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. All questions concerning proposal submissions, Fast Track applications and requirements, and award / contracting issues should be directed to the appropriate agency SBIR Program Manager listed beginning page AF-4. Addresses for proposal submission and numbers for administrative and contracting questions are listed on the following pages, AF-4 through AF-8.

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 *FastTrack* Phase II proposals, which will be selected for Phase II awards provided it meets the "technically sufficient standard in section 4.5.)** 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.

NOTICE: Only government personnel will evaluate proposals. However, base support contractors may be used to monitor contract performance and testing. Any contract award may require a nondisclosure agreement between base support contractors and awarded small businesses.

You must receive a written invitation before submitting a Phase II proposal (all Fast Track applicants will be sent a written invitation). 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. Phase II proposals are typically 24 months in duration not exceeding $750,000. 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 application 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. Should outside funding not be available at the time designated by the awarding Air Force activity, the offerer will not be considered for any Phase II award.

Air Force Phase II Enhancement Program

On selected active phase II awards, the Air Force will invite a limited number of 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 non-SBIR DoD matching funds. The main purpose of the Phase II Enhancement Program is to address new unforeseen technology barriers that were discovered during the Phase II work.

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.

SBIR Program Management Improvements

The Air Force reserves the right to modify the submission requirements. Should the requirements change, all Phase I awardees who are invited to submit Phase II proposals will be notified. The Air Force also reserves the right to change any administrative procedures that will improve management of the Air Force SBIR Program.

Submission of Final Reports

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

Proposal Submission Instructions

Your proposal will be ACCEPTED if you meet all of the following criteria. Failure to meet any one of the criteria will result in your proposal being REJECTED.

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 Is or IIs 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 Appendix A and B Appendices:

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 Proposal 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 Appendix A and B 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.

Please mail proposals as follows

AF01-001 thru AF01-011
Directed Energy Directorate
ARL/DE
3600 Hamilton Avenue SE BLDG 382
Kirtland AFB NM 87117-5776
(Robert Hancock, (505) 846-4418)
For contract questions call Dave Tuttle at (505) 846-8133.

AF01-014 thru AF01-037, AF01-039, AF01-041, AF01-043 thru AF01-046, AF01-048, AF01- 049
Space Vehicles Directorate
AFRL/VS
3600 Hamilton Avenue SE Bldg. 382
Kirtland AFB NM 87117-5776
(Robert Hancock, (505) 846-4418)
For contract questions, call Francisco Tapia at (505) 846-5021.

AF01-038, AF01-040, AF01-042, AF01-047
Space Vehicles Directorate
AFRL/VSOT
29 Randolph Road
Hanscom AFB MA 01731-3010
(Noreen Diamond, (781) 377-3608)
For contract questions, call John Flaherty at (781) 377-2529.

AF01-053 thru AF01-069
Human Effectiveness Directorate
AFRL/HEOP
2610 Seventh Street, Bldg. 441. Rm. 216
Wright-Patterson AFB OH 45433-7901
(Sabrina Davis, (937) 255-2423)
For contract questions, call Mary Jones at (937) 255-2527.

AF01-075 thru AF01-119
Information Directorate
AFRL/IFB
26 Electronic Parkway
Rome, NY 13441-4514
(Jan Norelli, (315) 330-3311)
For contract questions, call Joetta Bernhard at (315) 330-2308

AF01-121 thru AF01-146
Materials & Manufacturing Directorate
AFRL/MLOP
2977 P Street, Bldg 653, Suite 13
Wright-Patterson AFB OH 45433-7746
(Marvin Gale, (937) 255-4839)
For contract questions, call Terry Rogers at (937) 656-9001 or Bruce Miller at (937) 656-9883.

AF01-152 thru AF01-166
Munitions Directorate
AFRL/MNOB
101 W. Eglin Blvd., Suite 140
Eglin AFB, FL 32541-6810
(Richard Bixby, (937) 255-5499
For contract questions, call Stacey Darhower at (850) 882-4294, ext. 3411.

AF01-168 thru AF01-181
Propulsion Directoriate
AFRL/PROP
1950 Fifth Street, Bldg. 18
Wright-Patterson AFB, OH 45433-7251
(Dottie Zobrist, (937) 255-6024)
For contract questions, call Susan L. Day at (937) 255-5499, ext. 067.

AF01-182 thru AF01-193
Propulsion Directorate
AFRL/PROP
5 Pollux Drive
Edwards AFB, CA 93524-7033
(Sandi Borowiak, (805) 275-5617)
For contract questions, call Donna L. Thomason at (661) 277-8596.

AF01-200 thru AF01-237
Sensors Directorate
AFRL/SNOX
2241 Avionics Circle, Bldg. 620
Wright-Patterson AFB, OH 45433-7320
(Marleen Fannin, (937) 255-5285, ext. 4117)
For contract questions, call John Stovall at (937) 255-5380, ext. 097.

AF01-239 thru AF01-253
Air Vehicles Directorate
AFRL/VAOP
2130 Eighth Street, Bldg. 45, Rm. 173
Wright-Patterson AFB, OH 45433-7542
(Madie Tillman, (937) 255-5066
For contract questions, call Douglas Harris at (937) 255-3427.

AF01-267 thru AF01-274
Air Force Flight Test Center
AFFTC/XPST
195 East Popson Avenue
BLDG. 2750, Rm. 218
Edwards AFB, CA 93524-6843
(Abe Atachbarian, (661) 275-9266)
For contract questions, call Donna Thomason at (661) 277-8596.

AF01-275 thru AF01-282
Arnold Engineering Development Center
AEDC/DOT
1099 Avenue C
Arnold AFB, TN 37389-9011
(Ron Bishel, (931) 454 –7734
For contract questions, call Kathy Swanson at (931) 454-4409.

AF01-303 thru AF01-308
Warner Robbins ALC
WR-ALC/TIECT
420 Second Street, Suite 100
Robins AFB, GA 31098-1640

(Capt. James T. Rich, (478) 926-6617)

AF01-294 thru AF01-300
Ogden ALC
OO-ALC/TIEH
5851 F Avenue, Bldg 849, Rm A-15
Hill AFB, UT 84056
(Bill Wassink, (801) 777-2977)
For contract questions, call Martha Scott at (801) 777-0199.

AF01-285 thru AF01-292
Oklahoma City ALC
OC-ALC/TIET
3001 Staff Drive, Suite 2A670A
Tinker AFB, OK 73145-3040
(Don Beodeker, (405) 736-5364)
For contract questions, call David Cricklin at (405) 739-4468.

AF01-257 thru AF01-263
Air Armament Center
46 TW/XPP
101 W. D Avenue, Suite 222
Eglin AFB, FL 32542-5492
(Dave Uhrig, (850) 882-6434)
For contract questions, call Lt. Col. Ed Miller at (850) 882-2556, ext. 4501.

Air Force 01.1 SBIR Topic Index

Directed Energy Directorate, Kirtland AFB, NM

AF01-001	Advanced Concepts for the Chemical Oxygen-Iodine Laser
AF01-002	Wavefront Sensing for High Scintillation Environments
AF01-003	Control of Multiple Deformable Mirror Optical Systems for Performance Enhancement in High Scintillat
AF01-004	Affordable Laser System for Launch Vehicle and Satellite Tracking
AF01-005	Key Enabling Components for High-Power Fiber Lasers
AF01-006	Advanced Diagnostics and Analytic Tools for HF/DF Laser Technology
AF01-007	Atmospheric Measuring System using a Kite/Tethered-Blimp Platform
AF01-008	Active Remote Sensing Technologies for Chemical Effluent Detection
AF01-009	Antenna Back-lobe and Side-lobe Suppression
AF01-010	Space-Based Ultra-Wideband Antennas
AF01-011	Scintillation Resistant Wave-Front Sensors for Strong-Turbulence Adaptive Optics

Space Vehicles Directorate, Kirtland AFB, NM

AF01-014	Lightweight DC/DC Power System
AF01-015	High Speed Digital Isolator for Space Applications
AF01-016	Field Programmable System-On-A-Chip
AF01-017	Mixed Technology System-On-A-Chip
AF01-018	Radiation Tolerant System-On-A-Chip for Space
AF01-019	Low-Cost/Robust Nanosatellite Spacecraft for Distributed, Communication Systems Constellations
AF01-020	Optical Interconnects for Space-Based Field Programmable Gate Arrays
AF01-021	Radiation-Hardened CMOS Electronics Foundry Alternatives
AF01-022	Advanced Composite Acoustic Blanket Development
AF01-023	Design Innovation for Commercially Produced, High-Performance Space Electronics
AF01-024	Novel Thermionic Energy Converter for Space Application
AF01-025	Improved Analog-to-Digital Converter Fabrication Techniques
AF01-026	Single Event Transient Effects in Integrated Circuits
AF01-027	Thermal-to-Electric Conversion
AF01-028	Software for Distributed Nanosatellite Space Constellation Communication System
AF01-029	Miniature Radiation-Hard Analog Signal Isolator
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AF01-031	Smart Adaptive Power Converter
AF01-032	Novel Compact Thermionic Coolers
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AF01-034	Radiation-Hardened Non-Volatile RAM
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AF01-039	Long-Term Cryogenic Fluid Storage for On-Orbit Applications
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AF01-043	Integration Concepts for Space IR Sensing Component Technologies
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AF01-045	Serviceable Satellite Bus
AF01-046	Modular Miniature Satellite Subsystems
AF01-047	Novel Approaches to Optical Stand-off Detection
AF01-048	Autonomous Satellite Servicing to Increase Effective Mission Life
AF01-049	New Launch Vehicle Fairing Concepts

Human Effectiveness Directorate, Wright-Patterson AFB, OH

AF01-053	A Software Agent Advisor for Satellite Command Composition and Training
AF01-054	A Decision Aid for a Surveillance Satellite Crew Shift Supervisor

AF01-055	A Satellite Pre-Pass Contact Support Aid
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Information Directorate, Rome NY

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Materials & Manufacturing Directorate, Wright-Patterson AFB, OH

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AF01-129 Application Techniques of Appliques for Aircraft Topcoats
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Propulsion Directorate, Wright-Patterson AFB, OH

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AF01-171 Prognosis/Diagnostics for improved Gas Turbine Engine reliability and maintainability
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AF01-174 High Energy Density Dielectrics for Pulse Power Capacitors
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AF01-177 Electrochemical Systems for Micro Electro Mechanical Systems (MEMS) Applications on Microsatellites
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AF01-180 Pulsed Power Technology for Aerospace Applications
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AF01-188 Develop and Demonstrate a Hybrid Powered Missile Motor
AF01-189 Develop Mechanical Aging Criterion for Energetic Materials
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AF01-193 Sensors to Determine Composite Motor Case Damage

Sensors Directorate, Wright-Patterson AFB, OH

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AF01-201	Ultra Wide Band High Performance RF Links
AF01-202	Fusion of GMTI Reports from Multiple Sensors in Clutter
AF01-203	Dynamic Operational Re-Tasking of ISR Sensors
AF01-204	Standard Image Compression for Data Link Transmission
AF01-206	Mitigating Data Order Effects in Multi-Platform GMTI Tracking
AF01-207	Optimally Fuse Multiple Source SAR Images to Improve Combat ID
AF01-208	Tracking Densely Spaced Ground Targets with Data Fused from Moving Target Indication Radar
AF01-209	Evolving Onboard/Offboard Electronic Warfare Technology
AF01-210	GPS/IMU Ultra-Tightly Coupled Integrity Monitoring
AF01-211	Adaptive Array Processing for Targeting Radar Application
AF01-213	Analysis of Measurements on Resident Space Objects (RSO)
AF01-214	Tunable Superconducting Filters
AF01-215	Fast Polarization-Insensitive Optical Switches for Photonic Phased Array Control
AF01-216	Tactical User Antenna
AF01-217	Space Qualified GaN Communication Technology
AF01-218	GaN FET Based Re-Configurable Multiple Frequency Band Systems
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AF01-223	Adaptive Multispectral Signal Aperture
AF01-224	Synthetic Spectral Scene Simulator
AF01-225	RF Synthesis for Wireless Communication, Intellience, Surveillance, and Reconnaissance (ISR) Systems
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AF01-227	Miniature Sensor forAircrew Laser Warning
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Air Vehicles Directorate, Wright-Patterson AFB, OH

AF01-239	Aerospace Vehicle Structural Certification by Analysis
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AF01-242	Aerosol & Diamond Substrate Cooling for Airborne Platform Computers & Radomes
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AF01-247	Aeromechanics Technology for Mini Aerospace Vehicles
AF01-248	Adaptive Mesh Controller for Computational Analysis
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AF01-252	Aerothermoelastic Optimization Methods for Reusable Launch Vehicles
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Air Armament Center, Eglin AFB, FL

AF01-257	Long Range, High Altitude, Offshore Tracking and Scoring System
AF01-258	Conformal Scene Generation Display System
AF01-259	Automated Surface Mapping and 3-D Model Generation
AF01-262	Integrated Communications Module for Global Positioning System (GPS) Simulations
AF01-263	Rapid Assessment System for Flutter Configurations and Ejection Loads

Air Force Flight Test Center, Edwards AFB, CA

AF01-267	Robust Affordable Flight Termination (RAFT) System
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AF01-271	Advanced Data Link Simulator (ADLS)
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AF01-273	Integrated Anechoic Chamber Simulation
AF01-274	Wide Band Radio Frequency (RF) Infiltration Detection/Tracker (WAVES)

Arnold Engineering Development Center, Arnold AFS, TN

AF01-275	Real-Time Monitoring of Turbine Engine Data
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AF01-278	Advanced Hyperspectral Imager and Analysis System
AF01-279	Computational Aero-Optic Simulation System Development
AF01-280	Real-time Corrections to Multiple Channel Response Functions for Time-Correlating Transient Data
AF01-281	Solar Panel Designed for ESD Protection
AF01-282	Validation and Numerical Testing of Turbine Augmentors Combustion Computational Modeling

Oklahoma City ALC, Tinker AFB, OK

AF01-285	Enterprise-wide Strategic Planning and Management System
AF01-286	Mid-Infrared Laser Development for Environmental Monitoring Systems
AF01-287	Fuel Additives For Improved Turbine Engine Performance Under Extremely Cold Temperatures
AF01-290	Tube Hydroforming Simulation
AF01-291	Three-dimensional real-time Visualization of Air Quality Modeling Data
AF01-292	Trichlorcethylene Treatment via In-Situ Microbial and Chemical Oxidation Technologies

Ogden ALC, Hill AFB, UT

AF01-294	Functional and Diagnostic Analysis of Circuits using Laser or Electron Beam Scanning Technology
AF01-296	Tracking Current Flow through Units Under Test (UUT)
AF01-297	Remote Support via Multi-Terabit Networks
AF01-298	Imagery Manipulation for Simulator Database
AF01-299	High Speed Digital Timing Sets and Pattern Generator
AF01-300	Long Term Non-Interrupted Power Device (LTNPD)

Warner Robins ALC, Robins AFB, GA

AF01-303	Enhanced Digital Corrosion Detection System
AF01-304	Measurement of Residual Stresses in Difficult Locations
AF01-305	Smart Fuels Injection for the U-2
AF01-306	Helicopter Obstacle Guidance System
AF01-307	Compressed Natural Gas (CNG) Reformer to Supply Hydrogen to Fuel Cell
AF01-308	Detection of Hydrogen Embrittlement in High-Strength Steel Aircraft

AF01-001 TITLE: Advanced Concepts for the Chemical Oxygen-Iodine Laser

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop a scalable approach to achieving either pre-mixed atomic iodine generation or gravity-independent singlet-oxygen generation for the chemical oxygen-iodine laser.

