiber materials. In all cases, the increases of heat transport across the deployable radiator hinges require proper design and selection of materials. To this end, the sensitivities of the thermal design with respect to material characteristics and flight environment have to be well understood. This topic solicits proposals for innovative new concepts for new materials and systems having extremely good interface thermal conductance (100 Watts/degree C) and heat transport capability (1000 Watts). The radiator operating temperature range is -75 to 100 degrees C with the deployable angle which lies between 85 degrees to 185 degrees.

PHASE I: Address the identification of promising hinge materials for use in advanced deployable radiator systems. Emphasis should be placed on the heat path across and around the hinges and dependence of heat transfer on material properties and characteristics. Consider the dependence on hinge diameter, weight and contact area. Thermal analysis should include all heat transfer modes (e.g., radiation, conduction and convection). Identify candidate materials and hinge designs. Provide demonstrations of the heat transfer characteristics of breadboard material/hinge configurations.

PHASE II: Finalize material selection and hinge designs. Manufacture and test prototype, flight configuration, and material/hinge assemblies to mutually agreed specifications and environments.

PHASE III DUAL USE APPLICATIONS: Material/hinge assemblies developed as a result of this topic shall be applicable to future commercial and military satellites alike.

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KEYWORDS: deployable radiators, heat rejection, interface resistance, radiator hinges, spacecraft, waste heat

AF00-040 TITLE: Boiling Enhanced Micro-Channel Heat Sink for Electronic Cooling

TECHNOLOGY AREAS: Materials/Processes, Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop a heat removal device to enhance high density integrated circuit (IC) cooling.

DESCRIPTION: In recent years, advances in microfabrication technology have enabled the increasing miniaturization of many systems. Apart from the enabling technologies in electronic design, the importance of the associated problem of thermal control to prevent the electronic components such as IC (integrated circuit) chips from overheating cannot be overemphasized. For example, the large number of transistors on an IC chip, and the packing of multiple chips into a compact module, result in a substantial amount of waste heat dissipation that must be removed. The effectiveness of utilizing heat conduction or forced convection is limited by the available heat transfer area and by the relatively small effective heat transfer coefficient. There is a need for compact, higher capacity cooling devices. For example, micro heat exchangers consisting of numerous minute flow channels with hydraulic diameters ranging from 10 to 100 micrometers have an extremely high surface-to-volume ratio. For aerospace systems, the higher heat removal capability of micro heat transfer devices enables effective thermal control of densely packaged high power avionics/space-based equipment. A thermal control device with extremely high heat transfer rate--such as the Boiling Enhanced Micro-Channel Heat Sink (BEMCHS) which consists of numerous micro-channels with micro-configured surfaces--can be used to enhance boiling heat transfer for the cooling of electronics. BEMCHS is an active (mechanically pumped) device, as compared to other passive micro-scale heat transfer devices (e.g., micro heat pipes and micro heat exchangers). BEMCHS can consist of multiple parallel banks of micro flow channels of about 100 micrometers in hydraulic diameter, which are fabricated by microdiamond machining. The micro-configured surfaces, which are produced by microelectrical discharge machining, consist of a regular pattern of cavities on an otherwise smooth surface to serve as nucleation sites to enhance boiling. Heat transfer rates in excess of 1000 Watts/cm squared have been demonstrated. Boiling from micro-configured surfaces has been shown to increase heat transfer from smooth surfaces by over 300%. Successful, innovative development of BEMCHS will yield a substantial increase in the thermal control capability of high-power electronics and integrated circuits, resulting in substantially increased IC chip packing density of electronic devices.

PHASE I: 1) Investigate the feasibility and the application of BEMCHS for electronic cooling, as well as generate analytical data on the micro-scale transport processes. 2) Perform a trade study to determine the optimal operating limit of micro heat pipes and micro heat exchangers as compared to BEMCHS. Consideration should be given to utilization of passive fluid flow designs for BEMCHS application. 3) Design, construct, and demonstrate a breadboard BEMCHS device.

PHASE II: 1) Finalize the design and development of a BEMCHS device. 2) Construct, demonstrate and characterize its thermal performance by both test and analyses.

PHASE III DUAL USE APPLICATIONS: The application of BEMCHS in the thermal control of DoD and commercial aerospace will result in significantly denser packing of avionics equipment within a given space.

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KEYWORDS: boiling enhanced micro-channel heat sink (BEMCHS), electronic cooling, heat transfer coefficient, integrated circuit chips, micro heat exchangers, thermal control device

AF00-041 TITLE: Payload Fairing Active Noise Cancellation

TECHNOLOGY AREAS: Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MV)--Evolved Expendable Launch Vehicle (EELV)

OBJECTIVE: Develop/demonstrate an active noise cancellation system to reduce the acoustic energy within the launch vehicle payload fairing during launch.

DESCRIPTION: The acoustic energy generated during the launch process can damage the payload (spacecraft). Present methods to reduce acoustic energy levels in the payload environment include sound absorbing blankets and Helmholtz resonators. These methods consume payload fairing volume and introduce cleanliness problems. An active noise cancellation system would eliminate the need for these passive devices and could result in further reduction of acoustic levels. NASA Langley is currently developing piezo electric film systems to cancel noise in aircraft; this approach (among others) might be applied to launch vehicle noise reduction. Piezo electric films would consume negligible payload fairing volume.

PHASE I: 1) Conduct a thorough review and evaluation of applicable noise cancellation technologies. 2) Evaluate alternatives resulting in the selection of the design approach best suited to this problem. 3) Design a system using the selected alternative. 4) Simulate the design showing expected performance with typical launch vehicle acoustic levels and frequencies together with expected power consumption of the active system, estimated system energy level reductions, volume savings, and system cost.

PHASE II: 1) Produce final design/manufacture of a prototype active cancellation system to be used for testing. 2) Perform a complete test and analysis (to Air Force/contractor mutually agreed specifications) of system performance/reliability, including (among other issues) energy level reduction from 0 to 10,000 Hz, power consumption, and actual cost to manufacture the system.

PHASE III DUAL USE APPLICATIONS: An improved Active Noise Cancellation System design will be applicable to military and commercial satellite launch systems. A more effective system design would benefit commercial launch systems, allowing more payload area volume and simplified cleaning procedures.

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KEYWORDS: helmholtz resonator, launch vehicle noise reduction, noise cancellation system, piezo electric film, reduction of acoustic levels, sound absorbing blankets

AF00-042 TITLE: Artificial Intelligence Hybrid Range Scheduler

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/CW)--Satellite/Launch Control

OBJECTIVE: Develop hybrid artificial intelligence techniques for resource scheduling in mission systems.

DESCRIPTION: The scheduling of ground and space resources, e.g., antennas, communication lines, sensors, computers, etc. for complicated mission operations while satisfying many constraints in priority, temporal and location dependency, criticality, etc. is a very complex nonlinear problem. Conventional mathematical optimization techniques have not been able to solve this type of problems with reasonable computation time. Current automated scheduling schemes are not capable of producing near optimal results in real-time for maximum system performance and resource utilization. Use of a single artificial intelligence (AI) technique (e.g., neural networks, fuzzy-logic, genetic algorithms, adaptive problem solvers, etc.) for real-time, automated resource scheduling has been only successfully demonstrated for simple systems such as vehicle dispatching and data routing with small number of constraints. Each of the above-mentioned AI techniques has specific strengths and weaknesses in solving large complex scheduling problems. The purpose of this research is to develop innovative hybrid AI techniques for resource scheduling of large, complex mission systems such as satellite control operations with adaptive and learning capabilities that can respond to changing rules, constraints and scenarios in real-time. At least two intrinsically different techniques should be developed. Each candidate technique will be assessed in terms of computation (response) time, optimality of its scheduling results, generality, extensibility, and degree of human intervention required.

PHASE I: The Phase I effort shall include, but not limited to (1) characterization of resource scheduling problem for large complex mission systems, (2) establishment of scheduling performance measures and evaluation criteria for ranking different techniques developed, (3) formulation of candidate hybrid AI scheduling algorithms, (4), development of hybrid AI techniques suitable for resource scheduling application, and (5) demonstration of the feasibility and performance of each hybrid scheduling algorithms against a representative mission system such as the satellite contact scheduling of the Air Force Satellite Control Network.

PHASE II: The Phase II effort shall include, but not limited to (1) refinement of the scheduling algorithms developed in Phase I to improve scheduling performance and efficiency, (2) expansion of the scheduling generality and flexibility to cover more mission application areas, (3) implementation of a test bed for the experimentation and evaluation of various hybrid AI techniques against different mission systems, and (4) documentation of research results, algorithms coding and test bed for possible technology transfer and insertion to actual mission system development programs.

PHASE III DUAL USE APPLICATIONS: The hybrid AI scheduling techniques and algorithms developed from this research are applicable to a wide range of military and commercial systems that require resource scheduling capability.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-044 TITLE: GPS-based User Equipment (GbUE) for all Altitude Tracking

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/CW)--Satellite/Launch Control

OBJECTIVE: Develop a prototype low cost, low power, lightweight and miniaturized GbUE unit and GPS-based tracking operation procedure for all altitude satellite tracking applications.

DESCRIPTION: Driven by the need to reduce cost, and simultaneously to enhance tracking performance for the Air Force Satellite Control Network (AFSCN), the DoD has initiated studies in recent years to determine alternative navigation/tracking technologies for future implementation. GPS has emerged as the most promising candidate technology to achieve this ambitious goal. A GPS user needs to have four or more GPS satellites in view in order to determine its own position. This visibility requirement easily can be satisfied for users on or near the earth surface, even including low earth orbit (LEO) satellites. GPS applications to high-altitude space users pose special challenges. For instance, the number of GPS satellites visible to a geosynchronous orbit (GEO) user varies between zero and three, which is inadequate for a determinate position solution. If augmented by a Kalman filter, it has been shown that GPS tracking of space vehicles at high altitudes (up to GEO) is feasible, although the performance at those altitudes needs further exploration. Moreover, satellite thruster firings (for maneuvers, momentum unloading, etc.) can result in large tracking errors when the number of visible GPS satellites is inadequate, especially when it is zero. These errors may exceed AFSCN's tracking accuracy and timeline requirements. GPS-based user equipment technologies that deal with these issues and are compatible with AFSCN operations need to be developed. GPS tracking could significantly simplify the implementation of autonomous Guidance, Navigation and Control (GN&C) in upper stages and satellites. Even if full autonomy is not used, GPS tracking potentially could shorten the orbit determination process because a single contact would be adequate to determine the position of a satellite after a maneuver. This offers the potential for compressing the mission timeline for satellites using multi-burn transfers that could take days to reach mission orbit, or satellites requiring more frequent momentum unloading or other maneuver burns. The objectives of this project are: a) to develop a GPS-based tracking operation procedure including necessary software modules; and b) to determine the feasibility and benefits of autonomous operation and compressing AFSCN's operation timelines.

PHASE I: 1) Conduct a status review on space qualified GPS receivers and their flight experience. 2) Determine disturbance sources that can lead to significant transients. 3) Identify GbUE design options and GPS-based tracking operations procedure capable of dealing with these transients in the presence of poor GPS visibility at high altitudes. 4) Develop a preliminary GbUE design, including test plans, with emphasis on achieving low cost, low power, lightweight, and small size for long-life space missions at all altitudes. 5) Determine feasibility and benefits of timeline compression and autonomous operation for a candidate satellite system using GPS tracking as compared to using SGLS ranging.

PHASE II: 1) Develop a detailed GbUE design based on the preliminary design. 2) Develop a detailed test plan. 3) Fabricate and test a prototype GbUE. 4) Demonstrate performance and cost advantages to mutually (AF/contractor) agreed specifications.5) Deliver the prototype GbUE including hardware and software. 6) Develop detailed tracking operation procedure for tracking multiple satellites using GbUE and deliver software modules together with source code and documentation.

PHASE III DUAL USE APPLICATIONS: The prototype GbUE and GPS-based tracking operation procedure is applicable to DoD, Civil, and commercial satellites and their ground control networks. It is projected that as many as 1,500 commercial satellites may be launched during the next 10 years. Launch and satellite tracking and their traffic management will be paramount issues.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-047 TITLE: Low Power Fast Fourier Transform for Handheld GPS Receivers

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SCM/CZ)--Global Positioning System (GPS)

OBJECTIVE: Develop a very low power Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT).

DESCRIPTION: Frequency domain digital signal processing offers enhanced performance over time domain signal processing for navigation, radar, communications and computer systems with less complex hardware implementation. A major application of frequency domain processing is in the area of adaptive filters for the excision of narrowband jamming waveforms in spread spectrum systems such as the Global Positioning System (GPS). As jamming power increases, the need exists for filters with jamming suppression capabilities approaching 60 dB. Simulations have shown that these suppressions can be obtained by processing in the frequency domain. The current FFTs dissipate excessive amounts of power and are therefore not applicable for many GPS receivers such as handhelds. A need exists for the development/demonstration of a low power, low cost and small size FFT and IFFT prototype which can be integrated in a handheld GPS receiver.

PHASE I: 1) Investigate technologies applicable to the design of a low power, low cost, small size FFT/IFFT compatible with a handheld GPS receiver. 2) Develop detailed models of candidate FFT/IFFT designs. 3) Perform analyses/cost and trade studies. 4) Select final design based upon performance/cost/power criteria. 5) Based on selected design, provide a limited proof-of-concept demonstration to mutually (Air Force/contractor) agreed upon performance requirements. The basic focus would be the integration by simulation with a GPS receiver in the loop.

PHASE II: 1) Produce final detailed design of the FFT/IFFT. 2) Produce a prototype FFT/IFFT capable of demonstrating all key performance features. 3) Conduct tests/demonstrations to mutually (Air Force/contractor) agreed upon performance requirements to measure/verify FFT/IFFT performance. Provide final FFT/IFFT cost/power analysis.

PHASE III DUAL USE APPLICATIONS: Development of FFT and IFFT will have significant impact on both DoD and Commercial application in the future for communication. Currently, only 1 Watt FFT is available as COTS (commercial off the shelf).

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-048 TITLE: Extremely Rugged Electron Emission Sources

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop the technology to fabricate wide band semiconductor microtips and vacuum field effect transistors.

DESCRIPTION: Electron emitting microtips made of wide band gap semiconductor (WBGS) materials, such as diamond, SiC, etc., could have considerable potential to significantly improve high power, high frequency power sources for both commercial and military applications. In spite of the promise of cold cathode concepts, to date, concurrent requirements of high current, high voltage, fast switching and durability with efficiency have not been achieved. Present techniques lack efficiency and longevity and are not scaleable. Novel approaches are required that optimize emissions material and geometry and have tip stability and practicality. An array of these microtips should be capable of > 10A/cm2 emission flux while demonstrating no operational degradation over multiple mission intervals. A single microtip can also be used as the source in a vacuum field effect transistor (VFET), which is essentially a miniaturized solid state vacuum tube processed by microelectronic fabrication techniques. The conduction channel in the VFET is a vacuum. These types of devices can be modeled, designed and fabricated to create a new genre of space electronics that are faster, lighter, and less power consumptive than any present solid state microelectronic technologies. Because the conduction channel is a vacuum, VFET-based devices are expected to be highly immune to damage or upset by any form of man-made or natural radiation. These devices are exceedingly rugged and are expected to operate through extremely severe environments, short of thermal depositions that would melt the supporting framework.

PHASE I: Model, design, fabricate, and demonstrate prototype electron emitting microtip structures using WBGS materials. Demonstrate the fabrication of rugged, efficient two-terminal microtip devices such as diodes. The goal is to develop the knowledge and skill needed to design and fabricate three-terminal VFETs based on WBGS microtips.

PHASE II: Based on Phase I results, model and design prototype VFET devices. Fabricate and demonstrate the operation of WBGS microtip VFETs. Package these prototypes and determine their performance. Test the thermal stability and radiation hardness of the packaged devices over an extended range to determine the ruggedness of the VFETs. Using the information generated, define the Phase III manufacturing plan--i.e. market development, technology transfer, production device demonstration, etc.

PHASE III DUAL USE APPLICATIONS: The WBGS microtip VFET technology developed in Phases I and II will be transitioned to a commercial scale production process. The production plan shall include both military and commercial grade devices since this class of devices is expected to have numerous applications in both arenas. The superior radiation hardness of the VFETs should benefit both military and commercial satellite communities. The temperature stability will allow the VFETs to be used in environments hostile to conventional silicon or GaAs based technologies.

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KEYWORDS: cold cathode, electron emission source, microelectronic, microtips, vacuum field effect transistor (VFET), vacuum microtip

AF00-049 TITLE: New Space Power Electronic Components

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/CW)--Satellite/Launch Control

OBJECTIVE: Develop radiation hard, thermally and electrically rugged, reliable space power electronic components.

DESCRIPTION: In both commercial and military space programs, numerous on-orbit anomalies, permanent or intermittent, are frequently traced to the failure of the most simple, fundamental components of the electronic hardware--a capacitor blown, a resistor overheated, or a diode overdriven. Wide band gap semiconductor (WBGS) materials, such as SiC, GaN, and diamond, are very radiation tolerant, have very large breakdown tolerance, a large on-to-off current ratio, and large Joule and high thermal conductivity. These materials have been demonstrated to perform well as resistors, capacitors and diodes at the microelectronics level and may provide the technology needed to develop next-generation discrete electronic components that will have superior reliability and survivability for applications in extremely hostile environments. The goal of this SBIR is to develop the infrastructure necessary to design, fabricate and manufacture such WBGS electronic components.

The success of the manufacturing capability should be demonstrated by developing prototype analog and digital subcircuits such as a current mirror or a single SRAM cell. The technology should be able to withstand an interplanetary mission with expected radiation doses in excess of 20 Mrad and temperature variations between 100 and 600 degrees Kelvin.

PHASE I: Design fabrication process for WBGS counterparts for the following electronic components: resistors, capacitors and diodes that will operate in the thermal range of 100-500K. Demonstrate proof of principal for these designs.

PHASE II: Design, fabricate and characterize prototype WBGS counterparts of electronic components: resistors, capacitors and diodes. Demonstrate low power, high speed FET design, capable of operating in an extended temperature range. Measure and evaluate their power density, breakdown voltage, thermal stability, radiation hardness, etc.

PHASE III DUAL USE APPLICATIONS: Develop the production processes to manufacture WBGS electronic components with extended performance range (i.e. above 10 GHz, ultra low power for CMOS type of devices, very high operating temperature). Package and test the components for space and other high performance commercial and military applications. Characterize critical parameters such as size, weight, energy density, current density and thermal loading. Develop a technology insertion and manufacturing plan based on the knowledge gained.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-050 TITLE: Extremely Fast Variable Emitter Inertial Sensor

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop an innovative replacement technology for conventional inertial sensors and gyroscopes.

DESCRIPTION: An innovative replacement technology for conventional inertial sensors and gyroscopes is required for next generation military and commercial control systems. Such technology must be inexpensive, highly sensitive, rugged and conducive to miniaturization and large-scale production. The nature of the sensing mechanisms might be capacitance, atomic force, electron tunneling, coulombic attraction, field emission (Fowler-Nordheim process) or other means. In principle, the microelectro-mechanical system (MEMS) technology can be employed to build the entire gyroscope, or conversely, a gyroscope can be put together using discrete inertial sensors fabricated by the MEMS technology. An example of a MEMS inertial sensor would be a vacuum field effect transistor (VFET) with the emitter affixed on a flexible or deformable substrate. This variable emitter structure acts as the sensing element that converts weak inertial and related forces into strong electronic signals. With the use of the appropriate wide bandgap semiconductor (WBGS) materials, such as diamond, SiC, GaN, etc., this class of devices would be very insensitive to radiation, temperature, shock, and cross axis interference. Development of MEMS technology for the mass production of rugged, small and inexpensive inertial sensors and gyroscopes will have far-reaching benefits to both military and commercial space programs.

PHASE I: Develop the variable emitter structure. Design, fabricate and demonstrate prototype two-terminal devices with the emitter attached to a flexible platform. Characterize these prototype devices to establish dynamic range performance envelope. Finalize the variable emitter VFET design using the knowledge gained.

PHASE II: Fabricate prototype variable emitter VFET inertial sensors devices. Package these sensors and measure their performance. Design and fabricate prototype gyroscopes using the inertial sensors developed. Test the mechanical and thermal stability and radiation hardness of these devices over an extended range to determine their ruggedness. Using the information generated, formulate the Phase III manufacturing plan--i.e., market development, technology transfer, production device demonstration, etc.

PHASE III DUAL USE APPLICATIONS: The VFET inertial sensor gyroscope technology developed in Phases I and II will be transitioned to a commercial scale production process. Rugged, small and inexpensive inertial sensors and gyroscopes are expected to have numerous applications in control systems. The production plan will include manufacture of these devices for both military and commercial applications.

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KEYWORDS: force sensor, gyroscope, inertial sensor, microelectro-mechanical system (MEMS), vacuum field effect transistor (VFET), variable emitter

AF00-051 TITLE: Stacking of Magnetic Memory Chips

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop a technology to stack magnetic memory chips to increase data storage capacity.

DESCRIPTION: Stacking of memory chips has been shown to be an efficient way to increase the storage capacity of semiconductor memory devices for both advanced military and commercial applications. So far, the bulk of the development work has been carried out on SRAMs (Static Random Access Memory) and DRAMs (Dynamic Random Access Memory). Very little work has been done on stacking of non-volatile magnetic memories. Since non-volatile magnetic memory chips are becoming available as a result of both commercial and government funding, it is timely to develop a technology for stacking the magnetic memory chips. While a good deal of knowledge and technology developed for stacking SRAMs and DRAMs would be transferable, the stacking of magnetic memories presents its own unique set of challenges--stray fields from current lines, magnetic coupling between chips, etc. A program is needed to develop the methodologies required to overcome the challenges specific to stacking of magnetic memory chips. Successful development of this technology offers high payoff for space programs where volume and weight are at a premium.

PHASE I: Examine existing magnetic memory circuit layouts to determine their suitability for stacking. Develop design principles for laying out magnetic memory circuits for stacking. Investigate techniques for suppressing inter- and intra-chip magnetic interference. Provide breadboard demonstration of basic principles.

PHASE II: Fabricate memory stacks using existing magnetic memory chips. Demonstrate/verify the performance of the memory stacks. Develop designs to accommodate drop in of higher density memory chips as they become available.

PHASE III DUAL USE APPLICATIONS: High density non-volatile memories are expected to have numerous commercial applications, i.e. portable computers, mobile telephones, consumer appliances, etc. In military/commercial space programs, this technology has the potential of reducing weight and power requirements for the spacecraft and allowing the spacecraft to recover gracefully after an expected power interrupt.

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KEYWORDS: dynamic random access memory (DRAM), magnetic cross talk, magnetic interference suppression, magnetic memory, multichip stacking, static random access memory (SRAM)

AF00-052 TITLE: Radiation Hardened DSP

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop a high performance, ultra low-power, rad-hard Digital Signal Processor for satellite applications.

DESCRIPTION: Digital Signal Processing (DSP) performs a key role in both DoD and commercial communication satellites. To minimize size, mass, and power, and to maximize data throughput, it is necessary that the DSP hardware operate at low power and high speed. While leading edge commercial DSP components can satisfy most satellite system performance requirements, they are generally sensitive to both incident ionizing and particle radiation. Ionizing radiation degrades performance, leading to premature system failure. Single-event-effects (SEEs) produce frequent upsets and possibly catastrophic failure due to either single-event-induced latchup or transistor gate rupture. One approach to achieving the desired performance and alleviating the commercial DSP components' sensitivity to radiation is to fabricate the microelectronics on a Silicon-On-Insulator (SOI) substrate. Unfortunately, SOI processes are not available which can accommodate the direct translation of DSP components from their present commercial bulk CMOS (Complimentary Metal-Oxide Semiconductor) versions. For example, SOI process yields currently limit the chip size (and gate count) significantly below leading edge CMOS bulk processes. It is important, therefore, in developing an SOI DSP capability for communication satellites to identify the specific types of signal processing that are required so that the DSP architecture and chip partitioning can be customized to the limitations of the SOI fabrication process. In optimizing the DSP, it is also necessary to consider the types of memory components and the software macros that are required.

PHASE I: 1) Identify an optimized mix of memory, memory management, DSP architecture, and I/O bandwidth that maximizes the utility of the DSP chips across several space applications. 2) Investigate and identify high-level macros and super cells to develop in a radiation hardened SOI CMOS process. 3) Provide analysis which verifies that the designs are capable of withstanding total ionizing dose levels encountered in typical orbits, and that the designs are insensitive to SEEs. 4) Develop a report and/or a computer simulation that demonstrates feasibility of the concepts and provides a road map for Phase II and III.

PHASE II: Develop and fabricate prototype DSP chip(s) using an SOI process. Evaluate chips in terms of their electrical performance, their tolerance to total ionizing dose, and their sensitivity to SEE. Design a DSP subsystem based on the prototype DSP chips and the test results.

PHASE III DUAL USE APPLICATIONS: The DSP capabilities developed in this program could be exploited for use in many of the DoD and commercial satellite systems that are now under consideration for future development and deployment. There are also a variety of ground-based commercial applications in which the microelectronics are exposed to either high temperature or industrial radiation sources that could benefit from the chips and technologies that are developed in this project.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-053 TITLE: Non-Volatile RAMs Based on Self-Contained Energy Sources

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Design a high-capacity, radiation-hardened, non-volatile SRAM device with self-contained energy source for medium- to long-duration space missions.

DESCRIPTION: Satellite components may experience brief disruptions in power for a variety of reasons. Non-volatile memory is typically provided to preserve software programs and parameter states during these periods. Current total dose-hardened (100K to 1M rad) non-volatile memory devices (i.e., packaged die) are significantly less area efficient than comparably hardened volatile memory devices. The goal is to combine the latest technology hardened SRAMs (Static Random Access Memory) with an innovative approach to providing local (i.e., contained within the same package) energy storage which will supply sufficient power to retain memory contents during periods when regular satellite power is briefly disrupted. At least one such battery-based commercial solution with a 5-year lifetime exists for non-hardened electronics. Energy storage technology has evolved, and it is time to reassess the practicality of this approach to space-based, non-volatile memory. The desired solution should be an SCES capable of withstanding missions of up to 15 years with a total radiation dose exposure of up to 1Mrad while providing memory retention for periods of power supply disruptions up to one hour in duration. Local SCES energy backing can offer size/weight savings in localized circuits as well as provide an extremely rapid recovery mechanism over more centrally organized energy-backed storage schemes (e.g., programs retained in the relatively high-speed energy-backed SRAMs can be ready immediately for use without a need to wait for memory reload).

PHASE I: 1) Investigate alternative approaches to providing a single-package, radiation-hardened, energy-backed SRAM. 2) Investigate relative implementation difficulty, including impacts on boards and systems, of alternatives. 3) Assess relative performance and qualities, including life time and reliability, of alternatives and compare to typical spacecraft needs. 4) Select the (mutually agreed upon) leading alternative SCES configuration for prototype implementation. 5) Develop a preliminary design and provide a breadboard demonstration of operational principles.

PHASE II: Complete final prototype design of selected SCES and fabricate multiple copies of prototypes to evaluate critical characteristics. This design should be as faithful as possible to an expected production version of the selected concept in order to maximize the applicability of test results. Test prototype SCESs to mutually agreed specifications, to demonstrate as many key characteristics as possible given limitations of the prototype with respect to a production version of the design.

PHASE III DUAL USE APPLICATIONS: This technology will be useful for DoD/ commercial satellite applications to minimize service outages due to on-orbit events temporarily disrupting power.

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2. Dallas Semiconductor, "DS1270Y/AB 16M Nonvolatile SRAM," product description (April 1998).
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KEYWORDS: energy backed SRAM, microelectronics, non-volatile SRAM, radiation hardened SRAM, self-contained energy source (SCES), static random access memory (SRAM)

AF00-054 TITLE: Low Power Field Programmable Technology

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop the basic technology and architecture of a low-power, high-speed based field programmable devices.

DESCRIPTION: Field programmable technology enables circuit designers the ability to configure hardware to perform specific functions as needed. Commercially, Field Programmable Gate Arrays are extensively used as prototyping and initial production devices. The ability to configure existing hardware can save non-recurring costs for satellite and other manufacturers. Field programmable technologies can either be one-time, permanent configurations, or reconfigurable. Field programmable technologies could be applied to arrays of programmable logic (as in conventional Field Programmable Gate Arrays) or to the connections between more complex fixed logic elements, or to connections between arrays of analog functional blocks, as well as combinations of the above. Desirable qualities include high speed, low power, ability to meet a variety of applications, and applicability to utilize generally available manufacturing processes (silicon and non-silicon). For space use, insensitivity of the programming technology to single event effects (high energy particle strikes, for example) is required and low power is very important. Tolerance to ionizing radiation is also important for space use. For other potential markets, high performance is most critical. Due to the small size of the space market, synergy with commercial markets and processes is important. Development of this technology will contribute to “System-On-A-Chip” concepts that enable fewer components to perform a given function at lower cost, reduce non-recurring costs for prototype and limited production systems, and reduce turnaround times for equipment redesign and upgrade.

PHASE I: Develop a flexible field programmable technology concept, including process concept and utilization concept(s). Determine how the devices will be integrated into existing fabrication processes with little or no modification to the process. Determine how the devices will be integrated into usable architectures to form new products or reduce component counts on existing products.

PHASE II: Fabrication of working programmable structures and devices, including test structures for proof of concept and evaluation, and possibly small-scale product prototypes. Refine and improve manufacturing techniques and application techniques for the technology. Evaluation of structures and devices

PHASE III DUAL USE APPLICATIONS: Prototyping, limited production systems, field upgradeable systems, reconfigurable computing and processing. Limited production systems notably include military, civil, and commercial space electronics. Field upgradeable and reconfigurable computing and processing will also have applications in space.

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2. A. Haines, "Field-Programmable Gate Arrays with Non-Volatile Configuration", Microprocessors and Microsystems, Vol. 13, No. 5, pp. 305-312, June, 1989.
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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-055 TITLE: Space Qualified, Low Cost Compact Disk Data Storage/Retrieval System

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Demonstrate that commercial, formatted, CD/Mini disk recorders can be ruggedized/configured as spacecraft compatible, long life, data storage/retrieval mechanisms.

DESCRIPTION: Digital Compact Disk (DCD), and Mini Disk Recorders/Players use low cost magnetic media and electronics to record/transmit low to moderate Gigabits of data at medium data rates. A vast installed base of commercial hardware assures well exercised logic and control electronics; this same installed base assures robust media, low cost/extensive reliability statistics. Consumer implementation is focused on analog processing, but the core of the commercial Compact Disk/Mini Disk is digitally processed. Although conventional transport hardware and control electronics are in place for the consumer electronics market, the application of this technology in space requires conversion to more robust systems. Space use demands low weight, low power consumption devices that can survive the high shock/vibration of launch, years of low activity, no maintenance, high reliability, radiation hardness, large temperature excursions, and the rigors of a vacuum environment. Advanced electromagnetic bearing technology with integrated, low coging motors may provide the basis for a high reliability transport mechanism that is suitable for space environment. Development of this technology with control algorithms and associated electronics is needed to coordinate the electromagnetic actuators with the storage device. Space qualified transport mechanisms will require re-fitting conventional bearings and drive motors with enhanced electromagnetic devices based on state-of-the-art magnetic bearing technology. The standardized commercial formats for data storage should be maintained to the largest degree possible, including the physical characteristics of both the media and transport mechanisms. A flexible control interface system is required to handle format conversions from commercial storage format to a spacecraft compatible format. The control system should be capable of handling transport control as well as data transfer. Firmware developed for this program should provide a seamless interface between the spacecraft format and the drive's native format. For space application, a pure digital interface is required. Protocol and data format translation between the commercial device and established spacecraft format should be considered.

PHASE I: Evaluate commercially available DCD/Mini disk transport mechanisms and their potential for successful conversion to spacecraft use. Develop a conceptual electromagnetic based transport mechanism design. Design and prototype a combined motor/electromagnetic bearing and demonstrate its suitability for DCD/Mini disk transport mechanism application.

PHASE II: Design and retrofit a commercial transport mechanism with electromagnetic devices and appropriate control electronics. Demonstrate the modified transport mechanism and analyze a full-up model of the device to compare size, weight, power consumption, reliability and other appropriate parameters to space-based application requirements.

PHASE III DUAL USE APPLICATIONS: DCD/Mini Disks are natural candidates for low cost, pure digital storage/retrieval application in DoD and commercial space requirements. Digital still and video photography is just emerging as a consumer item. Photo/video transport--on the Internet, video conferencing and telephone--is finding acceptance in commercial application. The demonstration of a space grade, low cost, rugged, digital storage device could establish a new standard for consumer and commercial markets.

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KEYWORDS: control electronics, data storage/retrieval mechanisms, digital compact disk, digital interfaces, general purpose recorders, transport hardware

AF00-056 TITLE: Long Life, High Efficiency Pulse Tube Cryocooler

TECHNOLOGY AREAS: Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop, design and demonstrate a miniaturized, high efficiency, long life pulse tube cryocooler.

DESCRIPTION: Satellite-based infrared systems require cooling to temperatures of 77K or lower for high sensitivity discrimination. Ideal satellite-based cryocoolers have a life of 10+ years, are compact, operate efficiently, and are vibration free. None of today's cryocooling technologies meets these requirements: 1) (Staged) thermoelectric devices are inefficient. 2) Stirling cryocoolers offer efficiency and small size, but they demonstrate substantial (cryo-side) vibration and have too short a life, primarily due to their use of moving parts in the cryogenic zone. 3) Pulse tube cryocoolers demonstrate long life (no moving parts in the cryo-zone) and create minimal cryo-side vibration; they do not, however, provide the cooling capacity and efficiency of Stirling cryocoolers when miniaturized (e.g. on the order of 100's of milliwatts). In addition, some pulse tube cryocooler configurations do not lend themselves to the "cold finger" (cryostat) geometry favored in satellite IR (Infrared) systems. The purpose of this R&D effort is to improve the satellite dedicated cyrostat geometry, cooling capacity and efficiency of miniaturized pulse tube cryocoolers, making them superior to Stirling cryocoolers. Potential areas of investigation (among others) include: a) recovery of cold expansion work and implementation of a split compressor cycle to increase efficiency and cooling capacity, and b) development of an "L" shaped pulse tube configuration to improve "cold finger" access.

PHASE I: 1) Investigate Pulse Tube Cryocooler deficiencies in relation to satellite application requirements. 2) Devise innovative methods of improvement. 3) Design, develop, and demonstrate the feasibility of a breadboard prototype miniaturized pulse tube cryocooler suitable for efficient, vibration free, long life satellite application.

PHASE II: 1) Finalize design and build a prototype miniaturized Pulse Tube Cryocooler for satellite application. 2) Demonstrate prototype to mutually agreed specifications. 3) Finalize design of a flight-ready Pulse Tube Cryocooler suitable for satellite application.

PHASE III DUAL USE APPLICATIONS: Many DoD/commercial satellite applications (e.g. communications, weather) would benefit from the availability of a miniaturized, efficient, long life cryocooler.

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KEYWORDS: "cold finger" (cryostat) geometry, cooling capacity, cryo-side vibration, pulse tube cryocooler, stirling cryocoolers, thermoelectric devices

AF00-057 TITLE: Techniques for Assessing Approach for Migrating to Different Processors

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop techniques for assessing approach for migrating between different computer processors.

DESCRIPTION: The capability to introduce technologically advanced computer processors in an embedded system has become even more difficult to obtain with the rapid development and introduction of higher capacity processors in the market. Typically, an embedded system developer must assess the impact of introducing a different processor into a target system and must repeat the same assessment every time a potential new processor is identified. This process will occur more frequently with the expected increase in both the commercialization of military products and the adoption of commercial products for military use. In this project, a technique will be developed to efficiently assess all the factors affecting a target system during the migration to different processors. A template methodology (generic approach) shall be derived with directions on the critical processes under evaluation.

PHASE I: Identify both the critical and non-critical factors on migrating to different computer processors in an embedded system. Analyze the relationship between these factors and their effect on the migration process; utilize data from previous migration efforts in the commercial sector for these analyses. Air Force assistance will be available to obtain data to be analyzed from the military sector. Use the analysis results to develop/demonstrate one or more techniques that will increase the efficiency of the migration process.

PHASE II: Finalize development of all required migration techniques. Coalesce all the techniques developed into a single template methodology (generic approach). Provide the embedded system user with directions on the critical processes to follow in the migration process. Develop the capability for the user to extend the template methodology by enabling tailoring to specific processors. The result shall indicate the probability of success and the associated risks when migrating to a specific processor. Develop a standard which will allow for easily capturing processor-specific data for input into the methodology. The final product will be a prototype graphical tool executable in different computer platforms which will implement this methodology. Demonstrate the final prototype graphical tool to a mutually agreed specification.

PHASE III DUAL USE APPLICATIONS: The methodology developed under this project will benefit the military and commercial embedded system user in migrating from one processor to another. This benefit is magnified by the expected increase in both the commercialization of military products and the adoption of commercial products for military use.

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2. Panteleenko, V. V., Nelson, T. W., Cohn, D. L., "The AppCard: A Migrating Processor Card for General-Purpose Computing," Journal: Australian Computer Science Communications Conference, vol. 19, no. 1, p.236-44. Publisher: James Cook University, 1997.

KEYWORDS: computer processors, critical and non-critical factors, embedded system, migration to different processors, target system, template methodology

AF00-058 TITLE: High-Speed, Radiation-Tolerant Glue Logic

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop generic radiation-tolerant glue logic devices for space systems applications.

DESCRIPTION: Glue logic circuit(s) (GLCs), such as line drivers, latches, buffers, multiplexers, etc., comprise a substantial percentage of the part types in DoD and commercial spacecraft architecture, but are frequently overlooked during component development in favor of the microprocessors, signal processors, ADCs, and memory. The speed of many spacecraft functions is frequently determined by the performance of these GLCs. The relative simplicity of the GLCs allows their implementation as radiation-tolerant commercial Application Specific Integrated Circuits (ASICs) with general applicability to multiple space systems. This approach allows exploitation of the performance available from advanced radiation-tolerant foundry processes that can (through novel circuit design and cell layout) ensure immunity to single-event upset (SEU) and single-event latchup (SEL) in the space environment. A need exists to identify a radiation-tolerant ASIC design methodology that employs high-performance commercial foundry processes that ensure the manufacture of high speed GLC ASICs with substantial total dose tolerance immunity to SEU and SEL.

PHASE I: . Develop innovative approaches using developing technologies (such as LVDS and system-on-a-chip) to perform glue-logic functions and increase throughput rates. Select (with AF assistance) a typical spacecraft or payload architecture and identify at least six specific "glue logic" functions as candidates with emphasis on high-speed data transfer technologies. The techniques selected for study must be amenable to implementation as a radiation-tolerant ASIC Design one candidate part type using a radiation-tolerant ASIC methodology, and can be manufactured in a radiation-tolerant foundry process, with a goal total dose tolerance greater than 100 krad(Si), SEU immunity better than 1E-3 error/day in the Adams 90% worst-case environment, and SEL linear energy transfer threshold better than 60 MeV-cm2/mg.

PHASE II: Use the techniques explored in Phase I to design a candidate part to perform the glue-logic function as radiation-tolerant ASICs, and manufacture them in at least two radiation-tolerant foundry processes. Demonstrate the ASICs to the same radiation tolerance goals and specific speed performance goals as in Phase I.

PHASE III DUAL USE APPLICATIONS: This enabling technology effort develops the means to apply existing commercial CMOS foundry services to the manufacture of radiation tolerant hardware for space. The successful completion of this effort will make high-performance commercial microelectronics technologies available for both commercial and military space applications.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-059 TITLE: On-Board Intelligent Software for Spacecraft Autonomy

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop intelligent on-board autonomous satellite cluster control.

DESCRIPTION: Control of a spacecraft is costly in terms of number of operators, their training, and operations that run 24 hours, 7 days a week for the lifetime of the satellite. For a cluster of cooperating satellites the operations complexity is magnified. Based on existing technology (processors, memory, software, sensors), it is timely to develop the architecture and algorithms for on-board autonomous spacecraft cluster control and management. This involves both functions on-board a single satellite such as thermal management, power balancing, attitude determination and control, and payload control and inter-satellite functions such as communications, redundancy management, and distributed processing. From the ground perspective this requires an on-board cluster architecture which allows for the command and control of the cluster as opposed to individual satellites. On-board autonomous control of satellites provides benefits by: a) reducing the size of the ground crew; b) reducing the required bandwidth of the satellite-to-ground link; c) decreasing the need for scheduled or dedicated ground assets (antennas, control stations); d) handling complexity; e) being able to reuse the intelligent controller; and f) reducing cost. Development of an on-board control system for on-board subsystems must include functional control over state-of-health monitoring and maintenance, thermal control, power balancing, intelligent payload control, and automatic ephemeris generation, among other application-specific functions. Technologies such as model-based reasoning, case-based reasoning, diagnostic reasoning, fault tolerance, and intelligent agents may be useful development tools. Requirements (among others) for such a system include: high reliability, concurrent activity, ability to meet hard constraints and deadlines, system validation, adaptation to changing environments, cooperative/collaborative behavior, goal execution, reprogrammability, ability to respond to (ground or other) interrupts, graceful degradation, and intelligent data and information management. The intelligent system must communicate with other satellites, sensors, ground controllers, and other systems. It must be able to reason about time, context, location, and have the ability to learn, plan, and adapt.

PHASE I: 1) Create prototype designs for the architecture/ algorithms required for autonomous satellite cluster control and maintenance (based upon a thorough knowledge of the research approaches previously taken by NASA and the Commercial satellite industry from both intra- and inter-satellite perspectives). 2) Based on a minimum of three satellites select two to three generalized subsystems, one of which must be a payload, in which to apply the architecture/algorithms, define the requirements/constraints, develop a risk assessment and validation strategy, and demonstrate/validate a preliminary cluster control system. To ensure the prototype system meets Air Force objectives the preliminary architecture will be mutually agreed upon by the contractor and the government technical representative prior to implementation. An example of an acceptable payload from which to demonstrate the cluster control architecture would be a surveillance payload where payload data is shared across the cluster.

PHASE II: Develop/finalize/build the architecture/algorithms required to provide an on-board autonomous cluster control system covering at least three satellites and two to three subsystems, one of which is a payload subsystem. The developed prototype will integrate ground control with on-board cluster control. Develop an operations plan for how the system would be used and how the existing system might be transitioned to the autonomous system. Assess the risk of the proposed autonomous system, identifying critical and non-critical operations, and develop a plan to mitigate that risk (e.g. redundancy, ground-based backup, on-board diversity). Demonstrate/validate the architecture/algorithms of the autonomous, on-board cluster control system (to mutually agreed specifications).

PHASE III DUAL USE APPLICATIONS: On-board autonomous spacecraft control can be a significant cost saver for both commercial and military spacecraft. The capabilities that are developed for an on-board system may also be relevant for ground stations and mobile platforms (e.g., van-based satellite control, ships), as well as for control of complex terrestrial systems that need to be automated (e.g., ocean-based oil rigs, equipment operating in severe weather locations).

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-060 TITLE: RH (Optical) Microcircuit Interface

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop ASIC chips capable of increased signal throughput.

DESCRIPTION: Application Specific Integrated Circuit (ASIC) gate counts have been growing exponentially with shrinking feature size, and in order to accommodate the large amount of input/output (I/O) associated with higher gate counts, the ASIC pin counts have increased significantly in recent years. Both commercial and space electronics are rapidly reaching the point at which it will be no longer feasible to conventionally route all of the needed signals through the microcircuit package pins. It is evident that the single line Internet idea, and its protocols, can be applied to reducing the number of pins in ASIC designs; that is, serialization of groups of slow speed signals can be implemented. Of course, protocols will have to be defined for different types and rates of serial ports. These ports, embedded into the microcircuit package, should offer the opportunity to alleviate the pending connectivity shortfall. It is envisioned that groups of signals (like control, address, data) will need to be formatted then routed out of the chip through a transmitter. This high speed line could be electronic or optical. At the receiving device, a "receiver deformatter" would extract the values (states) of many signals. On-chip formatting and deformatting will entail embedding additional logic to accommodate the necessary protocols, but this real estate should be very small compared with the savings in number of pins. The testing of the chips should also be addressed by these implementations.

PHASE I: Define and propose several data format standards and protocols. Explore ASIC on-chip processing options to prepare data for transfer. Prepare simulations and timing analysis. Design an innovative rad-hard (RH), high speed and Single Event Upset (SEU) immune interface (electronic or optic) utilizing the design rules and chip technologies of well known rad-hard foundries to create an entire design and layout activity (i.e. Honeywell Complimentary Heterostructure Field Effect Transistor [CHFET] GaAs technology).

PHASE II: The contractor should work closely with a selected foundry to embed the designed interface into several prototype ASICs chips and demonstrate consequent pin-saving solutions.

PHASE III DUAL USE APPLICATIONS: ASIC chips, capable of increased signal throughput, are applicable/ desirable in almost any electronic assembly.

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KEYWORDS: application specific integrated circuit (ASIC), complimentary heterostructure field effect transistor, gate counts, increased signal throughput, pin counts, rad-hard foundries, single event upsets

AF00-061 TITLE: <u>High Speed RH Level-2 Cache</u>

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MC)--Military Satellite for Communications (MILSATCOM)

OBJECTIVE: Develop RH, SEU immune level-2 cache chips to reduce memory access time.

DESCRIPTION: The need for faster access time for program and data continues to grow with processor speed. Most integrated processor architectures already include a "cache on the chip" to accelerate the fetching of instructions and the read and write of data to and from memory. A second cache is becoming common on commercial computers; this "level-2 cache," as it is called, is placed between the processor and the memory with the goal of reducing the memory access time. An example of this, for Pentium and PowerPC chips, is the Mitsubishi M5M5V1132A 1Mbit synchronous. This and other similar parts existing or in development for commercial use do not meet needs of space users, most notably in the areas of radiation hardness (both ionizing dose and single event effects), high reliability, and low power.

PHASE I: Investigate feasibility of high speed, very low power synchronous RAM technology using innovative space-qualifiable processes. Device design should address the widest possible range of application to present and future space computer systems. Fabrication technologies to realize the design could include upcoming hardened CMOS processes, including Silicon On Insulator (SOI), modifications of commercial technologies for use in radiation environments, or other processes with radiation hardening potential such as complementary GaAs.

PHASE II: Develop detailed design strategies for implementation of memory device(s) at one or more foundries able to produce space-qualified microelectronic components. Fabricate proof-of-concept components for evaluation of environmental and performance characteristics.

PHASE III DUAL USE APPLICATIONS: Development of RH and SEU immune level-2 cache chips or level-2 cache on chip architectures would be employed on practically any DoD/commercial space-based computer to reduce memory access time.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-062 TITLE: Effective Low-Temperature p-type Doping for HgCdTe IR Photodiodes

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MT)

OBJECTIVE: Develop effective p-type doping of HgCdTe at low temperatures, and use it to develop p/n HgCdTe LWIR detectors with improved performance.

DESCRIPTION: The US Air Force is actively pursuing the development of high performance p/n HgCdTe long-wave infrared (LWIR) detectors for several applications. Growth of HgCdTe by molecular beam epitaxy (MBE) is being established as an important growth technique for these detectors, since it is a low temperature process and leads to sharp interfaces. In the p-on-n photovoltaic devices, the cap layer is usually doped with As because of arsenic's relatively low diffusion coefficient. However, at low temperatures, As atoms go into the Hg lattice sites, where they act as donors, leading to n-type HgCdTe cap layer. Activation anneals at temperatures of about 400C are needed to make the cap layer p-type. This procedure makes the sharp interfaces (obtained due to low temperature MBE growth) become diffuse, and degrades the device performance. Hence there is a need to develop effective p-type doping of HgCdTe at temperatures less than the currently used activation anneal temperature of As.

PHASE I: Develop/demonstrate the ability to obtain high quality p-type films of HgCdTe at temperatures significantly less than the currently used activation anneal temperature of As.

PHASE II: Optimize the p-type dopant element and doping process in order to obtain p/n HgCdTe LWIR detectors with quantum efficiency and zero-bias resistance better than that of As doped detectors annealed at 400C. Develop at least two (2) lots of detectors, evaluate their performance, and make the detectors available for government verification of improved performance.

PHASE III DUAL USE APPLICATIONS: Military applications of this innovation include improved surveillance and threat warning capabilities (the ability to detect fainter objects at greater distances). Commercial applications include industrial and auto- emission monitoring, tumor detection, environmental monitoring, fire and volcano detection etc.

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2. M.A. Berding, A. Sher, and M. van Schilfgaarde, "Behavior of p-type Dopants in HgCdTe," J. Electronic Materials, Vol. 26, No 6, p. 625-628 (1997).
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KEYWORDS: HgCdTe, LWIR detector, arsenic, infrared, molecular beam epitaxy, p-type dopant

AF00-063 TITLE: Multi-waveband Interconnect Technology

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MT)

OBJECTIVE: Develop interconnect technology between multi-waveband detector layers of a large-format detector array and its corresponding readout array which preserves detector fill-factor.

DESCRIPTION: Space-based platforms which host infrared (IR) sensors for the purpose of acquiring and tracking cold objects in space constitute one component of a national missile defense system. At large acquisition distances, such objects--possibly missile warheads, dummy warheads, or complicated decoys--can be tracked, but will not be spatially resolvable by the IR sensors. However, these potential targets will produce blur spots which contain spectral information that may be exploitable for purposes of object discrimination. In recognition of the value of simultaneously acquired, spatially co-registered spectral information, stacked dual-waveband IRFPAs have already been developed. A significant hurdle to the extension to three or more wavebands is the limitation posed by conventional interconnects (viz., indium bump bonding) between the detector and readout arrays. These indium bumps take up space and reduce detector fill-factor.

PHASE I: Develop/demonstrate the capability to achieve mechanical and electrical interconnection between stacked, multi-waveband detector arrays and their corresponding readout arrays while preserving greater than 85% fill factor in all detector wavebands.

PHASE II: Finalize interconnection methodology and demonstrate its approach by fabricating a large format (at least 64x64) multi-waveband (at least three wavebands) detector/readout array. Simulated detector and readout arrays would prove adequate for this demonstration; the goal is demonstration of innovative interconnection technology, and not the development of multi-waveband detector arrays or readout arrays.

PHASE III DUAL USE APPLICATIONS: Military applications of this innovation include discrimination of point targets in acquisition and tracking sensors onboard space platforms or interceptor seekers and background/clutter rejection for imaging sensors. The availability of affordable multi-waveband IRFPAs will enable commercial providers to offer IR spectral imagery of earth for environmental monitoring and natural resource management.

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1. P. Mitra, S.L. Barnes, and F. C. Case, 'MOCVD of Bandgap-Engineered HgCdTe p-n-N-P Dual Band IR Detector Arrays, J. Electronic Materials, Vol. 26, No. 6, p.482-487 (1997).
2. R.D. Rajavel, D.M. Jamba, J.E. Jenson, O.K. Wu,and C.Le Beau, 'MBE Growth of Integrated Two-color HgCdTe Detectors Operating in the Mid-Wave IR Band,' J. Electronic Materials, Vol. 26, No. 6, p.476-481 (1997).

KEYWORDS: detector array, focal plane array (FPA), infrared (IR), interconnection, multi-waveband, readout array

AF00-064 TITLE: Advanced Cryocooler Technology

TECHNOLOGY AREAS: Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center (SMC/MT)

OBJECTIVE: Develop/demonstrate cryocooler technology for next generation spacecraft cooling applications.

DESCRIPTION: Next generation space infrared sensing technologies and spacecraft cryocooling needs will require revolutionary improvements in cryocooling technology and revolutionary improvements in performance and ease of integration in order to meet projected requirements for high duty cycle heat loads, cryogenic component redundancy with low parasitic heat penalties, long cryogenic transport distances, highly flexible cryogenic transport, and versatile components with multiple applications at different cryogenic temperatures.. Exploitation of technology with minimal to no moving parts, minimal mass, minimal input power, minimal vibration, high efficiency, high reliability, and that meets advanced cryogenic needs for thermal storage, thermal transport, thermal switching, ease of integration, integrated cryocooler and cryogenic thermal management concepts, and reduction of thermal contact resistance are essential to meet cryocooling goals for increasingly compact/higher density Air Force and Department of Defense infrared sensing payloads. Specific interests include, but are not limited to advance thermoelectric coolers, low temperature (between approximately 10 and 20 K) regenerators, advanced regenerator technology and modeling, laser or fluorescent cooling, cooling across a gimbaled joint, continuous sorption cooling, single and dual volume cryogenic thermal storage units, passive and active cryogenic thermal transport systems, mechanical and gas-gap cryogenic thermal switches, cryogenic integration schemes, and cryogenic high thermal conductivity and low thermal contact resistance interface materials. In addition to these needs, producibility, reliability, and manufacturability are important to AF, DoD and commercial applications.

PHASE I: Phase I SBIR efforts should concentrate on demonstrating the adaptation of an innovative technology in a breadboard format. This should include demonstration of a fundamental physical principle in a format that illustrates how this technology can be utilized in a cryocooler. This effort should include plans to further develop and exploit this technology in Phase II.

PHASE II: Phase II SBIR efforts should take the innovation of Phase I and design/develop/construct an operational prototype device or cooler. This device may not be optimized to flight levels, but should demonstrate the ability of the working prototype device to meet mutually (Air Force/contractor) agreed operational specifications. Demonstration of the potential improvements in mass, input power, efficiency, reliability, and/or cryogenic system integration should be included in the effort. The contractor should keep in mind the goal of commercialization of this innovation for the Phase III effort.

PHASE III DUAL USE APPLICATIONS: Applications of this technology could potentially be far reaching. Typical AF and DoD military space applications relate to infrared sensing, cryogen management, electronics cooling, and superconductivity. Including NASA, civil, and commercial users, user applications include missile tracking, surveillance, astronomy, mapping, weather monitoring, and earth resource monitoring. The need for high reliability cryocoolers for terrestrial applications includes cellular bay station cooling and magnetic resonance imaging. If the developed innovation is low cost, potential applications include CMOS (Complimentary Metal-Oxide Semiconductor) cooling of workstations and personal computers.

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1. G. E. Cruz, R. M. Franks, “MODIL Cryocooler Producibility Demonstration Project Results,” Sponsor: Department of Energy, Washington DC, Report No.: UCRL-ID-112216, 24 Jun 93, 56p. Available through NTIS at 1-800-553-NTIS; NTIS No.: DE93019213.

2. R. C. Bowman Jr., B. D. Freeman, et al., “Design and Evaluation of Hydrogen Joule-Thomson Sorption Cryocoolers,” Proceedings of the International Absorption Heat Pump Conference, New Orleans 19-21 Jan 1994, p. 265-271.

3. Michael Rich, Marko Stoyanof, Dave Glaister, “Trade Studies on IR Gimbaled Optics Cooling Technologies,” IEEE Aerospace Applications Conference Proceedings, v 5 , p 255-267, Snowmass at Aspen, CO, 21-28 Mar 1998.

4. Davis, T. M., Reilly, J., and Tomlinson, B. J., USAF “Air Force Research Laboratory Cryocooler Technology Development” Presented at Cryocoolers 10 Monterey, CA (1998)

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6. Bugby, D., Kroliczek1, E. J., Ku, J., Swanson, T., Tomlinson, B. J., Davis, T., Baumann, J., Cullimore, B., “Design and Testing of a Cryogenic Capillary Pumped Loop Flight Experiment,” Space Technology and Applications International Forum (STAIF-99), Albuquerque, NM (1999).

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12. Nellis, G., F. Dolan, W. Swift, and H. Sixsmith, "Reverse Brayton Cooler for NICMOS," Presented at Cryocoolers 10 Monterey, CA (1998)

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-065 TITLE: Low Cost Miniature Flight Control System

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and demonstrate a low cost, lightweight, miniature flight control system capable of performing guidance, navigation and control functions for small launch vehicles.

DESCRIPTION: AFRL/VS is interested in developing innovative new concepts for a lightweight, low cost, miniature flight control system capable of performing guidance, navigation and control functions for small launch vehicles. The Air Force is currently evaluating the reuse of certain classes of missiles within its inventory for the launch of small satellites. In addition, the

Air Force is evaluating the use of reusable launch vehicle technology for launch on demand applications. As part of this evaluation, new technology concepts are being considered to decrease overall life-cycle cost and to upgrade and enhance system performance. One area of possible consideration is the development of low-cost, lightweight, flight control systems consisting of miniaturized avionics to perform the guidance, navigation and control functions of small launch vehicles. The preferred system would be developed with Commercial-Off-The-Shelf (COTS) parts to minimize overall cost and decrease fabrication time. The system must be designed to withstand launch loads or address how vibration isolation and thermal management will be handled to insure survivability.

PHASE I: Develop preliminary design, identify potential components, and conduct preliminary analysis to show packaging and system survivability.

PHASE II: Finalize design, develop prototype hardware, and conduct demonstration tests.

PHASE III DUAL USE APPLICATIONS: A successful product could be used in any of the SMC small launch vehicle programs, the orbital maneuver vehicle, and other small, inexpensive launch vehicles. Commercially, the system could be used on any number of new, small inexpensive launch vehicles developed in the past decade or currently in development. Currently, SMC is in the process of converting some ICBM assets to launch DoD payloads. The current flight control systems for these ICBM assets are outdated and heavy and need to be replaced with low cost and lightweight systems. There is also a potential market for DoD, NASA, and commercial reusable launch vehicles such as the Air Force's Space Maneuvering Vehicle, NASA's X-34 and X-38, Lockheed Martin's X-33, and Kistler's K1.

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KEYWORDS: GN&C, avionics, flight control, guidance, low cost, navigation

AF00-066 TITLE: Inflatable Structures for Lightweight Solar Arrays

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop concepts for inflatable masts for microsatellite deployable solar arrays (0.5-2 kW).

DESCRIPTION: Future large spacecraft missions may be accomplished through the use of collaborating constellations of microsatellites. These multiple satellite constellations are conceptualized to included small 1 kW satellites that can be packaged in very small volumes for launch and deploy on orbit. Several of these concepts include flexible solar energy generation structures that must be deployed from a very small package. Inflatable booms, with possible inflatable substrates, are being baselined for this mission due to their small stowed volume. One prominent concept of this type is the TechSat 21 concept which utilizes an inflatable cylindrical mast and a flexible solar array blanket. Other concepts include an inflatable mast and solar cell substrate for support of flexible thin film arrays. Several challenges still exist toward the development of such a mast including controlled deployment and downward scalability of the inflatable mast structure. The inflatable masts must have very small storage volumes, gentle & controlled deployment (bearing in mind the sensitivity of many array technologies), potential rigidization after deployment, high post deployment stiffness, and, if possible, high post deployment damping.

PHASE I: Develop inflatable boom concept and prove its ability to be analyzed and fabricated.

PHASE II: Fabricate full-scale structure for deployable mast, designed around an AF mission need for possible flight demonstration. Develop all necessary analysis, design and manufacturing methods to apply the new concept to space vehicle applications.

PHASE III DUAL USE APPLICATIONS: Potential commercial applications for this technology include all future commercial microsatellite space systems for space-based sensing and communications. Potential DoD applications include all future DoD microsatellite systems including space concepts like TechSat21. This technology will result in lighter, cheaper and more reliable DoD satellites and spacecraft.

REFERENCES:
1. "Requirements of Inflatable Collectors for Technology Applications", Paul A. Gierow, PL-TR-97-1166
2. "Inflatable Structures Technology Development Overview", C. Cessapakis and M. Thomas, AIAA-95-3738.
3. "Design Tool for Inflatable Space Structures", Arthur L. Palisoc and Yuli Huang, AIAA-97-1378, pp. 2922-2930.

KEYWORDS: MicroSats, TechSat21, energy generation, flexible solar array, inflatables, solar cell substrate

AF00-067 TITLE: Integrated Payload Dispenser for Multi Micro-Satellite Missions

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop advanced dispenser technologies for Micro-Satellites that will reduce the spacecraft life-cycle-costs.

DESCRIPTION: Despite growing worldwide interest in small satellites, launch costs continue to hinder the full exploitation of small satellite technology. In the United States, the Department of Defense (DoD), NASA, other government agencies, commercial companies, and many universities use small satellites to perform space experiments, demonstrate new technology, and test operational prototype hardware. In addition, the DoD continues to study the role of small satellites to fulfill operational mission requirements. However, US government agencies are restricted to the use of US launch vehicles, which eliminates many lucrative launch opportunities. Additionally, many small satellite users are faced with shrinking budgets, which limits the scope of what can be considered an "affordable" launch opportunity. In order to increase the number of space experiments that can be flown with a small, fixed budget, the government needs to develop a low-cost solution for the small satellite launch problem. An increasing number of DoD small/micro satellite programs could be launched on a single launch vehicle through the development of an integrated adapter. The Air Force has a need to develop advanced innovative technologies that can be integrated into a multi-satellite dispenser for micro-satellites. Existing technologies may not be able to meet mechanism requirements for future DoD micro-satellite programs. The use of pyrotechnics, for example, will expose fragile sensors and electronics to high shock levels, and sensitive optics might be subject to contamination. The dispenser shall accommodate 2 to 10 satellites of 40 to 150 lb. Technologies of interest include on-board propulsion, dispenser isolation, non-pyrotechnic satellite release systems, and composite materials. The technologies that are to be developed need to address issues such as reliability, safety, weight, reduced part count, low cost manufacturing and integration, and the ability to meet requirements of that spacecraft. It is desired that one or a combination of these advanced technologies be integrated into the dispenser.

PHASE I: Conduct supporting analysis for an innovative dispenser incorporating advanced technologies for micro-satellites. Define the problem---this includes specifications of the environment to be attenuated, and any potential restrictions or limitations faced in the implementation of the technology or technologies with the launch vehicle and satellite manufacturers. State system-level performance goals and develop system component/system-level conceptual designs. Analytical and simulation results will be presented to demonstrate performance of the system.

PHASE II: Perform component and ground tests to demonstrate and validate the concept developed in Phase I. Design, fabricate, and test a full-scale demonstration for evaluation. Phase III will provide a commercial dispenser system for flight demonstration.

PHASE III DUAL USE APPLICATIONS: Currently, there are a growing number of small/micro satellites being launched by the government and universities to support small space experiments. However, the launch industry has not adapted to this sudden shift in paradigm from the large single payload to several small payloads. In order to reduce soaring launch costs, DoD, NASA, and the commercial sector have a need to launch multiple small satellites on a single launch vehicle. Military applications include programs such as TechSat 21, XSS-10, and the Air Force's "Space Test Program"; commercial applications include the small/micro satellites, university payloads, and experiments that are now being launched.

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2. Spacecraft and Launch Vehicle Dynamics Environments Technical Interchange Meeting. September 10-11, 1996, Chapters 9-13.
3. Dr. Bernie F. Carpenter "Shape Memory Release Device Experiment". 11th ASCE Engineering Mechanics Conference, Fort Lauderdale, FL, May, 1996.

KEYWORDS: composites, deployment, low cost, mechanisms, multi-functional, multiple payloads, separation, spacecraft

AF00-068 TITLE: Miniaturized Vibration Isolation System (MVIS)

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Demonstrate a miniaturized, retrofittable isolation system to provide 14-20 dB (5:1 - 10:1) RMS reduction in transmitted vibration load to satellite payloads from the spacecraft bus.

DESCRIPTION: AFRL/VS is interested in developing innovative new concepts for a miniaturized vibration isolation system. The motivation is based on previous experiences where vibration of satellite optical systems due to on-board disturbances--such as reciprocating cryocooler components, solar panel gimbals, and attitude control system actuators such as reaction wheels--can seriously degrade the performance of such systems, consequently jeopardizing mission capability. These problems are often not detected until late in the design process for the system, where the costs of a system redesign are high, both financially and in terms of slipped schedules.

The resulting system is intended to be a retrofittable solution for payloads that discover during integration and testing that vibration loads from the spacecraft bus exceed their operating tolerance. The device is envisioned to be ultra-low profile, requiring less than 1.5 inches of clearance between the component to be isolated and its mounting surface. The proposed solution must have a passive baseline system in parallel with an active component for low-frequency isolation. Design emphasis must also include low power consumption and light weight. The system must also be able to withstand launch loads without latching or any other form of launch restraint system.

Micro-controller technology developed under a parallel AFRL program will be considered as potential GFP in the Phase II effort to decrease costs. System hardware design must show ability to be space qualified.

PHASE I: Complete preliminary hardware design of the hybrid passive/active actuator. The preliminary design must also include control system development and simulation results.

PHASE II: Develop prototype hardware and control system and demonstrate in a realistic environment.

PHASE III DUAL USE APPLICATIONS: Flight demonstration. A candidate optical system will be identified and the MVIS system will be offered as a retrofittable solution. Potential military applications include isolation for interceptors, surveillance, imaging, etc. Commercially, the system could be used on any number of new commercial imaging satellites to better stabilize the camera system. This technology can be used wherever a low-profile isolation system is required to meet system requirements.

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KEYWORDS: active vibration isolation, active/passive hybrid, low cost, low power, low profile, miniature, passive vibration isolation, retrofittable

AF00-069 TITLE: High Power, High Rate Launch Vehicle Batteries

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Demonstrate feasibility of new launch vehicle battery technology that would replace Silver Oxide/Zinc batteries used in launch vehicles.

DESCRIPTION: In the space battery arena, there has been a significant push toward designing and producing lighter, more robust, higher energy density batteries. This level of effort is not surprising when one considers that it can cost upwards of $40,000 per kilogram of payload to launch a satellite into a geosynchronous orbit, and that every kilogram by which the mass of the power system is reduced can result in an additional kilogram of satellite payload. While the majority of research has been in the area of satellite batteries, launch vehicle battery improvements could also yield increases in satellite payloads. Furthermore, current AgO/Zn launch vehicle batteries have significant problems, such as a very limited wet shelf life, poor cycle life, and high cost of cell components. The Air Force is interested in new launch vehicle battery technologies that meet or exceed the power density and the volumetric and gravimetric energy densities of AgO/Zn. These new batteries will also need to be capable of high rate discharges. In addition, a wet shelf life of at least 6 months is needed (compared to approximately 15 days for AgO/Zn), and a wet shelf life of several years would be preferable for military applications. Finally, a rechargeable system, while not required, is highly desirable.

PHASE I: Investigate potential chemistries for launch vehicle batteries. Demonstrate feasibility of concept with small capacity cells.

PHASE II: Initial optimization of chemistries identified in Phase I. Place several cells in several configurations on test (storage, shelf life, and sample mission profile). Identify industry partners interested in producing and commercializing final product.

PHASE III DUAL USE APPLICATIONS: With satellite launches increasing greatly, a large market exists for launch vehicle battery technology. Because the commercial sector produces those launch vehicles, they could be very interested in advances in the technology. Further, the military is trying to maintain its fleet launch vehicles, and battery upgrades may be necessary for that effort.

REFERENCES: Linden, David. Handbook of Batteries, 2nd ed., McGraw-Hill, New York, 1995.

KEYWORDS: battery, energy storage, launch vehicle, small capacity cells, space power, wet shelf life

AF00-070 TITLE: Advanced Space Particle Detectors for Microsatellites

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: Develop innovative and miniaturized charged and neutral particle detectors for microsatellites

DESCRIPTION: In-situ measurements of the near space environment are fundamental to situational awareness, mission planning, and improved performance of satellite, surveillance, communications, and navigation systems. The Battlespace Environment Division has requirements for measuring space particles ranging from meteoroids to thermal plasma to extremely relativistic ions, electrons and neutrals. This SBIR Topic seeks innovative and miniaturized instruments and techniques to measure space particles with a strong emphasis on suitable designs for micro-satellites (defined to be a satellite with much less than 100 kg total payload weight). Laboratory hardware needed to support the design and calibration of space particle detectors is within scope.

PHASE I: Develop conceptual designs or bench level prototype devices that can establish proof-of-principle for a detector. The Phase I results should allow for accurate estimation of the scope and cost of a flight test experiment. Designers should consider such issues as autonomous operation and scalability. The potential for application on both conventional and microsatellites should be addressed.

PHASE II: Develop and demonstrate a working prototype of the device or system. This prototype may be a complete flight-ready system depending on the complexity and result of the Phase I study. The contractor may assume that the USAF will provide access to space for flight-ready systems. At a minimum, the Phase II effort should provide a proof-of-principle demonstration of operational capability in the lab or, preferably, space. Commercial viability must also be established as a prerequisite to Phase III continuation.

PHASE III DUAL USE APPLICATIONS: In Phase III the prototype shall be developed to meet the requirements of power, size, weight, lifetime, volume, efficiency and cost necessary for a commercially viable product. Example applications include military microsatellites and civil/commercial satellites requiring data for anomaly resolution.

REFERENCES: "Compact Environmental Anomaly Sensor (CEASE): A Novel Spacecraft Instrument for In Situ Measurement of Environmental Conditions", IEEE Trans. On Nuc. Sci. Vol 45, NO 6, Dec 1998.

KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-071 TITLE: Spacecraft Charge Control Technology

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop detection and mitigation techniques for spacecraft charging.

DESCRIPTION: The survivability of both DoD and commercial spacecraft and mission success can be threatened by the buildup of electrostatic charge on spacecraft surfaces and within internal dielectrics. Areas of concern are high voltage charging in geosynchronous and polar earth orbits, dielectric charging in high radiation orbits, induced charging by onboard or external sources, and low voltage charging which can compromise the function of scientific instruments. Innovative solutions are sought that will provide small and efficient detection, control, and mitigation techniques.

PHASE I: Develop conceptual designs or bench-level prototype devices that can establish proof-of-principle by either analysis or laboratory testing. The Phase I products should be useful for estimating the scope and cost of an actual flight test experiment. Designs should consider such issues as autonomous operation and scalability. The potential for application on both conventional and/or micro (< 100 Kg total payload) sized satellites should be addressed.

PHASE II: Develop a working prototype of the device or system. The prototype may or may not be a complete flight ready system depending on the complexity of the proposed system, GFE components, or other considerations of scope which should be coordinated with the AF and addressed in the proposal. The contractor may assume the AF will provide access to space for flight ready systems. At a minimum, the effort shall provide for proof-of-principle demonstration in the lab or space and establish commercial viability as a prerequisite to Phase III continuation.

PHASE III DUAL USE APPLICATIONS: In Phase III, the prototype shall be developed to meet the requirements of power, weight, size, lifetime, volume, efficiency, and cost necessary for a commercially viable product. Both military and commercial spacecraft in GEO and polar orbits have need of a bolt-on solution for spacecraft charging to reduce losses of expensive satellites. It is expected that when the size, weight, and power consumption of charging mitigation devices become small enough, commercial owners and operators of large fleets of satellites will routinely employ them on their satellites to reduce their susceptibility to catastrophic failure or to operations interruptions due to spacecraft charging.

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1. "An Autonomous Charge Control System at Geosynchronous Altitude: Flight Results For Spacecraft Design Consideration", IEEE Trans. On Nuc. Sci. Vol 44, NO 6, Dec 1997.
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KEYWORDS: autonomous control, charge mitigation, dielectric charging, micro-satellites, spacecraft anomalies, spacecraft charging, spacecraft survivability

AF00-072 TITLE: Advanced Algorithms for Exploitation of Space-Based Imagery

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop innovative algorithms to optimize techniques for detection, identification and tracking of targets in structured environments.

DESCRIPTION: The Air Force Research Laboratory's Background Clutter Mitigation Branch (AFRL/VSBM) is interested in innovative techniques for the mitigation of clutter effects in an effective and computationally efficient manner to optimize the search, detection, and tracking performance of space-based optical (ultraviolet/visible/infrared) systems. Mitigation requires advanced algorithms based upon spatial, temporal, and spectral techniques. Data from airborne and space-based missions has led to a data base of optical data (ultraviolet, visible, and infrared) to characterize the optical properties of the environment. It is expected that the proposer will exploit these data bases to explore potential space-based detection techniques for clutter-mitigation/ contrast-enhancement techniques to optimize target detection, to identify materials, and to identify and quantify atmospheric constituents/effluents. It is expected that, as a result of this effort, new algorithms will be devised and tested. Figures of merit in assessing algorithm effectiveness include improvements in materials identification, enhanced probability of target detection in structured backgrounds and reduced false-alarm rates.

PHASE I: Conduct analyses, using real data, to develop algorithms for clutter-mitigation / contrast-enhancement techniques to optimize target detection, search, and track capabilities in structured environments, to identify materials, and to identify and quantify atmospheric constituents/effluents. Compare and contrast the candidate algorithms.

PHASE II: Perform detailed analyses and demonstrate the efficacy of algorithms for target detection, search, and track in structured environments, for materials identification and for the identification and quantification of atmospheric constituents/effluents. Conduct tests, as required, to assess the effectiveness of the algorithms. Develop and demonstrate an automated, near-real-time, processing system using real-world data sets.

PHASE III DUAL USE APPLICATIONS: The novel algorithms and processing techniques developed under this effort will potentially be useful in Phase III in military systems requiring autonomous stand-off detection under stressing conditions of sensor clutter induced by scene structure and the data-collection process, and spectral interferences. They will potentially also be useful for non-military applications involving autonomous detection under similar conditions of scene-induced and sensor-induced clutter and noise and spectral interferences; potential commercial examples include a processing system for application in fields such as medicine, industrial processing and quality control.

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KEYWORDS: Terrain Data, Elevation Data, Facet Models, Wire-Frame Models, NIMA, Data Format Conversion Tools

AF00-073 TITLE: Surface Luminescent Dust Sensors

TECHNOLOGY AREAS: Chemical/Biological Defense

OBJECTIVE: Develop luminescent dust for remote detection of hazardous chemicals on surfaces.

DESCRIPTION: It is well known that chemisorption of chemicals on surfaces can some times lead to emission of light. Reference studies have shown luminescence of molecules such as chlorine on surfaces of zirconium and sodium-doped zirconium. Similar observations have been made for hydrazine adsorbed on a variety of surfaces, including silica. The objective of this SBIR is to develop sticky polymeric material which can undergo reactions with specific families of compounds, such as the hydrazine family or chemical agents. Designing the polymeric materials so that they can be dispersed in the form of pellets or dust would then generate luminescence which would be detectable by remote passive sensors. The advantage of manufacturing the polymers in the form of dust or pellets is that they can be spread over large areas where contamination or use of dangerous materials is suspected, and the area can be monitored remotely. Further modification of the polymeric detectors can change their optical and infrared properties so that the products of their reaction with the chemicals of interest can fluoresce either in the infrared or optical regions of the spectrum, making it possible to conduct active remote probing, as, for example, by the use of a laser. The use of UAV platforms for either active or passive probing can, for example, save personnel from the need to be exposed to dangerous chemicals. Such techniques also have applications for surveillance. It is expected that the development to carry the program to large scale manufacturing will cost less than $10M.

PHASE I: Develop a preliminary sensor design and test polymer materials for passive/active optical detection of known hazardous chemical agents, e.g. members of the hydrazine family.

PHASE II: Develop a prototype of the selected design, extend the design to the generation of sticky, polymeric dust and test against an application specification.

PHASE III DUAL USE APPLICATIONS: These detectors have potential applications in the civilian sector. For example, they can be used to detect pesticides, chemicals that may be used in terrorist attacks, and dangerous chemicals near toxic waste sites. They can also be used to provide early warning of chemical agent attacks in civilian areas.

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KEYWORDS: airborne surveillance, chemical weapons detection, chemiluminescent dust, dust, encapsulate, luminescent chemicals, space-borne surveillance

AF00-074 TITLE: Innovative Techniques for Remote Sensing, Threat Detection and Typing

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: Develop electro-optical data collection and processing techniques for early threat detection, threat typing, and reduction of false alarm rates.

DESCRIPTION: A significant emerging surveillance requirement involves detection of foreign missile launches--both theater and longer range. These emerging missile threats require: 1) continuous global launch detection, preferably at the moment of ignition on the launch pad; 2) immediate information on the nature of the threat (typing) to optimally utilize scarce and expensive interceptors; and 3) significant reduction in false alarm rate, so that attention is drawn only to real threat events. The most stringent requirement is timeliness, as flight times may be measured in minutes. An additional requirement is false alarm reduction. The battlespace commander must not be diverted by false detections. Information must be provided under all battlespace conditions, including not only clear sky, but also optically thick cloud and haze cover and conditions of high temporal variability. Theater missile launches involve a very short time line, and detection at the moment of ignition is desired. Detection at ignition provides seconds of advance warning of a launch (with a potential time line of minutes), and permits deployment of radar resources for trajectory determination. The proposed technology should work both day and night, in all weather conditions, and be suitable for deployment from a space platform. The proposed technology ideally will make use of commercial hardware and data analysis techniques, and should be relatively inexpensive and robust. The Air Force Research Laboratory's Battlespace Environment Division (AFRL/VSB) is interested in innovative electro-optical techniques for earliest detection and characterization of threats under realistic battlefield conditions, and reduction of false alarm rates. The emphasis is on, but not limited to, space-based applications.

PHASE I: Develop the proposed concepts of threat detection and typing, make an initial proof-of-principle demonstration or justification of the proposed technology, and show commercial involvement. Demonstrate that the proposed technology does in fact have the potential for false alarm reduction and significantly improved threat detection and typing.

PHASE II: Develop, test, and deliver a prototype product or process that performs the proposed solution to threat detection, typing, and false alarm reduction. This phase should include rudimentary proof-of-principle data.

PHASE III DUAL USE APPLICATIONS: The development of the techniques and methodologies under this effort potentially will be useful in space-based, UAV-based, or aircraft-based (i.e. ABL) military systems requiring autonomous threat detection, threat typing, and false alarm reduction under actual stressing battlespace conditions of optically thick cloud and haze cover. The proposed technology ideally will make use of available commercial technology both in instrumentation and in techniques of threat recognition and characterization. Commercial applications include: resource definition, environmental monitoring, forest fire detection, pollution detection, chemical and biological detection and identification, remote sensing for prospecting, and a host of as-yet-unidentified applications involving the use of space-based remote sensing technology.

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KEYWORDS: false alarm reduction, imaging, missile launch detection, remote sensing, spectral signatures, threat-typing

AF00-075 TITLE: Behavioral Toxicology - Integration of Chemical Exposure Threats into Command Decision Processes

TECHNOLOGY AREAS: Information Systems, Biomedical, Human Systems

OBJECTIVE: Develop technology capable of predicting human behavioral/performance impact of chemical exposures typical of deployment operational settings.

DESCRIPTION: The Neurobehavioral Effects Laboratory of Tri-Service Toxicology has developed a comprehensive battery of animal neurobehavioral tests (NTAB). The government seeks innovative proposals to integrate existing data from standardized NTAB tests with human clinical performance endpoints, derived from data developed from positive control compounds with well-characterized human activity. NTAB data for up to 10 compounds (drugs of abuse or psychotherapeutics) will be provided to the successful proposal awardee. The Air Force seeks a tool that will predict the human effects based on NTAB analyses and subsequently report confidence boundaries of that prediction. The technology should be capable of analyzing NTAB data obtained from exposures to chemical compounds and presenting an easily understood summary report predicting the effect on human behavior/performance. The resulting analysis and prediction should be presented in a fashion that facilitates rapid comprehension by the user and that can be easily used for command decisions to prevent adverse impact on the performance of military personnel.

PHASE I: Explore how to collect human data from the literature and determine the feasibility of incorporating both human and animal (NTAB) data into the appropriate software. Because there is a broad range of existing human data, this phase must develop an approach which will lead to meaningful integration of all existing data. The government originator will provide NTAB datasets for as many as 10 positive control compounds. Develop a work plan and set of milestones for Phases 1-3.