DESCRIPTION: The Air Force Air Armament Center (AAC) is interested in investigating advanced concepts to improve the performance and operability of the Chemical Oxygen-Iodine Laser (COIL) for the Airborne Laser (ABL) program. (Ref's 1 and 2). There are two areas in which we are particularly interested:(1) The COIL operates on the lowest electronic transition in atomic iodine at 1.315 micrometers. The atomic iodine is typically generated by dissociating molecular iodine through collisions with singlet delta oxygen. This process for generating iodine atoms is less than ideal for several reasons: the injected iodine/He streams must mix adequately with the oxygen flow; the density of molecular iodine must exceed a threshold value; singlet delta oxygen is consumed in the dissociation process; and the water vapor present is a significant deactivator of I*. If atomic iodine could be generated in the oxygen flow premixed, all of these problems would be favorably affected. (Ref 3)(2) The COIL uses the reaction between aqueous basic hydrogen peroxide (BHP) and chlorine to generate singlet delta oxygen in the gas phase. This type of liquid-gas chemical reactor (singlet oxygen generator [SOG]) tends to result in a gas side output that contains small droplets of liquid. Key requirements of an SOG are high liquid surface area to maximize the amount of chlorine that can be reacted, and minimum gas volume to reduce gas phase deactivation of singlet delta oxygen. SMC is interested in concepts that can completely eliminate liquid content from the gas flow exiting the reactor and can operate without the aid of gravity. Mechanical approaches to droplet removal may be appropriate. (Ref 4)

PHASE I: Demonstrate the feasibility of the proposed approach through a combination of analysis and experiment. Generate a detailed design for a 1-kW class implementation of the concept.

PHASE II: Finalize Phase I conceptual designs, develop prototype hardware, conduct characterization experiments and conduct demonstrations at the 1-kW scale in order to establish concept utility.

PHASE III DUAL USE APPLICATIONS: The anticipated military application of these technologies is future technology insertion into the ABL or other future programs involving the use of COIL devices. The most likely commercial application of these technologies is efficiency and operability gains achieved for the use of COIL technology for industrial metal cutting, welding, surface treatment, etc.

REFERENCES:

1. T.L. Rittenhouse, S.P. Phipps, and C.A. Helms, "Performance of a High-Efficiency 5-cm Gain Length Supersonic Chemical Oxygen-Iodine Laser," J. Quant. El., vol. 35, pp. 857-866, 1999.
2. S.E. Lamberson, "Airborne Laser," in Gas and Chemical Lasers, Robert C. Sze, Editor, Proc. SPIE 2702, pp. 208-213 (1996).
3. V.S. Pazyuk, N.P. Vagin, and N.N. Yuryshev, "Repetitively pulsed chemical oxygen-iodine laser with a discharge generation of atomic iodine," Proc. SPIE, vol. 2767, pp. 206-208, 1995.
4. M.V. Zagidullin, A. Yu. Kurov, V.D. Nikolaev, V.M. Pichkasov, and M.I. Svistun, "Continuous-jet generator of singlet oxygen," Sov. Tech. Phys. Lett., 16, pp. 713-714, 1991.
5. J. Vetrovec, "Regeneration of basic hydrogen peroxide and chlorine for use in chemical oxygen iodine laser," Proc. SPIE, vol. 2987, pp157-165, 1997.

KEYWORDS: gravity-independent singlet oxygen generator,carryover-free singlet oxygen generator, Gas-phase iodine atom generation, electric discharge of alkyl-iodides

AF01-002 TITLE: Wavefront Sensing for High Scintillation Environments

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Demonstrate innovative wavefront sensing methods that lead to efficient wavefront reconstruction of an optical wavefront in the presence of high scintillation and the resulting branch points in the phase.

DESCRIPTION: The Air Force is interested in the propagation of laser beams from airborne platforms over long atmospheric paths. We are specifically interested in the Airborne Laser (ABL) system, but note that innovation for this system will also apply to airborne imaging and ground-based relay mirror applications and perhaps remote sensing. These systems require operation in high scintillation environments where branch points occur in the phase of the propagated beam. Typically, a probe beam gathers information about the atmospheric phase, and an approximate conjugate phase is applied to the outgoing beam. In current practice, the approximate phase is derived from the phase gradient as sensed by a Hartman-style wavefront sensor. The reconstruction of the phase from the wavefront sensor measurement is hampered by intensity scintillation plus the presence of branch points in the phase. Intensity scintillation yields low signal-to-noise ratios on some subapertures. Branch points complicate the phase reconstruction process and lead to difficulty in placing the optimal phase on a continuous face sheet mirror. This effort seeks innovative wavefront sensing methods that lead to efficient wavefront reconstruction of an optical wavefront in the presence of high scintillation and branch points.

PHASE I: Conceptualize and design innovative wavefront sensor, and demonstrate analytically or in simulation that the design is attractive and feasible for operation in a high-scintillation, branch-point environment.. Plan a feasibility demonstration of the wavefront-sensing concept, and outline a sound set of demonstration success criteria. A design review will cover the sensing concept, it's implementation, and the data processing methods used to extract the deformable mirror phase from the sensor output.

PHASE II: Demonstrate the wavefront sensor concept developed in Phase I and show that it leads to continuous faceplate deformable mirror commands which improve strehl in imaging or laser projection systems. The offeror may test the concept at his/her facility, or, at the offeror's request, the AFRL may arrange to conduct test at the ABL Advanced Concepts Laboratory operated by MIT Lincoln Laboratory or at the Air Force Research Laboratory's Airborne Laser Advanced Concepts Testbed located at the White Sands Missile Range North Oscura Peak Facility. These facilities will be provided to the contractor at no cost to the contractor or the SBIR Program. It is expected that this phase will provide a new wavefront sensing method that is sufficiently validated to readily facilitate transition to systems such as the Airborne Laser.

PHASE III DUAL USE APPLICATIONS: It is expected that an adaptive optics subsystem based on the concepts proposed under this research, with economical considerations folded in, would have both commercial and military applications. The military applications include all those with requirements for precise atmospheric compensation through turbulent media. These applications include ABL, Relay Mirror, remote sensing, and atmospheric imaging programs. The commercial market includes such areas as astronomy, communication, power beaming, and surveying. It is expected that the contractor will concentrate on flexible Phase I designs to maximize commercialization potential.

REFERENCES:
1. D. L. Fried, "Least squares fitting a wave-front distortion estimate to an array of phase difference measurements," J. Opt. Soc. Am. 67, 1977, pp. 375-378.
2. D. L. Fried, "Branch point problem in adaptive optics," J. Opt. Soc. Am., Vol. 15 No. 10, October 1998.

KEYWORDS: adaptive optics, scintillation, branch points, wavefront reconstruction, wavefront sensing, beam

AF01-003 TITLE: <u>Control of Multiple Deformable Mirror Optical Systems for Performance Enhancement in High Scintillat</u>

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop control algorithms to optimize the performance of multiple deformable-mirror, adaptive-optical systems and demonstrate their efficacy in hardware.

DESCRIPTION: The Air Force is interested in the propagation of laser beams from airborne platforms over long atmospheric paths. We are specifically interested in the Airborne Laser (ABL) system, but note that innovation for this system will also apply to airborne imaging as well as relay mirror applications and perhaps remote sensing. These systems require operation in high scintillation environments where branch points occur in the phase of the propagated beam. Both the scintillation and the branch points severely degrade the performance of conventional adaptive optical systems. The optimal solution to the beam control problem is to provide high-resolution, full-wave conjugation. However, current technology does not support this solution, particularly for high-power applications. A sub-optimal approach employs two or more deformable mirrors. The mirrors can be used in various ways to enhance performance. One approach places the mirrors conjugate to different planes along the propagation path; another uses one mirror to create a phase that, when propagated to the pupil, will reproduce the required scintillation pattern, while the second mirror fixes the outgoing phase. While these approaches provide performance improvement in theory, and even in simulation, real-time robust control algorithms for such systems remain elusive. It should be pointed out that there might be other approaches to two-mirror use. For example, one mirror may, upon appropriate propagation, recreate the rotational part of the phase, and the other the non-rotational part. The question is, given the sensor measurements, what control commands should be sent to the deformable mirrors? An even more fundamental question is: what should be sensed in the first place? The highly scintillated beam with consequent branch points in the phase makes the problem challenging. The requirement for high bandwidth in the adaptive optics loops further complicates the issue. This solicitation seeks innovative answers to these questions and a hardware demonstration of the resulting concepts.

PHASE I: Develop concepts and control algorithms for multiple deformable mirror adaptive-optics systems, paying full attention to optical design details that will impact the algorithms. Only those details of the optical design that are important for the control investigations and for system feasibility need to be investigated in this phase. Perform simulation and analysis to determine viability of the resulting algorithms. Select one or more candidates for implementation in Phase II and provide a preliminary optical design for the purposes of insuring feasibility of implementation.

PHASE II: Design and implement a multiple deformable mirror adaptive optics system based on the successful concepts from Phase I and test the various control algorithms. The tests can be conducted on a breadboard scale and tested over a real, or laboratory-simulated, horizontal path. The offeror may test the laboratory breadboard at his/her facility, or the AFRL may arrange to conduct the tests at the ABL Advanced Concepts Laboratory at MIT Lincoln Laboratory or at the Air Force Research Laboratory's North Oscura Peak Facility. Use of these facilities will be provided at no cost to the contractor or the SBIR Program.

PHASE III DUAL USE APPLICATIONS: It is anticipated that a multiple deformable mirror 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, Relay Mirror, remote sensing, and any DoD programs utilizing adaptive optics in high scintillation. Other applications include airborne imaging (military and 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 communication and power beaming. It is expected that the contractor will focus on Phase I designs that would maximize both the commercial potential and the military potential.

REFERENCES:

1. D. L. Fried, “Branch point problem in adaptive optics,” J. Opt. Soc. Am., Vol. 15 No. 10, October 1998.
2. M. C. Roggemann, B. Welsh, Imaging through Turbulence, CRC Press, Boca Raton, 1996.2.
3. T. D. Steiner, P H. Merritt, editors, Airborne Laser Advanced Technology, Proceedings of SPIE, Vols. 3381, 3706.
4. T. H. Steiner, R. R. Butts, "Airborne Laser Advance Technology Testbed (ABLE ACT)", Proceedings of SPIE, Vol. 3065, Airborne Laser Advanced Technology, Orlando 1998.
5. R. K. Tyson, P. 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.

KEYWORDS: multi-conjugate, adaptive optics, high scintillation, lasers, beam control

AF01-004 TITLE: Affordable Laser System for Launch Vehicle and Satellite Tracking

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a low-cost laser system that can acquire/track a launch vehicle or satellite.

DESCRIPTION: Satellite launch requires highly accurate, real-time tracking of the launch vehicle for safety operation, and the increasing density of commercial/military satellites also requires accurate tracking. The radio-frequency systems currently in use can not ensure a spatial resolution better than 100–500 m, which may not meet desired launch safety/on-orbit satellite operational requirements. One of the most effective methods to provide the required tracking capability may be a laser tracking system, which could achieve a spatial resolution accuracy in the tens-of-centimeters range. However, this approach is particularly challenging because of the large distance to the space object, the high Doppler shift, the dynamic object trajectory, and optical aberrations on the beam induced by atmosphere turbulence. Recent progress in high-gain phase conjugate mirrors and multiple-arm lasers with cavities connected through a non-linearly induced grating, makes it possible to build an efficient laser system with a remote object used as an “extended mirror”. In this case, the laser operation will be self-locked to such a “mirror”. Optical phase conjugation is used to eliminate the imperfections and aberrations in the laser cavity and to generate an output beam with controllable beam characteristics. Because of the ability to compensate for aberrations, phase-conjugate resonators are capable of sustaining the oscillation with a diffuse reflective-surface target as well as mirrors. The reflector used for this concept would incur a negligible weight and power penalty on the launch vehicle or satellite, depending on passive or active reflectors being employed. The objective of this project is to develop a (laser based) launch vehicle/satellite tracking system that is more than one hundred times more accurate than the best of current systems. Also of potential interest would be any secondary capabilities achievable by this system for use in telemetry communications, such as modulating the reflected signal by enabling/disabling the reflectivity of the system.

PHASE I: Develop a laser-based preliminary concept design for a high-gain optical phase conjugation ground-based laser complete with an extended “mirror” on the launch vehicle and/or satellite. Consider (among other issues) the losses and temporal turbulence of the atmosphere on the beam and the high relative speed/dynamic trajectory of the extended “mirror”.

Analyze and estimate the performance parameters that limit operation. Determine acquisition and pointing requirements and the accuracy required in the measurement of critical parameters such as the spatial (longitudinal and lateral) coordinates and corresponding velocity components of the moving space object. Provide a demonstration/simulation of basic system components.

PHASE II: Refine or finalize the concept design developed in Phase I and based on that design, develop a proof-of-concept prototype capable of a realistic demonstration with a launch vehicle or LEO satellite. Characterize the performance enveloped of this prototype phase-conjugate laser system for space object tracking. Part of the experimental demonstration will be a (mutually agreed to) attempt to track launch/satellite operating stages of selected space objects for extended periods under mutually acceptable performance requirements.

PHASE III DUAL USE APPLICATIONS: Both commercial and military satellite/launch vehicle tracking needs will benefit from the low cost, small size, and high accuracy of optical phase-conjugate laser tracking systems. This concept could also be applied as an automated landing beacon to passively track and guide aircraft landing, or as the beacon to facilitate satellite contact/communication.

REFERENCES:
1. A. Brignon, G. Feugnet, J.-P. Huignard, J.-P. Pocholle "Large-field-of-view, high-gain, compact diode-pumped Nd:YAG amplifier" Optics Letters, vol. 22, no 18, p.1421-1423, (1997)
2. Mailis, J. Hendricks, D.P. Shepherd, et all, "High-phase-conjugate reflectivity (>800 %) obtained by degenerate four wave mixing", Optics Letters, vol. 24, no 14, p.972-974, (1999)
3. O.L. Antipov, A.S. Kuzhelev, V.A. Vorob'yov, A.P. Zinov'ev, "Pulse repetitive Nd;YAG laser with distributed feedback by self-induced population grating", Optics Communication, vol. 152, p. 313-318, 1998.

KEYWORDS: launch vehicle/satellite tracking accuracy in centimeters phase conjugate mirror low cost spatial resoluation optical aberrations

AF01-005 TITLE: Key Enabling Components for High-Power Fiber Lasers

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop all-fiber coupled components for high-power, highly efficient, compact, electrically driven Yb-doped dual-clad fiber lasers.

DESCRIPTION: Fiber lasers have demonstrated efficient optical-to-optical power conversion into a diffraction-limited laser beam. Air Force Directed Energy (DE) missions require electrically efficient, compact, scaleable architectures leading to tens of kilowatts of continuous-wave power in a diffraction-limited laser beam for adjunct Space-Based Laser (SBL), Airborne Laser (ABL), and other DE/AF missions. This solicitation is for the development of key fiber optic components that make possible kilowatt-class, Yb-doped dual-clad fiber lasers. Enabling technologies sought include: 1) 1xN and NxN fiber optic couplers (multi-mode and single-mode core fibers with dual-clad designs), fiber bundles, tapers, optical isolators (both polarization dependent and polarization independent), circulators and power splitters; 2) Fiber Bragg gratings for high reflectance, nonlinear optical effects mitigation, and pump-coupling enhancement to fiber lasers and amplifiers; 3) Phase modulators and other integrated photonic devices aimed at high-power manipulation and power scaling. While similar devices are being produced commercially for low power telecommunications applications (milliwatts to several watts), at 1550 nanometers they are not compatible with high power optical amplifiers and fiber laser systems being developed. Fiber optic components for operation at 1100 nanometers, 10-1000 watts (cw) are not mature and require further research and development. The materials used in commercial telecom fiber devices may not be suitable for operation at high optical power levels. In particular, non-linear optical effects induced at high optical powers limit the performance of silica based fiber systems. Research and development in the selection and optimization of materials and processing is needed to scale fiber lasers and amplifiers to kilowatt levels. There is an immediate need for high-power components at the Yb-doped fiber laser pump and emission wavelengths (915nm, 975nm and 1100nm respectively). It is imperative that new designs be compatible with high-power fiber laser operation and dual-clad fiber designs.

PHASE I: Design and model concepts of high-power fiber laser components to establish feasibility

PHASE II: Based on Phase I designs, models, build prototype demonstrations, conduct in-depth characterization 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.

KEYWORDS: high-power optical fiber lasers, high-power optical fiber amplifiers, Ytterbium (Yb)-doped optical fiber, rare earth doped optical fiber, dual-clad optical fiber, Bragg gratings, master oscillator power amplifiers

AF01-006 TITLE: Advanced Diagnostics and Analytic Tools for HF/DF Laser Technology

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop an advanced diagnostics and theoretical analysis capability for interrogating the complex HF/DF chemical laser flow field.

DESCRIPTION: The Air Force Research Laboratory’s Directed Energy Directorate (AFRL/DE) is seeking new approaches for the development of advanced Hydrogen Fluoride/Deuterium Fluoride (HF/DF) laser technology in the area of advanced optical diagnostics and computational fluid dynamics (CFD). Successful approaches must demonstrate results in the following areas pertinent to HF/DF diagnostics and modeling: spectrally resolved lineshape measurement and analysis based on the fundamental and overtone transitions, planar and 3-D flow imaging techniques, and mixing nozzle studies using available computational fluid dynamic modeling techniques. State of the art in HF/DF laser technology is the advanced HYLTE mixing nozzle concept. State of the art, however, has advanced in adjunct technologies that may allow for potentially significant improvements to be made in the understanding of HF/DF mixing nozzles and the experimental diagnostic measurement devices used to test and scale these designs.Currently, the small signal gain for the fundamental HF laser is measured by a combustion-driven HF laser, which does not allow for measurement of the spectral line profile or the accurate determination of the peak gain at line center. To date, the small signal gain for the advanced HF overtone laser has not been directly measured. AFRL/DE has recently demonstrated the use of a tunable narrow linewidth diode laser to measure HF overtone absorption at ~1.3 micrometers in a flow reactor. (Ref. 1) This same technique had previously been used to determine gain, temperature, and flow rates in other chemical laser experiments. (Ref. 2) The technique could be adapted to measure small signal gain for the overtone HF laser system. For the fundamental HF laser, a similar, tunable, narrow linewidth source at 2.0-3.5 micrometers is required. Possible sources include cryogenic color center lasers and diode-pumped optical parametric oscillators (OPOs). Multi-dimensional flow visualization potentially can be accomplished via techniques such as Planar Laser-Induced Fluorescence (PLIF) or saturation spectroscopy.Similarly, advances in computer speed, memory, and fluid dynamic simulation have made high-fidelity computational fluid dynamic (CFD) simulations possible. CFD has been applied successfully to simulation of the HF/DF flow field (Ref’s 3, 4) and has been used to investigate mixing nozzle concepts for the chemical oxygen-iodine laser (COIL). (Ref. 5) A successful approach to HF/DF mixing nozzle analysis would use 3-D CFD simulations of the HYLTE nozzle as the basis for developing a greater understanding of the HF/DF flow field. Lower-dimensional 1-D and 2-D codes anchored against 3-D CFD simulations and experiments would be used to predict trends and suggest flow conditions for simulation with CFD.

PHASE I: Develop initial diagnostics design and model key elements. Based on the initial design and modeling results, develop a brassboard demonstration device. Conduct preliminary characterization and risk-reduction experiments.

PHASE II: Based on Phase I modeling, characterization analysis, and risk reduction experiments, design and develop a prototype diagnostics system. Characterize prototype performance and validate diagnostics in fundamental and overtone HF/DF chemical laser experiments. Develop and perform 3-D HF/DF flow-field simulations and analyze results.

PHASE III DUAL USE APPLICATIONS: Phase III dual-use applications include: environmental pollution and contaminant monitoring; development of combustion driven jet, automotive, and rocket engine systems; development and monitoring of chemical production processes; development of chemical laser systems both commercial and military.

REFERENCES:
1. G. C. Manke II, B. T. Anderson, R.F. Tate, and G. D. Hager, Air Force Research Laboratory / DELC, to be published.
2. P. B. Keating, C. A. Helms, B. T. Anderson, T. L. Rittenhouse, K. A. Truesdell, and G. D. Hager, Proc. Int. Conf. Lasers 19th, pp. 194-201, (1997).
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KEYWORDS: lasers and masers directed energy weapons atomic and molecular physics and spectros copy fluid mechanics optics numerical mathematics test facilities, equipment, and methods

AF01-007 TITLE: Atmospheric Measuring System using a Kite/Tethered-Blimp Platform

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop an atmospheric measurement system using a kite and tethered-blimp based platform

DESCRIPTION: There is a need in the atmospheric sciences community for in situ measurements of the refractive index structure parameter ( ), wind speed and direction, temperature, and humidity in the planetary boundary layer and above. The system is needed for fine-scale research measurements to understand the atmosphere, for assessments of pollution at various sites, and for calibrating and studying the "volume averaging" problem of many remote sensors. The feasibility of using kite platforms is documented in Balsley et al., (1992) and Daniels (1993). Primitive kites reached 9,740 m in 1919 (Yolen, 1968), so modern kites can easily carry sufficient packages to the required altitudes. A combination kite/tethered-blimp platform is required since the measurements must be made under all wind conditions (tethered-blimp for low speeds, kite for high speeds) and for long periods of time. The measurements need to be over long periods of time at given altitudes above typical tower heights for examining problems such as intermittency of turbulence and the nature and evolution of thin layers of refractivity and associated parameters. Capability for changing of the sensor altitudes, rapidly or slowly, is required. The new system should be easily transportable. Previously used sensors with such platforms are either slow response or single point with no component information that can be extracted. New sensors need to be researched and developed using these platforms that can determine all three components of velocity fluctuations, determine the inner and outer scales of turbulence, and determine the structure parameter at different spacings using spatially separated temperature sensors.

PHASE I: Produce a conceptual design and breadboard for the measurement system (including newly developed sensors) using a kite/tethered-blimp platform. Develop detailed analyses of the predicted performance (accuracy, precision, range of measurements, rates of altitude changes, data sampling characteristics, etc.) for the new system. Develop a complete data system that is appropriate for long term high speed measurements. Evaluations will be performed by comparison with TBD remote sensors at fixed sites.

PHASE II: Using results from Phase I, fabricate and validate a prototype sensing package that can be operated with a kite/tethered balloon platform. The results of these validation experiments will be used to compare data from the prototype sensors and an AFB-TBD remote sensor, such as radar or acoustic sounders.

PHASE III DUAL USE APPLICATIONS: The new kite/tethered-blimp measuring system not only will be useful for DOD programs such as the ABL, ground-based laser, and Space-Object imaging efforts, but will also fill a void now present in atmospheric research and sensing air pollution parameters. Commercial tethered balloon platforms are available and are used extensively by monitoring agencies, municipalities, and research organizations. However, these are restricted to low wind speeds as the balloon becomes unstable under high wind speed conditions. It is envisioned that a commercial kite/blimp atmospheric measurement system would be used by private industries that are required to assess air pollution, by consulting meteorologists, at power plants, by government agencies such as EPA, by NCAR, and by government agencies including NOAA and universities engaged in atmospheric research. The addition of a kite system would collect needed transport and diffusion data at higher wind speeds and at higher altitudes than can be achieved with a tethered-blimp alone. Also, the same system would measure profiles of chemical constituents by adding the appropriate instrumentation.

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KEYWORDS: kite platform, optical turbulence, tethered-blimp platform, air chemistry, refractive index structure parameter, atmospheric measurements

AF01-008 TITLE: Active Remote Sensing Technologies for Chemical Effluent Detection

TECHNOLOGY AREAS: Chemical/Biological Defense

OBJECTIVE: Develop component technologies that facilitate meeting performance requirements for active (laser-based) chemical effluent detection.

DESCRIPTION: The growing reality of the threat of chemical attack in both military and civil environments, as well as the ready availability of chemicals to process deadly toxins and narcotics, indicates a need for suitable chemical detection devices. Remote sensing technologies for counter-drug, counter-terrorism, or counter-proliferation applications do not currently exist but could provide early warning of a threat in the processing stages of chemicals, or could provide evidence of a suspected release. Chemical effluents may include fuel emissions, industrial by-products of chemical or biological production, as well as toxic chemical agents. Technologies that facilitate detection and quantification of chemical species using active remote sensing devices will be considered for development. Of particular interest are components or systems that improve detection and identification performance for an unknown chemical target, or that improve the operational effectiveness of devices, including compactness, ruggedization and reduced power requirements.Chemical spectral signatures extend across the entire infrared spectrum, but for detection purposes, the atmospheric transmission windows between 3–5 microns and 8–12 microns provide the greatest potential for detection. Required technologies follow: (1)Pulsed-laser source technology that shows promise of reaching average powers on the order of 10 W in MWIR and 100 W in LWIR over all lines in a 1–2 micron band, with relatively narrow line width (<0.5 cm[-1]) and high-pulse repetition frequencies (100 Hz–50 kHz) are of interest. Also of interest are tuning mechanisms that facilitate tuning over a sequence of 20 wavelengths across the operating band at rates of 100 Hz-10 kHz. (2)Technology that facilitates the development of wavelength-agile heterodyne DIAL systems is desired. Transmit lasers and local oscillators that provide single-shot wavelength tuning at 100 Hz pulse repetition frequencies, with single-mode operation are of interest, as well as associated analog and digital heterodyne receiver electronics and processing systems.

PHASE I: Define the proposed concept and develop key component technological milestones and preliminary design of system or components that address one or more of the above desired capabilities. The system approach is desired in order to ensure that the components developed have utility in meeting the requirements defined above and can be suitably field tested with existing government furnished equipment or hardware (GFE) in Phase II.

PHASE II: Complete component design, fabrication and laboratory characterization experiments. Define field test objectives and conduct limited testing with available GFE, if needed.

PHASE III DUAL USE APPLICATIONS: These lidar systems could be used in both the military and private sectors for industrial plant monitoring, and counter-drug and counter-terrorism purposes with little or no modification.

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KEYWORDS: lidar, gas lasers, chemical sensing, solid state lasers ,infrared detection, stand-off detection, chemometric analysis, chemical cloud detection, differential absorption lidar (DIAL)

AF01-009 TITLE: Antenna Back-lobe and Side-lobe Suppression

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Design, develop, and demonstrate new technology to suppress back-lobe and side-lobes for radio frequency/microwave antennas.

DESCRIPTION: Recently there has been increasing interest in deploying high-power radio frequency (RF) sources, both narrow-band and wideband, into electronic systems such as radar, communication, wireless data links and other applications. Whenever high-power RF emitters are installed into or around these electronic systems, there is the concern of possible electromagnetic interference (EMI) with other on-board or nearby electronic equipment. Many modern systems use sophisti-cated and complex electronic equipment for computers, communications, data transfer, etc. While interference with on-board or nearby receivers operating within the same or nearby frequency bands is of particular concern, “backdoor” coupling via unintentional paths onto low-level signal lines inside inte-rior compartments can also be a problem. New technical concepts need to be developed to minimize the side-lobe and back-lobe radiation from an antenna on a high-power system, and thereby minimize the undesired coupling to other electronic systems.

PHASE I: Research promising techniques for antenna back-lobe and side-lobes suppression technology. Investigate basic feasibility of the proposed technology to determine the specific approaches, identify critical development requirements and potential risks, and establish concept feasibility.

PHASE II: Define the optimal parameters for an antenna back-lobe and side-lobes suppression device for a high-power system. Design and fabricate a demonstration system, 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: Resulting technology will be applicable to all DoD components and any commercial industry requiring suppression of antenna back-lobe and side-lobes. Military use of this technology include minimizing aircraft electromagnetic interference (EMI) with on-board electronic equipment by reducing side-lobes and back-lobe radiation from on-board transmitters. The private sector does not only have similar requirements for commercial aircraft, but also has requirements to reduce radiation in unwanted directions for electronic systems such as radar, communications, wireless data links, and other applications.

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KEYWORDS: antenna back-lobe side-lobes suppression microwaves high power electromagnetic interference radio frequency

AF01-010 TITLE: Space-Based Ultra-Wideband Antennas

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop an inflatable ultra-wideband antenna that can be deployed in space using conventional launch vehicles.

DESCRIPTION: Increased emphasis on spaced-based surveillance, communications, and defense, requires that new antennas be developed that are lightweight, can be deployed using available launch vehicles, and will enhance current capabilities. The Ultra-Wideband (UWB) Impulse-Radiating Antenna (IRA) developed for ground-based applications has demonstrated that high-gain, directional antennas can be built either as a receiver or transmitter with a bandwidth that is flat over two frequency decades. The IRA uses a large parabolic antenna in its basic design combined with special impedance-matching structures and other features to achieve its broad frequency response. Other efforts have developed large inflatable parabolic antennas that are lightweight and capable of being deployed in space. This effort will combine the two technologies to produce a large inflatable parabolic antenna incorporating the technology developed for the UWB IRA. This integration of the two technologies will require the development of inflatable impedance matching arms that connect the parabolic antenna to the focal point receiver/transmitter. It will also require that the inflatable structure shape be maintained should it be punctured by meteorites once deployed. The entire structure must be capable of being stored in a launch vehicle and must automatically deploy once in orbit.