PHASE II: Develop prediction system that links NTAB databases with human performance. The system should address variability analysis techniques - such as Monte Carlo simulation - to report likelihood estimates for the accuracy of predicting various human behavioral changes.

PHASE III: This phase will result in an integrated software-based tool that rapidly assesses patterns among test datasets and reports analysis and prediction, including confidence boundaries, in a user-friendly, graphically-based platform. The tool will be adapted for implementation in a standard Microsoft Windows(r) operating environment.

PHASE III DUAL USE APPLICATIONS: Numerous industries use chemical compounds in manufacturing processes, production/repair, and fabrication. The Occupational Safety and Health Administration (OSHA) regulatory guidelines mandate worker health protection against injury or illness that could result from chemical exposures in the workplace. This technology will be essential for business managers seeking to prevent worker injury that could result from exposure-related performance or behavioral degradation. It also has the potential to become a powerful tool in the drug discovery process and will create the capability to quickly generate and interpret data on exposures to chemical mixtures, an area in which there is minimal existing information.

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KEYWORDS: neurobehavioral tests, behavioral degradation, software tool

AF00-076 TITLE: High-Resolution Visual System Development

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Development of advanced high-resolution visual system components for Distributed Mission Training (DMT).

DESCRIPTION: Long-standing problems associated with wide field-of-view head-mounted displays for ground-based simulator-training applications have been poor resolution, too much weight, and poor center-of-gravity characteristics. The resolution problem is being addressed through current Air Force efforts to develop color head-mounted imaging systems with greater than 5K x 4K, non-interlaced pixel resolutions. In an attempt to resolve the weight and center-of-gravity problems, the USAF solicits industry to design and construct light-weight, head-mounted visor optics for displaying high-resolution color imagery. The concept is to optimize the display's center-of-gravity and incorporate projection optics with curved surface visor display materials that could be integrated into a flight helmet. Projector systems with greater than 5K x 4K, non-interlaced pixel resolutions are in development by the Air Force. These projectors will present out-the-window imagery in high-performance flight trainers as well as other display applications. The Air Force is looking to capitalize on the rapidly developing PC-based graphics market to provide imagery for these systems and is seeking innovative PC-based technologies capable of presenting 5K x 4K, 60 HZ, non-interlaced video. Communication between the graphics system and the projectors will be via a non-proprietary parallel digital interface. Capabilities such as multiple view modes, multi-window, multi-channel, and large area databases should be considered a requirement.

PHASE I: Provide a technical report determining the feasibility of the concept and provide a feasibility demonstration.

PHASE II: Phase II will result in prototyping, demonstrating, and testing the concept proposed under Phase I and a technical report.

PHASE III DUAL USE APPLICATIONS: An improved light-weight, head-mounted visor optical system has the potential to provide tremendous improvements in weight and center-of-gravity characteristics of head mounted displays. This work, combined with ongoing Air Force efforts to increase image resolution, would have immediate benefit to the expanding world of virtual reality for industrial (auto, boat, manufacturing), medical, special effects applications in the electronic media and motion picture industries, and CAD/CAM.

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KEYWORDS: Helmet Mounted Optics, Helmet Mounted Display, Visually Coupled System, Helmet, Simulator, Crew Systems, Human Resources, Personal Computer, Graphics, High-Resolution, Image Generator, Low-Cost, 3-D

AF00-078 TITLE: Automated Material Classification Toolset

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a toolset to automatically classify materials contained in multi-spectral imagery for use in real-time multi-sensor simulation.

DESCRIPTION: In order to provide a realistic environment to support combat mission training and rehearsal, a high fidelity, correlated multi-sensor simulation capability is required. The solution for a given sensor requires that materials with their attributes be identified correctly at a high level of resolution. The source material is multi-spectral imagery obtained from satellites and aerial photography. The current process for material classification is extremely slow, costly and labor-intensive. Existing tools have little or no automatic features automated and low resolution. The development of an automatic material classification system would facilitate rapid database development, making high fidelity simulation affordable. The purpose of this effort would be to develop an automated capacity to accurately identify and classify materials. Given an image, the tool will be able to say, "that is concrete", "that is dirt", "that is grass". It is likely that such a tool will require the use of an intelligent agent that is capable of self-learning.

PHASE I: Provide a technical report assessing the feasibility of the concept, an analysis of alternative approaches for cost, accuracy, and speed, and recommended approach.

PHASE II: Development and demonstration of a system, which can accurately, automatically, and quickly, classify materials from satellite imagery sources at the pixel level for use in real time simulation. An initial goal would be to have the capability of automatically classifying materials at 1-meter resolution of a 2-deg X 2-deg area within 6 hours with 98% accuracy.

PHASE III DUAL USE APPLICATIONS: The toolset could be used by a wide variety of governmental agencies and commercial entities dealing with environmental imaging, geological, agricultural, space, and global resource management could use this tool and realize substantial savings in time and cost.

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KEYWORDS: Multi-spectral imaging, material classification, intelligent image processing, real-time simulation, databases

AF00-079 TITLE: Information Warfare Training Models

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: To develop a cost effective distributed situation assessment and decision making training system originating from inventive development tools in a C2 /C4ISR team performance environment.

DESCRIPTION: Training budgets within the DoD are undergoing massive cuts at a time when effective training is more essential than ever before. C2 and C4ISR training is critical to information and space warfighter support especially with the new methodology of war which is technologically faster, shorter, and more direct.

Training technologies are needed for global access to C2 and C4ISR among warfighting forces to ensure optimum linkage for maintaining real time global awareness and force execution capabilities. Anytime, anyplace virtual help for all C2 and C4 Centers training for both procedures and systems is critical. Cognitive modeling of information warfare operations and tactics is necessary in the development of simulated wargaming exercises to train real time, wartime critical thinking skills. Distributed interactive training is necessary in implementing a capability to relate simulated task training to actual event training with elements of operations security, psychological operations, deception, physical destruction, and electronic warfare. These studies are in support of military operations, planning, exercises, and training at the Air Staff, Joint Forces Air Component Commander, and Joint Command levels. This is an area of training research that has been completely missed due to size and depth of scope and lack of technological feasibility. The purpose of the SBIR is to create a distributed situation assessment and decision-making training system in a C2 /C4ISR team performance environment. Development tools containing characteristics like embedded training capabilities, the ability to create and maintain computer based training for National Sensors and Mission ground Stations, and methodologies for battlespace simulations gives this training system the flexibility in an ever-changing global battlefield. In addition, this training system will implement constructivist & experiential learning theories in a web-based, secure environment. The training system will include synchronous & asynchronous capability and real-time collaborative intelligent wargaming exercises in a virtual simulation environment while at the same time providing analysis routines for defining training needs based upon operator dynamics. This prototype is to be supported through both synchronous and asynchronous communications and can be used by military personnel to create C2 teams in a range of information warfare environments. Communications, classifications, recognition, collaboration, team performance, and human performance are the training areas that can be well integrated into the models being prototyped. Due to the nature of the subject area, security in a synchronous and asynchronous state must be demonstrated.

PHASE I: Phase I should end with a technical report describing the problem and technical challenge in layman's terms. A fully functional prototype development should also be completed demonstrating the feasibility of the training models in the secure asynchronous and synchronous environments. Training tool feasibility will also be demonstrated at the end of Phase I, as shown with prototype operation.

PHASE II: Phase II should end with a full-up training environment with a technical report which presents appropriate evaluation data reflecting student learning and team performance within the training models.

PHASE III DUAL USE APPLICATIONS: Training models have a specific commercial potential to all industry and public education and training sectors, as specific training development tools will be available for use in any training environment.

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http://huachuca-usaic.army.mil/SCHOOL/othrsite.html
http://www.cudenver.edu/~mryder/itc_data/constructivism.html
http://www.tiac.net/users/lsetter/learn.htm
http://www.c2tic.hurlburt.af.mil
http://www.c4isr.com/

KEYWORDS: Distributed training, team performance, asynchronous & synchronous, situation assessment, decision-making, mission rehearsal, information warfare, artificial intelligence, multimedia, computer-based training, performance measurement, security environment, desktop 3-D virtual simulation, web-based training, internet/intranet, constructivist learning model, experiential learning theory, adult learning, collaboration, wargaming, C2, C4ISR

AF00-080 TITLE: Agent-Based Measurement System for Advanced Distributed Learning Technologies

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Conduct exploratory research to develop deployable methods for capturing cognitive, behavioral, and affective information related to performance in operational contexts.

DESCRIPTION: A requirement exists to develop automated, deployable methods for capturing, representing and synthesizing individual operator and workgroup interaction, knowledge and core competencies for use in rehearsal, training and performance support. This effort will conduct exploratory research to develop deployable methods for capturing cognitive, behavioral and affective information related to performance in operational contexts. It will also develop methods for using this information to model individual activities and actions in intelligent software agents that can participate as passive or active members of a rehearsal, training, or operational event. Furthermore, this effort will demonstrate a capability to use these models to develop pedagogically valid learning technologies. Recent advances in distributed methods for training, simulation, and performance support indicate that it may be feasible to develop an online (near-real-time) capability to decompose elements of work activity into knowledge-, behavioral-, and competency-based components. The development of such a capability will permit near-real-time knowledge elicitation and specification for developing models of expertise and for identifying key aspects of performance required to meet mission requirements. Intelligent agents are computer programs that have the potential to participate in actively accomplishing tasks, providing feedback about key activities of a user, and can actually participate in team training and rehearsal activities. This effort will also demonstrate the use these components to develop autonomous agents that can represent the behavior of individuals for rehearsal and training purposes. Presently, eliciting key cognitive, behavioral and affective performance characteristics is time consuming, labor-intensive, and inaccurate. There are also no reliable tools that can take the information and instantiate it in the form of software agents that could become members of a training or rehearsal team as substitutes for human players. It might even be possible to demonstrate that reductions in crew size are possible with these agents in place.

PHASE I: Phase I activities will result in a proof-of-concept technology for representing knowledge and competencies to drive training and performance support development. Phase I proposals must include a detailed market survey activity and letters of interest/commitment from potential commercial partners must be obtained for Phase II consideration.

PHASE II: Phase II will fully develop, apply, test, refine, and validate the elicitation and representation methodology and will develop intelligent agent-based team instructional events. Proposals should assume that the technology and agents will run in a platform-independent environment.

PHASE III DUAL USE APPLICATIONS: Commercial application potential is significant as no assessment capability such as the one described herein exists. The benefits from such a capability to Government and Private Sector agencies could help organizations save considerable time and expenditures by developing models of human performance that are actually capable of assuming some interactive roles in training and operational contexts. There are many instances where an entire marketing or product development team cannot meet at the same time. Having a capability to insert software agents that can "participate" in the team interaction for training and other purposes is of considerable value. The results from this effort are of considerable interest to the Private Sector as competency-based selection, placement, and training approaches become commonplace with increased job enlargement and workforce globalization.

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KEYWORDS: Competency-based assessment, intelligent agent architectures, intelligent agent-based models, knowledge elicitation and representation, performance enhancement, performance measurement, team effectiveness, workgroup effectiveness

AF00-081 TITLE: Distributed Human Performance Management with Emphasis on Team Performance

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop innovative concepts, technologies, and methods to support distributed human performance management with emphasis on team performance.

DESCRIPTION: In recent years, human performance disciplines have demonstrated remarkable success in modeling and optimizing the performance of individuals. Team performance is not nearly as well understood as individual performance, and instructional models to optimize team performance are virtually nonexistent. No comprehensive taxonomies have been developed to provide systematic dimensions of variation across team tasks. The few postulated models of team performance account for very narrow categories of actual team task types, and are generally not specified sufficiently to support the generation of instructional models. One approach we are interested in pursuing would allow us to build on successful work in individual performance and combine that with promising approaches for modeling and optimizing team performance. Prior research in team performance has produced a variety of models for team performance. For example, the TADMUS (Technical Decision Making Under Stress) program (Salas, Cannon-Bowers, Johnston (1997) has shown the utility of identifying Shared Mental Models (using TADMUS) and Cross Training (using Team Model Trainer) methods. Salas, Dickenson, Converse, and Tannenbaum; 1992 propose a team performance model consisting of variables that are internal or external to the team. Variables external to the team include workload (Bowers, Urban, and Morgan, 1992; Kleinman and Serfaty, 1989), time pressure (Adelman, Zirk, Lehner, Moffett, and Hal, 1986), and task structure (Kleinman and Serfaty, 1989; Bowers, Urban, and Morgan, 1992; Urban, Bowers, Monday, and Morgan, 1995). Variables internal to the team include team cohesiveness (Gal 1986; Bowers, et al., 1992), task cohesiveness (Zaccaro, Gualtieri and Minionis, 1995), and interpositional uncertainty (Volpe, Cannon-Bowers, Salas, and Spector, in press. Situation Awareness in is probably an important concept in understanding team performance (Salas, Prince,Baker, Shrestha 1995), but team SA involves two poorly understood abstractions. Individual SA may be defined as an individuals ongoing awareness of changing contextual realities that modify task goals or contingencies, but much diversity currently exists in operational definitions of SA. Team processes are teamwork behaviors and cognitive processes that facilitate team process, but again there is little agreement in the literature on how to model these. The TeamTRAIN (Team Training Research for Automated Instruction) model (Regian & Elliott; 1997) is an example of a taxonomic approach to identifying the characteristics of team task. Dimensions include information distribution and display, differentiation of team member function, differentiation of team member expertise, and type of decision process (e.g. collaboration, negotiation, rule-based, autocratic). Fleishman and Zacarro (1992) proposed a taxonomy of team performance functions that has been applied to team performance assessment. In a structured approach to the measurement of team performance the TARGETs method (Fowlkes, Lane, Salas, Franz, et al; 1994) supports team performance measurement that encompasses theoretical, psychometric, and operational issues. This approach involves structured observation in which task events are introduced to provide opportunities for teams to demonstrate specific team-related behaviors; acceptable team responses to each of the events are determined a priori by utilizing team task analyses, subject-matter experts, and so forth; and the appropriate responses to events are scored as either present or absent.

PHASE I: Phase I should end with a technical report describing the problem, the technical challenge in layman's terms, and a review of the literature. Specifications for a software product to be constructed in Phase II should also be included.

PHASE II: Phase II should end with a software product related to the proposed topic, an application of the software product in a domain mutually agreed to by the proposer the AFRL technical monitor, and a final technical report.

PHASE III DUAL USE APPLICATIONS: Team training models have large commercial potential for industry, public education and training sectors, and the defense industry.

REFERENCES: http://train.galaxyscientific.com

KEYWORDS: team performance modeling, team situation awareness, team tasks, team training, team decision-making, performance measurement, collaborative training, command and control

AF00-082 TITLE: Psychological Warfare Training via Advanced Distributed Learning Technology

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: The goal is to develop a quality Advanced Distributed Learning approach for psychological warfare training.

DESCRIPTION: Information warfare (IW) involves the protection, manipulation, degradation, and denial of information. IW is not a separate technique for waging war, but rather the umbrella for several distinct types of warfare related to the ebb and flow of information. One example is psychological warfare (PSYW). PSYW seeks to utilize information against the human mind. Cognitive modeling of psychological operations tactics is necessary in the development of training exercises to train wartime critical thinking skills. Advanced Distributed Learning takes advantage of technologies for directing instruction at dispersed individuals via networking technology (e.g., internet).

This effort will: define cognitive principles of PSYW. Based on these principles, instructional strategies and methods for training these principles will be developed. The researchers will then determine if these strategies and methods are amenable to be implemented via Advanced Distributed Learning (ADL) technologies. If so, develop instructional, software, and networking specifications for PSYW ADL training will be developed. An ADL testbed for PSYW training will then be developed and evaluated.

This topic responds to training needs/ deficiencies identified by ACC/DR in the "Aircrew Training Needs" document (1 Nov 97), under the heading of "Predictive Modeling and Campaign Simulation." The specific focus area is "Information Warfare Models" and the need to model the effects of information warfare and integrate their effect into planning and campaign models.

PHASE I: End product is a description of cognitive principles of PSYW; an instructional strategy for teaching PSYW; instructional, software and engineering specifications for an ADL approach to distributed PSYW training.

PHASE II: Develop and test a prototype ADL system for PSYW. Users will be AF PSYW personnel. Evaluate instructional effectiveness of prototype testbed.

PHASE III DUAL USE APPLICATIONS: The instructional, software and networking specifications, which will result from this project, will be commercializable. Advanced Distributed Learning is required in the commercial sector for a variety of industrial and commercial purposes. In addition, education at all levels can make use of ADL principles and technologies.

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KEYWORDS: advanced distributed learning, team performance, asynchronous/synchronous, situation assessment, decision-making, mental modeling, cognitive modeling, mission rehearsal, psychological operations, psychological warfare, artificial intelligence, performance measurement, secure environment, adult learning, collaboration, wargaming

AF00-083 TITLE: Graphical User Interface Techniques for Assessing Autonomous Vehicle "Behavior"

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop graphical user interface techniques for presenting actions of multiple autonomous vehicles.

DESCRIPTION: Challenges for operators of future autonomous systems, e.g. an unmanned combat air vehicle (UCAV), will be understanding what the vehicle (or vehicles) is doing and planning to do, deciding if what is planned is acceptable, determining appropriate corrective actions if it is not, and then implementing these corrective actions. To carry out this responsibility, operators must have insight into the vehicles' current and projected 'behavior' and the context in which the behavior will occur.

UAVs are being developed to make higher order decisions independent of operator input. For example, if the UAV perceives a pop-up threat, it will determine the type of threat and its vulnerability and then decide the best course of action, e.g. avoidance, or attack. This capability to "decide" constitutes a new set of challenges for UAV operators; they need to understand system intent and, when appropriate, "get inside the head" of the UAV to determine how and why these decisions are being formulated. An effective graphical-user interface (GUI) is needed so that operators can gain insight into the intent of remote vehicle(s) under their supervision and assess the impact of planned actions on mission objectives.

PHASE I: Analyze current/projected UAV missions to identify design requirements and constraints for the operator-vehicle interface and specific operator-vehicle functionality that must be supported by the GUI. Identify human-computer interface technologies that augment the GUI and develop a GUI design. The Phase I deliverables shall be 1) a demonstration of a GUI for a portion of autonomous operations, 2) a report documenting the GUI, including drawings and descriptions of GUI formats/functionality and operating instructions. The report shall include design rationale and sufficient detail to permit GUI software development.

PHASE II: Develop, integrate, and demonstrate the GUI in a mission simulation of multiple autonomous UAV in the Vehicle-Pilot Integration Laboratory (VPIL) at WPAFB. Interface with VPIL's simulation environment and aero and mission planning models. The GUI shall be hosted on VPIL computers and be interactive allowing real-time GUI operation in the context of a mission scenario.

PHASE III DUAL USE APPLICATIONS: Interface methods developed apply to complex systems where operators must have insight into what an autonomous system is doing and why. The solutions could apply to air traffic control stations to alleviate uncertainties associated with 'Free Flight' operations, to power plant control stations to help an operator quickly understand automated diagnostics and prognostics, and to intelligent highway traffic management.

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KEYWORDS: Information Visualization, Graphical User Interface, Intent Inferencing, Supervisory Control, Distributed Decision-Making, Human-Computer Interaction, Intelligent Systems, Autonomous Vehicles, Autonomous Agents, Associate Systems, Automation, Unmanned Aerial Vehicle, Task Network, Concept Mapping

AF00-084 TITLE: Integrated, Hands-free Control Suites for Maintenance Wearable Computers

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop integrated control suites that provide maintainers with hands-free operation of wearable computer systems.

DESCRIPTION: The Air Force is evaluating the use of wearable computer systems to support aircraft maintenance operations. With the availability of electronic technical manuals and diagrams, wearable computers and head-mounted displays (HMDs) will permit technicians to readily access the required information without the need for bulky paper documents. Suites of nonconventional controls are needed to support hands-free interaction with wearable systems. Analysis of maintainer interactions with wearable computers suggests that these control suites must provide "point", "click" and text entry functions. Speech recognition is available with wearable systems, but it is inefficient for pointing operations and is constrained by the communication requirements and noise typical of many maintenance environments. In addition, the use of a multiple-controller approach enables the interaction to be tailored to task and environmental constraints, as well as user preferences. For example, a software-based speech recognizer, an inertial head tracker, and a facial gesture detector might be configured in a variety of ways to provide the required functionality (This is provided only as an example and should not constrain a company's innovation.). Companies should not propose the development of a single control technology unless it can efficiently support complete interaction with a wearable computer.

PHASE I: Select a future USAF weapon system and identify maintenance requirements supportable with wearable computer technology. Identify the requirements for interaction with the wearable computer system using tools such as projective task analysis. Identify potential hands-free control technologies that would support these requirements. Document the results of these analyses and the integrated design concept(s) in a technical report. A concept demonstration is a highly desirable product. Integration of low-cost, off-the-shelf, components functioning on a desktop computer is satisfactory for this demonstration.

PHASE II: Develop, demonstrate, and evaluate two prototype control suites that satisfy the requirements identified in Phase I. These control suites should be integrated with a wearable computer system including an appropriate HMD. The system should include prototype maintenance software that can support performance evaluations. Conduct preliminary evaluations with a sample of maintenance personnel to 1) provide data on the effectiveness of wearable computer interaction with the candidate control suites and 2) guide the development of a fully functional Phase III product design. At the completion of Phase II, deliver a final technical report, control suite prototypes, wearable computer system, and preliminary Phase III product design to the Air Force Research Laboratory.

PHASE III DUAL USE APPLICATIONS: Hands-free controllers for wearable computers have application well beyond maintenance environments. The Army and Navy are evaluating wearable systems for foot soldiers, damage control specialists, and medical ship connectivity. Civilian applications for disaster relief, inventory management, troubleshooting and repair are under consideration or development. Each of these represents commercialization targets for the control suites developed under this SBIR.

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KEYWORDS: Human-Computer Interaction, Wearable Computers, Head-Mounted Displays, Hands-Free Control, Nonconventional Control

AF00-085 TITLE: Novel Situational Awareness Concepts for Command & Control of Space Assets

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop visualization technologies to enhance situational awareness of space operation center personnel for satellite constellations.

DESCRIPTION: For effective space operations, space operation center (SOC) personnel must conceptualize the operational status (i.e. global coverage, continuous operation, system failure, intolerant environment, etc.) of on-orbit assets. Global coverage and continuous operations require a need for visualizing global continuous communications for both commanding the satellite as well as providing payload data to worldwide users. There is a need to be able to observe threat levels and to depict blue force operations so that the SOC staff can develop courses of action. Space operation visualizations should go beyond just the spatial dimension of the battlespace. They should describe and depict how and where space activities interact with other forces, assets (friend and foe), and movement in the battlespace. The proposition is that existing SOC capabilities can be greatly enhanced by understanding and developing specific visualization, and decision aiding technologies to improve the situational awareness and decision making in the SOC. Furthermore, training should be an integral part of any concept such that training, mission rehearsal, and operations should be conceptually indistinguishable. At the Air Force Research Laboratory, we have been performing a variety of command and control studies and experiments utilizing visual and auditory displays and cognitive analysis. Prior studies in North American Air Defense (NORAD) command and control have shown that adequate information presentations exist, but they are not optimized for problem solving, decision making, or cross-communication between command personnel. Understanding the operational environment is paramount in developing technologies to improve the situational awareness and decision making of SOC personnel.

PHASE I: Phase I efforts shall provide proof-of-concept technologies to apply in improving the situational awareness and decision making of SOC personnel. Specifically, Phase I shall (a) identify and document the SOC's electronics mapping requirements; (b) identify and document visualization (visual and aural) activities that can be most usefully integrated with other information presented to the SOC command staff; (c) identify measures of effectiveness that can be embedded in such visualizations; and (d) demonstrate selected visualization technologies that can aid space operations, giving special attention to human factors and human computer interactions.

PHASE II: Phase II efforts shall develop and a SOC visualization capability to demonstrate the effectiveness of applied technologies in performing SOC operations. Special considerations shall be given to designing these technologies such that they are compatible with distributed mission training environments and in making them affordable and maintainable.

PHASE III DUAL USE APPLICATIONS: Commercial applications of these technologies are possible for commanding and controlling equivalent commercial communication satellite constellations as typified by constellations such as Iridum and Teledesic.

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KEYWORDS: Displays; Visualization, Cognitive Analysis, Command and Control, Situational Awareness, Space Operation

AF00-086 TITLE: Auditory Devices for Remote Threat Detection

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Human Systems

OBJECTIVE: Develop innovative methods to detect, identify, and display remote threats using acoustic sensors to enhance the performance of the security force commander and deployed squads. Develop advanced acoustic signal processing in a stand-alone configuration or in conjunction with other detection techniques to reduce false alarm rates.

DESCRIPTION: Acoustic detection methods are sought in the following areas to improve human response to perceived threats: 1) Remote listening devices; 2) Improved algorithms for detection of personnel or vehicle motion and direction; 3) Adaptive algorithms for learning background sounds from transient threat actions; 4) 3D integration into command and control for security forces including 3D audio for deployed forces; 5) Improved low power wireless telemetry systems to feed full 3D audio and video signals to a remote receiver greater than 1-2 miles away; 6) Low power (microwatt) remote acoustic and video buffering systems for replay of captured signals.

Base security and Force security issues are mandating the use of remote detection to handle the reduction in manpower present in all areas of the military. The Force Protection SPO has developed the Tactical Automated Security System (TASS) that uses trip wires, infrared detectors, motion detectors and vibrations sensors to identify threats. This system concentrates on developing better sensors but not the processing of this information for threat identification and response. This system also does not contain any acoustic sensors or processing of acoustic data. Reduction of false alarms yet retaining a one hundred percent detection rate from remote systems is critical to the long-term success of any mechanical/electronic surveillance system. Use of multisensor and cross data type processing is critical to reducing false alarm rates yet retaining high detection rates.

The objective of this topic is to explore the use of acoustic data for rapid identification of threat location, motion and lethality. The concentration will be on using acoustic data along with other data collected by TASS and other systems to increase the probability of detection while reducing the false alarm rate of the overall system. Concentration will be on the unique methods to reduce human response time to threat and enhance the ability of deployed forces through the use of auditory signals.

PHASE I: Develop initial designs, methods, and associated analysis to select the most promising approach to reduce human response time to threats. Preliminary demonstration of the chosen design is preferred but not required. Document the approach, initial designs and preliminary results (if available) in a final report.

PHASE II: Fabricate, demonstrate, and deliver the final prototype system demonstrating the reduction in threat identification time and reaction time to threat situations. Evaluate results and develop a plan for follow-on commercial and military development. Prepare a final report describing the design along with the test results and recommendations for insertion of the design into applicable Air Force and commercial systems.

PHASE III DUAL USE APPLICATIONS: These problems are generic to security worldwide. Problems that can be solved to enhance the AF security forces have an immediate commercial application to civilian and corporate security forces such as gunfire localization within city limits and security of local and state governments.

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KEYWORDS: Audio Displays, Audio Detection, Audio Signal Processing, Audio Perception, Audio Motion Detection, Threat Detection, Crew Safety and Protection

AF00-087 TITLE: Sensor Fusion and Information Warfare

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace, Human Systems

OBJECTIVE: Develop a system to assess, integrate, and evaluate the robustness and vulnerabilities of sensor fusion technologies in an information warfare environment.

DESCRIPTION: With major advances in sensor-related and computing-related infrastructure technologies over the last several years, and with new visions of theater architectures depicting highly-distributed but highly-connected systems, extensive opportunities are evolving for the application of sensor fusion techniques. However, as much as these architectures and capabilities offer opportunities for significant improvements in the overall quality of information available to warfighters, they also create opportunities for information attack on such systems. In spite of the application of advanced concepts of information protection and security, it is generally agreed that perfect protection of these systems is either technically impossible or unaffordable, or both. Since sensor fusion processes will likely be important elements of these vulnerable systems and architectures, it is important to understand the specific vulnerabilities and dependencies of sensor fusion processes on informational components, and to conceptualize and specify how to both protect the integrity of the information within these processes and how to overcome the effects of information corruption on sensor fusion operations. Additionally, it is of interest to assess how new and creative concepts of employment of sensor fusion processes can contribute to the realization of effective counter-information and counter-deception techniques, and the general notion of employing the sensor fusion process as a weapon. Finally, since sensor fusion processes most typically function in a decision-aiding framework, it is of interest to understand and evaluate the impacts of information operations on the human role in sensor fusion systems.

PHASE I: Phase I will result in a proof-of-concept consisting of comprehensive performance evaluation of potential information warfare methods and of data/sensor fusion approaches. Emphasis will be on the role of the operator in systems in which the fusion processes are employed as decision-aiding capabilities and the information attack is directed against the decision-making process. Specific examples will be identified and described. The effects of dissonant information on decision making will also be explored. The methodology and findings of the Phase I effort will be documented in a technical report.

PHASE II: Phase II will result in the development and conceptual demonstration of a prototype consisting of a suite of analysis and design support tools which apply specifically to the sensor/data fusion capabilities of management and control systems. The demonstration will focus on the specific fusion applications identified during Phase I. A detailed technical report and a completed working model of the analysis/design system will be delivered.

PHASE III DUAL USE APPLICATIONS: Many non-military information systems and functions may well be the targets for information warfare (e.g., financial, transportation, power distribution, etc.). These systems all rely in some significant way on sensor/data fusion technologies and methods. This effort would provide methods and guidelines for assessing the vulnerability of this system to information warfare attacks and for enhancing their robustness against such attacks.

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KEYWORDS: Information Warfare, Cognitive Engineering, Sensor Fusion, Data Fusion, Decision Aiding

AF00-088 TITLE: Advanced User-System Interface Technologies for Untethered Computer and Visual Display Interactions

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Capitalize on emerging, low cost technologies such as large bandwidth personal data-links and smart room technologies to allow untethered, mobile access to computing and visual display capabilities within Information Operations (IO), and Command and Control (C2) environments.

DESCRIPTION: The Air Force currently seeks untethered, natural input and output devices (User System Interfaces) for use by operational personnel in multi-user Information Operations (IO), and Command and Control (C2) environments. These devices will allow IO and C2 personnel to physically move throughout the work environment for collaboration among work nodes without loss of data/information normally available only at a stationary work station. As a compliment to wearable computers, this technology will allow operators to stay linked to the collective knowledge base for both input and output while moving among collaborators, interacting with large screen information displays, or working in locations remote from desktop PC support. New untethered user-system interface (USI) technologies are necessary to facilitate communications and common understanding among co-workers (horizontally) and the command structure (vertically). The technology to be developed must support personnel tracking in IO and C2 multi-user environments, including tracking of the users orientation within the environment to allow use of speech recognition/speech generation, 3D audio, laser pen control of large screen displays, and eye tracking. User data input and system control devices must be portable, unintrusive, and have the ability to interact with common display systems (large screen video and audio speaker systems) through the appropriate datalinks. Interaction with visual display systems needs to include both continuous (e.g., pointing/cursor control) and discrete (e.g., "click"/toggle) inputs allowing full control of remote displays. It is expected that the technologies to be developed under this SBIR program will augment or replace the common use of the keyboard and mouse as USI technologies. Multi-sensory input and output mediums (audio, visual, sensory) are preferred.

PHASE I: Analyze operational use of the mobile computing interface, to identify requirements and constraints on the user and user environment. Complete a task analysis to identify input/output requirements for the projected IO and/or C2 tasks. Identify potential technology for integration into a mobile computing interface suite.

PHASE II: Develop and demonstrate a mobile interface satisfying the requirements of Phase I. The mobile suite should be completely integrated with stationary, wearable and remote desktop computer systems. Conduct evaluations with Air Force operational C2 users. Deliver the mobile suite to the Air Force Research Laboratory.

PHASE III DUAL USE APPLICATIONS: Commercial potential of this technology is very high. Computer systems supporting medical, package delivery, inventory management, traffic management (ground and air), and troubleshooting/repair operations (ground, air, and space) can be linked remotely to the user. Mobile information operations, and command and control suites, developed under this SBIR would be equally applicable in these commercial environments and to NASA Extra-Vehicular Activity (EVA) missions.

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KEYWORDS: User-System Interfaces, Communications, Mobile Computing

AF00-089 TITLE: <u>Human-Centered Technologies for Information Superiority</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop assessment techniques and enhancement, hardening, and/or remediation strategies to improve the performance of the human decision maker in the context of information warfare, specifically in cases where decision support and situation assessment capabilities may have been disrupted or degraded by information attacks. Support Defense Technology area Plan (DTAP) objectives in Human Systems (HS). Specifically, the information display and performance enhancement (ID&PE) HS subarea technologies support future joint and service-unique warfighting needs in data visualization and situational understanding, aural and visual interface, immersive interface, intelligent aiding and decision support, decision-centered staff process control, supervisory control and teleoperation, and physical aiding.

DESCRIPTION: The Air Force has established Information Superiority as one of its six core competencies. Fundamentally, Information Superiority is achieved when friendly decision-makers (commanders, intelligence analysts, etc.) can reliably execute faster, more flexible, and/or more thoroughly evaluated decisions than can an adversary. Friendly systems may, however, be susceptible to a wide range of information warfare attacks. AFDD 2-5, "Information Operations," identifies Information Superiority as an "enabling function" and points out that "through information operations new target sets emerge, new weapons are available, and the opportunity to directly influence adversary decision making through delays, disruption, or disinformation is a reality." Obviously, an adversary can attempt to conduct information operations against our information functions and processes.

One critical result of an information attack, actual or perceived, may well be the loss of trust which the decision maker has in the information or decision support system. Operators tend to adopt more conservative decision rules when the integrity of the human system interface is brought into question, reducing the effectiveness of the observe-orient-decide-act (OODA) command and control loop. A second, related, factor is that of decision making with dissonant information. If an information attack has taken place, some of the data sources or data bases may have become intentionally corrupted. Operators tend to become more uncertain, take more time, and commit more errors when confronted with dissonance. Technologies which may prove fruitful in quantifying and/or overcoming the trust and dissonance issues may include: operator/user models of intent (from the intelligent agent domain), advanced visualization capabilities, adaptive decision aids (e.g., data fusion), and cognitively-derived display formats.

The research and development/technical risks of this effort are assessed to be high because highly innovative and robust solutions will be required to overcome the emerging threats.

Specific metrics which are expected to be applicable to this effort include achieving and sustaining significant reductions (approximately 25%) in physical, perceptual, and cognitive workload and improvements (approximately 100%) of critical decision making accuracy and reliability in the context of information attack.

PHASE I: The Phase I effort will identify human-centered technologies which may reasonably be expected to contribute to achieving and maintaining human-centered Information Superiority in the face of a full range of adversarial capabilities to wage information warfare. The deliverable will be a proof-of-principal demonstration, including a quantitative performance analysis.

PHASE II: Optimize the technology(s) demonstrated in Phase I and design, produce and deliver a functional prototype for Air Force evaluation and testing.

PHASE III DUAL USE APPLICATIONS: Enhancements to training capabilities will have direct application in the commercial market, especially as employee reductions and corporate restructuring continue. Innovations in interface design technology and performance aiding will have wide application in the entertainment, services, strategic planning, crisis management, and process control/facility management industries.

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KEYWORDS: Information Superiority, Information Dominance, Information Warfare, Personnel Selection, Training, Decision Making, Decision Aiding

AF00-090 TITLE: Breakaway Helmet Mount for Night Vision and Targeting Displays

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop breakaway helmet mount for night vision and targeting displays when exposed to excessive forces.

DESCRIPTION: Current night vision devices (NVDs) employ a mount that attaches these devices to the helmet for use by pilots flying night missions. The NVDs remain firmly in place with all head movements and with maneuvering flight up to 9 Gz (1 Gz is a downward force equal to the pull of gravity; 9 Gz is equivalent to nine times the force of gravity). The NVDs will release with a downward force between 10-15 Gz, to protect aviators during crashes or with the rapid upward acceleration of ejection seats. However, there is not an engineered breakaway solution to upward or sideways forces applied to the NVDs as is seen with windblasts up to 600 kts, or with parachute risers pulled across the helmet. Such events exert large forces on the head and can tear the helmet off or cause lethal neck injuries. Helmet mounted displays (HMDs) in development likewise pose these hazards, but do not have an engineered release system.

The Combat Air Forces have expressed an interest in a low cost breakaway mount for helmet mounted NVDs, as well as other helmet mounted devices, that would release those devices when they are exposed to excessive forces regardless of the direction. It must be low cost, easily replaced, very lightweight, mount to currently used NVDs, and hold the NVD in place until released. Additionally, the mount must not require any modifications to equipment other than the helmet, adversely affect the wear and function of current equipment, or damage the helmet during breakaway.

PHASE I: Investigate the integration requirements of a helmet/NVD connector with other life support equipment components and with currently used NVDs. Design a test that measures the force required to release downward the current NVD from its mount with a slow pull as well as a jerk force. Design and demonstrate a breakaway mount that replicates the current NVD release under force, but in all directions.

PHASE II: Demonstrate the manufacturability of such a breakaway mount. Demonstrate a capability to similarly mount a dissimilar device (such as a flashlight) on a helmet. Test the mount's capability to maintain an NVD stable on a helmet with head movement and with forces up to 9 Gz. Test the device with windblasts at 450 and 600 kts using current flight gear on an instrumented manikin capable of recording neck forces.

PHASE III DUAL USE APPLICATIONS: A breakaway mount has application beyond protecting aviator's helmets and heads with NVD and HMD use. Parachutists, cyclists, spelunkers, construction workers, etc. often mount lights or cameras on their helmets that can translate forces from falls to their necks, or can point load the protective helmets causing failure. This breakaway device would protect surfaces (on vehicles, equipment, etc) from damage when force is applied to mounted devices, when weight and size is a factor.

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KEYWORDS: Night Vision Device, Helmet Mounted Display, Life Support Equipment, Helmet, Crew Systems, Human Resources, Aerospace Medicine, Individual Protective Equipment, Ejection, Head Injury, Neck Injury

AF00-091 TITLE: Laser Aircrew Safety and Education Demonstrator-Flight (LASED-F)

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Demonstrate the glare and flashblindness effects on aircrew caused by hostile situations, accidental or malicious misuse of lasers/laser pointers.

DESCRIPTION: A requirement exists for a portable, self-contained unit which has an integrated visible laser unit. The laser must be capable of safely producing flashblindness in the user within the human aversion response time. The desired degree of flashblindness is a one degree scotoma with respect to the display for 3-5 seconds. Anywhere the laser light can be seen outside the unit under proper use, the output must be eye-safe in accordance with ANSI Z136.1 safety standards. The timing of the laser light delivery must be random within a small window near mission-key flight events on the simulator such as take-off, landing, ordnance delivery, or any other flight essential activity requiring visual ability and appropriately timed user response. Viewing aperture of the unit must be compatible with a user who is wearing laser eye protection. User interface must be a reasonable representation of an aircraft cockpit (i.e. at a minimum flight stick or yoke control). The flight simulator should be easy to operate with a learning time necessary to operate the unit of less than 5 minutes. The simulator program should be turn-key and should not include activities extraneous to the key flight events. Operation of the unit should not require technical expertise on lasers. A users manual should be included. To be considered portable the unit needs to be crate-able for commercial airline transportation. A critical purpose of the device will be to educate aircrews on protective devices which will permit safe evasion without compromising the mission or safety of flight. The unit must be capable of safely but realistically demonstrating both the effectiveness and limitations of laser eye protection (LEP) in the simulated flight environment. For that reason, the successful offeror(s) must work closely with AFRL/HEDO to integrate the LEP training experience.

PHASE I: The first phase of this effort is to prove the feasibility of incorporating a visible laser into a standard cockpit simulator for both military and civilian multi-engine transport operations. The design should be robust enough to migrate to various flight simulators including military-unique fighter aircraft. The design must permit programming of the laser flash at certain points in flight operations such as take-off and landing.

PHASE II: This phase will refine the proposed design from Phase I and build a prototype of the laser simulator unit and accompanying software. Successful completion of Phase II will be demonstration of an integrated program in which the flight simulator will function as a replica of an in-cockpit experience of a laser exposure.

PHASE III DUAL USE APPLICATIONS: Instances of laser glare or laser flashblindness in commercial aviation are becoming more common. The FAA and the Airline Pilots Association worked with the Air Force and other agencies to develop and implement interim guidelines for outdoor Laser light shows because of some incidents connected with these entertainment venues. Despite cooperation from all recognized users of such devices, there still are incidents of laser beams for special events as well as from laser hooligans. Thus far there have not been any serious physical injuries, but in several cases the pilot was so startled that he had to hand controls over to a second pilot. This device would have widespread interest among commercial aviators who would rapidly come to an understanding of the proper procedures to follow in the event of an illumination. General aviation pilots could potentially benefit the most since, in most cases, they do not have a co-pilot to take over in the event of an incident.

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KEYWORDS: Laser, Laser flash, Laser flashblindness, Laser targeting, Laser safety, Laser incident, Laser education

AF00-092 TITLE: <u>Software to Manipulate Large 3-Dimensional Voxel-Based Computer Model</u>

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop an automated process to manipulate digital anatomical models to approximate natural poses.

DESCRIPTION: Increasing use of computer modeling to supplement and extend the applicability of empirical measurements has created a requirement for software to create and modify complex voxel-based computer models. An example of this is a digital anatomical model of the human body the Air Force has created to predict energy absorption during exposure to electromagnetic fields (EMFs). This model was created using photographic images from the National Library of Medicine's Visible Human Project. The EMF dosimetry model has a resolution of 1 mm and is over 365 million bytes in size. It is several orders of magnitude better than previously available EMF dosimetry human models. However, the detail that makes it a superior model, makes manual modification extremely labor intensive. Modifications, which would allow the model to be posed for specific applications such as kneeling or sitting in a cockpit or automobile, could require man-year(s) to implement manually. Existing technology developed to produce computer animation or computer aided design (CAD) avoids this problem in two ways. First, the level of detail is much lower and second, the models lack complex internal structures. Attempts to transport even the simplest 3-D voxel based models into the CAD environment have produced unmanageable results. Required is a 3-D editor for voxel-based models. The editor would allow for positioning of limbs while maintaining the integrity of internal structures such as muscles and blood vessels in the case of a human model. It would also allow the addition of objects such as helmets, headsets, and clothes. Models produced in this way could be used to simulate any action which could be described mathematically, including microwave dosimetry, collision simulations, projectile impacts, thermoregulation, etc. Of course, the list need not be limited to human models. Voxel-based models have been used to evaluate the radar signature of aircraft. This topic will require an innovative approach that may be forced to blend the CAD and voxel-based paradigms currently in use.

PHASE I: Demonstrate ability to modify the position of at least a single joint such as an elbow or jaw showing stretching and compression of appropriate voxels, appropriate movement/rotation in the joint and preservation of tissue structures adjacent to the joint (e.g., blood vessels or nerves).

PHASE II: Demonstrate ability to interactively manipulate the entire Air Force provided human EMF dosimetry model into arbitrary yet realistic poses such as sitting or kneeling. Also demonstrate ability to insert objects into the model space such as helmets and weapons.

PHASE III DUAL USE APPLICATIONS: Commercial applications of this software are numerous and include human factors, collision simulations, forensic reconstruction, simulating ballistic impacts, medical education, and more.

REFERENCES:

1. Visible Human Project, National Library of Medicine, 8600 Rockville Pike, Bethesda, MD 20894 (http://www.nlm.nih.gov/research/visible/visible_human.html).
2. Kunz K. S. and Luebbers R. J. The Finite Difference Time Domain Method for Electromagnetics. CRC Press, Boca Raton, Florida, 1993.
http://www.brooks.af.mil/AFRL/HED/hedr/dosimetry.html

KEYWORDS: Human Factors, Anatomy/Physiology, Modeling/Simulation, Directed and Kinetic Energy, Visible Human Project

AF00-093 TITLE: Universal Biological Sensor

TECHNOLOGY AREAS: Chemical/Biological Defense

OBJECTIVE: Develop passive, inexpensive sensors for biological warfare agents that can be read remotely or with a hand-held reader on a variety of surfaces without damaging the surfaces or otherwise revealing the sensors' presence.

DESCRIPTION: Currently, AFRL/HEDB has a Joint Services Tech Base Program funding to do basic research (6.1) and early applied research (6.2) to develop a biological agent sensing diode. It is coated with DNA and an organic semi-conductor that binds biological agents, in turn, causing changes in the light emission colors or the conductivity of the diode. A large array of DNA with different binding properties is generated by a random process and the binding properties are selected for a given collection of biological agents and for certain components that may be common to many such agents. Signature patterns on the array are generated for both categories, preventing technological surprise (the enemy using an agent for which a specific binding DNA has not been generated). The DNA not only binds other DNA but also proteins, lipids, carbohydrates, RNA, and even small molecules contained in or on the agents.

PHASE I: Determine the feasibility of a "spray paint" version of the sensor. This version can be sprayed on surfaces such as clothing, vehicles, aircraft surfaces (internal or external), buildings, grounds, etc. that are suspected of being contaminated with biological agents.

PHASE II: Collect the first "paint" signature response for a simulant agent, such as Bt or toxin. Breadboard a portable reader.

PHASE III DUAL USE APPLICATIONS: Commercial applications of this technology are use by first responders for suspected bioterrorism events, for determining bacterial contamination of walls, fixtures, and equipment in areas such as operating theaters and restaurants, and for ensuring a safe food supply from production facility all the way to the consumer.

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1. Kiel,J.L. The Ultimate Biosensor. Aviation, Space and Environmental Medicine 65 (5, Suppl.): A121-A124, 1994 .
2. Kiel,J.L., O'Brien, G.J., Dillon, J., and Wright, J.R. Diazoluminomelanin: A Synthetic Luminescent Biopolymer. Free Radical Research Communications 8: 115-121 (1990).
3. Kiel, J.L., O'Brien, G.J., Simmons, D.M., and Erwin, D.N. Diazoluminomelanin: A Synthetic Electron and Nonradiative Transfer Biopolymer. In Charge and Field Effects in Biosystems-2, (M.J. Allen, S.F. Cleary, and F.M. Hawkridge, eds.), Plenum Press, New York, pp. 293-300 (1989).
4. Kiel, J.L., and O'Brien, G.J. (AF Inv 18,422) Luminescent Polymer. U.S. Patent 5,003,050 (issued 26 March 1991).
5. J. L. Kiel, J. E. Parker, Eric A. Holwitt, and H. A. Schwertner; Biosynthesis of Diazomelanin and Diazoluminomelanin, Patent Number 5,856,108; Jan 5, 1999.

KEYWORDS: Bioagents, Sensor

AF00-094 TITLE: Vision Corrective Wraparound Spectacles for Laser Eye Protection (LEP)

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop and demonstrate technology to grind vision corrective prescriptions into LEP spectacle lenses for full wraparound configuration.

DESCRIPTION: The USAF has a requirement for laser eye protection (LEP) that provides full field-of-view protection, i.e., prevents laser light from even reflecting into the eye from angles greater than 90o off the forward visual axis, and that is also capable of being ground with optical prescriptions to correct myopia. We are currently investigating wraparound spectacles as a potential solution for this requirement. While it is possible to grind prescription corrections into large base curve optical blanks, such as those that would be used for wraparound spectacles, the resulting lens has an unacceptable level of aberration and distortion, particularly in the periphery. The problem is further complicated by the materials and manufacturing methods used to produce LEP based upon new reflective coating technologies known as dielectric stacks, rugates, and holograms. Currently, these coatings are applied to the external surface of an optical lens blank made from polycarbonate or CR-39 plastics and then, for holograms and dielectric stacks, a protective cap is applied creating a laminated structure. To date, shear forces accompanying the grinding of prescription corrections into the lens blank cause either damage to the reflective coating or separation of the cap and base. If successful, the desired technology will: (1) provide at least an eight diopter correction for ocular refractive errors in the central visual field using polycarbonate and/or CR-39 plastic lens blanks; (2) produce these corrective lenses while meeting current industry standards for aberrations and distortion in commercially available eyewear; (3) not cause base/cap delamination or damage to laser reflective optical lens coatings; and, (4) produce lenses complying with ANSI Standard Z87.1 for protective eyewear.

PHASE I: Perform a technology feasibility assessment and deliver, if determined to be feasible, a description of the conceptual solution and a technology/technologies development proposal.

PHASE II: Execute the technology development plan proposed in Phase I and demonstrate the solution by delivering six lenses each with ground prescriptions of two, four, six and eight diopter of myopic correction that also meet the four criteria set forth in the Description.

PHASE III DUAL USE APPLICATIONS: In addition to a significant military market for LEP (aviators and ground troops), possible commercial markets for this type of eyewear (laser protective or not) include the general public, commercial and private aviation, occupational/industrial safety, academia, and the entertainment and health care industries.

REFERENCES:

1. ANSI Standard Z136.1. American national standard for the safe use of lasers. Section 4.6.2, American National Standards Institute, Inc., New York. 1993.

2. ANSI Standard Z87.1 American national standard for occupational and education eye and face protection. American National Standards Institute, Inc., New York. 1993.

3. "Introduction to rugate filter technology." Johnson, Walter E. and Crane, Robert L. in Inhomogeneous and Quasi-Inhomogeneous Optical Coatings, SPIE Proceedings Vol. 2046, pp 88-108; Dobrowolski, Jerzy A. and Verly, Pierre G., Eds (1993).

4. "Graded period rugates." Rahmlow, Thomas D. and Tirri, Bruce A. in Inhomogeneous and Quasi-Inhomogeneous Optical Coatings, SPIE Proceedings Vol. 2046, pp 147-153; Dobrowolski, Jerzy A. and Verly, Pierre G., Eds (1993).

5. "Laser-protective technologies and their impact on low-light level visual performance." Sheehy, James B. and Morway, Phyllis E. in Laser-Inflicted Eye Injuries: Epidemiology, Prevention, and Treatment, SPIE Proceedings Vol. 2674, pp 208-218, Stuck, Bruce E. and Belkin, Michael, Eds. (1996).

6. "Rugate and discrete hybrid filter designs." Rahmlow, Thomas D. and Lazo-Wasem, Jeanne E. in Optical Thin Films V: New Developments, SPIE Proceedings Vol. 3133, pp 25-35, Hall, Randolph L., Ed. (1997).

KEYWORDS: Laser eye protection, Wraparound eyewear, Myopic correction

AF00-095 TITLE: Remote Thermographer

TECHNOLOGY AREAS: Biomedical, Sensors/Electronics/Battlespace, Human Systems

OBJECTIVE: Remotely acquire accurate temperature measurements for various climactic conditions.

DESCRIPTION: A requirement exists for accurate measurement of the thermal signatures of various objects in the battlefield including temperature measurements of inaccessible personnel. This physiological characteristic is vital for evaluating the physical well being of the warfighter. Some battlefield and other emergency situations require that vital physiological parameters be measurable when direct contact is not possible. Remote heart and respiration rate monitors have been developed but accurate determination of temperature is also needed. Solutions need to be found to compensate for the difficulties inherent in acquiring remote temperature measurements, such as variations in ambient conditions such as temperature, humidity, background noise, etc.

PHASE I: Create innovative approach to accurately acquire temperature measurements of human subjects that are at least a few meters from the device. Also demonstrate means to compensate for variations in environmental variations, including extreme ambient temperatures.

PHASE II: Optimize the Phase I design, produce, evaluate, and deliver a full-scale prototype so that more accurate temperature measurements (+ 1 oC) can be made at larger distances.

PHASE III DUAL USE APPLICATIONS: Commercial applications of these technologies are possible in the area of civilian search and rescue activities, the monitoring of environmental conditions associated with such things as industrial air and water quality, and meteorological data gathering.

REFERENCES:
1. Choi, J. K., Miki, K., Sagawa, S., and Shiraki, K. Evaluation of mean skin temperature formulas by infrared thermography. Int J Biometeorol 1997 Nov 41:2 68-75
2. Ring, E. F. Quantitative thermal imaging. Clin Phys Physiol Meas 1990 11 Suppl A 87-95
3. Barnes, R. B. Determination of body temperature by infrared emission. J Appl Physiol 1967 Jun 22:6 1143-6
4. http://www.brooks.af.mil/AFRL/HED/hedr/hedr.home

KEYWORDS: Temperature sensing, Thermography, Remote thermal sensor, Vital signs monitor

AF00-097 TITLE: Human Performance Model for High G

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a PC-based model of the human that characterizes task performance as a function of increasing G.

DESCRIPTION: Current performance models do not take into account the effect of extreme conditions on the human, such as the high, sustained G environment. The assessment of performance during taxing flight maneuvers has been traditionally compromised by the inability to provide a realistic environment to the subject. While individuals have been exposed to various acceleration time profiles and physiological and performance metrics have been recorded, the assessments have generally been open loop. Where closed loop performance has been studied, the exposure environment has not been close to the critical tasks required in a dynamic flight environment. This effort will seek to establish a set of critical tasks that have face validity and feedback control that will operate within the existing dynamic flight simulation capability of either AFRL centrifuge, as well as a model for predicting pilot performance in a high G flight environment.

PHASE I: Existing models for pilot performance under high sustained G will be evaluated for their relevance to an overall performance model. Products will include a final report and an approach for Phase II model development and validation.

PHASE II: The actual model will be developed and demonstrated on a PC. The final output of the model will be in terms of criteria that operators (pilots, operations personnel) understand--slower reaction, or percent loss of accuracy with a specific distribution of performance around the average. Exit criteria will include verification of validation of the model and the ability for the model to reliably reproduce results that are comparable to documented results of previous studies. If the model can accurately reproduce results from previous studies, where parameters such as G protection criteria, maximum G exposure, and difficulty of the performance task can be entered and monitored, then the model will have met validation criteria. In general, the model is considered complete when it can predict results of studies and then compare favorably with those results when the study is completed. Products will include (1) an interactive program to assess mishaps where sustained acceleration is considered a casual effect, and (2) an interactive program to predict pilot performance based on G protection provided, maximum G and G exposure duration, and the cognitive demands on the pilot. Both of these programs will be a part of the overall Acceleration Performance model that will be accessible in a workstation.

PHASE III DUAL USE APPLICATIONS: A model of human performance in the high sustained G environment may be adaptable to other extreme environments, such as extreme cold, heat, or altitude. In addition, these types of models will be applicable to a broad range of high workload vocations including driving trains, firefighting, and commercial flying.

REFERENCES:
1. O'Donnell, R., Cardenas, R., Eddy, D. Assessing the Performance Impact of G-Forces: Design of the Acceleration-Performance Assessment Simulation System (A-PASS). AL/CF-TR-1996-0093. AD # ADA320232
2. Chelette, T., Albery, W., Esken, L., and Tripp, L. (Sep 98) Female Performance at High G: Results of Simulated Flight after 24 hours of Sleep Deprivation, Aviation Space and Environmental Medicine, Vol. 69, No 9

KEYWORDS: Extreme Environments, Performance Model, Human Operator Model, High Sustained Acceleration, Maneuvering Acceleration, Dynamic Flight Simulation, Performance Measurement, Reaction Time, Percent Accuracy, G Protection, G Exposure

AF00-098 TITLE: Enhancing the Usability of Computer Generated Forces

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop technology to enhance the usability of computer generated forces and behavioral representation (CGF& BR) in joint synthetic battlespace exercises.

DESCRIPTION: The government seeks innovative proposals to enhance the usability of computer generated forces and behavioral representation (CGF & BR) in joint synthetic battlespace (JSB) exercises. We are interested in technology to improve the ease of developing, employing, modifying, and maintaining such models. Proposals should improve the usability of CGF& BR throughout an exercise's lifecycle. A successful project will address one or more of the following goals. Reduction in: 1) the manpower required to develop, employ, modify or maintain a CGF& BR; 2) the time required to develop, employ, or modify a CGF& BR; 3) the training required to employ, modify or maintain a CGF& BR; and 4) the errors associated with developing, employing, modifying or maintaining a CGF& BR. The government is interested in proposals that address CGF & BR models used in campaign level simulations, simulation-based acquisition models, and distributed mission training.

PHASE I: Develop and document a concept for improving the usability of CGF &BR in JSB exercises. The plan should include a concept of operations for the proposed tool, the projected payoff, and a commercialization strategy.

PHASE II: Phase 2 will result in a prototype technique/tool, a field test to demonstrate the feasibility and payoff, a cost/benefit analysis, associated documentation, and a commercialization plan.

PHASE III DUAL USE APPLICATIONS: This technology can be used to improve the usability and fidelity of most any commercial simulation application that involves human interaction and human representation, such as training simulations, entertainment simulations, product development, and others.

REFERENCES: Modeling Human and Organizational Behavior: Application to Military Simulations. R. Pew & A. Mavor. National Academy Press. 1998.

KEYWORDS: modeling and simulation; joint synthetic battlespace; wargames; computer-generated force

AF00-099 Title: Aircraft Prognostics: Identifying Imminent Failures in Aircraft and System Components

TECHNOLOGY AREAS: Air Platform, Human Systems, Weapons

OBJECTIVE: Develop a capability to predict failure of aircraft and system components before they occur, and be able to display this information to maintenance mechanics in an easy to use format, so that repairs may be made proactively.

DESCRIPTION: The AF needs better ways to more efficiently manage its spare parts so that the right part is available at the right place, at the right time. Efficient management of parts requires the ability to predict what parts will be required and when they will be required. Technologies exist for predicting requirements on a fleet wide basis, however, provisioning and distribution of spares and the management of maintenance operations could be greatly enhanced by the capability to predict when specific components on an aircraft are about to fail. This would permit repairs to be made before a component actually fails, and would reduce the risk that aircraft about to deploy will have components fail en route or shortly after arrival (reducing spares requirements at the deployment site).

This prognostics program would have many benefits for the Air Force. The ability to predict failures in advance will reduce mission aborts due to system failures, reduce aircraft accidents, provide more cost-effective management of spares, and reduce the deployment footprint, by ensuring that only those components likely to fail are deployed. More parts would be available when required and the parts would be at the right location at the time that the old part needs to be replaced.

Innovative approaches are needed to perform prognostics for all aircraft systems, including electrical, mechanical, propulsion, and avionics. Technologies may address one or more types of systems. In addition to providing analyses that identify components that are about to fail, the technical approaches must include methods of extracting and presenting the information for use by maintenance managers and technicians in determining when to replace the component and by logisticians responsible for ensuring that the necessary parts are available. It is essential that information be presented in an easy to interpret and use format and meets all of the user's information requirements.

PHASE I: Phase I will define requirements, and develop a proposed approach for predicting failures, including identification of potential prediction variables, display techniques, identification of data sources, and recommendations for development of failure prediction algorithms.

PHASE II: Phase II will develop a prototype suite and demonstrate the concept on an aircraft system or subsystem.

PHASE III DUAL USE COMMERCIALIZATION POTENTIAL: This product would have major benefits for the commercial airline industry. An effective capability for predicting failures could reduce incidents of in-flight failures and flight cancellations due to component failure.

REFERENCES:

1. G. Smith, J.B. Schroeder, S. Navarro, D. Haldeman, "Development of a Prognostics and Health Management Strategy for the Joint Strike Fighter", Proc. of AUTOTESTCON, September 1997, pp. 676-682.
2. G. Smith, J.B. Schroeder, S.Navarro,. Haldeman, "Development of an Integrated Diagnostic Strategy to Support Autonomic Logistics" Proc. of Air Force Logistics Symposium, March 1997
3. G. Smith, J.B. Schroeder, B. Masquelier, "Logistics for the Joint Strike Fighter, It Ain't Business As Usual," Proc. of 1998 Society of Logistics Engineers Symposium, August 1998
4. R Cowan, W Winer, "Integrated Diagnostics", February 1997, DTIC ADA324130, Georgia Institute of Technology Atlanta, GA Office of Naval Research/XB Contract #N00014-95-1-0539

KEYWORDS: Integrated Diagnostics, Prognostics, Failure Prediction, Predictive Maintenance, Sensor-Based Systems

AF00-100 TITLE: Force Protection Training Technology

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Conduct research to develop and validate strategies, methods and technologies to improve the effectiveness of team training and mission performance while deploying for specific contingencies.

DESCRIPTION: A potential problem arises when units of teams prepare for activities and missions without adequate advanced organizers or clear training and operational objectives. With the advent of advanced multimedia- and simulation-based training systems, there is a significant opportunity to develop and implement instructional strategies and mission objectives-based within high fidelity training modules that can be utilized at a home base, en route to theater, and in-theater. If the training content can be delivered to the point-of-need and is compatible with a variety of delivery systems and technologies, it can potentially improve mission performance significantly. Moreover, reducing the training support footprint by developing modules once and to reusing them to meet different training and mission objectives is a significant goal. Furthermore, these modules might incorporate a reachback capability to permit on-line interactions with content experts when needed in the field. It may even be feasible to provide coaching or guidance during a training event to enhance team member skill and proficiency for future performance. In addition, high fidelity environments can provide near-real time data for assessing the impact of different strategies and methods on actual mission execution and performance. There are a number of key research issues to be addressed. The first issue is related to an exploration of what constitutes an appropriate instructional strategy or strategies for a given operational content domain and objectives. The second issue is related to how to apply identified strategies within a training capability in a way that impacts the underlying competencies of mission personnel and their ability to execute the mission. A third issue is related to developing valid and reliable metrics to assess the impact of the strategies on mission performance. The fourth issue is related to examining the extent to which training content modules can be housed in a virtual library for use in different domains with similar objectives. Finally, this topic will develop proof-of-concept training content and will demonstrate the feasibility of delivery on multiple COTS computer hardware platforms and across multiple domains for similar objectives. It will also develop data integration and scoring methods to facilitate review for evaluation and remediation. Results will be of considerable relevance to both military and non-military clients for situations where near real-time training and multi-person integrated performance is required.

PHASE I: Phase I activities will result in proof-of-concept training development, modularization and delivery software tools. Phase I will also demonstrate the feasibility of distributing content just-in-time training during preparation for mission performance. The demonstration will be accomplished in a cross-training deployable environment and a civilian content domain. Phase I proposals must include a detailed market survey activity and letters of interest/commitment from potential commercial partners must be obtained for Phase II consideration.

PHASE II: This phase will fully develop, apply, test, refine, and validate the methods and technologies necessary to develop and distributed high-fidelity training content modules in a variety of delivery models and technologies. It will also refine and validate instructional approaches and architectures that generalize to cross-training to inter-discipline teams and variety of military and civilian operational systems (such as a medical disaster). As an additional activity in Phase II, an elaborated capability to efficiently develop and distribute training modules across operational contexts and potentially across mission objectives will be tested. Proposals should assume that the software will run in a platform independent environment.

PHASE III DUAL USE APPLICATIONS: The effort provides a unique capability to apply advanced distributed learning concepts to efficiently develop, deploy and evaluate modularized high-fidelity training. The results from this effort are of considerable interest to the Private Sector. The costs associated with developing and redeveloping training software are significant. The capability to systematically assess training requirements and occupational needs and to rapidly link needs to training modules has considerable practical value. In addition, the opportunity to develop a library of reusable training modules that permits identification of existing content to meet new requirements is unique and has not been demonstrated on a scale that makes it economical to reuse training content instead of developing new content. The benefits from such a capability to Government and Private Sector agencies include enhanced targeting training and performance support to reduce operator and maintainer time-to-proficiency, reduced error-rates, and reduced on-the-job training needs.

REFERENCES: Kraiger, K., Ford, J.K., & Salas, E. (1993). Application of cognitive, skill-based, and affective theories of learning outcomes to new methods of training evaluation. Journal of Applied Psychology, 78, 311-328.

Other Resources:
1. Force Protection Unit Advisor Course-Provides instruction for antiterrorism planning.
http://www.mcclellan.army.mil/usamps/dot/aletd/page24.htm
2. European Command Training and Equipment requirements for Force Protection: Antiterrorism measures, mine awareness training, explosive device instruction, medical threat, host country cultural aspects, rules of engagement, and use of deadly force. Also included are; NBC defense survival skills proficiency, weapons qualifications, medical training (endemic diseases, poisonous animals, environmental injuries, combat stress, sleep discipline and personal/dental hygiene).
http://www.eucom.mil/hq/escm/tng.htm
3. Transforming US Forces of the Future - Course topics include; Joint Vision 2010, information superiority, full-dimensional protection, focused logistics, counter proliferation, force protection and combating terrorism.
http://www.defenselink.mil/pubs/qdr/sec7.html
4. US Forces-Force Planning: Small scale contingency operations, major theater war, overseas presence, counter proliferation activities, force protection and combating terrorism.
http://www.dtic.mil/execsec/adr98/chap2.html
5. 7th Battalion, 95th regiment - Mission of Training battalion; mobilize and deploy to proponent schools, anti-terrorism and force protection
6. http://www.hallpage.com/f4bde/f805/7bnps.shtml

KEYWORDS: Force protection, contingency training, inter-discipline teams, advanced distributed learning, just-in-time training, mission performance, multimedia instruction, performance support systems, program evaluation, simulation, training

AF00-104 TITLE: Real Time Integrated Planner/Player (RIPP)

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Airborne Warning and Control System (AWACS) - Electronic Systems Center (ESC/AW)

OBJECTIVE: Develop/demonstrate simulation, analysis, and visualization technologies to collectively address a broad range of sensor-decision maker-shooter issues.

DESCRIPTION: The contractor shall research, develop and demonstrate innovative integrated constructive and virtual simulation technologies which provide an effective and measurable means to thoroughly investigate a broad range of sensor to decision maker to shooter information issues. Issues shall include how to best accomplish: 1) integrated in-time and coordinated sensor, decision maker and shooter/weapons system operations, 2) the generation and distribution of real time information (exp. threat data, imagery, etc.) and tasking feeds/distributions, 3) the accomplishment of real-time damage assessment, 4) flexible adaptive planning and coordination (exp. AOC response to platform mission re-planning, re-targeting, re-tasking), 5) full theater exploitation of integrated RTIC/RTOC 6) real-time multi-source fusion and display in the shooter cockpit, AOC, flying airborne command post, and other support facilities, 7) consolidated (i.e., shooter/AOC) response to time critical targets, and 8)optimized C4ISR exploitation. "Appropriate fidelity" functional models/simulations shall be developed and/or utilized for platforms (airborne, spaceborne, and ground-based) and associated platform sensors (EO, IR, RF, etc.) and will be functionally integrated to address full spectrum sensor to decision maker to shooter issues. Other features of the consolidated system-level modeling and simulation capability will include: 1)"tunable" off-board and on-board sensor characteristics (exp. SAR resolution) to allow determination of overall system performance versus cost for selected grades of sensors, 2) Visualization of the simulation scene, mission profile, platform and AOC functions, selected simulation parameters and weapon system performance, and 3) Data collection and analysis, and configuration control. Maximum use of commercial-off-the-shelf desktop, workstations, and distributed simulation technologies/facilities shall be employed to provide a virtual engineering development environment so that integrated information concepts can be evaluated in a realistic operational combat-like environment in a cost effective fashion.

PHASE I: The desired products of Phase I are: 1) identification of the enabling real-time or non-real-time technologies for sensor to decision maker to shooter modeling and simulation, 2) accomplishment of specific experiments to verify critical aspects of the defined concepts, 3) development of a system specification, implementation approach, and demonstration plan. The contractor shall also document the potential for a Phase II follow-on effort.

PHASE II: The contractor shall accomplish a detailed design, develop the prototype technology, and perform a demonstration of the developed technology. The contractor shall also detail his plan for his Phase III effort.

PHASE III DUAL USE APPLICATIONS: The desired product of Phase III is a robust M&S capability for use in defense and commercial information and sensor technology development. M&S is an enabling technology and a change in the way of doing business that will have major implications for the commercial and defense sector. The commercial marketplace is presently making greater use of generic simulation techniques, simulation infrastructure, and off-the-shelf components for applications in financial industries, manufacturing, industrial process control, biotechnology, healthcare, communication, and information systems. The aircraft and automotive industries have demonstrated the success of integrated computer assisted design with supporting modeling and simulation to bring products to market quickly. Advances in software and computer technology are making virtual prototyping possible and affordable for the small to medium business. Software development itself is a manpower intensive endeavor. Requirements definition remains a problem area where the user is unable to verbalize what he/she wants in detail. Virtual prototyping of software requirements and modeling of the software is a future growth area in which simulation is used to review completeness of software requirements and functionality.

KEYWORDS: Modeling and Simulation, Collaborative Virtual Prototyping, Real-Time Simulation

REFERENCES:
1) AFRL-IF-WP-TR-1998-1522, ITB System Integration and Test II, To-be-Released
2) WL-TR-95-1082, ITB System Integration and Test: Common Module and Distributed Kalman Filter Integrations, May 1995
3) WL-TR-92-1119, The Integrated Test Bed (ITB) System Integration Project, September 1992
4) SSTZ00001B, System Specification for the Integration Test Bed (ITB) Facility, March 1993
5) AFRL-IF-WP-TR-1998-1504, Reconfigurable Avionics Modeling and Simulation Station, January 1998
6) ESAI Report -- expected to be available in September 1999.

KEYWORDS: Modeling and Simulation, Collaborative Virtual Prototyping, Real-Time Simulation

AF00-105 TITLE: <u>Domain-Portable Shallow Ontology Builder</u>

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Intelligence, Surveillance and Reconnaissance (ISR) Integration System Program Office (SPO) - Electronic Systems Center (ESC/SR)

OBJECTIVE: Develop innovative domain-portable ontology builder to transform voluminous shallow information, extracted from text, into knowledge.

DESCRIPTION: Intelligence analysts need to exploit large volumes of free text in order to find information relevant to their topics of interest, and to gain situation awareness (knowledge) on them. Information Extraction (IE) technology is one step towards solving this problem. IE enables analysis and visualization (A & V) of free text by automatically extracting useful information from text and putting it into a structured form that A & V tools can use. The current state-of-the-art of IE is Shallow Extraction of relatively simple information like Named Entities (people, facilities, locations, dates, times, money, etc.) and Shallow Events. Shallow Events are events at a low level of text understanding. The shallow event's action corresponds to the clause's verb, with its associated location, start date, end date, and category. The Named Entities associated with the event (clause) are also known, although their role in the event may not be known. Please note that the definition of shallow events is still evolving and is interpreted differently by various IE researchers; the proposed solution needs to take this into account. The problem with IE is that it only gets us so far in the Cognitive Hierarchy, transforming voluminous data (text) into voluminous information. In order for analysts to gain situation awareness, they need to be able to transform this voluminous information into knowledge. This requires the use of ontologies, or some other form of knowledge representation, specifically designed to use the output of Shallow IE systems. Such ontologies should be capable of specifying the set of entities and concepts (including states, attributes, situations, events, etc.) being modeled or represented and the relationships that hold among them. Hierarchical structures (taxonomies) are typically used to organize the entities and concepts. The functionality of an ontological representation capability or tool typically includes creation and editing of entities, concepts, relationships; inference mechanisms; and search and retrieval mechanisms. Since analysts' domains of interest change, they need the capability to build new ontologies to capture their knowledge as they do their analyses and gain insight into the new domain; and since the world is dynamic, analysts need the capability to extend and modify existing ontologies, as well. It is also desirable that the ontology building capability be interoperable with other ontologies to the extent possible, to exploit the specialized knowledge they model. In short, the ontology-building capability needs to be robust, flexible, maintainable, domain-portable, and support knowledge sharing/reuse. This capability would enable timely situation awareness, help preserve corporate knowledge (e.g., senior analysts' domain knowledge), and facilitate training new analysts on these domains.

PHASE I: Perform preliminary research to determine the best approach to develop the ontology building capability described above. Develop preliminary software to assess concept feasibility.

PHASE II: Use the knowledge gained in Phase I as the basis for developing a full-scale Domain-Portable Shallow Ontology Builder.

PHASE III DUAL USE APPLICATIONS: An Ontology Builder would be valuable to organizations that exploit free-text to gain information and knowledge on a situation or topic of interest. This includes information analysts in the DoD, law enforcement community, research communities, and the financial world (e.g., competitive intelligence, market analysis, and stock analysis).

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2) "IJCAI Workshop on Ontologies and Problem-Solving Methods: Lessons Learned and Future Trends", http://www.swi.psy.uva.nl/usr/richard/workshops/ijcai99/home.html

KEYWORDS: Knowledge Representation, Ontology, Ontology Design, Information Extraction

AF00-106 TITLE: Operational Level Inter-Modal Lift Planner

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Intelligence, Surveillance and Reconnaissance (ISR) Integration System Program Office (SPO) - Electronic Systems Center (ESC/SR)

OBJECTIVE: Develop a system to plan, analyze, trade-off, and optimize air/land/sea inter-modal lift for SOF missions or logistics planning.

DESCRIPTION: Current SOF systems provide detailed "execution level" planning tools that help warfighters plan, analyze, rehearse, and execute SOF missions. These systems, however, lack automated tools to support "operational level" planning and coordination of air/land/sea resources. These same tools will have application to logistics planners who must make trade-offs between air, sea, and ground transportation options. This SBIR will provide a capability to help warfighters plan, analyze, trade-off, and optimize "operational level" inter-modal lift. It will use mission timing, detection risk, asset availability, and resource utilization as evaluation criteria. The warfighter will develop initial plans, and then iterate the process to: Capture and organize mission "objectives" and "task set"; define linkages and dependencies between tasks; input enemy sensor order of battle, and path constraints (e.g. terrain, no-fly zone, weather); select air/land/sea lift resources, "way-points" and "legs"; evaluate critical paths and optimize; recommend optimized Courses of Actions (COAs) for Commander's approval; and monitor "operational level" mission execution and re-plan, as necessary. AFRL encourages concepts that: 1) Run on an IBM PC Windows NT system, with a long-term plan of migrating to a Defense Information Infrastructure Common Operating Environment (DII COE) compliant environment; 2) Leverage existing products where appropriate; 3) Offer tabular, graphical, and map-based analysis/visualization; 4) Promote collaborative planning; and 5) Interface/integrate with existing DoD products and databases.

PHASE I: Develop initial concept. Perform analysis on concept feasibility. Prototype and demonstrate initial concept. Deliver report on initial concept performance - include user feedback and identify risk areas.

PHASE II: Extend concept. Integrate extended concept with USSOCOM CONOPS and/or mission applications. Demonstrate extended concept. Deliver report on extended concept performance - include user feedback and new risk areas.

PHASE III DUAL USE APPLICATIONS: Resulting technology will be applicable to any government or commercial industry that must move equipment over large distances using various types of vehicles (e.g., transportation management).

KEYWORDS: Optimization, Logistics, Planning, Intermodal Lift, Special Operations, Transportation Management

AF00-107 TITLE: Automated Multi-Level Security Digital Information Transfer Using Watermarking Technologies

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Investigate digital watermarking technologies for automated information transfer in a Multi-Security Level (MSL) environment.

DESCRIPTION: The U.S. military and the business community require the real-time ability to obtain and transmit information, based on need-to-know, with authenticity, confidentiality, and integrity across systems and networks at various levels of sensitivity, while protecting that information in storage, during processing, and in transit. MSL solutions, such as bi-directional high assurance guards, deliver much of this capability already. The portion of the problem set which has not been solved is the ability to accomplish the above transfer requirements in near real-time for complex data types. For fixed format information, solutions have already been developed and made ready for operational fielding. In fact, for complex data types such as imagery, filters which automatically examine the metadata for product classification have been developed, approved, and fielded. However, DOD MSL certifiers and accreditors have determined that metadata inspection is not sufficient. They require human inspection for all digital products being transferred across MSL boundaries. This means that in spite of many advancements in high assurance guards, digital product transfer from high-to-low still requires a "man-in-the-loop". The only process accredited for transferring, for example, secret image products (including image thumbnails) from a TS/SCI network to a Secret network is to use a high assurance guard that requires a human to manually open the image itself within a image viewer, ensure it is labeled "Secret" directly on the image, and enter confirmation of this into a verification screen. A similar shortfall exists for video products. Video purposely exploited for use in collateral environments must be manually reviewed by a MSL analyst before being streamed to the low side domain. This process severely hampers the ability to provide near real-time intelligence information to the warfighter. The integration of secure, key-dependent digital watermarking technologies, which have recently matured enough to be operationally demonstrable, into an accredited MSL guard has a very real potential to supply the last missing link in this information exchange challenge. The latest generation of digital watermarking algorithms contain the necessary robustness with respect to JPEG/MPEG compression, cropping, filtering, blurring, and uniform noise, to be used in the military's MSL environment. This effort will investigate and prototype the integration of digital watermarking technologies with both DOD approved and commercially available MSL guards. The selected guard(s) must have a modular architecture which separates the information inspection application from the actual boundary device application. The transfer of information between these applications should be based on Public Key Infrastructure technologies. The information inspection application architecture must be well suited for the integration of an algorithm which inspects the classification of the digital product via the watermark as part of the verification and validation pipeline process. This process determines if a product can be transferred to the destination sensitivity level. Successful demonstration of this capability will be a significant milestone in the military and commercial endeavor to exchange a growing assortment of information types between environments of different sensitivity levels.

PHASE I: Perform a detailed analysis of the readiness of digital watermarking algorithms for digital media to be integrated into a MSL guard for accredited automated transfer of low-side releasable products from a high-side network to a low-side network. This analysis should consider all network combinations practical within the DOD and industry. Digital media should include, but are not restricted to, digital imagery, digital video, and digital audio. Demonstrate a working prototype using a MSL guard provided by the government.

PHASE II: Develop a user interface for configuring, according to the data types, the run-time operation of the digital watermarking algorithms within a commercially available MSL guard. Generate a complete set of documentation to support certification and accreditation testing of the integrated prototype product. Investigate and integrate content authentication techniques to supplement the MD5 digital seal to ensure product integrity. Demonstrate the working prototype via a realistic business-oriented scenario.

PHASE III DUAL USE APPLICATIONS: Develop a certified and accredited product suite which can be integrated with one or more US Intelligence Community approved MSL guards. Install and support the accreditation of the integrated product at a DOD site requiring automated digital media transfer between a Top Secret and Secret network. Also install and support the certification of a commercially available integrated product in a business environment. With the increasing use of the Internet to promote the dissemination of information, there are numerous instances when an entity may want to restrict and control the release of sensitive information from an Intranet environment to the public domain Internet. This entity may want to protect its information regardless of whether it is a picture, a video, or a digital audio product. For example, a business enterprise may want to disseminate important marketing data, but may also wish to restrict the distribution of proprietary information to preserve its commercial viability. Law enforcement agencies may wish to share collected evidence with collaborating agencies, but may want to withhold public disclosure prior to the completion of the investigation. A distributor in the entertainment industry may wish to promote its new movie on the Internet, but may want to ensure that scenes of adult nature are not available to minors. A government office may wish to respect the Freedom of Information Act, but may want to ensure that sensitive or classified material is never released to the public.

KEYWORDS: Multi-Security Level (MSL), Digital Watermarking, Automated Imagery Transfer, Video Authentication Techniques, High Assurance Guards, Information Integrity

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3) Fridrich, J., "Methods for Detecting Changes in Digital Images", Proc. of the 6th IEEE International Workshop on Intelligent Signal Processing and Communication Systems (ISPACS '98), Melbourne, Australia, 4-6 Nov 1998.
4) Delaigle, J.F., C. De Vleeschouwer, B. Macq, "Digital watermarking of images", Proceedings of the IS&T/SPIE Symposium on Electronic Imaging Science and Technology, 1996.
5) Hartung, F., Girod, B. "Digital Watermarking of MPEG-2 coded video in the bitstream domain," Proc. ICASSP '97, pp. 2621-2624.
6) AFRL Website, "Secure Handling of Intelligence Data Using Modern Mathematics", http://www.if.afrl.af.mil/programs/shid/
7) Sterling Software, Inc., "ISSE Guard System Security Concept of Operations", P42-3.0-SCO-0598-AO, May 1998.
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KEYWORDS: Multi-Security Level (MSL), Digital Watermarking, Automated Imagery Transfer, Video Authentication Techniques, High Assurance Guards, Information Integrity

AF00-108 TITLE: Security Management and Protection for Large-Scale Information Systems

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Intelligence, Surveillance and Reconnaissance (ISR) Integration System Program Office (SPO) - Electronic Systems Center (ESC/SR)

OBJECTIVE: The objective of this effort is to develop security management and protection mechanisms for large-scale computer networks and information systems. The security management techniques include technologies for intruder deterrence, intrusion detection, and recovery. The security protection techniques include technologies for boundary protection, internal misuse control, and dynamic vulnerability assessment.