PHASE I: Evaluate 1) the design changes needed to adapt the IRA to the inflatable parabolic antenna, and 2) concepts to allow the impedance matching arms to be folded for storage within the launch vehicle. The design concept will address deployment of the combined IRA and inflatable parabolic antenna structure in a space environment. Formulate techniques to allow the IRA-inflatable antenna system to operate as a multi-band communications receiver/transmitter application.

PHASE II: Utilize and refine the design concepts developed in Phase I. Develop, characterize, and evaluate a working prototype system to determine the feasibility of deploying the system in space-based applications. The evaluations shall include the deployment and operational aspects of the antenna structure in space, and the electromagnetic characteristics of the system for wideband receiver and transmitter applications.

PHASE III DUAL USE APPLICATIONS: Successful demonstration of a large IRA antenna system that is space-deployable will lead to future commercial communications satellites with fewer antennas, higher performance, improved directionality, and fewer components. Military space-based communications systems will also be improved, but additional applications could include directed energy weapon applications, electronic surveillance, secure short-pulse communications, and impulse radar systems.

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KEYWORDS: electromagnetics ultra-wideband antennas inflatable space parabolic

AF01-011 TITLE: Scintillation Resistant Wave-Front Sensors for Strong-Turbulence Adaptive Optics

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop an optical wave-front sensor capable of operation in high scintillation environments where branch points abound.

DESCRIPTION: The Air Force is interested in the propagation of laser beams from airborne platforms over long atmospheric paths. We are specifically interested in the Airborne Laser (ABL) system, but note that innovation for this system will also apply to airborne imaging and ground-based relay mirror applications, and perhaps remote sensing. These systems require operation in high scintillation environments where branch points occur in the phase of the propagated beam. The current approaches to wave-front sensing involve the use of a Hartmann lenslet array. In this system, incident light is propagated through an array of subapertures onto the system focal plane, where spot-centroid displacements are interpreted as phase gradient information. This information is then used in a reconstruction process to yield an estimate of the incident wave front. Wave-front sensing limitations arise in both the spot measurement and reconstruction processes due to the nature of light after propagation through strong turbulence. Irradiance variations or scintillation over a Hartmann subaperture corrupt the spot centroid and its relationship to the true phase gradient. Furthermore, the centroid measurement corresponds to the weighted average of the phase gradient over the subaperture and is degraded by detector noise sources. Additionally, conventional wave-front reconstructors are insensitive to the rotational component of the wave front (branch-point phase), a major contributor to the atmospheric wave front in the strong-turbulence regime. A conceptual design is invited which would address the shortcomings of the Hartmann wave-front sensor in strong turbulence. This system need not work similarly in principle nor in design to a Hartmann wave-front sensor, but must be capable of providing accurate wave-front phase information at high bandwidths even when irradiance fluctuations would corrupt Hartmann wave-front sensor performance. Phase I should investigate the concept both analytically and in simulation.

PHASE I: Conceptualize and design an innovative wave-front sensor for operation in high scintillation environments, and demonstrate analytically or in simulation that the approach is attractive and feasible for meeting advanced Air Force requirements. This phase will demonstrate the feasibility of producing a demonstration of the wave-front sensor, and will outline a sound set of demonstration success criteria. Design reviews will cover the design, the individual components, the demonstration architecture, and the control concepts.

PHASE II: Demonstrate the wave-front sensor designed in Phase I. Finalize the wave-front sensor design developed in Phase I and then, based on the final design, develop a prototype demonstration wave front sensor. Demonstrate the prototype sensor in accordance with the demonstration success criteria developed in Phase I. The Airborne Laser Advanced Concepts Testbed at White Sands Missile Range would be available for the demonstration at no cost to the contractor or the SBIR Program. The proposed demonstration probably would take place at the Airborne Laser Advanced Concepts Testbed at White Sands Missile Range.

PHASE III DUAL USE APPLICATIONS: It is expected that a wave-front sensor based on the concepts proposed under this research, with economical considerations folded in, would have both commercial and military applications. The military applications include all those with requirements for precise atmospheric compensation through highly turbulent media. These applications include ABL, Relay Mirror, remote sensing, and atmospheric imaging programs. The commercial market includes such areas as astronomy, communication, power beaming, and surveying. It is expected that the contractor will concentrate on flexible Phase I designs to maximize commercialization potential.

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KEYWORDS: wave-front sensing adaptive optics scintillation branch points wave-front reconstruction laser beam control

AF01-014 TITLE: Lightweight DC/DC Power System

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Design a lightweight/scalable DC/DC system to interface power sources in parallel to a common power bus.

DESCRIPTION: Portable military electronics equipment requires reliable, lightweight power systems. This project goal is to develop a DC/DC power system that is lightweight, flexible in applicability, scalable, reliable, and utilizes radiation-hardened DC/DC converters that can be connected (in parallel via a power system bus) to various individual voltage sources such as solar cells, batteries, generators, etc. System weight may be minimized by utilizing state-of-the-art DC/DC converter integrated circuits, advanced magnetics, ultracapacitors for filtering, pulse power demands, and to provide power conversion. The components should be mounted on a flexible substrate. The flexible substrate allows for a wide variety of mounting considerations and allows more cells to be added for higher energy requirements. The DC/DC converter output should be capable of being set for the payload requirements and be capable of supporting peak power requirements. Since individual power sources would be connected (in parallel) through individual DC/DC circuits in the power system bus, failure of one source or power conversion circuit would only reduce the total energy, not result in total equipment failure.

PHASE I: Investigate current DC/DC conversion techniques, commercial devices, and associated circuit components, and develop a preliminary DC/DC circuit design. Place strong emphasis on the validation of the design that is expected to provide the stated performance enhancements; experimental and theoretical methods should be considered. Verify the design suitability for radiation hardening/packaging. Demonstrate the operation of a single prototype DC/DC power circuit; based on the results of the demonstration, estimate DC/DC converter power system performance and quantify improvements. Develop a plan for operational prototype development/ demonstration of the total multiunit DC/DC power system in Phase II.

PHASE II: Develop an operational prototype of the radiation-hardened DC/DC power system, utilizing multiple power sources and multiple DC/DC power conversion circuits connected in parallel. Means for evaluating, calibrating, and logging parameters during the demonstration shall be an integral part of the system design. Conduct and evaluate a total system demonstration and quantify improvements.

PHASE III DUAL USE APPLICATIONS: A lightweight power system of this type will be useful in any type of handheld or portable electronic equipment using a commercial (non-rad-hard) device. Space flight units would use the rad-hard device. Many portable communication devices and laptop computers use similar circuits, but connect the individual battery cells in series, so that one weak cell reduces the power system run-time, and one failed cell requires replacement of the battery. The parallel circuit could be used with a mixture of other power sources, such as batteries, generators or solar cells, wherein even the individual solar cells could be connected to individual DC/DC converter circuits. Any weight savings from the rad-hard power subsystem can be profitably used for additional payload, more spacecraft per launch, or possibly a smaller launch vehicle for both military and commercial satellites.

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KEYWORDS: energy conversion DC/DC converter parallel power conversion space power radiation hardened flexible substrate

AF01-015 TITLE: High Speed Digital Isolator for Space Applications

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Development of high-speed, lightweight radiation-hard, isolated digital communications interfaces for space applications.

DESCRIPTION: Spacecraft systems often require electrical signal isolation between interfacing subsystems on digital data lines. While silicon-based transceiver/line driver circuitry has evolved and been miniaturized at an unprecedented rate, the associated signal isolation technology has languished: existing isolation solutions are slow, power hungry and/or bulky; transformers are large and heavy; optical isolators degrade in performance over time and are not reliable in space applications; and capacitors have limited hold-off potential. None of these technologies can be integrated easily on-chip with associated circuitry. This topic calls for the development of a novel isolator that offers high performance in a tiny, low-profile form factor, compatible with multi-chip module assembly. The technology must have reasonable radiation tolerance and be compatible with current silicon processes. It should work well in applications such as low-voltage differential signaling transceivers, byte-wide isolated buffers, etc. Serial data throughput rates of 400Mbd/channel are desired, with power consumption of less than 20 mW per channel and functional silicon density of less than 1 mm sq. per channel. The technology will need to demonstrate that it has commercially viable applications. A candidate of such technology would be high-speed giant magneto-resistive (GMR) spin-valve.

PHASE I: Select design approach, simulate results, and define testing methodology for demonstrating feasibility of the concept. A concept-demonstration device shall be developed using discrete components to demonstrate feasibility of the concept. Produce the integrated isolator design using the results obtained from the simulation and actual concept-demonstration device development.

PHASE II: Design and develop prototype integrated isolator devices in complementary metal-oxide semiconductor (CMOS) and prepare a path to produce the devices through a space-hardened silicon-on-insulator (SOI) process. Construct testing hardware and use the methodology worked out in Phase I to evaluate prototype device performance.

PHASE III DUAL USE APPLICATIONS: A high-speed, light-weight digital signal isolation technology that is integratable into standard microelectronic processing is expected to have numerous commercial and military applications. It is applicable to any inter-subsystem digital data bus in either commercial or military satellites. Non-hardened versions would be cost effective for aircraft data links.

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KEYWORDS: isolators high-speed isolators spin valve GMR opto isolator transformer

AF01-016 TITLE: Field Programmable System-On-A-Chip

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Identify/resolve key issues that deter implementing programmable system-on-chip for space applications.

DESCRIPTION: In the commercial electronics world, highly integrated circuits (ICs) known as System-On-a-Chip (SOC) are being developed for performance and compactness reasons and are only now becoming possible through advances in semiconductor fabrication technology. Such ICs ultimately attempt to recreate a board-level or even box-level electronic system on a single piece of silicon by combining several functional elements—possibly from different vendor sources. These functional elements may include small- to large scale computational elements, memory elements or mixed signal elements combined with programmable technology such as that used by field programmable gate arrays (FPGAs). The result is a Field Programmable SOC (FPSOC). This FPSOC could be either one-time permanent programmable, or reconfigurable. SOC for space has additional challenges due to factors such as radiation environment, a need for higher levels of testability, a need to perhaps accommodate and manage redundancy and sparing, and unevenness in the radiation tolerance of different functional elements. It is understood that a complete solution to SOC is beyond the scope of a single project. Proposals are encouraged which present: (1) a range of underlying architectures enabled by the programmable SOC, (2) an emphasis on the special utility of programmable/reprogrammable SOC technology when applied to space systems, and (3) even partial solutions which still yield valuable incremental advances.

PHASE I: Provide evidence, through analysis and/or hardware demonstration, that key technology innovations can achieve a level of performance and producibility that will yield substantial improvements over current space state-of-the-art technology in either performance, cost, or both. Develop initial designs and concepts for products using the proposed technical innovations. Develop and describe a strategy to implement the technology innovations in a full-scale demonstration product. Identify key inhibitors for extending the technology to space applications, including radiation environment effects, and propose innovative solutions to overcome these inhibitors.

PHASE II: Implement, fabricate, and test selected Phase I solutions to mixed technology SOC for space applications on a demonstration vehicle IC. This demonstration vehicle need not implement a complete SOC as long as it fully addresses and demonstrates the proposed solutions to SOC implementation issues.

PHASE III DUAL USE APPLICATIONS: The described technology is equally applicable to commercial satellite systems which face many or most of the same reliability, environmental, size/weight/power, and performance needs as military systems. As an enabling technology for integrated electronics, it has broad potential for significantly improving the performance and characteristics of most future military space systems, including MILSATCOM programs.

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KEYWORDS: system-on-a-chip, integration, integrated circuit, radiation-hardened, space systems, satellite applications

AF01-017 TITLE: Mixed Technology System-On-A-Chip

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Identify/resolve key challenges to implementing varied technology types on SOC integrated circuits for space.

DESCRIPTION: In the commercial electronics world, highly integrated circuits (ICs) known as System-On-a-Chip (SOC) are being developed for performance and compactness reasons and are only now becoming possible through advances in semiconductor fabrication technology. Such ICs ultimately attempt to recreate a board-level or even box-level electronic system on a single piece of silicon by combining several functional elements which may even encompass different technology types. For this topic, these technology types would include some combination of the following: passive circuit elements (resistors, capacitors, inductors), analog elements, radio frequency (RF) elements, dynamic memory (DRAM), nonvolatile memory, or Micro-Electro-Mechanical Systems (MEMS). SOC is seen as particularly useful for handheld, battery-powered devices where size and power are critical. These advantages have obvious utility in satellites, particularly in microsatellites that are increasingly sought for many military and commercial space mission concepts. SOC for space has additional challenges due to factors such as radiation environment, a need for higher levels of testability, a need to accommodate and manage redundancy and sparing, and unevenness in the radiation tolerance of different functional elements. It is understood that a complete solution to SOC technology integration is beyond the scope of a single project. Responses to this topic should emphasize the integration of analog elements with digital circuits on a single chip. The analog elements could include active or passive circuit elements that act as filters, amplifiers, or other functional elements at frequencies that may range from DC to microwave. Proposals are encouraged that present different underlying architectures enabled by the mixed-technology SOC and emphasize their special utility when applied to space systems. Proposals that present significant incremental solutions can yield valuable incremental advances.

PHASE I: Provide evidence, through analysis and/or hardware demonstration, that key technology innovations can achieve a level of performance and producibility that will yield substantial improvements over current space state-of-the-art technology in either performance, cost, or both. Develop initial designs and concepts for products using the proposed technical innovations. Develop and describe a strategy to implement the technology innovations in a full-scale demonstration product. Identify key inhibitors for extending the technology to space applications, including radiation environment effects, and propose innovative solutions to overcome these inhibitors.

PHASE II: Implement, fabricate, and test selected Phase I solutions to mixed technology SOC for space applications on a demonstration vehicle IC. This demonstration vehicle need not implement a complete SOC as long as it fully addresses and demonstrates the proposed solutions to SOC implementation issues.

PHASE III DUAL USE APPLICATIONS: The described technology is equally applicable to commercial satellite systems which face many or most of the same reliability, environmental, size/weight/power, and performance needs as military systems. As an enabling technology for integrated electronics, it has broad potential for significantly improving the performance and characteristics of most future military space systems, including MILSATCOM programs.

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KEYWORDS: system-on-a-chip, integration, integrated circuit, radiation-hardened, space systems, passive circuit elements

AF01-018 TITLE: <u>Radiation Tolerant System-On-A-Chip for Space</u>

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Identify/resolve deterrents to implementing radiation tolerant system-on-a-chip levels of integration on space ICs.

DESCRIPTION: In the commercial electronics world, highly integrated circuits (ICs) known as System-On-a-Chip (SOC) are being developed for performance and compactness reasons and are only now becoming possible through advances in semiconductor fabrication technology. Such ICs ultimately attempt to recreate a board-level or even box-level electronic system on a single piece of silicon by combining several functional elements—possibly from different intellectual property ("IP") sources. For this topic, emphasis is on innovative ways to integrate elements on SOC that normally would be difficult to combine due to differences in fabrication processes. Overcoming these differences, even if initially on a small scale, reduces the number of discrete components necessary to accomplish a given processing task. These functional elements must include logic and memory, but may also integrate elements such as mixed signal circuits, bus interfaces, or others necessary to create a useful SOC solution. The end result should be adaptable to the space environment with minimal changes. SOC is seen as particularly useful for handheld, battery-powered devices where compact size and low power consumption are critical. These advantages apply well to satellites, particularly to microsatellites that are increasingly sought for many military and commercial space missions. SOC for space has additional challenges due to factors such as the space radiation environment, a need for higher levels of testability, a need to accommodate and manage redundancy and sparing, and variation in the radiation tolerance of different functional elements. It is understood that a complete solution to SOC is beyond the scope of a single project. Proposals are encouraged that present different underlying architectures enabled by this SOC concept, and emphasize their special utility when applied to space systems.