DESCRIPTION: Security management and protection in large-scale information systems is a daunting task. Currently there are a number of tools that address different parts of the security management and protection problem. The tools that exist today are stovepiped, the outputs are not integrated or fused into a common operational picture of the cyberspace environment, and they have very poor user interfaces. It is necessary to have the ability to provide security management and protection of mission-critical information systems on an all-day, every-day basis. Defensive Information Warfare (DIW) analysts need real-time knowledge about what is happening on their networks and information systems. They need to know in real-time that an intrusion has occurred and to not only contain the intrusion but to understand from a forensics standpoint what happened. This SBIR will address the design and development of an architecture that enables security management and protection tools to be integrated in a cohesive manner and provides modern user interface capabilities. The foundation of the integrated system is an information integration infrastructure that allows different types of tools to be easily ported to it. In addition, the infrastructure will have the capability that allows outputs from different tools to be fused into a common operational picture of the cyberspace. The tools that are hosted on the infrastructure will address intruder deterrence, intrusion detection, information recovery, boundary protection, internal misuse control, and dynamic vulnerability assessment. The security management and protection system will provide support for advanced analysis techniques. Heuristic or knowledge-based methods are required to provide the capability to adapt to emerging network technologies, reduce data analysis efforts, reduce error and false alarm rates, and provide automated response to intrusions. This system will also provide the DIW analyst the capability to perform security management of networks at different security levels thus addressing the difficult multilevel security problem.

PHASE I: Investigate the feasibility of using COTS/GOTS technologies for building the security management and protection system. Investigate the feasibility of using COTS software for the information integration infrastructure. Design the system architecture.

PHASE II: Develop a prototype and demonstrate an integrated security management and protection system.

PHASE III DUAL USE APPLICATIONS: Security protection and management is needed throughout the Government (both the military and civilian sectors). Additionally, potential commercial applications exist in all aspects of business and industry where electronic commerce is becoming pervasive.

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KEYWORDS: Defensive Information Warfare, Information Protection, Information Security

AF00-109 TITLE: DoD Information Exchange Using XML

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Intelligence, Surveillance and Reconnaissance (ISR) Integration System Program Office (SPO) - Electronic Systems Center (ESC/SR)

OBJECTIVE: Develop and demonstrate XML encoded text and binary message formats of converting United States Message Text Format (USMTF) message types.

DESCRIPTION: The commercial world is developing a standard for Internet data exchange, known as the Extensible Markup Language (XML), based on the power of Standard Generalized Markup Language (SGML). This semi-structured data format allows communities of interest to define their own Document Type Definitions (DTDs) for specifying the valid structure of messages, in particular problem domains. The DoD could greatly benefit from the ability to use Commercial-Off-The-Shelf (COTS) tools for authoring, validating, parsing, and processing XML documents and messages, if more of its data conformed to this emerging standard. This proposal is to develop and demonstrate syntax and methods for converting USMTF formatted data into equivalent XML encodings.

PHASE I: Investigate the set of available tools for creating and parsing both USMTF and XML that could be leveraged in this format conversion effort. Understand the objectives of the USMTF program, and the commercial trends and standards efforts including World Wide Web Consortium's (W3C) Document Object Model (DOM), and XML itself.

PHASE II: Build a prototype conversion tool using available message parsing/formatting tools and class libraries. Define the specific DTDs for all of the USMTF message types. Use commercial XML-based tools to show the added value of having DoD messages in industry standard forms. Evaluate the effects of such a conversion on message size, human readability, and ease of database population.

PHASE III DUAL USE APPLICATIONS: The commercial world will benefit from the information systems technology upgrades resulting from this research.

KEYWORDS: United States Message Text Format, Extensible Markup Language, Document Object Model, Standard Generalized Markup Language

AF00-110 TITLE: Component-Based Data Fusion Architectures

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Intelligence, Surveillance and Reconnaissance (ISR) Integration System Program Office (SPO) - Electronic Systems Center (ESC/SR)

OBJECTIVE: Develop standards-based component frameworks for data fusion.

DESCRIPTION: Combining data from multiple sources into a single coherent "picture" is a fundamental challenge to Intelligence, Surveillance, and Reconnaissance (ISR) missions. As the commercial world adopts distributed object-oriented "component" software architectures such as CORBA and Enterprise JavaBeans, there is a need to design new systems using a component approach. Applications such as data fusion need to be built to leverage the commercial developments, but provide frameworks for extension that take into account the special needs of their class of problems. This proposal is to develop a component-based framework for data fusion that provides the necessary infrastructure to leverage COTS technology in these areas, while creating a plug-in receptacle interface for specific data sensors and sources.

PHASE I: Understand the commercial distributed object computing standards, including CORBA v3, Sun's Enterprise JavaBeans, and Microsoft's COM+. Develop a generic data model supporting information fusion for physical battlefield entities and their temporal, spatial and other attributed characteristics. Include data mediation for physical measured quantity units conversion and general mechanisms for representing uncertainty.

PHASE II: Develop a component software framework for allowing domain specific data conversion, comparison, and fusion components to interact. Define the common services needed for supporting such a framework, and develop several example data aggregation, summarization, and fusion components to demonstrate the utility of the component software approach.

PHASE III DUAL USE APPLICATIONS: The commercial world will benefit from the upgrades in standards-based component frameworks for data fusion resulting from this research.

KEYWORDS: Fusion, Software Components, Java Beans, DCOM

AF00-111 TITLE: Rapid Knowledge Base Development Using Intelligent Agents

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Defense Information Infrastructure Air Force System Program Office (SPO) - Electronic Systems Center (ESC/DI)

OBJECTIVE: Investigate and develop techniques/tools for rapidly designing, developing, and accessing large-scale data/knowledge bases using dynamic and adaptive agents. The goal is to rapidly produce massive knowledge base(s) consisting of innovative memory mechanisms, high performance agent supported architecture innovations and layers of data/information/knowledge capable of coordinating, cooperating, and negotiating to provide just-in-time information and services.

DESCRIPTION: Investigate high performance agent mechanisms to enhance rapid knowledge development for massive high performance information data/knowledge bases. The growing diversity of different types of data is generating a problem because of the massive size of modern data/knowledge bases. Increased use of video, fax, graphics, images, voice, and textual data make these data types readily available, in different forms, to users. Advanced computational models need to address processing of data at very high speeds. Advanced data structures could provide innovative ways to both rapidly develop and re-develop various forms of data/knowledge. Intelligent agents to coordinate various forms of raw data, including restructuring and re-use, to discover information and to leverage new computational paradigms available in emerging high performance computing technology need to be investigated. Optical computing agent oriented techniques for interconnection and processing could provide breakthroughs in unique tools for secure knowledge development. Graphical tools and machine learning techniques using agents for knowledge development provide an opportunity for both adaptable and scalable innovations. Mobile computing designs, integrated with agent technology, offer real potential for incorporating new and reusable knowledge sources within local domains. Research innovations in these areas supporting rapid knowledge development will help provide ways data should be dynamically structured and stored for efficient retrieval as well as provide adaptable transformation techniques to structure knowledge which can be managed more efficiently so that information can be rapidly filtered, manipulated and summarized. Mechanisms to be investigated include (1) intelligent information rich hyperprogram web agents, (2) advanced adaptable memory design/configurations, (3) electro/optical special purpose architecture enhancements, (4) agent-based mobile hand-held computational mechanisms for seamless access, and (3) evolvable and revolutionary data/knowledge base configurations which can rapidly add new knowledge. Challenges include unique use of techniques based on adaptive data architectures, learning mechanisms, and dynamic databases integrated with intelligent agents to rapidly develop knowledge.

PHASE I: Phase I will investigate development of techniques for rapidly designing, developing, and integrating large-scale active knowledge bases using dynamic and adaptive intelligent agents.

PHASE II: Phase II will demonstrate a rapid data/knowledge base development for very large knowledge bases in appropriate scalable information processing domains/platforms.

PHASE III DUAL USE APPLICATIONS: Phase III will test and evaluate tool(s) for rapid knowledge base development and commercialize results of Phase I and II. Rapid accessibility to integrated systems and information increases choices for consumers in both civilian and defense applications. This technology could have a major impact on applications that require integrated decision making and timely and accurate information such as planning/scheduling systems, autonomous vehicles, aircraft operation, hospital life support systems, decision support systems and personal military command and control.

KEYWORDS: Intelligent Systems, Software, Adaptive Computers, Knowledge Base, Dynamic Data Base, Agent-Based Tools

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AF00-112 TITLE: Improved Command and Control Modeling and Simulation

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Modeling and Simulation System Program Office (SPO) - Electronic Systems Center (ESC/CXS)

OBJECTIVE: Develop improved modeling and simulation (M&S) capabilities to support and analyze current and emerging Command and Control needs.

DESCRIPTION: The Air Force Command and Control architecture and operational cycle is evolving from a set of stove-piped systems and a discrete ATO (Air Tasking Order) cycle to a set of networked systems and a continuous ATO cycle. This evolution suggests the need for improved modeling and simulation tools to support military worth analysis, operations analysis, mission planning, resource allocation studies, etc. Several issues arise when considering these areas where improvement is required. One is the characterization of multi-sensor fusion and sensor cross-cueing. Current M&S tools do not adequately estimate the "integrated" detection/classification capability of various sensors working in tandem. Another issue is the importance of timely Battle Damage Assessment (BDA), and the current lack of ability to model dynamic re-tasking of assets to effectively do BDA. With the development of new sensors, there is a need for a systematic target database (ranged over azimuth and elevation) to properly represent the effects of a specific sensor against a particular target in a clutter environment. Still another issue, which must be addressed in the models, is the Processing, Exploitation, and Dissemination (PED) of information. Advanced information management techniques will be at the heart of solving the PEDs problem associated with the anticipated network of existing and new sensors. Current models do a poor job in representing PEDs capabilities, and they are likely to be strained beyond credibility in the near future. The issues addressed above are representative of those which must be addressed, but they do not make up the complete list. In addition to providing the modeling and simulation community with improved capabilities, the new developments must be compatible with the DoD standard High Level Architecture (HLA).

PHASE I: Phase I activity shall include (among other issues): 1) An evaluation of current and planned operational concepts of operations to determine the elements which must be addressed in the tool, 2) Develop a modeling approach which addresses the Command and Control modeling and simulation need, 3) Demonstrate the feasibility of the approach, and 4) Determine requirements for full development in Phase II.

PHASE II: Phase II activity shall include (among other issues): 1) Develop and validate a full-scale model based on the approach defined in Phase I, and 2) Demonstrate that the model is HLA compliant by integrating it into an existing federation.

PHASE III DUAL USE APPLICATIONS: The improved modeling and simulation capabilities are not only applicable to the DoD. These would benefit the intelligence agencies, civilian and federal law-enforcement agencies, NASA, and any member of the scientific community who needs to process and disseminate sensor data related to Space, the atmosphere or the Earth.

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KEYWORDS: Command and Control, Modeling and Simulation, Sensor Fusion, Sensor Cross-Cueing, Battle Damage Assessment, Processing, Exploitation, and Dissemination, HLA

AF00-113 TITLE: A Robust Integrated Framework for Plan Generation and Execution

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Modeling and Simulation System Program Office (SPO) - Electronic Systems Center (ESC/CXS)

OBJECTIVE: Develop innovative technology approaches for the integrated generation and execution of plans in coalition environments.

DESCRIPTION: The development of coalition campaign plans (e.g., air, logistics, information ops) is a very labor intensive process, requiring a great deal of manual information gathering, and analysis. The process of plan development becomes even more uncertain when members of the planning staff are from other countries whose assets capabilities are not known, or whose culture does not allow certain missions to be carried out. Such differences can negatively impact the pace of plan generation as well the entire planning process. Current planning systems are primarily authoring systems in which the user still manually builds the plan, but much of the "book keeping" is done via an information system. Coalition planning is usually carried out ad hoc across multiple stove piped systems and then integrated together manually. The objective of this topic is to develop an intelligent planning and execution framework, utilizing software agents and plan templates which can generate a plan quickly, share a common plan perspective amongst coalition members, check for possible conflicts amongst coalition partners, offer solutions to these conflicts, and react/replan accordingly to changes in the world state. All solutions must be DII COE compliant and based on COTS products.

PHASE I: Develop initial framework concept. Perform analysis on concept feasibility. Prototype and demonstrate initial concept. Deliver report on initial concept performance - include user feedback and identify risk areas.

PHASE II: Extend concept. Integrate extended concept with a coalition air, logistics, or information CONOPS and/or mission applications. Demonstrate extended concept. Deliver report on extended concept performance - include user feedback and new risk areas.

PHASE III DUAL USE APPLICATIONS: The ability to automatically generate and monitor execution of plans for large-scale, multi-national organizations would have widespread applicability in both the military and commercial sectors, e.g., global transportation/delivery industries, communications providers, etc.

KEY WORDS: Intelligent Software Agents, Planning Templates, Execution Monitoring, Coalition Operations

REFERENCES:

1) "Is George Bernard Shaw Still Right? Lessons from Coalition Operations", Buster McCrabb, International Workshop on Knowledge-based Planning for Coalition Operations

2) "Coalition Information Operations", Larry Wentz, International Workshop on Knowledge-based Planning for Coalition Operations

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AF00-115 TITLE: Satellite Communications Systems Simulation

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Modeling and Simulation System Program Office (SPO) - Electronic Systems Center (ESC/CXS)

OBJECTIVE: Develop a Satellite Communications Toolkit to be used in a communications planning tool environment and integrated with other simulation and planning technologies.

DESCRIPTION: Satellite communication (SATCOM) is playing an increasingly important role in the military communications infrastructure. SATCOM is no longer a separate asset, but is quickly becoming an integrated component of communications at all levels, including mobile services, personal communications, reach back, inter- and intra- theater communications, and both high- and low-speed data services over both short and long distances. As SATCOM becomes a part of the integrated communications infrastructure, or global grid, it will become increasingly important to provide planners with adequate tools that can help determine the proper "mix" of satellite, wireless, and wired communication assets for meeting given requirements of an operational scenario. This hybrid combination of various communication assets must be simulated as a whole and tuned to meet requirements before deployment. The toolkit that will be developed under this effort to perform this task must be able to treat the overall communication system as a single entity, providing seamless integration of models and performance measures. Furthermore, the tool must provide tradeoff and multi-scenario analysis capabilities that can predict performance changes caused by equipment failures and/or dropped links, for example. The tool must also be capable of determining the effects of multiple, simultaneous failures. The toolkit to be developed under this effort will be based on commercially available platforms and simulation frameworks. It will be easy to use and provide graphical user interface (GIU) tools that include animation capabilities, interactive link break/restore functionality, the ability to quickly add new traffic profiles to the simulation, real-time simulation modes, statistical output of both instantaneous and aggregate results, and error-checking routines. Access to external dynamically linked libraries (DLL) should be provided, but programming skills should not be necessary for performing most standard analyses.

PHASE I: Create the system-level design for the satellite communication system toolkit such that it is implemented on commercially available products such as Satellite Toolkitâ (Analytical Graphics, Inc.), COMNET IIIÔ (CACI Products

Company), and/or NetCrackerâ Professional (NetCracker Technology). Goals, features, methodology, algorithms, software/hardware requirements, and user guidelines should be defined.

PHASE II: Implement the satellite communication system toolkit on a released version of an available product identified in Phase I. Demonstrate, validate, and provide samples/examples of SATCOM and hybrid systems. Provide all necessary documentation.

PHASE III DUAL USE APPLICATIONS: The resulting tool will be useful to military as well as commercial planners. Military planners will be able to rapidly plan the right "mix" of communication assets to be deployed and integrated in a given theater of operations. Within the fixed base environment, military planners will be able to plan and design the integration of various communications resources, both terrestrial and otherwise, in order to obtain the best performance and/or most efficient solution. Commercial providers will use the tool to plan redesign/optimization of existing infrastructure.

KEYWORDS: Communication, Simulation, Satellite, Network, Terrestrial, Performance Analysis, Failure Analysis, Planning Tool

AF00-116 TITLE: Advanced C2 Process Modeling and Requirements Analysis Technology

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Modeling and Simulation System Program Office (SPO) - Electronic Systems Center (ESC/CXS)

OBJECTIVE: Develop technologies for product/process modeling of integrated operational and system command and control architectures.

DESCRIPTION: The contractor shall research, develop and demonstrate innovative technologies supporting the specification and static analysis of integrated operational and system command and control architectures, and engineering methodologies for the spiral development and value analysis of command and control weapon system acquisitions. The innovative technologies should consider token-based architecture specification; enable the integration and visualization of data flow, control flow, and state transition information; specify and visualize each operational thread supported by the operational/system architecture; address resources (human, equipment, and computer) required to perform activities specified by each operational thread; and identify constraints imposed by operational and/or system requirements. Technologies should address entity relationship or object relationship data model schema specifying the syntax and semantics of all information referenced in the integrated operational/system architecture. Graph analysis metrics of the modeled system includes reachability, reversibility, absence of deadlocks, liveness, boundedness and mutual exclusion. Innovative business engineering technologies should be designed to enable the user to construct, annotate, retrieve, edit and store, in a data base repository, project requirements documents, proposed system architecture/design documents, underlying process/data models, proposed project management plan, and underlying work flow models throughout a spiral development of command and control systems. In order to identify system design and implementation risk factors and risk mitigation strategies for the weapon system, the project management workflow model must be highly correlated with the weapon system developer's architecture and design. Key supported metrics should include precision, evolvability, scalability, testability, formality, executability, tolerance, clarity, analyzability, and cost effectiveness. Maximum use of commercial-off-the-shelf desktops or workstations shall be employed. The resulting technology should be platform independent to support a substantial number of users. Graphical output should be as HTML pages, VRML worlds, and graphics metafile images for documents and slides. Any resulting graphical system should be designed to have the look and feel of a commercial graphical editor, where the user constructs, annotates, retrieves, edits and manipulates graphical objects that correspond to entities in a database to specify the integrated operational/system architecture. The system architecture should be open to support interfaces to other simulation and modeling tools.

PHASE I: Phase I activity shall include: 1) Specification of an innovative architecture modeling methodology and/or model-based, business engineering technologies used for the cost effectiveness evaluation of command and control system acquisitions, 2) developing a system architecture and design concepts, and 3) proof of concept demonstration.

PHASE II: The contractor shall accomplish a detailed design, develop, and demonstrate the system for command and control applications using the Collaborative Enterprise Environment (CEE) that is being developed by the Air Force Research Laboratory. The contractor shall also detail the plan for Phase III effort.

PHASE III DUAL USE APPLICATIONS: The desired product of Phase III is a robust, off-the-shelf modeling system or federation of systems for use in defense and commercial automated information system development applications and discrete manufacturing applications. The end product will directly support the command and control component of the AFRL CEE.

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KEYWORDS: Modeling and Simulation, Business Engineering, Affordability, Process Models, Product Models, Collaborative Environment, Command and Control, System Architecture

AF00-117 TITLE: Expert Interface for Network Design and Configuration

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Combat Air Forces Command and Control System Program Office (SPO) - Electronic Systems Center (ESC/AC)

OBJECTIVE: Develop an Expert Interface (EI) for a network simulation engine that provides for automated communications network design, planning, configuration, and simulation.

DESCRIPTION: The ability to design a communications network that can handle the transmission of mission critical data, in a timely manner, is crucial to the deployment of the warfighter. Artificial intelligence (AI) or a rules-based methodology that responds to user requirements must be designed and created to provide automated configuration and design as well as designer decision aid. The EI should: (1) provide a knowledge base (long-term memory), (2) use 'working memory' (short term memory), (3) be application and user driven, (4) be very intuitive and easy to use, (5) include animation for instant visual analysis, (6) provide speech capability, (7) provide a way to create new network components, and (8) come with a database of known devices. The major goal of helping the designer design a communications network should also include ease of use so that the designer does not have to be an 'expert' to get quick results and fast answers. The system would be driven by requirements that reflect the usage of the network, for instance the communications traffic on the network would need to be defined as well as the end points or nodes. Other requirements could include the use of certain equipment, network cost, or network performance. The EI would then create the optimal configuration based on the requirements. The EI would provide an interactive session with the designer, asking questions where more information is needed - and making recommendations with each question. The interface should not require programming or simulation skills. The designer should have a working knowledge of communications networks.

PHASE I: Create the design for an EI to be implemented on a commercially available simulation product. Goals, features, methodology, algorithms, and how to use the toolkit should be identified.

PHASE II: Implement the EI on a released version of a commercially available simulation product. Provide documentation needed to run the Expert. Work with actual examples that can include exercises and joint communications networks.

PHASE III DUAL USE APPLICATIONS: The commercial industry needs a tool that enables them to determine a network design based on the network utilization, cost, and performance. With an animated interface, the commercial user can demonstrate in real time the benefits and risks of several proposed communications systems.

REFERENCES: Russell, Stuart J., Norvig, Peter, "Artificial Intelligence: A Modern Approach", Prentice Hall Series in Artificial Intelligence, 1995

KEYWORDS: Network Management, Network Configuration, Expert Systems, Artificial Intelligence, Auto Configuration

AF00-118 TITLE: Operational Impact Estimation Toolkit

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Modeling and Simulation System Program Office (SPO) - Electronic Systems Center (ESC/CXS)

OBJECTIVE: Develop a tool suite that provides the ability to assess the potential operational impacts of discovered system software weaknesses as well as the lifecycle cost and operational impacts of proposed changes in the functionality and/or components of a software system before any implementation decisions are made.

DESCRIPTION: The role of the Air Force Operational Test and Evaluation Center (AFOTEC) is to plan, execute, and report independent operational test and evaluations (OT&Es). In support of OT&E on software intensive systems such as those in the C4I domain, HQ AFOTEC uses several codified reviews to evaluate software suitability and effectiveness. Referred to as "Vol.

Reviews," these reviews cover such topics as software support life cycle processes (Vol.2), maintainability (Vol.3), usability (Vol.4), support resources (Vol.5), maturity (Vol.6), reliability (Vol.7), and operational assessment (Vol. 8). Although these reviews provide information useful to AFOTEC Detachment Commanders in their assessment of weapon systems, these reviews could be enhanced by automation supporting the assessment of the operational impact of software weaknesses. For example, assessment of the operational impacts of low maintainability scores for software modules is not currently supported through automated means. In an attempt to identify areas for improvement in ways in which software suitability and effectiveness is measured, HQ AFOTEC chartered a Tiger Team in late FY98. This Tiger Team gathered inputs from AFOTEC Detachments and Operating Locations to include suggested improvements to the current software evaluation process and the identification of additional desired capability for software OT&E. Several respondents to the Tiger Team survey identified a requirement for a tool suite supporting traceability of operational scenarios to mission requirements down to source code and back, including an ability to assess potential operational impacts of discovered system software weaknesses, and estimate the lifecycle cost and operational impacts of proposed changes in the functionality and/or components of a software system before any implementation decisions are made. These capabilities are especially important due to the uncertainty of how change propagates through a system that operates within a system of systems (such as combat support and command and control systems). It is envisioned that such a tool suite will make use of several complementary technologies including scenario, requirements tracing/hypermedia, and program slicing technologies as follows. Scenario Technologies: Capture operational scenarios for weapon systems (that is, how a weapon system is expected to be used in various missions). Capture operational test scenarios and tie them to test resource requirements and to operational scenarios. Support scenario-based reuse where portions of various scenarios can be combined to define new scenarios. Support scenario-based traceability between operational and test scenarios to include the identification of operational scenario elements addresses by a given test. Requirements Tracing/Hypermedia Technologies: Support hyperlinks between scenarios, requirements, specifications, and other support documentation and software source code and back. Such traceability would support our need to be able to determine how software weaknesses are related to mission critical elements, and will help us identify which source code modules implement mission critical operations. The latter element may help reviewers focus AFOTEC Vol Reviews on those elements that have the potential for significantly affecting mission effectiveness. Automated support for requirements capture, to include automated support for transformation from paper-based requirements documents to hyper-linked requirements documents. Support capture of test data in such an environment. Program Slicing Technologies: Support investigation of error propagation. Support investigation of maintainability propagation. For example, modifying a package to make use of additional message types/formats may be infeasible even if the package itself is relatively easy to maintain if the overall communication package used to route and process these messages is not maintainable. Support test case maintenance and selection based on proposed software modifications. Such a tool suite should have an ability to use tools based on the above technologies in either isolated or integrated modes, and should be, to the maximum extent practical, compliant with the Defense Information Infrastructure (DII) Common Operating Environment (COE).

PHASE I: Investigate the technology areas cited above and develop a prototype implementation of the envisioned Operational Impact Estimation Toolkit.

PHASE II: Apply the prototype to an Air Force Operational Test and Evaluation (OT&E) problem and assess/implement appropriate enhancements to the toolkit based on the results of its application.

PHASE III DUAL USE APPLICATIONS: Operational Impact Estimation tools and techniques would equally apply to the commercial sector in such areas as aviation and satellite communications industries.

REFERENCES:

1) Evolutionary Design of Complex Software (EDCS) - http://www.if.afrl.af.mil/programs/edcs/
2) Defense Information Infrastructure (DII) Common Operating Environment (COE) - http://spider.osfl.disa.mil/dii/

KEYWORDS: Operational Scenarios, Impact Analysis, Program Slicing, Requirements Traceability, Hypermedia

AF00-119 TITLE: Multi-Disciplinary and Multi-Sensor Integrated Display Development

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Airborne Warning and Control System (AWACS) - Electronic Systems Center (ESC/AW)

OBJECTIVE: Develop new display concepts that facilitate presentation of multi-disciplinary data and on-board & off-board multi-sensor data on mission displays for C4I systems operators.

DESCRIPTION: There is an ever-increasing volume of information available to C4I system operators from a variety of on-board and off-board sensor systems. The data provided may be real-time, near-real-time, or non-real-time data. Operators from multiple disciplines (e.g. tactical C2, Strategic surveillance, EW, etc.) need a common set of display formats that will present multi-disciplinary and multi-sensor data in easily understandable and useable form so that C4I operators can fulfill their roles as decision makers, rather than human data integrators. The display formats must present an integrated picture of multiple sensor data, and be adaptable to a variety of different types of display system hardware. A common display concept is vital to the multi-disciplinary aspect of this system. Interfaces to the various sensor systems are necessary to include their data on a common set of displays. The display formats should be capable of allowing multi-disciplinary operators to use multiple types of hardware with little or no additional training. The display formats should be capable of presenting data and contacts in an effective and efficient manner. A concept for using multi-sensor data fusion for evaluating contact identification with an associated level of probability is central to the development effort. Consideration should be given to the ability to overlay multiple data types (at the contact or data level) effectively and to the presentation of logical guides to orient the operator to the scenario quickly. Development of automation type tools to help operators manage and follow multiple data types on the display is vital.

PHASE I: Formulate a display design concept, including display formats, automated and manual data drill-down concepts, operator-machine interface concepts (to include pointing devices) data source analysis, connectivity, target identification evaluation concepts, and data integration concepts.

PHASE II: Prototype the proposed display concepts on a commercial workstation similar in nature to C4I system workstations, using simulated data and stored sensor data. Integrate a broad selection of pointing devices for testing. Include sufficient functionality to clearly demonstrate the integration of data presentation from multiple sensor systems and demonstrate operability.

PHASE III DUAL USE APPLICATIONS: Implement fully the proposed multi-sensor display system in a combat system test-bed or development facility, including connectivity to real data from multiple sensors. Demonstrate the data integration and operability features in a realistic environment of real time multi-sensor data inputs.

KEYWORDS: Multi-Sensor Fusion, Real-Time, Near-Real-Time, Non-Real-Time, Common Display Formats, Automation Type Tools

REFERENCES:

1) Locker, E., AWACS System Program Office, Private Communication, April 1999

2) Alford, M. (et. al.), Proceedings of the Second International Society of Information Fusion, v. 1,2 p. vii., FUSION '99, 6-8 July 1999

3) Ibid., Fusion for Fault Detection and Diagnosis, v.2, p. 935.

AF00-120 TITLE: Wavelet Modulation Techniques for Digital Communications

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Evaluate wavelet modulation methods for channel performance and feasibility/practicality of implementation in military communication systems.

DESCRIPTION: Two primary concerns in communications system design are the efficiency and reliability of the information transmission. The demand for bandwidth-efficient modulations, and the ever-more-harsh channel scenarios encountered in modern systems makes these concerns more critical, motivating a reassessment of current source and channel coding approaches. Several generic channel environments and system user requirements are challenging current communication technologies. One scenario involves multi-user systems with time-varying fading channels, such as encountered in battlefield situations using digital mobile radios. In other cases, noisy channels of unknown time duration and bandwidth are present, such as occurs for point-to-point and multiple access users, covert and LPI (Low Probability of Intercept) communications, and systems that broadcast to a number of receivers of different front-end bandwidths and processing rates. A third example is found in UHF (Ultra High Frequency) and EHF (Extremely High Frequency) satellite communications systems and wireless local area networks, wherein channels with severe intersymbol and narrowband interference are commonplace. Until recently, both source and channel coding were based on classical Fourier techniques. An alternative scheme is wavelet modulation, which has been used in a variety of real-world applications such as image and data compression, remote sensing, seismic analysis, and medical imaging. In addition, wire-based wavelet modulation has shown great success in applications such as Asymmetric Digital Subscriber Loops (ADSLs) and Hybrid Fiber-Coaxial Networks (HFCNs), the former exhibiting 8 Mb/s data throughput on ordinary telephone lines, while the latter showing 10 Mb/s with full RFI (radio frequency interference) noise immunity. Wavelet modulation technology, and the engineering flexibility afforded by wavelet modulation techniques, may significantly enhance the performance of new wireless RF (Radio Frequency) systems.

PHASE I: Phase I shall include the following tasks: Investigate current baseband WMSs (Wavelet Modulation Systems)-for example, ADSLs and HFCNs-with respect to design procedures, CAE (Computer Aided Engineering), hardware implementation, and performance benefits. Migrate acquired knowledge base to the RF regime, considering both amplitude and phase modulation approaches, to arrive at a RF WMS design methodology. Specify relevant channel scenarios (upon consultation with customer representatives) and apply design procedure, identifying important system trades, assessing performance benefits, and evaluating hardware implementation/integration feasibility. Develop a plan for the operational prototype development/demonstration of a representative-and mutually agreed upon by the Air Force-candidate WMS in Phase II.

PHASE II: Fabricate and check out the WMS operational demo identified in Phase I and conduct initial tests to verify/validate design procedures, CAE tools, and performance benefits. Under the supervision of the Air Force, conduct a field over-the-air laboratory test (with full documentation of test parameters and outcomes) of the WMS.

PHASE III DUAL USE APPLICATIONS: Because of the inherently generic nature of wavelet modulation techniques (they can be thought of as a generalization of all current uncoded modulation approaches), the results of this effort could easily be transitioned to a wide variety of commercial wireless communications applications, ranging from personal communications systems to future High Definition Television broadcast services.

REFERENCES:
1) G. M. Wornell, "Emerging Applications of Multirate Signal Processing and Wavelets in Digital Communications," Proc. IEEE, Vol. 84, 586-603, Apr. 1996.
2) S. D. Sandberg and M. A. Tzannes, "Overlapped Discrete Multitone Modulation for High Speed Copper Wire Communications," IEEE Journal on Selected Areas in Communications, Vol. 13, 1571-1585, Dec. 1995.
3) A.R. Lindsey, "Wavelet Packet Modulation for Orthogonally Multiplexed Communication," IEEE Transactions on Signal Processing, Vol. 45, pp. 1336-1339, May 1997.

KEYWORDS: Satellite Communications, Bandwidth Efficient Modulations, Wavelets, Signaling Design, Robust Channels, Battlefield Theater Communications

AF00-121 TITLE: Voice Authenticated Wireless Communication

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a secure method of communication utilizing commercial satellite systems.

DESCRIPTION: With the extension of MSS (Mobile Satellite Service) to include STS (Satellite Telephone Service) the concept of utilizing commercial satellite systems (for example: Iridium, GlobalStar, ICO, Ellipso and Constellation) for private/secure commercial/government voice quality communication becomes a very real potential. To bring this potential to reality, the need exists to develop voice authentication/scrambling/unscrambling algorithms and translate the algorithms into cost effective miniaturized circuitry capable of being installed in hand held satellite telephones. The next step is to demonstrate the algorithms/circuitry over MSS and wireless communication systems and evaluate interoperability with existing cellular and SATCOM (satellite communications) systems. The final step is to investigate the effect of geolocation on the operability of the authentication algorithms.

PHASE I: Develop basic cost effective voice authentication/scrambling/unscrambling algorithms for MSS/STS systems. Design/fabricate breadboard circuitry and demonstrate/evaluate the baseline MSS/STS algorithms based system interoperability with existing SATCOM and wireless systems.

PHASE II: Finalize algorithm/circuit design. Design/construct prototype production hand set circuitry. Install circuitry in commercial hand sets. Test system in stressed demonstrations and for deployed operational, beyond line of sight (BLOS) extension of private communications. Investigate the effect on (mutually agreed) geolocation sites as a part of the system authentication. Devise/demonstrate specific algorithms to optimize various geolocation/stressed situations. Explain metrics used to determine which algorithm performs better in a given situation.

PHASE III DUAL USE APPLICATIONS: Voice authentication can be utilized for commercial and government private or secure communication. Techniques developed from this contract can be used to qualitatively evaluate interoperability between DoD systems and commercial MSS and wireless communication systems.

REFERENCES:
1) A. Vaisnys, J. Berner, "Secure Voice for Mobile Satellite Applications," NASA, Washington, DC, 1990, 6p. NTIS: N92-24190/0.
2) H. S. Cruickshank, "A Security System for Satellite Networks," Fifth International Conference on Satellite Systems for Mobile Communications and Navigation (Conf. Publ. No. 424) p. 187-90, IEE, London, UK 1996.
3) A. M. Odlyzko, " Public Key Cryptography," AT&T Technical Journal, vol. 73, no. 5, p.17-23, Sep-Oct 1994.

KEYWORDS: Satellite Telephone, Mobile Satellite, Speaker Verification, Wireless Communication

AF00-122 TITLE: Hyper-Spectral Sensor Resolution Enhancement Techniques (RET)

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Reconnaissance System Program Office (SPO) - Aeronautical Systems Center (ASC/RA)

OBJECTIVE: Design and develop techniques for resolution enhancement of overhead digital imagery and video.

DESCRIPTION: Process data collected at different instances in time and space to deliver data that is significantly more robust and revealing. Potential solutions can address all available sources of overhead reconnaissance imagery and video: satellites, aircraft, and Unmanned Aerial Vehicles (UAV). Sensor types can include: multi-spectral and hyper-spectral imagery, electro-optical imagery, infrared (IR) imagery, synthetic aperture radar (SAR) imagery, video sequences and video frames. Data from the various sensors each has unique resolution and properties. These differences can be exploited to provide data products with super-resolution and/or useful composite views of targets or scenes of interest. Proofs-of-concept can utilize commercial imagery. Commercial satellite imagery is becoming a key information source to enable Air Force operations. It can meet requirements that go unfulfilled due to gaps in national imagery coverage. An example problem scenario is a collection of data from reconnaissance satellite(s), gathered during a chosen time span, being processed to provide products that can be exploited to provide greater battlefield awareness in less time. Industry has accomplished much related work for the private sector that could be leveraged for defense purposes. Existing capabilities for imagery enhancement can logically be extended to exploiting video. The role of UAV's is also becoming more prevalent in Air Force operations, with the utility for such platforms filtering down to ever-lower echelons. With this advancement of UAV technology comes the challenge of effectively exploiting the large amounts of data that is collected. A typical UAV has a high resolution video camera with long-range telephoto zoom lens, a forward-looking IR sensor package for night operations (or a SAR sensor), and a laser rangefinder/designator. The UAV platform may or may not be stabilized, or have data from a Global Positioning System (GPS) or Inertial Navigation System (INS) readily available. The UAV makes multiple passes over an area or object while the cameras pan and zoom. Development can include robust techniques for automatic registration of imagery, video frames, video sequences, and video mosaics. This enhancement can be obtained from any combination of same-platform, same-sensor, cross-platform, and cross-sensor techniques. A by-product of the resolution enhancement is likely to be data reduction enabling more efficient transmission, processing, and storage of data, and lessening the human involvement necessary for analysis and interpretation.

PHASE I: Develop overall system design and specifications for hyper-spectral sensor resolution enhancement techniques. Develop and demonstrate proof-of-concept software that demonstrates feasibility of approaches and solutions.

PHASE II: Develop and demonstrate a prototype system. Conduct testing to prove feasibility with representative data under realistic conditions.

PHASE III DUAL USE APPLICATIONS: Innovations in this technology area would readily prove useful in any number military and civilian applications: reconnaissance, surveillance, peacekeeping, land use, law enforcement, environmental, regulatory, etc.

REFERENCES:

1) "Fusion of Hyperspectral Imagery", NASA Technical Reports, 01 Jan 1998, Boeing North American Inc.
2) "Perceptual-Based Image Fusion for Hyperspectral Data", IEEE Transactions on Geoscience and Remote Sensing, 01 Jul 1997, AFIT - Wilson, Rogers, Kabrisky
3) "Resolution Enhancement of Multispectral Image Data to Improve Classification Accuracy", Photogrammetric Engineering and Remote Sensing, 01 Jan 93, Rochester Inst. Of Technology - Munechika, Warnick, Salvaggio, Schott

KEYWORDS: Remote Sensing, Imagery, Spectral Imaging, Electro-Optical, Infrared, Radar

AF00-123 TITLE: Smart Data Processing for Radar, Multispectral, & Hyperspectral Sensors

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Reconnaissance System Program Office (SPO) - Aeronautical Systems Center (ASC/RA)

OBJECTIVE: Build an intelligent image correlator that allows for discrimination and identification of object materials from radar and hyperspectral scenes.

DESCRIPTION: The amount of information that can be derived from a suite of various imagery products can significantly enhance the quality, detail, reliability and confidence of analysis. The objective of this effort will focus on correlation of the informational content of these various data sets so that only objects of interest will be further interrogated. Hyperspectral imagery can entail hundreds of narrow spectral bands. The proper selection of which bands to isolate for object/target detection or identification should not only depend on spectral properties of object/target materials, but also on the spatial and temporal aspects of these materials as well. The concept would be to develop signatures of items of interest and maintain these in a database for use as required by operational forces. Correlation of features, radiance, and signatures from multi-imagery sources (IR, Radar, HSI, MSI, etc) pertaining to a particular event will enhance an analyst's ability to identify objects/targets and events not possible with single imagery products. The objective is to propose image processing correlation techniques capable of multiple-sensor "smart systems" that can enhance identification and provide location coordinates for sensor-to-shooter systems. In essence, these techniques should use data synergy, correlation, and distillation while incorporating smart use of MASINT technology and utilizing an actively accrued dynamic repository of spectral signatures. This initiative addresses requirements to detect, locate, and identify difficult/protected CCD targets. The challenge is to be able to visualize various types of datasets in either a fused or overlaid viewspace or in a smartly managed contiguous screen set-up, allowing for linked images and dynamic overlays which refrain from altering the original "raw" datasets. The need to automatically run specific algorithms tailored for real-time display of specific spectral bands, based on the automatic processing of spatial and temporal datasets, could further enhance the Battlespace Analyst's decision-making capabilities through the confirmation of suspected situations or detected targets. Thus, the correlation of various MASINT sources could be used to drive confidence levels.

PHASE I: Develop overall system design that includes the specification of tailored decision-based algorithms for multi-imagery correlation to facilitate the development of a continuously accrued or dynamic repository of spectral signatures, and the demonstrated feasibility of a phase II prototype.

PHASE II: Develop and demonstrate a prototype system in a realistic environment. Conduct testing to prove feasibility of discrimination and ID of target materials from radar, multispectral, and hyperspectral scenes through the use of data synergy, correlation, and distillation.

PHASE III DUAL USE APPLICATIONS: This system could be used in a broad range of military and commercial applications where multiple data types are needed to derive a final assessment. For example, real-time tracking of hazardous pollutants after a large explosion; or geologic mining of remotely placed minerals; or detecting targets under modern camouflage, concealment and deception (CCD) techniques.

KEYWORDS: Multi-Imagery Correlation, Synergy, Decision-Based Algorithms, Hyperspectral, Radar, Multispectral, MASINT, Target Detection

AF00-124 TITLE: Dynamic Architecture Signal Processor Technology

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Reconnaissance System Program Office (SPO) - Aeronautical Systems Center (ASC/RA)

OBJECTIVE: To process Radio Frequency Signal Intelligence (RFINT), Radar and Optical data streams on reconfigurable computers (RCs).

DESCRIPTION: RCs have been demonstrated to offer a high performance to cost benefit for applications such as those listed in the objective. Because this hardware can be reconfigured in system, it also offers advantages in size over non-reconfigurable commercial processors since one RC can be reconfigured to support algorithm processing for multiple sensors. This technology also has several key advantages over high performance custom implementations since unlike custom hardware solutions RCs can be "reprogrammed" just like static Random Access Memory (SRAM) can be written to. This key technology feature adds a level of flexibility never before attainable for high-performance signal processing systems which are size/weight/power or SWAP constrained. However, there are barriers to extensive military application of RCs. Mapping algorithms onto fine-grained Field Programmable Gate Array (FPGA) based RCs or newer generation coarse-grained RCs, in an optimal manner that provides high-performance and good resource utilization, is very challenging and time consuming. This mapping requires the combined skills of a hardware designer, a software programmer, a system level designer, and an FPGA designer. The use of higher order language compilers as well as visual programming technology are now plausible front-end design entry points for RC, but no commercial tool is in place. Debugging tools for RC programs are virtually nonexistent. Compilation tools for coarse-grained RCs are not commercially available. The feasibility of automatic design partitioning and FPGA floorplanning has been demonstrated, but there are no commercial vendors for this technology. RC programming and design tools are not seamlessly integrated into one design environment. Rugged, standard bus RC hardware for military equipment is not available. RCs are still finding their way into operational systems despite these barriers and the associated premium that must be paid to surmount them in the form of manually developed programs and custom processor boards. This topic is soliciting research and development of commercial products that will remove the barriers to widespread use of RC in military systems which require signal processing equipment. The benefits of this program would be a lower SWAP and cost for a multi-sensor platform, a much higher degree of system flexibility, as well as reduced system life cycle cost. This effort could directly impact the MARS and UAV programs by developing key enabling technology.

PHASE I: Develop a program concept as related to the topic description and perform technology feasibility demonstrations. Develop a high-level plan for a follow-on Phase II program.

PHASE II: Develop prototypes for technology concepts demonstrated in Phase I and further demonstrate technology feasibility by performing application mapping for at least one algorithm as described in the program objective.

PHASE III DUAL USE APPLICATIONS: The prototypes developed in the Phase II effort will be commercialized and made available to the public. Any RC hardware and/or software tools developed under this topic will be inherently dual use. This is because the same methods used to design electronics for military systems are applicable to commercial systems.

KEYWORDS: Digital Signal Processing (DSP), Adaptive Computing Systems (ACS), Computer Aided Engineering (CAD), Field Programmable Gate Arrays (FPGAs), Reconfigurable Computing (RC)

AF00-125 TITLE: Airborne JTIDS Net Controller

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Reconnaissance System Program Office (SPO) - Aeronautical Systems Center (ASC/RA)

OBJECTIVE: Design and simulate a multi-net, dynamic JTIDS (Link 16) network and manage the network from the ground by linking to an on-station High Altitude Endurance (HAE) Unmanned Aerial Vehicle (UAV) for robust communications to allied aircraft.

DESCRIPTION: DoD C3I Tactical Data Link Policy, dated 18 Oct 94 designated Link 16 "…as the DoD primary tactical data link for all services…". Link 16 has begun to proliferate throughout the services and is becoming a large operational system. The benefits and utilization of Link 16 to increase mission effectiveness are just beginning to be discovered. Current Link 16 operations utilize a small portion of the theoretical capabilities of the data link. Link 16 utilizes several communications techniques that allow for multiple "networks". The multiple networks are often depicted as "stacked rings" where each ring is called a net. Current Link 16 operations only utilize two nets (or rings) out of 128 total possible. As Link 16 proliferates, utilization of the data link will increase. Multiple net operations (greater than two nets) will be required to meet the increased utilization of the data link. Advancements are needed in multiple net operations. Furthermore, a substantial amount of preplanning and mission planning is required to design a Link 16 network. In today's dynamic battlefield environment, flexible and real-time Link 16 operation is and will be required. Often, the assets required to established and maintain a Link 16 network (AWACS, JSTARS) are not on station. When Link 16 control assets are not available or on station, establishment and management of a Link 16 network from the ground via a HAE UAV is desired. This has the benefit of reducing operating costs (network up even if "heavy" aircraft such as AWACS are not on station) while increasing flexibility of Link 16 operations. Advancements are needed in Link 16 control and management. Areas of interest include reduced mission planning time and assets, dynamic network management, real-time network establishment and increased throughput.

PHASE I: Develop overall multi-network (more than two nets) Link 16 operations and real-time control on a HAE UAV from ground units.

PHASE II: Develop and demonstrate multi-network Link 16 operations and real-time control. Conduct simulations and actual RF testing.

PHASE III DUAL USE APPLICATIONS: Commercial airlines have requirements for data link communications. Air Traffic Control (ATC) is evolving into Air Traffic Management (ATM) where increased application of data links will play an essential role. The Services are responding to this evolution via the Global Air Traffic Management (GATM) initiative. Technologies and techniques for information systems developed and demonstrated under this effort could be applied to the commercial airline industry and play a role in the services response to GATM.

REFERENCES: "Tactical Digital Information Link (TADIL) J Range Extension (JRE)," Proceedings, MILCOM '97.

KEYWORDS: Link 16 (JTIDS, MIDS), Multi-Net, GATM

AF00-126 TITLE: Innovative Information Technologies

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop innovative information technologies for enhancing the performance, availability, and affordability of C4I systems and subsystems.

DESCRIPTION: Proposals may address any aspect of Information pervasive technologies not specifically covered by other SBIR topics. Areas of interest include, but are not limited to, innovative concepts and technologies in: Global Awareness, Dynamic Planning and Execution, and Global Information Exchange.

1. Global Awareness

Global Awareness entails the affordable operational capability, from local to global level, for all pertinent personnel to understand militarily relevant situations on a consistent basis with the precision needed to accomplish the mission. Specific areas of interest include:

- Information Exploitation
  - -- Image/Video/Text
  - -- Signals
- Information Fusion
  - -- Algorithms or families of algorithms to perform information fusion must be developed and refined to make the fusion process more efficient and accurate. Algorithms are sought which can adapt to new patterns in the data or environmental situations, as well as provide feedback to the data collection process.
- Global Information Base: This is defined as a distributed, heterogeneous data/information management system which stores Global Awareness information, and provides information services to Dynamic Planning and Execution operations.

2. Dynamic Planning and Execution

This thrust concentrates on the aerospace commander's ability to rapidly acquire and exploit superior, consistent knowledge of the battlespace through a worldwide distributed decision-making infrastructure of virtual battlestaffs and intelligent information specialists. Specific areas of interest include:

-- Configurable Aerospace Command Center
-- Time Critical C2
-- Real-Time Sensor-to-Shooter Operations
-- Targeting

- Joint/Combined Coalition C2: There is a critical need for the capability and enabling decision-making infrastructure needed to achieve dynamic synchronization of large-scale missions and resources from components and coalition forces. This area will seek to develop new command and control technology enabling a future coalition planning staff to take into consideration the differing influences of all members of a coalition force; including differing military Rules Of Engagement (ROE), force structures, authority roles, capabilities, doctrine, and culture.
- Collaboration/Simulation/Visualization: This technology will provide planners and decision makers with the ability to view, understand, and analyze the vast amounts of information available from C4ISR systems. Collaborating teams require a common, shared context data environment where the visualization of the data is tailored to the application domain and the user preference. Specific modeling and simulation capabilities will assist in both proactive and reactive assessment.

3. Global Information Exchange

Global Information Exchange is the ability to interconnect all members of the Air Force via a netted communication and information system, available anywhere, at any time, and for any task or mission. Specific areas of interest include:

- Global Communications: The technical goals center on wireless information exchange systems and technologies that interconnect remotely separated command and control systems and users, providing high quality, timely, secure, and low probability of exploitation communications to air, land, and space. The required capabilities provide line-of-sight and beyond-line-of-sight connectivity spanning the frequency ranges "from DC to light," in point-to-point, broadcast, or networked modes.
  - -- Multiband/Multifunction Communication Systems
  - -- Robust Tactical/Mobile/Wireless Networks
  - -- RF Communications Systems
- Defensive Information Warfare (DIW): DIW is concerned with the defense of friendly information systems and signatures and ensuring the authorized use of the information spectrum. This technology seeks to protect against corruption, exploitation, and destruction of friendly information systems; ensure confidentiality, integrity, and availability of systems; integrate actions (offense, defense, and mitigation) to ensure an uninterrupted flow of information for weapons employment and sustainment.
  - -- Information Systems Protection
  - -- Attack Detection
  - -- Computer Forensics
  - -- Secure Computing

PHASE I: Provide a report describing the proposed concept in detail and show its viability and feasibility.

PHASE II: Fabricate and demonstrate a prototype device, subsystem, or software program.

PHASE III DUAL USE APPLICATIONS: Many Information Technologies have substantial dual-use potential and will impact competitiveness and performance of the commercial sector as well as the military sector. All solutions proposed must have potential for use/application in the commercial as well as military sector, and potential commercial applications must be discussed in the proposal.

KEYWORDS: Information Technology, Command and Control, Communications, Computers, Intelligence, Global Awareness, Dynamic Planning and Execution, Global Information Exchange

AF00-127 TITLE: Intermediate-Level Event Extraction for Temporal and Spatial Analysis and Visualization

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop domain-portable, intermediate-level event extraction to automate event analysis and visualization from voluminous free-form text.

DESCRIPTION: AF Intelligence organizations suffer from textual "data overload"; analysts are inundated with free-form text messages, documents, and Open Source texts. This can negatively impact the timeliness and quality of Intelligence assessments, and that of the decisions based upon them. Ideally, analysis of voluminous text should be a more automated and conceptually oriented process. Analysts would prefer to perform temporal and spatial analysis of events visually on timelines and maps. This would improve the timeliness and quality of Intelligence products, and that of the decisions that depend on them. Progress has been made in recent years in domain-portable event extraction; e.g., AFRL's "Intelligence Analyst Associate (IAA) Build 2" performs domain-independent extraction of "shallow events" from free-form text. While this is believed to be the state-of-the-art for domain-independent event extraction, there is still much room for progress and innovation; e.g., IAA's shallow events are clause constituents, where the "event" corresponds to the verb. This represents a fairly low level of text understanding. Analysts need more conceptually meaningful event information at a high level of accuracy. In addition, focused research and development needs to be conducted in high accuracy temporal and spatial Information Extraction (IE). This is essential to achieving reliable temporal and spatial visualization of events. Furthermore, these capabilities must be flexible enough to support dynamically changing temporal and spatial areas of interest; e.g., some analysts may be interested in spatial analysis of events in Kosovo, others in events in North Korea. These capabilities must also be flexible enough to support varied levels of granularity; e.g., temporal analysis may be for large-scale events occurring over many years, or for smaller-scale events that occur over hours or minutes. Defining what "intermediate-level" event information consists of is up to the proposer. Likewise, the proposed approach to domain-portable, intermediate-level event extraction is open for definition (e.g., domain-independent extraction of events of higher complexity vs extraction of "generic" events applicable to multiple domains, like "procurement events").

PHASE I: Perform research to determine the best approach to developing a capability meeting the above description. Develop preliminary software to assess concept feasibility.

PHASE II: Use the knowledge gained in Phase I as the basis for developing a full-scale capability for domain-portable event extraction from voluminous free-form text.

PHASE III DUAL USE APPLICATIONS: Domain-portable event extraction would be valuable to anyone that exploits free-form text to gain useful information. This includes information analysts in law enforcement, the DoD, research communities and in the financial world (e.g., competitive intelligence, market analysis, and stock analysis).

KEYWORDS: Natural Language Understanding, Natural Language Processing, Information Extraction

AF00-128 TITLE: Attack Assessment Tools for Information Warfare

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: The objective of this program is the development of a toolkit comprised of computer analytic techniques for information warfare attack assessment. This work will focus on the detailed organization, evaluation and in-depth analysis of data related to unauthorized access and use of computers, computer networks, and information systems.

DESCRIPTION: Classic computer forensics has focused on the process of evidence extraction from computer media. In the information age, our focus must be widened to include real-time, on-line attack assessment and recovery as well as traditional off-line forensic analysis. Information warfare attack assessment includes analysis of a wide spectrum of data (e.g. intrusion detection, firewall logs, audit trails, network management information), location, and identification of clues indicating malicious activity and assessment of the damage resulting from an information attack. Attack assessment traces the source and path of an attack and determines its impact on the information system. The traditional tools available to computer forensic examiners are inadequate to deal with today's networked, distributed environments. Information warfare attack assessment is especially difficult when the pertinent information has been intentionally or maliciously hidden, destroyed, or modified for the purpose of eluding discovery.

PHASE I: Design and prototype techniques that address deficiencies in networked computer system attack assessment. Specific technology areas to be investigated include: rapid discovery, analysis, and tracking of potentially malicious activity, integration of data from various supporting data sources and attack verification, and impact assessment. The products of this phase should be a toolkit framework and proof of concept demonstration.

PHASE II: Build and test the toolkit specified in Phase I.

PHASE III DUAL USE APPLICATIONS: The Air Force needs attack assessment tools in order to maintain its complex, large-scale information systems and networks in an operational status in spite of successful penetrations by adversaries. As a result of the current movement to electronic commerce environments, business, and industry require reliable attack assessment tools to mitigate the effects of the increased exposure and vulnerability of their information assets to malicious attack from the outside as well as misuse by insiders. Business needs this technology to identify the full impact and possible source (i.e. what, where and who) of criminal activities. Also, this ability will help maintain customer confidence in business' ability to quickly correct any corrupted information and to return to the status quo ante.

REFERENCES: Joint Pub 3-13 "Joint Doctrine for Information Operations" , 9 October 1998.

KEYWORDS: Defensive Information Warfare, Information Protection, Information Security, Information Attack Assessment

AF00-130 TITLE: Dynamic Effects Based Command and Control

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop and demonstrate a new generation of planning and assessment technologies and tools enabling aerospace commanders to determine and create the desired operational effects at the right place at the right time. An effects-based approach for planning will provide AEFs the flexibility to adapt to changing situations and threats and allow tomorrow's commanders to dynamically assess what is happening across the battlespace, determine what measures will create the desired effect, and then command near-real time employment of forces to execute those measures.

DESCRIPTION: Today's dynamic and ever-changing battlespace demands an effects-based model that is predicated on a comprehensive, coherent, and integrated C2 system of organizations, processes, and technical means that ensures unity of effort. Aerospace power has the potential to create effects concurrently at all levels of war and throughout the entire depth and breadth of the theater. The inherent flexibility of aerospace power makes it possible to employ the whole weight of available airpower against selected areas in turn; such concentrated use of an aerospace force is a battle-winning factor of the first importance. Central to this vision is an integrated information infrastructure that sparks shared situational awareness and joint strategy and campaign plan development, thus providing future commanders the ability to determine what effects will best achieve operational objectives, and to systematically link those effects to actions taken across the battlespace. Determining the ends, ways, and means that encompass the operational strategy, and identifying appropriate mechanisms that will reflect its efficacy, mandates a seamless link between command, strategy, and assessment functions. Tasks and measures of merit (MOMs) must focus on delivering a measurable effect via certain key indicators, or "mechanisms." In addition, MOMs must not only describe the desired effect, but also provide the necessary qualifiers regarding the degree of the effect, the intended duration, and necessary constraints imposed on creating the effect. In essence, effects-based operations demand effects-based analysis that continually determines the efficacy of the aerospace strategy in terms of achieving the desired tactical, operational or strategic effects, and recommends improvements to the aerospace strategy or suggests phase changes or branch development/initiation to the aerospace commander.

PHASE I: Perform preliminary investigation of innovative new technologies and tools that are capable of realizing a strategy-to-task approach to aerospace maneuver warfare exploiting a link between command, strategy, and assessment functions. Cost, benefit, risk, portability for use of effects based operation planning and other related technical concerns shall be addressed.

PHASE II: Develop and demonstrate prototype effects-based integrated command, strategy and assessment decision support tool(s) on both an AEF and a Chemical/Biological operational scenario. Metrics such as time to complete task, completeness of the result, end to end connectivity, strategy development impact, level of uncertainty and others shall be documented showing increased capability over existing systems and capabilities.

PHASE III DUAL USE APPLICATIONS: In both the civilian and military environment, the effects of actions could have extreme positive or negative impacts on finance, manpower, market share, or winning the war. Technologies and tools developed under this program will have a dramatic impact on corporations and military commands as 2nd and 3rd level effects of proposed actions can be determined based on a proposed decision.

REFERENCES: Effects-Based Operations: The Road Ahead, Major John Sims, 8 Apr 99. Available upon request.

KEYWORDS: Effects Based Operations, Command and Control, Planning, Execution Monitoring, Near-Real Time, Uncertainty, Knowledge Based Software, Coalition Forces

AF00-131 TITLE: Distributed Collaborative Environment Technology

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop technologies that support cross-discipline collaboration including dynamic planning, engineering, simulation, mission rehearsal, and analysis.

DESCRIPTION: The contractor shall research, develop, and demonstrate innovative collaborative technologies that support the overall concepts of the AFRL Collaborative Enterprise Environment (CEE). Technologies developed shall be consistent with the Joint Technical Architecture and Defense Information Infrastructure and support interoperability of distributed collaborative environments such as collaborative planning systems, mission rehearsal systems, distributed logistics, command and control, and collaborative engineering, simulation based acquisition, and distributed collaborative simulation. Special emphasis is placed on innovative approaches to show the impact of technology on affordability of weapon systems. Collaborative technologies offer the opportunity to develop consistent, shared plans and consistent battlespace pictures, conduct split operations and perform distributed, collaborative, fully interactive mission rehearsal and training. Maximum use of commercial-off-the-shelf desktop, workstations, web-based, and distributed information and simulation technologies shall be employed to provide a virtual development and operational environment so that integrated information concepts can be evaluated in a realistic combat-like scenario. Research from this effort shall play a critical role in the rapid cost effective spiral development of information and weapon systems. Technologies developed shall provide characterizations, performance data, life-cycle cost information to assess mission benefits, generate designs and implementations, and/or generate affordability, cost of function, and measure of effectiveness estimates. The following technical areas are of major concern: product and process modeling, innovative affordability and cost modeling, multi-level security, human collaboration tools, workflow management, web-based simulation, and advanced distributed visualization.

PHASE I: The desired products of Phase I are: 1) identification of the enabling collaborative environment technologies, 2) conduct of specific simulation experiments to verify critical aspects of the defined concepts, and 3) development of a system specification, implementation approach, and demonstration plan. The contractor shall also document the potential for a Phase II follow-on effort.

PHASE II: The contractor shall accomplish a detailed design, develop the prototype technology, and demonstrate the proposed technology in the appropriate Information Directorate simulation facility. The contractor shall also detail his plan for his Phase III effort.

PHASE III DUAL USE APPLICATIONS: The desired product of Phase III is a robust collaborative environment/collaborative simulation capability for use in defense and commercial information and sensor technology development. Collaboration is a crucial enabling technology for the 21st century and a change in the way of doing business that will have major implications for the commercial and defense sector. The commercial marketplace is presently making greater use of product and process modeling, generic simulation techniques, simulation infrastructure, and off-the-shelf components for applications in financial industries, manufacturing, industrial process control, biotechnology, healthcare, communication, and information systems. The aircraft and automotive industries have demonstrated the success of integrated computer assisted design with supporting modeling and simulation to bring products to market quickly. Advances in software and computer technology are making virtual prototyping possible and affordable for the small to medium business. Software development itself is a manpower intensive endeavor. Requirements definition remains a problem area where the user is unable to verbalize what he/she wants in detail. Virtual prototyping of software requirements and modeling of the software is a future growth area in which simulation is used to review completeness of software requirements and functionality.

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1) "Put a Virtual Prototype on Your Desktop," Program Manager Magazine, 94-99, September-October 1997.
2) "Air Force Modeling and Simulation Trends," Program Manager Magazine, September-October 1997.
3) "A Collaborative Engineering Environment For 21st Century Avionics," 1998 IEEE Aerospace Conference Proceedings, March 1998.

KEYWORDS: Modeling and Simulation, Collaboration, Collaborative Environment, Virtual Prototype, Cost Models, Product Data Model, Visualization, Collaborative Engineering

AF00-132 TITLE: Database Accelerating Reconfigurable Computer

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: To develop database acceleration co-processors based on reconfigurable computing technology.

DESCRIPTION: Advanced command and control systems heavily utilize database technology. The need to quickly receive the information derived from these databases is also on the rise. There is a need to achieve a step function in performance of database systems without greatly increasing their cost. Reconfigurable computers have been demonstrated to offer a high performance to cost benefit for many data intensive applications. Reconfigurable computers are an emerging class of digital processors that are built with commercial Field Programmable Gate Array (FPGA) components. By their nature reconfigurable computers can have their hardware logic "re-wired" repeatedly while in the system in order to optimally perform a specific task. Reconfigurable computers can be co-processors that reside in a host system and off-load time critical functions from the host processor. Conventional computers can compare either 4 characters or 8 characters at a time depending on whether they have 32-bit or 64-bit internal data paths. Assuming that the reconfigurable computing system is architected to receive the data quickly enough, it conceivably can compare a hundred characters at a time. Conventional computers must also use software to perform sort functions. With a reconfigurable computer these functions can be implemented in hardware for faster performance. This research seeks a solution to the requirement for high performance database services by taking advantage of the low-cost and high-performance characteristics of reconfigurable computers.

PHASE I: The preliminary design of the reconfigurable computer hardware and application software products will be performed. The functionality and interfaces will be completely specified. The expected performance improvements will be estimated.

PHASE II: The detailed design of the hardware and software products will be constructed, evaluated, and demonstrated. Reference manuals and user guides will be developed.

PHASE III DUAL USE APPLICATIONS: The database acceleration product(s) will be readied for market and tested by potential commercial and military customers. Production, marketing, and support plans will be developed and the products will be offered to users. No differences are anticipated between the requirements of commercial and military products.

KEYWORDS: Database Acceleration, Reconfigurable Computer, Reconfigurable Computing, Database Searching, Database Sorting, Field Programmable Gate Array

AF00-133 TITLE: Data Intensive System Implementation for Battlespace Awareness

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: To implement selected battlespace awareness algorithms on Data Intensive Systems.

DESCRIPTION: The battlespace awareness problem involves looking for significant activity over a broad area. There is generally little prior detailed information about the area, but sensors can be targeted over the area for repeated surveillance. In order to detect and identify military targets, one first has to identify locations in which a likely target has been imaged. Physical sources such as small structures, abandoned vehicles, foliage etc. are a persistent source of false alarms. Object level change detection (OLCD) attempts to reduce the false alarms by using a historical database. By maintaining a "map" of the location of false alarms one can eliminate them in future looks. Database transactions support the primary functions of OLCD which include detection and segmentation, feature extraction and discrimination, registration association and change detection and feature prediction from target models. These features require a large processor to memory bandwidth and computational horsepower. The mission of the Data Intensive Systems (DIS) program is to develop a new memory architecture for computing systems that allows applications to manage the placement and flow of their data as well as allowing them to manipulate data in the memory subsystem itself. The focus is to greatly improve the memory to processor bandwidth bottleneck and could include placing the processing hardware directly in the memory itself.

PHASE I: Evaluate candidate battlespace awareness algorithms for key bottlenecks that could be improved through the use of data intensive computing architectures. This will also include an evaluation of emerging DIS architectures to determine which "flavor" of DIS architectures will provide the most performance gain.

PHASE II: Develop and demonstrate a prototype DIS based architecture which implements the battlespace awareness algorithms chosen in Phase I demonstrating their performance.

PHASE III DUAL USE APPLICATIONS: This system could be used in a broad range of military and civilian applications where image detection and identification are necessary - for example in military target identification or cancer tumor identification.

KEYWORDS: Data Intensive Systems, Processor-in-Memory, Dynamic Database, Image Detection/Recognition

AF00-139 TITLE: Durable Coatings for Carbon-Carbon Development & Demonstration

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To develop and demonstrate survivable and repairable high temperature oxidation-resistant coatings for carbon-carbon (C-C).

DESCRIPTION: C-C offers a lightweight alternative to many high temperature metallic alloys, ceramics, and active/inactive thermal protection systems. Despite its benefits, C-C is vulnerable to oxidation above 750oF. Past efforts have developed coating and inhibition systems that have demonstrated oxidation protection to over 2500oF, but none of the efforts have demonstrated reliable performance nor addressed supportability issues such as life cycle costs or reparability. These issues will be important to future military hypersonic systems such as the Space Operational Vehicle and the Common Aero Vehicle. The proposed topic will build from the previous efforts while considering new systems that have been derived since these efforts ended. Established coating/inhibition systems will be evaluated to assess their high temperature capability (2000o+F) as well as their commercial availability. New innovative high temperature coating systems will be investigated and evaluated on their high temperature oxidation performance, ease of deposition, commercial scale-up capability, and likelihood for technology transfer. Subsequently, each coating system will be evaluated for ease of repair in a depot-level or field-level environment without cumbersome and intensive support equipment. From the compiled coatings list and the operational requirements, a test plan that combines compatible coating system constituents with the appropriate repair methodology will be created that will demonstrate the capabilities of at least two coating/repair designs applied to a minimum of two commercially available C-C substrates. The results will be evaluated and summarized, and a commercialization report will be prepared. A government panel made up of representatives from the Air Force, Navy, and NASA will assess the technical results and the military/ commercial viability of the coating systems throughout the effort.

PHASE I: The objective of Phase I will be to evaluate the five most leading coating system candidates for coating system make-up, deposition method, environment use, vendor availability, and reparability. The specific data required to evaluate the system for durability and survivability will be determined and the information obtained from the coating vendor and/or generated using the appropriate test methods. A military and commercial application will be determined, the design requirements identified, and the coatings assessed against the design requirements.

PHASE II: Phase II will take the data generated in Phase I and match coating capabilities with the operational environment of the military and commercial applications. A minimum of two coatings per application will be evaluated on multiple substrates, and any refinement of the coating system or deposition methodology will be made. In addition, the optimized coating system will be evaluated for durability of repairs as well as reparability in a depot-level or field-level environment. To conclude Phase II, subcomponent test specimens supplied by the military and commercial partners will be coated and tested, then subsequently damaged, repaired, and tested to demonstrate the success of the effort. A final report summarizing the findings and a commercialization report will be written.

PHASE III DUAL USE APPLICATIONS: Military and civil reusable launch vehicles and reentry systems for space, military and civil aircraft turbine engines, airborne laser heat exchangers, directed energy protection schemes, pistons for internal combustion engines, and incinerators for waste disposal.

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KEYWORDS: carbon-carbon, oxidation protection, coatings, inhibitors, thermal protection materials, supportability

AF00-141 TITLE: <u>Processing of Inflatable Parabolic Reflectors from Polymeric Thin Films</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop polymer processing methods to produce net-shape parabolic reflectors for deployable optics applications.

DESCRIPTION: AFRL has demonstrated the feasibility of a mirror concept which employs reflective (i.e., metal coated) polymeric films as parabolic reflectors for optical imaging telescopes in which the film is opposed by a clear polymer film and the structure then inflated to a parabolic shape. In such a structure, the seam boundary is held planar by use of a rigidized torus or an otherwise stiff (yet deployable) precision ring. This polymer-based mirror should be stowable to an effective diameter no larger than 20% of the size of the deployed mirror. While high quality polymeric reflectors are now commercially available, AFRL studies have shown that the use of mechanically isotropic films of uniform thickness intrinsically suffer from shape aberrations which cannot be corrected with state-of-the-art adaptive optics. The purpose of this SBIR topic is to develop polymer processing techniques for the production of uniformly thin films (5 - 100 microns +/- 1%) which are parabolic in shape with a relatively small focal number (f # < 2), such that deployment by inflation will unfold the packaged film to yield the optically satisfactory shape. The films should possess a uniformly glossy surface with surface roughness less than 5.0 nm. In addition, the processing of a polymeric torus to be deployed with a rigidation material, along with active control, should be conceived and developed to satisfy stringent planarity (<100 nm) and circularity requirements. This effort should focus on the processing of both the reflector and torus, not on the development of a new polymer; however, material selection should consider stability in low earth orbit (atomic oxygen, ultraviolet, thermal cycling), resistance to creasing incurred on polymer film packaging, and resistance to creep deformation. Consideration must also be given to the ability to scale the proposed processing methods to large diameters (D > 8 meters).

PHASE I: The contractor should conceive processing schemes for both the parabolic reflector and the polymeric torus. Relevant fluid mechanics and heat transfer calculations should be performed to develop working models for the processes, with particular attention given to the influence of processing variables and polymer fluid properties on the resulting shapes. Methods for characterizing the perfection of the reflector's parabolic shape and the torus planarity and circularity should be designed and demonstrated on a prototype parabolic reflector with a diameter no larger than 25 cm and no smaller than 10 cm. The potential synergistic effects of future types of adaptive optics (e.g., phase conjugation with 4-wave mixing) will be explored and evaluated.

PHASE II: Based on the results of Phase I research, the contractor should further develop the reflector and torus processing methods to be implemented for the production of a mirror with a diameter of 1 meter. The process model should be modified, as needed, to account for scale-up issues. Material selection should be conducted based on design factors detailed in the project description and characterization of the processed reflector shape should be performed. The process should be altered, with guidance from the process model and characterization results, to yield the desired precision.

PHASE III DUAL USE APPLICATIONS: The processing of large, deployable mirrors will have significant military and commercial applications. These include surveillance, communications, target designation, imaging through clouds, space-based laser satellite characterization system, remote sensing, wind profiling, target illumination, nighttime imaging, assessing soil conditions and vegetation types, camouflage detection, detection of cruise missiles, ballistic missile defense, ground-based laser relay mirror, and space-based counterforce.

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KEYWORDS: polymers, membranes, polymeric thin films, membrane mirrors, membrane optics, parabolic films, inflatable mirrors

AF00-142 TITLE: Durability of Bonded Joints for Low Cost and LO Repair of High Performance Composite Structures

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: To develop engineering models to predict the durability of adhesively bonded composite structures and LO structural repairs subjected to realistic service environments.

DESCRIPTION: The use of adhesively bonded polymer matrix composite structures has lead to dramatic reductions in assembly cost as well as significantly lighter weight designs over traditional bolted joint assembly methods. Advanced composites are viewed as system enabling in many weight critical applications. In addition, the repair of highly loaded structures, as seen on the B-2, F-22, and V-22, for example, requires the use of adhesively bonded scarf joints for repair to maintain a flush surface contour to meet LO requirements. These critical applications require the ability to predict the long-term lifetime durability of the bonded joint under realistic service conditions. Realistic service conditions include cyclic moisture, cyclic temperature, as well as cyclic mechanical loading. Currently, knowledge of their lifetime performance in the demanding service environments is limited, and no rational comprehensive approaches exist to evaluate materials for performance in their service environments over the expected lifetimes of the systems. Research under this topic area should develop and validate an engineering model that incorporates the appropriately coupled transport, chemical kinetics, and boundary conditions relevant to the coupled problem of oxidative and hydrolytic degradation in high temperature organic matrix composites. In addition, these effects must be coupled to models for predicting the initiation and progression of matrix microcracking, interfacial debonding, and the corresponding loss of mechanical properties.

PHASE I: Approach and procedure for modeling service lifetime of high temperature adhesively bonded composite joints under coupled oxidative and hygrothermal environment must be demonstrated and validated.

PHASE II: Refine modeling procedure and software into a transitionable product. Selection of two candidate material systems and perform extensive environmental aging to validate the models.

PHASE III DUAL USE APPLICATIONS: Future civil aircraft and spacecraft will require substantial use of adhesively bonded composite structure with a high degree of confidence. This level of confidence can only be achieved by the development of rational, comprehensive, and validated models to predict bond degradation.

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KEYWORDS: composites, adhesives, repair, environmental, modeling, degradation, oxidation, hygrothermal, hydrolysis

AF00-143 TITLE: Novel Durable Polymer Based LO Hardcoats for Canopy Exteriors Using Benign Processing Techniques

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Design, synthesize, and develop novel durable polymer-based hardcoats to be processed in monolayer film by state-of-the-art methods for aircraft canopy LO characteristics.

DESCRIPTION: Current aircraft canopy coating systems are composed of multiple layers of various materials compositions and thickness. The inherent problem with the concept of "one material, one application" is the materials mismatches in properties, such as refractive index, optical transmission, coloration, coefficient of thermal expansion (CTE), thermal stability, and mechanical strength. An additional problem is encountered in the concept when factoring in the acoustic and radar cross-sectional reductions of stealth along with personal protective design concepts. The state-of-the-art methods by which some of these coatings are applied to very large doubly curved surfaces are very exacting processes in order to control layer thickness and are very cost prohibitive for future aircraft and retrofits. Organic polymer-based hardcoating systems may provide a more compatible system with the substrate plastics because organic polymers are more similar to the substrate plastics in chemical composition or can be tailored by the addition of functional chemical groups or by copolymer compositions to be more like the substrate. Various atomic bonding schemes are also employed with organic polymers to promote adhesion. Organic polymers are amenable to "alloying" with other dissimilar materials through chemical miscibility, such as photochromic dyes and the like. A processing advantage of using polymer-based hardcoats is the design flexibility to allow for some of the more recently described deposition techniques under very benign processing conditions while controlling film thickness. Some monolayer films have been shown to be mechanically robust to the extent that vigorous mechanical forces have been unable to dislodge the films from the substrate. What is sought in this technical effort is an organic polymer hardcoat material that is multifunctional in purpose, i.e., environmentally and thermally durable but also of low radio frequency cross-section, which is applied in controlled thickness by a cost effective, novel coating process.

PHASE I: The goal of the Phase I effort is the preparation of novel aromatic or heteroaromatic polymers as monoliths or alloys as monolayer (one molecule thick) films whose deposition will result in a coating profile on a flat bisphenol A polycarbonate substrate coupon. The ability to prepare the monolayer by an accepted low temperature coating method, such as sol-gel, Langmuir-Blodgett, or other flowcoating or dipcoating technique, will greatly reduce the costs of processing the final polymer composition and will accelerate the technical transition of the candidate composition. Methods for test of the proposed system shall include determination of the coating profile on the substrate; basic spectroscopic and chemical analysis; full thermal analysis with long-term thermal aging in air, 2-D, and 3-D CTE; molecular weight determination; solution viscosity; appropriate ASTM hardness tests, adhesion tests, abrasion tests, and solvent crazing under tensile load. A key element of the Phase I effort shall be the delivery of 12 replicate coupons on 4 in. sq. x ¼-½ in. thick polycarbonate with the coating applied at Month 5-6 of the technical effort for further testing at AFRL. The final key element of the successful Phase I program will be the proof of concept of the composition by successful completion of the following ASTM transparency tests: refractive index, luminous transmittance, yellowness index, and haze at both room temperature and near the glass transition on the free-standing films (if available) and the laminate, and falling dart impact on the laminate alone. Preliminary acceptance of the coating using accelerated aging techniques shall comply with a minimum equivalent 1530 flight hours simulation and meet hardness criteria near the current values for state-of-the-art materials. Deliverables for this portion of the effort include the coupons enumerated above and data.

PHASE II: In Phase II of the effort the technical work shall require the acquisition and fabrication of larger and more complex shaped specimens with a double curvature employing the technology demonstrated as proof of concept in Phase I. Reproducible scale-up of the candidate composition shall be required to a minimum of one to five pounds. Basic chemico-physical, thermomechanical, and optical property evaluations of the materials shall continue to prove reproducibility of process. Accelerated wear techniques, such as QUV and rain erosion for 6100 flight hours simulation and the previously cited optical, abrasion, and adhesion tests, shall be accomplished. It is understood that optical quality of the monolayers may not be an issue if true monolayers are obtained. Compatibility with substrates other than polycarbonate shall be required as demonstration in this phase to show breadth of process utility. Acoustic and radio frequency test profiles will be provided by the government project engineer in this phase of the technical effort. Potential offerors must include qualification of their facility and personnel to DoD 5200, 5220, and 5230 security directives for this phase of the effort. Deliverables for this portion of the effort include data and two double curvature demonstration articles of the full laminate.

PHASE III DUAL USE APPLICATIONS: Many commercial industries have similar harsh degradative environment reliability concerns. Several of these industries are (1) solar cells, (2) commercial aerospace, and (3) military aircraft and military personnel vehicles. Many of the transparent products of these applications require durable exterior hardcoats that have good optical properties and long lifetimes with resistance to solvents, electromagnetic radiation, and scratching.

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KEYWORDS: aircraft transparencies, coatings, thin films, hardcoats, topcoats, radar, monolayer, flowcoat

AF00-144 TITLE: Detection of Flaws Under Thermal Barrier Coatings Repairs

TECHNOLOGY AREAS: Materials/Processes, Biomedical

OBJECTIVE: (Should not exceed 15 words): The objective of this topic is to provide the aerospace component manufacturers with a methodology to detect and quantify flaws, e.g., cracks, under highly attenuative coatings. This would be a new nondestructive inspection (NDI) capability for coated materials.

DESCRIPTION: (Should not exceed 500 words; preferably keep under 300 words): There are many situations where cracks and other defects must be detected under coatings. This situation occurs on airframes where the paint is often stripped before surface breaking cracks and corrosion can be detected. For turbine blades the problem of detecting cracks under Many other types of coatings, e.g., thermal barrier coatings (TBC), are even more difficult because the coating is porous and therefore highly attenuative . The presence of porosity scatters ultrasound and soaks up so much penetrant to render both of these often used techniques useless. Radiographic techniques are also difficult to apply because there are insignificant differences between the porous coating and the defects that must be detected. It is for this reason that a new and novel method of detection of cracks under coatings on turbine blades is sought. Of course, eddy current methods could be used to effect here, but changes in both lift-off and conductivity of the substrate limit their usefulness to the situations where the coating is stripped from the structure before this inspection method can be reliably used.

PHASE I: (Describe desired end product. Expectation should be specific. Describe task and/or results which can reasonably be accomplished within the established SBIR cost and time constraints (Phase I - $100K/9 mos.). Require Proof-of-Concept Demonstration.) During this phase of the program the proof of the concept should be demonstrated on laboratory specimens approaching the configuration of actual aerospace components, e.g. turbine or compressor blades.

PHASE II: : (Describe expected work to be accomplished.. Expectation should be specific. Describe task and/or results which can reasonably be accomplished within the established SBIR cost and time constraints (Phase II - $750K/24 mos.). Require Proof-of-Concept Demonstration.) During this phase of the program most of the engineering aspects of the new capability should be developed. Additionally, testing of actual blades showing direct evidence of the viability of the methodology. Finally, the definition of the exact engineering parameters for a production piece of equipment must be worked out and a prototype piece of equipment constructed and tested.

PHASE III DUAL USE APPLICATIONS: (Must contain a strong, concise description of it's Dual Use/Commercialization Potential. Briefly list the DoD/commercial areas which have requirements for this particular technology; what end application is envisioned and what sort of benefits are anticipated.) An example of a dual use application for this technology would be in the inspection of the thermal barrier coating (TBC) on turbine blades of land based gas used for power generation. The next generation of these turbines will depend on the thermal barrier coating to meet the service life requirements. Coating conditions that need to be detected included the following conditions: 1) detection of oxidation beneath the bond coat. 2) bonding of the TBC to the bond coat. 3) thickness of the TBC. If it is too thin, then local oxidation will occur and shorten the blade life. If the TBC is too thick, then it may crack because the thermal strain between the TBC and the bond coat may be too much for the TBC to sustain and severe cracking can occur. Please note the TBC may contain intentional longitudinal cracks to limit cracking due to this expansion mismatch. Areas of interest include the platform radius where the blade transitions from the airfoil to the base. During this phase of the program a piece of equipment installed on a production line and data acquired demonstrating the economic utility of this new methodology. Additionally, sufficient data should be collected to validate the reliability of the process in a production environment.

REFERENCES:
Ultrasonic Testing of Materials, Third Edition, J. Krautkramer and H. Krautkramer, 1983, Springer-Verlag, New York
Radiological Imaging, H. H. Barrett & W. Swindell, Vol I & II, 1981, Academic Press, New York, NY.
The Nondestructive Testing Handbooks, Second Edition; Vol. 3, Radiography and Radiation Testing, Ed. L. E. Bryant; Vol. 4, Electromagnetic Testing, Ed. M. L. Mester; Vol. 5, Acoustic Emission, Ed. R. K. Miller; Vol. 7, Ultrasonic Testing, Ed.s A. S. Birks & R. E. Green, Jr.; Vol. 9, Special Nondestructive Testing Methods, Ed. R. K. Stanley; American Society for Nondestructive Testing, Columbus, OH.

KEYWORDS: Nondestructive evaluation (NDE), Nondestructive inspection (NDI), Coatings, Multilayer coating, Corrosion, Oxidation

AF00-145 TITLE: NDI for Diffusion Bonded Components

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The objective of this topic is to provide the jet engine manufacturers with a methodology to guarantee minimum properties of diffusion bonded components through a new nondestructive inspection (NDI) capability.

DESCRIPTION: Currently, there are no NDI methods of guaranteeing the bond integrity of bonded components. Ultrasonic methods have been tried but they can not detect the difference between two surfaces in intimate contact and those with good bonds. Therefore, a new approach is sought that places the bond under a local proof test and at the same time examines it for fracture. Methods are sought that will permit the implementation of such a concept. Methods that are non contact have obvious advantages as well a those which are based on existing technologies. Existing methodologies not common to the NDI community should be explored before examining those classically investigate and known to be of minimal value - see the references below for several NDI techniques that fit this latter category. The advantage associated with modification of existing technologies are the reduced cost to bring them to operational levels and enhanced probability of success. If an approach is found that will load a joint to a substantial fraction of its ultimate load bearing abilities, then its operational reliability is substantially enhanced. If the bond is broken during such a test and that fracture is detected, then a part with marginal or unacceptable properties can be eliminated from those acceptable components.

PHASE I: During this phase of the program the proof of the concept should be demonstrated on laboratory specimens approaching the configuration of actual aerospace components, e.g. turbine or compressor blades.

PHASE II: During this phase of the program most of the engineering aspects of the new capability should be developed. Additionally, testing of actual blades showing direct evidence of the viability of the methodology. Finally, the definition of the exact engineering parameters for a production piece of equipment must be worked out and a prototype piece of equipment constructed and tested.

PHASE III DUAL USE APPLICATIONS: An example of a dual use application for this technology would be in the inspection of the diffusion bond in hollow core titanium turbine blades of land based gas used for power generation. The next generation of industrial gas turbine steam generators very likely will depend on titanium blades tot meet the erosion requirements of the back ends where the steam has condensed to water. Hollow titanium blades have obvious advantages but are not currently used for a variety of reasons; one being the lack of ability to adequately inspect the diffusion bond line for life limiting flaws and metallurgical conditions. Without an adequate inspection capability, then continued used of solid metal blades will be required with the obvious deficit to performance and increased cost of operation. During this phase of the program a piece of equipment installed on a production line and data acquired demonstrating the economic utility of this new methodology. Additionally, sufficient data should be collected to validate the reliability of the process in a production environment.

REFERENCES:
"Acceptance Criteria for Nondestructive Evaluation of Adhesively Bonded Structures," E. Segal & S. Kenig, Materials Evaluation, Vol. 47, No. 8, p. 921-927, 1989.
"Bonded Joints and Nondestructive Testing - 1," D. J. Hagemier, Nondestructive Testing, Vol. 4, No. 12, p. 401-406, 1971.
"Bonded Joints and Nondestructive Testing - 2," D. J. Hagemier, ibid, Vol. 5, No. 2, p. 38-47, 1972.
"Nondestructive Testing of Bonded Metal-to-Metal Joints," D. J. Hagemier, ibid, Vol. 5, No. 6, p. 144-153, 1972.
"Evaluation of Sonic Methods for Inspecting Adhesive Bonded Honeycomb Structures, I. R. Kraska & H. W. Kamm, Air Force Materials Laboratory Technical Report, AFML-TR-69-283, 1970.
"Detection of Unbonds in Multi-Layered Fuselage Sections with the Bondascope 2100," R. Bosco, Applications Report #521, NDT Instruments, Inc., Huntington Beach, CA.
"Ultrasonic Study of Adhesive Bond Quality of a Steel-to-Rubber Interface by Using Quadrature Phase Detection Techniques," A. C. Smith & H. Yang, Materials Evaluation, Vol. 47, No. 12, p. 1396-1400, 1989.

KEYWORDS: Turbine engines, Nondestructive testing, Bonding

AF00-146 TITLE: Turbine Engine Airfoil Thermal Barrier Coating Reliability Enhancement

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop robust thermal barrier coatings for turbine blades that reduce the occurrence of early coating failures and increase the meantime between inspections.

DESCRIPTION: Coatings are used as both oxidation and thermal barrier coatings on airfoils in gas turbine engines. Thermal barrier coating (TBC) systems consist of a metallic bondcoat applied to a Ni-based superalloy substrate on top of which a ceramic coating, commonly yttria-stabilized zirconia (YSZ), is applied by either plasma spray or electron beam-physical vapor deposition processes. Since the YSZ coating is transparent to oxygen and thus does not protect the substrate, the bondcoat must be resistant to both thermomechanical fatigue and oxidation [1]. The oxidation of the bondcoat is a primary failure mechanism of TBCs and a weak link for improving coating lifetimes [2]. New approaches are requested to develop and characterize bondcoat systems that yield improved lifetimes for thermal barrier coatings.

PHASE I: This program will focus on critical issues, which when successfully addressed, will provide proof of concept. Proposal should demonstrate reasonable expectation that proof of principle can be obtained within Phase I.

PHASE II: This program will be structured to develop and refine those feasible concepts to the point where performance is physically demonstrated (burner rig or engine test) on a scale (coupon or representative airfoil) to permit an evaluation of the ultimate application potential to meet Air Force needs.

PHASE III DUAL USE APPLICATIONS: The developed approaches would have broad commercial applicability due to the large number of commercial engines that currently incorporate thermal barrier coatings.

REFERENCES:
1. B. A. Pint, et al., “Substrate and bond coat compositions: factors affecting alumina scale adhesion,” Materials Science and Engineering, A245 (1998) pp. 201-211.
2. A. M. Freborg, et al., “Modeling oxidation induced stressed in thermal barrier coatings,” Materials Science and Engineering A245 (1998) pp. 182-190.

KEYWORDS: Thermal Barrier Coatings, Bondcoat, Oxidation

AF00-147 TITLE: Boron Based Ceramic Matrix Composites for Aircraft Brake Friction Materials

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop and characterize boron based ceramic matrix composites as high performance aircraft brake friction materials.

DESCRIPTION: Carbon-carbon composites (C/C) are the state-of-the-art friction material for aircraft brakes. C/C is expensive to produce and suffers from a relatively low friction coefficient, a high variability in friction coefficient as a function of temperature, moisture content, and pressure, susceptibility to oxidation at the use temperature, generation of a nuisance dust (through brake wear), and degradation from fluids commonly used on and around the aircraft. Ceramic matrix composites (CMCs) offer an alternative to C/C which may ameliorate many of these deficiencies. [1-3]. Silicon based CMCs (i.e., SiC, Si-O-C) have been the primary focus of attention to date, but boron based CMCs, such as those based on boron nitride (BN), appear to also be viable candidates [4].

PHASE I: Survey the composites community for candidate boron based CMCs and select one or more materials which would be suitable for an aircraft brake. Selection criteria should include consideration of material cost and scalability of fabrication technique, as well as performance and maintainability issues. Fabricate coupons and subject them to a battery of mechanical and friction tests. Assess the test results, identify material and process refinements, and identify the most promising candidate.

PHASE II: Optimize the processing and performance of the chosen boron based CMC through fabrication and testing (mechanical and friction) of coupons in an iterative fashion. Demonstrate material performance through fabrication and dynamometer testing of a generic aircraft sized rotor/stator pair [~12” diameter] at energy levels typical of a modern military aircraft. Develop scaleup and marketing plans.

PHASE III DUAL USE APPLICATIONS: The resulting advanced friction materials will be directly applicable to the large commercial aircraft brake market, where improved performance will result in reduced cost per landing.

REFERENCES:
1. W. Krenkel, "CMC Materials for High Performance Brakes," Proceedings of the ISATA Conference on Supercars, Aachen, 1994.
2. W. Krenkel and R. Renz, "C/C-SiC Components for High Performance Applications," Proceedings of the European Conference on Composite Materials (ECCM), Naples, 1998.
3. A. Ibott, "The China Syndrome," FastBikes Magazine, Nov. 1996.
4. C. G. Cofer, A. W. Saak, and .J Economy, "Carbon/Boron Nitride Composites: An Alternative to Carbon/Carbon," Cer. Eng. Sci. Proc., Vol. 16, 5, p 663-671 (1995).

KEYWORDS: Aircraft Brakes, Ceramic Matrix Composites (CMCs), Friction Materials, Boron based CMCs, Process Development

AF00-148 TITLE: Improved Life Prediction of Turbine Engine Components

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Develop improved fracture-mechanics based tools for predicting fatigue lives under service conditions for gas turbine engine materials.

DESCRIPTION: Gas-turbine engine structural materials, such as titanium and nickel-base superalloys, are subjected to a complex spectrum consisting of numerous temperature and load excursions, depending upon the mission. Fatigue damage processes under engine operating conditions can be very complex, involving effects of loading frequency and stress ratio, creep, environment, and the interactions of these variables. [Ref 1,2] Presently, components are life managed based on TACs (total accumulated cycles) or TECs (total equivalent cycles), which represents a rough form of cycle counting, wherein a number or fraction of an "equivalent cycle" is assessed for certain throttle excursions. At the completion of a flight the number of TECs is added to the running total for a particular engine, and the components are life managed based on that number compared to the predicted (or design) life - also given in TECs. Due to the inexact application of "equivalent cycles" in accounting for the wide envelope of potential effects and interactions, numerous safety factors have evolved in fatigue predictions to minimize the effect on safety of flight. This has led to the possibility of an overly conservative life estimate for components. Significant advances in a variety of computational and materials technologies now offer the possibility for much improved accounting of the actual service mission on the nucleation and growth of cracks, and innovative prediction tools are required to account for the actual mission conditions experienced by turbine engine rotating hardware. Ultimately, these tools need to take into account the effects of thermomechanical loading, dwell times, load-interaction effects, etc. on the growth of initial damage and small cracks, transition from small to large cracks, and the growth of microstructurally large cracks.

PHASE I: Develop fracture-mechanics based algorithm(s) to predict or assess the useful fatigue life as a function of the key variable(s), i.e. temperature, load, frequency, hold time, environment, etc. Establish the feasibility with available data, or generate laboratory data to demonstrate the utility of the algorithm(s).

PHASE II: Further development of fracture-mechanics based analytical technique(s). Demonstration of the utility of the technique on laboratory and/or subelement tests under mission-like load and temperature spectra. Delivery of software code, developed under the SBIR contract, would be for evaluation purposes by AFRL and/or ASC in subcomponent, component, and/or engine validation testing. Additional distribution of software would occur only as a result of separate contractual agreements. All computer codes should be PC compatible with Windows NT.

PHASE III DUAL USE APPLICATIONS: The fracture-mechanics based algorithm(s) and software codes developed to predict or assess the useful fatigue life of engine structural materials should be applicable to a wide variety of commercial applications including, but not limited to, commercial aircraft (engines and airframes), land based turbines, automotive and other transportation vehicles, and any industrial applications where fatigue and/or thermomechanical fatigue is the primary failure mechanism. All computer codes should be PC compatible with Windows NT.

REFERENCES:
1. Nicholas, T. and Larsen, J. M., "Life Prediction for Turbine Engine Components," Fatigue: Environment and Temperature Effects, Plenium Press, New York, New York, Editors J. J. Burke and V. Weiss, pp.353-375, 1983.
2. Larsen, J. M. and Nicholas, T., "Cumulative-Damage Modeling of Fatigue Crack Growth in Turbine Engine Materials,"Engr. Frac. Mech., Vol. 22, No. 4, pp. 713-730, 1985.
3. Larsen, J. M., et. al., "An Assessment of the Role of Near-Threshold Crack Growth in High-Cycle Fatigue Life Prediction of Aerospace Titanium Alloys Under Turbine Engine Spectra," Int. J. of Frac., Vol. 80, pp. 237-255, 1996.
4. Nicholas, T. and Zuiker, J. R., "On the Use of the Goodman Diagram for High-Cycle Fatigue Design," Int. J. of Frac., Vol. 80, pp. 219-235, 1996.

KEYWORDS: Fatigue, Thermomechanical fatigue, Fracture Mechanics, Crack propagation, Small cracks, Mission spectrum, Creep, Environment, Titanium, Nickel-base superalloy

AF00-149 TITLE: Durability of Turbine Engine Materials

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Life extension of turbine engine components through the demonstration of material durability and life management improvements.

DESCRIPTION: The inability of some key fielded, turbine-engine components to meet or exceed their original design life is of increasing concern and expense to the Air Force. For major, fracture-critical components, reduced lives can result from inadequate nondestructive evaluation (NDE) capabilities, inadequate understanding of the material response to the engine operating environment, unanticipated or premature wear-out modes, or excessive conservatism in the life management system. It is postulated that a large fraction of these costly parts could be safely used well beyond their predicted LCF “design” life through the application of appropriate life-extension technologies. These technologies include improvements in NDE techniques and procedures, more accurate and robust fracture-mechanics models, innovative repair or refurbishment processes, and better understanding of initial surface finish and residual stress conditions. For fan blades and hot-section components high cycle fatigue, foreign object damage (FOD), hot corrosion, oxidation, and creep are major causes of decreasing, useful component life. Improvements in control, mitigation, and understanding of the damage modes are crucial steps required to maximize the useful economic life of components, without increasing the risk of failure. In addition, advanced materials, material-coating schemes, and material processes, which may be candidates to replace existing practice, must demonstrate improved durability, or increased resistance to the active damage mode.

PHASE I: Demonstrate the potential for service life extension and quantify the associated improvements in life cycle cost or cost savings. Proof of concept shall be demonstrated through initial formulation, bench- or coupon-level testing and evaluation in support of an advanced model, material, coating, surface treatment, process, or NDE technique. A specific engine component, or components, and the degree of life extension or increased capability should be individually addressed.

PHASE II: Demonstrate the feasibility to scale the technology. This could be accomplished through sub-element or full-scale testing in support of models or advanced materials and processes. For improved NDE techniques, material processes and surface treatments, optimization and scale-up are required to establish feasibility for manufacture and widespread use. The degree of life extension, when applied to specific components, should be demonstrated under realistic test conditions.

PHASE III DUAL USE APPLICATIONS: The technology developed should be applicable to a wide variety of commercial applications, including, but not limited to, commercial aircraft, land-based turbines, and automotive and other transportation vehicles.

REFERENCES:
1. Larsen, J. M. and Nicholas, T., “Cumulative-Damage Modeling of Fatigue Crack Growth in Turbine Engine Materials,” Engr. Frac. Mech., Vol. 22, No. 4, pp. 713-730, 1985.
2. McDowell, D. L., “Basic Issues in the Mechanics of High Cycle Metal Fatigue,” Int. J. of Frac., Vol. 80, pp. 103-145, 1996.
3. A.M. Freborg, et al., "Modeling oxidation induced stresses in thermal barrier coatings," Materials Science and Engineering, A245, pp. 182-190, 1998.
4. S. L. Semiatin and T. R. Bieler, "Microstructural Evolution during the Hot Working of Superalloys," JOM, Vol. 55, No. 1, p. 13, 1999.
5. Harris, J. A., Engine Component Retirement for Cause, AFRL-TR-87-4069,1987.
6. Berens, A. P., “Analysis of the RFC/NDE System Performance Evaluation Experiments,” Review of Progress in Quantitative Nondestructive Evaluation 6, D. O. Thompson and D. E. Chimenti, eds., Plenum Press, New York, 1987.
7. Keller, S., et al., “Performance Experience and Reliability of Retirement for Cause (RFC) Inspection Systems,” RTO-MP-10, NATO Research and Technology Organization, Neuily-Sur Seine Cedex, France, November 1998.

KEYWORDS: Durability, Materials, Processing, Nondestructive evaluation (NDE), Modeling, Life management, Life extension, Damage Modes, Turbine Engines

AF00-150 TITLE: Titanium Processing for Low Cost Airframe and Engine Components

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The development of lower cost titanium metal and processing techniques that will significantly reduce the cost of airframe and engine components.

DESCRIPTION: The cost of titanium sponge is the largest single raw material contribution to the cost of titanium forgings and castings (25% and 17%, respectively). The use of titanium in the F-22 is approximately 40% by weight in the airframe and in the F119 engine. In comparison, there is only 15% aluminum in the airframe and 4% in the engine. Since the cost of titanium is close to seven times that of aluminum, methods to reduce the cost of titanium can lead to significant cost reductions in the unit cost of the F-22. New approaches are requested to develop techniques that reduce the cost of titanium sponge or a comparable sponge substitute [1]. In addition, new approaches are requested which investigate the feasibility of near-net-shape processing using titanium powder [2]. The powder-based technologies must demonstrate final material properties comparable to cast/wrought titanium components at a lower cost.

PHASE I: This Phase I effort will focus on techniques that will reduce the cost of titanium sponge or a comparable sponge substitute. Near-net-shape processing techniques that significantly reduce the manufacturing cost of titanium components shall also be investigated. Proposals should demonstrate reasonable expectation that new approaches and techniques will lead to lower cost titanium airframe and engine components that demonstrate materials properties superior to or equal to current cast/wrought components.

PHASE II: This Phase II effort will refine those new techniques developed in Phase I and demonstrate comparable mechanical properties and lower cost manufacturing to current titanium aerospace components. Raw material production concepts and near-net-shape techniques will be demonstrated by the manufacture of prototype aerospace component(s). Mechanical properties of the finished prototype components shall be tested. A cost analysis shall be conducted to verify the cost savings projected in phase I.

PHASE III DUAL USE APPLICATIONS: The developed approaches should have broad commercial applicability due to the large number of commercial airframes and engines that are fabricated from titanium. Potential customers shall be identified. Benefits of the new technology to the customer base shall be established, and the cost of implementing the technology into the customer base shall be determined.

REFERENCES:
1. A. D. Hartman, et al., “Producing Lower-Cost Titanium for Automotive Applications,” JOM, Vol. 50, No. 9, pp. 16-19.
2. F. H. Froes, “The Production of Low-Cost Titanium Powders,” JOM, Vol. 50, No. 9, pp. 41-43.

KEYWORDS: Titanium Sponge, Powder Processing, Near Net Shape Processing, Forgings, Castings, Airframe Components, Engine Components

AF00-151 TITLE: The Control Stick of the 21st Century "C21"

TECHNOLOGY AREAS: Air Platform, Information Systems, Materials/Processes

OBJECTIVE: Design and develop the control stick of the future while considering the requirements to potentially retrofit the CS21 stick technology into aircraft currently in development and production.

DESCRIPTION: This is a requirement of the F-22 System Program Office for the re-design and re-engineering of the stick used by the pilot to control the aircraft. The size and complexity of the current stick technology must be drastically reduced in order to provide more functionality and improved human factors considerations. The switch bodies are huge which causes the stick and throttle grips to be very large. More functionality is needed at the pilot's fingertips in order to improve the pilot's performance during flight and war fighting. The current stick technology user friendliness and other human factors also leave a lot to be desired. The offeror must develop a comprehensive set of CS21 user needs, supporting technical engineering requirements to resolve the issues of the user, and provide a new and innovative solution to the aerospace industry.

The offeror must consider establishing a CS21 design team that is composed of the required knowledge and skills, including component suppliers. The offeror should consider using a process such as Integrated Product and Process Development (IPPD) to ensure completeness, consistency, quality, and cost control of their CS21 strategy. The offeror should develop an interface with the F-22 and JSF SPO engineers for the CS21 technology development to ensure that the prime contractors, major subcontractors, and their suppliers participate appropriately. The offeror should use modern CAD and simulation and modeling technologies to demonstrate recommended CS21 concepts as early as possible in Phase I to enable confidence in the Phase II proposal potential. These CS21 demonstrations should depict how the war fighter's needs and the technical engineering requirements will be satisfied.

PHASE I: This phase will define the requirements, prototype designs, and simulation models demonstrating CS21 conceptual physical and functional profiles, operations, and interactive interfaces in a war fighter's simulated environment. The offeror will use a carefully selected Technical Review Board (TRB) of subject matter expert users, potential developers, and suppliers of CS21 technologies for project over site.

PHASE II: Phase II will convert the selected CS21 conceptual design into a physical product using a systems engineering approach to satisfy CS21 requirements and specifications from the IPPD and TRB evaluations. The offeror will develop and productize the CS21, commercialize it, and work with the SPO and prime contractors to install and validate CS21 technology in hardware. The CS21 engineering designs and analysis, simulation models, and data will be installed in the AFPMO Product Affordability Realization Testbed (PART) facility for possible prototyping and for demonstrating the CS21 to potential users and developers.

PHASE III DUAL USE APPLICATIONS: The models, methodologies, techniques, and resulting technologies will be used to convey the CS21 project results to companies developing commercial and military systems.

REFERENCES: TIB/B94-04983, Application of Active Side Arm Controllers in Helicopters, Knorr, R.; Melz, C.; Faulkner, A.; Obermayer, M., Eurocopter Deutschland GmbH, Ottobrunn (DE), 1992.

KEYWORDS: Functional Capabilities, Control Stick, Re-design

AF00-153 TITLE: Development of Improved Mold Facecoat Technology

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To develop a lower cost, more robust, and more detectable facecoat system for the titanium investment casting industry.

DESCRIPTION: Titanium investment castings have gained wide usage in aerospace propulsion systems to reduce cost. The investment casting process offers the ability to make complex parts of one piece construction, thus eliminating the expensive fabrication of parts from multiple pieces. Recently, the F-22 has made use of titanium investment castings for large critical airframe structure. Significant cost savings will be realized through the successful use of titanium investment castings in future military and commercial airframe structure. Unfortunately, the F-22 has experienced significant processing related issues with their castings that can be attributed to the mold facecoat system.

The investment casting process involves making a mold by systematically pouring ceramic slurries over a wax “copy” (referred to a “wax”) of the part to be cast. The wax is then melted out of the ceramic mold and the ceramic mold is cured during a “wax burnout” process. The metal is then poured into the ceramic mold. The first ceramic slurry poured over a wax is the facecoat system. This facecoat system is selected to reduce the reactions with liquid titanium as the titanium is pored into the mold and the metals cools. If great care is not taken during the fabrication of the ceramic mold, the mold can be stressed and weakened thus increasing the possibility of ceramic inclusions contaminating the titanium casting. X-ray techniques are employed to detect ceramic inclusion in titanium castings. Unfortunately, the delectability of the ceramic inclusion material in titanium castings is not good enough to take full advantage of the benefits that titanium investment castings offer.

PHASE I: This phase I effort will focus on titanium investment casting facecoat materials and/or mold systems that are cheaper, more robust, and more detectable via non-destructive inspection than current state-of-the-art mold systems. Proposals should demonstrate that the offeror has experience in the development of facecoat materials for investment casting. However, the facecoat “system” need not be limited to the facecoat alone. Cost effective materials, material systems and/or techniques shall be identified which can, decrease the chance of foreign inclusions ending up in titanium investment castings and increase the chance of detecting them if they do end up in the casting. Robust mold systems that show a very low chance of ever ending up in a final casting should also be considered. Proposals should demonstrate reasonable expectation that new approaches and techniques will lead to robust, highly detectable (if applicable), and cost effective mold systems. Demonstration will require association with a casting house of the offeror’s choice.

PHASE II: This phase II effort will refine those new materials, systems, and techniques developed in phase I and demonstrate the robustness and delectability of the new materials and/or systems. Prototype molds shall be fabricated. Test shall be developed and conducted which can evaluate the robustness (strength) of the mold materials and/or systems. The ability of the new mold materials and/or systems to withstand the typical manufacturing process of an F-22 side-of-body “like” casting shall be determined. Prototype titanium castings shall be poured and inspected by non-destructive inspection (NDI). NDI results shall be compared to destructive test and used to, develop probability of detection (POD) curves for mold materials in titanium, or demonstrate that the mold material does not end up in the casting. A cost analysis of the new mold technology shall be conducted and reported.

PHASE III DUAL USE APPLICATIONS: The developed approaches should have broad commercial applicability due to the large number of commercial airframes and engines that are fabricated from titanium. Potential customers shall be identified. Benefits of the new technology to the customer base shall be established, and the cost of implementing the technology into the customer base shall be determined.

REFERENCES: Air Force Contract F33615-95-2-5555, Engine Supplier Base Initiative

KEYWORDS: Titanium , Investment casting, Lost wax process, Ceramic mold, Slurry, Facecoat, Alpha case

AF00-154 TITLE: Advanced Adaptive Optical Coating Process Technologies

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Design adaptively controlled optical coating processes to either infer or enable direct measurements of optical properties.

DESCRIPTION: In order to produce state-of-the-art, low stress, low absorption, environmentally stable optical coatings, all material parameters must be well characterized and controlled during the deposition process. Dielectric molecules are characterized to first order by the molecular electric polarizability while molecules of a birefringent material will have a permanent electric dipole moment. Other molecules may have higher moments, quadrupole, etc., for both the polarizability and the permanent moments. Magnetic materials have the corresponding quantities for the magnetic field. Conductive materials have free electrons and therefore non-zero electrical conductivity. In the general case, a material has all of these properties. Knowledge of these parameters is necessary for all constituent species of molecules to be modeled and controlled during processing. In addition, the arrangement of molecules as well as the interaction of different species will induce stresses and strains in the molecules, which in turn induces permanent dipole moments and therefore stress birefringence. Additionally, the properties are a function of temperature and pressure. The goal of this SBIR topic is to design and develop technologies for an advanced adaptive process to monitor and control the above discussed properties during the deposition of optical coatings. One current deposition process of choice is reactive dc Magnetron sputtering to deposit dual wavelength optical coatings with very high reflectance which are also dense, with very low absorption (~10 ppm) and scatter (surface roughness ~1 nm), and promise long-term stability and durability in a space environment. We believe this process can easily be adapted to ultra lightweight materials to produce rapid, low cost, uncooled mirrors for space optical applications, as well as environmentally stable/durable coatings for leading edge aircraft applications. However, in order to satisfy the stringent material property specifications for all optical applications, particularly those of high aspect ratio optics, extremely close control of source profiles and deposition parameters must be maintained. Continual evaluation of deposition parameters, and more to the point, coating performance, during deposition, would ensure specified performance from the finished product, essentially without the need for witness samples.

PHASE I: Demonstrate the feasibility of an advanced processing technology (e.g., integrating gas cluster ion processing with a compatible deposition process and/or use in situ monitoring of relevant material parameters via evanescent microwaves as the basis for tuning through the gas cluster ions). The objective of Phase I is to demonstrate improvements in the quality and uniformity of optical coating properties across a range of optical coating materials to include interfaces, i.e., inter-layer and film-to-substrate. The primary candidate materials for this investigation would be titanium dioxide (TiO_2), tantalum pentoxide (Ta_2O_5), and Silicon dioxide (SiO_2). Titanium dioxide has a broad spectral range of transparency (0.4 mm to 8.0mm), and a high refractive index. Previous investigations indicate that good quality films of this material can be grown using IAD.[1,2] It has also been demonstrated that the stress of evaporated TiO_2 and SiO_2 films can be altered by IAD.[1,2] Tantalum dioxide has a lower refractive index than TiO_2, but is transparent in the ultraviolet spectral region and has extremely good resistance to radiation damage. SiO_2 is the most durable low index material available, and has good resistance to radiation damage. Characterization of the films on various substrate materials will be necessary. Although stress caused by different thermal expansion coefficients is usually of secondary importance, in some cases it may be significant. Of more importance would be the adhesion of the film structure to the substrate. This may differ depending on the substrate, and some investigation of adhesion related to surface preparation prior to coating may be useful.

PHASE II: Develop an advanced optical coating process prototype to enable near real-time monitoring and control of deposited single-layer, multi-layer, and/or gradient films relative to optical properties, electro-magnetic conductivities, and morphology (grain size, orientation, roughness, etc.) for both defense and commercial applications. Thin face-sheet mirror materials should be first investigated to demonstrate the prototype's ability to monitor and control adhesion and stress.

PHASE III DUAL USE APPLICATIONS: With the increasing need for lighter-weight optics, large investments are being made in lightweight mirror and membrane materials, including deployment techniques, but not in the durable high-performance optical coatings necessary for their implementation. A high reflectivity, low absorption, low stress optical coating is key to enabling highly efficient operations. Such lightweight high reflector membranes not only would serve to increase operational efficiency for space and airborne applications, but as well to reduce the cost of deployment to operational altitude. Low stress coatings in particular could provide the key to enabling thin materials and facesheets to be used in any optical application. Of particular interest is the need for a process which has the potential to produce rapid, low cost, uncooled mirrors for space optical applications; and this potential is tremendous. Studies such as AFRL's Lasers and Space Optical Systems indicate that such large lightweight space optics are the enabling technologies to answer warfighter requirements, as well as those of commercial applications such as laser communication, including lighter-weight mirrors for crosslink and large apertures for down and up links. With such large apertures, far-reaching technologies such as optical imaging through clouds could be realized, opening the full military realm to laser applications, including covert communications. Eventually, even directed energy type applications may also benefit, including the Next Generation Space Based Laser. In any of these applications, launch weight savings alone would be phenomenal, not to mention the capability produced by having this large optic in space.

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KEYWORDS: Thin Film Optical Coatings, Adaptive Control Technologies, Environmentally Stable Optical Coatings

AF00-155 TITLE: Guided Wave Electro-Optic Materials

TECHNOLOGY AREAS: Materials/Processes, Sensors/Electronics/Battlespace

OBJECTIVE: Develop new electro-optic materials with superior properties as compared to those presently available.

DESCRIPTION: Guided-wave electro-optic technology is required for optical communication between satellites and for highly-dense data handling on satellites. It offers high bandwidths for data transfer exceeding 100 gigabits per second, significantly reduced susceptibility from electro-magnetic pulse interference, reduced radar cross-section, reduced e-m noise generation, and a high tolerance against space radiation effects. However, the current state-of-the-art material, lithium niobate, is limited in a number of respects, including high modulation voltage, large device size, an inability to directly integrate with electronics, instability problems (temporal and thermal), piezoelectric ringing, a large dielectric constant, a moderately large index of refraction, and sensitivity to various forms of ionizing radiation. Currently, polymeric films (including both self-assembled organics and electro-optic poled polymers) appear to offer the best compromise of properties based on both the present state of materials development and the potential for improvement. The objective of this effort is to develop polymeric thin films with enhanced electro-optic (EO) coefficients of at least 50 pm/V at a wavelength of 1550 nm. Besides the enhanced EO coefficients, additional characteristics of the films must include processibility, thermal stability (125C depoling temperature), temporal stability, and suitability for low-loss optical waveguides (<1dB/cm). Materials suitable for operation at a variety of wavelengths will be considered, but the greatest Air Force interest is at 1550 nm. Nonlinear optical devices may be fabricated only as a minor part of a materials effort to evaluate and demonstrate the properties of the material(s).

PHASE I: The objective is to demonstrate a new material, the feasibility of a proposed new growth technique, improved functionality of a material through innovative processing techniques, or improved materials properties resulting from either growth or processing advancements.

PHASE II: The objective is to further develop the proposed material and / or the relevant processes to fully demonstrate the materials properties and usefulness for commercial and military applications. Establish all necessary manufacturing processes for commercialization of a product.

PHASE III DUAL USE APPLICATIONS: Materials technology is fundamental to all applications, military and commercial. Examples of commercial applications are optical switches for cable TV, optical phase shifters for phased array radar, optical interconnects for electronic packages, and switching networks for communications.

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KEYWORDS: electro-optic materials, nonlinear optical materials, NLO materials, optical communications

AF00-156 TITLE: Materials for Superlattice Infrared Detectors

TECHNOLOGY AREAS: Materials/Processes, Sensors/Electronics/Battlespace

OBJECTIVE: Research and development of innovative epitaxial growth techniques for III-V superlattice materials with controlled mixed anion interfaces.

DESCRIPTION: The Air Force requires new, very long wavelength infrared (VLWIR) detectors with increased operating temperature, >40K in VLWIR, and improved detectivity for space based applications. These detectors will be required to operate at wavelengths beyond 16 micrometers. The presently available detectors are based on extrinsic silicon. Due to excessive dark current, the operating temperature of these detectors is below 20K. Detectors with increased operating temperatures with equivalent or better detectivity will have significantly reduced launch costs due to reductions in the weight of the cryocooler. The principle alternatives to extrinsic silicon at present are compound semiconductor superlattices based on group III antimonides and arsenides. So far, detector structures fabricated from InGaSb/InAs and InAsSb/InAs superlattices have not been demonstrated beyond 12 micrometers, and are Shockley-Read noise limited due to defects in the materials. This task seeks to develop improved and innovative epitaxial growth techniques for growing superlattices based on mixed anion interfaces such as InGaSb/InAs. The key areas to be addressed are the interface purity, abruptness and smoothness between the thin InGaSb and InAs layers. Examination of these parameters on the scale of a few Å's is required. Also, the controlled repeatability of the superlattice layer thicknesses and compositions over 1-2 micrometers of material growth should be examined. Both molecular beam epitaxy (MBE) and metal organic chemical vapor deposition (MOCVD) will be considered as well as other novel growth techniques. Growth on novel substrates is encouraged.

PHASE I: Phase I will address process development and growth of simple heterointerfaces along with the minimum characterization to demonstrate improved interfaces. A deliverable of a representative test sample to the government is encouraged.

PHASE II: Phase II will optimize the growth process demonstrated in Phase I with more extensive characterization. Modeling of the growth process is appropriate. Growth and evaluation of superlattice structures suitable for VLWIR detectors will be used to demonstrate the success of the program. Delivery of test materials to the government for evaluation is encouraged.

PHASE III DUAL USE APPLICATIONS: Structures based on mixed anion heterointerfaces have applications in a wide variety of electronic and opto-electronic areas. In particular, room temperature operating infrared detectors based on III-V semiconductor superlattices or multiple quantum wells are of interest to the automotive and aviation industries, among others. Microwave transistors based on mixed anion heterointerfaces have applications in many commercial areas such as cellular phones, and direct broadcast satellite television. The technical product from this effort is expected to be high quality, antimonide based epitaxial materials. The commercial product can either be wafers of these materials designed to user needs, or devices fabricated from these materials.

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KEYWORDS: Infrared, Materials, Superlattice, Semiconductor, Epitaxy, Hetero-interfaces

AF00-157 TITLE: Growth of Semi-Insulating Silicon Carbide (SiC)

TECHNOLOGY AREAS: Materials/Processes, Sensors/Electronics/Battlespace

OBJECTIVE: Develop innovative bulk growth processes for semi-insulating silicon carbide for microwave and RF applications.

DESCRIPTION: Air Force Tactical RADARs and other RF systems currently employing vacuum tube technology have inherent shortcomings including lifetime reliability issues due to overall fragility and cathode burnout, size and weight issues and rigid cooling requirements. It is desired to replace vacuum tube technology in these systems with high power solid state electronics affording reduced space and weight requirements, less stringent cooling needs and greater reliability. Conventional semiconductors such as bulk silicon and gallium arsenide cannot meet these requirements. Semi-insulating silicon carbide has many unique properties such as wide band gap, high breakdown field and high resistivity, which make it attractive for high performance, high temperature and power microwave operation. This task seeks to develop improved and innovative approaches for the growth of semi-insulating bulk silicon carbide. Innovative techniques to obtain semiinsulating behavior will be addressed. The focus of this effort will be on the 4H-SiC polytype with secondary interest in 6H-SIC. Other polytypes or amorphous SiC compounds will not be considered. Hybrid materials combined with SiC will also not be considered.

PHASE I: Phase I will address process development and initial testing to show proof of concept. Phase I goals shall include confirmed growth of semi-insulating bulk silicon carbide with overall resistivity greater than 1017 ohm-cm. Modeling studies of growth processes or materials properties are appropriate. A deliverable of a representative test sample to the government is encouraged.

PHASE II: Phase II will develop the advanced growth processes and techniques to demonstrate the potential application. Phase II goals shall reflect state-of-the-art parameters for semi-insulating bulk growth including but not limited to total resistivity variation of 10% or less over the total wafer diameter and entire boule length. Minimum wafer size and boule length output as a result of the Phase II effort shall be at least 2-inch in diameter with minimum boule length of 1 inch. Other goals include bulk micropipe defects less than 50 per square centimeter. Deliverables of test materials to the government for evaluation are encouraged.

PHASE III DUAL USE APPLICATIONS: Microwave devices made from SiC will exhibit high power, high frequency operation (e.g., 20 watts in X-band at room temperature) with higher package density and reduced cooling subsystem requirements. In addition to military application in tactical RADARS, commercial application of semi-insulating silicon carbide includes @ and HDTV transmitters for the broadcast industry and tube technology replacement in airport surveillance and tracking RADARS. The development of semi-insulating bulk SiC will be required to successfully commercialize these high frequency, high temperature and power devices.

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KEYWORDS: Semi-Insulating Silicon Carbide, Materials, Crystal Growth, High Power Microwave

AF00-158 TITLE: Development of Liquid Crystal Materials for Directed Energy Control

TECHNOLOGY AREAS: Materials/Processes, Biomedical, Sensors/Electronics/Battlespace

OBJECTIVE: Develop new liquid crystal technology (materials and/or processing) with enhanced performance and utility for energy control, switching, and redirection.

DESCRIPTION: Liquid crystal materials are pervasive through commercial based applications ranging from simple twisted nematic-based devices to more complicated display architectures. They are also used in a number of commercial imaging, shuttering, novelty, and entertainment applications. Most of these devices take advantage of the switchable anisotropic optical properties of the LC fluid. The objective of this topic is to improve upon and exploit inherent LC properties for their application in state-of-the-art energy control, switching, and redirection applications. Some examples of appropriate research areas are: new materials with switchable grey scale properties including fast ferroelectric compounds; new switchable polarization materials and schemes with improved contrast and speed; novel passive thin films for compensator and out-of-band filtering applications; new approaches and materials to enhance current switchable and tunable filter materials properties; and approaches to increase contrast in existing architectures. Proposals submitted to this topic should focus on the materials and processing necessary to improve device performance; they should not be device demonstrations.

PHASE I: The offeror will demonstrate proof-of-principle with respect to new materials or processing schemes. The offeror will demonstrate applicability and discuss the issues to be addressed during Phase II.

PHASE II: The offeror will optimize the approach demonstrated in Phase I and will design and characterize the improved article to demonstrate advancement with respect to state-of-the-art technology.

PHASE III DUAL USE APPLICATIONS: Because liquid crystals are pervasive in the commercial sector, improvements to particular materials and/or processes will have wide scale applicability in numerous markets including display, entertainment, and research areas.

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KEYWORDS: Energy control, Liquid crystals, Nematic liquid crystals, Switching speed, Contrast ratio

AF00-159 TITLE: Bulk Growth of Aluminum Nitride for Space and Propulsion Applications

TECHNOLOGY AREAS: Air Platform, Materials/Processes, Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: The objective is to grow 2 inch diameter single crystal Aluminum Nitride substrates.

DESCRIPTION: Wide energy bandgap aluminum gallium nitride (AlGaN) has potential in high temperature, radiation hardened, and ultra-violet (UV) wavelength applications. However, there is no suitable substrate available. It is not practical to have GaN as a substrate due to the extremely high pressures needed to grow the material by conventional Czechrolski techniques. Therefore, alternative substrate materials, such as sapphire which has a large lattice mismatch of 14% to GaN and others, have been used. The large mismatch causes a large amount of dislocation defects (108-1010 cm-2) in the epitaxially grown GaN. These defects reduce device yield and reliability. Silicon carbide (SiC) and zinc oxide (ZnO) have smaller lattice mismatches to GaN, but are not of the same elemental constituents, which also results in high defect densities. ZnO has the additional problem that it thermally degrades at temperatures where GaN is grown epitaxially. A potential substrate that has not been looked at seriously is bulk grown aluminum nitride (AlN). The lattice constant mismatch is small (about 2%) to that of GaN and even smaller to that of AlGaN. It has the same crystal structure and is thermally stable at high temperatures. In addition, nitrogen is a common element in both GaN and AlN. Therefore, the use of such a substrate may be extremely valuable in high temperature electronics for propulsion applications, space electronics where radiation hardening is imperative, and UV solid state emitters and detectors for missile defense, optical communications and data storage.

PHASE I: The first phase of this effort will consist of the development of a single crystal AlN boule growth of a hexagonal crystal structure. The boule can be grown by any method that produces a 1-inch or larger round AlN wafer for delivery at the end of Phase I.

PHASE II: The second phase will be to extend the knowledge gained in Phase I and develop the capability to grow single crystal 2-inch AlN boules with low dislocation densities (<106 cm-2), no twin defects and a resistivity of greater than 107 ohm-cm. As an indication of progress, two 2-inch round wafers will be delivered with at least a single side polished for material characterization, halfway through the program. A final delivery will be made at the end of the contract with six 2-inch round single crystal AlN wafers with at least one side polished from the same best effort boule. Two of the wafers will be from each of the two ends and the final two will be from the middle of the boule. Also, the remains of that boule will be delivered.

PHASE III DUAL USE APPLICATIONS: Two inch AlN substrates will be made available to the public and may be extremely valuable for uses in high temperature electronics for propulsion applications, space where radiation hardening is imperative in satellite communications, and in UV solid state emitters and detectors for missile defense, optical communications and data storage. There is great commercialization potential for data storage and optical communications with wide bandgap materials.

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KEYWORDS: Crystal growth, Substrate, Aluminum Nitride

AF00-160 TITLE: Qualifying Light, High-Performance Materials for Airborne and Space-Based Laser Systems

TECHNOLOGY AREAS: Materials/Processes, Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop a rapid materials-selection strategy and demonstrate efficacy on critical high-energy laser components.

DESCRIPTION: The Airborne Laser (ABL) Weapon System, based on the chemical-oxygen-iodine-laser (COIL) concept, represents a major advancement in weapon system technology. The development and acquisition of traditional Air Force weapon systems has required the expertise of many engineering disciplines but not typically chemical process engineering, as does the ABL. The unique chemistry of a COIL presents new challenges in chemical processing, material handling, process material selection, logistics, and safety.

Airborne and space-based chemical laser systems require lightweight, high-performance materials to achieve system performance objectives. The chemicals used in chemically driven laser systems are incompatible with many materials used in the chemical processing industry. In addition, materials that have been used for ground-based chemical laser systems pose extreme weight penalties for aircraft and space applications. Conventional material evaluation techniques require long test periods and are very labor intensive. A rapid, high-confidence evaluation technique is required to predict material performance for critical laser system equipment in a compressed time frame.

PHASE I: Comprehensive materials testing and evaluation strategy involving the use of sub-scale process elements representative of full-scale operational equipment intended for use on high-energy chemical laser systems. Chemical exposure duration of as much as 3000 hours is required with intermittent material assessment. Strategy (Phase I) should include: (1) material selection, fabrication, and identification (government and contractor specified), (2) performance evaluation criteria, (3) material performance data correlated to system design (size, weight, process fluid interactions) and operation (reliability, availability, maintainability) and (4) material performance data correlated to equipment service decisions (MC , NMC , MC with waiver).

PHASE II: Demonstrate rapid material qualification on selected process materials for Chemical-Oxygen-Iodine-Laser (COIL) system. Provide equipment failure modes, assessment techniques for full-scale system evaluation, and mean-time-between-failure for system critical components. Demonstration (Phase II) should include: (1) identification and qualification of materials and material suppliers, (2) sub-scale component fabrication, (3) test configuration and chemical exposure, and (4) post-exposure material inspection, analysis, and qualification. The strategy and demonstration should be an iterative process based on statistical experimental design that will result in the greatest amount of information in the shortest amount of time. Materials should be selected that will result in decision alternatives; i.e., plan B, C, etc., should any selected material fail to meet performance criteria. Process materials must be suitable for use in systems exposed to basic-hydrogen peroxide, chlorine gas, chlorine liquid, hydrogen peroxide (70-wt. %), and ammonia (anhydrous). Specific conditions will be provided upon request.

PHASE III DUAL USE APPLICATIONS: The procedures and methods developed in this effort will compress significantly the development time for advanced chemical-based weapon systems by reducing the time for selecting and qualifying new materials and new material applications. Air Force weapon systems of the future require new methods and tools for managing programmatic and technical risk such as the one specified herein. In addition, developments in this area will be of value in other process industries, such as production of polymeric materials and manufacturing that requires rapid prototyping.

REFERENCES: Oxygen-Iodine Supersonic Technology Program, Area I Supersonic Laser, Subsystem Design Analysis Report, October 13, 1983, Unclassified, TRW Space and Technology Group, Redondo Beach, CA 90278, Contract Number F29601-82-C-0083.

KEYWORDS: chemical oxygen iodine laser, COIL, basic hydrogen peroxide, BHP, chemical decomposition

AF00-161 TITLE: Fuel Processor for Air Expeditionary Force Deployable Fuel Cells Power Generator

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: Develop a highly efficient, lightweight, and small size multi-fuel processor for more reliable fuel cells power generators.

DESCRIPTION: The rapid evolution of fuel cell technology as a replacement for conventional electric power generators has provided a gateway to future efficient and reliable power generating systems using hydrogen as primary fuel. The major drawback to the use of fuel cells as electric generators for deployed forces is the inability to effectively use battlefield fuels (diesel and JP-8) as the primary energy source. The ability to reform battlefield fuels to highly enriched hydrogen gas would allow the use of fuel cells in place of conventional diesel engine powered generators. This would result in a reliable electric generation system with higher efficiency, lower emissions, and lower noise signature. Because of these potential advantages, the objective of this effort is to develop an efficient fuel processor to reform diesel/JP-8 fuels to a high purity hydrogen gas stream for Air Expeditionary Force (AEF) applications. Existing fuel processing can be categorized into stream reforming and partial oxidation technologies with processes to purify the enriched hydrogen gas from sulfur and carbon monoxide. Both technologies yield heavier and bigger units with longer start-up time to compete with diesel engine powered generators. A new concept is sought to develop a lightweight, small size, and quick start-up time fuel processor unit suitable for deployable electric generators.

PHASE I: Develop a conceptual design for a small size, mobile, and highly efficient multi-fuel processor for fuel cells power generator. The conceptual design shall be presented in a technical report and will include details on recommended equipment design and construction, expected performance and durability, total expected weight and size, energy conversion efficiency, and unit cost.

PHASE II: A prototype unit will be constructed based on Phase I recommendations. A demonstrated performance through a single integrated system will be conducted, validated, and presented in a Phase II technical report with further development or commercialization recommendations.

PHASE III DUAL USE APPLICATIONS: A successful, efficient, lightweight, and small size diesel/JP-8 fuel processor with over 85% reforming efficiency will have a multitude of commercial airline facility-emergency power applications, in addition to DoD's use of this technology as a deployable military power generator in a Bare Base scenario. Portable and backup generators are very much in demand during natural disasters (hurricanes, floods, earthquakes, etc.) by emergency response teams.

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KEYWORDS: Logistic Fuel Reformer, Fuel Processor, Fuel Cell

AF00-162 TITLE: <u>Nondestructive Characterization of Titanium Castings and Weldments</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Identify reliable, cost-effective technology for detection and characterization of large titanium casting and weldment defects.

DESCRIPTION: Advancements in airframe structural design and the drive towards greater performance have lead to the incorporation of large complex titanium castings and weldments within new advanced Air Force weapons systems. The design margins of such structures allow for the tolerance of only very small defects. Reliable and accurate flaw detection and sizing is critical in ensuring the structural integrity of the airframe. Defects of greatest concern are subsurface defects such as alpha stabilized inclusions, shell inclusions, porosity, shrinks, and voids within castings, and lack-of-fusion, porosity, and inclusions in titanium casting weld repairs, and titanium electron beam welds. The coarse grain structure of titanium, in particular beta-annealed titanium castings, significantly increases the difficulty in accurate flaw characterization through thick structure. In addition, the move toward large complex castings and electron-beam welded structures significantly increases the difficulty in inspection access. Currently applied methodologies such as delta-scan, shear-wave, longitudinal-wave ultrasonics, and film radiography have proven unreliable in accurately detecting, locating, and sizing such defects within manufacturing environment. Technologies such as phased-array ultrasonics, used extensively in medical imagery, have begun to demonstrate application in industrial inspections were greater flexibility is required for the inspection of complex geometries. This solicitation requests the development and application of phased array ultrasonics, or other NDI imaging technologies, which provide significant improvement in signal-to-noise, signal interpretation, defect characterization, and application flexibility than currently applied technologies. The system, at the end of Phase II, should provide a demonstrable, low-cost system to detect and characterizing defects in titanium castings and weldments, and explore the application of the technology to other Air Force inspection challenges.

PHASE I: Research and develop entire sensor and image acquisition system concept. Develop approach for accurate signal characterization (i.e. defect sizing and location). Build proof-of-concept hardware, software and sensor for the inspection of both titanium weld repairs and titanium electron beam weldments. Demonstrate and define system capability and limitations.

PHASE II: Develop system prototype incorporating data acquisition into a user friendly interface. Data acquisition hardware and operating systems should be PC and Windows 95 based. Sensor and imaging system shall demonstrate full capability for detect detection and characterize of weld defects in both titanium electron-beam weldments and titanium casting TIG weld repairs. Defect hardware can be provided, in part, by the Government. Perform "capability study" to determine inspection sensitivity and reliability. In addition, other applications should be explored such as inspection of steel and aluminum weldments and casting, crack detection in aluminum airframe structures, composite structure inspection, and detection of shell inclusions in titanium castings.

PHASE III DUAL USE APPLICATIONS: Potential applications include inspection metallic or composite structures in aircraft, naval vessels, automobiles, rail systems, or building structures. This technology may have additional application to corrosion detection and characterization in aircraft, ship, and oil pipeline structures. Potential customers include aerospace, nuclear, marine, automotive, and rail industries, FAA, DOD, and the DOE.

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KEYWORDS: Titanium castings, Titanium weldments, Nondestructive Inspection, Phase Array Ultrasonics

AF00-163 TITLE: Aircraft Battle Damage Repair (ABDR) of Substructural Core Repair

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop the capability to repair and replace substructural core to aircraft that have been damaged in an ABDR environment.

DESCRIPTION: The US Air Force has established an ABDR program whose primary purpose is to restore sufficient strength and serviceability to a damaged aircraft that will permit the aircraft to fly additional operational sorties within time to contribute to the outcome of an ongoing battle. Therefore, repairs of this nature need to be rapidly accomplished, with little special materials and equipment, restoring full strength while often disregarding normal fatigue and corrosion issues. Repair of substructural core materials poses a concern due to the wide variety of core materials in service, the skill required for machine replacement plugs of core, and the difficulties of bonding these replacement plugs in place. This program investigates two-part “foam-in-place” materials and develops procedures for repair of substructural core on-aircraft.

PHASE I: The contractor shall investigate two-part “foam-in-place” materials for potential repair of substructural core. The contractor shall test these materials for capability to fill component cavities, structural strength, temperature limitations, shelf life, and time required to mix and cure.

PHASE II: The contractor shall develop procedures for replacing core in battle damaged aircraft components. These procedures shall be simple to perform on a variety of component configurations including upward and downward facing openings. The contractor shall demonstrate repair of a representative US Air Force aircraft component with damaged core and validate through structural tests.

PHASE III DUAL USE APPLICATIONS: The process developed would be beneficial for repair and manufacturing of commercial aircraft.

REFERENCES:
1. Sanders, A.L., Stewart, G.G., Regnery, A.M., Rapid Repair of Battle Damaged Aircraft Structure, AFWAL-TR-84-3034, May 1985.
2. Snyder, David L., Battle Damage Repairs Applied to Ballistically Damaged F-15 Horizontal Stabilators and Vertical Stabilizers, JLF-TR-88-9, July 1990.
3. Carter, Douglas W., Validation of F-15 Horizontal Stabilator Battle Damage Repairs, WRDC-TR-91-3003, February 1991.

KEYWORDS: Repair, Substructure, Honeycomb Core

AF00-165 TITLE: Directed Electromagnetic Radiation Energy Curing of High Temperature Repair Adhesives

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Achieve uniform curing of high temperature capable adhesives, on-aircraft, via electromagnetic radiation energy.

DESCRIPTION: Bismaleimide (BMI) composites are constituting more of the structure of advanced fighters due to the high temperature requirements of these aircraft, however, the ability to repair these materials far lags manufacturing capabilities. A major cause of this is due to the necessity to postcure BMI adhesives to temperatures exceeding 400°F, for long durations, in order to achieve the required elevated temperature properties. For on-aircraft repair, this long hot soak is intolerable as is it can potentially damage the surrounding structure, the substructure (i.e., exceeds the degradation temperature of many fuel sealants), as well as pose a safety risk (i.e., exceeds the flash point of aviation fuel). An alternative to the utilization of heat as the primary curing mechanism for high temperature adhesives (>350°F) is therefore needed. This alternative mechanism should have the capability of achieving uniform curing across the bondline despite thermally complex structures and also uniform curing of bondlines in deep core repair.

PHASE I: The contractor shall demonstrate the capability to cure an adhesive bondline, uniformly, with electromagnetic radiation energy so as to achieve adequate elevated temperature properties. The contractor shall demonstrate, at a laboratory scale, adhesive properties which are comparable to autoclave cured BMI adhesives.

PHASE II: The contractor shall optimize curing mechanisms, energy disbursement methods, spacing, energy source, wavelength and intensity. The contractor shall optimize to achieve high strength bondlines. The contractor shall demonstrate proof-of-concept on a large component (one-foot repair area within deep core) to include evaluated temperature (i.e., "hot/wet") repair properties.

PHASE III DUAL USE APPLICATIONS: Commercial airframe and engine manufactures are being driven to higher operating temperatures for their material systems in the pursuit of efficiency and performance. This is and will continue to necessitate the use of higher temperature capable materials such as BMIs (e.g. for engines BMIs are being used in thrust reversers and acoustic damping plates of commercial engines). As with the military systems, there exists no current capabilities for repairing these structures, on-aircraft, due to the temperature restrictions imposed by substructure, subsystems, and the flashpoint of jet fuel. Directing electromagnetic radiation into the bond area could potentially overcome these temperature restrictions.

REFERENCE: Sennett, Michael S. and Wentworth, Stanley E., Evaluation of Resins Cured by Ultraviolet Radiation and in Conjunction with Fiber Optic Systems for use in the Field Repair of Composite Materials, MTL-TR-87-15, March 1987.

KEYWORDS: Repair, Adhesive, Processing

AF00-166 TITLE: Low Observable Maintainability

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop technologies, compatible with aircraft low observable requirements, which allows quick and easy removal and replacement of access panels and doors without degradation of aircraft signature.

DESCRIPTION: The US Air Force has relied heavily on low observable (LO) technologies in recent aircraft designs to perform critical deep theater missions. Although, these technologies have proven very effective against the latest air defense systems in recent conflicts, maintenance of these LO aircraft is the number 1 concern for Air Combat Command. One of the leading causes of LO aircraft downtime is the removal and replacement of LO treatments around access panels and doors. LO treatments, such and tapes and caulks, are applied to conductively bridge the gap between panels and the aircraft structure. Furthermore, fastener heads are covered to fulfill conductivity and smoothness requirements. Removal of these LO treatments before panel removal is very time consuming and risk damage to the panels and aircraft structure. Also, replacement of the LO treatments is even more time consuming due tedious processing steps of the materials including long cure times.

PHASE I: The contractor shall investigate technologies that allow quick and easy access through aircraft panels and doors without degradation of aircraft signature. The contractor shall investigate innovative "in place" seals and fastening methods which completely eliminates the current practice of removing and replacing LO treatments. Furthermore, the contractor shall investigate methods to reduce procedural and material cure times of LO treatments. The contractor shall propose feasibility of investigated methods for signature tests.

PHASE II: The contractor shall develop the most promising solutions investigated during Phase I. These methods shall be compatible to current maintenance skill level and have minimal impact to support equipment available in the field. The contractor shall measure signature loss of developed methods and compare to existing methods.

PHASE III DUAL USE APPLICATIONS: Commercial aircraft utilize conductive sealants around panels and door for lightning strike and EMI protection. Gaining access through the panels or doors for maintenance purposes requires removal and replacement of these conductive sealants. This causes long and costly maintenance downtimes of the aircraft due to the tedious processes and required cure of the material. Technology developed under this program would alleviate or completely eliminate these maintenance processes.

REFERENCES: Yamashita, G., Structural Battle Damage Repair for Low Observable Aircraft, AFRL-VA-WP-TR-1998-3006/7, December 1997.

KEYWORDS: Low Observable, Maintenance, Repair

AF00-167 TITLE: Protective Hard Film Coatings and Solid Lubricants

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop coatings and coating techniques to control friction and wear in moving mechanical assemblies in air and space vehicles.

DESCRIPTION: Recent advances in the design, deposition, and processing of inorganic materials allow fabrication of hybrid composite coatings that are both hard and lubricious. New chemical and microstructural designs, to the nanometer scale, even permit oxides to perform as solid lubricants. These engineered hard films and solid lubricants offer the advantage of improved performance and lower systems weight in rotating and dynamic components for turbine engines, flight control actuators, and spacecraft mechanisms. Control of fretting and galling, as for example between blade roots and disk slots in turbine engine fan and compressor sections, is also of interest. This program would research and develop innovative coatings, coating compositions, and coating processes for specific applications. Additional high payoff topical areas such as micro-electromechanical systems (MEMS), quasicrystals, adaptive materials, and lubricious oxides could be explored.

PHASE I: Develop a viable coating composition and deposition technique to address the key elements of the research and development areas described above .

PHASE II: Follow-on efforts in Phase II will further develop and optimize the materials, coatings, deposition technique, and/or complete lubrication systems using the approaches established in Phase I.

PHASE III DUAL USE APPLICATIONS: The materials and technology developed under this program would have numerous dual use applications. The commercial aircraft and spacecraft industries will benefit because the technology developed will be directly applicable to their needs for reduced size and weight and increased life and performance. Any industry in which miniaturization is important, or that uses sensors in a critical application may also benefit.

REFERENCES:
1. “Microelectromechanical Systems: Advanced Materials and Fabrication Methods,” NMAB-483, National Academy Press, Washington D.C. 1997.
2. “Recent Developments in the Design, Deposition, and Processing of Hard Coatings,” J. Vac. Sci. and Tech. A, 16(3) (1998), 1890-1900.
3. “Advanced Solid Lubricant Coatings for Aerospace Systems,” AGARD-CP-589, (1996).

KEYWORDS: Coatings, Lubrication, Hard, Friction, Wear, Tribology, MEMS, Solid Lubricant, Bearings, Engines, Fasteners, Space lubrication, Gyros, Slip Rings, Gimbals, Gears

AF00-168 TITLE: Computational Fluid Mechanics Models for the Processing of Superalloys and Aerospace Titanium Alloys

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop Computational Fluid Dynamics (CFD) based process metallurgy models for the production of nickel-based superalloys and aerospace titanium alloys.

DESCRIPTION: The production of clean, fully dense, homogeneous castings of superalloys and aerospace titanium alloys via remelting, refining and solidification is crucial to the production of defect-free components using these materials. Quality problems occurring during these steps can potentially lead to the catastrophic failure of critical components during service[1]. In addition, these steps often constitute a significant portion of the ingot cost to component manufacturers. These operations represent a complex interaction of electromagnetic, heat transfer, fluid flow, mass transfer and chemical reaction processes. Computational Fluid Dynamics (CFD) models of processing operations such as electroslag remelting, vacuum induction melting, vacuum arc remelting, and cold-hearth melting, are needed in order to develop process improvements by computing realistic descriptions of the melting process so that solidification defects, (e.g., macrosegregation in nickel-based alloys, and impurities, such as hard-alpha inclusions in titanium alloys), can be eliminated from the ingot. Reduction or elimination of these defects is anticipated to significantly increase the useful life and reliability of cast-wrought components fabricated from these ingots. Furthermore, process optimization using these models will reduce the cost of the ingots to component manufacturers [2].

PHASE I: This program will focus on the development and subscale validation of a model that demonstrates a fundamental understanding of the processing operation. Proposal should demonstrate reasonable expectation that this proof of principle can be obtained within Phase I. Proposal must incorporate interaction with the primary aerospace metals processing industry.

PHASE II: This program will be structured to develop and refine the model to the point where performance is physically demonstrated on an industrial scale. The model will provide quantitative information of the affects of changes in process parameters to permit an evaluation of the ultimate application potential to meet Air Force needs.

PHASE III DUAL USE APPLICATIONS: The developed approaches would have broad commercial applicability due to the large number of commercial airframes and engines that are fabricated from titanium and nickel-based superalloys.

REFERENCES:
1. J. A. Van Den Avyle, et al., “Reducing Defects in Remelting Processes for High-Performance Alloys,” JOM, Vol. 50, No. 3, p. 22.
2. D. K. Melgaard, et al., “Controlling Remelting Processes for Superalloys and Aerospace Ti Alloys,” JOM, Vol. 50, No. 3, pp. 13.

KEYWORDS: Computational Fluid Mechanics Models, Processing of Ni-based Superalloys and aerospace Ti alloys, Remelting and solidification

AF00-172 TITLE: In-situ Monitoring of Bondline Integrity for Adhesive Bonded Repairs

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop an in situ sensor capable of monitoring the integrity of a bondline in a repair.

DESCRIPTION: As the USAF aircraft fleet continues to age, the major sustainment issues for metallic structures are cracking (due to fatigue) and corrosion. Adhesive-bonded repairs, primarily using composite patch materials, can play an important role in keeping the aging aircraft operationally ready by stopping or retarding fatigue cracks and by restoring strength to structure thinned by corrosion.

Bonded repairs have several distinct advantages over traditional mechanically-fastened repairs. The most significant of which is the transfer of structural loads in an efficient manner without load concentration points created by rivets or bolts. Bonded repairs are also generally more aerodynamic, lighter and less expensive than mechanically fastened repairs. In many cases, bonded repairs are the only economically viable alternative to component replacement. For these reasons, bonded repair technology has been utilized in a number of applications within the USAF (and elsewhere), primarily to repair fatigue cracked structures.

Despite the advantages of bonded repairs, there is still reluctance among many aircraft maintainers to consider them as a permanent structural repair. Although testing can demonstrate that a given repair design (if properly implemented) will resolve a structural problem, there are currently no nondestructive techniques available for determining either the initial bondline quality or the long-term environmental durability of a proposed repair. Because of these limitations in bonded repair, the USAF’s engineering authority requires a “fail-safe” approach for repair-bonding on safety-of-flight structure. With this approach, fatigue cracks must be nondestructively inspected using the inspection interval required for an unrepaired defect (i.e., one-half the time necessary for the unrepaired crack to grow to critical length). As these inspections are costly and time consuming, bonded repair is not considered an economically viable option for cracks approaching critical length. If a means or a technique can be found which can monitor the integrity of a bondline in a repair, this may obviate the need for the "fail-safe" approach thus increasing the use of bonded-repair technology and concomitantly increasing operational readiness while decreasing life-cycle cost.

PHASE I: At the completion of this phase, the contractor shall demonstrate the feasibility of an in-situ sensor for monitoring, nondestructively, the integrity of a bondline in a composite patch (both conductive & nonconductive) applied to cracked 2024-T3 aluminum substructure. The sensor should be able to verify that the initial bond is adequate for the repair and/or detect the beginning stages of deterioration in the bondline (initially of adequate quality) due to exposure to the environment.

PHASE II: The contractor shall optimize the in situ sensor for the verification of the initial integrity of the bondline and/or the on-set of bondline degradation due to environmental exposure. The contractor shall demonstrate proof-of-concept on a cracked 2024-T3 aluminum structure repaired with a composite patch bonded to the metal surface following state-of-the-art Air Force procedures for repairing metallic structures. The sensor must be capable of operating under typical aircraft conditions and must not degrade the bondline due to its presence. Data acquisition should be able to be performed with at most, off-the-shelf portable computers.

PHASE III DUAL USE APPLICATIONS: An in situ sensor, with the above mentioned capabilities, would benefit the commercial aircraft industry through increased confidence and subsequent increased use of bonded-repair technology in the maintenance of their aging aircraft

REFERENCES:
1. USAF 1994 Scientific Advisory Broad Summer Study on Life Extension and Capability Enhancement of Existing Air Force Aircraft.
2. Committee on Aging of U.S. Air Force Aircraft, National Research Council, Aging of U.S. Air Force Aircraft, Final Report, National Academy Press, 1997.
3. G.D. Davis and D.K. Shaffer, "Durability of Adhesive Joints," Handbook of Adhesive Technology, K.L. Mittal and A. Pizzi, eds., Marcel Dekker, New York, 1997.

KEYWORDS: Adhesive Bonding, Bondline Integrity, In-situ Monitoring

AF00-173 TITLE: <u>Munition Effectiveness Modeling & Technology Integration Research</u>

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Research new munition component technologies; provide research tools to assess weapon lethality, effectiveness, and utility.

DESCRIPTION: The Assessment and Demonstrations Division is seeking new and innovative ideas in areas that include highly-agile air-to-air missile concepts, air-to-surface munition concepts, such as unitary penetrators, dispensers, submunitions, and projectiles. Technologies under consideration include aerodynamic shaping, advanced structural/material designs, innovative flight controls which can be integrated into future space delivery platforms and unmanned flight vehicles. Other key areas of interest include technologies for time-critical target defeat, bomb-damage identification, and counterweapons of mass destruction. Modeling and simulation tools of interest include high-fidelity physics-based codes for warhead design and penetration analysis, engineering-level tools for weapon/target interaction analysis, and analysis tools for theater-level modeling. New concept and innovative tools are sought for assessments/evaluations, the prediction of functional relationship of fire and/or blast effects on fixed structures, and dispersion of chemical/biological neutralization agents in a high-temperature environment. Commercial dual-use applications for innovative flight vehicle technologies could improve air vehicle performance, as would air foil products, i.e., wind turbines, turbomachinery, etc. Simulations of effects would reduce test costs and provide greater capability for safety officials and insurance underwriters to assess associated hazards. Improved simulation models could benefit commercial building demolition, safety-related assessments, auto safety research, explosives research, mining, drilling, and a wide range of product analysis and evaluation activities.

PHASE I: Determine the scientific or technological merit and feasibility of the innovative concept. Merit and feasibility must be clearly demonstrated during this phase. A technical evaluation of the concept or methodology, a demonstration of proof of principle, or a thorough description of the technical approach, alternative approaches, and risk factors may be appropriate.

PHASE II: Produce well defined deliverable technology demonstrator hardware or simulation/model capability.

PHASE III DUAL USE APPLICATIONS: Each proposal submitted under this general topic should have an associated commercial application stated in the Phase I proposal. Specific application should be determined and planned during Phase I.

Phase II proposals should contain a complete commercialization plan. For instance, innovative and low cost munition flight vehicle technologies could be used in the general aviation area. Simulations of munitions effects will reduce test costs and could provide safety officials and insurance underwriters a more accurate tool to assess industrial hazards. Improved simulation models using advanced analytical methodologies would be of value to a wide variety of commercial interests for analysis of operations effectiveness or process performance. General commercial applications include building demolition, mining and drilling operations, safety assessments, auto safety research, explosives research, and a wide range of industrial production analyses.

REFERENCES: http://www.munitions.eglin.af.mil/public/weapflgt.html

KEYWORDS: airframe, flight control, simulation, warhead effects, target penetration modeling, weapon lethality

AF00-174 TITLE: Guidance Research

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop innovative concepts in guidance technologies for air deliverable autonomous munitions

DESCRIPTION: The Advanced Guidance Division of the Air Force Research Laboratory Armament Directorate seeks new and innovative ideas/concepts in areas related to closed loop guidance, navigation and control of autonomous munitions. Topics of primary interest in navigation include very small, low cost inertial measurement units (IMUs), Global Positioning System (GPS) guidance, jam resistant GPS, and transfer alignment. Topics of interest in guidance technology include innovative approaches for integrating the guidance law, target state estimation, and autopilot functions. Topics of interest related to seekers include electrooptical, millimeter-wave, and radio-frequency seeker technology and the components and signal processing systems used in such seekers for autonomous guided munitions. This includes, but is not limited to, sources, detectors, polarization-sensing elements and systems, modulators (both single element and pixelated), pattern recognition and processing systems, and basic material and device development for accomplishing all of these; polarization-sensing elements and systems for studies of the utility of such systems for target characterization and discrimination; developing algorithms for use within autonomous target acquisition (ATA) applications; innovative signal and image processing algorithms used, for example, in synthetic aperture radar (SAR), millimeter-wave (MMW), imaging infrared (IIR), and laser radar (LADAR), needed to autonomously detect and recognize target signatures embedded in backgrounds; operations/functions associated with the ATA process involving noise elimination, detection, segmentation, feature extraction, classification (e.g., truck vs. tank), and identification (e.g., tank A vs. tank B); utilization of Image Algebra in the development of non-proprietary ATA algorithms. Algorithms capable of processing/fusing multi-sensor data are of particular interest. Key research areas include signal and image processing, pattern recognition/classification, image understanding, artificial neural networks, fuzzy logic, superresolution, knowledge- and model-based vision, and data fusion. Of particular interest are cutting edge methods for the design of closed loop guidance and control systems for munitions with numerous MEMS-based sensors and control actuators; both biomimetic and mathematics-based approaches are of interest. Topics of interest related to modeling and evaluation include synthetic target signature generation and scene projection technology for hardware-in-the-loop applications. Concepts must have a good dual use/commercialization potential.

PHASE I: During Phase I, the offeror shall determine the technological or scientific merit and the feasibility of the innovative concept.

PHASE II: The Phase II effort is expected to produce a well defined deliverable product or process.

PHASE III DUAL USE APPLICATIONS: Each proposal submitted under this general topic should have an associated dual-use commercial application of the planned technology. The commercial application should be formulated during Phase I. Phase II will require a complete commercialization plan.

KEYWORDS: LADAR, seekers, jam-resistant GPS, artificial neural networks, guidance of autonomous munitions, algorithms for autonomous target acquisition (ATA), MEMS

AF00-175 TITLE: Ordnance Research

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Identify, develop, and demonstrate commercial components having application to air deliverable munitions.

DESCRIPTION: New and innovative ideas/concepts are needed in the area of air delivered, non-nuclear munitions that have a dual use/commercialization potential. Military products include bombs; penetrators; submunitions; warheads; projectiles; fuzes (including safe and arm devices); explosives/energetic materials; time delayed, polymer binders for shock survivable explosives; solid state inertial components; exterior ballistics; test technology; modeling and simulation resources and techniques; and conventional weapon environmental demilitarization and disposal techniques. Examples of desired research are target detection sensors for deeply buried targets; warhead initiation; self-forging fragment warheads; shaped charges; reactive fragment warheads; hard-target weapon/penetration technology; energetic materials; and low velocity deep earth penetrators. Concepts and methodologies for defeating and neutralizing chemical and biological agents during production, storage, and employment in weapons of mass destruction are desired. Technologies for denying enemy access to weapons of mass destruction are also of interest. Rapid solid-state reaction, combustion and detonation process models for metallic particle systems are of interest. These models should include energy extraction rate, theoretical descriptions of initiation, and kinetics of reaction. Process models shared also account for the physical processes unique to metallic particle energetic systems. Metallic particle sizes of interest are 10-100 nanometers. Models developed should provide insight into the impact of parameterization of particle size, surface area, and heat conduction rate as related to initiation and reaction behavior.

PHASE I: Determine the technological or scientific merit and feasibility of the concept.

PHASE II: Provide a deliverable product or process.

PHASE III DUAL USE APPLICATIONS: A wide range of commercial products could be produced from this research. Typical products include propellants, initiators, gas generators, high strength and high strain rate materials, low cost sensors/detectors, and environmentally compatible recycling processes for energetic materials. Each proposal submitted under this topic should have an associated dual-use commercial application. Phase II will require a complete commercialization plan.

REFERENCES:
1. Progress in Astronautics and Aeronautics: An American Institution, by Martin Summerfield, Volume 21, Academic Press, 1963.
2. Dynamic Aspects of Detonation: Progress in Astronautics and Aeronautics, Volume 153, Book Publication of AIAA.

KEYWORDS: Fuzes, Target Detection, Warheads, Chemical neutralization, Hard Target, Defeat Agent Defeat, Explosives, Safe and arm, Counterproliferation

AF00-176 TITLE: Laser Research for Imaging LADAR Seekers

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Investigate new pulsed lasers for use with focal plane array based imaging LADAR receivers

DESCRIPTION: We are interested in proposals that would pursue research into new pulsed lasers for use with focal plane array (FPA) laser radar (LADAR) architectures. Such lasers are characterized by very high pulse energies and low pulse repetition frequency (PRF). Of particular interest are proposals for lasers with: 10 Hz - 2 kHz PRFs; greater than 10 megawatt peak power; short pulse widths (full-width half-maximum in the neighborhood of 15 nanoseconds); and, lasing at wavelengths in the near to mid-IR atmospheric windows (between 1 - 5 micron output). The Munitions Directorate of the Air Force Research Laboratory has been involved in the research and development of LADAR seeker technologies suitable for air-to-surface munitions. Increasing emphasis is being placed on the use of two dimensional detector arrays to gather single pulse range and intensity imagery. The military and commercial advantages of FPA based LADAR include increased frame rates, wide instantaneous field of view, and elimination of mechanical scanning mechanisms leading to reduced cost and increased maintainability. We are primarily interested in high efficiency, low-cost, compact, heat-sinked, air-cooled or thermo-electrically cooled laser designs. For munition applications, proposals are encouraged to address low-cost thermal management techniques that allow stable lasing for up to 30 minutes before shutdown. In addition, designs good for only a few shots (less than 5) are also of interest.

PHASE I: Phase I of this project should investigate the performance of the proposed laser through detailed modeling and experimentation to demonstrate critical elements of the design. The investigation results would be incorporated into a detailed prototype laser design to be reported at the end of Phase I.

PHASE II: Phase II of this project would involve the construction and delivery of a prototype laser based upon the design investigated in Phase I.

PHASE III DUAL USE APPLICATIONS: A wide range of commercial and military applications exist for new pulsed, high-power IR lasers including medical applications, manufacturing processes, and remote sensing. Commercial LADAR applications include geographic surveying (e.g. tree height, mine surveying, tunnel profiling), industrial monitoring applications (e.g. saw positioning, quality control in steel manufacturing, conveyor belt loading), and collision avoidance sensors for transportation systems. Military LADAR applications include seekers for autonomous munition guidance, sensors for surveillance and reconnaissance, and precision targeting systems.

REFERENCES:
1. J. T. Sackos, R. O. Nellums, S. M. Lebien, C. F. Diegert, J. W. Grantham, T. C. Monson, "A Low-Cost, High-Resolution, Video-Rate Imaging Optical Radar", SPIE Proceedings, Vol. 3380, pp. 327-342, 1998.
2. C. G. Bachman, "Laser Radar Systems and Techniques", Artech House, Boston, 1979.
3. A. Jelalian, "Laser Radar Systems", Artech House, Boston, 1992.
4. Verdeyen, Joseph T., "Laser Electronics, Third Edition", Prentice-Hall, Englewood Cliffs NJ, 1995.
5. Shen, Y. R., "The Principles of Non-Linear Optics", John Wiley & Sons, New York, 1984.

KEYWORDS: Laser, Laser Radar, LADAR, Munitions, Imaging, Laser Ranging

AF00-177 TITLE: Innovative Imaging LADAR Techniques for Munition Seekers

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop new techniques for imaging laser radars

DESCRIPTION: The goal of this topic is to develop laser radar (LADAR) systems that promise a substantial performance improvement and/or cost reduction over current LADAR systems. Low-cost, medium-range (1-4 km) imaging LADARs with range resolutions less than 1 foot are needed. Current long-range LADAR systems rely on one of two basic schemes to find the distance to an object: pulsed direct detection, which measures the photon time-of-flight; or coherent mixing of an intensity modulated output and/or return. New LADAR systems or new techniques for range measurement which result in improved performance and/or reduced cost are solicited. Proposals should address research into a new technique or system architecture expected to result in improved LADAR performance or reduced system cost. System designs that improve performance or reduce cost by implementing new LADAR components other than lasers or optical detectors, e.g. optical scanners, transmit and receive optics, and ranging electronics, are of interest. Of primary interest are techniques to improve signal-to-noise ratio for laser ranging. Techniques that lend themselves to implementation in compact packages are of great interest. Furthermore, techniques that can be used at near-IR to mid-IR wavelengths, allowing more eyesafe operation of LADAR systems, are of great interest. Exploration of multi-spectral LADAR systems is encouraged. Proposed systems and techniques should be capable of implementation in small packages at low cost appropriate for use on autonomously guided airdropped munitions. Proposed schemes should be appropriate for implementation in a laboratory breadboard setup.

PHASE I: Phase I of this project should investigate the performance of the proposed component or technique through modeling, construction, and experimentation with critical elements of the proposed design. The investigation results will be incorporated into a detailed prototype component or LADAR system design to be reported at the end of Phase I.

PHASE II: Phase II of this project would involve the construction and delivery of a prototype component or LADAR system based upon the design developed in Phase I.

PHASE III DUAL USE APPLICATIONS: Advances in LADAR systems and components can result in new system capabilities appropriate for a variety of uses in the military and commercial sectors. Potential commercial uses of LADAR systems include remote sensing applications for environmental monitoring, security systems, geographic surveying (e.g. tree height, mine surveying, tunnel profiling), industrial monitoring applications (e.g. saw positioning, quality control in steel manufacturing, conveyor belt load volumes), and collision avoidance sensors for transportation systems. Potential military uses include munition seekers, airborne reconnaissance and surveillance, and targeting systems. Advances in individual LADAR components may result in a wide variety of commercial and military applications, depending upon the particular component and the nature of the advance. Lasers, optical detectors, and optical scanners have many uses in a wide range of commercial and military systems.