PHASE I: Develop SOC innovations and provide evidence, through analysis and/or hardware demonstration, that these key technology innovations can achieve a level of performance and producibility that will yield substantial improvements over current space state-of-the-art technology in either performance, cost, or both. Develop initial radiation tolerant SOC designs and concepts for products using the proposed technical innovations. Develop and describe a practical strategy to implement the technology innovations in a full-scale demonstration product. Identify issues which might prevent the extension of the proposed technology to space applications, including radiation environment effects, and propose innovative solutions to overcome these issues.

PHASE II: Implement, fabricate, and test selected Phase I solutions to mixed technology SOC for space applications on a demonstration vehicle IC. This demonstration vehicle need not implement a complete SOC as long as it fully addresses and demonstrates the proposed solutions to SOC implementation issues.

PHASE III DUAL USE APPLICATIONS: The described technology is equally applicable to commercial satellite systems which face many or most of the same reliability, environmental, size/weight/power, and performance needs as military systems. As an enabling technology for integrated electronics, it has broad potential for significantly improving the performance and characteristics of most future military space systems, including MILSATCOM programs.

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KEYWORDS: system-on-a-chip, integration, integrated circuit, radiation-hardened, space systems, high testability, radiation environment

AF01-019 TITLE: Low-Cost/Robust Nanosatellite Spacecraft for Distributed, Communication Systems Constellations

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Investigate nanosatellite communications architecture for highly parallel space communications network systems.

DESCRIPTION: Current military space-based communications systems consist of a few large, expensive spacecraft operating as constellations. The overall reliability of such systems is heavily dependent on the performance of each individual member. Achieving high dependability in each spacecraft comes at high costs. The advent of advanced spacecraft technologies, miniature electronics and novel packaging concepts, and MicroElectroMechanical Systems (MEMS) have introduced new paradigms for achieving mass-produced miniature satellites (nanosatellites) that could operate in distributed, highly parallel space communications network systems (in constellations or clusters) each containing a number of nanosatellites. While individual nanosatellites are small and somewhat limited in capability, the “highly parallel distributed constellation of nanosatellites for robust communications space systems” concept represents an effectively large (virtual) space system, that is inherently low cost, with individual and easily replaceable elements, and has system-wide failure tolerance. Failure of any one element or local cluster of elements does not disable the complete system. Such a system may be dedicated exclusively to highly critical, limited and secure communication—i.e., a private or personal space network. The system offers extreme robustness that is akin to a telephone network that exploits alternative paths through the constellation to transmit and receive critical communications. This robustness and extreme survivability is attainable at relatively low cost. The purpose of this project is to explore these ideas and develop technologies for networks of nanosatellites to perform communications missions.

PHASE I: Explore concepts and technologies to enable distributed, highly parallel nanosatellite MEMS based communications network systems. Develop architecture for dense constellations of communications nanosatellite. Identify required nanosatellite technologies. Where appropriate, validate key technology concepts by simulation or limited components testing.

PHASE II: Finalize high-level prototype design of a MEMS based space communications nanosatellite. Develop and demonstrate technologies for enabling components/subsystems. Verify by extrapolation any performance and/or cost advantages to be realized in a full system application.

PHASE III DUAL USE APPLICATIONS: Based upon a successful Phase II, the contractor should have high probability of attaining commercial/government backing for production/space qualification of a complete nanosatellite and deployment of an initial MEMS based communications network. Successful achievement of this technology and architecture can have profound impact on low-cost space-based voice/digital data communication, that may be achievable by small commercial enterprises and applicable to localized geographical areas and third world countries.

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KEYWORDS: MEMS, nanosatellite, semi-conductor processing, parallel space communications systems, silicon fabrication infrastructure, micromachining

AF01-020 TITLE: Optical Interconnects for Space-Based Field Programmable Gate Arrays

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop/validate designs for optical interconnects for field programmable gate arrays that are applicable (but not restricted to) in space systems.

DESCRIPTION: Field programmable gate arrays (FPGAs) are programmable digital microelectronic devices that can be custom configured during the programming process for a variety of applications. Since their development, the number of gates arrayed on these devices has increased to the point where external data transmission by electrical relay is limited by the same input-output (i/o) bottlenecks limiting the performance of other microelectronic devices. New schemes for i/o must be considered for such devices in order to avoid a more severe data extraction bottleneck. In an effort to overcome these limitations, systems designers have been exploring the use of optical/optoelectronic interconnects. The integration of photonic devices (i.e., transmitters and receivers) on-chip allows data transmission chip-to-chip at rates exceeding 10 gigabits per second and avoids many of the bottlenecks associated with current system architectures. Data is transferred either through waveguides (e.g., optical fibers) or by free-space transmission. However, there has been little, if any, work done to explore the advantages of optical interconnects for FPGAs used in the space environment. Use of these optical/optoelectronic interconnection schemes on-orbit will require the development of transmitters and receivers suitable for integration on-chip or by bonding a transmitter/receiver array in close proximity to the FPGA. Either approach will require technology that can survive both the launch and the hostile space environment. Proposals facilitating the application of optical/optoelectronic interconnects to FPGA applications of greatest utility to USAF programs such as MILSATCOM, SBIRS, etc., in addition to private sector space-based applications, will be ranked highest. These approaches are not restricted to use in space, of course, but reduction of the wiring harness problem is of crucial importance and most important in space systems.

PHASE I: Develop and validate innovative schemes for the use of optical/optoelectronic interconnect approaches (e.g. VCSELs, fiber-optic, polymeric waveguides, free-space approaches) in conjunction with FPGAs for space-based applications. These efforts should include proof-of-principle validation of the survivability and performance of optical/optoelectronic interconnects for systems consistent with the use of FPGAs for applications of interest to MILSATCOM. Address I/O and performance scale-ability as well as aggregation approaches, as well as the possibility of using the optical medium for total/partial/dynamic bitstream reconfiguration of the devices.

PHASE II: Apply the results of Phase I to the design, fabrication, and experimental validation/optimization of space-based FPGAs utilizing optoelectronic interconnect approaches.

PHASE III DUAL USE APPLICATIONS: These photonically interconnected FPGAs will be of high interest to designers of both DoD and commercial satellite systems. They will also be of interest to device designers required to use microelectronic devices in other hostile environments—e.g., nuclear reactors or nuclear waste depositories, security systems, and in applications currently requiring complex hard wiring.

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KEYWORDS: optical interconnects, opto electronic interconnects, field programmable gate arrays, data transfer, space environment, radiation effects

AF01-021 TITLE: Radiation-Hardened CMOS Electronics Foundry Alternatives

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Research and Develop affordable, foundry independent fabrication techniques for radiation-hardened CMOS-based electronics.

DESCRIPTION: In order to achieve what is referred to as radiation-hardened electronics, a dedicated foundry using a specialized process must be used. Radiation-hardened electronics must withstand 500 Krad (Si) to 1 Mrad (Si) or more total dose of radiation and still operate within parameters, in addition to achieving a high level of dose rate, neutron fluence, single event and latchup hardness. The end product of this research is to determine if, based on existing commercial methods, there are viable alternatives to achieve a high-level of hardness without relying on expensive, dedicated radiation-hardened microelectronics foundries. Previous research has resulted in producing partial solutions that have hardened only one or some, but not all of the hardness characteristics. Possible solutions may include an incremental improvement in the performance and quality of existing commercial foundry hardening solutions, but preference will be given to high-risk, innovative approaches. Improving the intrinsic hardness in all areas of the design and fabrication process flow should be the focus of the research.

PHASE I: Research alternative solutions to dedicated radiation-hardened electronics foundries. Propose foundry-independent methods for fabricating radiation-hardened electronics. (Recommend at least two process flow alternatives for future evaluation based on computer simulations.)

PHASE II: Fabricate test articles, which allow complete hardness and yield evaluation, using recommended methods proposed in Phase I. Evaluate total dose, dose rate, neutron fluence threshold, single event upset threshold and latchup characteristics for single events and dose rate as well as yield and cost. Establish two process flows for future fabrication of radiation hardened electronics for both the military and the commercial space sector.

PHASE III DUAL USE APPLICATIONS: This SBIR research area has excellent potential for dual use applications. Beyond meeting military requirements, the commercial space sector will be able to consider using hardened electronics (with scaled down hardness levels) to increase availability and reliability. Current radiation-hardened electronics are impractical for commercial use due to their high cost and reduced performance when compared to commercial counterparts. Commercial access to high-performance, low-cost radiation-hardened electronics will strengthen the defense of our economic infrastructure, which is a vital interest to our national security.

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KEYWORDS: electronics, radiation, hardened, foundry, process, rad-hard, CMOS, silicon

AF01-022 TITLE: Advanced Composite Acoustic Blanket Development

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop an advanced composite lightweight blanket to maximize acoustic attenuation through a launch vehicle payload fairing.

DESCRIPTION: New expendable launch vehicles use higher performance engines and lighter weight composite fairings. The resulting increase in payload acoustic levels may require costly redesign and re-qualification of spacecraft components. New innovative techniques to mitigate the high acoustic levels are needed. Acoustic attenuation techniques such as vibration damping, active noise and vibration control, and use of noise reducing containers or enclosures are often ineffective or result in higher system weight, complexity, and cost. Recent advances in porous materials, composite blanket design, and tuned acoustic absorbers make it possible to develop advanced blankets that will provide the needed acoustic environment reduction. Existing blanket designs often fail to meet current design objectives, particularly at low and mid frequencies. The use of specialized barrier blankets to reduce the acoustic environment has been demonstrated for the NASA Cassini program. However, the Cassini blankets were designed as an add-on treatment and did not take advantage of new composite fairing designs. Improved composite blanket designs will give greater acoustic attenuation and lower additional weight. The use of advanced acoustic blankets can provide a lower-risk, lower-weight, and lower-cost alternative to these other techniques. The objective of this project is to develop a composite blanket design procedure that allows users to design blankets to meet specific acoustic objectives.

PHASE I: Develop a composite blanket design procedure. The procedure will allow trade-off of blanket performance, weight, thickness, coverage, and cost to meet specific acoustic objectives. Select a launch vehicle configuration to demonstrate the design of an improved blanket. Fabricate a sample of the improved blanket and conduct ground tests to demonstrate the acoustic reduction that is achieved.

PHASE II: Develop and test selected designs in a realistic full-scale environment to demonstrate that acoustic design objectives can be met and that the design can withstand flight environments and also meet all flight requirements. Document blanket performance versus weight, thickness and coverage for various designs will be developed.

PHASE III DUAL USE APPLICATIONS: Composite acoustic blanket designs developed in Phase II could be used to reduce the acoustic environment for all Air Force, NASA, as well as commercial launch vehicles. Applications to the High Speed Commercial Transport aircraft are also possible.

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KEYWORDS: acoustics composite spacecraft expendable launch vehicle slow cost sound absorption blankets

AF01-023 TITLE: Design Innovation for Commercially Produced, High-Performance Space Electronics

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop new field effect transistors-and layout and design practices for high-performance, radiation-hardened integrated circuits using commercial fabrication technology.

DESCRIPTION: The ionizing radiation environment outside of Earth's atmosphere poses an ever-present threat to the microelectronic devices used in space vehicles. As device sizes get smaller, their susceptibility to total ionizing dose (TID) induced edge leakage, as well as to single event effects, increases. Traditional radiation-hardening techniques that involve special manufacturing processes are considered to be too expensive with too much required lead-time for most of today's space missions. Radiation-hardening by design (RHBD), on the other hand, makes use of available commercial fabrication lines. This approach involves designing circuits in such a way as to minimize susceptibility to harmful radiation effects. RHBD uses transistor and layout and design practices which are less susceptible to the radiation environment. The drawback to these devices and practices is that they require larger area and greater power consumption than their un-hardened counterparts. Consequently, the computational performance of these devices significantly lags that of their un-hardened counterparts. Larger area, higher-power consumption, and slower performance are currently accepted as necessary compromises to obtain the necessary radiation hardness. It is envisioned that novel RHBD advances can be made that would ultimately close the gap between radiation-hardened and non-hardened performance to the extent that, with the benefit of the original design licenses, current generation processors such as the Pentium III and G4 could be manufactured to withstand up to 1 Mrad of TID. Phase I efforts should be directed towards the development of novel, radiation-hardened by design concepts, at the transistor and primitive cell level, that are spatially compact in comparison to currently used, radiation-hardened designs. Careful attention should be given to overcoming single event latchup (SEL) vulnerability, which increases with increased packing density. The design should be immune to SEL up to a linear energy transfer (LET) of 120 MeV cm2/mg, and immune to single event upset (SEU) up to a LET of 65 MeV cm2/mg. The key operational parameters of several different primitive cells utilizing the innovative design should be determined. The designs should not optimize performance on the primitive level at the expense of performance on the macro level, nor should they require high supply voltages.

PHASE I: Identify an innovative radiation-hardened, circuit design technology that can be integrated into existing silicon CMOS fabrication processes, including SOI. Demonstrate that this innovation can be applied to the design of a primitive logic and memory cell. Calculate key operational parameters of the designed cells. Execute calculations to indicate that the designs will tolerate radiation exposure to the levels specified in the topic description.

PHASE II: Finalize preliminary proof-of-concept designs initially developed in Phase I. Based on the finalized designs, fabricate prototype primitive logic and memory cells; as well as delay chains and shift registers. The prototype devices must be developed using standard test packaging. Electrically characterize prototype devices and demonstrate radiation-hardness to TID, SEL and SEU.

PHASE III DUAL USE APPLICATIONS: Every federal and commercial organization that is involved in putting vehicles into space would benefit greatly by having access to high-performance, radiation-hardened microelectronics that are readily and cost-effectively produced. DoD also has many non-space applications for radiation-hardened microelectronics.

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KEYWORDS: RHBD, design, rad-hard, COTS, microelectronic, tolerant

AF01-024 TITLE: Novel Thermionic Energy Converter for Space Application

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a technology for the conversion of thermal energy to electrical energy through thermionic emission.

DESCRIPTION: Almost all US spacecraft, military and commercial, rely exclusively on photovoltaic solar cells as the primary source of energy on orbit. The efficiency of most advanced solar cells under development with multiple junctions and concentrator is about 40%. Increase in conversion efficiency of solar energy translates directly to enhancement of mission capability or extension of mission life. This request for proposal seeks the development of a novel high-efficiency thermionic energy converter that capitalizes the recent advances in the microtip array technology. Electron emitting microtips made of wide band gap semiconductor materials, such as AlN, GaN, SiC or diamond, have considerable potential to convert energy efficiently between thermal and electrical forms. Microtip arrays are capable of emission fluxes greater than 10 A/cm2 under room-temperature operation. The high current densities suggest that high efficiency of solar thermal energy conversion is possible. Research is required to demonstrate the feasibility and the superior conversion efficiency of microtip array thermionic energy converters and to optimize the geometry and band/field structure of the microtip arrays for maximum durability and energy conversion efficiency and capacity. The goal of this SBIR is to develop thermionic energy converters will offer excellent performance as compact power generation devices for both space and terrestrial applications.

PHASE I: Develop a theoretical model to predict efficiency of thermionic energy converters. Design/fabricate a laboratory demonstration device microtip array thermionic energy converter to demonstrate the concept of thermodynamic energy conversion. Gather and analyze performance data on the laboratory demonstration device.

PHASE II: Develop techniques/materials to enhance energy conversion efficiency and capacity. Use model predictions and measurements on the Phase I laboratory demonstration device to design/fabricate/demonstrate an engineering prototype. Prepare a manufacturing and commercialization roadmap to market the technology.

PHASE III DUAL USE APPLICATIONS: Thermionic energy conversion is a new energy conversion technique that is similar to solar energy conversion, and if proven to be practical, is expected to have many commercial and military spacecraft applications. Terrestrial applications include solar battery chargers, home/pool heating, etc.

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KEYWORDS: thermionic energy converter, cold cathode, self emission, microtip array, field emission, field emitters

AF01-025 TITLE: Improved Analog-to-Digital Converter Fabrication Techniques

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop alternative Analog-to-Digital Converter fabrication techniques for improved satellite systems performance.

DESCRIPTION: Analog-to-Digital Converter (ADC) technology is critical for remote sensing or communications satellite applications and other spacecraft housekeeping functions. Acquisition of high-performance ADCs for space applications is difficult due to the need to procure small quantities of space-qualified, radiation-hardened ADC devices. The objective of this project is to evaluate alternate ADC technology approaches which may have broad commercial and military benefit. Typically, incremental improvement of ADC technology is based upon specialized knowledge of particular fabrication facilities. The emphasis in this effort shall be on developing a novel ADC design or manufacturing approach that is not dependent on a single manufacturing process. The offeror should propose an ADC design or manufacturing technique that has potential to improve at least one of the critical parameters of speed, power, dynamic range, and/or accuracy, without adversely impacting the other critical parameters, but while providing a degree of radiation tolerance. A design or manufacturing technique which holds the potential of fabrication facility portability will be considered a plus. The technique may be either totally new or a different approach to a standard technique. An estimate of overall benefit to current and future ADC technology should be included in the proposal. Intended facilities for fabrication and testing should also be identified. This project also requires the Phase II demonstration of the proposed technology with a low-quantity fabrication run, along with an evaluation of the portability of the ADC technique to other fabrication facilities, which may include radiation-tolerant processes or dedicated radiation-hardened fabrication lines.

PHASE I: Develop one or more novel approaches to ADC design or manufacture, with analysis showing how the proposed approaches will enhance ADC performance for space applications. Based on the analysis, select an approach and develop a test vehicle design, fabrication method, development and test plan. Provide analysis showing how the test vehicle will be used to assess the potential of the new ADC technology in terms of speed, power, dynamic range, accuracy and radiation-tolerant fabrication portability. Run simulations of the test vehicle design based on the proposed approach(es). Document results and provide a recommended optimal approach based on the simulation results.

PHASE II: Present the final test vehicle design to be submitted for fabrication. Fabricate the test vehicle on a radiation-tolerant fabrication line and accomplish subsequent characterization of performance in a natural radiation space environment. Additional test vehicle samples will be provided for evaluation by the Air Force. The final report should include fabrication methods, the radiation test plan, and results of the natural space radiation characterization.

PHASE III DUAL USE APPLICATIONS: In addition to military and commercial space-based applications, ADCs have wide application for industrial, automotive, and wireless communications use.

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KEYWORDS: analog-to-digital converter data acquisition satellite systems radiation tolerance digitzer sampling space applications remote sensing

AF01-026 TITLE: Single Event Transient Effects in Integrated Circuits

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop/demonstrate a power/speed/area-efficient approach to harden deep sub-micron microelectronics against single event transient upset.

DESCRIPTION: Single event upsets (SEUs) are caused in digital integrated circuits (ICs) by cosmic rays and other energetic particles. Traditionally, these particles have only been considered to affect contents of storage elements (e.g., random access memory [RAM] cells, register bits, etc.), and SEU hardening and testing are normally conducted under that assumption. One type of SEU, single event transients (SETs), may occur in combinatorial logic outside of storage elements, but studies have suggested that this is infrequent. To be “captured” as logic upset (or “soft error”), the transient would need to occur at the input of a storage element just prior to the exact instant when the clock switches. For integrated circuit (IC) technologies at the micron level or slightly below, combinatorial logic is susceptible to SETs, but signal perturbations generally dampen out before reaching a storage element. In deep sub-micron technologies, it is expected that the higher speeds of logic gates will allow SETs to propagate without dampening. In such a case, combinatorial logic preceding storage elements funnels false logic signals into the element. Coupled with higher clocking rates (providing more capture “windows” per second for the SETs) in state-of-the-art and future technologies, a significant new single event upset threat will result. While simulations/analyses of SET capture mechanisms are appropriate to understand relevant factors, they must also be verified with empirical measurements. For this, test structures and procedures should be designed to allow discrimination of upsets originating outside of storage elements. After understanding the extent of the problem and its contributing factors, innovative methods for SET hardening can be proposed, implemented, and evaluated.

PHASE I: Develop an innovative approach to accurately projecting and evaluating, through analytic and empirical methods, the soft error rate contribution of SET-induced errors for current and near-term digital space microelectronics technologies. Design test structures to verify simulation and analysis. Based on simulation and analysis results, determine primary factors contributing to SET susceptibility. Develop a preliminary SET mitigation strategy.

PHASE II: Implement, fabricate, and test Phase I test structures to SET effects. Compare to expectations and iterate simulation and/or test as required. Develop an innovative approach to hardening deep sub-micron circuits to the effects of SETs, minimizing detrimental effects on power, throughput, and layout area. Quantify those effects for typical IC types. Final result is a demonstration of feasibility and a path toward full application by space programs.

PHASE III DUAL USE APPLICATIONS: This technology would be equally applicable to commercial satellite systems which face many or most of the same reliability, environmental, size/weight/power, and performance needs as military systems. An innovative design approach that can mitigate the SET threat to advanced electronics, will have broad potential for maintaining high reliability in future military and commercial space systems, including MILSATCOM, while minimizing detrimental implementation effects.

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KEYWORDS: single event effects SEU transient integrated circuit SET cosmic ray

AF01-027 TITLE: <u>Thermal-to-Electric Conversion</u>

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a compact, low mass, efficient, high-power thermal-to-electric conversion system for satellite platform use.

DESCRIPTION: Technologies are sought to efficiently convert thermal energy to electrical energy onboard a satellite platform. The technologies must possess desirable attributes including: low mass (i.e. greater than 15 Watts electric per kilogram [We/kg]) long life (approximately 7 to 10 years), low system volume, high output power levels (50 to 100kWe), ability to withstand radiation environments (desirable), high heat reject temperature, and relatively high output voltages (120V, relative to radiation environment). To date, the most promising thermal-to-electric converters being developed for space systems rely on the principle of creating a chemical potential difference by thermally driving alkali-metal ions across a concentration barrier. The advancement of these alkali-metal thermal-to-electric converters (AMTEC) has been hampered by a lack of: good joining technologies, electrode materials with long lifetime and no degradation in performance, and compatible containment materials having desirable thermal properties. These deficiencies have resulted in lower than expected performance and degradation of performance over time. Under this program innovations in several of the following areas are anticipated: (1)development and application of novel new joining technologies which are more robust, allowing for higher temperature operation, and longer lifetimes (2)development of new electrodes which are more robust, less susceptible to contamination, and provide longer life at higher performance levels (3)development of cell containment materials which are compatible with sodium and other materials in the system in a high temperature environment and provide desired thermal properties for increased performance (4)novel new cell designs in terms of geometry, size, shape, etc… which significantly enhance efficiency, specific power, and reduce the complexity and cost of cell fabrication (5)development of new fabrication techniques which significantly decrease costs and increase reliability (6)development of new processes or techniques to lower the ionic resistance and/or increase the ultimate operating temperature of beta alumina solid electrolyte The proposal should lead to the test and demonstration of the complete system from collector to output terminals and show compatibility with power management and distribution systems. Testing could be performed at lower power levels, but scalability to higher powers must be shown. Suitable modeling must be performed to show system longevity. Phase III testing of successful systems can be accomplished at Air Force Research Laboratory facilities. Testing will be provided at no cost to the contractor or SBIR Program. Testing will be limited to current-voltage characterization, efficiency measurements, and performance degradation characterization. Further testing may be performed if deemed necessary by the project officer. Duration of testing will be at the discretion of the project officer. Test devices must be compatible with current test facilities at the Air Force Research Laboratory.

PHASE I: Demonstrate that the thermal-to-electric converter can achieve an improvement in performance over present state-of-the-art alkali-metal thermal-to-electric converters (AMTEC). Design, fabricate, and demonstrate a small-scale prototypical converter or a portion of the converter as proof of concept. Demonstrate through modeling and simulations, that an electrical power system based on this converter would achieve a substantial improvement over state-of-the-art power systems at some power level and orbit in terms of power density, fabrication cost ($/We), launch cost, efficiency, power level, radiation hardness, or an impact on temperatures.

PHASE II: Finalize Phase I design and develop a prototype converter based on continued development from the original proof-of-concept device. This prototype device must be robust and capable of being integrated into a satellite electrical power system. Demonstrate the system can achieve mutually acceptable performance requirements. Based upon meeting mutually agreed performance requirements, a fully developed converter shall be delivered to AFRL for evaluation in a prototypical space environment, at temperature, and for a duration of time suitable for understanding lifetime and degradation response. The AFRL testing will be conducted at no cost to the small business or the SBIR Program.

PHASE III DUAL USE APPLICATIONS: Thermal-to-electric converters show promise for use as bottoming cycles for power plants, co-generation systems, remote power systems where maintenance is an issue, and for specialty applications such as stand-alone furnaces which can operate when power is lost to the grid. Generation applications are very dependent on $/We and the technology must eventually reach approximately one (1) dollar per watt to be competitive with present power generation equipment.

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KEYWORDS: power conversion, thermal-to-electric conversion, efficiency, high power, satellite electrical power system, alkali metal thermal to electric converter

AF01-028 TITLE: Software for Distributed Nanosatellite Space Constellation Communication System

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Investigate architecture for wireless cross-link/uplink/downlink software to support communications throughout a parallel distributed nanosatellite constellation.

DESCRIPTION: Recent advances in many spacecraft microtechnologies are envisioned to support the development of miniature satellites (nanosatellites) that could operate cooperatively in distributed, highly parallel space communications constellations. Each constellation represents an effectively large (virtual) space system that is inherently low cost, with individual elements easily replaceable and having considerable failure tolerance. Such a system may be dedicated exclusively to highly critical, limited and secure communication— i.e., a private or personal space network. These features offer a degree of robustness akin to that of a telephone network that exploits alternative paths through the constellation to transmit and receive critical communications. In this concept the communications system (cross-link/uplink/downlink) software must be applicable to parallel constellations of nanosatellites, each of which have constraints on power and size. Such software should be compatible with the nanosatellite command and data handling options, memory sizes and types, and the signal processing protocols evolving in microelectromechanical systems and microsystems developments. The goal of this project is to explore these ideas and architectures for applicable software systems to support nanosatellite communications networks.

PHASE I: Identify the significant limitations that are imposed on system software by the specific characteristics of a parallel array of nanosatellites distributed over large area in space (and over a large terrestrial “uplink/downlink” area) and limited by the on-board technology for power, data handling, etc. Based on these assessments, define the architecture for such a software system and simulate the main/basic concepts. Devise a plan for proving power-efficient constellation software, including space-flight (or air borne) demonstration of the basic concepts.

PHASE II: Develop a proof of concept prototype of the constellation software system and demonstrate via simulation with a large number of virtual nanosatellites. Finalize (a commercial/government-supported) plan for a space or airborne software system-proof demonstration utilizing a large number of nanosatellites.

PHASE III DUAL USE APPLICATIONS: Achievement of super power-efficient communications networks have a number of potentially attractive applications (some of which are currently the subject of DARPA funding). Commercial applications could include broad area security systems, chemical surveillance systems, hazard monitors, and other concepts such as “smart streets and highways.” Government applications parallel commercial applications plus tactical warfighter/peacekeeping/anti-terrorist communication systems.

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KEYWORDS: MEMS signal processing protocols, communication systems software, nanosatellite, parallel constellations, MEMS, micromachining, semiconductor processing

AF01-029 TITLE: Miniature Radiation-Hard Analog Signal Isolator

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a miniature radiation-hard analog signal isolator with ohmic isolation and high-density hybrid packaging compatibility.

DESCRIPTION: A key function within many space electronics subsystems is analog signal isolation between circuits at different ground potentials. A critical example is the error amplifier feedback from the secondary side to the primary side of a DC-DC converter. In some cases, the behavior of the various grounds is well controlled and junction isolation (such as with isolation amplifiers) can be used. In many other cases, however, true ohmic isolation to levels of hundreds of volts is required. This topic addresses the latter cases. The problem is presently addressed with either transformer or optical isolation. These solutions are satisfactory with low-density power electronics packaging, but are increasingly problematic with recent high-density packaging. Additionally, many isolator solutions are intended specifically for digital data buses and fail to consider the linearity, noise figure, and single-event transient requirements of analog signal isolation. Transformer isolation requires circuitry to chop the signal at a rate well above the signal bandwidth and then rectify it on the other side of the transformer. In rad-hard applications, this circuitry becomes fairly complex. The transformer function is difficult with hybrid packaging and is not amenable to integrated circuit fabrication. Optical isolators are often soft to radiation, and are seldom packaged in a manner suitable to next-level hybrid packaging. The isolator, which is the objective of this project, would be packageable in the manner of an integrated circuit chip and be characterized for (and useable with) radiation environments of 300 krads total dose, heavy ions to linear energy transfer (LET) 60, and dose rate to 10 (to the 8th) rads/sec. Goals for bandwidth and isolation voltage are 5 MHz and 500V. Minimum acceptable bandwidth is 200 kHz.

PHASE I: Develop innovative solutions to the isolator problem. Analyze all processes and components involved in the solution with respect to space quality procurement (or manufacturability) compatibility with hybrid packaging including High Density Interconnect, radiation environment tolerance, and ability to meet performance goals. Perform analyses or experiments to demonstrate credibility and the projected characteristics of the proposed solution.

PHASE II: Finalize detailed design and analysis of one isolator component for a space DC-DC converter application. Coordinate the design and performance specifications with the space DC-DC converter products produced by at least one manufacturer. Fabricate demonstration samples of the isolator, plus special test structures if applicable, and perform electrical characterization. Perform total-dose and heavy-ion radiation testing. These demonstrations must support a clear path to final product development.