REFERENCES:
1. A. Jelalian, "Laser Radar Systems," Artech House, Boston, 1992.
2. Fox, Clifton S. (ed.), “The Infrared & Electro-Optical Systems Handbook”, Volume 6: “Active Electro-Optical Systems”, SPIE Optical Engineering Press, Bellingham WA, 1993.
3. J. T. Sackos, R. O. Nellums, S. M. Lebien, C. F. Diegert, J. W. Grantham, and T. C. Monson, “A Low-Cost, High-Resolution, Video-Rate Imaging Optical Radar”, SPIE Proceedings, Vol. 3380, pp. 327-342, 1998.
4. C. G. Bachman, “Laser Radar Systems and Techniques”, Artech House, Boston, 1979.

KEYWORDS: laser radar, LADAR, laser ranging, direct detection, coherent laser radar, laser applications, optical scanners, optical detectors

AF00-178 TITLE: Shock Mitigating Technology

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop technologies capable of mitigating/attenuating the high shock loads associated with high-speed impact.

DESCRIPTION: Active decision making fuzing, which monitors impact deceleration, has been demonstrated for penetrating warheads with impact velocities up to 2200 ft/sec. Future weapons are postulated to obtain impact velocities up to 6000 ft/sec. The resultant impact loads imposed on the sensitive electronics, accelerometer, and power supply are unknown. Past experience with very high (hundreds of kilo-"g") explosively induced shock loads indicate that some type of shock mitigation must be employed to assure electronic survivability. The shock mitigation techniques employed in the past suffer various shortcomings; i.e., modulus change with temperature, susceptibility to off-axis loads, excessive volume, etc. Designs, fabrication techniques, and material compositions are sought that will provide mechanical filtering and energy absorption while allowing acceleration monitoring of rigid body motion.

PHASE I: Phase I of this program should investigate by analysis and laboratory test, methods and materials applicable for mechanical filtering and/or energy absorption of very short duration, high G shock. Designs can be considered for filtering internal to the fuze package (e.g., circuit boards and/or components) and/or designs for isolating the entire fuze. Typical fuzes range in volume from 9 to 20 cubic inches with weights from one to five pounds. Long duration loads (multiple millisecond) can be in the 30 to 100Kg range with loads greater than 200Kg at higher frequencies.

PHASE II: Phase II of this program will involve the detailed design, fabrication and field test of one or more of the concepts. These tests should include a simulated fuze containing an accelerometer and onboard data recorder. Tests should include high speed impact and/or explosively induced shock.

PHASE III DUAL USE APPLICATIONS: This technology has direct applicability to mitigating shock in high-speed crash survivability and aircraft inflight data recorder survivability.

REFERENCES:

1. Alcone, J. A., "Analysis of the Inverting Tube Energy Absorber", Shock and Vibration Bulleting (1970)
2. Bateman, V. I., R. G. Bell, & N. T. Davie, "Evaluation of Shock Isolation Techniques for a Piezoresistive Accelerometer", Proceedings of the 60th Shock and Vibration Symposium, David Taylor Research Center, Portsmouth, VA (1989)

KEYWORDS: Energy Dissipation, Shock Mitigation, Shock Attenuation, Shock Isolation, Shock Absorbing, Energy Absorbing

AF00-179 TITLE: Recrystallization of Nitramines

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop processes to desensitize RDX and HMX explosives by eliminating microvoids/defects within the crystals.

DESCRIPTION: It is hypothesized that defects in the crystalline structure increase the sensitivity of explosives to shock initiation, since voids provide interaction sites or foci for the deposition of shock energy. Hot spots are created by the shock-induced collapse of voids, and may lead to detonation. AFRL is interested in the development of processes that produce void-free nitramines or reduce the number and/or size of voids in nitramines. Small voids should be more difficult to collapse and would release less energy during the collapse. A lower void concentration should result in less energy deposition per unit volume. The proposed process should be environmentally friendly and cost-effective.

PHASE I: This project should include development of a process to create void-free nitramines, and identification of analytical techniques for measuring the product quality (i.e., void detection and quantification).

PHASE II: Should include the production of nitramines using the processes developed in Phase I and a comparative analysis of void-free nitramines with conventional nitramines, particularly in the measurement of shock sensitivity.

PHASE III DUAL USE APPLICATIONS: The recrystallization processes used by U.S. producers have resulted in nitramines containing a large number of defects; this has led the DoD to consider foreign sources that have the capability to produce defect-free nitramines via proprietary processes. There is a need for a reliable U.S. market source for defect-free nitramines. The commercial application for this product can be found in the mining and demolition industries. Desensitized nitramines could be used to make improved, safer explosive boosters.

REFERENCES: V.J. Krukonis, M.P. Coffey, and P.M. Gallagher, "Exploratory Development on a New Process to Produce Improved RDX Crystals: Supercritical Fluid Anti-Solvent Recrystallization," U.S. Army Ballistic Research Laboratory, January 1989.

KEYWORDS: Recrystallization, Nitramine, Crystal, Defect, Void, Sensitivity, Energetic Materials, Explosives, HMX, RDX

AF00-180 TITLE: High-Frequency Motion Simulation for Hardware-In-The-Loop Testing

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop a high-bandwidth simulator for the deterministic representation of missile airframe dynamics, either as a stand alone test system or as an integral part of a conventional flight motion simulator.

DESCRIPTION: Advanced interceptor systems using reaction jets for divert and attitude control can induce very high frequency dynamic motion. This motion can be in the form of airframe rigid body response or vibration. With increasing accuracy requirements for defensive missiles, the impact of high-frequency sensor line-of-sight errors on missile closed-loop guidance is a critical testing issue. The most advanced flight motion simulators currently available have bandwidths of 60 to 100 Hz. This limited level of response can be shown to introduce artifacts into hardware-in-the-loop simulations in the form of modified control system duty cycle and can lead to questionable test results. Past efforts to develop high bandwidth systems have concentrated on magnetic bearing approaches that have never reached maturity due to control system complexity, cost, and limited performance.

A method is desired to deterministically simulate motion at frequencies ranging from 0 to 1000 Hertz. Stand-alone devices specifically designed to test missile sensor packages, as well as high-frequency inner gimbal approaches to augment traditional flight motion simulators are of interest. In order to achieve the accurate representation of motion at these high frequencies, significant risks must be overcome. Actuators typically have bandwidths much lower than 1000Hz due to structural and fluidic resonance inherent in their design. Actuators with sufficient force and displacement capability to stimulate missile sensor payloads do not generally exist in sizes compatible with the desire for a flight motion simulator inner gimbal. Design of an integrating structure and test article mounting structure with a resonance outside the desired control bandwidth is extremely difficult. The design of a feed-forward control scheme that can account for the effect of resonance within the control bandwidth are difficult to implement and result in a non-robust point design. Dynamic coupling between the simulated degrees of freedom can result in degraded accuracy. Following are the anticipated products of this program.

PHASE I: Define a high frequency motion simulator conceptual design that can accurately represent low amplitude airframe dynamics (0-1000 Hz). A demonstration of key components is desired. Concept control, accuracy, limitations, and system interface requirements should be defined.

PHASE II: Develop and demonstrate a hardware prototype of the simulator concept.

PHASE III DUAL USE APPLICATIONS: This system could be used in characterization of a broad range of sensors in severe dynamic environments. Examples include sensors used in missile guidance systems and closed-loop pointing/tracking systems operating on dynamic platforms. This system would provide a means for the deterministic representation of the severe environments associated with automobiles, aircraft, and launch vehicle operation. Deterministic duplication of launch vehicle environments for closed-loop demonstration of active control systems could potentially result in great cost savings to commercial launch operations.

REFERENCES: J.M.Carter, K.E.Willis, “History of flight motion simulators used for hardware-in-the-loop testing of missile systems,” SPIE Proceedings Volume 3368, 13-15 April 1998.

KEYWORDS: flight motion simulator, hardware-in-the-loop, structural vibration.

AF00-181 TITLE: Real Time Bomb Damage Indication (BDI) Sensors and Processing Algorithms

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Identify critical data needs and develop munition borne sensors and associated algorithms for real time bomb damage indication.

DESCRIPTION: The advent of smart munitions enhances the probability of a successful air to ground engagement. However, the real-time, efficient assignment of the minimum amount of ordnance per target remains elusive. The development of munition borne BDI capability is a step toward addressing this deficiency. Technological improvements in areas such as seekers, fuzes, cameras, data fusion and telemetry may provide a means to generate pertinent BDI data and provide it directly to the user or to a real-time BDI algorithm. Wherever possible, we are interested in making maximum use of seeker and fuze sensors which are already part of the munition. However, we are also interested in investigating new low-cost sensors which could be incorporated into the munition and/or deployed off-board by the munition prior to impact. One of the more critical elements of on board munition BDI capability is a raw data processing algorithm that quickly determines the likelihood of a designated target having been destroyed by a given munition, based on sensor information either on board or deployed off board by the munition. Processing must be sufficiently fast to support target reassignment for remaining munitions as part of the strike package. Future concepts envisioned might include autonomous target reassignment by the BDI algorithm. In order to support this, the algorithm should be capable of establishing priorities for retargeting of remaining, in-flight ordnance. The goals of this effort are: 1) to analyze, develop, and test inexpensive sensor concepts 2) determine a prioritized list of sensor data from which a minimum data requirements set can be established, and 3) develop algorithms capable of using this data to provide real-time bomb damage indication.

PHASE I: Phase I should develop a concept for the munition-borne sensor and determine a prioritized list of sensor data from which a minimum data requirements set can be established for algorithm development. The concept should include, but not necessarily be limited to, consideration of the information content for the proposed sensor, cost considerations, how the sensor could be integrated into a munition, and an operations concept for using the munition-borne sensor.

PHASE II: Phase II would involve fabrication and test of the munition-borne sensor. Test concept need not include an all-up round test, but should be sufficient in scope to demonstrate the feasibility and utility of the overall concept. Phase II would also involve the development and validation of the real-time bomb damage indication algorithms. Although the algorithms may initially be deployed off board using telemetry inputs, the long term vision is to enable on board deployment with real time target reassignment for remaining munitions.

PHASE III DUAL USE APPLICATIONS: Potential military applications for this Real Time Bomb Damage Indication (BDI) Sensors and Processing Algorithms include integration with current munitions for enhanced, all-weather BDI capability. In addition, the sensor/algorithm may be applied to advanced seeker concepts for autonomous operations. Real-time battle damage sensors and processing algorithms will have many commercial applications as well. One example is remote sensing of hazardous environments or use on covert operations. The sensor/algorithm can be used to determine change from a known state that can provide real time information and aid in autonomous surveillance.

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2. Dickenson, Glenn, Battle Damage Assessment, Military Intelligence, 1 Oct 97
3. McCain, John J., BDA Analysis, Using Automation to Speed the Process, Military Intelligence, 1 Jul 94

KEYWORDS: Battle Damage Assessment, Bomb Damage Indication, Information Processing Algorithms, Algorithms, Munition Sensors, BDA, BDI

AF00-183 TITLE: Powered Submunition Communication Architecture

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop a low cost wireless network technology that will enable multiple munitions to communicate

DESCRIPTION: In the near future, a new class of low cost autonomous miniature munitions will become a vital part of the Air Force weapons inventory. One of the distinguishing features of miniature munitions is their ability to be deployed in large numbers against threats that are either mobile, relocatable or difficult to distinguish by high altitude reconnaissance. In concepts currently being developed, such as Low Cost Autonomous Attack System (LOCAAS) and cruise missile programs such as Tomahawk Land Air Missile (TLAM), Conventional Air Launched Cruise Missile (CALCM), and Joint Air to Surface Standoff Missile (JASSM), the deployed munitions independently search for and attack a target. Clearly the performance of groups of miniature munitions could be dramatically improved by permitting communication and cooperation between the individual munitions. This topic seeks technologies that will enable a wireless communications network to be established between a group of miniature munitions. Technical challenges/design goals include the following. (1) The added cost of the networking hardware must be very low as these munitions must remain inexpensive. (2) The network must be autonomous and self generating; that is, no mission planning involving human interaction should be required before or during the mission to establish a network. (3) The network should be designed to be functional during a midcourse guidance phase where the distance between munitions and their individual orientations may be constantly changing. As such, the network must be robust to channel fades, antenna nulls, near-far effects, and jamming. (4) The network should be capable of supporting up to 100 munitions flying over a broad range of altitudes within a realistic 1000 km2 battlefield. (5) The network must be robust to weather and smoke. (6) Ideally, the data from any single munition should be reachable from any other munition on the battlefield, however, less complete networks should also be explored. (7) The data relayed from each munition is assumed to be digital, consisting of munition and target state information of moderate bandwidth. (8) The link must be covert so that transmissions can not practically be intercepted.

PHASE I: Establish link requirements, survey and trade protocol, modulation, channel assignment, and transmitter and antenna technologies appropriate to requirements.

PHASE II: Design and build prototype transmitter and antenna hardware. Demonstrate design goals.

PHASE III DUAL USE APPLICATIONS: This network technology is obviously relevant to autonomous munitions but is also extendable to broader autonomous battlefield concepts that include manned and unmanned aircraft and satellites. Satisfaction of cost goals strongly recommends commercial networking and transmission technologies be used to the maximum extent. Other applications include autonomous robot manufacturing cells and emergency rescue/response in remote regions with no communications services.

REFERENCES: J. Sharony, “An architecture for mobile radio networks with dynamically changing topology using virtual subnets,” Mobile Networks and Applications 1, pages 75-86, (1996).

KEYWORDS: Networks, munitions, wireless, self-generating, adaptive, autonomous, low cost

AF00-184 TITLE: Recycling/Recovery of Energetic Materials and Polymer Binders

TECHNOLOGY AREAS: Chemical/Biological Defense, Weapons

OBJECTIVE: Develop processes to recover nitramines from explosive formulations, particularly plastic-bonded explosives.

DESCRIPTION: The need to recover and recycle energetic materials is driven by two factors--increasingly strict environmental legislation, and reduced life cycle cost for munitions. Traditional methods for disposal of excess or obsolete explosives, such as open burning / open detonation (OB/OD), are being challenged by Federal and state environmental regulatory agencies. And, large price increases for HMX and RDX have occurred in recent years as nitramine production capabilities have transitioned from a government-owned, contractor-operated (GOCO) activity to the private sector. Recovery of nitramines from excess or obsolete explosives would reduce the pollution burden and should be less expensive than the combined costs of new material production and disposal. Environmental impact and life cycle costs may be reduced by: (1) incorporating recovered energetic materials in new formulations, (2) developing new energetic formulations that are easily demilled, or (3) developing cost efficient recovery technologies for existing explosive formulations. It is the third option that is of most interest in this solicitation. The proposed process should be environmentally friendly and cost-effective. Common explosive binder systems of interest include hydroxyterminated polybutadiene (HTPB), acrylate, polypropylene glycol (PPG), or Viton.

PHASE I: Phase I of this project should investigate process development for binder degradation and extraction.

PHASE II: Phase II should investigate process efficiency and product characterization.

PHASE III DUAL USE APPLICATIONS: This technology would have two product lines, energetic materials and polymer feedstocks. The primary customer for the recovered nitramines would be the military with excess going to commercial explosive and rocket propulsion markets. The polymer feedstocks would be sold to the chemical commodity market. Since the process requires the chemical decomposition of the polymer binder, it would have commercial applications in the plastics/polymers industries. For example, the recycling of automotive plastics would reduce landfill expenses and produce commodity chemicals.

REFERENCES: D.F. Hartline and A.F. Spencer, "Separation and Recovery of HMX from Octol", Proceedings of Energetic Materials Conference, pp. 240-244, Fullerton CA, 29 March - 1 April, 1998.

KEYWORDS: Recycling, Recovery, Demilitarization, Plastics Explosives, Energetic Materials, Binder Polymer

AF00-185 TITLE: Miniature Munition Control Actuation

TECHNOLOGY AREAS: Weapons

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Miniature Munition Capability

OBJECTIVE: Design, construct, and test an adaptive material control actuator for miniature munitions.

DESCRIPTION: Adaptive materials exhibit the unique characteristic of "remembering" their shape upon application of an electric current, magnetic field, etc. This characteristic has led to their use in industry for a variety of applications. A new application of these materials could be for flight control actuation of munition control surfaces. Conventional electro-mechanical actuators are expensive components of an overall weapon system. Adaptive or smart material actuators could reduce this expense by at least an order of magnitude (from $5000 to $500). Furthermore, with an increased emphasis on miniature or even micro munitions, smart material control actuation could be crucial as they could be much smaller than conventional electro-mechanical actuators. Miniature munitions currently under technology development are on the order of 30 inches long, 19 inches wide and 13 inches high. A penetrator version is 72 inches long and 6 inches in diameter. Current small electro-mechanical actuators are difficult to house in the small volume available in these miniature munitions, and are challenged to provided the actuator performance needed. The focus of this effort is to explore the possibilities of flight control actuation for miniature munitions using smart materials. The goal is a low-cost, highly compact control actuation device. The challenge is the development of a smart material actuator that will provide the control performance and response that is equal to or better than today's conventional actuators.

PHASE I: Phase I of this effort will investigate the range of smart materials that have potential application to flight control. Evaluation of their performance to meet the miniature munition control requirements will be made. Selection of preferred designs will be made for development and test in Phase II.

PHASE II: Phase II will involve the construction of one or more smart material control actuation devices. Integration of the devices into a miniature munitions flight control system will be accomplished. Hardware-in-the-loop testing will be performed to evaluate the performance of the design in realistic flight scenarios.

PHASE III DUAL USE APPLICATIONS: Smart materials are already making their mark in the commercial market. This project can further benefit their application in other commercial areas, such as general aviation, as well as in influencing the current market through the miniaturization of components. In aviation, smart materials can be used not only for control actuation, but also to affect the airflow over wings, and reduce drag or delay stall.

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1. A. Seifert, "Use of Piezoelectric Actuators for Airfoil Separation Control", AIAA Journal, Aug 1998, Vol. 36, Number 8
2. K.B. Lim, "Effective Selection of Piezoceramic Actuators for an Experimental Wing", Journal of Guidance, Control, and Dynamics, Sep 1998, Vol. 2, Number 5
3. J. Ball, "A Comparison of Shaped Piezoelectric Actuators for Divergence Control", Sep 1995, Vol. 5, Number 5

KEYWORDS: Adaptive Materials, Control Actuators, Smart Structures, Flight Control, Shape Memory Alloys, Piezoelectric Material

AF00-186 TITLE: <u>Real Time Kinematic (RTK) Carrier Phase GPS from Start-up to Impact</u>

TECHNOLOGY AREAS: Weapons

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Miniature Munition Capability

OBJECTIVE: Develop a tightly coupled GPS/INS RTK approach that can deliver a decimeter accuracy navigation solutions.

DESCRIPTION: Navigation error is a significant contributor to the overall weapon CEP (circular error probable) and may become the dominant contributor as target location error and guidance errors drop below 3 meters and 1 meter, respectively. Current civilian GPS applications, specifically precision farming, use real-time kinematic GPS solutions to generate navigation accuracy measured in centimeters. Unfortunately, these solutions depend on an additional GPS receiver, at a known location, to remove several important obstacles to resolving the integer ambiguity problem. One approach for the use of RTK in tactical munition navigation is to use the onboard weapon GPS/INS and a wide-laning technique to overcome the ambiguity resolution hurdle. However, additional errors in the GPS system complicate the problem. The ephemeris errors of the GPS satellites and ionospheric propagation delays can obscure the integer ambiguity resolution. In theory, these problems may be solvable by propagating the position estimate forward to the next GPS update using the inertial navigation system (INS) inputs to the Kalman filter and then estimating the pseudorange errors based on that a priori knowledge of position. The practicality of this approach remains to be demonstrated and is expected to be accomplished in the following manner.

PHASE I: Develop a system design that eliminates the need for a separate GPS receiver for carrier cycle integer ambiguity resolution by making use of the onboard inertial information. Demonstrate the resulting system design via simulation.

PHASE II: Design a breadboard system that demonstrates the basic technique via testing on the Mobile Test Vehicle.

PHASE III DUAL USE APPLICATIONS: High accuracy remote surveying, automated precision unmanned vehicles, cooperative robot manufacturing cells.

KEYWORDS: Kinematic GPS, Navigation, Inertial Navigation, Munition

AF00-187 TITLE: Complementary Ladar/Millimeter-Wave Seeker (CLAMS)

TECHNOLOGY AREAS: Weapons

OBJECTIVE: To determine whether a munition-size package of complementary MMW and LADAR sensors is feasible

DESCRIPTION: Advances in the development of Solid state LADAR seekers and their associated 3-D autonomous target acquisition algorithms coupled with advances in GPS/Inertial guidance systems are bringing about the long sought era of very smart if not brilliant weapons. These advances are being followed almost certainly by countermeasures. It has long been acknowledged that the best counter-counter measure is to complement a given sensor technology with another, one whose operational characteristics are widely separated from the first. This usually takes the form of operation in a different portion of the frequency spectrum. Although a large variety of possible combinations of two or more sensors and means to combine them exists, this investigation should focus on a millimeter-wave imager as the complementary sensor. Millimeter-wave (MMW) offers adverse-weather and poor-visibility conditions wide-field-of-view cueing for the LADAR. If the MMW sensor is passive, it can also provide a degree of covertness for the smart munition. Finally, under the worst of conditions, it offers the potential to operate in a stand-alone attack mode. The purpose of this effort is to determine whether a munition size package of MMW and LADAR sensors is feasible, whether an active or passive MMW complement is better, whether MMW imaging is a necessity, and whether such a package is affordable.

PHASE I: Investigate the potential for hybrids of LADAR and active MMW or LADAR and passive MMW sensors to improve the operational limitations of stand-alone LADAR seekers. Mission scenarios are those that can be viewed on the AFRL/MN Web site at <http://www.mn.afrl.af.mil>. Various sensor configurations such as shared or common aperture, conformal antenna, etc., should be explored. Modes of operation such as Simultaneous, Either-Or, Handoff, etc., and associated algorithmic complexity should be evaluated. A preliminary cost estimate for the various configurations should also be provided. Viable approaches should be determined and risks associated with each identified. A preferred approach should be selected and a preliminary design prepared.

PHASE II: Develop a detailed design, prove this design employing Government furnished sensors in a near co-boresighted configuration and through realistic simulations of approved operational scenarios. Produce a detailed estimate for unit production cost for the integrated, detailed, hybrid-sensor design.

PHASE III DUAL USE APPLICATIONS: A compact, light weight, affordable hybrid LADAR/MMW sensor has potential applications for light-aircraft adverse weather landing guidance, for base, post, and yard surveillance and intrusion detection, for lake, river, canal, inland waterway navigation, and a myriad of like applications. The commercial potential for such a hybrid sensor would appear to be enormous.

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1. Smith R.M., et al., "Passive Millimeter Wave Imaging," IRIS Passive Sensors Symposium, Albuquerque, NM, March 1994.
2. Browne, Jack, “MM Waves Aid Commercial Applications,” Microwaves & RF, Vol. 31, No. 7, pp 113-1116, July 1992
3. “Ten Kilometer Imaging Solid State LADAR Demonstration,” Apr-95, IRIS Active Optical Systems

KEYWORDS: Smart Munitions, Seekers, Millimeter-wave, Active MMW Seeker, Passive MMW Seeker, solid-state LADAR, Hybrid Seeker, Dual Mode Seeker

AF00-188 TITLE: Optical Detector Research for Imaging LADAR Seekers

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop room temperature infrared optical detectors for use in laser radar systems

DESCRIPTION: This topic pursues the development of low-cost, near to mid-IR optical detectors (peak spectral response between 1 - 5 microns) for use in laser radar systems. We are ultimately interested in low-cost, scalable, two-dimensional detector array concepts. Of interest are projects that explore either new materials for room temperature operation, or, new manufacturing techniques for existing materials that might result in fewer defects or lower cost. Current room temperature mid-IR detectors are high-cost, high-defect items (relative to Silicon detectors). Both fast response (nanosecond rise time) array designs and implementations of integrating, CCD-like arrays (with frame readout rates greater than 10 Hz) are of interest. Integrating designs that allow fast (MHz) gain modulation are highly desirable. Array proposals of at least 32 x 32 elements are of interest, but architecture concepts that can be scaled (e.g. to 512 x 512) in a cost-effective manner are desired. The Munitions Directorate of the Air Force Research Laboratory is placing increasing emphasis on the use of two dimensional detector arrays to gather single pulse range and intensity imagery. The military and commercial advantages of FPA based LADAR include increased frame rates, wide instantaneous field of view, and elimination of mechanical scanning mechanisms leading to reduced cost and increased maintainability. Detectors that can be thermo-electrically cooled to improve performance are of interest. Proposals should include at least a conceptual implementation of their detector in an imaging LADAR system. Such systems should be capable of range resolution on the order of 1 foot or less.

PHASE I: Phase I of this project should investigate the performance of the proposed detector through detailed modeling and experimentation to demonstrate critical elements of the design. The investigation results would be incorporated into a detailed prototype detector design to be reported at the end of Phase I.

PHASE II: Phase II of this project would involve the construction and delivery of a prototype detector based upon the design investigated in Phase I.

PHASE III DUAL USE APPLICATIONS: A wide range of commercial and military applications exist for new room-temperature near to mid-IR optical detectors including medical applications, manufacturing processes, and remote sensing. Commercial LADAR applications include geographic surveying (e.g. tree height, mine surveying, tunnel profiling), industrial monitoring applications (e.g. saw positioning, quality control in steel manufacturing, conveyor belt loading), and collision avoidance sensors for transportation systems. Military LADAR applications include seekers for autonomous munition guidance, sensors for surveillance and reconnaissance, and precision targeting systems.

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2. C. G. Bachman, "Laser Radar Systems and Techniques," Artech House, Boston, 1979.
3. A. Jelalian, "Laser Radar Systems," Artech House, Boston, 1992.
4. W. L. Wolfe, G. J. Zissis, "The Infrared Handbook," Environmental Research Institute of Michigan, Ann Arbor MI, 1989.

KEYWORDS: Optical detectors, infrared, electro-optic devices, focal plane array, laser, laser Radar, LADAR

AF00-189 TITLE: Doped Nanoparticulate Silicon Fabrication and Blending

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop new semiconductor devices based upon doped silicon nanoparticles uniformly dispersed in a polymer matrix

DESCRIPTION: Ball milling of bulk crystalline semiconductor grade silicon is tedious and inefficient, generally resulting in submicron particles of approximately 300 to 500 nm average size. This is an order of magnitude too large for synthesis of useful layer structures required for optoelectronic device fabrication. Development of semiconductor devices based upon nanoparticulate silicon would be aided by a more direct means of making considerably smaller (50 to 100nm) particles of silicon of fixed doping concentration ("p-type" boron or "n-type" phosphorus doping at a controlled level within the range of 10 to 1000 ppm). In addition, techniques must be developed for blending and consolidating the tiny silicon particles with polymers for fabrication of thin film devices. Passive infrared (from 8 to 14 micron wavelength) detectors for military and commercial applications would be the primary result of this work. Military air target fuzing would be greatly enhanced by this type of passive proximity detection, especially with regard to all-weather capability.

PHASE I: Phase I of this effort would involve demonstration of a viable method for fabrication of doped silicon nanoparticles. Techniques for surface stabilization and consolidation of the silicon nanoparticles with adequate electronic coupling must also be demonstrated using a polymer matrix that facilitates thin film processing and assessment of semiconductor behavior.

PHASE II: The Phase II effort would focus upon development of passive infrared detectors and conformal detector arrays of potential use for all-weather air target proximity fuzing.

PHASE III DUAL USE APPLICATIONS: DUAL USE COMMERCIALIZATION POTENTIAL: There are numerous applications for infrared detectors, including telecommunications, heat detection for security systems, night vision or surveillance systems, fog vision systems, thermometers, pyrometers, temperature controllers, cameras for nondestructive evaluation or process control/monitoring systems, and remote control systems.

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KEYWORDS: nanoparticle, nanocomposite, doped silicon, polymer dispersion, proximity fuze, passive infrared detector

AF00-190 TITLE: <u>Real Time Failure Prediction Sensor</u>

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Determine the feasibility of failure sensing during impact with reactive decision making.

DESCRIPTION: On-target effectiveness of penetrating weapons has been improved by utilizing accelerometers to monitor axial rigid body position within the target and detonate the warhead at the optimum point. However, in a number of cases, the penetrator will fail due to ricochet, tail slap, or high bending loads. In the majority of cases high angular rates (hundreds of radians/sec) and/or accelerations (hundreds of kiloradians/sec2) are present. In the past, case failure sensors have been implemented using break wires, but these techniques are not applicable for concrete penetrating weapons due to case yielding (i.e., bending, ovaling, etc.,) without failure.

PHASE I: Phase I of this program will include analysis of the proposed sensor(s) performance during penetrator impact and penetration. Laboratory test shall be conducted to demonstrate the sensor's applicable performance characteristics. The effort will also result in a Phase II test plan to demonstrate the sensor (and any associated circuitry) effectiveness during target penetration.

PHASE II: This phase will include the detailed design, fabrication and field test of the proposed sensing mechanism. It is envisioned that these tests would include concrete impacts up to 1000 ft/sec in a nominally 3.3 inch diameter projectile 24 inch in length. These tests can be conducted by the government with contractor-supplied penetrator and instrumentation.

PHASE III DUAL USE APPLICATIONS: The sensors and associated discriminating algorithms may be applied to automobile crash dummies to determine rotational rates or other injury causing environments. Sensor suites could be used to deploy multiple airbags from different directions depending upon the area of the vehicle impacted. Other applications include sensing/decision making for automated/robotic manufacturing, deep drilling operations and remote machine processes.

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2. Johnson, G., R. Stryk, and M. Nixon, "Two- and Three-Dimensional Computational Approaches for Steel Projectiles Impacting Concrete Targets," Proceedings of the Post-SMIRT Seminar on Impact, Lausanne, Switzerland, August 1987.
3. Schwer, L.E. and J. Day, "A Computational Technique for Predicting Ricochet of Perforation of Steel Plates," Proceedings of the International Conference on Computational Engineering Science, Vol. 1, Chapter 6, Atlanta, Georgia, April 1988.

KEYWORDS: Bomb Impact, High Rotational Rate, Bomb Case Failure, Penetration Prediction, Ricochet, Concrete Penetration

AF00-195 TITLE: Aero Propulsion and Power Technology

TECHNOLOGY AREAS: Air Platform, Space Platforms

OBJECTIVE: Explore innovative approaches for turbine and advanced propulsion systems and electrical power concepts for manned and unmanned applications.

DESCRIPTION: The Propulsion Directorate aggressively pursues major performance advances in all components of gas turbine engines under the Integrated High Performance Turbine Engine Technology (IHPTET) initiative. Technologies derived under this initiative have resulted in higher thrust to weight rations and improved efficiencies. The focus of this topic is to consider those aspects in the design of gas turbine engines and other prime propulsion concepts, electrical power systems and energy storage devices that could support manned and unmanned mission requirements. The innovative approaches may include, but are not limited to, the use of microelectromechanical (MEMS) and mesoscopic machine technology. Emphasis would be on affordability, reliability, and lightweight designs without compromising range and payload. New analysis techniques, innovative designs, hybrid propulsion systems and electrical power concepts to support manned and unmanned air vehicle (UAV) applications (especially long duration flights) are solicited.

PHASE I: Define the proposed concept and predict the performance of the proposed design. Explore the feasibility of a new concept or concepts, through analysis and/or small scale testing to demonstrate the merits of a flexible modular design that can meet various mission applications.

PHASE II: Provide detailed analytical derivations and prototypical device or hardware demonstrations.

PHASE III DUAL USE APPLICATIONS: UAVs can present an effective alternative for some civil sector missions, for example, meteorological data gathering, atmospheric sampling and surveillance. Forest Service mapping and fire spotting, agriculture and ranching support, coastal and border patrol and surveillance, and storm tracking and disaster assessment are some specific areas that may be exploited with UAVs.

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2. Air Force Research Laboratory Propulsion Directorate website address: http://www.afrl.af.mil/pr.html

KEYWORDS: High speed propulsion, turbine engines, scramjets, fuels, lubrication, power systems, MEMS, mesoscopic machines

AF00-196 TITLE: Advanced Life Determination of Turbine Engine Components

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Accurately determine individual gas turbine engine component life, real time, at any given time in service, operational role or environment.

DESCRIPTION: A good understanding of local operational environment for an engine component can greatly enhance our ability to accurately predict engine life. The solutions sought in this project must be practical to implement in an operational aircraft, and not just in an engine test cell environment.

Turbine engines are designed using the flight system's mission profile, a profile that often resembles 'worse case'. It is assumed that all aircraft will basically experience the same mission. History shows, however, that each aircraft is flown differently from the original mission, as well as from each other. Hence, the engine does not see exactly the same environment that it was predicted to see and useful life is often lost. In a fleet of engines, a component from one engine will experience different mechanical and thermal loads than that from another engine. This variability in cyclic loading leads to different levels of component life being used. Unique and innovative approaches are sought for obtaining a more accurate assessment of life used and remaining component life, for metal and/or composite components. Some example techniques that could apply include: (1) using advanced analysis methods that would provide improved accuracy in their life predictions, such as taking into account environmental effects in the analysis; (2) measuring the physical state of the component that may indicate the life used and life remaining, such as measuring its residual stress to determine how the diminishing effect will impact life; and/or (3) monitoring and modeling the environment that the component is being subjected to. Specific technical examples include taking into account environmental and operational effects in the component life prediction and measuring residual stress to determine how its diminishing effect will impact the life. Other innovative approaches are encouraged.

PHASE I: Identify an approach that will provide a capability for evaluating the life of a turbine engine component. Show feasibility and applicability of the approach, for a turbine engine environment, by performing preliminary investigations and proof-of-concept demonstrations.

PHASE II: Further develop the approach identified in Phase I to a prototype level. Validate/demonstrate the approach using a spin pit or rig test of a turbine engine component. Demonstrate the practicality of using the approach on an operational aircraft. Develop a technology transition path for implementing the approach.

PHASE III DUAL USE APPLICATIONS: An improved capability of determining component life will be useful for all military engines, as well as commercial flight engines. It could also be applied to land-based turbine engines that are used for generating power and transferring fluids in the water, fuel and oil industries.

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2. "Multiaxial Life Prediction System for Turbine Components," ASME Journal of Engineering for Gas Turbines and Power, 109,1; January 1987, pp. 107-114.
3. "Engine Health Monitoring System for Advanced Diagnostic Monitoring for Gas Turbine Engines," Roemer, M.J., Report Number: AD-A359658 AFRL-PR-WP-TR-1998-2120, February 1998, ADA 359-658.
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KEYWORDS: Turbine Engine Component, Structures, Component Life Prediction Analysis, Component Life Determination, Residual Stress Measurement, Environmental Effects on Component Life

AF00-197 TITLE: Process for Applying Fretting/Galling Material Resistant Film on Engine Compressor Disks

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: To develop antifretting and antigalling protective coatings and to develop the process for applying the coatings to the blade and disk interfacial surfaces.

DESCRIPTION: The fatigue life of the turbine engine compressor can be significantly reduced due to the occurrence of fretting or galling. This reduction in fatigue strength leads to shorter inspection intervals, to infant mortality part removal, and in some cases, to part and engine failure. Furthermore this type of fatigue reduction decreases aircraft reliability, decreases fleet readiness and increases operational expense. According to recent estimates, about one in six of all in-service mishaps can be linked to fretting, galling and associated mechanisms prevalent at the blade-disk interface. The phenomenon of fretting and galling, primarily, depends on the interaction of the contacting bodies. Protective coatings are currently in use but they need to be improved in order to reduce the operational costs associated with the blade-disk interface. Therefore, improved coatings are needed to reduce the material interaction of the mating surfaces and the associated operational expense.

PHASE I: Develop innovative coatings for Titanium based alloy to reduce the occurrence of fretting and galling. Perform adequate proof of concept that the coating significantly enhances the fretting and galling resistance.

PHASE II: The process for applying the coating to the blade-disk interfacial surfaces should be optimized in this effort. The end product should be a prototype system that can be used to coat the blade-disk interfacial surfaces.

PHASE III DUAL USE APPLICATIONS: The techniques developed to enhance fretting and galling resistance will be useful for a wide variety of commercial applications to include, but not limited to commercial aircraft engines, land-based turbine engines for electrical power generation and the automotive industry.

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1. Waterhouse, R.B. and Lindley, T.C., Fretting Fatigue, ESIS Publication No. 18, European Structural Integrity Society, Mechanical Engineering Publications Limited, London, 1984.
2. Calcaterra, J.R. and Mall, S., "Investigation of Small and Large Stress Amplitude Interaction on the Fretting Fatigue Behavior of Ti-6Al-4V, Proc. of 3rd National Turbine Engine High Cycle Fatigue Conference," HCF 98, San Antonio, Feb 2-5, 1998.

KEYWORDS: Fretting Fatigue, Galling, Low Cycle Fatigue, High Cycle Fatigue

AF00-198 TITLE: Data Fusion for Gas Turbine Engine Diagnostics and Predictive Diagnostics

TECHNOLOGY AREAS: Air Platform

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Joint Strike Fighter

OBJECTIVE: To integrate engine health monitoring data and create a total systems approach for engine diagnostics and prognostics.

DESCRIPTION: The key to producing more confident, real-time, on-wing diagnoses resides in the processing and validation of multisensory data. The abundance of carefully chosen sensory data on future aircraft engines will not maximize engine health awareness unless the data is processed and fused in the most optimal and meaningful way.
Current aeroengines give data from a range of sensors that, when processed, provide separate information on engine health; these may be vibration, oil condition, and typical engine-sensed parameters like temperature, pressure, fuel flow and pilot's power lever angle. This data is usually processed and read manually on landing but is seldom cross-referenced or trended to provide good engine health information. For example, a vibration signal may have been forewarned many hours earlier by an increase in oil debris, gas-path temperature and fuel flow.

This topic seeks to fuse data from engine and ac sensors, and allow for the addition of state-of-the art sensors, to provide best information on the health and performance of a gas turbine engine. This will validate the data sensed by one sensor, from data provided by one or several others, and increase the diagnostic and prognostic capabilities of health monitoring systems. This will provide a highly accurate tool for engine and fleet management, and provide a key for the Intelligent Engine in the VATE program.

Advance real-time sensory systems, such as non-contact tip vibration monitoring systems, on-line oil monitoring, inductive debris detection, and crack detection systems, need a Data Fusion Center to autonomously process and fuse the sensory data so that diagnostic assessments can be performed. The statistically confident engine fault diagnoses generated in the Data Fusion Center, coupled with component and engine fleet histories, and a priori engineering analyses, make for the accurate predictive diagnoses of impending faults. This is critical to enable the best Air Force fleet management decisions to be made to enhance safety and reliability, and ensure the optimum use of engines and airframes.

PHASE I: Design and develop innovative and effective concept(s) to fuse and integrate modern engine sensory data from a range of sensors and, in so doing, demonstrate that more effective diagnostic and predictive diagnostic information can be obtained. Perform adequate proof-of-concept demonstrations to show confidence for the success of a Phase II program.

PHASE II: Based on the initial designs and proof-of-concept demonstrations from Phase-I. Develop a full-scale data fusion system, with an open architecture, that allows for the addition of state-of-the-art sensing technologies to provide complete engine health management. Build a prototype system and demonstrate it on a demonstrator engine.

PHASE III DUAL USE APPLICATIONS: By optimizing the retrieval and processing of sensory data, data fusion technology has potential in virtually any real-time control or monitoring systems. It is the focus for Prognostic Health Management in JSF and will be a key technology in achieving the VATE goal to reduce maintenance costs by 67%. Also, it has the potential to increase time on wing and operational effectiveness, and reduce time to diagnose faults. The Data Fusion Center concept could also play a role in improving the performance of military surveillance or intelligence equipment where fast and confident situational diagnosis is vital. Once developed, the system described above would be highly sought by the commercial airlines to drive down support costs, while improving safety and heightening their competitive edge. Beyond the arena of gas turbines, robotic control systems, which rely on quick response and autonomous, decisive initiatives, would benefit greatly from commands generated from optimally useful combinations of multisensory information.

REFERENCES: Society of Automotive Engineers E32 Conference on Engine Condition Monitoring.

KEYWORDS: Data Fusion, Prognostics, Diagnostics, Predictive Diagnostics, Gas Turbine Engine Health Monitoring and Health Management

AF00-199 TITLE: Advanced Temperature and Composition Sample Instrumentation for High Fuel-Air Ratio Combustor Applications

TECHNOLOGY AREAS: Air Platform, Materials/Processes, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Joint Strike Fighter

OBJECTIVE: Development of innovative non-or minimally intrusive sensor designs for high performance aircraft gas turbine engine combustors.

DESCRIPTION: As high performance calls for higher combustor inlet and exit temperatures, advanced environmental and temperature sensors are needed to support the next generation of high temperature, military and commercial, low fuel consumption gas turbine engines. In order to optimize the combustion process, aerodynamic design, and cooling technology to achieve these goals, real-time accurate temperature sensing and chemical sensing of the combustor/turbine flowpath are required. Particular emphasis will be placed on temperature and chemical species sensing devices that can accurately survey gas-path flows at the high temperatures (up to 40000F) and high pressures (20 to 40 atm) of advanced gas turbine hot sections while tolerating increased temperatures and pressures of cooling flows. This technology will enhance current computational capabilities by increasing the extent of their experimental validation and will be an enabler technology for exceptional diagnostic capability requirements associated with the use of active combustion control.

PHASE I: Phase I will require the identification of innovative prototype sensor design concepts and a feasibility analysis for their design, fabrication and practical implementation.

PHASE II: Phase II work will be focused towards demonstrating design concepts. These design concepts shall be consistent with the practical features and environmental limitations of gas turbine engines. The information gained under Phase I will be used to design and fabricate a subscale test article, which exhibits the anticipated conditions in a modern gas turbine engine. A test plan shall be prepared identifying the testing and development work required to validate the concept identified. Testing shall demonstrate both the capability of the test article and the effectiveness of the proposed instrumentation system.

PHASE III DUAL USE APPLICATIONS: All commercial gas turbine engines require combustion systems. Demonstration of advanced temperature and environmental instrumentation concepts will provide great benefits in improving efficiency and performance by cooling and weight reduction, and extending hot section life, therefore, directly benefiting commercial gas turbine engines.

REFERENCES:
1. “Velocity and Temperature Measurements in a Can-Type Gas Turbine Combustor,” Bicen, A.F.; Heitor, M.V.; Whiteman, J.H.; Nov 1986.
2. “Advanced Instrumentation for Aero Engine Components: Conference Proceedings of the Propulsion and Energetics Panel Symposium,” May 19-23, 1986, pp. 14-1-14-12.
3. “Gas Turbine Combustor Exit Temperature Measurement,” Sullivan, John D.; Kendall, John E.; TR-91-11, AEDC, Final Report AUG 91.

KEYWORDS: Gas turbine combustor instrumentation, data reduction, gas path temperature sensor, high temperature measurements, test and evaluation

AF00-200 TITLE: <u>Stochastic Modeling of Gas Turbine Engine Blade High Cycle Fatigue (HCF) Capacity</u>

TECHNOLOGY AREAS: Air Platform

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Engine System Program Office (SPO)

OBJECTIVE: The objective of this task is to develop a stochastic model of the high cycle fatigue (HCF) “capacity” in Titanium gas turbine engine blades, and to develop the supporting material database.

DESCRIPTION: In developing a stochastic model to predict probability of HCF failure for a gas turbine engine blade, it is necessary to compare stochastic models of mission profile, aeromechanical loading, blade modal analysis, and material capability (other models may also be required). The primary factors that influence material capability include: fretting, foreign object damage (FOD), and the interaction between HCF and low cycle fatigue (LCF). The purpose of this research is to develop experimental and analytical approaches for probabilistically assessing the HCF capacity of Titanium gas turbine engine blades. It is essential that the new model is capable of including an initial damage state due to material defects and FOD. An effort is underway with the major US turbine engine manufacturers to develop a probabilistic framework for the prediction of gas turbine engine blade HCF life. It is envisioned that a stochastic model of blade HCF capacity could operate as a stand-alone code, or as a part of an overall HCF life prediction code.

PHASE I: Develop an approach for stochastic modeling of HCF capacity in Titanium gas turbine engine blades. Identify requirements for blade and specimen data necessary to support development and validation of the stochastic model.

PHASE II: Conduct blade testing to evaluate the influence of various controlling parameters on fatigue crack initiation/growth. Develop a stochastic model of the HCF capacity in Titanium gas turbine engine blades. Validate the model with at least two specific test cases.

PHASE III DUAL USE APPLICATIONS: Turbine engine HCF is a significant cause of blade failure in both military and commercial applications. HCF is of special concern in single engine fighter aircraft, resulting in significant losses. A probabilistic assessment of HCF capacity will aid designers in solving this critical problem.

REFERENCES: AFRL-PR-WP-TM-1998-2148, High Cycle Fatigue (HCF) Science and Technology Program—1998 Annual Report, Multiple Authors, January 1999, Section 2.0 – Materials Damage Tolerance Research, Section 4.0 – Component Analysis.

KEYWORDS: Gas Turbine Engines, High Cycle Fatigue, Foreign Object Damage, Fretting, Probabilistic, Stochastic Modeling

AF00-201 TITLE: Innovative Damping Concepts for Extreme Environments Capacity

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop damping concepts for structures subjected to high temperatures, centrifugal loading, and oxidizing environments.

DESCRIPTION: Although there are a number of relatively mature technologies associated with damping nonrotating structural components at temperatures below 500 degrees Fahrenheit, there is a critical need for damping concepts appropriate for static structure and rotating component applications that are subjected to high temperature vibratory loads and other extreme conditions. Existing polymeric viscoelastic damping materials are only effective over a narrow temperature range, and become susceptible to creep or material decomposition when exposed to elevated temperatures and/or when subjected to large steady state loads. For extreme environments, damping concepts using polymeric materials must include an innovative application scheme to address these problems. Alternative approaches to the use of polymeric viscoelastic materials may be identified for the damping concept, and damping treatments that are relatively insensitive to temperature would be very useful in many applications. An analytical model that can be used in the design of the damping treatment is required so that the damping design will not be based on an empirical "trial and error" approach. The damping treatments may be designed for specific extreme environment applications of interest to the Air Force, including engine nozzles, hypersonic vehicle structures or exhaust washed structures, and rotating components within air vehicle engines. One application of special interest is the damping of aircraft turbine engine blades, which supports research to reduce the effects of high cycle fatigue (HCF) in aircraft engines.

PHASE I: Demonstrate the feasibility of the damping concept, including its compatibility with elevated temperatures and sustained steady state loads. The feasibility study should include analytical studies of the concept that predict the level of damping to be seen in the component and an experimental evaluation of the effectiveness of the damping treatment in the defined environment.

PHASE II: The damping treatment must be fabricated and then tested to demonstrate its effectiveness in the application considered. The testing must effectively demonstrate the damper's durability in the environment for which it is designed. The Phase II program must also demonstrate that the treatment can provide effective damping without adding excessive weight, cost, or maintenance requirements and that the damping effectiveness can be accurately predicted in a structure.

PHASE III DUAL USE APPLICATIONS: There are several commercial markets for damping technologies that are capable of withstanding elevated temperatures and large steady state loading, including vibration isolation devices for heavy machinery. Damping concepts can also be used in the commercial aircraft and automotive industries to reduce undesirable vibration in vehicular structures and engines. Added damping reduces resonant response, which reduces requirements for maintenance and enables the development of lighter weight, higher performance turbine engines. Large turbines used in the power generation industry, which have realized benefits from lower temperature damping concepts, could also benefit from high temperature damping concepts.

REFERENCES:
1. Jones, D.I.G., Lewis, T., and Michael, C., "Partial Coverage Air Film Damping of Cantilever Plates," 1997, J. Sound and Vibration 208 (5), pp 869-875.

KEYWORDS: Turbine Engine Components, Passive Damping, High Cycle Fatigue, High Temperature, Durability

AF00-202 TITLE: Smart Fuels for the Future Air and Space Force

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop "Smart" fuel additives that enhance the operation, performance, component durability and environmental compliance of current and advanced propulsion cycles as a function of the flight envelope.

DESCRIPTION: The Air Force Research Laboratory (AFRL) is developing future propulsion concepts that will enable operation of advanced weapon systems in both the atmosphere and space. In addition, AFRL is exploring ways of enhancing the performance, reliability, durability, environmental compliance and affordability of advanced weapons systems as well as legacy systems. The United States military consumes between 4 and 5 billion gallons of jet fuel per year which is one of the most expensive components of the operational and support budget of weapon systems. Logistically, a common kerosene base fuel used by both the military and commercial fleet is attractive for global operations, however, military aircraft fly a more demanding mission and require fuels that are better than the standard commercial fuels. The number two largest footprint item for the Air Expeditionary Force (AEF) is fuel. In addition to the weight and bulk of the product itself, equipment needed to clean, dispense, additize and test the fuel adds to the number of cargo aircraft loads needed to support a contingency. Increased utilization of commercial fuels enhanced at location with a new generation of "smart" additives could achieve deployment objectives and enhance the operation of our weapon systems. Development of these additives could lead to the simultaneous deployment of convention and trans-atmospheric vehicles from a single location anywhere in the world. The commercial industry has a long history of watching the military make the significant improvements in jet fuel technology and implementing them after the technical risk has been reduced to near zero. Environmental legislation and corporate earnings requirements are forcing the commercial industry re-think there requirements for enhanced fuels and may readily partner in the development and demonstration of these additives.

Conventional jets fuels such as JP-8 have been optimized based on performance, cost and availability and contain additives such as lubricity additives to extend pump life, antistatic additive to reduce static discharge, and fuel system icing inhibitor (FSII) to prevent water in fuel from freezing. Recently, the Air Force began fielding a new additive "+100" that increases the thermal stability of fuel by 100°F and has been demonstrated to reduce fuel system maintenance in the field. It is currently being used at 59 locations in over 2500 aircraft. As part of the research effort, it was identified that fuel additives technology could be developed that would significantly enhance propulsion system operations as a function of the flight envelope. "Smart" fuel additives will feature components which can be selectively "controlled" by temperature or shear, to react in the fuel system or combustor to enhance a specific property. For example, signatures could be reduced by reducing the amount of particulates generated by the combustor, altitude limits could be increased with additives that improve low temperature behavior, cold starts and high altitude relight limits could be improved with ignition enhancers and rocket performance could be enhanced with high energy additives. "Smart" fuel additives can potentially increase aircraft, helicopter, and unmanned air vehicle (UAV) system reliability, increase or extend aircraft service life, reduce time-phase interval inspections, and reduce vulnerability. Furthermore, the smart fuel concept can potentially increase infrastructure systems' reliability, maintainability and supportability, and increase aircraft ground support, supply, transportation, and test equipment interoperability, reliability and maintainability.

Initial goals for "Smart" fuel additives include a 50% reduction in particulates produced by turbine engines, 20 degree F reduction in fuel freezepoint (from –53°F), ignition enhancers that increase altitude relight envelop by 10,000 feet. In addition, additive mixtures ("cocktails") need to be developed that reduce the number of additives that need to be injected at the forward operating locations and would reduce the volume of additive needed by 50%. Pure additives may be difficult to mix and may react adversely when mixed in a concentrated state, thus additive cocktails must contain blending agents to minimize incompatibility. The desired additives should have all the functionality of the current (FSII, lubricity enhancer and static dissipater additive) as well as the new "smart" additives. Innovative, light weight, small physical size injection systems and advanced in-situ diagnostic techniques need to be developed to make it easy to deploy the additive cocktails. Goals for the injection equipment are that it fit in a suitcase size space (or smaller) and be easily transported and operated by a single person. Goals for the diagnostics include identification of basic fuel properties and quality and measurement capability for the additives in a small easily to use package.

This program requires the development innovative fuel additives (or an additive "cocktail" package) that react in the fuel system or the combustor to selectively enhance a specific property at discrete operational points. The desired additives should have all the functionality of the current packages (FSII, lubricity enhancer and static dissipater additive) as well as the new "smart" additives. Cocktails to make commercial fuels JP-8 and JP-8+100 should be developed as baselines. In addition, advanced additive injection techniques such as light weight "suitcase" size injectors with throw away bottles of additive, "fizzy" tablets, premixed additive balls, or heat (or shear) activated microcoatings of tablets could be explored to improve usability in the field and reduce the volume of material that would be needed. Finally, advanced field diagnostic techniques (requiring operation over conditions ranging from desert to arctic) are required for smart fuels. For example, a "smart nozzle" concept could be used to incorporate state-of-the-art diagnostics equipment into a single package that is attached to the single point refueling nozzle (or on the refueling truck) to test for key fuel properties as the fuel is dispensed. The technical risk is rated medium for this effort.

PHASE I: The Phase I goals are to identify suitable smart additives, additive "cocktail" mixes, advanced additive injection techniques and/or in-situ diagnostic concepts. The contractor shall demonstrate the feasibility of the technology, and quantify the payoffs for both military and commercial applications and conduct a cost benefit assessment to determine affordability. Size, weight and deployment footprint reductions shall be determined.

PHASE II: The goals of Phase II are to demonstrate a prototype of the technology (sample of new additive, sample of additive cocktail, additive injector (hardware) and/or in-situ diagnostic device), validate performance at true operating conditions, and refine cost/benefit predictions for both military and commercial applications. Size, weight and deployment footprint shall be compared to conventional systems.

PHASE III DUAL USE APPLICATIONS: All technologies developed under this topic have both military and commercial jet fuel applications due to the similarities of the jet fuels (i.e., JP-8 is commercial Jet A-1 fuel with a military additive package).

REFERENCE: Coordinating Research Council, "Handbook of Aviation Fuel Properties," CRC Report No. 530, 1983, ADA 132 106.

KEYWORDS: Smart fuels, smart nozzles, additive cocktails, fuel additives, emissions, sub-freezing properties

AF00-203 TITLE: <u>Turbine Burner for Near-Constant Temperature Cycle Gas Turbine Engine</u>

TECHNOLOGY AREAS: Air Platform, Space Platforms

OBJECTIVE: Develop innovative strategies for an ultracompact turbine burner that can enable a near-constant engine cycle by combusting in between the high-and low-pressure turbines.

DESCRIPTION: The driver for this program is the need to enhance performance and reduce life-cycle cost for advanced air-breathing propulsion and power systems. The development of a revolutionary propulsion system that operates on a highly-efficient constant-temperature (CT) cycle instead of the constant-pressure cycle of today's engines is a high-payoff, high-risk approach to an enhanced performance low-cost gas turbine engine. An ultracompact combustion system, that efficiently adds heat between the turbine stages, is the key to a CT cycle aircraft or missile engine. Such a combustor is referred to in the literature as a turbine burner. Cycle analysis studies indicate that afterburner level thrust can be achieved with a non-afterburning, CT cycle engine without a large increase in specific fuel consumption (SFC). This topic seeks the development of an efficient, lightweight, ultracompact turbine burner that would enable the development of a CT cycle gas turbine engine for use in aircraft or missile systems. A turbine burner must be short and lightweight so as not to significantly increase the length/weight of the turbine, thereby nullifying performance gains. The combustion efficiency of the burner must be high so that almost all of the fuel is consumed. The pressure drop across the burner must be low so that the engine performance is not lost. Also, a turbine burner concept must take into account the fact that guide vanes are required to turn the flow before going into a rotor.

PHASE I: Conduct suitable studies to demonstrate that the proposed turbine burner concept has a reasonable chance of success. Conduct a preliminary design of the turbine burner

PHASE II: Design, fabricate, and test the turbine burner concept. Tests must be designed to demonstrate the validity of the turbine burner concept.

PHASE III DUAL USE APPLICATIONS: The development of an efficient, ultracompact turbine burner would stimulate the development of high thrust-to-weight ratio commercial aircraft engines but also more efficient engines for power generation. More work can be extracted from a CT cycle engine than for a Brayton cycle engine because it more closely simulates the Carnot cycle. However, CT cycle gas turbine engines currently have limited use in the power generation industry because of the lack of efficient turbine burners.

REFERENCES: AIAA-97-2701, J. Prop. & Pow, Vol 14, No. 6, 1998, "Selected Challenges in Jet and Rocket Engine Combustion Research," W.A. Sirignano, J.P. Delplanque, and F. Liu Department of Mechanical and Aerospace Engineering University of California, Irvine, CA.

KEYWORDS: Combustion, Turbine Burner, Constant Temperature Cycle Engine, Reheat Cycle

AF00-204 TITLE: Active Combustion Stability Control During Scramjet Altitude and Mach Number Transients

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a control strategy and instrumentation/actuation hardware that enables active control of combustion instabilities during scramjet transients such as engine cycle transitions, vehicle acceleration, and altitude changes.

DESCRIPTION: A scramjet engine is an open duct from inlet to exhaust nozzle. The shock system that is established upstream of the combustion section is a function of the flight Mach number, the vehicle angle of attack, the engine's internal geometry and the rate of heat release within the combustor. Perturbations in the heat release couple to movements in the shock system. Extreme changes can force the shock system out of the inlet and unstart the engine, or can cause regions of intense local heat flux and compromise the structure. Smaller changes in the heat release-shock structure system can reduce the combustion efficiency or blow out the flame. Operation of a scramjet as part of a combined cycle engine can be expected to exacerbate the challenge of maintaining stable combustion during a system transient. Fuel preparation, fuel injector placement, and igniter strength are the main control parameters available to manage combustion instabilities, especially in fixed geometry engines. Sensing temporal changes in the flow field and the attendant spatial changes in the shock structure, having the algorithms in place to know what action will counter the evolving flow changes, and having control over parameters that can implement the desired action, all at a time scale adequate to damp the instability, are crucial to managing the stable flight of a scramjet. This topic solicits development of control strategies for scramjet engines, especially for those with fixed geometry. Development of flight-weight instrumentation, control algorithms, and flow-control hardware are within the scope of this topic.

PHASE I: The effort under this program is expected to demonstrate a sensing and control strategy for managing transitions within a combusting, supersonic flow field. The demonstration is expected to be experimental on a bench-scale device.

PHASE II: The effort is expected to develop a sensing and control package for installation in an existing scramjet component test fixture and for demonstration of the control functions on hardware that is near full scale.

PHASE III DUAL USE APPLICATIONS: Active stability control of a combustion process has far ranging implications for both military and commercial applications. In combined cycle engine concepts, the transition from one cycle to the next is a source of flow instability that can lead to catastrophic failure of the system. In more conventional systems such as the gas turbine engine, active control over combustion instabilities enable operation of the engine with less stability margin which enhances performance. Further, combustion induced instabilities may drive component fatigue. These would be reduced or eliminated.

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KEYWORDS: Combustion, Control, Scramjet, Active Stability Control

AF00-205 TITLE: Oil and Material Compatibility for Improved Bearing and Gear Durability

TECHNOLOGY AREAS: Air Platform

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Joint Strike Fighter and F-22 Systems Program Office

OBJECTIVE: Develop material evaluation methodologies and compatibility solutions to enable large step improvements in bearing and gear capability.

DESCRIPTION: The gas turbine engine main-shaft bearings, power gear train and the associated lubricant are backbone elements of the propulsion and power systems which power USAF aircraft. Those machine elements and lubricants are also pervasive in commercial power systems. Improving the capability of those elements has fundamental potential to enable many capability and reliability improvements in the systems they support. Improved bearing performance capability, that can only be obtained through the use of new emerging candidate materials, is required in advanced USAF engines that are under development. Material compatibility problems have occurred in attempting to utilize some of these new materials. Those problems must be solved to enable fully successful designs. The Air Force is seeking the development of innovative design and testing processes and methodologies to enable selection and accurate evaluation of the tribological, material science, and chemistry properties that control the state-of-the-art capabilities of bearings and gears. In conjunction with these evaluation methodologies, the Air Force is seeking solutions to these compatibility problems that will allow large step increases in gear and bearing capabilities. Some gear and bearing capability improvements that are desired are (1) Maximized rolling element bearing DN capability. (DN refers to the product of bearing bore diameter and rotor speed. DN is usually expressed as the product of RPM and millimeters) (2) Maximized load-carrying capability of rolling element bearings either at low or high values of DN (3) Corrosion resistant bearings, gears and oils. This is a high pay-off area. If corrosion of these elements could be eliminated, large cost savings and durability improvements would result. (4) Increased operating temperature capability of gears, bearings, and oil.

PHASE I: Should identify and explain the major compatibility issues between advanced materials and lubricants limiting the advancement of durability and life of bearings and gears. An example is the degree of "reactivity" compatible with lubrication and corrosion resistance. A comprehensive technical approach should be identified to economically test the contact system for competitive surface or near-surface failure modes. Phase I should demonstrate, by way of simulation tests, the tradeoffs associated with conflicting requirements of lubricants, for high temperature or corrosion inhibition and materials tigue life, wear resistance or corrosion resistance.

PHASE II: Should prototype innovative design and testing processes and methodologies enabling large step increases in bearing and gear tribological performance. The technical approaches should utilize opportunities in oil formulation and/or surface engineering technologies. It is anticipated that the Phase II effort be conducted in conjunction with one or more supporting companies for material and lubricant technologies and at least one turbine engine manufacturer. The prototyping demonstration should be applied to emerging candidate material systems identified by the engine company(s) and should be evaluated for its potential to enable component insertion of new material systems enabling large step improvements.

PHASE III DUAL USE APPLICATIONS: Applications of the design and testing processes developed in this SBIR program would have wide application in Phase III. The specific design enhancements of gas turbine engine designs, developed by the engine companies using this technology, would be applied to both military and commercial jet engines. The resulting design and testing processes would be applicable to any commercial or military power train system in any application from Army tanks to Space systems.

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KEYWORDS: Tribology Bearings, Gears, Oil, Metallurgy, Chemistry, Material Science, Lubrication.

AF00-206 TITLE: Non-Intrusive, Flight-Weight Instrumentation of High-Speed, High-Temperature Flow Fields

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop robust, flight-weight instrumentation that can be used in conjunction with a process control system to monitor and/or control combusting flow in high-speed propulsion systems.

DESCRIPTION: Non-intrusive instrumentation has been extensively developed for research and ground testing of high-speed propulsion devices such as ramjets and scramjets. Laser Doppler velocimetry, planar imaging velocimetry, planar laser induced fluorescence, spectroscopy, and other non-invasive methods routinely measure gas velocity, species concentration and temperature in very harsh flow environments. The techniques have yielded wonderful insight into very complex processes. They have the potential to provide continuous, real-time assessments of the performance and structural health of practical, in-service combustion device. Developments in diode lasers and chip-based detectors may be sufficient to enable use of these laboratory techniques in a flight environment. However, identification of a parameter that can be measured with sufficient accuracy, and over a broad enough area of the engine flow-field to enable a near-instantaneous assessment of the state of the process, has yet to be accomplished. As an example, measurement of the OH radical is a good indicator of the extent of a reaction and the location of the flame front. However, measurement of OH through absorption spectroscopy is best performed with a small, intense column of laser light transiting the flow-field. The measurement can be made with adequate accuracy, but not over a broad enough area of the flow-field nor with sufficient speed to permit active engine control. Multiple line measurements of OH at a given engine station could be deconvolved to define the extent of reaction at the measurement plane. However, the deconvolution algorithm would take time and its accuracy would be diminished relative to the line measurement. The loss of speed and accuracy may make engine control impossible. Identifying what to measure and how to use it in order to assess structural integrity or to optimize system performance are of equal importance to the actual task of miniaturizing the diagnostic tool. This topic solicits development of non-intrusive, flight-weight instrumentation for propulsion applications, especially for ramjet and scramjet engine cycles. The only acceptable responses are those in which the development can be expected to lead to devices to measure parameters with sufficient precision and at time scales conducive to managing internal flows of an engine.

PHASE I: The phase I effort of this program is expected to identify the measurement strategy, the information processing approach, and one or more parameters that could be actuated to actively control a high speed, chemically reacting flow. The focus of the effort is on measurement strategy and must identify the specie(s) to be measured as well as the required precision of the measurement, required coverage of the flow field, and required speed. The Phase I effort is expected to define a development effort to prototype such an instrument for in-flight use.

PHASE II: The phase II effort of this program is expected to culminate in prototype testing of sensing instrumentation that can function in a high speed, high temperature flow and measure one or more parameters suitable for active process control. The prototype must be bench tested, addressing issues of effectiveness and packaging suitable for flight.

PHASE III DUAL USE APPLICATIONS: Non-intrusive instrumentation is routinely used in laboratory environments to evaluate performance. Such instrumentation also has the potential for process control. However, for such applications it requires miniaturization and durability in excess of current technology, and it must be integrated into a reliable and rapid measure-evaluate-actuate process. Potential applications are numerous in both military and commercial sectors. Propulsion systems, power generation, chemical processing are all areas that would benefit from such instrumentation.

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KEYWORDS: Measurement, nonintrusive instrumentation, process diagnostic

AF00-207 TITLE: <u>Air Film Bearing for Oil-Free Turbomachinery</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop affordable air film bearings with predictable performance for rotor support in midsize oil-free aerospace turbomachinery.

DESCRIPTION: Traditional rotor support for aerospace gas turbine engines and turbomachines for power units consists of rolling element bearings which are lubricated with a recirculating oil system. Advantages of this approach include high load capacity and well characterized, predictable performance. The recirculating lubrication system accounts for a substantial portion of the cost and weight of the turbomachine (typically 15% in a gas turbine engine). Additionally, this approach limits performance in advanced machines because extensive cooling is required to maintain bearing temperatures within the operating limits of conventional ester lubricants (400°F max), and friction and inertia forces within the rolling element bearings limit rotor speeds to less than 3 MDN (MDN = 106 x shaft diameter (mm) x rotational speed (rpm)). Other drawbacks include high maintenance and limited storability between uses.

Air film bearings present an attractive alternative approach to rotor support in some systems. They do not require a lubrication system, thus substantially reducing machine cost and weight. Operating temperature has been demonstrated to 1200°F. Rotor speeds are essentially unlimited, they are potentially maintenance free, and have unlimited storability. Air film bearings are currently in use in applications requiring relatively small rotors and loads, such as aircraft air cycle machines (ACMs). The application of air film bearings to larger machines has been limited by their low load and damping capacity, and limited scalability. Recent advances in these areas are making air film bearings feasible for midsize turbomachinery applications such as gas turbine engines for cruise missiles and Unmanned Air Vehicles (UAVs), and aerospace power units such as Integrated Power Units (IPUs) and integrated power/cooling packages. Another limiting factor is that traditional design methodologies are inconsistent in predicting performance, thereby requiring a semi-empirical development for each new application. This results in long lead-time and high cost in the final machine. Additionally, fabrication of some bearing designs can be labor intensive, with inconsistent performance in units produced within the same lot. These shortfalls must be overcome if air film bearings are to be viable and cost effective over the range of midsize turbomachine applications.

PHASE I: Define the range of required performance characteristics for rotor support in proposed midsize turbomachine applications (cruise missile engine, UAV engine, and power units). Define a proposed air film bearing concept and modeling approach. Through analysis and/or small scale testing, explore the feasibility and flexibility of the proposed bearing concept to satisfy the performance requirements over the range of target applications. Demonstrate the validity of the modeling approach through correlation with test data.

PHASE II: Develop prototype air film bearings and demonstrate performance at required end application operating conditions in demonstrator turbomachines. Correlate test data with predicted performance to refine and validate modeling methodology.

PHASE III DUAL USE APPLICATIONS: This technology has application in gas turbine engines for cruise missiles and UAVs, and turbomachines for aerospace power units. Potential commercial applications include turbochargers, air compressors, gas turbines, auxiliary power units, and gas turbine engines for general aviation aircraft.

REFERENCES:
1. “Advancements in the Performance of Aerodynamic Foil Journal Bearings: High Speed and Load Capability,” Heshmat, H., ASME Paper No. 93-Trib-32, STLE/ASME Tribology Conference, New Orleans. LA., Oct 1993.
2. “A New Foil Bearing Concept,” Scharrer, J., Hibbs, R., and Lindsey, T., final report for NASA contract NAS8-40536, 1995.
3. “Effects of Static Load on Dynamic Structural Properties in a Self-Acting Foil Journal Bearing,” ASME Trans., J. of Vibration and Acoustics., Vol. 116, No. 3, pp. 257-262, July 1994.
4. “Foil Air/Gas Bearing Technology – An Overview,” Agrawal, G.L., ASME Paper No. 97-GT-347, 1997.

KEYWORDS: Foil Bearings, Air Bearings, Air Film Bearings, Aerodynamic Foil Bearings, Gas Bearings, Oil-Free Bearings

AF00-208 TITLE: <u>In-Flight Engine Start System (ASC-017D)</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop techniques, devices and components for aerospace advanced power generation to support in-flight engine restarting and electrical power generation.

DESCRIPTION: In-fight power generation and engine starting systems are needed to provide power for propulsion engine start assist and increased payload power over the operational range of an aircraft, tailored to high altitude vehicles, including UAVs. Existing systems of interest do not have engine restart capability and exhibit less than 50% shaft to electrical conversion efficiency while being severely limited in electrical power generation growth potential for payload power. Present technologies and approaches cannot meet the stated needs. To minimize the weight and volume of the secondary power system, new and innovative solutions in electrical power generation/motoring technologies as well as conversion approaches are needed; emergency power for in-flight engine restarting, auxiliary power if needed, normal engine starting power, and 2x-3x increase in power generation capability are desirable. Since high altitude exacerbates any thermal control and propulsion engine/power generation coupling issues, achieving the goals inherently involves high risk. Current and planned systems use a variety of methods/components to provide secondary power, auxiliary power, emergency power, and/or in-flight engine starting capability; monopropellants, stored compressed air, fast starting jet fuel starters and auxiliary power units (APU's), and electrochemical energy storage for electrically driven accessories are examples. It is desirable that logistics support requirements of the secondary power system are minimized. Concepts are solicited that utilize the best characteristics of candidate technologies while introducing new technologies to produce a system, potentially a hybrid, which can provide full secondary power system functionality in a compact, lightweight, and low cost power unit. Crossover functionality to emerging directed energy weapon power requirements is also desirable. Any proposed technologies should be fully compatible with the current thrust to make power units fully self- sufficient, both electrically and from a thermal control standpoint. The suggested propulsion engine to be used for evaluating candidate technical approaches for in-flight start assist is the AE3007H series engine produced by the Rolls-Royce Allison company. The number (minimum goal of two desired) of successive in-flight propulsion engine restart attempts at high altitude (greater than 45000 ft altitude desired) should be evaluated for weight and volume impacts as well as operational impacts.

PHASE I: Develop a detailed technical definition of the problem, identify a proposed solution, and demonstrate key technologies enabling the use of that solution.

PHASE II: Concentrate on exploratory component development..

PHASE III: Hardware development and subsystem demonstrations.

PHASE III DUAL USE APPLICATIONS: These technologies may have application for all high speed motors, generators, actuators, and power electronics which may be used in future high power density electric/hybrid transportation vehicles (commercial air, high speed rail, and electric car), power generation, and manufacturing facilities.

REFERENCES:
1. "Integrated Power Unit For A More Electric Airplane", Colegrove, P.G., AIAA Paper 9'@-l 188, Feb. 16-19, 1993.
2. "More-Electric Integrated Power Unit Designed For Dual-Use", Klaass, R.M., McFadden, B.B., SAE Paper No. 94115, 1994.

3. "Integrated Power Unit - Advanced Development", Smith G., Halsey D., Hoffman E.. SAE Paper No. 981281,1998.
4. "High Temperature Generator Development," AFAPL TR 74 69, Robert Fear, et al., Westinghouse Electric Corporation, AD-786 046; NTIS, 5285 Port Royal Rd., Springfield, VA.

KEYWORDS: Power generation, motors, fault tolerant PM machines, switched reluctance machines, emergency power, engine starting

AF00-209 TITLE: Space Based Radar Thermal Control

TECHNOLOGY AREAS: Air Platform, Sensors/Electronics/Battlespace

OBJECTIVE: To develop techniques, devices and components for space based radar thermal control.

DESCRIPTION: Innovative thermal control concepts are sought for space based radar (SBR). Several SBR concepts require antennas of large area on a low earth orbit (LEO) platform. The possibility of large peak-to-peak temperature variation exists because operating windows lasting about 18 minutes may occur at anytime during an orbit (i.e., when the platform is at its high or low temperature extreme). Curvature of the antenna and temperature-induced out-of-phase conditions occur if the antenna does not remain flat and isothermal in a phased array system. These may be corrected via electronic calibration and steering means, but these approaches alone may not be sufficient or desired. Directly solving the problem (that is, controlling the thermal state of the antenna) is heavy, difficult, and practically infeasible with today's technology. Thus, it is desired to develop innovative thermal control technologies that mitigate peak-to-peak temperature fluctuation as well as to assure an isothermal antenna. Potential technologies include, but are not limited to, passive or active radar transparent coatings, integrated phase change thermal energy storage, and passive or active deployable heat transport systems. These technologies are not fully developed and their application in the space based radar involves a medium level of risk. Concepts that are integrated with the antenna structure and offer mass savings are of great interest. Successful offerors must demonstrate a basic knowledge of phased array radar systems and space craft thermal control issues. For the purpose of thermal control problem definition, a notional SBR platform would have a 6m x 44m antenna and a highly distributed power system with up to 15000 power converters integrated with the transmit/receive (T/R) modules. The SBR would be in a 500nm (~104 minute) orbit with two 18-minute operating periods, each occurring anytime during orbit and possibly back-to-back. The antenna would have a peak radiated power of 60kW and average radiated power of 15kW, (i.e., 25% duty cycle). A T/R module efficiency of 35% and a power conditioning component efficiency of 90% may be assumed. The goal is to control temperature variation across the antenna to less than 10°C.

PHASE I: Develop a detailed technical definition of the problem, identify proposed solutions, select the optimum solution, and demonstrate the key technologies enabling the use of that solution. Efforts devoted to modeling and simulation of the thermal control technologies in the space based radar application are also appropriate for Phase I.

PHASE II: Concentrate on development of prototype components and prototype subarray-scale demonstrations with a focus towards commercialization.

PHASE III DUAL USE APPLICATIONS: These technologies have application for commercial high power spacecraft and terrestrial radar or electronics cooling applications.

REFERENCES:
1. Cantafio, L.J., Editor, Space-Based Radar Handbook, Archtech House, Inc., Norwood, MA, 1989, 701 p.
2. Keener, D., Reinhardt, K., Mayberry, C., Radzykewycz, D., Donet, C., Marvin, D., and Hill, C., "Directions in US Air Force Space Power Technology for Global Virtual Presence," AIAA Paper 98-1021, presented at the 36th AIAA Aerospace Sciences Meeting & Exhibit, Reno, NV, Jan. 12-15,1998.
3. Eatock, B.C., "Progress in DND's Space-based Radar R/D Project," Proceedings of the Sixth CASI Conference on Astronautics, 1990.
4. Christensen, E.L., Skou, N., Dall, J., Woelders, K.W., Jorgensen, J.H., Granholm, J. and Madsen, S.N., "EMISAR - An Absolutely Calibrated Polarimetric L- and C-band SAR," IEEE Transactions on Geoscience and Remote Sensing, Vol. 36, No. 6, Nov. 1998, pp. 1852-1865.
5. Kutscheid, T. and Gilg, W., "Configuration of an Antenna Subpanel for a Spaceborne High Resolution X-Band SAR," Proceedings EUSAR '98 - European Conference on Synthetic Aperture Radar, Friedrichshafen, Germany, May 25-27, 1998, pp. 225-228.

KEYWORDS: Space based radar, spacecraft thermal control, phased array radar

AF00-210 TITLE: Drag and Thermal Load Reduction by Nonequilibrium Plasmas

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop nonequilibrium plasma model and validate results by experimental test of drag and or thermal load reduction under high speed flight conditions.

DESCRIPTION: The effect of nonequilibrium plasmas on high speed flights has recently been investigated in Russian, British, in the US laboratories and test centers. Measurements of shock attenuation, dispersion, and shock velocity increase have been reported which cannot entirely be explained by gas heating in a self-sustained discharge. Russian wind tunnel experiments have shown 20-30% drag reduction when a nonequilibrium plasma is injected in front of a projectile moving at Mach 6 in air as well as in inert monoatomic gases. Based on some of the preliminary experimental test results, it suggests that the understanding of the energy transfer mechanism in plasma-shock interactions may lead to a revolutionary high speed vehicle design. Injection of weakly ionized gas flow may be used to reduce skin friction, thermal loading, inlet and nozzle flow control, and enhance combustion efficiency for very high speed flights. The primary emphasis of the experimental and theoretical research should be to understand energy coupling mechanisms between the floe field energy and nonequilibrium plasma.

The experimental and/or theoretical results should be applied to permit scale-up of the test configuration, and/or to show the trade-off between the input electrical energy requirement for plasma generation, versus high speed engine performance enhancement, thermal load minimization and/or drag reduction.

PHASE I: Define the atmospheric boundary conditions where nonequilibrium plasma generation and injection may have significant impact on shock modification and high speed flow field modification. Design experimental /computer simulated test setup to demonstrate the effect.

PHASE II: Conduct test under well defined conditions to permit accurate theoretical model development for energy exchange mechanism between plasma and flow field. Also define optimum electrical configuration for plasma generation for any conceptual high speed aerospace vehicle.

PHASE III DUAL USE APPLICATIONS: Economical space access vehicle design for global telecommunication satellites.

REFERENCES:
1. “Drag Factor”, Janes Defence Weekly, 17 July 1998.
2. 2nd Weakly Ionized Gases Workshop,” Norfolk, April 24-25, 1998

KEYWORDS: Shock wave, nonequilibrium plasma, high speed flights.

AF00-211 TITLE: Directed Energy Weapon Power Generation and Pulsed Power Technology

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop electrical power generation and pulsed power conditioning for potential directed energy weapon systems concepts. Perform related analysis and simulation to understand system performance improvement with the new components.

DESCRIPTION: The Air Force seeks innovative concepts for electrical systems, electrical power generation and pulsed power conditioning for electrically powered directed energy weapon (DEW) concepts for potential air, space, and missile defense systems. The types of DEW systems considered in this program include high power microwaves devices, gas dynamic lasers, free electron lasers, and particle beams. The average power levels of these potential vehicle systems range from 100’s kW up. The voltages in these systems range up to 100’s kV for microwave and radio frequency based systems. High-voltage generator technologies that can be directly integrated with vehicle propulsion will be considered in this program. The magnetic technologies of interest include lightweight high temperature superconducting magnets with coated conductors, especially with yttrium-barium-copper oxide. Compact pulse power conditioning technologies of interest in this effort include high voltage pulsed power switches, pulse-forming network components, and solid-state pulse forming lines. Pulsed power components will need to produce microsecond pulses ranging from the kilovolt, megawatt level up to the megavolt, gigawatt peak level. All computer models of components and systems should be reduced ordered models to produce fast computations. All software developed in this program must be compatible with operating systems on personal computers.

PHASE I: Develop conceptual designs of components, perform preliminary tests of materials, develop analysis tools that predict system performance with new components.

PHASE II: Develop prototype components, develop analysis that predicts detailed performance of the system.

PHASE III DUAL USE APPLICATIONS: Software and component technologies will have potential commercial applications for high power and high voltage generators and power electronics used in utility power systems, and civilian space missions.

REFERENCES:
1. V. Fraishtadt, A. Kuranov, E. Sheikin, “Use of MHD Systems in Hypersonic Aircraft”, Technical Physics, Vol 43 Number 11, November 1998, pp. 1309-1313.

2. H. Cohen, F. Lehr, T. Engel. Spear II: High Power Space Insulation, Texas Tech University Press, 1995.
3. B. Gamble, T. Keim, "A Superconducting Generator Design for Airborne Applications," Advances in Cryogenic Engineering, Vol 25, 1980, pg. 127.