PHASE III DUAL USE APPLICATIONS: This technology is applicable equally to commercial and military satellites. It is particularly important in microsatellites, which place a special premium on compact packaging. Variations on the specific isolator demonstrated in Phase II would be useful in power converters and analog telemetry locations throughout the satellite.

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2. P. Vettiger, "Linear Signal Transmission with Optocouplers", IEEE Journal of Solid-State Circuits, Vol. SC-12, no.3 p.298-302, June 1977

KEYWORDS: ohmic isolation analog signal isolator radiation hardened space electronic subsystems ground isolation DC-DC converter

AF01-030 TITLE: Radiation-Hardened Synchronous SRAM

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a radiation-hardened, high-speed synchronous SRAM to support digital signal processors and other special memory applications.

DESCRIPTION: Digital Signal Processing (DSP) performs a key role in both DoD and commercial communications satellites. The process technology considered best suited to meet the low-power, high-speed, total ionizing dose, and Single-Event-Upset tolerance required by most DoD space systems, is the CMOS/SOI (Complimentary Metal-Oxide Semiconductor/Silicon-on Insulator) process. DSP chip sets made with such a process are now envisioned which will operate at clock speeds of 75 to 100 MHz. Static Random Access Memories (SRAMs) capable of supporting such processor speeds must have access times of 7 and 9 ns for the processor clock rates to 100 and 75 MHz, respectively; the only currently available memory chip made with a radiation-hardened SOI process, a 1M SRAM [1], has an access time of only about 25 ns. In fact, even the 4M version of this SRAM that is now in development will not be fast enough. The most promising way to increase the data transfer rate of an SRAM would be to generate pre-determined memory addresses and clock them into the memory synchronously with the system clock [2]. This will require the development of a new memory chip—a synchronous SRAM. Depending on the capabilities of the radiation-hardened SOI process that is selected, it might be possible to incorporate a programmable address generator on the SRAM chip. Therefore, consideration should be given to converting an existing radiation-hardened SRAM into the synchronous SRAM, as well as to designing a new memory component.

PHASE I: Design a synchronous SRAM to support radiation-hardened digital signal processing and other special high-speed memory applications. Thought should be given to the word length and memory depth required for typical DSP algorithms and other data processing applications. Trade-off studies should be conducted to optimize the design with respect to the features that could and/or should be incorporated on-chip.

PHASE II: Develop the mask set for the synchronous SRAM designed in Phase I consistent with a radiation-hard CMOS SOI process. Fabricate SRAM prototypes and verify their performance with respect to speed and radiation hardness.

PHASE III DUAL USE APPLICATIONS: A radiation-hardened high-speed synchronous SRAM will be useful for commercial and government satellites as well as other space applications. Radiation-hardened memories are needed for satellite nuclear power sources. Ground-based nuclear power supplies require radiation-hardened detector electronics for data collection. Radiation-hardened memories are needed for power control valves and active sensors. There are also niche industrial and scientific applications in which radiation-hardened memories are required, such as those in which radiation-hardened detector systems microelectronics are needed in the vicinity of particle accelerators and other radiation sources.

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1. Fechner, P. S., et al., “Radiation hardened SOI CMOS and 1 M SRAM,” IEEE Int’l SOI Conference 1997, p. 172.
2. Lieberman, D., “Vector processor to challenge DSPs,” EE Times, February 17, 1999.

KEYWORDS: static RAM high speed radiation hardened single-event-upset silicon-on-insulator synchronous

AF01-031 TITLE: Smart Adaptive Power Converter

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop an innovative high-density radiation-hard DC-DC converter with continuous adaptive performance optimization.

DESCRIPTION: Radiation-hardened power converter design presently involves difficult trade-offs in the selection of power stage topology and in design of the control loop. Often, the most power-efficient topology is usable over too narrow a range of load currents to handle the anticipated load range. Control loop design is complicated by modern digital subsystem loads using board-level redundancy and software-controlled clock selection. Switching of redundant boards causes the board capacitance, as well as the resistive load, to be added or shed instantly, causing stability concerns. Finally, the control loop design must allow for radiation and temperature effects. Recent developments in radiation-hardened mixed-signal integrated circuits may make feasible an innovative approach to power converter control in which the source and load characteristics (including the load reactance), the loop response, and various parameters within the power stage are all monitored continuously. From that data, the optimal settings of a tunable power stage and control loop may be determined and updated. Such a system would be expected to operate at near-optimal efficiency and bandwidth at all times, including adjusting for radiation effects, temperature effects, and manufacturing variability.For broadest applicability, the power converters ultimately resulting from this research should be analyzed, tested, and specified for radiation environments of 300 krads total dose, heavy ions to linear energy transfer (LET) 60, and dose rate to 10(8) rads/sec. For future MILSATCOM and similar commercial applications, good target applications are a regulated input bus at a known voltage in the 50-100V range and a 2.5V output at 20-40 amps peak. However, the choice of a different target application is not excluded. Goals for efficiency and power density are 90% and 300W/pound.

PHASE I: Develop an innovative solution for an adaptive space power converter. Analyze candidate power stages and control algorithms. Investigate all processes and components involved in the solution with respect to space-quality procurement (or manufacturability) compatibility with hybrid packaging including High-Density Interconnect, behavior in the various radiation environments, and ability to meet performance goals. Perform analyses or experiments to demonstrate credibility and the projected performance of at least one specific implementation of the proposed solution.

PHASE II: Perform detailed design and analysis of at least one specific space DC-DC converter embodying the selected adaptive control approach. Coordinate the design and performance specifications with at least one space electronics subsystem manufacturer’s products. Fabricate a prototype of the power converter with sufficient fidelity to the final space-quality packaging and components to allow realistic performance measurements. Perform electrical characterization. Perform analyses to predict total-dose and heavy-ion response. This demonstration must support a clear path to final product development.

PHASE III DUAL USE APPLICATIONS: This technology is applicable equally to commercial and military satellites. It is particularly important in mainstream high-power commercial communication satellites, where power efficiency is critical and large digital processing loads are found. Variations on the specific converter demonstrated in Phase II would be useful in power converters, motor drivers, and other power electronics throughout the satellite.

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2. W. Chen, G. Hua, D. Sable, F. Lee, “Design of high efficiency, low profile, low voltage converter with integrated magnetics”, Proc. Twelfth Annual Applied Power Electronics Conference vol.2 p.911-17 (1997)
3. B.S. Jacobson, “Design of sequential switching series resonant converter with fixed frequency phase shift control”, Proc. Thirteenth International HFPC '98 (High Frequency Power Conversion) p.104-12 (1998)

KEYWORDS: power converter DC-DC converter radiation hardened adaptive space power converter continuous adaptive performance tunable power stage hybrid packaging

AF01-032 TITLE: Novel Compact Thermionic Coolers

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a novel technology to provide efficient localized cooling for military and commercial applications.

DESCRIPTION: The ability to control the operating temperature of various satellite components is critical to mission success. This requirement is becoming increasingly difficult to meet as space systems continue to proceed on the path of miniaturization. Conventional cooling systems require moving parts that are often unreliable when scaled down to micro or meso scales. Solid-state thermoelectronics offer an alternative, but their thermodynamic efficiencies are typically low. There is need to develop a highly efficient and compact cooling technology for space application.Dissipation of thermal energy by electron emission can be a potential candidate for such technology. An array of extremely sharp microtips can provide large electron fluxes by field emission and offer high cooling capacity/efficiency to a small localized area. In addition to having the potential to offer high thermodynamic cooling efficiency, electron emission cooling devices contain no moving parts. Electron-emitting microtip arrays made of wide band gap semiconductor materials, such as diamond, silicon carbide, etc, could be the technology needed to enable the development of a new class of cooling devices that dissipate thermal energy by electron emission. In vacuum field effect transistor applications, these microtip arrays are found to be capable of emission fluxes greater than 10 Amp/cm2 under room-temperature operation. Such high-current densities suggest that high rates of thermal energy transfer are possible (> 10 W/cm2). Other potential technologies exist for solid-state cooling including laser illumination florescent cooling and advanced materials for thermoelectric cryocoolers. This topic calls for a research program to develop electron emission cooling devices or other advanced solid-state cooling devices that can offer compact/localized refrigeration with the potential for high thermodynamic efficiency.

PHASE I: Design/develop/demonstrate proof-of-concept cooling by electron emission device(s) or other solid-state cooling device(s). Develop a theoretical model to predict efficiency of solid-state coolers. Gather and analyze performance data on breadboard device(s).

PHASE II: Use Phase I model predictions and measurements on the prototype device(s) to optimize the material/geometry and band/field structure of these solid-state devices for cooing efficiency and capacity. Design/fabricate/demonstrate prototype devices. Prepare a manufacturing and commercialization roadmap to market the technology.

PHASE III DUAL USE APPLICATIONS: Electron emission coolers and other solid-state cryocooling devices represent a new class of coolers that can offer compact and localized cooling. This new class of coolers is expected to have many commercial/military terrestrial and space based applications. Commercial applications include cryogenic medical devices for heart and other human tissue ailments, cost-effective and small Magnetic Resonance Imaging systems where the expensive G-M cryocooler is replaced with long-life, compact solid-state devices, cryogenic cooling of CMOS and other electronics for computers, and cooling of cellular bay station electronics. Each of these areas could result in $M of commercial potential. Military space applications include sensor, optics, and shield cooling for both conventional and nanosat applications, long term on orbit cryogen storage, and terrestrial applications include many of the commercial applications and Forward Looking Infrared (FLIR) applications.

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2. J.J. Hren, Proceedings of the 11th International Vacuum Microelectronics Conference, Piscataway, NJ, IEEE, Inc. 1998

KEYWORDS: thermionic cooler cold cathode self emission microtip array field emission field emitters

AF01-033 TITLE: High-Efficiency Amorphous Solar Cells on Polyimide Web

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop/validate innovative designs for ultra lightweight amorphous silicon solar arrays for space applications.

DESCRIPTION: Presently, ultra lightweight amorphous silicon solar cells using a polyimide web substrate are being produced for the terrestrial market. To date, the best efficiency for the terrestrial product is approximately 5%. Finished solar cells of this type are presently capable of a specific power of 750 W/Kg. Space-qualified amorphous silicon solar arrays, fabricated on stainless steel or glass substrates, have been produced with efficiencies approaching 10%. The specific power for amorphous silicon solar cells fabricated on each type of substrate, assuming a cell efficiency of 8%, would be 1200 W/Kg for 2 mil thick polyimide, 1050 W/kg for 0.5 mil thick stainless steel, and 644 W/Kg for 3 mil thick glass. Work is underway to develop processes for the fabrication of amorphous silicon cells onto a polyimide substrate for space application. However, there is no work ongoing at this time to improve the performance (efficiency) of the amorphous silicon cells fabricated on a polyimide substrate. For Phase I efforts, a strong emphasis should be placed on the validation/demonstration of the design that is expected to provide the stated performance enhancements. Experimental and theoretical demonstration/validation methods/facilities should be considered/identified. Based on the performance results of these demonstrations, the performance of amorphous silicon solar cells on polyimide substrate should be estimated and improvements quantified.

PHASE I: Develop innovative approaches for producing high efficiency (10%) thin film amorphous silicon multi-junction solar cells fabricated on a polyimide substrate. The thin film amorphous silicon solar cell design should be compatible for long term performance in the near earth space environment ranging from low earth orbit to geosynchronous earth orbit. Perform cell fabrication process demonstration experiments in a laboratory environment to illustrate performance of the selected thin film solar cell design with small area devices.

PHASE II: Apply the results of Phase I to develop and functionally demonstrate that the cell design can be scaled up from small area laboratory devices to large area devices. Perform fabrication of large area solar cells in a laboratory environment to demonstrate that the efficiency goals of this project can be met for practicable devices.

PHASE III DUAL USE APPLICATIONS: Dual use commercialization would occur through the development of low cost high efficiency amorphous silicon solar cells which could be used for terrestrial/space applications. The market place for terrestrial solar arrays (battery chargers, home/pool heaters, etc.) is strong and growing at a rapid rate. The outlook for DoD and commercial space based arrays would be very strong. Development of a prototype production facility for producing high efficiency solar cells for the terrestrial and space markets.

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3. Grimmer, D., Jeffrey, F., Martens, S. et al., “Lightweight, flexible, monolithic thin-film Amorphous Silicon Modules on continuous Polymer Substrates,” International Journal of Solar Energy, Vol. 18, No. 3, pp. 205-212, 1996.

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KEYWORDS: energy conversion efficiency, thin film amorphous silicon solar cells, specific power, solar arrays, polyimide substrate, roll-to-roll process

AF01-034 TITLE: Radiation-Hardened Non-Volatile RAM

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop and demonstrate an innovative, high-speed, high-density, non-volatile, random-access memory technology suitable for radiation environments.

DESCRIPTION: One of the key components used in many electronic systems, including space systems, is non-volatile memory. Despite years of development with various technologies, all non-volatile solutions to date possess one or more shortcomings which limit their use as a convenient solution for the majority of (military and commercial) space systems applications--lack of substantial radiation hardness, low density, slow performance, need for unusual power-supply levels, limited life cycles, etc. An innovative approach is needed which substantially overcomes most of the limitations of current non-volatile radiation-hardened memory systems. To have the broad application capability being sought, this approach should be: hard to all radiation environments (including man-made), random-access, high-density, high-speed (read and write), long-retention, high-endurance, and single-voltage (e.g., same as external logic levels). It should further be capable of operating over the full military temperature range (i.e., -55 degrees C to +125 degrees C). It is the intent of this SBIR topic to innovatively develop (or adapt existing) technology for a suitable non-volatile memory solution for space.

PHASE I: Investigate and compare innovative non-volatile memory technologies to each aspect of potential space radiation (e.g., trapped radiation, cosmic ray, man-made, etc.). Adapt selected approach as needed, and perform basic analyses/experiments to demonstrate credibility and projected characteristics of proposed technology.

PHASE II: Based on the finalized Phase I approach, fabricate/implement prototype elements of proposed non-volatile memory technology in a demonstration vehicle. Subject demonstration vehicle to representative radiation environments. Characterize limits of operation for radiation as well as temperature, voltage, cycles, and any other stresses relevant to the technology. Demonstrate that exposure to above environments had no adverse effects on prototype non-volatile memory devices. This demonstration must support a clear path to final product development.

PHASE III DUAL USE APPLICATIONS: This technology would be equally applicable to commercial satellite systems which face many or most of the same reliability, environmental, size/weight/power, and performance needs as military systems. As a key supporting technology for space electronic systems, and with comparable contemporary technology generally lacking the robustness desired, a successful innovative approach has broad potential for significantly improving the characteristics of most future commercial and military space systems, including MILSATCOM programs.

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KEYWORDS: non-volatile memory radiation-hardened random-access RAM space

AF01-035 TITLE: High-Frequency Low-Loss Ferrite

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a low-loss magnetic material for use in high-density DC-DC converters operating at 5–10 MHz.