KEYWORDS: Electric power, power generation, magnetohydrodynamics, superconducting generators

AF00-212 TITLE: Power Electronics and Conditioning for Electrical Actuation

TECHNOLOGY AREAS: Air Platform, Sensors/Electronics/Battlespace

OBJECTIVE: Reduce DC power requirements for flight control actuators

DESCRIPTION: As the amount of electric flight control actuation increases in future aerospace vehicles, increased electrical capacity is required. Innovative concepts are requested to reduce the DC power required by these actuators. Proposals should address the development of power electronic devices, controls and/or subsystem architectures for aerospace actuation systems that will result in more efficient operation. Candidate device, controls, and subsystem technologies should demonstrate advancements in efficiency and power density. Approaches that modulate power to various actuators working simultaneously will be considered. Other approaches including advanced switch modules, innovative controls and innovative motor designs that improve efficiency are desirable.

PHASE I: Goals include analyses and proof-of-concept experiments

PHASE II: Goals include detailed analytical deviations and prototypical devices, components, or hardware demonstrations.

PHASE III DUAL USE APPLICATIONS: Much of the technology is of direct interest to future commercial utilization by the automotive, portable electronics, power generation, and motor drive industry, where high power density, high current fault tolerant switching, and/or high reliability are required.

REFERENCES:
1. "An Electromechanical Actuator for a Transport Aircraft Spoiler Surface," Proceedings of the 32nd Intersociety Energy Conversion Engineering Conference, 1997 pg 694-698.
2. N. Mohan, T.M. Undeland, W.P. Robbins, "Power Electronics: Converters, Applications and Design," John Wiley & Sons; NY, NY, 1989.

KEYWORDS: Power conditioning, actuatory, power electronic devices

AF00-213 TITLE: Power Systems for MEMS and UAV Applications

TECHNOLOGY AREAS: Air Platform, Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: Develop lightweight, long duration electrochemical propulsive power and energy storage systems for MEMS and/or UAV flight platforms.

DESCRIPTION: This topic seeks proposals with innovative concepts related to electrochemically powered (batteries, fuel cells, and electrochemical capacitors) microelectromechanical systems (MEMS) and unmanned aerial vehicles (UAVs). There are many challenges for enabling MEMS for specific applications that will provide a benefit in cost, weight, manufacturing, reliability, etc. MEMS devices have had limited evolution from novel micro devices to specific applications. For the most part, the development of microsensors such as accelerometers, pressure sensors, chemical sensors, and the like have been the primary focus for transitioning this micro-technology to real world applications. One barrier to applying MEMS technologies in specific applications has been a lack of suitable micro-power systems. These systems could be composed of any devices capable of converting energy from the environment, such as solar energy, thermal energy, or the energy of motion, to electrical energy. Then, some means of storing and conditioning that energy is needed, such as microscopic batteries, fuel cells, and/or electrochemical capacitors. UAVs are primarily powered by internal combustion engines. To enhance UAV endurance and survivability, electrochemical power sources for prime power and energy storage are being sought. Electrochemical propulsive power and energy storage systems can provide lightweight, cost-effective, low-observable solutions to the power/energy storage needs for UAV platforms. The power requirements can range from several watts for MEMS to tens/hundred of kilowatts for large high-altitude long-endurance (HALE) reconnaissance/directed energy weapons platforms. The mission times range from several hours/days for primary power applications, to months/years for solar regenerative applications. Rechargeable energy storage capacities greater than 300 watt-hours/kilogram are desired. Electrochemical propulsive power weight goals are mission dependent, however, doubling the energy density compared to existing propulsion systems is the desired goal.

PHASE I: Define the proposed concept, predict the performance of the proposed design, and through analysis and sub-scale testing, demonstrate that the proposed design can meet the desired weight goal for the MEMS/UAV mission application.

PHASE II: Provide an operable prototype component or system that is completely suitable for the intended application. The prime consideration must be deliverable hardware and a clear demonstration of a manufacturable device, component or system that improves the existing technology either through exceptionally high performance, significantly reduced cost, or improved robustness.

PHASE III DUAL USE APPLICATIONS: Electrochemical batteries, fuel cells, and capacitors for MEMS/UAVs would be utilized in civilian MEMS/UAVs, electric vehicles, and various other portable power applications.

REFERENCES:

1. P. B. Koenenman, I.J. Busch-Vishniac, and K.L. Wood, Feasibility of Micro Power Supplies for MEMS, Journal of Microelectromechanical Systems, Vol. 6, No. 4, Dec. 1997.
2. S.F. Brown, The Eternal Airplane, Popular Science Magazine, p70, Apr 94.

KEYWORDS: UAV, power, energy storage, electrochemical, battery, fuel cell, capacitor, ultracapacitor

AF00-214 TITLE: High Speed Power Generation Technology for Aerospace Vehicles

TECHNOLOGY AREAS: Air Platform, Space Platforms

OBJECTIVE: Develop technologies in support of high speed electrical machinery for application in space power systems and oil-free integrated power units for aircraft.

DESCRIPTION: Electrical machines are needed that operate at high speeds (45-70 kRPM) and high power levels (up to 300 kW) for aircraft and spacecraft applications. Typical aircraft applications are integrated power units (i.e., turbomachinery with shaft-mounted electrical machines); these are generally switched reluctance machines (SRMs) due to their mechanically robust rotor. Typical spacecraft applications are expected to be the energy input/output mechanism for flywheel-based power systems for space-based radar, space-based laser, space station, or other missions. Proposals are solicited which address these technology areas. Examples of areas of interest include but are not limited to the following. For aircraft applications, foil thrust and journal bearings for integrated power units and integrated power/cooling packages are of primary interest, particularly design and analysis approaches which allow accurate prediction of dynamic performance. Oil-free auxiliary bearings for magnetic bearing systems and hybrid bearing configurations for this class of machine are also of interest. For space-based flywheel systems, high speed machines are of interest, particularly those which can compensate for voltage variation with speed, which offer extremely low heat rejection rates (i.e., very high efficiency), and which can physically be integrated with a magnetically-suspended flywheel. Common to all applications are control approaches to integrate the magnetic bearing with the electrical machine, thus eliminating one magnetic bearing or providing additional rotor system stability by active control of electrical machine flux. Related areas of interest are approaches to understanding interactions between the SRM and the rotor (estimation and measurement) and pulse-testing techniques applicable to health monitoring of SRM/rotor systems.

PHASE I: Develop a detailed technical definition of the problem or opportunity, identify a proposed solution, and demonstrate key technologies which enable the use of that solution. Correlate any experimental data from technology demonstrations with analytical predictions.

PHASE II: Develop prototype components, conduct subsystem demonstrations, and fabricate hardware suitable for incorporation into system technology demonstrations if appropriate. Correlate test data with results from models or simulations in order to demonstrate clear understanding of any technology development.

PHASE III DUAL USE APPLICATIONS: These technologies have application for all high speed machines which may be used in future aircraft, spacecraft, hybrid or electric vehicles, and stand-alone or backup/uninterruptible power supplies for utilities or critical facilities.

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1. "Integrated Power Unit For A More Electric Airplane," Colegrove, P.G., AIAA Paper 93-1188, Feb. 16-19, 1993.
2. "More-Electric Integrated Power Unit Designed For Dual-Use," Klaass, R.M., McFadden, B.B., SAE Paper No. 94115, 1994.
3. "Integrated Power Unit - Advanced Development," Smith G., Halsey D., Hoffman E., SAE Paper No. 981281, 1998.
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5. "A New Foil Bearing Concept," Scharrer, J., Hibbs, R., and Lindsey, T., final report for NASA contract NAS8-40536, 1995.

KEYWORDS: Power generation, motors, fault tolerant PM machines, switched reluctance machines, emergency power, engine starting

AF00-215 TITLE: Propulsion and Power Systems Commercial Design Philosophies and Practices

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Evaluate current commercial design philosophies and industrial practices for aerospace propulsion and electrical power systems and compare with those used in similar military systems. The evaluation will identify opportunities to incorporate best commercial practices into military products; this would reduce manufacturing and assembly costs as well as expedite production of modular propulsion or power systems.

DESCRIPTION: Modular assembly, which would allow cost effective production with minimum production times, is typically not designed into military propulsion and power systems. For example, the production rate of the F-22 is 3 aircraft per month (approximately 7 days per aircraft). Unfortunately, the aircraft and its major component systems (engines, structures, etc.) are built using a sequential assembly approach that can require many months to complete the work in many assembly stations. This results in excessive tooling costs, due to the many jigs and fixtures needed to support the multiple aircraft and major components being assembled at any one time. Also, operator teaming and use is ineffective due to the months required to produce a final product and the fact that each operator is not involved in the production of every system. Excessive assembly time can be further affected by delays due to turnover in trained personnel, sick leave and holiday schedules. Another significant problem with a system's lengthy production time is the lost opportunity to incorporate design and process improvement ideas; this then results in significant wasted resources if these improvements can only be incorporated through retrofit. This research topic addresses the resolution of this problem by identifying commercial best-practices; it is recognized that some risk is involved due to the difficulty associated with identifying key process parameters and obtaining accurate raw data upon which evaluations can be based.

PHASE I: Defuse the technical roadblocks to parallel production and modular assembly of propulsion and power systems as used in modern fighter aircraft. Perform research on adapting current commercial design philosophies and practices for propulsion and power systems from several commercial sectors (i.e., aircraft, automotive, farm equipment, etc.) in order to determine common factors and processes and to identify application areas in military systems. If appropriate, develop a modular design to incorporate best commercial practices and designs into the production of fighter aircraft propulsion and power systems. The goal is to design and model a system that could be produced in balanced manufacturing stations. For the F-22 example, each station should have a cycle time of 7 manufacturing days. Additionally, parallel operations should be maximized and series operations minimized in order to achieve the shortest lead-time possible for a complete system or subsystem.

PHASE II: Estimate production times and manufacturing costs associated with assembly and production, and compare these with existing norms in the military propulsion and power systems industry for demonstration hardware and modules using a modular design. Extrapolate the model to include other aircraft components (structures, avionics, etc.). Identify propulsion and electrical power and other aircraft systems hardware and modules to demonstrate the modular design approach, incorporating the commercial designs and best commercial practices. Estimate implementation costs and payback factors associated with changing existing manufacturing and production processes and procedures and select candidate system or systems for implementation in Phase III.

PHASE III DUAL USE APPLICATIONS: The technologies being developed would have application in the production processes of both military and commercial aerospace systems. In particular, efficiencies introduced would result in more cost-effective processes that would more readily support incorporation of improved technologies.

REFERENCES: US Navy Best Commercial Practices Program and Reports 2. DoD Manufacturing Technology Program and Reports

KEYWORDS: electric power, power generation, manufacturing technology, jet engines, avionics, aircraft structures

AF00-219 TITLE: Advanced Rocket Propulsion Technologies

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop innovative components, manufacturing and processing techniques, and integration technologies aimed at doubling existing rocket propulsion capabilities by the year 2010.

DESCRIPTION: There is a critical need for novel, innovative approaches to develop technologies which can double existing rocket propulsion capabilities by the year 2010, and for bold, new, nonconventional aerospace propulsion-related technologies which will revolutionize aerospace propulsion in the next century. These revolutionary concepts, based on sound scientific and engineering principles, are essential in order to increase performance and mission capability which either maintaining or decreasing existing life-cycle costs. The proposed solutions shall emphasize "dual use technologies" that clearly offer civilian/commercial as well as military applications. Proposals emphasizing "spin-on technology transfer" from the civilian/commercial sector to military applications will receive additional consideration.

Our technological goals include: (1) Improve specific impulse and mass fraction for boost and orbit transfer, spacecraft, and tactical missile propulsion. (2) Reduce the stage failure rate as well as hardware and support costs for boost and orbit transfer propulsion. (3) Improve the thrust-to-weight ratio for liquid rocket engines. (4) Improve the total impulse to wet mass ratio for electrostatic and electromagnetic satellite propulsion systems. (5) Improve density impulse of monopropellants for satellite propulsion systems. (6) Improve the delivered energy of tactical missile propulsion systems. In the conduct of rocket propulsion research we strive to reduce environmental hazards from propellant ingredients and processing, propulsion exhaust, and rocket motors while either maintaining or surpassing current propulsion efficiency.

Improvements in the operability, reliability, maintainability, and affordability of space launch applications, for example, might include development of novel systems which can be launched with short lead times for relatively low life-cycle costs. An example of such a concept may include the design and development of a rocket-based combined cycle (RBCC) engine. Such systems would need to demonstrate high reliability and maintainability levels.

Subsets of advanced rocket technologies would have lengthy shredouts of potential research subjects but are not stated here in detail. These technologies might include innovative combustion and plume diagnostics (i.e., application of electro-optical devices and sensors), performance predictions, modeling of exhaust plume radiation and combustion characterization, propellant and component service life prediction technologies, and environmental contamination.

Additionally, bold, new advanced propulsion and related technological concepts and products for space activities are solicited for development. These topics include revolutionary concepts in very advanced fuels and oxidizers, metastable high energy nuclear states, nanotechnology products and techniques applied to rocket propulsion, enigmatic energy devices, and field propulsion thrusters. Research in these advanced rocket propulsion topics are included and structured to provide a maximum of innovative flexibility while yielding promising commercial applications/dual-use technology applications for prospective investigators.

Proposals also submitted for any other Department of Defense FY98 Small Business Innovative Research (SBIR) topic shall not be considered for this topic.

PHASE I: Further develop the concept and perform analyses required to establish the feasibility of the proposed approach.

PHASE II: Complete the Phase I design and develop a demonstrator or prototype. Document the R&D and develop a technology transition and/or insertion plan for future systems and commercial ventures.

PHASE III DUAL USE APPLICATIONS: DUAL USE COMMERCIALIZATION POTENTIAL: Advanced rocket propulsion technologies will transition to new, higher performing and/or lower cost U.S. military and commercial rocket engines and motors or advanced propulsion systems. This will enable the U.S. aerospace industry to increase global market share for space launch opportunities by reducing the life-cycle cost and increasing the efficiency of inserting payloads in orbit. Advanced rocket propulsion technologies also serve the commercial sector by enhancing our ability to remanufacture components to maintain and monitor the health of the U.S. ballistic missile fleet.

REFERENCES: "Selected Bibliographies, Handbooks, Manuals, and Reviews," CPIA SB-94, Nov 1994.

KEYWORDS: rocket plume, rocket engine, rocket propellants, advanced propulsion, satellite propulsion, boost and orbit transfer

AF00-220 TITLE: <u>High Temperature Catalyst for Nontoxic Monopropellant Applications</u>

TECHNOLOGY AREAS: Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: ICBM Stage IV / Ballistic Missile Defense Organization (BMDO) Interceptor Program

OBJECTIVE: Develop an ignition system for nontoxic monopropellants that will survive higher combustion temperatures than current catalyst bed systems

DESCRIPTION: Hydrazine is currently the monopropellant of choice for spacecraft maneuvering engines and gas generator applications. The high vapor toxicity and vapor pressure of hydrazine presents a challenge in such applications. As a result, new monopropellants are under development which pose no vapor toxicity hazard. One approach favored by industry and DoD is the use of energetic ionic compounds to replace hydrazine. However, a difficulty encountered with monopropellants containing a high concentration of energetic salts is that the combustion temperature is significantly higher than that of hydrazine. These high temperatures, up to 2500 K, render present catalytic ignition sources unusable. A technical need exists for a highly reliable ignition method with very low weight. Such an ignition method would accelerate the development and use of new high performance monopropellants for spacecraft attitude control systems and main propulsion systems. Also, such combustion systems would be useful in gas generator and emergency power applications.

PHASE I: Research catalyst support media that can withstand the higher operating temperatures of energetic salt monopropellants. Prepare and test actual catalyst pellets, in a catalyst bed, under actual temperatures and flow conditions as produced by energetic salt propellants. The flow media initially may be inert gas, but must be followed by actual propellants.

PHASE II: Refine and perfect manufacturing processes for production of the final catalyst, and demonstrate the process full scale. Also, perform full-scale firings of propulsion systems (in cooperation with the government) using the new catalyst

PHASE III DUAL USE APPLICATIONS: Gas generators and turbine systems using such nontoxic propellants promise to be useful for commercial and military aircraft applications. Depending on propellant cost and availability, commercialization could extend to public and private transportation as well.

REFERENCES:

1. Cort, Robert, Hurlbert, E., et al., Non-toxic On-orbit Propulsion for Advanced Space Vehicle Applications, AIAA Paper 95-2974, July 1995.
2. Walls, T. T., Dillinger, R. B. et al., Performance and Safety Aspects of Monopropellant and Non-toxic Bipropellant Liquid Divert/ACS Propulsion for Navy Theater Ballistic Missile Defense Applications, AIAA Paper 93-2634, June 1993.
3. Eberstein and I. Glassman, "Consideration of Hydrazine Decomposition," pp. 351-365, Liquid Rockets and Propellants, L.E. Bollinger, M. Goldsmith and A.W. Lemmon, Editors, Progress in Astronautics and Rocketry Series, Academic Press, 1960.
4. Hurlbert, E., Applewhite, J., et al., "Nontoxic Orbital Maneuvering and Reaction Control Systems for Reusable Spacecraft," Journal of Propulsion and Power pp. 676-687, Vol. 14, No. 5, Sept-Oct 1998.

KEYWORDS: catalyst, high temperature, ignition, energetic, monopropellant, propulsion

AF00-221 TITLE: <u>Microthruster Attitude Control System (ACS) for Laser Lightcraft</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and demonstrate small-scale propulsion components for a flight-weight ACS system to be used in vertical flights of subscale Laser Lightcraft vehicles.

DESCRIPTION: The "Lightcraft" concept is a laser propelled, trans-atmospheric vehicle concept developed in the late 1980's designed to reduce, by several orders-of-magnitude or more, the production and launch costs for sensor satellites. This novel launch system will employ a megawatt-class ground-based laser to transmit power directly to an advanced, hypersonic/combined-cycle laser engine that will propel a 1.4-meter diameter nanosatellite (1-10 kg), with a mass fraction of 0.5, to low earth orbit. The Lightcraft is a concept in which the laser propulsion engine and satellite hardware are intimately shared. The electronics and payload are packaged in the forebody section. The tankage for a working fluid is packaged into the center and aft portions of the vehicle. The forebody aeroshell acts as an external compression surface during the airbreathing mode. The afterbody has a dual function as a primary receptive optic for the laser beam and as a plug nozzle during the rocket mode. The primary thrust structure is the annular shroud, which serves as both inlet and impulsive thrust surface during the airbreathing mode. In the rocket mode, the annular inlet is closed, and the afterbody and shroud combine to form the rocket thrust chamber. The goal of the Lightcraft Technology Demonstrator program is to demonstrate technology readiness by placing a one or two kilogram functional nanosatellite in low earth orbit by the second quarter of 2005.

PHASE I: The results of the upcoming report on Dynamics and Control of Laser Lightcraft Vehicles1 will be used to design a flight-weight attitude control system for the Laser Lightcraft. The system components could include, but not necessarily be limited to, microthrusters, propellant feed system, tankage, and electronic control system. Unique and/or innovative approaches to accomplish this task are essential to minimize weight under the anticipated dynamic stresses and thermal loads. The analysis should predict performance parameters and physical characteristics of the subcomponents and the overall system. Compatibility with the current Laser Lightcraft (family) design features and operating characteristics must be maintained. Cost analysis for the entire ACS system will be used to predict and minimize cost during manufacture, installation, and operation.

PHASE II: The goal of this phase will be to completely develop and demonstrate a flight-weight microthruster attitude control system that meets Laser Lightcraft requirements. The proof-of-concept demonstration will come from vertical flight experiments on Laser Lightcraft to significant altitudes where turbulent atmospheric conditions will require precise attitude control. The design from Phase I will be fabricated, tested, and demonstrated under flight conditions. Design iterations will be accomplished based on test data, and analyses will be reviewed and updated to correspond with measured performance and other results.

PHASE III DUAL USE APPLICATIONS: If successful, microthruster attitude control systems will be applicable to trans-atmospheric, laser propelled space launch systems for both military and civil nanosatellites, as well as other very small satellite systems.

REFERENCES:
1. Bielawa, R.L., "Dynamics and Control Analysis of Laser Lightcraft Vehicles," AFRL-PR-ED-TR-99-?, AFRL Propulsion Directorate, Edwards AFB CA, to be published in 1999.
2. Myrabo, L.N. et al., "Transatmospheric Laser Propulsion," Final Technical Report, prepared under Contract No. 2073803 for Lawrence Livermore National Laboratory and the SDIO Laser Propulsion Program, 30 Jun 89.

KEYWORDS: lightcraft, laser propelled vehicle, dual mode, pulsed detonation engine, transatmospheric, single-state-to-orbit, micropropulsion

AF00-222 TITLE: Lightweight, High-Temperature Thermoplastic Case and Motor Insulation for Solid Rocket Motors

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a new high temperature thermoplastic insulation for solid rocket motors that dramatically increases the high temperature limit and reduces the weight of the insulative material. The polymer should be easily processed and relatively inexpensive to address the cost requirements of the IHPRPT program (see goals in Description section).

DESCRIPTION: Near and long-term material goals for solid rocket motors (SRM's) include replacement of composite and thermoset case and motor insulation with inexpensive, high-temperature polymers that are easily processed (e.g., injection molded, co-extruded). Unfortunately, many high-performance polymers are incapable of withstanding the severe temperatures and/or erosion environment required for SRM insulation. Under the Department of Defense's Integrated High-Payoff Rocket Propulsion Technology (IHPRPT) initiative, dramatic decreases in weight and processing of insulation, along with increased use temperature, is required. For case insulation this amount to a 50°C increase in high-end use temperature, and a 50% reduction in the weight of the material. For rocket motors, reduced ablation of the protective char layer formed upon incineration of the insulation is required. A 50% reduction in ablation would amount to a 44% decrease in insulation weight, and a 6-7% payload increase. For both systems, combining the low-cost, toughness, and processibility of organic polymers with the high-temperature/oxidation resistance properties of inorganic polymers offers an attractive solution to these problems. A variety of hybrid polymer systems are available, and the proposal should address how the combination of properties required will be achieved. An innovative proposal would also include how to combine the dramatically different requirements for case and motor insulation into one polymeric system.

PHASE I: Identify and synthesize candidates for SRM insulation. Tests for use-temperature, decomposition temperature, decomposition products, tensile strength, and small-scale processibility should be performed. Then samples should be classified as being acceptable for case insulation, rocket insulation, or both. Sufficient testing should be done to demonstrate the viability of the candidate materials for their specific application.

PHASE II: Scale-up the selected insulation candidates and conduct intensive thermal and rocket motor tests. Equally important, the ease of processing of the material should be demonstrated, with processing parameters supplied.

PHASE III DUAL USE APPLICATIONS: The resulting high-performance insulation would have great potential for use in aircraft, automotive, electronic, and household appliances/furniture where higher use temperatures are required.
REFERENCES:
1. Jensen, G.E., editor; Netzer, David W. Journal Prog. Astron. And Aeron. Vol. 170, 1996
2. Wu, H.; Xu, J; Liu, Y; Heiden, P.J. Applied Polymer Science, Vol. 72, 1999, pp. 543-552
3. Khan, M.B.; Polymer-Plastics Technology and Engineering, Vol. 35, 1995, 719, pp. 187-206
4. Kuznetsov, G.V.; Rudzinskaya, N.V. Mechanics of Composite Materials, Vol. 33, 1997, pp. 275-281

KEYWORDS: insulation, thermoplastic, lightweight rockets, casing, temperature

AF00-223 TITLE: Rapid Prototyping of High Temperature Ceramic and/or Metal Liquid Rocket Engine (LRE) Combustion via Low Pressure Spray

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Design and fabricate selected liquid rocket engine (LRE) combustion components, such as injectors, thrust chambers, and nozzles or inserts. The resulting components will be fabricated from advanced materials that will survive in an oxidizing environment about 2400 deg C using state-of-the-art Low Pressure Plasma Spray (LPPS) techniques.

DESCRIPTION: Low pressure Plasma Spray (LPPS) techniques are attractive alternatives to current state of practice fabrication methods for Liquid Rocket Engine (LRE) components. Successful application of LPPS techniques to LRE components will allow low-cost near-net shape production of articles such as thrust chambers, injectors, nozzles, inserts, etc. However, the material systems needed to operate in an oxidizing environment above 2400 deg C and the property requirements of the fabricated components, present unique challenges to LPPS. To meet the stringent thermal and mechanical requirements of the LRE environment, the sprayed refractory metal or ceramic must be of near theoretical density and largely stress-free. The LPPS parameters required in the production of complex LRE components meeting these two criteria, for material systems of interest to the rocket propulsion community, are largely unknown.

PHASE I: Perform appropriate analysis and design an appropriate LRE component(s) that takes advantage of the LPPS process and the properties of the materials outlined above. Show ability to manufacture the chosen materials by fabricating test coupons and delivering a single hot-fire test specimen.

PHASE II: Develop, fabricate and upscale component(s) using LPPS technology. Model the thermal spray process in terms of its various parameters.

PHASE III DUAL USE APPLICATIONS: The use of ceramic, refractory metal, and cermet materials have huge industrial potential in the auto, aircraft, medical, and general materials industries. They are, generally, strong, lightweight, and heat resistant. They are however, very expensive. Exploitation of these rapid processing techniques will decrease the cost (by >50%) and manufacturing time (by >90%) of these materials, making them attractive for applications such as automotive engines and aircraft brakes.

REFERENCES: T.N. McKechnie, F.R. Zimmerman and M.A. Bryant, "Vacuum Plasma Spray Applications on Liquid Fuel Rocket Engines," AIAA 92-3527S

KEYWORDS: Low Pressure Plasma, ceramics, metals, oxidation protection, thermal barrier

AF00-224 TITLE: Extraction of Rocket Propellant Physical Properties Via Computed Tomography

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Determine a method for extracting propellant material properties from CT data

DESCRIPTION: The Air Force has invested heavily in Computed Tomography (CT) systems to help maintain its missile fleet. Currently, CT data is used to determine the structural integrity of a motor by detecting any critical flaws during the inspection. Use of non-invasive techniques allows good motors to be returned to the fleet rather than destroyed during testing, saving money and increasing the reliability of the assets. Critical flaws are only one failure mode possible in missiles, however. Rocket motor propellant physical properties (elastic properties, fracture properties, etc) change with time and storage environment and can be the root cause of failure as well.

Currently, the Air Force does not have a reliable, non-invasive technique for determining propellant material properties. Assets must be destroyed, tested, and the results applied in a statistical fashion to the remaining assets. Computed Tomography should be able to non-invasively measure material properties, although how accurately and to what extent has not been fully established. Successful determination of material properties using this technique would allow good motors to be returned to the fleet without the time and cost of destruction and testing.

PHASE I: Determine the feasibility of measuring a propellant's CT signature as a function of mechanical properties and strain. Demonstrate feasibility by comparing CT-gathered data of propellant samples to property data gathered by standard mechanical tests.

PHASE II: Demonstrate reliability of the technique by calculating material properties for a full-scale asset and compare to mechanical (destructive) testing results for that asset.

PHASE III DUAL USE APPLICATIONS: Computed Tomography will decrease the need for destructive testing of military rocket motor assets to determine material properties. The same technology is applicable to industrial materials such as polymers and composites and would decrease industry's need for destructive testing and associated costs.

REFERENCES:
1. Standard Guide for Computed Tomography (CT) Imaging. AS'I'M E-144 1
2. Standard Practice for Computed Tomography (Cry) Examination. ASTM E-1570.
3. Standard Test Method for Measurement of CT System Performance. ASTM E1695.

KEYWORDS: Computed Tomography (CT), Material Properties, Energetic Materials, Propellant, Solid Rocket Motor (SRM), ICB

AF00-225 TITLE: Advanced Materials and Cooling Schemes for Rocket Engine Combustion Chambers

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Identify and demonstrate materials for rocket engine combustion chamber applications with higher heat transfer or higher temperature capability; identify and design cooling schemes for rocket engine combustion chamber applications in a hydrogen/oxygen combustion environment

DESCRIPTION: Current regeneratively cooled rocket engine combustion chambers are relying heavily on copper alloys as a chamber material in contact with the combustion products. Copper offers good heat transfer properties and to some extent reduces the low cycle fatigue seen in the Space Shuttle Main Engines. Future rocket engines will need to operate at higher chamber pressures and temperatures to increase their performance while reducing any losses. In order to accomplish this, better cooling schemes such as transpiration cooling, or better materials with higher temperature capability or heat transfer are necessary. For example, transpiration cooling a rocket engine reduces the chamber wall temperature and potentially extends the life of the chamber while reducing the needed coolant flow. A reduced cooling flow requirement also reduces the pressure requirements on the turbopumps. In another example, for expander cycle engines to further increase their performance, complex cooling schemes or higher heat transfer materials must be developed. Such materials will allow higher-performing, longer-life, reusable chambers. This research and development effort addresses the need to develop high performance rocket engine combustion chambers employing an advanced cooling scheme such as transpiration cooling or higher heat transfer/temperature capable materials that can be cooled using cryogenic hydrogen. This chamber needs to operate at higher pressures and heat loads in a hydrogen/oxygen combustion environment.

PHASE I: Consult with rocket engine, launch vehicle and aerospace vehicle manufacturers to identify material properties, cooling scheme requirements, and manufacturing techniques available for hydrogen/oxygen combustion chambers. b) Identify potential materials, cooling schemes, and manufacturing techniques allowing higher performing combustion chambers. Identify the processes required to prove these schemes are acceptable in this application. c) Formulate several conceptual designs incorporating the cooling scheme for either a 50,000 to 80,000 lb cryogenically cooled engine or as a component for a planned system. d) From among the various conceptual designs select and justify the component with the greatest performance advantage for further development. e) Initiate a preliminary design and test plan for this cooling scheme.

PHASE II:

a) Finalize the design and test plan.
b) Manufacture prototype hardware.
c) Conduct testing in a simulant fluid or actual rocket propellant using test plan to prove the validity of the material or cooling scheme and design.
d) Review results of testing and consult with rocket engine, launch vehicle and aerospace vehicle manufacturers and users.
e) Identify any prototype modifications needed to meet established requirements.
f) Modify design and/or material system as required.
g) Re-accomplish testing as required and create manufacturing plan.

PHASE III DUAL USE APPLICATIONS: The commercial aerospace industry to include aircraft, combined cycle vehicles, and launch vehicles would have widespread use of such a material. Any industry requiring cooling of a surface would greatly benefit from such cooling schemes. Higher heat transfer materials can be applied to several industrial applications such as refrigeration, automotive, and electronics.

REFERENCES:

1. Sutton, George P. Rocket Propulsion Elements: An Introduction to the Engineering of Rockets. 5th Edition, New York: John Wiley & Sons, 1986.
2. Andrus, J.S. and R.G. Bordeau. "Thrust Chamber Material Technology Program," NASA-CR-187207, Aug 86.
3. Kazaroff, J.M. and A.J. Pavili. "Advanced Tube Bundle Rocket Thrust Chamber," Journal of Propulsion and Power, Vol. 8, No. 4, Jul-Aug 1992, pp. 786-791.
4. Popp, M. and G. Schmidt. "Rocket Engine Combustion Chamber Design Concepts for Enhanced Life," AIAA-96-3303, July 1996.

KEYWORDS: rocket, cooling, low cost, high performance, combustion chamber, rocket engine

AF00-226 TITLE: Micro-Newton Thrust Measurement System

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a system to accurately measure thrust performance of propulsion systems for micro-satellites.

DESCRIPTION: The technological challenge is to mitigate thermal effects (drift) on micro-Newton thrust measurement systems. This would result in a thrust measurement system that can measure micro-Newton thrust with micro-Newton to sub-micro-Newton resolution. The micro-satellite propulsion systems will be operated in a space simulation chamber. All controls and recording devices will be external to the chamber and at atmospheric pressure. The system must operate without impacting propulsion system performance. It must be capable of measuring both continuous and single pulses. The measurement system must be able to mount/support the entire propulsion system mass (< 25 kg). The measurement system must have provisions for supplying the propulsion system with two (2) separate gaseous propellant feed lines, 2 pairs of high voltage dc power feeds, 10 low voltage dc instrumentation channels. The sensing apparatus must be able to withstand ultra high vacuum, highly energetic plasmas, and high EMI environments. All chamber feedthroughs must use standard conflat flanges

PHASE I: Demonstrate the feasibility of a micro-Newton thrust stand with the indicated resolution

PHASE II: Demonstrate a completely functional micro-Newton thrust stand. Must include all equipment necessary for calibration, measuring, and recording (via personal computer) thrust.

PHASE III DUAL USE APPLICATIONS: The military uses of this work would be to analyze performance of developing micro-satellite propulsion systems. Commercial uses would also be along the same lines of analyzing developing micro-satellite propulsion systems.

REFERENCES:

1. T.W. Haag, "PPT Thrust Stand," 31st Joint Propulsion Conference and Exhibit, San Diego, California, July 1995, AIAA 95-2917

2. Edward A. Cubbin, et. al., "Laser Interferometry for Pulsed Plasma Thruster Performance Measurements," 24th International Electric Propulsion Conference, Moscow, Russia, September 1995, IEPC-95-195.

KEYWORDS: micro-newton, performance, continuous, pulsed, propulsion

AF00-227 TITLE: Fluid System Nonvolatile Residue Test Process

TECHNOLOGY AREAS: Materials/Processes

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center - Launch Programs

OBJECTIVE: Develop a method for testing fluid systems in place (liquid or gaseous interfacing systems) for both hydrocarbon and fluorocarbon residues.

DESCRIPTION: Liquid oxygen and high pressure gaseous oxygen systems in any application are sensitive to contamination by hydrocarbon deposits. Such contamination can easily result in explosion and fires. In the Air Force, many launch vehicles use liquid oxygen as a rocket oxidizer, and hydrocarbon contamination can be catastrophic. At the same time, such systems, as well as interfacing gas systems, use fluorocarbon lubricants such as Krytox as a "LOX (Liquid Oxygen) compatible" lubricant for valves, regulators etc. Though chemically compatible, this material accumulates in the system and can cause clogging and sticking of orifices and mechanisms - especially at cryogenic temperatures. Hence contamination concerns encompass both types of materials. The traditional means of detecting and quantifying these materials has been by solvent rinse of systems with CFC-113 (which readily dissolves both hydrocarbons and fluorocarbons) followed by gravimetric analysis of the rinse. CFC-113 was found to be a Class 1 Ozone-Depleting Substance under the Clean Air Act, and its manufacture by the Montreal Protocol nations was banned after 1995. At this point, no other single solvent has been found which dissolves both types of contaminant and has the other properties needed for nonvolatile residue (NVR) testing. Some progress has been made in finding a dual-solvent combination which may be usable, but a fully developed and demonstrated/proven procedure for using them separately or together is needed. In addition to the solvency requirements, candidate materials must have vapor pressures suitable for low temperature evaporation processes, and be reasonably safe to handle from fire and toxicity standpoints. It should be noted that a completely different alternate technology to the solvent rinse approach is acceptable and even encouraged. The basic requirement is for confident verification of cleanliness of a system to Level A per MIL-STD-1246C.

PHASE I: Phase I shall include investigating potential single/dual solvents for the subject purpose, and performing tests to determine surface contaminant pickup efficiency and gravimetric analysis effectivity. Develop and demonstrate the effectivity of selected solvent(s) in as a field inspection process. Downselect Phase II candidate solvents

PHASE II: Phase II shall select a final solvent(s) and develop a complete procedure for use, along the lines of an ASTM Test Procedure. The procedure shall also be demonstrated successfully on a fluid system with known contaminant levels, either laboratory fabricated or in a field installation.

PHASE III DUAL USE APPLICATIONS: A practical contamination-measuring technique of this type has a large number of potential military and commercial applications, wherever liquid oxygen or high pressure oxygen gas are handled. This would include aircraft systems, submarines, hospitals, welding gas handlers, and air reduction plants.

REFERENCES:
1. Arnold, G. S., Uht, J. C., Nonvolatile Residue Solvent Replacement, Aerospace Report No. TR-95(5448)-1, 1 March 1995, The Aerospace Corporation. Contact Aerospace Corp. Reports Distribution at 310/336-7260.
2. The Development of Methodologies and Solvent Systems to Replace CFC-113 in the Validation of Large-Scale Spacecraft Hardware, NASA-CR-202520, C.A. Clausen, Univ. of Central Florida, Oct. 1996.
3. Beeson, Harold L. and Hornung, Steven, Development of CFC-free Cleaning Processes at the NASA White Sands Test Facility, CPIA Conference Paper, Allied-Signal Tech Services, Las Cruces NM, July 1995.

KEYWORDS: nonvolatile residue, ozone-depleting substance, freon 113, liquid oxygen, hydrocarbon/fluorocarbon solvents, gravimetric analysis

AF00-228 TITLE: Low Cost, High Performance Rocket Motor Technology

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To develop and demonstrate an innovative new technology for manufacturing next generation rocket motors in a more reliable, safe, cost efficient, and environmentally acceptable manner, while maintaining high performance (>245 lbf-sec/lbm). The payoffs should include reducing manufacturing costs by >50%, increasing mass fraction by 4%, the potential of reducing case weight by 25% and insulation by up to 50%, while reducing hazards.

DESCRIPTION: The Air Force Research Laboratory (AFRL) Motor Branch is seeking to develop and demonstrate an innovative new technology for manufacturing next generation rocket motors in a more reliable, safe, cost efficient, and environmentally acceptable manner, while maintaining high performance (>245 lbf-sec/lbm). The payoffs should include reducing manufacturing costs by >50%, increasing mass fraction by 4%, the potential of reducing case weight by 25% and insulation by up to 50%, while reducing hazards and. The problem with manufacturing high performance rocket motors is that many of the steps are very labor intensive and time consuming, such as assembling and preparing the case mandrel prior to winding the composite case. After the case is cured, the tooling must be disassembled and removed. Once the case is finished, it must be insulated, which often involves laying up the insulation by hand. Then the core tooling must be assembled and prepped before casting then disassembled after propellant cure. It is analogous to building a ship in a bottle only significantly more hazardous when the propellant is added. Past manufacturing method improvements such as winding the composite case over the propellant grain have shown benefits in time and cost savings, as have alternative solid propellant approaches such as Thermal Plastic Elastomer (TPE) propellants and liquid oxidizer/solid binder solution propellants.

PHASE I: Demonstrate the feasibility of an innovative new technology for manufacturing next generation solid rocket motors in a more reliable, safe, cost efficient, and environmentally acceptable manner, while maintaining high performance. Trade and manufacturing studies should show the cost and hazards reduction and mass fraction payoffs. To be considered successful, a subscale solid propellant motor manufactured with the new technology shall demonstrate an Isp of >245 lbf-sec/lbm under standard conditions in a test firing.

PHASE II: Implement the demonstrated approach in manufacturing a larger motor. Perform longer duration motor firings. Perform modeling and trade studies for applications into current DoD systems.

PHASE III DUAL USE APPLICATIONS: Aside from wide-spread DoD applications in missile propulsion and gas generators, high performance, low cost rocket motors would have even wider possibilities for space boosters, satellite propulsion, gas generators and air bag inflators.

REFRENCES:
1. Sutton, G. P., Rocket Propulsion Elements, John Wiley & Sons Inc, New York.
2. http://www.munitions.eglin.af.mil/public/weapflgt.html

KEYWORDS: Low Cost Solid Rocket Motor Manufacture, High Performance Low Cost Solid Rocket Propellant, Low Cost Solid Propellant, Optimized Rocket Motor Manufacture, Reduced Hazards Solid Rocket Propellant, Reduced Hazards Solid Rocket Motor

AF00-229 TITLE: Micro Propulsion Technology Development

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and validate innovative thrusters, propulsion system components, and/or test capability required for the development and deployment of microsatellite propulsion systems

DESCRIPTION: Many future Air Force and NASA missions will rely on maneuverable microsatellites to increase capability while reducing both launch and fabrication costs. These microsatellites will operate either alone or in fleets to perform such missions as on-orbit satellite servicing, space-based radar, or direct measurements in high-risk areas such as planetary rings. The microsatellites are extremely mass, volume and power limited. For the near-term missions supported by this solicitation, propulsion development is sought for microsatellites with total mass below 100 kg in support of the Air Force TechSat21 flight. Full realization of microsatellite capability is expected to require satellites below 25 kg and 25 W. Therefore, proposed technologies and systems should be able to address both regimes.

The microsatellite missions have requirements for both high thrust maneuvers and high specific impulse maneuvers. For example, high thrust is needed to quickly form a space-based radar formation. Once formed high specific impulse propulsion is required to perform stationkeeping within the propellant mass restrictions. To address this need, the proposed propulsion system may use chemical, solar-thermal, solar-electric, tethers or other novel methods of creating thrust. The objective of this effort is to radically push the technological envelope in the field of micropropulsion. Propulsion system components may include novel propellant storage and feed devices, improved intermediate energy storage for the Pulsed Plasma Thrusters, miniaturized power processing units, etc. For a proposed component, a comparison should be provided between what is currently available and what is proposed, in terms of mass, cost, power requirements, and efficiency. Improved test capabilities that may be proposed include methods for accurately assessing the performance of the micropropulsion devices, with an accuracy comparable to that presently achieved at higher power levels.

For Phase I efforts, a strong emphasis should be placed on the validation of the design that is expected to provide the stated performance enhancements; experimental and theoretical methods can be considered. Government and commercial test and evaluation facilities may be utilized; documentation of efforts to secure these facilities should be provided. Based on the results of these tests, performance should be estimated and improvements quantified.

PHASE I: Develop and validate innovative micropropulsion concepts, components and/or testing capability suitable for supporting satellites with total mass below 100 kg. The proposed concept should also be valid for a microsatellite mass down to the 25 kg or less level. The primary interest is the impact of the developed concept on the propulsion system mass, power requirement, cost and reliability. For a developed testing capability, the primary interest is the impact on the propulsion system developmental costs and time. During Phase I a working bench-top prototype system should be fabricated and tested. Measurements should be made that enable a viable assessment of the impact of developed concept on micropropulsion.

PHASE II: Apply the results of Phase I to the design, fabrication, experimental validation, and optimization of the micropropulsion concept. The design process is expected to be iterative with the best overall design prototype being reproduced and delivered to the Air Force at the end of the Phase II period. For a micropropulsion thruster or system component, the final product at the end of Phase II should be flight-like with a minimal amount of engineering required prior to thermal, vibration, and vacuum testing and spacecraft integration. For a proposed testing capability development, the final product should be a turn-key unit suitable for commercialization

PHASE III DUAL USE APPLICATIONS: Dual use commercialization would occur through the development and validation of flight quality micropropulsion systems for microsatellite and space experiment applications. The development of microsatellites, and their propulsion systems, is one avenue for greatly reducing satellite launch and fabrication costs. The higher performance thrusters will result in greater mission capability including both satellite life and maneuverability, which are areas of interest to government and commercial customers. Both mission capability and profitability will increase through the introduction of these thrusters into the marketplace. The outlook for commercialization therefore appears very strong.

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KEYWORDS: micro propulsion, electric propulsion, tethers, solar-thermal, chemical propulsion, microsatellites, propulsion, satellites

AF00-230 TITLE: Health Monitoring of Rocket Motors Using Embedded Miniature Sensor Technology

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop and implement a cost-effective method of monitoring aging of rocket motors in the field by using embedded sensor technology.

DESCRIPTION: Miniature sensors technology is expanding rapidly with potential use for service life assessment of solid rocket motors (SRMs). Current methods of service life assessment of SRMs require expensive destructive testing to determine existing chemical and mechanical states. Having the capability to determine physical states of SRMs nondestructively would decrease the number of aging propellant assets required for surveillance programs and reduce the costs associated with destructive characterization.

Embedded sensors would be in place for the entire service life of a solid rocket motor. As a result, the sensors must not harm or degrade the aging characteristics, storage life, or operation of the motor over long time periods. The materials in which the sensors would be embedded include solid propellants using any of the typical binders (PBAN, HTPB, CTPB, etc.), liners, insulators, and composite cases.

As aging of solid rocket motors is a complex phenomenon, many properties could be considered for measurement by embedded sensors. These include, but are not limited to, stress, strain, deformation, chemical concentrations, and diffusion in any or all of the above-mentioned materials or at interfaces between materials.

PHASE I: Demonstrate the feasibility of embedded miniature sensors to monitor physical properties and/or chemical state of a solid propellant analog motor.

PHASE II: Implement the demonstrated approach on a SRM. Conduct tests to demonstrate sensor performance. Determine if technology can be integrated into the rocket-based weapon system.

PHASE III DUAL USE APPLICATIONS: Microelectromechanical systems and miniature sensor technology are finding widespread industrial uses. Health monitoring devices used to assess the integrity of components nondestructively is much safer and provides quicker and less expensive evaluation methods.

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KEYWORDS: microelectromechanical system (MEMS), service life, micro sensors, chemical sensors, solid rocket motor, health monitoring

AF00-231 TITLE: High Maneuverability, Small Chemical Propulsion Systems

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and validate innovative design concepts for micro-satellites propulsion systems

DESCRIPTION: High thrust small satellites currently utilize storable hypergolic propellant combinations with pressurized feed systems. Propulsion system requirements for this class of satellite are increasing due to large maneuvering requirements and more precision attitude control. Substantial improvements in propulsion system mass fraction are required to increase overall vehicle delta-V capability. The objective of this effort is to investigate alternate propulsion system concepts to increase propulsion system mass fraction. Proposed concepts must show promise for increased propulsion system mass fraction. Projects proposing enhancements to existing systems will also be considered. The propulsion system should be sized for vehicle mass of 20 kg to 50 kg. Main engine thrust levels up to 100 lbf and attitude control thrust levels of 5 lbf. Particular interest lies in reduced toxicity propellants, ignition systems of non-hypergolic propellants (monopropellants or bipropellants) and alternate propellant feed systems.

For Phase I efforts, a strong emphasis should be placed on the validation of the design that is expected to provide the stated performance enhancements; experimental and theoretical methods can be considered. Government and commercial test and evaluation facilities may be utilized; documentation of efforts to secure these facilities should be provided. Based on the results of these tests, vehicle performance should be estimated and improvements quantified.

PHASE I: Develop and validate innovative propulsion components for small satellite (20 kg to 50 kg) applications: primary interests are reduced toxicity propellants, increased propulsion system mass fraction, minimal impact on spacecraft volume, minimal spacecraft contamination, environmental compatibility, and reliability. The focus of the effort should be on space inspection and orbit maneuvering applications.

PHASE II: Apply the results of Phase I to the design, fabrication, experimental validation, and optimization of micro-satellite propulsion components. The design process is expected to be iterative with the best overall performance being reproduced and be deliverable at the end of the Phase II period.

PHASE III DUAL USE APPLICATIONS: Phase III military applications/commercial applications of this technology include maintenance or refueling of satellites to extend their lifetimes, retrieval or salvage of satellites, or removal of dead satellites.

REFERENCES:
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3. Barnhart, D.A., et al., "XSS-10 Micro-Satellite Demonstration", AIAA Paper 98-5298, 1998.
4. Rockey, E.D., et al., "Development of a Pump Fed Monopropellant Hydrazine Bootstrap Pressurization System", Final Report AFRPL-TR-70-133, Air Force Rocket Propulsion Laboratory Research and Technology Division, Feb 1971

KEYWORDS: hypergolic propellants, microsatellites, monopropellants, reduced toxicity propellants, ignition systems, pumps, biopropellants

AF00-232 TITLE: Lightweight Low Cost Nozzle for Boost Engines

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Identify and demonstrate materials for lightweight nozzle can be manufactured for boost engines.

DESCRIPTION: To meet current boost-phase engine goals, lightweight low-cost rocket-nozzle concepts must be improved. The SBIR effort should identify materials and prove key design and fabrication parameters, which will allow a significant lead-in to a future laboratory or commercially funded program. The goal is a 45% weight reduction in nozzle weight relative to the Space Shuttle Main Engine (SSME) baseline nozzle (1395 lbs.).

PHASE I: a) Consult with rocket engine, launch vehicle, and aerospace vehicle manufacture to identify beneficial rocket nozzle integration concepts for current or planned vehicle propulsion systems. b) Identify the rocket nozzle performance requirements or desires for such systems. c) Formulate several lightweight, low manufacture cost nozzle conceptual designs, which support the identified requirements/desires. d) From among the conceptual designs, select and justify the rocket nozzle concept with the greatest overall (performance, weight, cost, operations, maintenance, etc.) benefit to the current or planned vehicle system. e) Initiate a preliminary design and test plan for this new design

PHASE II: a) Finalize the design and test plan. b) Manufacture prototype hardware. c) Conduct testing in a detailed simulation-using test plans to prove the validity of the material and design. d) Review results of testing and consult with rocket engine, launch vehicle and aerospace vehicle manufacturers and users. e) Identify any prototype modifications needed to meet established requirements/desires. f) Modify design as required. h) Re-accomplish testing as required and creates manufacturing plan

PHASE III DUAL USE APPLICATIONS: DUAL-USE APPLICATIONS: New rocket nozzle designs are in demand in both the civil and military launch vehicle markets. We recognize the technology advancements in cost, weight reduction, and performance improvement that need to be applied to today's space vehicles. One of the major drivers in weight, cost, and performance is the nozzle component. Improvements here will show significant payoff in launch vehicle cost, both commercially and military, across the board.

REFERENCES:
1) Batchelor, J.D., "Castable Carbon for Nozzle Applications," AFRPL-TR-66-11, Atlantic Research Corp, Alexandria, VA, Jan 1966. [AD: 369071]
2) Huzel, Dieter K, and Huang, David H., "Modern Engineering for Design of Liquid-Propellant Rocket Engines," AIAA Progress in Astronautics and Astronautics Series, Volume 147, pp 67 - 104, 1992.
3) Sutton, George P., "Rocket Propulsion Elements An Introduction to the Engineering of Rockets," Sixth Edition, pp 41-88 and pp 281-298, 1992.
4) NASA SP-8120, "Liquid Rocket Engine Nozzles," July 1976, Available through National Technical Services.

KEYWORDS: lightweight, nozzle, rocket engine, launch vehicle, boost engine

AF00-233 TITLE: High Purity Solvent Processing for Nonvolatile Residue Testing

TECHNOLOGY AREAS: Materials/Processes

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space and Missile Systems Center - Launch Programs

OBJECTIVE: A methodology for small-scale purification of solvents for nonvolatile residue (NVR) testing.

DESCRIPTION: Liquid oxygen and high-pressure gaseous oxygen systems (in any application) are sensitive to contamination by hydrocarbon deposits. Such contamination can easily result in explosion and fires. In the Air Force, many launch vehicles use liquid oxygen as a rocket oxidizer, and hydrocarbon contamination can be catastrophic. At the same time, such systems, as well as interfacing gas systems, use fluorocarbon lubricants such as Krytox as a "LOX (Liquid Oxygen) compatible" lubricant for valves, regulators, etc. Though chemically compatible, this material accumulates in the system and can cause clogging and sticking of orifices and mechanisms - especially at cryogenic temperatures. Hence contamination concerns encompass both types of materials. The traditional means of detecting and quantifying these materials has been by solvent rinse of systems with CFC-113 (which readily dissolves both hydrocarbons and fluorocarbons) followed by gravimetric analysis of the rinse. CFC-113 was found to be a Class 1 Ozone-Depleting Substance under the Clean Air Act, and its manufacture by the Montreal Protocol nations was banned after 1995. Some progress has been made in finding a dual-solvent combination that may be usable, but a source for the solvents with adequate purity is needed. Because of the very limited demand for such high purity solvents, they are not commercially available. Logically, any facility that uses the NVR (Nonvolatile Residue) test should be able to prepare the test solvent(s) from reagent-grade chemicals when and as needed in an economical manner. For purposes of this effort, the solvents will be (1) ethyl acetate, (2) cyclohexane and (3) AK225 (Asahi Chemical) and the purity requirement will be 1.0 mg/liter of NVR maximum, with a goal of 0.1 mg/l.

PHASE I: Develop and demonstrate a scalable preproduction method for purifying small amounts (1 to 10 gallons) of each solvent to the required purity on a repeatable basis. Equipment may be commercial, modified commercial, or new design, selected for ease of operation, cost effectiveness and repeatability.

PHASE II: Develop/document/demonstrate a cost effective production process for purification technique(s) and equipment for solvents 1 through 3 and others. Include data on purity verification and storage requirements to maintain purity and chemical stability.

PHASE III DUAL USE APPLICATIONS: A practical NVR test solvent preparation technique of this type has a large number of potential military and commercial applications, wherever liquid oxygen or high-pressure oxygen gas is handled. This would include aircraft systems, submarines, hospitals, welding gas handlers, and air reduction plants.

REFERENCES:
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2. The Development of Methodologies and Solvent Systems to Replace CFC-113 in the Validation of Large-Scale Spacecraft Hardware, NASA-CR-202520, C.A. Clausen, Univ. of Central Florida, Oct. 1996.
3. Beeson, Harold L., Hornung, Steven, Development of CFC-free Cleaning Processes at the NASA White Sands Test Facility, CPIA Conference Paper, Allied-Signal Tech Services, Las Cruces NM, July 1995.

KEYWORDS: nonvolatile residue, high purity, solvent, processing, hydrocarbon/fluorocarbon solvents, gravimetric analysis

AF00-235 TITLE: Kinematic Carrier Phase Tracking and Attitude Estimation with GPS in an Interference Environment

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Global Positioning System (GPS)

OBJECTIVE: Demonstrate GPS Attitude Determination and Kinematic Carrier Phase Tracking with a Controlled Reception Pattern Antenna/Electronics (CRPA) in an Interference Environment.

DESCRIPTION: The ability to: 1) perform carrier phase tracking and attitude determination with GPS (Global Positioning System) in a benign environment and 2) to use a phased array of antenna elements for spatial filtering of jammers by adjusting the gain and phase of each antenna element is well known in military GPS systems. As military and civil systems attempt to become more interference resistant and used for more precision applications, the need to perform carrier phase tracking and attitude determination in the presence of interference will become a requirement. A case in point is the planned use of

Kinematic Carrier Phase Tracking for JPALS (Joint Precision Approach and Landing System) to obtain centimeter levels of accuracy. Carrier phase measurements from multiple antenna elements (e.g., Controlled Reception Pattern Antenna or CRPA) can also be used for attitude determination. However, after the phase adjustment of the signal by an anti-jam spatial filter (Antenna Electronics or AE), attitude determination presents a serious challenge. The very same carrier phase measurements needed for attitude estimation have been adjusted in gain/phase for jammer attenuation. The future trend in low-cost navigation systems is to go to MEMS (Micro-Electro-Mechanical Systems) IMUs. MEMS IMUs will require continuous calibration of their associated systematic errors. The continuous calibration process in a GPS/IMU navigation system normally relies on the dynamic coupling of the IMU (acceleration) errors into position and velocity errors for observability. This becomes more difficult during low acceleration dynamics, because the acceleration-sensitive errors in the IMU are not excited. Another observable that can be used to maintain calibration of the IMU is attitude knowledge. Additional measurements from low-power attitude sensors may be aided with GPS attitude to provide continuous attitude observables with which to maintain IMU calibration. This will permit the use of Ultra-tight GPS/IMU coupling with MEMS IMUs in a jammed environment, which has been proposed as one solution to anti-jam.

PHASE I: 1) Conduct a theoretical analysis of performing carrier phase tracking/GPS attitude estimation in the presence of jamming. 2) Define spatial/temporal/spectral processing that would be applied to the data from each element of a CRPA to establish a baseline 3) Define signal processing required to perform carrier phase tracking in the presence of jamming. 4) Combine carrier phase data with other aiding sensors to perform attitude determination in the presence of jamming.

PHASE II: Implement Phase 1 approach. Demonstrate/verify performance using realistic GPS and jammer signals in prototype hardware. The architecture of the Phase II system must be adaptable to an operational configuration.

PHASE III DUAL USE APPLICATIONS: The signal processing for this technology will have wide application in future, DoD and commercial precision applications.

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2. A Complete GPS/INS Integration Technique Using GPS Carrier Phase Measurements by Kim, Jee and Lee, PLANS ’98 Proceedings pp. 526-533

3. The Enhancement of INS Alignment Using GPS Measurements by Park, Kim, Lee, Park, Jee and Oh, PLANS ’98 Proceedings pp. 534-540

KEYWORDS: Carrier Phase Tracking, GPS Attitude Determination, GPS/IMU Navigation System, Spatial Filtering of Jammers, MEMS IMUs

AF00-237 TITLE: Ultraminiature Laser-Based Atomic Clocks (ULAC)

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Weapons

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Global Positioning System (GPS)

OBJECTIVE: Develop/Apply Ultraminiature Laser-Based Atomic Clocks to GPS Receivers.

DESCRIPTION: The use of GPS receivers under battlefield conditions can be restricted by: signal jamming; an obscured view of the sky which may prevent acquisition of enough satellites; and after loss of contact with a satellite, time for reacquisition may be too long. Placing an ultraminiature laser-based atomic clock (ULAC) on GPS receivers would mitigate all of the above conditions and allow for direct-Y code acquisition capability, resulting in a more reliable receiver which could be used in applications which push current technological boundaries. Y-code signal is the GPS P-code signal encrypted for Military, Special Operations and other classified DoD users. The development of a ULAC is to aid military acquiring Y-code directly, whereby, minimize military dependency on Coarse Acquisition (C/A) code. Atomic clocks suitable for use in GPS receivers for battlefield applications, such as smart weapons, portable receivers, etc., need to be very small, consume little power, have short warm-up time and high frequency accuracy. Innovative technology will be required to develop such devices. Microcomputer-controlled quartz-crystal oscillators (MCXO) are alternative small-size, low power clocks for the above applications, but they have frequency stability’s lower than those achievable from miniature atomic clocks. Major ULAC issues to be corrected, prior to GPS application, include resolution of causes of long-term frequency instability and development of methods to minimize long-term frequency noise. Clock dynamics following turn-on (warm-up and accuracy issues) is an area in which little is known, and must be developed. Quantitative goals are a clock that uses 600Milliwatts or less in a -55 degrees Celsius to 60 degrees Celsius, has a volume of 40 Cubic Centimeters or less, and has a total variance no greater than 1.0 X 1.0 E -12 seconds for Tau greater than 1000 sec. and less than 90,000 sec. Production unit costs should be less than $900 for lots of 6000 or greater.

PHASE I: 1) Explore applicable analytic theory and physical component requirements to develop/apply Ultraminiature Laser-Based Atomic Clocks to GPS receivers. 2) Determine causes/remedial methods in reference to the constraints specified in

"Description" above. 3) Down select a clock design from several candidate configurations. 4) Demonstrate basic clock functions by means of a breadboard demonstration unit.

PHASE II: Upon successful completion of phase I, finalize design and manufacture a prototype ULAC. Demonstrate the prototype clock to mutually (Air Force/contractor) agreed/configurations/specifications.

PHASE III DUAL USE APPLICATIONS: Ultraminiature Laser-Based Atomic Clocks can be used in both DoD and commercial aircraft, space vehicles and ground stations in the future. As the Radio Frequency (RF) communication spectrum gets more and more crowded with consumer-market wireless users, having very accurate time and frequency control available in devices such as cell phones, RF modems, smart pagers, etc., will allow much more efficient use of the RF spectrum (i.e., more users and more varied applications). That has a much wider market impact than direct -Y acquisition.

REFERENCES:
1. P.J.Chantry, B. R. McAvoy, J. M. Zomp and I. Liberman, "Towards a miniature laser-pumped cesium cell frequency standard," Proceedings of the 1992 IEEE Frequency Control Symposium, pp. 114-122 (IEEE Press, 1992).
2. G. Mileti, J. Deng, F. L. Walls, D. A. Jennings and R. E. Drullinger, "Laser-pumped rubidium frequency standards: new analysis and progress," IEEE Journal of Quantum Electronics, Vol. 34, pp. 233-237, 1998.

KEYWORDS: GPS Receivers, Direct Y Code, Frequency Instability, Ultraminiature Laser-based Atomic Clock, Quartz-crystal Oscillators (MCXO), Long Term Frequency Noise

AF00-238 TITLE: Automatic Cartographic Data Translation and Registration

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace, Weapons

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Global Air Traffic Management (GATM) System Program Office (SPO)

OBJECTIVE: Develop a capability that uses data from national assets to develop instrument approach/departure procedures for tactical and special mission operations.

DESCRIPTION: The need exists to provide a near real-time capability to develop instrument approach and departure procedures for tactical and special missions, where little or no current mapping or imagery data exists. The capability, to collect imagery and mapping data required to develop instrument approach and departure procedures, exists today from national assets (e.g., Satellite Data, Joint STARS Data, Unmanned Aerial Vehicles Data, Etc); although the translation of this data into a usable format, to develop the instrument approach and departure procedures, does not exist. Algorithms need to be developed, that translate this data into the information necessary to develop the instrument approach and departure procedures.

PHASE I: Phase I activity shall include (among other issues): 1) A thorough review of the data required to prepare instrument approach and departure procedures to include resolution and accuracy requirements; 2) a review of current data collection assets that have the potential to collect the identified data within 24 hours; 3) and an approach on how to translate the data.

PHASE II: Phase II activity shall include (among other issues); 1) tradeoff analysis that identifies the value of the data versus the time to acquire the data 2) development of the algorithms 3) prototype demonstration of the capability.

PHASE III DUAL USE APPLICATIONS: Instrument approach and departure procedures are used in every airport throughout the world. This capability could be implemented in civil procedure development.

REFERENCES:
Multiple Database Integration and Update (MDBIU)
POC Jim McNeily, AFRL/IFEA (315) 330-2110
Email: mcneely#m#_Jim@irdpost.ird.rl.af.mil

KEYWORDS: Cartographic Data Translation and Registration, Instrume45, NT Approach and Departure Procedures, Mapping or Imagery Data from National Assets

AF00-239 TITLE: High Sensitivity LWIR and MMW Sensor Fusion on One Chip

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

OBJECTIVE: Develop a true sensor fusion array combining LWIR and MMW band passive imaging in a single focal plane array.

DESCRIPTION: There is a need for systems incorporating long wavelength infrared (LWIR) and millimeter wavelength (MMW) detection capability in the same focal plane array (FPA) chip. Both military and commercial sensor and surveillance systems currently face the limitations of size, weight and cost. The areas of commercial adverse-weather navigation/guidance and object recognition/identification, mid-course detection and discrimination, and space-based surveillance would benefit from sensors with high resolution, low power, reduced weight, robustness and lower cost. Though the technology is ready to provide such sensors, working hardware has not been achieved. Innovation is needed to achieve true sensor fusion, where the information from multiple bands is fused at the sensor, rather than combined further downstream in the data flow. Some performance needs include low thermal time constants, fast frame imaging rates around 1kHz, wide bandwidth, and in situ image processing and data multiplexing.

A focal plane array and processing electronics should be capable of a noise equivalent temperature difference < 0.05 ºK for LWIR and < 0.5 ºK for MMW detection. Atmospheric sensors should be capable of receiving images through clouds and turbulence, should deliver real-time images, and have outputs compatible with conventional multiplexing architectures. Space-based sensors, in addition, should have high data processing capability, and power and weight requirements lower than currently available configurations. Dual mode sensor fusion assemblies, as opposed to true sensor fusion configurations, will not meet this topic's requirements, because the dual sensor arrays have size, weight, and cost, which are too high.

PHASE I: The phase I activity shall include, but not be limited to, the design/fabrication/demonstration of a proof-of-concept sensor assembly. One potential sensor configuration (among others) might consist of a blocked-impurity-band-type detector, or bolometer, merged with a micromachined cavity waveguide thermal sensor and two band processing electronics. The bands most appropriate would be in the MMW and LWIR range.

PHASE II: Based on the developments in Phase I, the Phase II activity will design/fabricate/demonstrate a true sensor fusion assembly amenable to assembly-line production. For various applications, the FPA chip design shall be merged with multiplex signal processing architecture electronics allowing flexibility to address mutually (Air Force/contractor) agreed applications such as: 1) smart target vs. decoy identification; 2) fast-frame imaging in the LWIR and MMW bands; 3) filtering and imaging in the mid-wavelength infrared (MWIR) (3-5µm) range; 4) filtering and imaging in both LWIR and MWIR colors for discrimination and long range detection of selected objects independent of weather; 5) active and passive modes; 6) comparisons with stored reference images. Performance specifications, performance test data reports, and information on specialized test equipment shall be documented for the agreed applications.

PHASE III DUAL USE APPLICATIONS: The basic sensor fusion/processing arrays developed in Phase II, together with application specific versions, will significantly enhance air traffic control, vehicle traffic control, satellite-borne surveillance, and aircraft landing site stored image vs. pilot view operations.

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3. G. M Rebeiz, et al., "Monolithic Millimeter-Wave Two-Dimensional Horn Imaging Arrays," IEEE Transactions on Antennas and Propagation, Vol. 38, No. 9, pp. 1473 1482, Sep 1990.

KEYWORDS: Long Wavelength Infra-Red (LWIR), True Sensor Fusion, Micromachined Cavities, Millimeter, Wavelength (MMW), Fast Frame Imaging, Multiplexing Architectures

AF00-240 TITLE: Analog-to-Digital Converter Development

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Airborne Communication Node (ACN); Global Positioning System (GPS); and Military Satellite Communications (MILSATCOM)

OBJECTIVE: To investigate and comprehend the complex balance associated with assembling digital receivers for multi-platform applications.

DESCRIPTION: The manufacturing of receivers with more digital components is an effort to bring the digitization functions closer to the antenna portion of the receiver and reduce the number analog receiver components which tend to be temperature sensitive. This can result in a higher performance (dynamic range > 80 dB; bandwidth > 100 MHz) digital receiver that meets the demands evolving commercial and military applications. One example of this pertains to global positioning satellite (GPS) receivers, which must operate effectively against higher (120 dB) jamming-to-signal ratios (J/S). Another is the development of space-based communication and radar functions which minimally require the greater bandwidth mentioned above plus increased distributed processing capability (> 5 GOPS). A compact digital receiver will play a key role as the preliminary signal-processing hub integrated to the ground-based or space-based sensor.

Although efforts have made to reduce the size, weight and power of digital receivers on aircraft platforms, all of these factors need to be reduced by at least an order of magnitude for ground-based and space-based operations. An important aspect of a hand-held or space-based digital receiver is the reduction of power in the components, which comprise the digital receiver. This includes components such as RF filters and amplifiers, mixed-signal electronics, digital signal processing electronics, and associated power converters/conditioners. These electronics also must consider the aspect of being capable of reliable operation within unique environments for at least ten years. Initially, a trade-off study should look at the eventual demonstration of a digital receiver which dissipates less than 10 Watts of power and have all of its electronics operate from a single power supply with point of load power distribution designed into the digital receiver components. Emphasis needs to be placed on balancing the performance versus power aspects of the analog-to-digital converters (ADCs), which can dissipate up to 50% of the receiver's total power.

PHASE I: Complete tradestudy examining the assembly and packaging of the necessary components required to have a functional digital receiver operate within a ground and/or space environment at a power dissipation level of less than 10 Watts. Identify the commercial uses for such a digital receiver. Effort should concentrate on the development of a high performance (resolution > 12 bits, sample rate > 200 Msps), reduced power dissipation (< 3 Watts) ADC, as it often dictates the overall receiver design. Examination of advanced device technologies (e.g., SiGe HBT, GaAs CHFET, InP HBT, etc.) coupled to unique mixed-signal circuit architectures (e.g., sigma-delta, sub-ranging, pipeline-interleaving, etc.) is appropriate in order to achieve the necessary ADC operating specifications and drive a high performance digital receiver solution.

PHASE II: Assembly and test of a prototype digital receiver for either ground or space as determined through component and packaging tradestudy. Reliability data must be gathered with predictions as to the receiver lifetime and which components are most likely to fail under unique environment operation. Cost analysis of the digital receiver unit must demonstrate applicability to commercial and military platforms and should drive the necessity for continual improvement to the receiver's critical components.

PHASE III DUAL USE APPLICATIONS: Advancements to hand-held GPS units could provide more widespread insertion of navigation units into automobiles. Performance improvements to ADCs will always be of great interest to the cellular communications industry. Space satellite communications would benefit greatly from reduced power digital receivers with increased functionality and programmability. Encourages vendors of space qualified electronics to improve their specifications recognizing that increased bandwidth and data transmission in space is of future commercial need.

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2. Robin Getz, "Single-Slope A-D Conversion for High-Resolution Measurements", Computer Design, V. 34 (Nov. 1995), pp. 112-114.

KEYWORDS: Digital GPS Receivers, RF (Radio Frequency), ASIC (Application Specific Integrated Circuit), ADCs (Analog-to-Digital Converters), J/S (Jamming-to-Signal Ratios), Space Qualified Electronic Component

AF00-241 TITLE: Improved Spacecraft Telemetry, Data Acquisition Systems

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: Develop a user-configurable analog signal processing/data conversion array to improve integration/reliability/radiation tolerance of spacecraft telemetry data acquisition systems.

DESCRIPTION: Acquisition of analog components suitable for spacecraft telemetry signal conditioning and data acquisition systems remains especially difficult for many satellite programs which must operate in either radiation-hardened or radiation-tolerant environments. Radiation-hardened analog component types, in many instances, cannot be found. Instead, in many cases commercially produced components are screened on a lot basis for radiation tolerance, and with appropriate mitigation techniques, can be used under certain program- specific circumstances. This approach is time consuming, expensive, risky, and yields program-specific, low-integration solutions to the general problem of spacecraft telemetry data acquisition systems. This development is intended to result in a modular, user- configurable analog signal conditioning and data conversion array with application to telemetry and potentially other satellite systems (possibly termed as a "Field Programmable Analog Array," FPAA). Just as the radiation-hardened Field Programmable Gate Array (FPGA) has solved certain satellite digital implementation issues, the FPAA seeks to solve analog implementation issues for satellite telemetry signal conditioning and data acquisition systems. Each module of the array has several analog components which can be internally connected together (or simply not used), as the user decides, after most or all circuit fabrication steps have been completed. Some components in the module may have user- selectable options (such as gain). The resulting circuits are not expected to be high-performing, but should be adequate for telemetry systems. The array modules inputs and outputs may be interconnected to each other within the array. The number of modules per array may be small, and the number of module types is expected to be few. The user configuration may be volatile, non-volatile, or mixed. Another product of this effort is a design environment, which allows the user to design the program-specific circuit within the array, accurately model its performance, and facilitate programming of the array.

PHASE I: Phase I activity shall include: 1) investigate current modular, user- configurable analog data acquisition components, 2) determine a set of requirements which would satisfy many spacecraft telemetry signal conditioning and data acquisition systems, 3) perform tradeoffs and define an appropriate architecture, 4) develop a plan to design, fabricate and characterize a prototype, 5) determine requirements for a Computer Aided Design (CAD) environment which predicts user-configured performance in a standard, widely useable output (i.e. Spice model), 6) develop a plan for the user to configure the array, with rapid turnaround and 7) provide breadboard demonstration of basic principles.

PHASE II: Develop, fabricate, characterize and deliver prototypes, including: 1) detailed design and simulation of the array architecture, 2) fabrication, test, and detailed characterization/demonstration of several array prototypes, 3) delivery of prototypes for customer, and user evaluation, 4) develop a user-environment to design, model, and define configuration of the array, which can interface with industry-standard tools, 5) develop a plan for the user to configure the array, and facilitate customer programming of prototypes for evaluation, 6) develop a plan to migrate the design to a radiation-hardened production facility.

PHASE III DUAL USE APPLICATIONS: The Array should be useful for the large number of commercial satellites planned for the near future. The Array (produced on regular, non-rad tolerant processing lines) would have broad applicability for manufacturing, automotive, and energy production industries.

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1. Julio Faura, Chris Horton, et al., "A New Field Programmable System-on-a-chip for Mixed Signal Integration," European Design & Test Conference 1997, http://www.sidsa.es/fipsoc_r.htm.

2. Robert C. Moore, Spacecraft Command and Telemetry, In: Fundamentals of Space Systems (A94-34826 11-12), New York, Oxford University Press, p. 601-627, 1994.

KEYWORDS: Spacecraft Telemetry, Field Programmable Gate Array (FPGA), Circuit Fabrication, Program-Specific Circuit, Analog Components, Array Modules

AF00-242 TITLE: Low Power InP MMICs for Low Noise Receivers

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

OBJECTIVE: To minimize the dc power consumption in phased array receive antennas by circuit design and device modifications.

DESCRIPTION: Phased array antennas provide multiple beam opportunities with agile scanning capability. Arrays for satellite receivers will contain several hundred elements to allow the formation of narrow beamwidths. These arrays will dissipate excessive power unless the dissipation per element is low. Unfortunately, low power dissipation is hard to maintain with stringent requirements on noise figure (NF) and intermodulation products (IP3). Paths to reduced power dissipation have included the use of indium phosphide (InP) technology with low drain voltage and series-connected devices that share drain current. These and other techniques such as feedback and use of hybrid technologies can be used to reduce dc power consumption while maintaining suitable NF and IP3 capabilities. The intent of this program is to explore the best approach to achieving minimum (phased array antenna element) power dissipation and demonstrate the level of performance that can be achieved in associated low noise amplifiers for satellite application at 44 GHz.

PHASE I: The first phase of this program will include a study of ways to reduce power consumption through innovations in circuit design and device modifications. This will lead to the establishment of dc power goals for Microwave Monolithic Integrated Circuit (MMIC) technology as a function of NF, gain, bandwidth, IP3 and frequency. Specific goals will be projected for a mutually agreed (Air Force/Contractor) receive array. Also, a plan and working relationship with a foundry will be developed to demonstrate the performance of circuit concepts at N4MIC level and to implement any proposed device modifications.

PHASE II: Based on the receive array selected in Phase 1, mask sets will be designed using foundry design rules, novel circuit concepts and simulations to produce low power, low noise MMIC performance at 44 GHz. Wafer lots will be fabricated and tested to demonstrate performance. Devices will be tested in Radio Frequency (RF) fixtures but a complete module design will not be required. Proposed device design innovations will be evaluated and introduced into the foundry process if found to be advantageous.

PHASE III DUAL USE APPLICATIONS: Phase III is the process of completing the development of a product to make it commercially available. Military applications account for less than a third of the present III-V semiconductor device market. Commercial applications include personal telecommunications systems, wireless local area network, automobile sensors, security systems, and intelligent highway systems.

REFERENCES:

1. Lo, D. C. W., et al. "A High-Performance Monolithic Q-Band InP-Based HEMT Low-Noise Amplifier," IEEE Microwave and Guided Wave Letters, vol. 3, pp 299- 301, 1993.

2. Kobayashi, K. W., et al. "A 44 GHz InP-Based HBT Double-Balanced Amplifier with Novel Current Re-Use Biasing," in IEEE MTT-S Int. Microwave Symp. Dig., 1998.

3. Kobayashi, K. W., et al. "The Voltage-Dependent IP3 Performance of a 35-GHz InAlAs/InGaAs-InP HBT Amplifier," IEEE Microwave and Guided Wave Letters, vol. 7, pp 66-68, 1997.

KEYWORDS: Phased Array Antennas, Noise Figure (NF), Inter-nodulation Products (IP3), Microwave Monolithic Integrated Circuit (MMIC), Feedback, Hybrid Technologies

AF00-243 TITLE: Antenna Control Computer for TT&C Phased Array Antenna

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Air Force Satellite Control Network (AFSCN)

OBJECTIVE: Develop/demonstrate a low-cost processor and associated software that will provide antenna control for TT&C operations in satellite control.

DESCRIPTION: Phased array antenna offers improved performance over the existing parabolic dish antenna presently used in ground stations for satellite control. However, high phased array cost due to stringent tracking, telemetry and commanding (TT&C) requirements (hemispherical coverage, simultaneous transmit and receive, multiple beams, and high gain/noise temperature (G/T)) prevent it from adapting for satellite control application. There is no phased array control computer in existence today that can support control of phased array antenna for TT&C operation. The objective of this research is to develop a low cost array control processor and software for phased array antenna in support of satellite TT&C operations such as the Air Force Satellite Control Network (AFSCN). This antenna control computer should be capable of performing antenna monitoring, diagnostic, beam steering and scheduling, as well as other command and control functions. It should also be able to interface with ground station satellite operations control through a communication network and input/output units for operator interface. Successful development of a low cost array control processor will provide a key element in the implementation of an affordable, multi-beam, conformal phased array antenna for simultaneous multiple satellite control operations.

PHASE I: Phase I activity shall include: (1) develop general performance, software and data processing requirements for supporting TT&C operation; (2) identify and assess technical issues associated with the selection of different control approaches; (3) design candidate software and processor architectures which can provide a range of operating modes from minimal impact to the existing ground station to full utility of phased array antenna capabilities. Alternative control and beam scheduling concepts will be assessed in terms of their effectiveness, cost, portability and expandability. Rank candidate designs for Phase II selection and implementation.

PHASE II: Based on the results of Phase I, the contractor shall: (1) select two most promising software and processor designs for further trade-offs on throughput, coding complexity, cost, operational flexibility, etc.; (2) employ incremental software and hardware-in-the-loop simulation to predict the effectiveness of the two candidates for antenna control operations; (3) down-select to a single design and implement a control processor to interface with a simulated subarray of 64/128 elements; (4) test and evaluate the performance of processor and software against various operational scenarios; (5) analyze the feasibility and performance of integrating the antenna control computer into a full-scale conformal array for AFSCN satellite control operation; and (6) assess the required modifications of the existing AFSCN ground station elements and operations as a result of replacing existing dish antennas with phased array antennas.

PHASE III DUAL USE APPLICATIONS: The antenna control computer developed in this research is equally applicable to both commercial and military satellite control operations. Low-cost phased array antennas are capable of improving commercial satellite control network performance and reducing maintenance and operational cost.

REFERENCES:

1. Liu, S. F., Survey of Phased Array Antenna for AFSCN Application, May 1998. Available from S. F. Liu, The Aerospace Corp., P.O. Box 92957, M5/656, Los Angeles, CA 90009-2957; Telephone 310/336-7670, FAX: 310/336-0562

2. Tomasic, B., Analysis and Design Trade-Offs of Candidate Phased Array Architectures for AFSCN Application, Presentation to the Second AFSCN Phased Array Antenna Workshop, Hanscom AFB, 31 March – 1 April 1998. Available from Dr. B. Tomasic, Telephone 781/377-2055, FAX: 781/377-5040.

3. Wu, T. K., "Phased Array Antenna for Tracking and Communication with LEO Satellites,"1996 IEEE International Symposium on Phased Array Technology, Boston, MA., Oct. 1996.
4. Mailloux, R. J., Phased Array Antenna Handbook, Artech House, 1994
5. Larson, W. J. and Wertz, J. R., Space Mission Analysis and Design, 2nd Ed., Microcosm,Inc. and Kluwer Academic Publishers, 1993
6. Air Force Satellite Control Network Space/Ground Interface, Aerospace Corporation TOR-0059(6110-01)-3, Rev. I, March 1992. Contact Aerospace Corp. Reports Distribution at 310/336-7260; Address: ATTN: Reports Distribution, The Aerospace Corporation, P. O. Box 80966, M1199, Los Angeles, CA 90080-0966.
7. The Air Force Satellite Control Network Capabilities Document, Aerospace Corporation TOR-96(1567)-2, September 1996. Contact Aerospace Corp. Reports Distribution at 310/336-7260; Address: ATTN: Reports Distribution, The Aerospace Corporation, P. O. Box 80966, M1199, Los Angeles, CA 90080-0966.

KEYWORDS: Satellite Control, Conformal Phased Array Antenna, Beam Scheduling, Beam Steering, Beamforming Computation, TT&C

AF00-244 TITLE: Low Cost T/R Module for TT&C Phased Array Antenna

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Air Force Satellite Control Network (AFSCN)

OBJECTIVE: Develop/demonstrate the feasibility of low-cost T/R modules to support tracking, telemetry and commanding (TT&C) operations in satellite control.

DESCRIPTION: Phased array antenna offers improved performance and reduced operational and maintenance cost over the existing parabolic dish antenna presently used in ground stations for satellite control. However, high phased array cost due to stringent TT&C requirements (hemispherical coverage, simultaneous transmit and receive, multiple beams, and high gain/noise temperature (G/T)) prevent it from adapting for satellite control application. An affordable active transmit/receive (T/R) module suitable for such application does not exist today. The objective of this research is to develop low cost T/R module technology for phased array antenna in support of satellite control operations, such as in the Air Force Satellite Control Network (AFSCN). Candidate modules will have dual-band (L and S), simultaneous transmit and receive, and switchable right-hand/left-hand (RH/LH) circular-polarization capabilities. This research will materially contribute to the implementation of an affordable, multi-beam, conformal phased array antenna for simultaneous multiple satellite control operations.

PHASE I: Phase I activity shall include: (1) develop module design requirements for supporting TT&C operation; (2) identify and assess technical issues that will impact the selection of constituent components and module architectures; (3) specify the required performance parameters of the T/R components such as phase shifter, power divider/combiner, power amplifier (PA), 90 deg hybrids, filter/limiter, variable attenuator, low noise amplifier (LNA), beamsteering controller, interface to beamforming network and array elements, power supply, etc.; and (4) design low cost (less than $100/module) candidate T/R modules. Component and module design concepts will be assessed in terms of their performance, cost, manufacturability, reliability and maintainability. The module must accommodate multi-layer RF beamforming network for two simultaneous independent, transmit and receive beams with full duplex operation. The module shall also be constructed as a line replacement unit to support hot maintenance requirement. Rank candidates for Phase II selection and fabrication.

PHASE II: Based on the results of Phase I, the contractor will: (1) select two most promising T/R module designs, (2) perform numerical simulation and refine design trade-offs on performance, packaging, cost, manufacturability, reliability, adaptability, etc.; (3) down-select to a single design and fabricate four T/R modules; (4) test individual T/R modules and compare the measured with simulated results; (5) develop efficient manufacturing process, test and quality control for large quantity production; and (6) perform realistic production cost and timeline analysis.

PHASE III DUAL USE APPLICATIONS: The T/R modules developed in this research are equally applicable to both commercial and military satellite control operations. Low-cost phased array antennas are capable of improving commercial satellite control network performance and reducing maintenance and operational cost.

REFERENCES:
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2. Tomasic, B., Analysis and Design Trade-Offs of Candidate Phased Array Architectures for AFSCN Application, Presentation to the Second AFSCN Phased Array Antenna Workshop, Hanscom AFB, 31 March - 1 April 1998. Available from Dr. B. Tomasic, Telephone 781/337-2055; FAX: 781/377-5040.
3. Wu, T. K., "Phased Array Antenna for Tracking and Communication with LEO Satellites,"1996 IEEE International Symposium on Phased Array Technology, Boston, MA., Oct. 1996.

4. Mailloux, R. J., Phased Array Antenna Handbook, Artech House, 1994
5. Larson, W. J. and Wertz, J. R., Space Mission Analysis and Design, 2nd Ed., Microcosm, Inc. and Kluwer Academic Publishers, 1993
6. Air Force Satellite Control Network Space/Ground Interface, Aerospace Corporation TOR-0059(6110-01)-3, Rev. I, March 1992. Contact Aerospace Corporation Reports Distribution at 310/336-7260; Address: ATTN: Reports Distribution, The Aerospace Corporation, P.O. Box 80966, M1199, Los Angeles, CA 90080-0966.
7. The Air Force Satellite Control Network Capabilities Document, Aerospace Corporation TOR-96(1567)-2, September 1996. Contact Aerospace Corporation Reports Distribution at 310/336-7260; Address: ATTN: Reports Distribution, The Aerospace Corporation, P.O. Box 80966, M1199, Los Angeles, CA 90080-0966.

KEYWORDS: Satellite Control, Conformal Phased Array Antenna, Simultaneous Transmit and Receive, Hemispherical Coverage, Active T/R Module, TT&C

AF00-245 TITLE: Affordable Beamforming Network for TT&C Phased Array Antenna

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Air Force Satellite Control Network (AFSCN)

OBJECTIVE: Develop/demonstrate feasibility of low-cost beamforming network for phased array antenna to support satellite TT&C operations.

DESCRIPTION: Phased array antenna offers improved performance and reduced operations and maintenance cost over the existing parabolic dish antenna presently used in ground stations for satellite control. However, high phased array cost due to stringent tracking, telemetry and commanding (TT&C) requirements (hemispherical coverage, simultaneous transmit and receive, multiple beams, and high gain/noise temperature (G/T)) prevent it from adapting for satellite control application. A low cost feed network that distributes radio frequency (RF) power to, and combines RF signals from individual transmit/receive (T/R) modules suitable for such application does not exist today. The objective of this research is to develop low-cost beamforming network technology for phased array antenna in support of satellite TT&C operations, such as in the Air Force Satellite Control Network (AFSCN). The feed network must accommodate two independent transmit and receive beams with full duplex operation. This research will materially contribute to the implementation of an affordable, multi-beam, conformal phased array antenna for simultaneous multiple satellite control operations.

PHASE I: Phase I activity shall include: (1) develop general performance and array feed/control network design requirements for supporting TT&C operation. The multilayer network must provide: RF beamforming (two transmit and two receive simultaneous beams), beamsteering and direct current (dc) power supply; (2) identify and assess technical issues associated with the selection of different RF/dc multilayer beamforming architectures and fabrication approaches; (3) design candidate network architectures using affordable technologies; and (4) assess candidate design concepts in terms of their performance (amplitude and phase errors, frequency bandwidth, isolation, loss, power handling, etc.), feasibility, manufacturability, reliability and cost. The network shall interface T/R modules/array elements and must accommodate real-time replacement of T/R modules to support hot maintenance requirement. Rank network candidates for Phase II development.

PHASE II: Based on the results of Phase I, the contractor shall: (1) select two most promising beamforming network designs; (2) perform numerical simulation and refine trade-offs on performance, manufacturability, reliability, cost, adaptability, etc.; (3) down-select to a single design and fabricate a complete network assembly capable of supporting a 64/128 planar subarray; (4) test the network and compare measured values with simulated results; (5) develop efficient manufacturing process, test and quality control for large quantity production; (6) perform realistic production cost and timeline analysis; and (7) assess the feasibility and cost of integrating the feed network into a full-scale conformal array (including distributed power supply) for AFSCN application.

PHASE III DUAL USE APPLICATIONS: The beamforming and control networks developed in this research are equally applicable to both commercial and military satellite control operations. A low-cost phased array antenna is capable of improving commercial satellite control network performance and reducing maintenance and operational cost.

REFERENCES:
1. Liu, S. F., Survey of Phased Array Antenna for AFSCN Application, May 1998. Available from S. F. Liu, The Aerospace Corp., P.O. Box 92957, M5/656, Los Angeles, CA 90009-2957; Telephone 310/336-7670, FAX: 310/336- 0562.
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3. Wu, T. K., "Phased Array Antenna for Tracking and Communication with LEO Satellites,"1996 IEEE International Symposium on Phased Array Technology, Boston, MA., Oct. 1996.

4. Mailloux, R. J., Phased Array Antenna Handbook, Artech House, 1994
5. Larson, W. J. and Wertz, J. R., Space Mission Analysis and Design, 2nd Ed., Microcosm, Inc. and Kluwer Academic Publishers, 1993
6. Air Force Satellite Control Network Space/Ground Interface, Aerospace Corporation TOR-0059(6110-01)-3, Rev. I, March 1992. Contact Aerospace Corporation Reports Distribution at 310/336-7260 ; Address: ATTN: Reports Distribution, The Aerospace Corporation, P.O. Box 80966, M1199, Los Angeles, CA 90080-0966.
7. The Air Force Satellite Control Network Capabilities Document, Aerospace Corporation TOR-96(1567)-2, September 1996. Contact Aerospace Corporation Reports Distribution at 310/336-7260; Address: ATTN: Reports Distribution, The Aerospace Corporation, P. O. Box 80966, M1199, Los Angeles, CA 90080-0966.

KEYWORDS: Satellite Control, Conformal Phased Array Antenna, Simultaneous Transmit and Receive, Hemispherical Coverage, Beamforming Network, TT&C

AF00-246 TITLE: Miniaturized Antenna Array for GPS Anti-Jam Applications

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Global Positioning System (GPS)

OBJECTIVE: Accurately determine individual gas turbine engine component life, real time, at any given time in service, operational role or environment.

DESCRIPTION: The Spatial filter or adaptive antenna nuller/beamformer is the most effective method of mitigating the effects of intentional and unintentional interference on the reception of GPS signals. These systems rely on an array antenna or Controlled Reception Pattern Antenna (CRPA), and an antenna controller or antenna electronics unit to create spatial nulls in the antenna pattern. These spatial nulls adapt to the changing environment around the air vehicle continuously placing reduced gain toward the interference sources and increasing gain toward the desired signal. Current CRPAs contain 4-7 antenna elements, with sizes ranging up to 14 inches in diameter. The large sizes of the arrays have prevented their use on several space-constrained platforms that could benefit from the capability provided by a CRPA antenna. The objective of this project is to develop a CRPA containing at least 7 elements in a maximum of 8-inch diameter footprint. The desired antenna should be capable of working with current antenna electronics (AE) units (AE/1A and GAS-1) and be compatible with conformal installations. Since antenna size is conventionally mandated by frequency of operation, this effort must go beyond conventional antenna techniques to research new methods and develop new techniques to create an antenna almost half it's normal size, while still maintaining antenna performance of a larger antenna. The ability to control the antenna pattern will provide the flexibility to negate GPS interference, regardless of direction, and the small antenna size will enable installation in a wide variety of military and commercial platforms.

PHASE I: Investigate technologies applicable to the size reduction of a seven element conformal array for use with current AE units. Model several candidate antennas using electromagnetic modeling software to determine the ability of the antenna to provide sufficient null depths, antenna patterns, VSWR and mutual coupling for use with the GPS system. Select a viable candidate based on performance and cost trades.

PHASE II: Fabricate a proof-of-concept breadboard antenna system based on the selected design that demonstrates all key performance and physical features. Conduct laboratory and/or antenna range testing to mutually (Air Force/contractor) agreed upon specifications to measure CRPA performance with and without an AE like unit.

PHASE III DUAL USE APPLICATIONS: As GPS receivers become standard equipment in many civilian applications, particularly in general and commercial aviation, the necessity to ensure high availability of the GPS signals under all operating conditions will increase dramatically. The susceptibility of GPS signals to even low level interference is well documented. The CRPA/AE is the only approach capable of defeating all interference sources. Development of a small, low cost CRPA/AE will have high commercial potential.

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1. Rolf Johannessen, “The Role of Adaptive Antenna Systems When Used With GPS,” In: ION, Satellite Division’s International Technical Meeting, Colorado Springs, CO, Sep. 19-23, 1988; Proceedings (A90-13976 03-17), Washington, DC, Institute of Navigation, 1989, p. 267-270.
2. A. Gecan, M. Zoltowski, "Power Minimization Techniques for GPS Null Steering Antenna,” Proceedings of ION GPS-95, Part 1 of 2, pp. 861-868, September 1995
3. A. Gecan, P. Flikkema, A. D. Snider, “Jammer Cancellation with Adaptive Arrays for GPS Signals,” IEEE SOUTHEASTCON ’96. Bringing Together Education, Science and Technology (Cat. No. 96CH35880) p. 320-3, IEEE, New York, NY, l996.

4. D. J. Moelker, E. van der Pol, Y. Bar-Ness, “Adaptive Antenna Arrays for Interference Cancellation in GPS and GLONASS Receivers,” IEEE 1996 Position Location and Navigation Symposium (Cat. No. 96CH35879) p. 191-8; IEEE, New York, NY 1996.

KEYWORDS: Spatial Filter, Adaptive Antenna Nuller/Beamformer, Controlled Reception Pattern Antenna (CRPA), GPS Satellites, Antenna Controllers, Anti-Jam Applications

AF00-248 TITLE: Re-configurable Embedded Spacecraft Antenna

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Space Based Radar

OBJECTIVE: Develop and test the principles of embedding re-configurable RF transmitting and receiving framework in the structure of spacecraft.

DESCRIPTION: The ability to convert a part or all of the structure of the spacecraft into a single antenna or separate antennas will enhance the capability and survivability of space communication systems. One manifestation of this concept would be to design and incorporate Radio Frequency (RF) transmitting and receiving elements into the spacecraft frame and its various appendages. These elements can then be configured into an antenna, whose shape can be changed in real time to maximize its effectiveness depending on the position and attitude of the spacecraft. If proven feasible, such an antenna may be a weight and space saving replacement for the primary antenna. Alternatively, it could serve as a back up in case the primary fails. This concept will become more important as the footprints of satellites continue to shrink in the future. A project is needed to determine how to implement this concept to different types of spacecraft. The results of this program will benefit both military and commercial satellite systems.

PHASE I: Develop basic ideas of embedding RF transmitting and receiving elements in various spacecraft materials, components, and subsystems. Design and verify the technique to form an antenna and change its shape in real time. Model the efficiency of such antennas for several commonly used satellite types.

PHASE II: Design and build prototype structures to verify modeled predictions. Develop and test real-time re-configurable linkages between RF elements. Build and test real-time re-configurable antennas. Collect engineering and cost-benefit data needed to establish the feasibility and practicality of the concept.

PHASE III DUAL USE APPLICATIONS: The results of this project will provide extremely useful information to both military and commercial spacecraft designers. As the size of spacecraft continue to shrink, it is clear that the primary antenna systems are the least scalable of all subsystems. Substantial savings in weight and space will result if the frame could be used to replace the primary antenna on any spacecraft, military or commercial.

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1. C. Puente, R. Pous, "Fractal Design of Multiband and Low Side-Lobe Arrays," IEEE Transactions on Antennas and Propagation, vol.44, no.5, pp.730-739, May 1996.
2. N. Cohen, "Fractal Antennas: Part I," Communications Quarterly, pp.7-22, Summer 1995; "Fractal Antennas: Part 2," Communications Quarterly, pp. 53-66, Summer 1996.

KEYWORDS: Spacecraft Structure, Secondary Antenna, Spacecraft Attitude Related References, Embedded RF Transmitting/Receiving Elements, Omni-Directional Antenna, Embedded Re-configurable Antenna

AF00-249 TITLE: Digital Receiver Development for AWACS Electronic Support Measures

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

OBJECTIVE: Accelerate the development and availability of digital receiver modules.

DESCRIPTION: This topic seeks to leverage recent advances in digital receivers and high speed analog to digital converters for use in ESM systems. The emphasis is to produce a digital receiver module with a very small size and weight. The spurious free dynamic range requirement is a minimum of 80 dB. The receiver module will contain RF amplifiers and filters and have a tunable RF front end between 100 and 500 MHz and a bandwidth of at least 1 MHz. The incoming RF will need to be bandpass filtered and directly sampled with a very high speed analog to digital converter operating at or above 1 GHz. The digital receiver module will also contain a digital sampling and filtering section, so a connection can be made directly to a signal processing system.

PHASE I: Develop a detailed digital receiver design, prediction, and simulation demonstrating the performance listed in the description.

PHASE II: Construct a prototype of the Phase I design and compare measured performance to the Phase I design and simulation.

PHASE III DUAL USE APPLICATIONS: The development of digital receivers will improve performance and decrease costs for numerous consumer applications including land mobile radios, portable high definition television receivers, air traffic control communication receivers and other satellite receivers. The advancement of this technology will also have application in making consumer electronics more portable.

REFERENCES:
1. CP204N16708 Part 1 of 2; dated 12 July 1988, Prime item Development Spec. for ESM Group Configuration item 23N708A, for NATO E-3A and BLOCK 30/35 E-3 Systems Contract F1628-87-C-0030

2. CG204N16715-3; dated 10 June 1988, Program Performance Specification CPCEI 20N715A ESM Operational Computer Program for E-3 System Contract F1628-87-C-0030

KEYWORDS: Digital Receiver, RF, Radar, Signal Processing Systems, Electronic Support Measures, Small Size and Weight

AF00-250 TITLE: Recognition Algorithms for Combat Identification

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace, Weapons

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Intelligence Surveillance and Reconnaissance (ISR) Integration System Program Office (SPO)

OBJECTIVE: Develop and prove new data processing techniques to detect, recognize and identify targets of interest from sensor returns.

DESCRIPTION: The need to identify targets has never been greater than it is today. The advent of beyond visual range (BVR) weapons means visual identification of targets is no longer optimal—more reliable long-range combat identification (CID) information is required to support optimal employment of weapons. Unfortunately, CID technological developments have not historically received the priority necessary to keep pace with developments in many other technology areas. As a result, CID systems currently possess significantly less capability than the weapon systems they support. There are two major technological areas that need to be addressed in attempting to develop robust Combat Identification solutions for the warfighter. They are: (1) sensor system (hardware) development and techniques to provide target signature (phenomenological) data on air and surface targets at long range/all aspect and (2) data processing techniques (software) to exploit the data and yield a high confidence, unambiguous identification of the target. This SBIR topic addresses the second of these two areas. New data processing techniques are needed to detect, recognize, and identify targets of interest from sensor returns. Classification algorithms may exploit any type of electromagnetic (and other) target signature, such as radar, infrared, laser, etc. Fusion techniques are of special interest. Key goals are to raise probability of correct identification and to reduce identification time. Techniques that reduce or eliminate the need for a extensive target signature libraries and identify targets irrespective of aspect or orientation should also be considered. Although the techniques must be suited for air-to-air, air-to-surface and/or surface-to-air combat identification applications, they should also be transferable to civil and commercial use.

PHASE I: Phase I activity shall include: 1) developing new data processing techniques, 2) performing analysis on feasibility of new techniques, and 3) limited demonstration of selected techniques to provide proof of feasibility.

PHASE II: Phase II activity shall include: 1) final development of the selected data processing techniques identified in Phase I; 2) prototype demonstration of the data processing algorithm applied to relevant target signatures; and 3) development of a comparative cost/efficiency analysis of the new data processing algorithm against current combat identification capabilities.

PHASE III DUAL USE APPLICATIONS: Resulting technology will be applicable to all DoD components and any commercial industry with detection/identification requirements (e.g., transportation management, law enforcement).

REFERENCES:
1. Proceedings of the 1999 IEEE Aerospace Symposium, Aspen, Colorado (March 1999).

2. Cranos, Roger, "Combat Identification in the Future: Maintaining a Balance," presented at the Society of Photo-Optical Instrumentation Engineers (SPIE) 11th Annual International Symposium on Aerospace/Defense Sensing, Simulation and Controls, 20-25 April 1997.

KEYWORDS: Data Processing Techniques; Detect, Recognize, Identify; Reduce Identification Time; Probability of Correct ID; Combat Identification; Air-to-Air; Air-to-Surface; Surface-to-Air

AF00-251 TITLE: Sensor Systems for Combat Identification

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Intelligence Surveillance and Reconnaissance (ISR) Integration System Program Office (SPO)

OBJECTIVE: Develop and prove new methods of target identification by exploiting target signatures in electromagnetic spectrum.

DESCRIPTION: The need to identify targets has never been greater than it is today. The advent of beyond visual range (BVR) weapons means that visual identification of targets is no longer optimal—more reliable long-range combat identification (CID) information is required to support optimal employment of weapons. Unfortunately, CID technological developments have not historically received the priority necessary to keep pace with developments in many other technology areas. As a result, CID systems currently possess significantly less capability than the weapon systems they support. There are two major technological areas that need to be addressed in attempting to develop robust Combat Identification solutions for the warfighter. They are: (1) sensor system (hardware) development and techniques to provide target signature (phenomenological) data on air and surface targets at long range/all aspect and (2) data processing techniques (software) to exploit the data and yield a high confidence, unambiguous identification of the target. This SBIR topic addresses the first of these two areas. This SBIR is to develop or modify sensor systems to provide target signature data for the purpose of target identification. The sensors may exploit any type of electromagnetic (and other) target signature, such as radar, infrared, laser, etc. Sensors may be airborne, space, or surface based. Collection techniques should not provide any indication or warning to the target. Application to autonomous platforms is of particular interest. Although the systems must be suited for air-to-air, air-to-surface and/or surface-to-air combat identification applications, they should also be transferable to civil and commercial use.

PHASE I: Phase I activity shall include: 1) developing new sensor concepts for target identification, 2) performing analysis on feasibility of new sensors, and 3) limited demonstration of selected sensors to provide proof of feasibility.

PHASE II: Phase II activity shall include: 1) final development of the selected sensor systems identified in Phase I; 2) demonstration of the sensor system; and 3) development of a comparative cost/efficiency analysis of the new sensor system against current combat identification systems.

PHASE III DUAL USE APPLICATIONS: Resulting technology will be applicable to all DoD components and any commercial industry with detection/identification requirements (e.g., transportation management, law enforcement).

REFERENCES:
1. DTO: Modern Network Command and Control Warfare Technology (WE.23) SE.76
2. Cranos, Roger, "Combat Identification in the Future: Maintaining a Balance," presented at the Society of Photo-Optical Instrumentation Engineers (SPIE) 11th Annual International Symposium on Aerospace/Defense Sensing, Simulation and Controls, 20-25 April 1997.

KEYWORDS: Sensor Systems, Target Identification, Data Collection, Airborne, Space-Based, Air-to-Air, Air-to-Surface, Surface-to-Air, Autonomous Platforms

AF00-252 TITLE: Modern Network Command and Control Warfare (Compass Call Block 40 Improvements)

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Intelligence Surveillance and Reconnaissance (ISR) Integration System Program Office (SPO)

OBJECTIVE: To investigate and develop new concepts and technology in modern network command and control warfare, specifically to detect, deinterleave, and predict the frequency hopping scheme used by non-cooperative communicators in a network for the purpose of conducting electronic warfare.

DESCRIPTION: This concept investigates, simulates, analyzes, develops, and tests software and hardware enhancements to target command and control, frequency hopping networks. The use of frequency hopping offers anti-jam (AJ), low-probability-of-intercept (LPI), and protection from Anti-Radiation Missiles and it is well known that such systems will proliferate. These networks employ sophisticated digital techniques that provide multiplexing and multiple access that offer many advantages for the modern warfighter. Future fast frequency hopping techniques will possibly preclude the use of current follow jamming techniques. It will be necessary to develop new and effective techniques to detect, deinterleave, and identify in real time.

PHASE I: Investigate the feasibility of developing advanced recognition and countermeasure techniques for targeting adversarial frequency hopping radio networks. Investigate how operational and tactical requirements can be satisfied by recently developed algorithms and project performance capabilities based on realizable, state-of-the-art technology.

PHASE II: Develop a prototype system and demonstrate software and hardware enhancement for providing non-lethal means of disrupting enemy frequency hopping command and control networks.

PHASE III DUAL USE APPLICATIONS: The resulting technology will have direct application to civilian law enforcement and drug interdiction where the use of frequency hopping, tactical, radio are proliferating. Also, the algorithms will have potential application in commercial radio system that employ frequency agility and require fast acquisition schemes.

REFERENCES: DTO: Modern Network Command and Control Warfare Technology (WE.23) SE.76

KEYWORDS: Frequency Hopping + Spread Spectrum + Electronic Warfare; Denying and Disrupting Enemy Command and Control; Target Command & Control Systems; Software/Hardware Enhancement for Frequency Hopping

AF00-253 TITLE: Modulators for Analog RF Distribution

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

OBJECTIVE: Develop modulators to meet the performance goals for RF analog distribution.

DESCRIPTION: Photonically implemented (fiber optic) RF analog distribution links exhibit many desirable characteristics, such as small size and weight, low loss, and low electromagnetic interference. The external modulator is a key component in the RF link. Improved modulator performance characteristics over currently available modulators are needed to meet the requirements for Air Force applications. In particular, a reduction in the half wave voltage (or equivalent modulation voltage) is needed. This SBIR seeks the development of wide bandwidth (0.002 to >20 GHz) modulators with half-wave voltage less than 1 Volt, operating in the 1.3 to 1.55 micron wavelength range. Other important factors which should be addressed, include optical power throughput and losses, dynamic range, size, and cost. Integrability with electronics is a desirable feature.

PHASE I: Develop a proposed concept, including experimental results, which demonstrates the viability and feasibility to meet the above requirements.

PHASE II: Fabricate and demonstrate external modulators which meet the above requirements, and commercialize the product.

PHASE III DUAL USE APPLICATIONS: The potential for dual use commercialization is excellent. Although RF distribution links and commercial fiber optic communications are similar technologies, the performance requirements for military systems are much greater than for commercial applications. Modulators meeting the Air Force’s requirements, will easily exceed the commercial requirements, and would most likely drive new commercial applications.

REFERENCES:
1. High-Frequency Photonics by TRW Space & Defence Sector Space and Electronics Group, D.T. Nichols and J.D. O’Keefe, Report 98056117
2. Compact Optica Payloads by Hughes Space and Communications Company, D.A. Rockwell and R.J. Francis, Report 98151927
3. RF/Optical Modulator Integration by Tracor Inc. Tracor Aerospace Electronic Systems, J.T. Gallo and A.N. Feineman, Report 98203905

KEYWORDS: Fiber optic link, Microwave, Modulator, Wideband, Analog distribution

AF00-255 TITLE: Laser Navigation Aid

TECHNOLOGY AREAS: Air Platform, Sensors/Electronics/Battlespace

OBJECTIVE: Develop a rugged, eyesafe, rangefinder system to accurately locate aircraft runways for landing.

DESCRIPTION: A compact, low-cost laser transmitter-receiver system is needed for acquisition and ranging of runway locations and altitudes for aircraft landings at unfamiliar or radio-silent locations. The laser source must be totally eyesafe yet be capable of measuring ranges to < 1 m accuracy and distances greater than 5 km. Passive marking of the runway endpoints for enhanced signal return to the rangefinder system is allowed. Typical laser sources operating in this regime are large and complex Nd lasers frequency converted to 1.5 microns. Research and development are desired, which can demonstrate an innovative way of achieving the required rangefinding with a low-cost, highly-robust, compact, airworthy system. A cost goal of less than $15,000/unit for greater than 100 units is desired.

PHASE I: Demonstrate the feasibility of an innovative technique, concept, or device, which would lead to major improvements in cost and size compared to currently available airborne rangefinding systems.

PHASE II: Demonstrate a complete device suitable for flight testing which incorporates the innovation demonstrated in Phase I. Device performance will be tested under a full suite of environmental extremes including lifetime, failure modes, vibration and temperature changes.

PHASE III DUAL USE APPLICATIONS: The contractor will develop a packaged rangefinding system based on lessons learned in Phase II. Follow-on contracts to build electro-optic brassboard systems for specific military applications may be possible. The technology developed to make an eyesafe rangefinder system will also be of interest for some commercial applications. An inexpensive rangefinder system would provide added safety for small aircraft using primitive runways. Once a source becomes available, additional new applications are likely to appear.

REFERENCES:
1. Conference on Lasers and Electro-Optics, 1998 Technical Digest Series, Volume 6 (Optical Society of America, Washington DC).
2. Advanced Solid State Lasers, 1999 Technical Digest, (Optical Society of America, Washington DC).
3. Kamerman, Gary W., ed. Laser radar technology and applications. Bellingham, WA : Society of Photo-Optical Instrumentation Engineers, v2748, 1996. 394p.

KEYWORDS: Laser Radar, Altimeter, Compact, Rangefinder, Navigation, Eyesafe, Low Cost

AF00-256 TITLE: Low Cost Electro-Optical Reconnaissance Sensor System

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

OBJECTIVE: Develop and demonstrate sensor techniques and/or hardware capable of significantly reducing the cost of airborne reconnaissance sensors for high altitude, long range E-O imaging.

DESCRIPTION: Airborne reconnaissance sensors for electro-optical (E-O) imaging, particularly those developed for high altitude aircraft, have historically been high cost, low rate production systems designed to achieve exceptional performance in terms of sensitivity, spatial resolution, and area coverage. With the recent and continuing emergence of lower cost Unmanned Aerial Vehicles (UAVs), however, The Air Force needs to develop more affordable EO sensor systems in possibly greater numbers without excessively diminishing the performance capabilities. The objective of this project is to develop and demonstrate sensor techniques and/or hardware capable of significantly reducing the cost of airborne reconnaissance sensors for high altitude, long range E-O imaging. Proposed concepts should focus on using manufacturing techniques grown from commercial digital still camera processes and/or employing real-time on-board digital processing techniques to relax cost-driving sensor requirements.

PHASE I: Develop a thorough approach for employing the proposed techniques and/or hardware in current or planned E-O reconnaissance sensor systems. In addition the contractor shall make supported predictions of the expected cost savings and the impact on the critical sensor performance parameters.

PHASE II: Develop and demonstrate a prototype sensor system employing the proposed techniques and/or hardware. The prototype demonstration should directly support the critical performance parameters and cost savings predicted in Phase One, and mitigate technical risks associated with future insertion into an airborne reconnaissance system. If feasible, Phase Two could include an airborne prototype demonstration to address airworthiness issues.

PHASE III DUAL USE APPLICATIONS: A low cost E-O reconnaissance sensor would greatly expand the potential applications of high performance reconnaissance systems. Potential commercial applications include airborne remote sensing for geological, land use monitoring, agricultural, and mineral exploration purposes.

REFERENCES: Proceedings of the 1999 IEEE Aerospace Symposium, Aspen, Colorado (March 1999).

KEYWORDS: Airborne reconnaissance, Passive imaging, Electro-optic

AF00-257 TITLE: Global Reference Information Management

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: Develop multiple platform reference system simulation tools for space-based data collection and imaging sensors.

DESCRIPTION: Future military operational concepts emphasize the exploitation and fusion of multi-platform information to support effective reconnaissance and combat operations. Exploitation of space-based resources, in conjunction with theater-wide assets, will enable military leaders to dominate the theater of operations by providing global communications, precision navigation, accurate meteorological data, early warning of missile launches, and signals and imagery intelligence support. However, to exploit the full potential of space-based systems, many technical issues must be resolved. Of particular interest and technical challenge are issues related to the processing and sharing of imagery generated from space and the process of geo-locating objects of interest within those images. This geo-location process requires ultra-precise reference information of the imaging platform. Reference systems information includes position, velocity, attitude, and time, as well as the associated coordinate transformations. Recent Air Force Research Laboratory efforts have been oriented toward the paradigm of multiple aircraft within a theater of operations and have generated simulation software to assess the impact of reference systems errors on the fusion of multi-platform data and imagery, focusing on techniques for selecting the most appropriate coordinate frame/datum for each stage of the fusion process, techniques for maintaining precision and numerical stability during data transformations, and techniques for accurately assessing uncertainty and exploiting it as part of the measurement and sensor management processes. This effort will extend the multi-platform work to include radar imaging from space as an additional off-board data source. The focus of this effort will be on determining reference systems requirements to support space based radar including 1) space-based Synthetic Aperture Radar (SAR), 2) space-based interferometric SAR (IFSAR), and 3) Bistatic SAR (space transmit and air vehicle receive).

PHASE I: Develop software modules to simulate SAR, IFSAR, and Bistatic data collection from space and all pertinent reference information associated with those images. This will be accomplished by utilizing orbital mechanics and models for space based SAR and interferometric SAR for both aircraft and space-based sensors. The preferred approach is to develop Matlab modules that add a space-to-ground geo-location and targeting capability to the Air Force owned TRIMSIM (Theater-wide Reference Information Management Simulation Tool). Acceptable alternatives would be a stand alone simulation capability or modules compatible with another reference system/ targeting simulation tool. This will provide a basis for (a) determining the translation and rotation errors present in satellite-based images as a function of reference system errors for image registration, (b) providing pointing and targeting error for satellite-based SAR targeting for fusion with aircraft-based targeting, and (c) providing stereo SAR and interferometric SAR space to ground surface mapping errors. The simulation capability will be demonstrated using existing images from the Air Force Dynamic Database program or other suitable alternatives.

PHASE II: Use the software tool developed under Phase I to identify and test reference system technologies required for precisely registering remotely sensed data with data from onboard sources and/or other off-board sources. Investigate and define candidate space-based SAR imaging capabilities for target location based on IFSAR, stereo SAR, and Bistatic SAR. Key to these capabilities is accurate reference information to enable the generation of precision terrain elevation data and subsequent precise target location and mutual coherence between Bistatic platforms. One or more system level simulations will be used to determine expected pointing accuracies for actual digital elevation data, which will be compared to ground "truth" and to the pointing accuracies determined by the system level simulations. System level simulation will also be used to investigate spacecraft/spacecraft and spacecraft/aircraft Bistatic performance.

PHASE III DUAL USE APPLICATIONS: Dual use applications include environmental and geophysical monitoring, which would require precise registration of imagery or digital terrain data from varied sources, such as onboard resources, other airborne platforms, space-based assets, and fixed ground sites.

REFERENCES:

1. Berning S., Howe P., Jenkins,T. “Theater-wide Reference Information Management,” Proceedings of The National Aerospace and Electronics Conference (NAECON) 1996.

2. Chao, A., Beck, G., Berning, S., "Precise Reference Image Calibration and Alignment," Proceedings of the Institute of Navigation (ION) Annual Meeting, June 1999.

KEYWORDS: Space-Based Synthetic Aperture Radar, Reference Information, Digital Terrain Data, Space-Based Bistatic SAR, Integrated Navigation, SAR Image Registration, Interferometric SAR, SAR Image Geolocation, Multi-platform

AF00-258 TITLE: Hybrid Multi-Function FLIR/MWIR Ladar

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

OBJECTIVE: Develop advanced, multifunction FLIR/ladar techniques and components for long-range, Air/Space non-cooperative identification, ranging, and tracking.

DESCRIPTION: With the advent of multi-national conflicts involving a variety of friends, foes, and non-combatants, long range detection, non-cooperative identification (NCID), and targeting of both air and ground targets has become an extremely important aspect of battle management. In addition, cramped airframe space and diminished budgets continue to push technologies towards multi-function systems. This effort would investigate technologies needed to support a truly multi-function system consisting of a FLIR merged with an MWIR ladar system. The heart of the research would be a hybrid FLIR/Ladar focal plane. The entire focal plane would support FLIR operations; however, the center segment of the focal plane would possess additional performance characteristics necessary to support ladar functions, which may include but are not limited to active 1-D, 2-D, and 3-D imaging, vibration detection and imaging, precision range and velocity. The characteristics of the high performance sector of the array would be tailored to the requirements of the functions included in the design and may include but is not limited to, high spectral/temporal bandwidth, onboard pixel digitization & readouts, and temporal gating. Approaches to provide both active and passive multi-spectral capabilities may also be addressed with particular emphasis on target ID, missile warning and NBC detection and characterization. The technology would provide an optimal mix of passive and active technologies with the potential for enhanced performance in a wide variety of circumstances.

PHASE I: Design and assess system architectures and critical component technologies for airborne applications with secondary consideration for long-term space applications. Perform tradeoff analysis to maximize functional envelope, identify required observables, and define top level focal plane and component/system specifications. Critical issues associated with the technique including focal plane designs, feasibility demonstrations of key technologies, and atmospheric propagation from both air and space based platforms will be investigated.

PHASE II: Fabricate, demonstrate, and quantitatively evaluate a Multi-function FLIR/Ladar for long range, detection characterization, and ID of air, ground, and distributed targets. Critical issues associated with the system would be addressed and fabrication approaches would be demonstrated.

PHASE III DUAL USE APPLICATIONS: A multi-function FLIR/Ladar would greatly increase the potential applications of laser radar systems. Potential commercial applications include surveying, time-of-flight imaging for medical diagnostics, ocean research, and space object imaging applications. Imaging in factories for process control, imaging for nondestructive testing, and imaging for surveillance and security are also examples, where this technology can be applied.

REFERENCES:
1. G.R. Osche, et al., "Laser Radar Cross-section Estimation from High Resolution Image Data", Applied Optics 31:14, 31 (1992).
2. K. Costello, et al., "Transferred Electron Photocathode with Greater that 20% Quantum Efficiency beyond 1 Micron", SPIE 2250:177, (1995)
3. J.C. Hebden, and K.S. Wong, "Time-resolved Optical tomography", Applied Optics 32:4, (1993)

KEYWORDS: Laser Radar, Laser Vibrometry, Active Imaging, Laser Rangefinder, Passive Imaging, Range Imaging

AF00-259 TITLE: Synthetic Prediction Technologies for Multiple Target Scenario Modeling

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace, Weapons

OBJECTIVE: Develop innovative target data collection techniques and phase history modeling techniques for complex settings.

DESCRIPTION: Target classification and identification are capabilities required by the Air Force to successfully carry out many of its combat missions. However, the variability in target signatures as a function of frequency, aspect angles and sensor operating scenarios makes reliable target identification a most formidable task. The Air Force is actively pursuing synthetic data prediction techniques for targets in complex scene settings to support Automatic Target Recognition (ATR), data fusion development and evaluation, space based targeting technologies, reference system sensitivity analysis and battlefield awareness applications. Advances in target Radar Cross Section (RCS) prediction techniques and Computer Aided Design (CAD) geometry modeling tools are allowing synthetic predictions of tactical targets to be used in ATR development. However, enhancements in target geometry and signature data collection and innovative signature modeling techniques for complex natural settings are required to model complex targeting scenarios. Factors that have to be taken into account include scattering mechanisms, target modeling accuracy, measurement costs, computer simulations, and operating scenarios (moving targets, foliage, camouflage, and terrain-target interactions). To examine these issues, both physical and computer models having increasing levels of complexity in terms of materials and numbers and types of scattering centers can be formed and comparisons made between the actual physical electromagnetic scattering and the results from computer simulations. This topic solicits innovative solutions for one or more of the following items: (1) target geometry and material data collection techniques including ground truthing, (2) target signature and clutter measurement techniques, and (3) signature prediction techniques capable of generating phase history data for targets and/or clutter backgrounds.

In regards to item 1, accurate sampling of the target geometry and detailed construction by a specialized modeler are required to build an accurate CAD geometry model for a complex target body. Existing target geometry and material collection techniques for CAD modeling of complex targets are time intensive. Geometry collection methods that support target model builds for RF, IR, and EO models are needed. Novel techniques that use hand portable equipment to efficiently collect target geometry and material information on tactical targets are also of interest. The development of time efficient point collection methods that accurately sample the target of interest and techniques are required. This method must document point and material property data collected to support rapid CAD builds for tactical targets.

A thorough understanding of ground truthing is required to support algorithm development and evaluation in multi-sensor data collection of multi-target scenarios. Innovative field target ground truthing techniques documenting target type, position, pose, configuration, and articulation for both single target and multi-target scenario data collections are needed to support measurement data analysis. Ground truthing techniques that define the background terrain, measurement range clutter and terrain discretes are also of interest.

In regards to item 2, target signature and clutter measurement techniques are essential in the validation of geometry models. Multi-Sensor validation of CAD geometry models involves the comparison of synthetic signature data predicted from the CAD model to high quality measurement data over aspect angles existing in the measurement data. A measurement system to collect high quality calibrated target signature data over broad aspect coverage in elevation and azimuth in the field must be developed and suitable for CAD model validation efforts. In addition to support validation efforts, innovative clutter measurement techniques are needed to assist in characterizing clutter in natural settings. Special emphasis should be given to the RF system working from VHF to W band; however, innovative systems in the IR/EO 12 microns to broad band visible are also of interest.

In regards to item 3, existing full scene image prediction models are image domain based, thus, sensor specific. New phenomenology modeling techniques that support scene simulation for multiple sensors are needed to predict phase history returns from a complex scene including background terrain, trees, vegetation, and cultural clutter objects. These modeling techniques should allow for the prediction phase history such that radar processing for HRR, SAR and signature exploitation techniques can be applied as a post-processing step. These new modeling techniques should also assist in analysis of space based radar applications.

Target predictions take in account complex levels of materials and scattering mechanisms. Synthesizing wideband electromagnetic scattering from target models having increasing numbers of and types of scattering centers is important in producing coherent signatures. Computer modeling requirements are of interest to reproduce the scattering over the desired frequency ranges for successive targets. Accurate and efficient techniques for RCS prediction are also of interest.

PHASE I: Develop a design or limited proof of concept of one or more of the following: (Item 1) a target geometry and material collection system that supports target model builds; (Item 2) a man portable field measurement system capable of collecting calibrated target signature data, or any system capable of innovative and efficient means of characterizing clutter; (Item 3) a prototype a phase history modeling tool for synthesizing clutter scattering, or techniques for synthesizing wide-band electromagnetic scattering predictions with emphasis on target/background interactions. All synthetic signatures should be validated using measured results where possible. Document these efforts and prepare an outline of a program for Phase II.

PHASE II: Demonstrate via actual measurements or computer simulations one or more of the following: (Item 1) a target geometry and material collection system that supports target model builds; (Item 2) a man portable field measurement system capable of collecting calibrated target signature data, or any system capable of innovative and efficient means of characterizing clutter; (Item 3) a prototype a phase history modeling tool for synthesizing clutter scattering, or techniques for synthesizing wide-band electromagnetic scattering predictions with emphasis on target/background interactions. All synthetic signatures should be validated using measured results where possible. Document these efforts and prepare an outline of a program for Phase III. Pay particular attention to documentation on potential for commercialization.

PHASE III DUAL USE APPLICATIONS: The commercial potential is excellent. The development and/or enhancements of synthetic prediction techniques for targets in complex scene settings is expected to be useful in forecasting large area site modeling for cellular communication network design. Also the technology resulting from this effort is expected to be useful for developing more reliable collision-avoidance radars in commercial vehicles, industrial inspection, and manufacturing automation.

REFERENCES:
1. Bhalla, R. , H. Ling, J. Moore, D. J. Andersh, S. W. Lee, and J. Hughes, “3D Scattering Center Representation of Complex Targets Using the Shooting and Bouncing Ray Technique: A Review,” IEEE Antennas and Propagation Magazine, Vol. 40, No. 5, October 1998, pp. 30 – 39.
2. Sullivan, D., D. Andersh, T. Courtney, N. Buesing, and P. Jones, “Development of SAR Scene Modeling Tools for ATR Performance Evaluation,” Proc. SPIE, Vol. 3721, Algorithms for Synthetic Aperture Radar Imagery VI, April, 1999.
3. T. D. Ross, J. Mossing, "The MSTAR Evaluation Methodology" Proc. SPIE, Vol. 3721, Algorithms for Synthetic Aperture Radar Imagery VI, April 1999.
4. De Carolis, G., F. Mattia, G. Pasquariello, F. Posa and P. Smacchia, “X-Band SAR and Scatterometer Data Inversion based on Geometrical Optics Model and Kalman Filter Approach,” Journal of Electromagnetic Waves and Applications, Vol 8., No. 8, 1994, pp. 1017-1039.

KEYWORDS: Automatic Target Recognition, Computer Aided Design Geometry Modeling, Dynamic Ground Truthing, Signature Measurements, Data Collection, Scene Modeling

AF00-260 TITLE: ATR/Fusion Virtual Development and Evaluation Testbed

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace

OBJECTIVE: Develop a virtual distributed collaborative ATR and Fusion algorithm development and evaluation GUI based simulation environment.

DESCRIPTION: There is a significant and growing number of manned, unmanned, and national intelligence, surveillance, and reconnaissance data collection platforms. With all this vast amount of available data, there is a considerable requirement to develop and transition both ATR and fusion algorithms to the war fighting community to process, identify, and abstract the data to formulate useful information. In order to tackle such a large and difficult problem, ATR and fusion researchers located throughout the country need to collaborate together and leverage existing methodologies and algorithms to avoid duplicating research. In order to facilitate this type of collaboration, modeling and simulation environments must be assembled to design, develop and evaluate ATR and Fusion Algorithms i.e. multi-sensor tracking, ID, registration, and reference exploitation. The key building blocks of this environment would be as follows: 1) web based access to ATR and fusion data through distributed intelligent agents. 2) common algorithm interfaces to allow for re-use and sharing of algorithms. 3) hierarchical GUI based system to allow for easy algorithm cataloging and web based dynamic execution. 4) single algorithm or module code level collaboration among distributed researches. 5) provide deterministic simulation behavior. 6) ability to mix real time and non real-time algorithms. 7) algorithm and code level configuration management capability. 8) light weight modular components that are based on commercial standards such as CORBA, JAVA, DCOM, OpenGL, etc., and DOD standards such as the High Level Architecture 9) ability to function on Heterogeneous computer systems will the ability to incorporate other types of computing systems such as High Performance Computers (HPC) or embedded computer systems. 10) provides ability to operate with web based security and firewalls to allow protected sites to work together. 11) provides scripting capabilities for multiple unattended test runs for easily algorithm evaluation or metric based comparisons, and 12) produces modules which comply to DOD's High Level Architecture.

PHASE I: Design a virtual ATR/ fusion algorithm development and evaluation testbed incorporating the key characteristics described above. Identify potential Government off the Self (GOTS), Commercial off the Self (COTS) or other components that would be necessary to develop the Virtual Testbed. Identify any additional key characteristics that would be necessary or beneficial to the development of the Virtual Testbed. Develop a prototype-distributed testbed, which implements a few of the key characteristics described above and demonstrates the feasibility of developing the whole system along with a transition path to HLA compatibility.

PHASE II: Develop and implement an HLA compliant distributed collaborative Virtual Testbed. The contractor shall demonstrate the salient features of the distributed system on a least two different systems located at least 10 miles apart from each other.

PHASE III DUAL USE APPLICATIONS: Dual use applications of this technology would include distributed modeling and simulation, collaborative code development, and distributed component level configuration management across multiple development sites.

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2. T. D. Ross, J. Mossing, "The MSTAR Evaluation Methodology," Proc. SPIE, Vol. 3721, Algorithms for Synthetic Aperture Radar Imagery VI, April 1999.

KEYWORDS: Automatic Target Recognition, Sensor Data Fusion Modeling and Simulation, Distributed Computing, Collaborative Engineering, Client Serve

AF00-261 TITLE: Integrated Aperture for Passive and Active Electro-Optical Systems

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

OBJECTIVE: Develop architectures and components for optical apertures that integrate passive electro-optical (EO) search sensors with active EO systems. The active EO systems can include infrared countermeasure systems and targeting sensors (both coherent and direct detection sensing).

DESCRIPTION: Many future EO systems will consist of a combination of a passive infrared system, which provides some form of wide area search and detection, coupled with an active (laser) system, such as an infrared countermeasure system or a targeting system. To minimize the impact on the host platform, it is desirable for both systems to use the same optical aperture for interface to the external environment. Such a common aperture will have a number of requirements beyond the apertures currently used. These requirements include broad spectral band coverage (minimum 1 – 5 micrometers, possibly 1 – 12 micrometers), wavefront quality suitable for coherent laser radar operation, ability to tolerate large peak powers, and some form of agile steering capability. In addition, some form of device that will enable the passive and active systems to share the same aperture will be required. Because of the advantages of steering both the passive field of view and the laser beam at the output aperture,* methods that will integrate large angle steering into compact, low cost optical apertures are solicited.

PHASE I: Definition of aperture requirements, concept design, concept analysis, and proof-of-concept experiments.

PHASE II: Design, fabrication, and testing of integrated passive/active optical aperture with large angle beam steering. Aperture can be of a few centimeters in size.

PHASE III DUAL USE APPLICATIONS: Development of optical aperture suitable for operation with significant laser fluences and suitable for integration on tactical aircraft. Many sensing systems, including those for medical imaging, can benefit from the integration of passive and active systems. The techniques developed under this effort for integration, as well as for beam steering, will benefit such systems.

REFERENCES:
1. E. A. Watson, et al., "Optical design considerations for agile beam steering," in Laser Beam Propagation and Control, Proc. SPIE Vol. 2120, 186-193 (1994).
2. E. A. Watson, et al., "Application of dynamic gratings to broad spectral band beam steering," in Laser Beam Propagation and Control, Proc. SPIE Vol. 2120, 178-185 (1994).
3. P. F. McManamon, et al., "Optical Phased Array Technology," Proc. IEEE 84(2), 268-298 (1996).

KEYWORDS: Common Aperture, Laser Radar, Infrared Imaging, Beam Steering, Beam Shaping, Achromatic, Compact

AF00-262 TITLE: Registration of Images for Polarimetric Dual-Band FOPEN Radar

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

OBJECTIVE: Develop a automatic image registration algorithm for VHF and UHF radar target detection applications.

DESCRIPTION: The Government is developing a "foliage penetrating" (FOPEN) synthetic aperture radar (SAR) that serves the broad objectives of military counter camouflage, concealment, and deception (CC&D) programs. In order to meet the required specifications for the detection of concealed targets, a dual band design that operates at both UHF and VHF will be implemented. The VHF portion of the radar will provide greater target detection capabilities due to the lower levels of attenuation from the foliage whereas the higher resolution UHF portion of the radar will provide better target/clutter discrimination capabilities.

PHASE I: Analyze algorithm approaches to correlate dual band radar images. These algorithms should take into account aspect-independent features, and other image alignment issues.

PHASE II: Involves the development and testing of algorithms for FOPEN VHF/UHF images. Issues such as the robustness of possible registration features with regard to UHF polarizations should be investigated and addressed.

PHASE III DUAL USE APPLICATIONS: Emergency search and rescue missions that rely on the detection of man-made objects that are embedded in forested regions. Remote sensing applications such as environmental pollution tracking in forested areas.

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1. Y Zhang, Y.E. Yang, H. Braunisch, and J.A. Kong, "Electromagnetic Wave Interaction of Conducting Object with Rough Surface by Hybrid SPM/MoM Technique-Summary," Journal of Electromagnetic Waves and Applications, vol 13, pp. 983-984, 1999.
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3. Zheng, Qinfen and Rama Chellappa, "A Computational Vision Approach to Image Registration", IEEE Transactions on Image Processing, Vol. 2, No. 3, July 1993, pp. 311-326.

KEYWORDS: Synthetic Aperture Radar, Foliage Penetration, Image Registration, Target Detection, Polarimetric Radar, VHF/UHF Radar

AF00-263 TITLE: Real-Time High Fidelity Dense RF Environment Simulation Technology

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace

OBJECTIVE: To advance the state-of-the-art in real-time high fidelity/dense RF environment simulation.

DESCRIPTION: Evolving 21st Century operational concepts utilize onboard/offboard sensors to significantly enhance situation awareness and response strategy in dense threat environments. Advanced sensors and information processing is a key critical technology base for these concepts. This technology base is even more critical for the protection of space assets. The development and evolution of this technology base through open air/space range research and evaluation is expensive with limited productivity. This limited productivity is due to the lack of good experiment control that is a problem inherent with open air/space range evaluations. In addition, open air/space ranges cannot generate the dense RF environments that would be experienced in actual combat situations. The current RF environment generation technology performance and its associated costs limit the fidelity of the generated combat scenario where the RF waveform/pulse density accuracy must be traded-off with the number of simultaneously active emitters in a dense threat environment. This limitation must be overcome if the DoD High Level Architecture (HLA) concepts/requirements being sponsored by the Defense Modeling and Simulation Office are to become a reality in the defense community. This limitation is even more critical with sensors used for space asset protection because they must operate in a larger environment of RF emitters. The primary focus of this research is to define/evolve affordable real-time high fidelity/dense RF environment generation technology that will enable the defense community to minimize the need for open air/space range evaluation where the advanced sensor/information processing capabilities are evolved and matured in the laboratory through hardware-in-the-loop simulation. This new RF environment generation technology will enable the battlefield to be brought to the laboratory where the advanced sensor/information processing capabilities can be subjected to multiple realistic combat situations making it possible to identify/resolve technical issues before ever flying/fielding the capability. This initiative will provide key simulation technology to evolve/apply electronic warfare concepts/capabilities for the protection of space assets. This simulation technology will make it possible to significantly reduce the time, risk and cost associated with transitioning advanced sensor/information processing capabilities. This research addresses the incorporation of HLA standards per the DMSO M&S Master Plan.

PHASE I: The Phase I effort will identify affordable innovative real-time high fidelity/dense RF environment generation technologies that utilize HLA architecture concepts where demonstrations are linked via HLA standards, a collaborative enterprise technology concept in the Defense Technology Area Plan. The key objective of this research is to minimize the need for open air/space range research/evaluation and enable the development/evolution of advanced sensor/information processing technologies in the laboratory. The Phase I research will identify the critical RF generation technology challenges and define the Phase II approach for developing/demonstrating in the Sensors Directorate Integrated Demonstrations and Applications Laboratory (IDAL), the critical real-time technology required for real-time high fidelity/dense RF environment generation. Phase I risk reduction experiments will be conducted to demonstrate the feasibility of the proposed Phase II approach.

PHASE II: The Phase II effort will implement and demonstrate the critical real-time high fidelity/dense RF environment generation technology in the Sensors Directorate Integrated Demonstrations and Applications Laboratory (IDAL) through linked simulation via the HLA standards per the DMSO M&S Master Plan.

PHASE III DUAL USE APPLICATIONS: Real-time high fidelity/dense RF environment generation technology is a dual-use technology that has extensive commercial applications for markets such as the telecommunications industry. This RF generation technology can be utilized to develop telecommunications equipment and processes that enable cheaper/more flexible service. This technology can also be utilized to develop and evaluate new multiplexing communications concepts that enable more simultaneous users of the service. This technology will reduce development costs and accelerate product movement to the market place through laboratory rapid prototyping in a RF development environment that realistically represents real-world effects. The real-time high fidelity/dense RF environment generation technology can be implemented in government laboratories and test ranges for the development and evaluation of advanced sensors.

REFERENCES: Edward Eberl, “Changing Requirements for EW Threat Simulation,” 22 Oct 98 AD A355202

KEYWORDS: RF Simulator, Threat Environment, Simulation, Situational Awareness, High Level Architecture, Electronic Warfare

AF00-265 TITLE: Distributed Control Evaluation System for Multi-Platform Applications

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace

OBJECTIVE: Develop a methodology and test bed for systematic evaluation of distributed sensor control techniques in a multi-platform multi-sensor environment to measure performance, limitations and progress in the state of the art.

DESCRIPTION: Current and future military operational concepts emphasize cooperative multi-platform operations based on shared information from distributed sensor and database resources. Before the concepts for sharing such resources are operationally feasible, many fundamental technical issues must be resolved with respect to evaluation of sensor utilization, data communication, data processing, and command and control strategies. Of particular interest here is the ability to evaluate control of sensors located on multiple cooperating platforms to best achieve global or group objectives. For example, electronically scanned radars on different aircraft might be directed toward different high-priority targets to yield the best total view, based on relative locations and velocities, detection ranges, visibility or pointing constraints, communication bandwidth, available sensor modes, and other factors. Sensor modes, such as Synthetic Aperture Radar and High Range Resolution, may be mutually exclusive. For robustness and reliability, the participating platforms should be able to operate as autonomously as possible, while contributing effectively to the group’s mission objectives. In the past 10 years, significant progress has been made in developing new methods for distributed optimal estimation, and methods for evaluation of these techniques are evolving.

However, distributed control strategies and methods for their evaluation are often ad hoc, heuristic, or developed on a case by case basis. This often makes meaningful comparison of these strategies problematic. Hence, a general-purpose evaluation methodology and test bed are required. Developing such a capability is especially challenging because there are few working examples of such strategies from which generalizations can be inferred.

PHASE I: Examine recent distributed control methods and identify a generalized set of characteristic features. Develop distributed control metrics suitable for use in multi-platform multi-sensor operations. Demonstrate feasibility by implementing prototype software and evaluating a small number of control strategies and baseline scenarios. The Government will help to identify and provide descriptions, analytical models, and software that can be used in implementing simulations. Expect to use sensor models and associated parameters of a generic nature for exercising algorithms and testing ideas. Define how methods can be readily adapted to testing of new candidate control strategies or problem spaces. Identify limitations of methods and suggest means to circumvent these.

PHASE II: Develop a control strategy evaluation toolkit based on methods and metrics developed in Phase I. The toolkit will consist of software that as a minimum allows the user to readily define scenarios, insert control strategies for evaluation, and measure and assess the appropriate performance metrics. The simulated mission environment will include realistic multi-aircraft operations, target/threat scenarios (envision both air-to-air and air-to-ground), and varied sensor and environment models.

PHASE III DUAL USE APPLICATIONS: Evaluation of distributed control strategies in manufacturing operations where physically distributed monitoring sensors and multistage production processes must be controlled. The FAA can potentially use the distributed control method to enhance aircraft collision avoidance systems. Intelligent vehicle control systems can also potentially use a good distributed control method. Other potential applications include robotic systems with distributed sensors and controllers, and large space structures with distributed sensors and controllers.

REFERENCES: Borman,V.; Pack, J. “Effectiveness Measurements for the Distributed Data Fusion Problem”, Jun 94, Report Number: NCCOSC/RDT/E-TR-1648, ADA 283084

KEYWORDS: Distributed Control, Simulation, Sensors, Evaluation

AF00-266 TITLE: Space Based Sensors

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: Develop large lightweight deployable antenna aperture concepts for Space Based Radar applications.

DESCRIPTION: Very large aperture antennas for future space based radar applications will require highly calibrated multi-beam functionality, and for some applications also be able to operate at multiple frequencies with minimum prime power consumption. Possible candidate architectures could include extremely large fully populated phased arrays, constrained feed arrays, and space fed lens arrays. Integrated antenna apertures and innovative beamforming concepts that allow the deployment of multiple subarrays by smaller, less expensive launch vehicles may play a pivotal role in reaching the desired sensor performance requiring less aggregate weight and power. Lightweight, deployable, and mass producible antenna systems concepts are required that will ultimately succeed in achieving reduced life-cycle costs for spaced based radar surveillance. Concepts developed under this SBIR have the potential to greatly enhance and encourage a quickly growing multi-faceted market.

PHASE I: 1) Perform antenna system coverage analyses and trade-offs, concerning one or more concepts. 2) Develop preliminary antenna concept system performance simulation to evaluate beam coverage and illumination efficiency functions. 3) Document results and detail a plan for prototype development/demonstration/simulation in Phase II.

PHASE II: 1) Produce a comprehensive antenna concept system performance simulation to validate plausible antenna system architectures. 2) Identify key sub-system antenna performance requirements. 3) In conjunction with AFRL Sensor personnel select crucial antenna sub-system demonstration hardware and produce a working prototype.

PHASE III DUAL USE APPLICATIONS: Improved space based antenna system performance clearly will save costs for both military and civilian satellite systems. For military radar satellite systems, large saving in the life cycle cost for surveillance radar is expected. Civilian systems, especially the new low orbit system with multiple beam earth coverage, will benefit by the lower cost of mass producible antenna subsystems.

REFERENCES: Proceedings of the Antenna Application Symposium, September 1997, 1998 Electromagnetics Laboratory University of Illinois Urbana-Champaign.

KEYWORDS: Lightweight Antennas, Space Based Radar, Multi-Beam Antennas, Multi-Frequency Arrays, Digital Beamforming Arrays, Space Fed Arrays

AF00-268 TITLE: Affordable Bonded Textile Reinforced Composite Double-Lap Clevis Joints

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Develop bonded textile reinforced composite clevis joint concepts for improved structural integrity and producibility.

DESCRIPTION: The Air Force has a goal to reduce the cost, yet improve the performance of air vehicle structures. Unitized composite structures with low part and low cost assembly approaches are key to achieving this goal. This topic seeks to develop innovative bonded joints design concepts for high performance unitized composite structures. Bonding is critical for low cost assembly. The design and manufacturing benefits of assembling large numbers of bonded parts allow a low cost alternative to the expense associated with tooling for unitized cocured structure. Historically, the costs to maintain part tolerance on a large unitized structure that is built with complex tooling have been a significant challenge that has inhibited the implementation of composites. Bonded joints will allow the designer to assemble parts that are, in general, flat or slightly curved to allow for low cost fabrication with improved tolerance control. The clevis joint offers a way to react pull-off loads while placing the adhesive in double lap shear as opposed to peel, which is the strongest loading mode for adhesives. This program shall specifically focus on the design aspects of the bonded composite clevis joints reinforced with woven textile fiber preforms. The development shall emphasize concepts to allow for bondline thickness control in the lap joint, stiffness tailoring for improved load distribution and elimination of stress risers, fail-safety using 3D technologies, and definition of guidelines for design of clevis joint structures.

PHASE I: Develop a textile preform reinforced bonded joint design concept, fabricate joint elements, and test to quantify improved joint producibility, static strength, and durability. Design features to be considered include concepts to control bondline thickness, and approaches to improve ultimate load capability and durability, such as hybridized fiber architectures and metallic inserts using low temperature and low pressure cure resins such as electron beam curable materials.

PHASE II: Refine the concept developed in Phase I and apply it to a representative portion of aircraft structure. The refinement of the design will be directed towards understanding the correlation of effects between skin stiffness and joint architecture. Demonstration will be conducted to characterize the producibility, performance and cost of the concept through fabrication and static and durability test of a large scale component. This Phase will provide an evaluation of the concept for weight and assembly cost payoff potential.

PHASE III DUAL USE APPLICATIONS: This technology will find numerous applications in commercial transportation systems where cost and weight are always critical for commercial viability. Applications of this joint concept in the frames and bodies of fuel efficient cars, buses, trucks, and trains will improve structural efficiency, integrity and safety. This joint concept can also be scaled to meet the increasing demand for application of composites in infrastructure, such as highway and pedestrian bridges and other support structures.

REFERENCES:
Robust Composite Sandwich Structures, AIAA 98-1873, Patrick Sheahen and Larry Bersuch, Lockheed Martin Tactical Aircraft Systems, Fort Worth TX, Tom Holcombe and Bill Baron, Wright Laboratory, Dayton OH, 39th AIAA Structures, Structural Dynamics, and Materials Conference, Long Beach CA, 20-23 April 1998.

KEYWORDS: Structure, Composite, Bonding, Assembly, Textile, Adhesive

AF00-269 TITLE: Repair of Ceramic Matrix Composite Structures

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop and demonstrate an economical and reliable repair technique for ceramic matrix composite hot structures.

DESCRIPTION: Ceramic matrix composites (CMCs) are increasingly being considered for a variety of exhaust impinged aircraft structures and engine components. Compared to existing materials used for these applications, CMCs offer potential improvements in durability and maintainability, as well as higher temperature capability and reduced weight. Demonstration of reparability is desired before they can be used in fielded systems. Preliminary development of repair techniques has been accomplished [1-4], however, repair optimization, demonstration of repair durability, and other issues remain to be addressed. Some of these components may be layered or cored structures and contain arrays of cooling holes; this further complicates repair. Repair development efforts proposed here need to dovetail into existing technology demonstrations, such as the AFRL/VA Structurally Integrated Thermal Energy Management (SITE-M) program [4], in order to ensure that they are being accomplished on a realistic component geometry and have a demonstration outlet.

PHASE I: Review the prior and current work on CMC repair and identify a suitable component demonstration path. Select the approaches that are most applicable to the CMC of interest. Fabricate, damage, repair, and mechanically test CMC coupons. Assess the test results and identify repair processes, material improvements, and risk issues associated with repair of the relevant component (e.g., fatigue resistance of repair, repair of damage near an attachment, cost/ease/flexibility of repair technique, etc.). Define support and support related impacts associated with each repair procedure.

PHASE II: Fabricate, damage, repair, and test CMC sub-elements to optimize the repair approach. This iterative task should include specialized testing and repair of damage to various component areas, as needed to address the risk issues identified in Phase I. Damage and repair a representative CMC component to be tested in the previously identified rig or engine test. Thoroughly document the repair procedure. Summarize the test, analyze the results, and identify remaining issues, including supportability and maintainability related issues.

PHASE III DUAL USE APPLICATIONS: CMCs are being developed for a variety of commercial applications, many of which are large components (e.g., heat exchangers, radiant burners, etc.). Repair of damaged or failed regions of these components is expected to be highly desirable from an economic standpoint, and will facilitate their commercial application. Similarly, the repair approaches (e.g., bonding a patch in place) are expected to be applicable to joining of CMCs to themselves. This ability is expected to present additional commercial applications.

KEYWORDS: Repair, Ceramic Matrix Composites (CMC), Hot Structures, Testing, Process Development

AF00-270 TITLE: Design for Limited Life Airframes

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop Design Technology and Acceptance Procedures for Airframes having short (100-1000 hour) usage life.

DESCRIPTION: It is proposed that future air vehicles, especially unmanned air vehicles, will be manufactured in limited quantities and stored in a near ready to fly condition until use. Regular training will not be conducted using these air vehicles. Therefore, the requirements for structural integrity can be expected to be significantly different than those currently in place. This is expected to provide the opportunity to reduce airframe weight through the elimination of the structural material required to meet current durability and damage tolerance requirements. Additionally, shorter lived airframes designed to lower durability and damage tolerance requirements may provide the opportunity to exploit materials, design concepts, and manufacturing processes not currently considered acceptable for aircraft structural use. Although a limited number of vehicles are expected to be manufactured for storage, use for a sustained period of time may require surge manufacturing to maintain inventory, so it is essential that rapid and low cost manufacturing processes be integral to the vehicle design. The Air Force Research Laboratory is seeking innovative design concepts for future air vehicles, using advanced, emerging, or current material systems and advanced, emerging or current manufacturing processes that will reduce the manufactured cost and structural weight of future air vehicles.

PHASE I: A notional vehicle and mission will be identified and the design concepts appropriate to achieving such a vehicle will be demonstrated on a subcomponent or component basis. These components will be selected in such a manner as to develop reasonable confidence in the cost and weight reduction potential. They will also address technical challenges associated with the details of the design methodology and manufacturing processes used. Appropriate failure and durability criteria to assure meeting mission requirements will be proposed, and examined for feasibility through test and/or analysis.

PHASE II: The suitability of the proposed criteria for actual air vehicle structure will be demonstrated through the fabrication and test, according to a proposed plan, of a more complex aircraft structure representative of a critical area of the unmanned vehicle identified in Phase I. This is a demonstration test, and need not be conducted to the standards of a certification effort.

PHASE III DUAL USE APPLICATIONS: The low cost rapid manufacturing technology will be further developed and transitioned. Potential users could include, but not be limited to, the aerospace industry for temporary repair or modification of airframes. General aviation may also benefit from this technology in instances where vehicle use life is shorter or the requirements less stringent.

KEYWORDS: Design Concepts/Criteria, Unmanned Air Vehicles, Reduced Life Cycle Cost, Low Cost Manufacturing, Structural Reliability/Integrity, Advanced Composites

AF00-271 TITLE: Development of Advanced Structural Life Analysis/Enhancement Methodology

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Develop or refine methodologies to assess and mitigate the effects of aircraft damage.

DESCRIPTION: There is a focus on reducing fixed-wing vehicle operations and support (O&S) cost. A portion of these costs are expected and associated with typical post-procurement life cycle costs for usage below the aircraft's service life goal. Scheduled inspections are an example of this type of cost. O&S costs also increase as these aircraft approach their structural fatigue service life goal and the incidence of cracking increases. Costs related to time-dependent damage, such as general corrosion and environmentally assisted cracking, are also found at greater frequencies. Additionally, O&S costs are incurred as unexpected damage states are found on aircraft, either due to changes in usage or the inaccuracy inherent in structural analysis used to predict structural damage onset, damage progression or failure. O&S costs associated with the various forms of damage can be reduced. One potential way of reducing costs is through the use of more accurate and/or complete analysis methods. Another way to reduce costs is through the application life enhancement methods such as cold-working, riveted, or bonded repair. The relief of parasitic residual stresses, such as those developed through fabrication and assembly, may also reduce the incidence of damage onset. Unconventional design, fabrication and assembly methods may also result in O&S cost savings. For example, unitized structure may offer cost savings during manufacture and fabrication, and it should also result in reduced cracking. However, the cost of repair or other form of damage mitigation, during operations and support, may offset those savings. Analysis methods, to determine the impact of the environment on unitized structure, need to be developed, refined and verified.

PHASE I: Develop structural analysis tools and/or damage mitigation technology for fielded and future aircraft structure.

PHASE II: The structural analysis tools and damage mitigation technology, developed in Phase I, will be refined and/or enhanced and then validated by testing.

PHASE III DUAL USE APPLICATIONS: Many problems plaguing military aircraft are evident in the commercial fleet as well. Close coordination between the USAF and FAA in the area of aging aircraft research has yielded, and will continue to yield, products of mutual benefit. The analysis tool, entitled "Repair Assessment Procedure and Integrated Design (RAPID)," is an example of such a product.

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2. Harris, C. E., "FAA/NASA International Symposium on Advanced Structural Integrity Methods for Airframe Durability and Damage Tolerance," N95-14453, Symposium held in Hampton, VA 4-6 May 1994. Available from www.Amazon.com.
3. Grandt, A. F., "Materials Degradation and Fatigue in Aerospace Structures," AD-A329 663, August 1997.

KEYWORDS: Structural Analysis, Structural Integrity, Repair Design, Structural Life, Enhancement, Advanced Design, Widespread Fatigue Damage, Aircraft Corrosion, Stress Corrosion Cracking

AF00-272 TITLE: Verification and Validation of Integrated and Adaptive Control Systems

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop the theory and processes for the affordable analysis, testing, and verification of adaptive and intelligent control systems performing safety critical tasks.

DESCRIPTION: By their nature, flight and safety critical control systems require extensive certification testing and analysis prior to fielded application. The process involves validating system requirements, verifying performance needs, and demonstrating safe operation for all conceivable fault modes. Historically, reliability for flight critical systems has been achieved through (1) redundant, channelized hardware configurations with cross channel voting, (2) segregated critical functions (i.e. "firewalls"), (3) deterministic software carefully analyzed against timing and performance predictions, (4) test, and (5) more test. Such efforts to assure dependable operation have led applications (such as digital flight control systems) to be relatively expensive and long-lead-time items. However, trends in industry and military applications are leading to more complex and integrated systems, using advances in control theory, and processing capability to implement them. Research and development for the military has also demonstrated the utility of diagnostic capabilities and reconfigurable control. As such, systems now can have the ability to self-diagnose failures and adapt to compensate for them. Such technologies also give the systems the ability to optimize performance against a wide range of unpredictable and changing conditions. All of these advancements are critically important in the application area of Uninhabited Air Vehicles (UAV's). In many cases, these vehicles are smaller and lighter than manned aircraft, and must cost much less for comparable applications. Also, in the absence of an on-board pilot/controller, the UAV must have the on-board capabilities to identify and react to changes in flight characteristics, damage, or failure. The UAV's will also need to be somewhat autonomous in operation, and be adaptable in their reaction to flight conditions and mission changes. As such, it is projected that future combat UAV's will require extensive and complex on-board software systems, hosted on compact and affordable processing configurations such as envisioned for Vehicle Management Systems architectures being developed within the Air Platforms DTAP. To ensure reliability of the UAV system, revolutionary techniques will need to be developed to adequately analyze and ver4i these critical on-board systems. Fundamentally, these techniques must be robust enough to handle adaptive (up to intelligent and on-line learning) systems, yet be as cost effective as current capabilities. Simply put, current software analysis and test techniques are inadequate to handle these emerging adaptive systems with nondeterministic behavior. Innovative solutions for the validation and verification of adaptive/intelligent software systems are therefore desired.

PHASE I: Evaluate limitations of current analysis and test techniques as applied to emerging adaptive/nondeterministic functionality. Establish "Design for Analysis/Test" technique that enables the evaluation/verification of performance without conventional exhaustive/ comprehensive test. Define analysis tools as required. Project design cycle time as compared to current techniques.

PHASE II: Establish and apply three diverse test cases of adaptive systems functionality. Develop conceptual tools as required. Apply techniques to demonstrate ability to verify bounded systems performance.

PHASE III DUAL USE APPLICATIONS: The market for affordable analysis and verification of adaptive/intelligent safety critical systems encompasses a multitude of military and commercial applications. In addition to aircraft, spacecraft could benefit due to the reduced cost and development time required for mission design and certification. Spin-off applications would involve certification of any real-time safety critical systems, such as "free flight" air traffic control, nuclear power plant control, life critical medical systems, and hazardous material handling equipment.

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3. Hitt, E.; Webb, J.; Lulcus, C., Bridgman, M.; Eldredge, D.; Handbook-Volume 1, Validation of Digital Systems in Avionics and Flight Control Applications; DOT/FAA/CT-82/115; Jun 8-Jul 82.

KEYWORDS: Verification and Validation, Flight Critical System, Safety Critical System, System Integration, Integrated Control, Adaptive Control, Intelligent Systems, Autonomous Systems, Software Development, Software Analysis, Determinism

AF00-273 TITLE: Plasma Flow Control Technology

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Develop technology to modify aerospace vehicle flowfields using plasmadynamics.

DESCRIPTION: Sustained hypersonic flight offers potential revolutionary improvements in warfighting and space launch. Limiting factors in vehicle performance include aerodynamic heating, pressure and viscous drag, and maneuverability. Recent research indicates that flowfields may be modified by the creation and manipulation of plasmas near the vehicle. Plasma flow control presents novel challenges in the creation of large volumes of plasma in high-speed flowing gas, computation and measurement of weakly ionized magneto-gasdynamic flows, integration of control schemes for realistic vehicles, and other areas. Innovative solutions to these problems are required in order to bring plasma flow control to full technological maturity.

PHASE I: Define the proposed concept and develop relationships (theoretical or empirical) between the input and desired output. Define tests and computations to demonstrate the feasibility of the concept. Present concepts for integration and maintainability.

PHASE II: Demonstrate the concept in bench-scale laboratory tests. Analyze the costs and benefits of the technique as applied to an aerospace vehicle in flight or ground test in a production-scale facility.

PHASE III DUAL USE APPLICATIONS: Flow control and measurement concepts developed under Phases I and II may potentially be applied to civilian space launch and high speed air vehicles. Plasma flow control hardware and diagnostics are likely to have civilian application in high temperature environments such as furnaces, engines, materials processing, and manufacturing.

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KEYWORDS: Magnetogasdynamics, Plasmadynamics, Fluid Dynamics, Plasma, Aerodynamics, Magnetohydrodynamics

AF00-274 TITLE: Simulation Techniques to Coordinate Large Numbers of Air Vehicles

TECHNOLOGY AREAS: Air Platform

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Aeronautical Systems Center - Engineering

OBJECTIVE: Develop an advanced simulation environment that will support command, control, and optimization of large numbers of air vehicles working together in a force structure.

DESCRIPTION: The Air Force is seeking innovative or creative approaches to optimize the effectiveness of large force structures through the use of modeling and simulation tools or simulation subsystems. The Simulation Based Research and Development technology sought should be applicable to evaluate interactions of large numbers of entities such as found in coordinated force structures. These tools should enable Air Force researchers to conduct technology tradeoff studies to determine the best compromise between force effectiveness, size, and control technique. They should be capable of evaluating mission effectiveness, and demonstrating an end-state capability for large numbers of offensive weapons such as Uninhabited Air Vehicles (UAV). Force structures including "swarms" of smaller UAVs are of particular interest. Real time, full-mission simulation tools are needed to permit the Air Force to determine the most effective way to control large numbers of small offensive and surveillance entities. The proposing company is encouraged to offer innovative approaches to provide simulation techniques supporting large numbers of air vehicles Some potential areas of research include: a) novel concepts to simulate command and control systems for large numbers of air vehicles, b) force structure tactics development using simulation, c) pilot and/or controller evaluation tools, d) force effectiveness via real-time simulation, e) rapid prototyping tool for research, f) novel simulator system technology to improve cues presented to pilots and operators, and g) application of virtual reality technologies to improve coordinated force research.

PHASE I: Define the proposed approach, investigate alternatives, and predict performance of the proposed design.

PHASE II: Conduct the research, and demonstrate the approach, or high risk portions of the approach. The design, including results of any performance tests, shall be documented in a final report.

PHASE III DUAL USE APPLICATIONS: Simulation tools resulting from this SBIR will have diverse application to both commercial and military applications. For example, a tool that supports control optimization of large numbers of entities can be used for air or ground traffic control applications, optimization of biological agents and system-of-systems.

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KEYWORDS: Uninhabited Air Vehicle (UAV), Air Superiority, Control System, Simulation, Air Vehicle, Real-time, Rapid Prototyping, Networking

AF00-275 TITLE: Flow Control for Vehicle Propulsion/Weapons Integration

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Remove operability limitations of weapon systems through the application of active flow control.

DESCRIPTION: The proposed use of active flow control for altering local aerodynamic phenomena has been flourishing with the recent development of small devices to enable such control. These include, but are not limited to, Micro Electromechanical Systems (MEMS) devices, steady or pulsating jets, and virtual jets. These typically small, low power devices, show promise for localized control of shear layers, state of turbulence, and unwanted secondary flows. They also have potential for providing an apparent aerodynamic surface that can be tailored to different operating conditions (virtual shaping). The purpose of this topic is to apply these devices to problematic issues associated with advanced air vehicles and the integration of their propulsion systems and weapons systems. Specific examples include boundary layer separation control, virtual inlet shaping for optimal pressure recovery across a broad Mach range, secondary flow control of compact inlet ducts for elimination of turbine engine distortion, virtual nozzle shaping for area control and thrust vectoring without large mechanical flaps/devices, nozzle jet mixing for reduction of plume temperature and exhaust noise, control of the damaging acoustic environment of weapons bays, and enhancement of store separation characteristics within weapons bays. The applications range from subsonic transports to transonic/supersonic combat vehicles. A key consideration will be that the developed technology is consistent with or enables low observable characteristics of the air vehicle. Areas of interest include: integration of existing devices into air vehicle systems, new actuator designs with expanded frequency, amplitude, or inherent flexibility characteristics, development of rapid flow control design methods allowing designers to utilize the technologies in tradeoff studies, development of control systems (neural net or conventional) for optimization of the device performance, experimental validation of a potential device, or numerical simulation of the device to enhance understanding of the relevant flow physics.

PHASE I: Experimental demonstration of active control device, simulation of single isolated device flow control characteristics, simulation of a flow control strategy, simulation determining optimal sensor/actuator locations.

PHASE II: Demonstration of active device under simulated flight conditions, simulation of bank of devices, implementation of breadboard mockup of control system with sensors/actuators, simulation showing impact of installed devices on mission performance.

PHASE III DUAL USE APPLICATIONS: High-payoff military applications include flow distortion control in low-signature compact inlets for UCAV (unmanned combat air vehicles), separation and acoustic control for integrating Small Smart Weapons onto UCAV, and low-cost, low weight fluidic (vs mechanical) thrust vectoring. Virtually, every commercial market which deals with some aspect of flow control stands to benefit from this technology. High efficiency commercial aircraft, quiet aircraft, more efficient aircraft engines, electronics cooling, enhanced turbine cooling, enhanced fans, compressors, quiet car interiors, are just some of the more obvious examples of the potential commercial applications. The competitive posture of the United States with respect to designing, manufacturing, and selling highly energy-efficient devices is greatly enhanced by this technology. Increased emphasis in the commercial market on quiet products (planes, dishwashers, automobile cabins, hairdryers) , and on higher density electronics (more heat generated in a smaller package) means that active control of aerothermal and aeroacoustic environments will play a major role in new product development.

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2. McGrath, S. and Shaw, L., "Active Control of Shallow Cavity Acoustic Resonance," AIAA Paper 96-1949, June, 1996.
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KEYWORDS: Flow Control, MEMS – Micro Electromechanical Systems, Weapons Bay, Inlet, Nozzle, Wing Performance Enhancement

AF00-276 TITLE: Network Centric Distributed Vehicle Management Systems

TECHNOLOGY AREAS: Air Platform, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Aeronautical Systems Center - Engineering

OBJECTIVE: To extend Vehicle Management System (VMS) paradigms to develop a safe, multi-ship coordinated control network.

DESCRIPTION: Vehicle Management Systems (VMS) projected for unmanned air vehicles integrate the critical control functions (flight control, engine/propulsion control, thermal management, landing gear, etc) needed to operate safely. Included are elements of sensing (air data, pilot inputs, inertial data, etc), data communications (data links and busses), processing (data conversion, computers), and effecting (control surfaces, thrust vectoring, etc). In projected unmanned vehicle applications, the role of VMS will expand to encompass further responsibilities. One area of importance will be the safety critical management of multiple unmanned vehicles operating in close proximity. In future battlefield scenarios, unmanned tactical aircraft will be working in close coordination as a force multiplier. The combination of the close proximity, precision operation and machine-controlled lethal capacity will foment new requirements for mission/flight safety. To increase the probability of mission success and decrease the probability of fatal mishap, extensive safety checking will be required rapidly and continually.

Recent technology advances have created the means to process large amounts of data in computing systems. For the Network Centric VMS designer, the challenge is to determine data transfer solutions to effectively process the required data among multiple unmanned vehicles for safe, coordinated operations. In normal computer-based VMS architectures, the redundant data bus provides the means to transfer flight critical data between the on-board computation sites. In the multi-aircraft control application, the VMS data bus must extend outside the individual aircraft to encompass and network the rest of the mission unit. This extension across free space will complicate and hinder the overall operation of the network. Most of the free space data communication mechanisms lack the required deterministic, low latency performance required for flight critical networked systems. Environmental factors, both within and outside each aircraft, shall also affect the network performance. To accomplish the project goal, the performance of the free space communication must be made compatible with that of the data bus. As always, volume, weight, and cost will be design constraints, so the implementation of the network must be concise and it must be seamless to minimize latency.

In short, solutions are sought to enable the efficient, deterministic, and safe management/processing of data to be used in network centric control of multiple unmanned aircraft.

PHASE I: Conduct preliminary design trades and analysis of network centric VMS architectures. Techniques for fault tolerant multiprocessor architectures will be extended to develop a physically distributed, multi-vehicle network with capability. Tasks encompass Network Concept Definition, Requirements/Risk Definition, and Technology Trades.

PHASE II: Develop and demonstrate selected architecture. Provide measurement of flight critical performance. Tasks encompass System Simulation/analysis and Key Component Technology Demonstration(s).

PHASE III DUAL USE APPLICATIONS: Network Centric VMS techniques can be applied to a wide range of distributed safety critical applications including nuclear power plant management and "open skies" air traffic control.

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2. USAF Scientific Advisory Board; New World Vistas, Air and Space Power for the 21st Century: Aircraft and Propulsion Volume; Department of the Air Force.

3. Barnett, Thomas P.M.; “The Seven Deadly Sins of Network Centric Warfare”; U.S. Naval Institute Proceedings Magazine. June 1999.

KEYWORDS: Network Centric, Adaptive Control, Safety Critical, Control Architectures, Distributed Networks, Fault Tolerant

AF00-277 TITLE: Simulation Based R&D for Space Vehicle Concepts

TECHNOLOGY AREAS: Air Platform, Information Systems, Space Platforms

OBJECTIVE: Develop an innovative simulation tool to evaluate space vehicle concepts.

DESCRIPTION: The Air Force is seeking innovative simulation tools to support research and development of advanced space concepts in a high fidelity virtual environment. Competing concepts for space vehicle systems and subsystems need to be efficiently evaluated to support optimization of vehicle performance. For example, there is a need to optimize space vehicle design concepts to reduce vehicle weight and drag, increase payload, reduce fuel consumption, reduce cost and turn-around time, etc., while simultaneously supporting Air Force operational requirements. A rapid prototyping evaluation tool is needed to be able to quantify and predict the performance of proposed space vehicle system prior to investing in system development. The tool must predict space vehicle performance interaction with a detailed atmospheric and environmental model. There is also a need to be able to predict or interact with simulated ground based control stations, and air/space communications. Innovative simulation tools which support space vehicle concept investigations including energy management, actuation technology, propulsion, launch/landing systems, and/or vehicle structures are sought.

PHASE I: Define the proposed approach, investigate alternatives, and predict performance of the proposed design.

PHASE II: Conduct the research, and demonstrate the approach, or high risk portions of the approach. The design, including results of any performance tests, shall be documented in a final report.

PHASE III DUAL USE APPLICATIONS: Simulation tools resulting from this SBIR will have direct application to commercial space ventures, such as the X-33/Venture Star, or could be modified to support development of a variety of commercial products. For example, a tool that supports space vehicle energy optimization could be directly applied to commercial satellite launch operations. Space based research tools supporting rapid prototyping could be modified to support commercial development of aircraft or control systems and reduce time-to-market. Space vehicle drag reduction simulation tools could be easily adapted to reduce drag for commercial products such as trucks, racing vehicles, or commercial aircraft. By changing the environmental model, the tool could even be used to optimize performance of ships or submarines.

REFERENCES:
1. AIAA 97-3519 Lessons Learned in the Use of Real-Tim Simulation for Technology Assessment; B. Stadler and J. Nalepka, 1997.
2. I/ITSEC 97 Latency – The Adversary of Real-Time Distributed Simulations; D. Barnhart, R. Johnston., S. Monson, 1997.
3. AGARD-CP-513; Full Mission Simulation for Research and Development of Air Combat Flight and Attack Management System; Goddard & Zeh, 1991.

KEYWORDS: Space Vehicle, Space Superiority, Modeling, Simulation, Space Operations Vehicles (SOV), Pathfinder

AF00-278 TITLE: Evaluation of Vehicle Wiring Systems

TECHNOLOGY AREAS: Air Platform, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: F-15 Systems Program Office

OBJECTIVE: This topic seeks to conceive and develop sensors and systems to manage the health and status of complex aircraft wiring systems. The method or technology must itself be low cost, passive (does no harm), convenient, easy to use, and comprehensive in its ability to detect, isolate, and perform prognostics on wiring problems that occur during use and maintenance. Most important is the ability to accurately estimate the residual life of the wiring system (or subsystem) being monitored or tested. Prognosis and risk assessment is essential as a means to prevent catastrophic loss of life, as well as loss of aircraft systems. The resulting capability will enable real-time determination of wiring system integrity and provide a means to manage the health of the wiring system like that of Line Replaceable Units (LRUs) as a cost effective means to operate air, space and naval vehicles.

DESCRIPTION: Finding wiring faults is a maintainer's worst nightmare. A number of vehicle performance and maintenance problems can be attributed to poor wiring quality due to aging, or damage. As an example, a recent incident involving the space shuttle Columbia's wiring system ended up delaying a launch for Endeavour three weeks and causing numerous man-hours to inspect dozens of miles of wiring for potential short circuits. The short circuit occurred five seconds after the shuttle Columbia's July 23, 1999 launch because a raised metal portion on a stripped screw had abraded insulation on several wires. Launch vibrations caused intermittent shorting to ground and knocking out power to two of the three engines. Back-up systems took over functions averting a shutdown of the engine system. Wiring damage can be due to maintenance, abrasion, crimping, disconnect cycles, corrosion, vibration, as well as battle damage. These maintenance problems impact safety, life cycle cost, and system operational readiness. Aging effects on the wiring can except the same failures but will take longer to appear and many may start as intermittent type problems.

Generally, wiring is tested only on installation, at major depot overhauls, or inspected when some vehicles are diagnosed with wiring related problems. Trouble shooting wiring problems is a time consuming procedure of studying schematics, testing, using tools such as a Digital Storage Oscilloscopes (DSOs), Digital Volt Ohm Meters (DVOMs), and inspection of wiring and interfaces to perform end to end tests. The time to troubleshoot is often spent just trying to get to wire harnesses and components. Often years of training and experience are required to be proficient in isolating wiring problems. Deficiencies are usually hard to quantify and some faults are only evident during system operations. This creates an additional burden on technician's whose primary responsibility is not wiring but systems maintenance.

The USAF is seeking research leading to development of new sensors and systems with the capability of determining with precision wiring health and an accurate estimate of the life remaining. Promising technologies in prognostic capabilities for detecting degradation due to physical anomalies include pattern recognition techniques, time domain and frequency domain reflectometry. The basic concept is to determine wiring quality during pre-flight checks, or on demand from flight crew or flight line technicians. In some instances (e.g. post battle) it may be necessary to perform health and status checks in flight, or on demand of the crew. Additionally, there is a need for the ability to retest and certify wiring repairs and harness replacements after it is installed to avoid expensive rework and potential damage that might been caused by incorrectly assembled wiring. As a concept of operation, this can include assessing the health, status, and remaining life of the components of the wiring system, e.g. wiring insulation integrity, metallic fibers, connectors, shields, fiber optics, signal, and power.

PHASE I: Review the prior and current work on prognostics and health management systems. Identify technologies suitable for demonstration. Fabricate and demonstrate a proof-of-principal prototype incorporating sensors integrated to wiring for fault detection and fault isolation. Define potential prognostic algorithms that can predict the life remaining of the wiring system.

PHASE II: Building on the success of Phase I, the Phase II objective will demonstrate a health management system for use on an operational aircraft system that will detect, isolate, and predict the time to wiring failure. The system will provide the knowledge necessary to give the technician enough time to make a repair prior to failure.

PHASE III DUAL USE APPLICATIONS: Transition the system to into a fleet of aircraft, both military and commercial, as an enhancement to present health management systems. Aircraft certification, vehicle safety and manufacturer liability concerns are major reasons for utilization of this technology. With the continued aging of both commercial and military fleets, wiring problems will continue to grow. The diagnostic tools developed under this SBIR will have widespread use. This technology would be applicable to commercial aircraft, ships, auto industry, manufacturing equipment and any complex electronic/electrical systems subject to environmental effects.

REFERENCES: Proceedings of the SAE Aircraft Safety Conference, April 1999, Paper #61472.

KEYWORDS: Wiring, Prognostics, Diagnostics, Sensors, Reflectometry, Life Remaining

AF00-279 TITLE: Guidance and Control Techniques for Hypersonic Vehicles

TECHNOLOGY AREAS: Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Aeronautical Systems Center - Engineering

OBJECTIVE: Develop innovative methods for integrating adaptive/reconfigurable control systems with autonomous guidance systems for hypersonic vehicles.

DESCRIPTION: Adaptive/reconfigurable control systems have been successfully demonstrated on fighter aircraft under manual control. These systems minimize the effect of control surface failure or damage on the human's ability to control the vehicle by maintaining stability and preserving the nominal response characteristics of the vehicle to the greatest extent possible. The human is burdened with the responsibility of modifying his guidance strategy when faced with off nominal responses resulting from surface damage or failure. Hypersonic aerospace vehicles will depend upon autonomous guidance systems for trajectory generation. Even if the inner loop control system is adaptive/reconfigurable, tracking performance degradation is inevitable. Thus the guidance system should make use of the failure information available from the inner loop and make appropriate modifications to the commanded trajectory. Neighboring optimal control approaches could be used to develop guidance laws that adapt to perturbations in control effectiveness. Guidance systems are sought that employ feedback of perturbations in identified control effectiveness to modify commands to the inner-loop such that the vehicle follows a new "neighboring" optimal trajectory to the desired final state. Algorithms and methods that allow real-time estimation of the attainable set of trajectories are sought to determine whether or not the desired final state can be achieved in the presence of the control-failure or damage. The Air Force is seeking methods for creating integrated adaptive/reconfigurable guidance and control strategies for hypersonic aerospace and reusable launch vehicles.

PHASE I: Develop and demonstrate in a non-real-time simulation a candidate method of synthesizing integrated adaptive/reconfigurable guidance and control strategies.

PHASE II: Develop refined methods and tools that allow for rapid development of integrated adaptive/reconfigurable guidance and control systems for prototype vehicles.

PHASE III DUAL USE APPLICATIONS: The methods and tools developed under this effort will be directly applicable to commercial launch vehicles. The methods could also be used in conjunction with inner-loop adaptive/reconfigurable control systems to provide pilots with estimates of the set of attainable flight paths in the presence of control effector failures or damage. Such a system would reduce pilot workload and maximize the likelihood of a safe flight termination.

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KEYWORDS: Multivariable Control, Adaptive Control, Hypersonic Vehicle Control, Reconfigurable Flight Control, Parameter Identification, Integrated Control

AF00-280 TITLE: Enhanced Boundary Layer Transition Prediction

TECHNOLOGY AREAS: Air Platform, Space Platforms

OBJECTIVE: Develop prediction methods for laminar-to-turbulent boundary layer transition which take into account realistic flow conditions.

DESCRIPTION: Sustained hypersonic flight offers potential revolutionary improvements in warfighting and space launch. Aerodynamic heating is a major factor in the design of hypersonic vehicles of all classes. Because heat transfer to the vehicle increases dramatically when the boundary layer transitions from laminar to turbulent, the prediction of the transition location is fundamental to vehicle design. Transition prediction is difficult because of the sensitivity of boundary layer transition to initial and boundary conditions. Prediction methods in the past have largely relied on data correlations. Recent advances in our knowledge of boundary layer stability and computational methods now make it possible to take complex variations in initial and boundary conditions into account in a rational manner. A need exists to incorporate these advances into a self-contained computer program accessible to designers and researchers.

PHASE I: Define the scope of the effort by identifying what initial and boundary condition specifications will be incorporated into the program. Determine how the user will specify initial and boundary conditions in practical use, and how these will be used in transition prediction.

PHASE II: Develop prototype software for transition prediction. Demonstrate the method by computing transition locations for several cases with varying initial and boundary conditions and comparing them to experiment.

PHASE III DUAL USE APPLICATIONS: Software developed under Phase II would be used in the design of advanced vehicles for transport and space launch both in the military and civilian sectors. Weight savings arising from improved transition prediction would lead to increased payload and cost savings. Modeling of initial conditions would allow reliable extrapolation of ground test results to flight.

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1. Malik, M. R., “Boundary-Layer Transition Prediction Toolkit,” AIAA paper 97-1904, June 1997.
2. Choudhari, M., Streett, C., “Boundary Layer Receptivity Phenomena in Three-Dimensional and High-Speed Boundary Layers,” AIAA paper 90-5258.

KEYWORDS: Boundary Layer, Hypersonic, Laminar, Turbulent, Transition, Prediction

AF00-281 TITLE: Innovative Structural Concept Modeling for Affordable Vehicles

TECHNOLOGY AREAS: Air Platform, Information Systems, Materials/Processes

OBJECTIVE: Develop structural design concepts data for affordable Space Operations Vehicles (SOV) and Uninhabited Air Vehicles (UAV) design processes.

DESCRIPTION: The process of designing an air vehicle can be significantly improved in the early stages. Currently, technologies and costs are intuitively locked-in during the concept design process without the appropriate analysis resulting in failed objectives and unexpected costs. The R&D performed in this topic develops and automates key features of an innovative systems engineering procedure which rapidly reduces this costly gap between intuition and information in the process of synthesizing complex air vehicle system designs. Proposers are encouraged to emphasize process innovation.

Current design processes do not adequately support design or technology innovation or risk reduction. The current process becomes intractable where tomorrow's emerging technologies are required to realize today's design plans. This is the situation the USAF faces today in the identification of critical technologies which facilitate the air platforms for tomorrow's missions. The R&D performed in this topic will identify a set of technologies and concepts which will be folded into an innovative system engineering process. The R&D will identify design process features which lead the designer to select innovative technologies and procedures which rapidly reduce risk. Fixed wing vehicle concepts of immediate interest include any high speed vehicle (TAV (Trans-Atmospheric Vehicles), SOV) or any uninhabited air vehicle (UAV). The design process can expand to include any vehicle concept.

A large number of recent R&D advancements in mathematics and computer science will facilitate the design process. For instance, confidence intervals and fuzzy numbers convey a measure of uncertainty. Object oriented programming can be used to decompose, recompose and prioritize the data and processes. Automated dependency-tracking facilitates the modeling and redesign of highly integrated systems. Data mining may be used to efficiently search out missing pieces of data. These advancements and many others may be considered to create a conceptual design process which leads to the development of tomorrow's flight vehicles.

A successful design concept arises from a team which includes key technology developers. Part of the design process involves the development of relevant data which is important to the vehicle designer. Aircraft structures is unquestionably a key ingredient in a vehicle design has a major influence on the affordability of the concept. New structural concepts are emerging as new materials and process technologies are developed. The concept designer requires relevant data which includes mechanical properties, manufacturing, cost etc. Therefore, the design process is improved if design data is rapidly transferred between the laboratory and the designer.

Examples of new structural concepts include: z-pinning, structural pre-forms, truss core laminates and carbon-carbon structures. A knowledge-based design model will require the data associated with these concepts to be encapsulated in a unified object-oriented format, which will address all aspects of design including (but not limited to) geometry, mechanical properties, process times and material cost. To determine accurate costs for designs with new technologies, the designer needs to synthesize a more accurate activity-based cost (ABC) model. The difficulty with synthesizing ABC models is that the amount of data needed is large, time-consuming to generate, and not available for new technology until late in the design process. The failure, stiffness, and thermal mechanics of emerging structural concepts (e.g., sandwich structures, woven structures, hot structures, etc.) are not well understood. Efforts have focused on developing statistical models and on micro-mechanical models. Regardless, today's designer requires high fidelity design data before proposing expensive engineering developments. The performing company has flexibility in selecting mathematical and software innovations which address these design process challenges. Innovative and creative approaches are encouraged are encouraged.

PHASE I: Identify vehicle component based on a TAV or UAV concept and a suite of structural concepts. Identify requirements for a design environment to develop a unified design object for each structural concept. There will be an emphasis on geometry, loads, mechanical properties (weight, thermal, stress, stiffness), process modeling, and cost. Demonstrated modeling process with one structural concept.

PHASE II: Expand process to include a number of structural concepts. Design a new integrated component with some combination of structural concepts. Examples may be low cost processes for expendable UAV wing carry-through structure or integrated structural concepts for actively cooled thermal structures. Incorporate probabilistic metrics where cost or failure uncertainty is a factor.

PHASE III DUAL USE APPLICATIONS: The proposed aerospace design product transitions to any transportation system such as the automotive or shipbuilding industry.

REFERENCES:
1. Rapid Modeling with Innovative Structural Concepts, AIAA-98-1755, Max Blair, Stephen Hill, Terry Weisshaar and Robert Taylor, 39th Structures, Structural Dynamics and Materials Conference at Long Beach CA, 20-23 April 1998.
2. Structural and Manufacturing Analysis of a Wing Using the Adaptive Modeling Language, AIAA 98-1758, co-authored with Jeffrey V. Zweber, Geetha Bharatram and Hilmi Kamhawi, Structural Dynamics and Materials Conference at Long Beach CA, 20-23 April 1998.

KEYWORDS: Design Modeling, Structural Analysis, Knowledge-Based, Cost Modeling, Probabilistics, Process Modeling

AF00-282 TITLE: Aeronautical Sciences and Flight Control Technology for Military Aerospace Vehicles

TECHNOLOGY AREAS: Air Platform, Space Platforms

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: C-130 Aeronautical Systems Center

OBJECTIVE: Develop innovative configuration concepts, integrated design methodologies, and aerodynamic and control technologies for future USAF air and space forces.

DESCRIPTION: The United States Air Force has a vital interest in developing manned and unmanned air and space vehicles that are markedly superior to today's aircraft in the areas of affordability, reliability and mission capability. Affordable access to space requires the development of vehicles that are capable of routine, aircraft-like operations to and from space. Technologies are sought that allow safe operations, enable rapid turnaround, and provide the aerodynamic and control performance levels needed to efficiently operate in and out of contemporary military air fields. Increased affordability in the development, acquisition, and operation of aerospace vehicles requires the creation of new, highly automated design methods and tools. These tools must provide designers with the ability to rapidly synthesize and analyze new vehicle concepts. Multidisciplinary design methods are sought that insure synergistic blends of aerodynamic, thermodynamic, structural, and control system properties are obtained through optimal integration. Improvements in mission capability requires innovative aerodynamic and flight control technologies that enable new levels of speed, reliability, maneuverability, range and payloads to be attained. Advanced configuration concepts and technologies that provide increased system effectiveness (e.g. reduced drag, increased payload, lower weight, etc.) are sought. Adaptive/reconfigurable flight control technologies have been demonstrated that improve the reliability of conventional fighter type aircraft. This technology must be transitioned to unmanned aerospace vehicles that rely on autonomous guidance systems for trajectory control. Integrated adaptive/reconfigurable guidance and control methods are needed that will improve fault tolerance of aerospace vehicles to control effector failures. The methods and tools developed must be applicable to a wide range of aerospace vehicles that will conduct operations in the subsonic, hypersonic and orbital flight regimes. These vehicles will allow the Air Force to realize current objectives in the areas of sustainment, global presence, flexible response, and force projection.

PHASE I: Define the proposed concept, outline the basic principles, and establish the method of solution. Present an example of the advanced performance that will result from the technology. Determine the risk and extent of improvement over existing methods.

PHASE II: Build a prototype application of the equipment or software. Demonstrate the advanced technology under actual engineering conditions.

PHASE III DUAL USE APPLICATIONS: Improved performance and safety of commercial and private aircraft will be realized with the application of this technology. New areas of commercial growth will result from aircraft design tools that allow fast and accurate development of air vehicles to respond to aircraft needs around the world. Examples are devices that allow aircraft to operate from remote fields, carry large payloads at low cost, and are economical to produce and operate. New integrated adaptive/reconfigurable guidance and control methods will substantially enhance safety of flight for the global commercial air fleet. New aerodynamic and flight control design and analysis tools will improve education methods and allow industry to produce with lower initial investment.

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2. "Propulsion Integration Issues for 21st Century Fighter Aircraft." Marvin Gridley and Steven Walker, Paper #42 in Proceedings of AGARD Propulsion Energetics Panel, Seattle, Washington, Sep 1995. (96N36606)
3. "Proceedings and Design Data for the Formulations of Aircraft Configurations," T.R. Sieron, et al, WL-TR-93-3068, Wright Laboratory, Air Force Materiel Command, Wright-Patterson AFB OH, Aug 1993. (ADA 270 150)
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19(6): page 1270-1277.

KEYWORDS: Aerodynamics, Aerothermodynamics, Computational Fluid Dynamics, Hypersonic Configurations, Multivariable Control, Adaptive Control

AF00-283 TITLE: Innovative Weight Efficient Combined Structure/TPS Concepts

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Explore feasibility and establish the weight benefits of structural load-carrying thermal protection system (TPS) concepts.

DESCRIPTION: Traditional TPS approaches are largely parasitic in nature, in that a separate TPS transmits the local aerodynamic loads to an underlying, highly efficient, primary structure. Hot structure requires no separate TPS, in that the structure itself sustains the thermal loading. This approach, however, suffers from having to use generally less structurally efficient, high temperature materials to sustain the thermal environment. The approach proposed by this topic is to investigate more unitized designs in which a highly efficient structure can be given an integral, load sharing, heat resistant, outer surface. An example might be to employ integral weaving to achieve a unitized fibrous preform in which a ceramic matrix material is employed for the outer surface and a more structurally efficient intermediate temperature matrix material is employed for the inner layer. To form a basis for evaluation, a representative vehicle component will be selected upon which to base design development. Candidate approaches will be conceptualized and subjected to thermal structural analyses to assess weight and thermal compatibility. For those approaches deemed feasible, coupon and small panel specimens will be designed, fabricated, and tested in Phase I to assess feasibility. Phase II will involve the scale-up, design, fabrication and testing of larger size components typical of the vehicle's outer moldline structure.

PHASE I: Develop analytical methodologies and concepts

PHASE II: Methodologies and concepts developed in Phase I will be validated by experimentation.

PHASE III DUAL USE APPLICATIONS: The development of structures using advanced materials can be transferred into the commercial market in both the aircraft and automotive industries. The development of these new structures will result in stronger, lighter more efficient commercial aircraft and automobiles.

REFERENCES:
John T. Dorsey, Chauncey Wu, Kevin Rivers, Carl Martin, Jr. and Russell Smith, Airframe Integration Trade Studies for a Reusable Launch Vehicle, Space Technology and Applications International Forum (STAIF '99), Albuquerque, New Mexico, January 31-February 4, 1999.

KEYWORDS: Hypervelocity Vehicles, Military Space Plane, Space Operations Vehicle, Integrated Thermal Protection Systems, Hot Structures, Cryogenic Tanks, Ceramic Matrix Composites

AF00-284 TITLE: Multifunctional Structures

TECHNOLOGY AREAS: Air Platform

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: C-130 Aeronautical Systems Center

OBJECTIVE: Develop structural concepts that provide subsystem functionality.

DESCRIPTION: Future war fighting forces, such as the Expeditionary Air Force, need small, agile, lightweight, and affordable systems. A revolutionary level of vehicle integration will be required. The airframe and its subsystems functions must be unitized to minimize volume and weight while maintaining affordability. The current approach of airframe and subsystem integration is parasitic secondary attachment of equipment and devices. The goal of this effort is to develop and demonstrated highly innovative multifunctional structures that enable the airframe to concurrently react flight loads and perform thermo-mechanical and/or electro-optical functions in a single component. The distinction between structure and subsystems will be eliminated. The airframe structure will contain the subsystem functionality. Candidate subsystem functions include but are not limited to, thermal management, transmission of onboard electrical and hydraulic power, emission and reception of radio frequency signals, and flight control actuation. The major technical challenge for this effort is the application and processing of multifunction materials and the application of analytical tools to predict functional performance under flight loads. Typical structural material requirements are usually incompatible with electrical and thermal requirements. Materials and concepts that exhibit desired properties for subsystem functionality such as, electrical conductivity or insulation, thermal conductivity or insulation, electromagnetic permittivity, fluid resistance, etc., typically do not possess optimum structural properties, such as modulus, strength, toughness, and fatigue life. Advanced modeling and simulation capabilities must be applied to model intra-dependencies between subsystems functions and structural integrity. Highly innovative solutions are required. For example, conductive fibers may be embedded in molded or laminated composite structures to provide power transmission eliminating cabling and its attendant attachments. Proposed concepts must be highly efficient.

PHASE I: Develop a design concept and materials processing approach for a multifunction structural application. Demonstrate feasibility of the concept through analysis or experiment.

PHASE II: Demonstrate scale up of the multifunctional, structural concept developed in Phase I. Fabricate a critical element of the concept representing the significant structural and subsystem functionality features. Conduct combined structural and functionality testing, and correlate with analytical test data. Emphasis should be placed on durability of the design concept. Potential repair concepts shall also be developed. Quantify weight, volume and affordability payoffs.

PHASE III DUAL USE APPLICATIONS: This technology will find numerous applications in commercial air vehicles and space vehicles where cost and weight are critical for economic viability. A wide variety of applications are also envisioned, for ground transportation vehicles (cars, buses, trucks, and trains) where cost and weight savings are also extremely critical for commercial viability. In addition, increase application of microprocessor technology in “smart” commodity products will also benefit from this technology by allowing embedment of the electronic chips, wiring, power, and other devices. Products such as household appliances, tools, and sporting goods will have embedded electronic function and actuation systems.

REFERENCES: “Ultralightweight Structures,” D. M. Kane and J. A. Hangen, WL-TR-3034, Wright Laboratory, Air Force Material Command, Wright-Patterson AFB OH, Sep 1988 to Feb 1991.

KEYWORDS: Structures, Composites, Subsystems, Embedment

AF00-285 TITLE: Low Speed Test Techniques for Powered Lift Configurations

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Demonstrate low speed test techniques for powered lift configurations without Reynolds number sensitivity.

DESCRIPTION: Current approaches for measuring the low speed static and dynamic characteristics of powered lift configurations in a wind tunnel typically provide poor results for high aspect ratio wings with rounded leading edges. This is due to the inability to properly match Reynolds number. A wide variety of new vehicles, such as dual-mode air vehicles (rescue, targeting, and damage assessment), and the advanced theater transport, will use powered lift systems and operate at low speeds. Several low speed wind tunnel facilities exist that provide the ability to gather extremely large amounts of static and dynamic data at very low cost. These facilities have not been used for high aspect ratio powered lift configurations, due to the Reynolds number problem. It is possible that recent advances in flow control devices, and the understanding of separated flows, now allow a simple, reliable means to obtain quality static and dynamic test data at low speeds using small modifications to a configuration. New configurations could be studied in a much more efficient manner, if this capability was available. This would reduce flight control system development cost.

PHASE I: Expectations for this phase would be a computational assessment or limited wind tunnel test to investigate the feasibility of small configuration modifications which provide adequate results in the absence of Reynolds number matching.

PHASE II: Expectations for this phase would be a validated computational tool or test technique, which provides adequate results for a wide variety of configurations.

PHASE III DUAL USE APPLICATIONS: The analysis tool could be used for dual-mode vehicles designed for law enforcement, gas-petroleum-utility checks, and medical rescue.

REFERENCES: "V/STOL Wind Tunnel Testing," D.G. Koenig, AGARD R-710, April 1984.

KEYWORDS: Dual-Mode Air Vehicles, Advanced Theater Transport, Low Speed Aerodynamics, Flow Control

AF00-292 TITLE: Jet Engine Test Cell Air Pollution Control

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop new technologies to reduce and control by 50% air pollution emissions associated with jet engine test cell operations.

DESCRIPTION: The testing of off-aircraft jet engines at fixed stands is part of the normal aircraft flight test and maintenance operations at Edwards AFB. Jet engines are tested to assess flight characteristics, results of engine modifications and success of maintenance work. When tested, the engines are typically run at thrust settings that vary from idle to full military power, and can include use of the afterburner. A jet engine tested off-aircraft at a fixed stand (a test cell), is considered to be a fixed stationary source for air pollution emissions, and typically emits large amounts of nitrogen oxides (NOx), hazardous air pollutants (HAPs) and volatile organic compounds (VOCs).

Because of these emissions, and the fact that Edwards AFB is in a US Environmental Protection Agency (EPA) designated "serious" ozone non-attainment area (where NOx and VOCs emissions are regulated), jet engine test cells at Edwards AFB are regulated by the local air pollution control district and under Title V of the 1990 Clean Air Act Amendments (CAAA). In November 2000, US EPA is required under the CAAA to issue a National Emission Standard for HAP (NESHAP) emissions from jet engine test activities (40 Code of Federal Regulation Part 63). At present, it is not clear how US EPA will regulate jet engine testing under the NESHAP. However, if controls are mandated under the NESHAP, Edwards AFB will be required to either implement controls, or face possible negative mission impacts by limiting jet engine test activities to reduce emissions.

Previous research into developing control technologies for jet engine test cells had demonstrated reductions in NOx and VOC emissions. However, these efforts were based on existing air pollution control technologies, were impractical or too expensive to implement, and imposed too many limitations on the operation of the test cell. The requirement of this project is to develop completely new control technologies that will reduce NOx, HAP and VOC emissions by 50% without imposing any operational restrictions on jet engine test cells.

PHASE I: Research and develop a proposed system design to achieve project goals, including feasibility analysis and cost analysis.

PHASE II: Build a prototype of the proposed system and demonstrate at an Air Force facility that accomplishes off-aircraft jet engine testing.

PHASE III DUAL USE APPLICATIONS: Technologies developed to accomplish this work can be applied to all DoD activities associated with jet engine testing and maintenance, and by commercial industries involved in jet engine manufacturing, testing, maintenance and aircraft construction.

REFERENCES:
1. Nelson, S. G.; Wander, J. D. Control of NOx and Other Pollutants at Jet Engine Test Cells; 89th Annual Meeting; Air & Waste Management Association, Nashville, TN, 3rd Floor, 1996, 1 Gateway Center, Pittsburgh, PA 15222.
2. Durham, M. D.; Haythornthwaite, S. M.; Rug, D.; Wander, J. D. Application of Pulsed Corona Induced Plasma to Jet Engine Test Cells; 90th Annual Meeting; Air & Waste Management Association, Toronto, Ontario, Canada, 1997, 3rd Floor, 1 Gateway Center, Pittsburgh, PA 15222.

KEYWORDS: jet engines, test cells, emission controls, nitrogen oxides, hazardous air pollutants, volatile organic compounds.

AF00-293 TITLE: Embedded Global Positioning System (GPS)/Inertial Navigation System (INS)-Encoded Radar Transponder

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: Using GPS time-space-position information (TSPI) technology, develop a method for improving the performance of a metric tracking radar to obtain constant 15-meter or better positional accuracy at slant ranges from up to 1,000 Km.

DESCRIPTION: This project will perform advanced development directed at satisfying a test & evaluation requirement for safe testing of future manned and unmanned aerospace vehicles. These include endo- and exo-atmospheric aerospace vehicles (X-33, X-34, X-38, and Future X-Vehicles) and surface-to-air missiles for theater missile defense (PAC-3, THAAD, and Navy Lower and Upper Tier). Flight termination decisions are based on TSPI obtained from multiple acquisition systems. The primary TSPI source could be a GPS receiver onboard the vehicle. The GPS receiver data could be transported from the vehicle to the ground stations via telemetry and/or radar transponder links. The GPS receiver data could be imbedded in the telemetry stream, and it could also be modulated onto the radar transponder output signal. The TSPI from the onboard GPS receiver would provide 15-meter or better positional accuracy over the entire flight envelope. This would satisfy the range safety requirement for observing high-quality TSPI from the vehicle in real-time via two independent paths. When tests fail to go according to the plan, the radar approach degrades gracefully. If the GPS receiver drops lock, then the radar can continue to track the vehicle using the transponder return. If the transponder fails to respond then the radar can still skin-track the vehicle. This project will develop the GPS-augmented radar transponder and the associated ground support capabilities. The suggested approach, using a GPS receiver coupled to a radar transponder on board the vehicle under test is not a firm requirement. Careful consideration will be given to other innovative methods of achieving the goal at hand.

PHASE I: Conduct a feasibility analysis and prepare a recommended system design. Submit a final report covering the analysis results and the system design.

PHASE II: Build a proof-of-concept system and demonstrate its operation at the Air Force Flight Test Center (AFFTC), Edwards Air Force Base, CA. Submit a final report on results of the demonstration.

PHASE III DUAL USE APPLICATIONS: Air Traffic Control (ATC), Global Air Traffic Management (GATM). AIR FORCE PROGRAMS SUPPORTED: Manned and unmanned air-vehicle programs (such as F-22, JSF, F-16, F-15, B-1, B-2, X-33, X-34, Global Hawk, and Darkstar). BMDO PROGRAMS SUPPORTED: Theater Missile Defense programs (such as PAC-3, THAAD, and Navy Lower and Upper Tier). NASA/AIR FORCE PROGRAMS SUPPORTED: X-programs (such as X-33, X-34, X-38, and Future X-Vehicle).

KEYWORDS: time-space-position information, radar transponder, global positioning system receiver

AF00-294 TITLE: Directional Airborne Telemetry Antennas

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace

OBJECTIVE: Develop affordable, directional airborne telemetry (TM) antennas to functionally replace existing omni-directional antennas on a variety of test vehicles.

DESCRIPTION: Telemetry of data from an air vehicle to ground processing and display facilities is required in many test and training missions. The test and training communities have seen a twenty fold increase in the telemetry data rates over the past 10 years. When this increase in need is coupled with the reduction in available spectrum, caused by the sell-off of government spectrum, the combination creates a major test and training cost and schedule impact to major weapons system programs. Capabilities are needed to increase the efficiency and quality of aeronautical telemetry systems.

Advances in technology may make the application of directional antennas to telemetry practical. Usually these antennas are too large for aircraft installation and difficult to keep pointed to the ground acquisition site. Being able to point the antenna at the receiving site (via positioning cues from the ground and aircraft) will increase the signal to noise ratio (Eb/No) and possibly allow telemetry users to operate on the same frequency, on the same range, with different acquisition antennas. This will allow the ranges to support more missions without additional spectrum.

The development of a directional telemetry antenna may provide a solution to the spectrum encroachment problems. Directional antennas offer the capability to place antenna nulls and lobes to minimize interference and RF coupling. Also a steerable antenna may be configurable in a directional mode to provide point-to-point linkage between the aircraft and the ground. The characteristics of the antenna, driven by position clues from the onboard time/space and position information data and the known location of the acquisition antenna, must be able to steer rapidly enough in a high dynamic maneuvering aircraft. Considering the scope of the unknown involved in this research, the development risk inherent in this project is considered moderate-to-high.

PHASE I: Research emerging technology applicable to directional antennas. Determine the feasibility of developing a directional antenna that meets the size and maneuverability requirements of fighter aircraft. Propose a plan for the development and integration of an airborne directional telemetry antenna for the Phase II effort.

PHASE II: Develop technologies required to support the development of an airborne directional TM antenna. Demonstrate the use of directional antennas for use in the DoD flight test environment.

PHASE III DUAL USE APPLICATIONS: Small, directional antennas could potentially revolutionize the commercial communications industry. Initial commercial applications include commercial airliners, freight companies, and telecommunications companies (proposing the use of UAVs and LEO satellites as data relays).

KEYWORDS: Directional Antennas, Telemetry Antennas, Phased Array Antennas, Steerable Antennas.

AF00-295 TITLE: Low Cost Global Positioning System (GPS)-based Collision Avoidance System

TECHNOLOGY AREAS: Air Platform, Weapons

OBJECTIVE: Develop a low cost GPS-based system that transmits and receives position data through an onboard system.

DESCRIPTION: Air Force Flight Test Center (AFFTC) pilots have routinely identified a midair collision between military aircraft in R2508 as the most likely cause of our next mishap. Currently, collision avoidance is based on "see-and-avoid," SPORT/Joshua traffic advisories, or onboard aircraft sensors. Even using all of these aids to avoid collisions, pilots routinely experience what they perceive as close passes with other military aircraft. Low cost technology is now available which could provide information on other participating aircraft to the aircrew. A low cost GPS system with strap on antenna(s) could be used to determine the participating aircraft's position. As many of the aircraft operating in the R2508 airspace perform close formation and highly dynamic maneuvers, any GPS/antenna implementation should be designed with a high update rate and to preclude the loss of GPS signal lock. Using a modified transponder (possibly Mode S), the aircraft's GPS estimated position could be encoded as is now currently done with altitude (Mode C). Mode S also has the capability to receive encoded data from ground agencies or other aircraft (currently used by traffic alert and collision avoidance system (TCAS)). It should be possible to gather position and altitude data (velocity and heading information is also desired, but is not required) from other participating aircraft and present the information to the pilot on a small, low cost display. The display could also be heading oriented (based on GPS determined ground track) and contain a database which incorporates airspace boundaries, etc.

PHASE I: Development and technical assessment of a low cost prototype system, including at least an end-to-end bench test of all the necessary hardware and software components for at least a ten airplane scenario.

PHASE II: In-flight evaluation of the system in the R2508 complex. This phase would be accomplished in cooperation with the USAF Test Pilot School and would utilize two to three aircraft provided by the school.

PHASE III DUAL USE APPLICATIONS: General aviation collision avoidance, high dynamic vehicle ground collision avoidance.

REFERENCES: A.W. Warren, R.W. Schwa, T.J. Gels and Ark Saharan,
Conflict Probe Concepts Analysis in Support of Free Flight, NASA CR-201623, January 1997, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

KEYWORDS: global positioning system, collision avoidance

AF00-297 TITLE: Motion Enabling Device for Virtual Flight Test Application

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop and demonstrate a fully functional motion enabling-device capable of mounting VFT test hardware in transonic wind tunnels.

DESCRIPTION: Recent efforts at the AEDC have focused on the development and demonstration of a new wind-tunnel test capability called Virtual Flight Testing (VFT). The new capability will provide aircraft and missile designers with a mechanism to evaluate and validate autopilot and flight-vehicle control systems design in a wind-tunnel environment.

Since the wind-tunnel model translational motion must be restrained, a digital reconstruction of the translational motion will be simulated using wind-tunnel measured forces and moments. A critical need for the VFT concept is a motion-enabling device that interfaces directly with the VFT test hardware (i.e., scaled models of aircraft and missiles) in a wind tunnel and measures model forces and moments in a fast-response environment. Listed below are the criteria necessary to successfully incorporate a motion-enabling device into the VFT concept. The motion-enabling device must:

1. Allow for 3-degrees of freedom rotational motion, while restraining any translational motion. The motion-enabling device must provide 360 degrees of rotational motion in both the roll and pitch axes, while allowing for a limited range of angles about the yaw axis. The maximum/minimum yaw angles required are ± 45 degrees.
2. Allow for near friction-free rotational motion.
3. Be able to measure restraining forces due to aerodynamic loads on the model. The motion-enabling device should be designed to support maximum restraining forces of 15,000 lbf. in the pitch and yaw planes and 2000 lbf. in the axial plane. The measuring device must be able to resolve the forces within an accuracy of ± 0.5 % of the full scale value in a fast response environment. It is desired that the measuring device be able to acquire data at a rate of 20,000 samples per second.
4. Be able to generate a retarding force that will damp out any divergent conditions experienced during testing. The requirement to damp out divergent conditions should they exist is a necessary safety feature that would allow for system protection in the event of autopilot failure or a divergent condition being reached.

5. Be designed such that aerodynamic interference affects between the device and test hardware are minimized. The test articles could range in size from 10%-scale models of aircraft to full-scale models of missiles. Test conditions will range from Mach numbers 0.2 to 1.6.

PHASE I: Demonstrate on a limited scale the ability to digitally reconstruct the translational motion of a model in a wind tunnel using measured forces and moments.

PHASE II: Develop, demonstrate, and deliver to the Air Force a full-scale motion-enabling device that meets the requirements listed above.

PHASE III DUAL USE APPLICATIONS: The proposed motion-enabling device will have commercial applications in the development of prosthetic devices that include bio-feedback sensing to induce or assist in movement.

REFERENCES:
1. E. Marquart, C. Ratliff , "An Assessment of a Potential Test Technique: Virtual Flight Testing (VFT)," AIAA Paper 95-3415.
2. American Institute of Aeronautics and Astronautics, Suite 500, 1801 Alexander Bell Drive, Reston, VA 20191-4344.

KEYWORDS: Virtual Flight Testing, translational motion, wind tunnel, motion-enabling device, Mach number, missile .

AF00-298 TITLE: Turbine Engine Augmentor Rumble and Screech Indicator

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms

OBJECTIVE: Design and develop a fully functional high-speed turbine engine augmentor combustion monitoring system.

DESCRIPTION: Augmentor (afterburner) operation is often associated with combustion instability that can be potentially detrimental to the turbine engine if the resonant amplitude levels are excessive. During testing of an engine, known to have poor augmentor combustion characteristics, obscuration of the visible augmentor-camera images was noted. The source of the obscuration is believed to be unburned-fuel spray or smoke. The correlation of obscured image and combustion instability could provide the basis for a combustion instability indicator.

Augmentor rumble is generally associated with longitudinal combustion instabilities with acoustics frequencies between 50 -100 Hz. The acoustic frequencies of screech are considered to be as high as 600 Hz and are generally associated with circumferential or transverse modes. A current method to control the potentially devastating combustion instabilities, after the instabilities have begun, is to reduce the fuel flow to the augmentor. A simple, rugged, and low cost sensor system that can determine incipient combustion instability and provided feedback for combustion control is desired. Any sensors used would be expected to be located downstream of the augmentor and must endure the harsh engine exhaust environment

PHASE I: Select and evaluate a promising concept. A proof-of-concept demonstration of the key concept is required in this phase.

PHASE II: Design, assemble, test, and deliver to the Air Force a functional rumble-screech sensor system suitable for use in production turbine engines.

PHASE III DUAL USE APPLICATIONS: Commercialization potential lies within the military aircraft industry. Modifications will also allow the device to be used as part of a feedback control device for non-augmented operation in commercial aircraft turbine engines as well as in stationary gas turbines used for power generation.

REFERENCES:
1. "The Aerothermodynamics of Aircraft Gas Turbine Engines," AFAPL TR 78-52, Gordon C. Oates, July 1978, AD A059 784 (DTIC), Defense Technical Information Center, Suite 0944, 8725 John J. Kingman Road Ft. Belvoir VA 22060-6218.
2. "The Aerothermodynamics of Gas Turbine and Rocket Propulsion," AIAA Education Series, AIAA, NY, NY, Gordon C. Oates ,1984. 59 John St., 7th Floor 10038.
3. "Augmentor Stability Management Program, Final Report," AFWAL-TR-82-2001, R. Ernst, February 1982, AD A117 926 (DTIC) National Technical Information Service, 5285 Port Royal Road, Springfield VA 22161.

KEYWORDS: Turbine Engines, Combustion Instability, Augmentor

AF00-299 TITLE: Thin High Z Converter Foils

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop methods of producing thin high Z foils for low cost nuclear weapons effects simulations.

DESCRIPTION: X-ray production efficiency at low voltages (less than 1 MV) is reduced by self-adsorption. Electrons are typically accelerated across a gap into a high Z (atomic number) foil where bremsstrahlung radiation is produced. Most of the radiation produced is adsorbed before it can exit the foil and be used. Techniques for constructing reflex triodes have been proposed where a hollow cathode is placed on either side of a thin anode/converter and electrons passing through from each cathode are reflected by the electric field of the second converter. The electrons then bounce back and forth through the anode losing a small percentage of their energy and generating additional emissions of x-ray with each pass. This process could result in much more radiation output than a standard diode if the high Z material can be made sufficiently thin to reduce self-adsorption. The development of a technique for producing low cost 2- to 6- micrometers thick Au or Ta foils that are 6 to 18 inches in diameter is needed. To be useful, the foils should have a uniform thickness within +/- 20% and be capable of being stretched flat to within +/-0.2. For Phase I, a sample that will be a support ring 30-mil thick with a 6.5-inch inside diameter (free foil diameter) and 7.75-inch OD is needed. The sample is to be the mass equivalent of a 3-micrometer thick gold foil. The foils must be strong enough to survive careful handling and be mounted in a machine. The cost to fabricate the foils is a critical factor.

PHASE I: An evaluation and demonstration of a proof-of- concept sample foil on the Modified Bremsstrahlung Source (MBS).

PHASE II: Demonstration of layer foils up to 18 inches free diameter on large x-ray simulators. Demonstrate mass producibility and ability to fabricate large very thin diameter foils.

PHASE III DUAL USE APPLICATIONS: The ability to make these foils will allow the rapid generation of high quality transmission electron microscopy (TEM) samples. This will be a milestone in the improvement of metallurgical techniques. Other commercial applications include the general use of thin films and in direct applications for very short pulse x-ray inspection.

REFERENCES:

1. B.V. Weber et al., "Bremsstrahlung X-Ray Source Enhancement Using Reflexing Converters," Journal of Radiation Effects, 12 No 1, 232 (1994).

2. G. Cooperstein et al., "Potential Enhancements of Warm X-Ray Dose from a Reflexing Bremsstrahlung Diode," IEEE Transactions on Nuclear Science, Vol. 42 No 6 (1995). The Institute of Electrical and Electronic Engineers, 445 Hoes Lane, Post Office Box 1331, Piscataway, NJ 08855-1331.

KEYWORDS: X-Rays, Ionizing Radiation, Thin Films, Reflex Diode

AF00-300 TITLE: Miniaturized Robust Multichannel Telemetry System

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a robust telemetry system that can survive in a hostile temperature and vibration environment while transmitting sensor data from an aerospace ground test article.

DESCRIPTION: Heat flux, pressure, strain gauge, vibration, and temperature data have traditionally relied on extensive wiring or slip-ring schemes to transfer the signal off-board of wind-tunnel models or turbine engines. This leads to long installation and setup times. Aerospace ground-testing customers would like to reduce test costs and cycle times and add more instrumentation by eliminating wires/slip rings. The future telemetry system should fit in a small volume (1/2 inch by 1/2 inch by 1/4 inch) and operate reliably in a 1000°F temperature environment using 100° F cooling water. The system must transmit across a distance of at least 10 feet in a variety of ground test facilities with the potential for significant transmission signal interference. The device must operate with applied G loads in excess of 50 "G's" in a near vacuum and/or operate reliably at temperatures of 350-450°F concurrently with G loads in excess of 50,000 "G's." To be useful, the telemetry system will have to survive in these hostile environments for at least one hour, accept inputs from 50 measurement instruments, and transmit 50 channels of data at rates of at least 500 samples/second per channel. Each channel should have at least 16-bit resolution and must be remotely programmable during a test period without hard wire connections.

PHASE I: Analytically and experimentally investigate the feasibility of developing a telemetry system that can meet the requirements stated in the Description above. A proof-of-concept demonstration is required.

PHASE II: Produce, test, and deliver to the Arnold Engineering and Development Center a working prototype system that meets the requirements stated in the Description above.

PHASE III DUAL USE APPLICATIONS: In addition to companies involved in aerospace ground test facility testing, the technique can be applied to other rotating machinery such as turbine engines. The turbine engine manufacturers are actively searching for a telemetry device of this description. Helicopter rotor track and balance procedures currently utilize mechanical slip rings for data transmission. The telemetry system could be readily adapted for this application providing a more reliable diagnostic method for rotor track and balancing.

REFERENCES:

1. Marquart, E. , Dix, R., and Walker, G., "Kinematic Telemetry in Wind Tunnels," AIAA Paper 95-3984, 1995, American Institute of Aeronautics and Astronautics, Suite 500, 180 Alexander Bell Drive, Reston, VA 20191-4344.

2. Mehregany, M., DeAnna, R.G., and Reshotko, E. "Microelectomechanical Systems for Aerodynamics Applications," AIAA Paper 96-0421, 34th Aerospace Sciences Meeting & Exhibit, Reno, NV, January 1996. American Institute of Aeronautics and Astronautics, Suite 500, 180 Alexander Bell Drive, Reston, VA 20191-4344.
3. Shaver, Joel E., Jones, Gil R., and Walker, Greg P., "Application of Gun-Launched Telemetry at the AEDC Range G Facility," AIAA 96-4508 AIAA 7th International Aerospace Plane and Hypersonic Technologies Conference, Norfolk, VA, November 18-22, 1996. American Institute of Aeronautics and Astronautics, Suite 500, 180 Alexander Bell Drive, Reston, VA 20191-4344.

KEYWORDS: Telemetry, Wind Tunnel Instrumentation. Turbine Engine

AF00-302 TITLE: Intelligent Near Net-shape Manufacturing Cell

TECHNOLOGY AREAS: Materials/Processes

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: C-141 Program Management Directorate

OBJECTIVE: Develop an integrated, near net-shape manufacturing cell to provide improved mission effectiveness and manufacturing supportability.

DESCRIPTION: This topic addresses an intelligent, integrated manufacturing cell that is intended to produce detail machined aircraft structural members directly from digital engineering data through near net-shape metalworking processes as an integrated, intelligent process. This system would employ accepted computer integrated manufacturing (CIM), computer integrated design (CID), finite element modeling (FEM), intelligent processing of materials (IPM) and nonlinear analytical techniques to convert digital engineering data to the appropriate intelligent manufacturing models. The models provide the design for, and allow the manufacture of, metalworking tooling and dies that will be used in the production of the near net-shape high strength aluminum alloy replacement structures. These models are also shared in the detail machining of the near net-shaped products. Furthermore, to improve efficiency and maintain the properties and quality of the original wrought products, the intelligent near net-shape manufacturing cell shall employ additional intelligence by integrating a material or alloy selector as part of the modeler and nonlinear analysis to identify and idealize mechanical properties and to predict and minimize distortion.

PHASE I: The Phase I goals include 1) the evaluation and testing of candidate concepts, 2) an ROI cost assessment, and 3) a feasibility evaluation addressing requirements and capabilities, including capitalization, environmental impact, and facilities and personnel issues. The leading technological concept will be developed to demonstrate proof of concept and to include a conceptual model for evaluation and testing.

PHASE II: After the conceptual model has been tested and refined, a prototype shall be developed and evaluated to demonstrate the intelligent characteristics of the integrated system. The conceptual prototype of the intelligent, integrated system shall include demonstration that the manufactured product complies with the digital data in both the metal-worked and finished machined conditions.

PHASE III DUAL USE APPLICATIONS: The successful application of this technology may revolutionize organic manufacturing capability at this center and result in substantial improvements in weapons system supportability of all the prime weapons systems managed and maintained here. Therefore, this potential also applies to each of the other centers and similar counterparts in other DoD services. But supportability is not just of concern in military applications. The commercial and other civil aviation fleets also require manufacture of structural members in small quantities to support maintenance, repair, and overhaul. In other words, there is a substantial potential for commercialization if this effort is successful.

REFERENCES: Net Shape Technology in Aerospace Structures, ADA176508, NTIS DTIC/STINET; Industrial Technology Modernization Program, ADA208799, National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, DTIC/STINET; Intelligent Processing of Materials, ADA269250, DTIC/STINET; The Role of Manufacturing Workstations in Computer Integrated Manufacturing, ADD802105, IFS (Publications) Ltd., 35-39 High Street, Kempston, Bedford MK 427BT, England.

KEYWORDS: Intelligent Manufacturing, Process Integration, CIM, CID, FEM, IPM

AF00-303 TITLE: Reduction of EMI from Hybrid Electric Drivetrains

TECHNOLOGY AREAS: Ground/Sea Vehicles

OBJECTIVE: Research and develop technologies to reduce inherent EMI from high power hybrid electric drivetrains.

DESCRIPTION: Hybrid electric vehicles offer significant military advantages over conventional vehicles, such as reduced fuel consumption, greater torque and a pure electric "stealth" capability with minimal thermal and acoustic signatures. But hybrid power trains inherently produce more electromagnetic interference than conventional drivetrains due to the high power, high speed, switching that takes place for vehicle control. The level of EMI produced in today's hybrid drivetrains is well above limits specified in Mil-Std 461E, and SAE 551, Electromagnetic Interference for vehicles. R&D goal of this topic is to identify causes of EMI in the drivetrain, develop methodologies to minimize EMI and to develop alternative technologies that produce less EMI. Shielding has been found to be a less than cost-effective means of lowering the EMI level for current systems. This research should concentrate on innovative drivetrain design considerations and/or alternative technologies that meet hybrid electric operational parameters. WR-ALC/LEE has deployed three (3) hybrid electric step vans. Electrical schematics detailing available energy will be provided to successful Phase I offeror(s) as GFI. One of the deployed vans will be provided to the offeror for Phase II as GFE to demonstrate the onboard power generation capability.

PHASE I: Identify causes of EMI from existing hybrid electric vehicles. Research, develop and test new technologies to reduce EMI on hybrid electric drivetrains, as described above. Integration with the hybrid drive system must be considered.

PHASE II: Integrate the technologies developed during Phase I into a prototype hybrid drivetrain system. Demonstrate validity of the new technology by testing the drivetrain in an existing Air Force hybrid electric van, bus, and tow tractor. Electromagnetic interference (EMI) as specified in Mil-Std 461, and SAE 551 (latest versions) shall be a prime consideration. Equal in consideration is the overall business case to include reliability, maintainability, environmental impact and commercialization.

PHASE III DUAL USE APPLICATIONS: Hybrid electric drivetrains would have numerous potential commercial applications, including commercial flightline vehicles and support vehicles and support. The cost-effective reduction of EMI from these systems will accelerate the use of hybrid drivetrains in military and commercial applications.

REFERENCES: Statement of Objectives for Hybrid Electric Vehicle, Electric and Hybrid Vehicle Program, DE000189, DTIC/STINET, Electric Vehicle EMI/EMC Test Program, DN816153, DTIC/STINET.

KEYWORDS: Hybrid Electric, electromagnetic interference, hybrid drivetrain.

AF00-305 TITLE: Portable, Field-Functionalized, Multi-component Vapor Detector

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a low-cost, lightweight, easy-to-operate instrument for monitoring hazardous air pollutants.

DESCRIPTION: There are increasingly stringent requirements, including recent aerospace NESHAP standards, to monitor and then control vapor-phase concentrations of organic pollutants in industrial settings. These requirements dictate the use of (1) dedicated analytical instruments for individual or small groups of compounds, (2) use of costly, bulky, and difficult-to-maintain broad-spectrum analytical instruments, or (3) field samples with subsequent, off-line laboratory analyses. All of these approaches are costly, require highly trained personnel, and take significant amounts of time.

This project seeks an innovative multi-component air monitoring system which addresses each of the shortcomings outlined above. Inherent in these goals are concepts which address: (1) Ability to measure low concentrations of multiple organic vapors in the presence of typical ambient water vapor concentrations, (2) the need for detectors which do not require cooling, and (3) the need for a rugged, portable instrument which could be successfully operated by a trained technician.

PHASE I: Design a prototype, field-functionalized OP-FTIR unit with the following target capabilities: (I) A cost of $25K or less, (ii) Simplified operation and output, and (iii) Small, lightweight design. Demonstrate its capabilities by direct comparison with an existing, commercial open-path Fourier transform infrared spectrometer unit.

PHASE II: Develop the prototype design into a commercially viable unit which meets many of the routine air monitoring requirements typically found at industrial sites. The unit must also be developed in such a manner as to ensure data integrity and credibility within the framework of EPA guidance documents and other regulatory requirements (see Refs 1 and 2 as examples for one type of instrument).

PHASE III DUAL USE APPLICATIONS: The proposed field-functionalized OP-FTIR air monitoring system will have numerous benefits to the environmental, military and industrial communities. These include:

- o Users obtain powerful, multicomponent gas analysis at low cost
- o Detection limits are easily improved by coadding additional spectra
- o Rapid temporal scanning of multiple paths is available
- o Path-integrated chemical species concentrations are obtained
- o Samples are not altered by the measurements
- o Inaccessible areas can be monitored

REFERENCES:
1. Russwurm, G. M., METHOD 16 Long-Path Open-Path Fourier Transform Infrared Monitoring of Atmospheric Gases, U.S. Environmental Protection Agency, Cincinnati, OH, EPA/625/R-96/010b, January 1997.
2. Russwurm, G. M. and Childers, J. W., FT-IR Open-Path Monitoring Guidance Document, U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA/600/R-96/040, April 1996. NTIS PB 96170 477, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.
3. Strang, C.R., S.P. Levine, and W.F. Herget. 1989. A Preliminary Evaluation of the Fourier Transform Infrared (FTIR) Spectrometer as a Quantitative Air Monitor for Semiconductor Manufacturing Process Emissions. American Industrial Hygiene Association Journal 50(2):70-77.
4. Levine, S.P., and G.M. Russwurm. 1994. Fourier Transform Infrared Optical Remote Sensing for Monitoring Airborne Gas and Vapor Contaminants in the Field. Trends in Analytical Chemistry 13(7):258=262.
5. Griffiths, P.R., R.J. Berry, and B.K. Hart. 1998. A Low-Resolution Spectrometer for Open-Path Fourier Transform Infrared Spectrometry. Submitted for publication in Field Analytical Chemistry and Technology.
6. Griffiths, P.R., R.J. Berry, and B.K. Hart. 1998. Effects of Resolution, Spectral Window, and Background on Multivariate Calibrations used for Open-Path Fourier Transform Infrared Spectrometry. Submitted for publication in Field Analytical Chemistry and Technology.

KEYWORDS: Open-Path Air Monitor, Environmental Site Monitoring, Industrial Hygiene Monitoring, Real Time Pollutant Monitoring, Air Pollution Monitoring Instruments.

AF00-306 TITLE: Conversion of Static Models and Stimulus Files to Digital Test Interface Format (DTIF)

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop software to automatically convert static models and static stimulus files to the DTIF IEEE standard format for LASAR.

DESCRIPTION: Digital circuits are tested on Automatic Test Equipment using a LASAR generated software routine. Many of these routines use LASAR 5 static models and stimulus patterns. The new version of LASAR uses a different file format for models and stimulus patterns. Static files are plagued with supportability problems and need to be upgraded to match the DTIF standard or the latest version of LASAR. To do this, engineers are required to manually convert the files. This is very time consuming, diverse, and requires constant judgement making. Thus, when making complex digital circuit conversions, mistakes are inevitable.

The LASAR files are in an ASCII format. The data in the files varies widely and there are several variations that require interpretation. Many factors become critical and when the engineer is dealing with thousands of different signal variations and possibilities, mistakes can be made and problems can be compounded.

Conduct research to determine if static LASAR 5 files can be automatically converted into LASAR DTIF files on a personal computer platform. The dynamic software package is needed to augment the engineer’s skill and accomplish the proper conversion to LASAR DTIF standard files.

PHASE I: Research will focus on a software approach that will demonstrate the conversion of static LASAR 5 files to LASAR DTIF format files.

PHASE II: Develop a software prototype of the approach(es) defined during Phase I.

PHASE III DUAL USE APPLICATIONS: Will aid in the resolution of major problems like retest-OK (RTOK), and could-not duplicate (CND) in aircraft equipment repair. Significantly improves LASAR test software development time. Significant commercial markets exist for this technology in industrial process control and medical process applications.

REFERENCES:
1. B.V. Weber et al., "Bremsstrahlung X-Ray Source Enhancement Using Reflexing Converters," Journal of Radiation Effects, 12 No 1, 232 (1994).
2. G. Cooperstein et al., "Potential Enhancements of Warm X-Ray Dose from a Reflexing Bremsstrahlung Diode," IEEE Transactions on Nuclear Science, Vol. 42 No 6 (1995). The Institute of Electrical and Electronic Engineers, 445 Hoes Lane, Post Office Box 1331, Piscataway, NJ 08855-1331.

KEYWORDS: X-Rays, Ionizing Radiation, Thin Films, Reflex Diode

AF00-308 TITLE: Model Characterizing Electromagnetic Pulse Response from Continuous Wave Electromagnetic Data

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Provide methods and tools to estimate aircraft survivability/vulnerability to threat level electromagnetic pulse from low amplitude continuous wave data

DESCRIPTION: Directed Energy (DE) weapons are on the drawing boards of both allies and potential adversaries. Electromagnetic pulse generation is anticipated to be the mode of operation of the DE weaponry. USAF systems are currently tested using continuous wave electromagnetic energy. It would be cost effective to develop an analysis methodology/model that could convert system response to continuous wave bombardment to system response to pulse bombardment.

The process shall utilize continuous wave data from the Portable Hardness Surveillance Test System (PHSTS) and other available data as appropriate. The model will extrapolate continuous wave data to enable characterization of system response to high amplitude short duration radiated pulse energy. Testing shall verify model performance. The modeling effort should first extrapolate continuous wave data to estimate system response for relatively low amplitude short duration radiated pulse energy, verify with test, then extend the extrapolation in steps to high amplitude short duration pulse energies specified for a threat level environment for strategic aircraft.

PHASE I: Develop theoretical basis for model, develop preliminary model parameters and algorithms, and devise strategies for test and verification. Deliver documentation describing theory of operation, model parameters and algorithms, and verification test plan.

PHASE II: Finalize model parameters, translate algorithms to program code, and complete test and verification of model. Deliver process documentation, program codes, and final reports of successful verification test. Process must be reliable and maintainable with repeatable results.

PHASE III DUAL USE APPLICATIONS: This inference model would allow extrapolation of relatively low cost and low energy test methods to higher energy broad band interference sources. Potential commercial utilization of this process includes test and verification of commercial aircraft for susceptibility to EMI/EMC from proliferating consumer electronics, proliferating commercial and private RF sources, or EMP from development and terrorist deployment of transportable and inexpensive directed energy weapons.

REFERENCES: EMP Interaction: Principles, Techniques and Reference Data (AD Number A100508), Portable Hardness Surveillance Test System (AD Number ADB143895), Hardness Maintenance/Hardness Surveillance (HM/HS) Baseline Data Report (AD Number ADB162318)

KEYWORDS: survivability, nuclear hardness, hardness maintenance/hardness surveillance (HM/HS), Electromagnetic pulse (EMP), electromagnetic interference/electromagnetic compatibility (EMI/EMC)

AF00-309 TITLE: Virtual Office Application for Next Generation Internet (NGI)

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Take Virtual Office or Concurrent Engineering Applications to more advanced level with NGI utilization.

DESCRIPTION: The Next Generation Internet is planned to be 100 to 1000 times faster than today's Internet. The objective of "Virtual Office Application for NGI" is to research and develop a more advanced Virtual Office Application that can take advantage of the higher level Internet. Limitations of the current Internet, such as speed and security, have affected how virtual offices are being designed and used. For example, speed limitations have affected how real-time concurrent engineering or conferencing is done, have limited the ability to easily access and use large volumes of information, and have limited the degree of real-time activity. In today's Integrated Data Environments, the requirements exist, for example, to easily assemble a group of technical experts that are geographically dispersed, to view a system malfunction immediately, then proceed in real time to collect the information needed to resolve the problem, conduct the analysis, reach consensus, and initiate the logistic activities required to support the results. The NGI provides the technology that can greatly reduce the cycle time of many, if not most, acquisition activities. To take advantage of this technology, we need to redesign and research how to utilize NGI for virtual office applications. The specific functions that will be examined include the following:

1) Planning and Management Capabilities: Explore how NGI can be used to improve how virtual offices are being used to develop and manage strategic plans and program plans. Also explore how issues can be better tracked, managed, and resolved.

2) Data Collection and Management: Explore how NGI can be used to quickly access information that exists in different media and prepare the information to be used quickly. Also explore how this information can be quickly accessed and used, and maintained in a distributed Product Data Management (PDM) system.

3) Communication: Explore concepts for creating virtual offices where the participants, regardless of their location, can interact with one another as though they were physically in the same office performing such activities as Concurrent Engineering and Desktop Video Teleconferencing.

The probability of success is very high based on commitment that the Federal Government has made to developing NGI and the demonstrated success already being experienced using virtual offices. The opportunity is to take the technology and the benefits to another level.

PHASE I: Research the Virtual Office concept that is currently being used within DoD and explore and demonstrate how this concept can be improved using the NGI. An introduction to this capability can be found at the web site www.inforumsolutions.com.

PHASE II: The expectation during Phase II is to expand the demonstration into all functions described above into a production capability such as the Integrated Data Environment for Major End Items, IDE(M), or any Acquisition/Logistics Process.

PHASE III DUAL USE APPLICATIONS: Within all of DoD as well as communication to DoD Industry manufacturers and technical partners, collaboration can make high utilization of this product when developed.

REFERENCES: Information on the Next Generation Internet (NGI) may be found at web site http://www.news.com/News/Item/0,4,10750,00.html.

KEYWORDS: Next Generation Internet, Virtual Office, Desktop Video Teleconferencing, Integrated Data Environment.

AF00-310 TITLE: Micro-Miniature, Wireless, Telemetry Sensors

TECHNOLOGY AREAS: Sensors/Electronics/Battlespace, Space Platforms, Weapons

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Air Force SEEK EAGLE Office

OBJECTIVE: Develop micro-miniature, wireless, telemetry sensors for use in weapons and aircraft testing.

DESCRIPTION: Testing today's ultra-modern military aircraft and weapon systems requires extensive and expensive modification to fleet aircraft and weapon stores to install sensing and transmitting equipment. Once the aircraft is modified it becomes the "test aircraft" and all testing must be scheduled around the "test aircraft's" availability. Not only is this expensive, it is inefficient. A more efficient solution would require development of micro-miniature, wireless, telemetry sensors for measuring the parameters of interest (i.e., pressure, strain, acoustics, temperature, shock, etc.). These sensors could be installed on any available aircraft or weapon, using an epoxy type adhesive, and then transmit the measured parameter to a local (within 50 meters) relay station, the relay station would transmit the data to the ground. The sensors that are developed need to be small and not interfere with the aircraft and weapon airflow and withstand the rigorous flight environments associated with aircraft internal and external carriage. The sensors need to be self-powered, inexpensive (some would be destroyed along with the weapon) and reusable/rechargeable.

PHASE I: Develop a conceptual design, using currently available technologies, for a low profile, streamlined, sensing and telemetry capability for each parameter to be measured. The end product should be a detailed report stating the feasibility of accurately measuring and transmitting the desired parameters using subscale, micro-miniature sensors. Estimated sensor costs should be included.

PHASE II: Finalize the design, develop and test prototypes for a number of different sensors in an aircraft environment. The end product would be low cost, robust, sensors that can be produced in larger quantities.

PHASE III DUAL USE APPLICATIONS: There are numerous applications for wireless sensors in the commercial market. Potential areas are: wind-tunnel use, nuclear power plant monitoring, automotive industry, remote oil field monitoring, and medical monitoring.

REFERENCES: DTIC accession number: ADA310032 "Mobile and Wireless Communications;" ADP010211 "A Distributed, Wireless MEMS Technology for Condition Based Maintenance," National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

KEYWORDS: telemetry, sensors, wireless, miniature, spread spectrum, radio communications, mems technology.

AF00-311 TITLE: Advanced Global Positioning System Hybrid Simulator

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: 746TS Navigation Test and Evaluation Laboratory

OBJECTIVE: Produce a Global Positioning System simulator incorporating new signals and controlled reception pattern antenna simulation.

DESCRIPTION: Due to the vulnerability of Global Positioning System (GPS) receivers to jamming, many technologies are being developed to make receivers more robust in a jamming environment. These technologies include a new military signal structure announced in July 1999. They also include developments such as controlled reception pattern antennas which prevent jamming signals from entering the GPS receiver. Additionally, due to recent presidential directives, the current civilian GPS signal will soon be augmented by two new civilian GPS signals. These changes to the GPS will make current GPS simulators obsolete. Therefore, this SBIR project will develop a new GPS simulator to support testing of new GPS technologies and signals. This simulator will replace current simulators when they become obsolete. The Advanced GPS Hybrid Simulator (AGHS) must be flexible enough to incorporate current GPS signals, near term future GPS signals, and GPS signals that are currently unforeseen. Additionally, the AGHS must support testing of controlled reception pattern antenna (CRPA) systems.

PHASE I: The Phase I SBIR effort will produce a system design for the Advanced GPS Hybrid Simulator. This design will incorporate capability to test new GPS technologies, including but not limited to; the new civilian and military signal structures, the Wide Area Augmentation System (WAAS), the Local Area Augmentation System (LAAS), and the Joint Precision Approach Landing System (JPALS). The AGHS design will also include capability to test Navigation Warfare technologies including receivers incorporating controlled reception pattern antennas (CRPA). The Advanced GPS Hybrid Simulator (AGHS) must be a hybrid digital and radio frequency (RF) GPS simulator. The AGHS must be based on reprogrammable signal generators to allow easy upgrading to support changes in GPS signals. Digital reprogrammability will make the AGHS flexible enough to allow easy upgrading to support changes in GPS signals. This effort will culminate in a system engineering design report detailing how the AGHS will be built, what technologies it will incorporate, what capabilities it will have, and how it will ensure potential for future upgrades.

PHASE II: The Phase II SBIR effort will use the design from Phase I to produce an Advanced GPS Hybrid Simulator. This phase will produce an AGHS prototype and will culminate in its demonstration.

PHASE III DUAL USE APPLICATIONS: If successful, the AGHS will be produced, tested, and integrated into the Navigation Test and Evaluation Laboratory (NavTEL), at the 746th Test Squadron, 46th Test Group, Holloman AFB, NM. Additional potential customers for this product include GPS receiver manufactures such as Rockwell Collins, Trimble, Novatel, and Ashtech. Furthermore, tri-service military research and test agencies such as the Air Force Research Labs, SPAWAR Systems Center, and the Electronic Proving Grounds are likely customers for this technology. Finally, academic institutions involved in GPS research are also likely customers for this technology.

REFERENCES:
1. Parkinson, B., Darrah, J., Remondi, B., Spilker, J.J., Van Dierendonck, A.J., Panel Discussion: GNSS for the 21st Century, Increasing Worldwide Capability and Robustness, Proceedings of the ION GPS-98, Nashville, TN, September 15-18, 1998.
2. Leva, J. L., Pacheco, P., GPS C/A-Code Interference Tests with Proposed Lm Waveforms, Proceedings of the ION GPS-98, Nashville, TN, September 15-18, 1998.
3. Architecture and Requirements Definition Test and Evaluation Master Plan (TEMP) for Joint Precision Approach and Landing System (JPALS) ACAT ID (Potential), Version 3.0, 30 October 1998.
4. Anderson, J., Lucia, D., GPS Modernization Advanced Signal Development Waveform Development Plan, Revision 0, http://www.laafb.af.mil/SMC/CZ/homepage/lm/downld.htm, 20 March 1998.

KEYWORDS: Global Positioning System, GPS, Navigation Warfare, NAVWAR, Controlled Reception Pattern Antenna, CRPA, Wide Area Augmentation System, WAAS, Local Area Augmentation System, LAAS, Joint Precision Approach Landing System, JPAL

AF00-312 TITLE: <u>Directed Energy Weapons (DEW) Vulnerability and Lethality Analysis</u>

TECHNOLOGY AREAS: Information Systems, Sensors/Electronics/Battlespace

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Air Armament Center Test and Evaluation Mission Support

OBJECTIVE: Develop analytic methodologies and processes for estimating DEW effectiveness and target vulnerability to DEW.

DESCRIPTION: High-power radio frequency (HPRF) DE systems are characterized by high frequency bandwidth or power level. Narrowband systems are commonly referred to as High Power Microwave (HPM) while wideband systems are commonly referred to as Ultra Wide Band (UWB). AS DEWs, these RF systems are designed to defeat, destroy or degrade electronic equipment. Their effects can range from temporary lapses in performance to permanent circuit degradation to burnout or destruction. As weapons and weapon systems become more complex, they are increasingly dependent upon sophisticated electronics. This dependency on sophisticated electronics brings with it an increased vulnerability to DE RF radiation, either intentional or via "electronic fratricide." Compact, high-efficiency lasers are critical for Electro-optical (EO) countermeasures (CM), Infrared CM (IRCM) and DEW applications. Diode-pumped lasers, non-linear frequency conversion and laser designs have matured to a point where it has become feasible to incorporate these devices into tactical vehicles and aircraft for self-protection and missile defense. Current methods and models used for estimating weapons effectiveness and target vulnerability were designed to solve problems associated with conventional munitions. Using state-of-the-art, object-oriented languages (like C++) and cutting edge graphical user interface design techniques, the process and procedures for accurately predicting DEW effectiveness and target damage assessment can be enhanced dramatically. This upgraded capability allows for direct linkage to the model-test-model methodology that is critical to today's streamlined, acquisition process. Current damage assessment predictions, using expected value outcomes, do not lend themselves easily to this practice. Innovative concepts are required to increase the utility of model based damage predictions. Finally, this new process should run on both PC based Windows or UNIX operating systems.

PHASE I: Research current technologies and M&S models, determine and document current deficiencies, develop innovative concepts and establish measures of merit for selecting the best value concept. Research feasibility of the selected concept. Define hardware and software requirements.

PHASE II: Design, develop and implement the vulnerability assessment model concept selected in Phase I. Verify and validate the system performance through realistic testing and demonstration.

PHASE III DUAL USE APPLICATIONS: In addition to providing strong M&S support to DoD DEW weapons development and blue system susceptibility testing and analysis, this development will have broad use within the US commercial community. Weapons developers will have an accurate and accepted program for demonstrating the effectiveness and survivability of their products. DEW effectiveness, vulnerability, and lethality (WEVL) forecasting capabilities are of interest to all industries that develop information technology. There have been for example, documented cases of use of lasers to blind military pilots and severely degrade aircraft visual aids (night vision goggles) and flight critical instrumentation/sensors. In addition, modern commercial aircraft rely heavily on computers for autopilots, flight controls, and automated landing systems. These aircraft are particularly vulnerable to terrorist attack using commercially available low-power laser systems and easily developed pulsed or CW RF generators during take-off and landing. In addition, any heavy users (commercial or DoD) of communications and computer systems, e.g. command and control centers, electrical switching stations, computer centers, the internet, etc. may be similarly vulnerable to this kind of attack. In addition, the phenomenology associated with HPRF systems is virtually the same as that seen associated with lightning strikes, exposure to high power radars or any other unintended power surge. The ability to predict, with a credible model, the effects of any type of induced or direct power surge to electronics will be of great interest to any industry that relies on uninterrupted communications or electronic monitoring capability.

REFERENCES: Army Science and Technology Master Plan 10(d,e).

KEYWORDS: Vulnerability, Assessment, Model, Prediction, Probability of Kill, Target Geometry Model, Directed Energy Weapon, Stochastic

AF00-314 TITLE: Electro-Optical Scene Simulation Projector (EOSSP)

TECHNOLOGY AREAS: Information Systems

DOD ACQUISITION PROGRAM SUPPORTING THIS PROGRAM: Air Force Guided Weapons Evaluation Facility

OBJECTIVE: Develop a visible spectrum scene projector mountable on a flight motion simulator that is high resolution, flickerless, and highly uniform.

DESCRIPTION: Current generation weapon systems and upgrades to older weapons that operate in the visible spectrum ("TV-guided") are adopting high resolution charged coupled devices (CCDs) as the detector of choice and are using complex image processing algorithms. The technology to generate the required complex scenes has evolved with the weapon systems but the ability to project the complex scenes to the guidance unit has lagged behind. Current projectors support low-resolution image projection for older vidicon tube technology and low-resolution CCDs. These projectors do not provide the resolution, light intensity, spectrum, image uniformity, and "flickerless" operation required by the newer imaging systems. A new capability must be developed to match image projection capability to the sensors being tested in order to provide realistic hardware-in-the-loop test capability for these systems. Anticipated requirements are:

a. Pixel resolution two times greater than supported CCD imagers (currently 640 x 480 pixels). The display should have a minimum pixel count of 1280 x 1024;

b. Flickerless projection with no synchronization from the CCD imager (no adverse scan related artifacts);

c. Highly uniform image;
d. High contrast ratio (~100 to 1 or better);
e. Minimum of 256 shades of grey;
f. Realistic light intensity levels as compared to measured targets and backgrounds;
g. Realistic spectrum as compared to sunlight;
h. High frame rate operation (30 to 120 frames per second);
i. Variable projected field-of-view from 2 to 20 degrees (zoom or interchangeable optics);
j. Large collimated beam (4 to 12 inch diameter);
k. Multiple video input standards (RS-170, RGB, SVGA/XGA/SXGA, and Onyx Digital Interface required);
l. Weight, form factor, and durability to allow mounting and operation on a flight motion simulator.

PHASE I: Develop the specifications for the EOSSP. Evaluate current technology that may be used to build the projector. Perform requirements, design, and cost trade-off analyses, and define all hardware requirements needed to build the EOSSP. Identify the requirements that cannot be met by current technology and may require further research and development. Using one or more of the most promising display/projection technologies, perform experimental proof-of-principle demonstrations for key requirements to give confidence for the success of a Phase II program. Document the results and prepare a validation test plan.

PHASE II: Design, develop, produce, and deliver a prototype EOSSP that meets the system requirements defined in Phase I. Demonstrate and validate the performance of the EOSSP against a typical high-resolution CCD based imager. Document the results, the design, and the method of operation.

PHASE III DUAL USE APPLICATIONS: Numerous dual-use applications exist for improved display and projection capabilities. Current display systems (monitors and liquid crystal devices) suffer from low brightness and contrast levels when used in high ambient light environments (e.g. outdoors). Large-screen projection systems have brightness and image uniformity problems. Military applications include lightweight, rugged, high brightness and high-resolution displays for aircraft, tanks, and other military vehicles as well as improved display and projection systems for training simulators. Potential commercial applications include high-definition television displays; lightweight, energy efficient computer monitors; improved large-screen projectors; and photographic printing. Microdisplays, in the form of liquid crystal on silicon (LCOS) devices and digital micro-mirror devices (DMD), are an emerging technology that has high potential for being the basis of these dual-use applications.

REFERENCES: Smith, J. Lynn, Visible Projector Design, 16 July 1998.

KEYWORDS: Hardware-in-the-loop simulation; Image projection; Scene projection; Visible projector technology