DESCRIPTION: Present ferrite core materials used in the magnetics of DC-DC converters have unacceptable losses above 1 MHz. Yet, there is a drive to develop power converters operating at much higher frequencies to take advantage of the reduced magnetics size at such frequencies. Space and aircraft applications in both the commercial and the military domains are pushing lighter weight and higher functional densities. Advances in power electronics packaging are enabling extremely high-density packaging of all the non-magnetic components, and require the use of small planar magnetics if the magnetic elements are to be placed in the same package. At 1 MHz, the magnetic components occupy most of the space of a high-density power converter. At 5-10 MHz, core sizes would no longer be the dominant factor. Very high frequency (100 MHz +) air-core magnetics are also being pursued and may eventually prove useful, but that approach has its own risks and drawbacks. This topic seeks innovative formulations and manufacturing methods for very small inductor and transformer cores for magnetic elements operating at 5-10 MHz. The goal is a material with a core loss less than 0.1W/cm3 at 300 Gauss and 10 MHz (similar to present materials at 1 MHz). A manufacturing process for small complex core shapes using this material is also required.

PHASE I: Develop innovative formulations of ferrite or other magnetic materials having efficient operation in the 5-10 MHz range. Investigate alternative formulations with respect to magnetic performance, producibility, repeatability of bulk properties, and ability to be fabricated into small complex shapes. Fabricate simple demonstration shapes using one or more candidate formulations and characterize over the 100 kHz-10 MHz range. Perform other analyses or experiments as required to provide confidence that the selected formulation(s) can be produced with repeatable properties and can be fabricated into complex shapes.

PHASE II: Develop and demonstrate detailed manufacturing procedures for the selected material. Characterize magnetic properties of multiple samples to demonstrate repeatability. Investigate issues of winding design and the component assembly process related to proper use of the new material. Fabricate multiple complete assemblies of at least two transformer or inductor designs, in coordination with the products of at least one manufacturer of high-frequency spacecraft power converters. Characterize the magnetic and thermal properties of these assemblies, including unit-to-unit variations. Demonstrate compatibility of these assemblies with hybrid packaging including High-Density Interconnect.

PHASE III DUAL USE APPLICATIONS: This technology is applicable equally to the commercial and military markets for both satellites and aircraft. It is particularly important in microsatellites and in unmanned air vehicles, which place a special premium on compact packaging. Magnetic elements using the material and fabrication techniques demonstrated in Phase II would be useful in power converters, motor drivers, and other power electronics throughout the satellite or aircraft.

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KEYWORDS: ferrite core materials magnetic materials high-frequency low-loss power converter inductor/transformer cores complex core shapes

AF01-036 TITLE: Modular, Protective Container for Payload Transportation

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a modular payload transport container to isolate payloads from external transport/launch process forces.

DESCRIPTION: Currently, spacecraft are packed into crates at the manufacturing plant and transported to the launch site by trucks or other similar ground vehicles. The vibration caused by the transportation process is often severe and increases the probability of spacecraft systems failure. There are a wide variety of transport containers in use by the spacecraft industry. However, most often these containers are an afterthought to the spacecraft design process, and are not optimally designed. These containers must protect their contents from environments that can be quite severe. For example, ground tests conducted at the Air Force Research Laboratory using a 900-pound payload in a 1-ton truck indicated that acceleration as high as 13.3g can be experienced during ground shipping. These loads can be even higher that the accelerations typically encountered on a ascent to orbit. In addition, the payload can be exposed to ambient air temperatures a high as 120°F and as low as -50°F as well as wide range of humidity conditions. While the outside of the container is exposed to these environments, the inside of the container must maintain the payload within a temperature range of 50-70°F and a relative humidity range of 35-50%, for which a dry nitrogen gas purge is often required. In addition, the limit on dynamic loading may be as low as 6g. For future reusable launch vehicles, the same container could be considered for both ground and space transport, thereby requiring low weight. Many new structural design/materials technologies are now available to develop low-cost modular transport container systems. These could be multi-functional structures in which vibration and acoustic damping, thermal insulation, and acoustic suppression are integrated into the structure. For future reusable launch vehicles, the same container could be considered for both ground and space transport, thereby requiring low weight. Many new structural design/materials technologies are now available to develop low-cost modular transport container systems. These could be multi-functional structures in which vibration and acoustic damping, thermal insulation, and acoustic suppression are integrated into the structure. Examples of these for consideration (among others) are Grid-stiffened structures, Chambercore structures, Wavy Fiber Composites, and Multifunctional structures1. Other areas of research could be tapped to provide lightweight deployment mechanism2, shock isolation systems3, and radiation protection4. Careful consideration should be given to designing the system so that it could be integrated easily and directly into the launch vehicle (expendable or reusable) after delivery to the launch site. This could have the added benefit of a dramatically reducing payload integration time and cost.

PHASE I: Develop conceptual designs for a payload transport container system that would protect sensitive spacecraft from exposure to unacceptable temperature, humidity, and dynamic loading environments. Select the most promising conceptual design from which a prototype design shall be developed. The container should be capable of transporting a 400 pound satellite within a volume of 28" x 28" x 38", and which may be cantilevered at its base. The container may be modular or expandable to house as many as six of these satellites.

PHASE II: Finalize the selected transport container design. Construct a prototype container, and conduct a full-scale demonstration in compliance with mutually acceptable performance requirements.

PHASE III DUAL USE APPLICATIONS: A successful payload transport container derived as a result of this development will have high potential for application to many DoD/ NASA/commercial launches and their respective payloads.

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4. Spieth, B.D., "Lightweight Composite Spacecraft Shielding," PL-TR-97-1031, May 1997.

KEYWORDS: Transport Container, Composite Container, Acoustic Isolation, Multi-Functional Structures, Vibration Isolation, Chamber core

AF01-037 TITLE: Optimal Design of Active Noise Control Systems

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop techniques using Active Noise Control System to attenuate noise and vibration for realistic structures.

DESCRIPTION: Active control of sound and vibration is now a relatively mature technique that has found commercial and military application in a number of areas. Current applications generally implement simple feed forward control algorithms to address well-characterized acoustic environments. These environments typically involve small volumes with relatively low noise levels such as aircraft cockpits or sound rooms. The acoustic environment for space platforms including launch vehicles and spacecraft consists of extremely high levels of complex, time varying noise interacting with large flexible payload fairings and spacecraft. Present control system design techniques (1) are very costly and inflexible when applied to the operational envelope of the launch environment, (2) often overestimate the performance of the active system and often lead to an inefficient design, and (3) result in huge hardware implementation costs and weight based on anticipated performance. Research and development is needed to establish the feasibility of new control system optimization techniques to address complex noise control problems within the constraints of limited cost, volume, and weight. Several methods are being investigated and developed to predict the phase of response in a reverberant multiple degree of freedom (MDOF) system that should be considered for application to realistic structures in the launch environment. An innovative approach is required to extend these technologies to develop a means of relating predicted amplitude response of one method with the predicted phase of response of another. There is significant technical risk in associating these parameters as each method involves different assumptions. A successful concept will allow for the predicted amplitude and phase versus frequency distribution to be used in conjunction with conventional control analysis to develop a more accurate statistical prediction of the control performance. Furthermore, statistical confidence bonds on the influence of causality need to be developed; once these methods have been developed, they should be applied to the problem of control system design of a large, realistic system such as rocket payload fairing etc.

PHASE I: Demonstrate the feasibility of an innovative numerical method for efficiently analyzing the dynamics of large realistic structures such as launch vehicles and spacecraft for active structural/acoustic control studies. Assess the efficiency and performance of the control design tool. Investigate the viability of a complex SEA method to accurately predict the maximum payoff of active control approaches on a large, realistic system.

PHASE II: Analytically test the method initialized in Phase I on at least two dynamically complex ground test beds where traditional control approaches have already been established to control vibration. In addition, test the technique on a current active payload shroud model to predict control performance. Depending on the availability of hardware, measurements will be taken on at least one of the test beds to confirm the accuracy of the approach in predicting maximum control performance.

PHASE III DUAL USE APPLICATIONS: The method and experimental results developed in the first two phases of the SBIR program will be applicable to DoD and commercial launch vehicles and can be integrated into either an existing commercial software package or a stand alone tool. Other applications requiring this sound or vibration control technology include commercial and military aircraft, concert halls, theaters, and optics platforms.

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KEYWORDS: active sound/vibration control, complex frequency domain, structures, active noise control, statistical energy analysis, structural/acoustic control

AF01-038 TITLE: Advanced Modeling of the Ionosphere and Upper Atmosphere

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop novel techniques to forecast and specify regional ionospheric density profiles.

DESCRIPTION: The near-earth space environment has a direct and sometimes deleterious effect on military operations. Charged particles in the ionosphere enable high-frequency communications by reflecting radio waves. However, systematic variations and perturbations in the ionospheric density can adversely affect communications, spacecraft charging, Global Positioning System (GPS) navigation, radar surveillance, and geolocation. Changes in the upper atmosphere modify the orbits of satellites and degrade our ability to predict their position and reentry. Military and civilian operations, both terrestrial and near-space, therefore rely on accurate models of the upper atmosphere. Between the altitudes of 80 and 1500 km, the upper atmosphere has two components: a neutral component—the thermosphere, and a charged component—the ionosphere, which form a strongly coupled system. The objective of this SBIR is to devise innovative methods to characterize and predict regional ionospheric electron density profiles. The methodology can include a combination of empirical and physics-based models of the ionosphere and thermosphere, as well as innovative techniques to assimilate data from satellite and ground-based operational sensors. Physical quantities to be assimilated include neutral and ion composition, neutral and ion densities, temperatures, winds, and electric fields. Of particular interest to the Air Force are data derived from the next generation (Block V) Defense Meteorological Satellite Program (DMSP) sensors, including Ultra Violet imagers and particle detectors. Proposed models may include advanced modeling and numerical techniques that facilitate the assimilation of ionospheric and upper atmospheric observations and that substantially improve the local characterization of the upper atmosphere and ionosphere.

PHASE I: Develop an assimilation model concept that provides an improved modeling capability for the upper ionosphere and atmosphere. Produce a detailed design for an algorithm based on a concept that utilizes the next-generation DMSP space environment sensors.

PHASE II: Based on the Phase I design, further develop, verify, and validate algorithms. AFRL will evaluate the prototype algorithm for its ability to demonstrate and quantify the performance of assimilation techniques. The AFRL evaluation will be conducted at no cost to the small business or the SBIR Program. Demonstrate that the prototype leads to improved performance, as compared with existing AF operational models such as the Parameterized Realtime Ionospheric Model.

PHASE III DUAL USE APPLICATIONS: Industries interested in this work include telecommunications, aviation, and GPS manufacturers. SBIR results will be applied to these industries by providing technologies that make spaced-based communications and navigation more secure and reliable. Anticipated benefits include High Frequency communication, improved communication through the Military Satellite Communication System, as well as improved radar range and angle of arrival estimates. This model has significant dual-use potential. There is a need for the commercial sector to develop space weather products tailored to a specific application. This was pointed out in the National Security Space Architect Space Weather Architecture Study which states: "Military users expect tailored space weather products while civil policy is to provide access to basic data and rely on third party product tailoring."

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KEYWORDS: space weather, electron density, radio frequency propagation, HF communications, ionospheric scintillation, satellite drag

AF01-039 TITLE: Long-Term Cryogenic Fluid Storage for On-Orbit Applications

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop, design, and demonstrate long-term cryogenic fluid storage techniques for next generation spacecraft applications.

DESCRIPTION: This topic seeks proposals with innovative concepts relating to systems capable of providing long-term storage of cryogens in space for periods greater that 20 years. Future long-duration space missions for space based transportation propellant, reactant, and life support missions will require on-orbit systems capable of long-term storage of subcritical cryogens. Applications under consideration by the Air Force are space-based lasers, orbit transfer vehicles, and propellant storage depots. The stored cryogens for these advanced applications include helium, hydrogen, deuterium, oxygen, nitrogen triflouride, and nitrogen. There are many challenges for enabling long-term storage for specific applications in microgravity that must integrate improved / innovative technology. Examples include, but are not limited to, using thick multilayer insulation (MLI), composite and/or disconnecting supports, thermodynamic vent system (TVS), and the components of reliquefaction systems. Additonally, cryogenic integration technology to enable low heat parasitic redundant cooling connections, high conductivity cryogenic thermal interfaces, and long cryogenic heat transport distances are also system concerns. Boil-off losses per year of 2% for liquid hydrogen in space have been predicted using passive technology. Fluid storage systems must be compatible with integration of cryocooler technology in order to be feasible for future AF and DoD systems.

PHASE I: Define the proposed system concept, specific system requirements, and predict the performance of the proposed design. Demonstrate basic system concepts in a laboratory environment.

PHASE II: Provide a prototype component or system and laboratory demonstration to mutually agreed performance parameters. Demonstration vehicle must be capable to support ground demonstration in a government space research facility and be qualifiable for a space experiment. The prime consideration must be clear system hardware demonstration of the integrated high-performance system that will demonstrate a 20-year lifetime.

PHASE III DUAL USE APPLICATIONS: Long-term storage of cryogens would be utilized in NASA's International Space Station, NASA's Mars In-situ Propellant Generation for return missions, the proposed DARPA Orbital Express for resupply of national security and future civilian satellites.

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KEYWORDS: thermodynamic vent, cryocooler, thick multilayer insulation, minimum boil off, micro gravity environment, cryogenic

AF01-040 TITLE: Algorithm Development Based on Analysis of Remotely Sensed Optical Data/Imagery

TECHNOLOGY AREAS: Information Systems Technology

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 database of optical data (ultraviolet, visible, and infrared) to characterize the optical properties of the environment. It is expected that the proposer will exploit these databases 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: Using real data, conduct analyses to develop algorithms for clutter-mitigation/contrast-enhancement techniques to (1) optimize target detection, search, and track capabilities in structured environments, (2) identify materials, and (3) identify and quantify atmospheric constituents/effluents. Compare and contrast the candidate algorithms.

PHASE II: Perform detailed analyses and demonstrate the efficacy of algorithms for (1) target detection, search, and track in structured environments, (2) materials identification, and (3) 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 potentially will be useful 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 also potentially will 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: multispectral hyperspectral ultraspectral data analysis data processing imaging non-imaging

AF01-041 TITLE: Plug-and-Play Scalable Interface Electronics for Satellites

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Establish approaches to simplify complex interfaces, permitting rapid development, integration, and launch of space systems using radiation-hardened electronics

DESCRIPTION: Current systems are often plagued with interface problems that could be simple to correct, but which compound overall program risk due to the critical path relation of program schedule. Worse than that, it is impossible to construct systems of non-trivial complexity that are in fact engineered with sufficient modularity to enable rapid assembly of sub-systems into a spacecraft bus. Inevitably, every interface must be individually crafted as a set of custom electronics with custom protocols. The interactions in hardware and software are decidedly ad hoc, and it is seemingly more or less luck that systems are eventually fielded at all. With the hope of avoiding some of these problems, such concerns have in part led to the zealous simplification of bus designs. We believe there is a better way. While concepts such as the plug-and-play systems used in Windows-based PCs are a step in the right direction toward ease of use, they are not suitable for use in embedded systems, particularly space systems. We seek novel exploitation of concepts in reconfigurable hardware and software, and definition or adaptation of protocols for truly open systems with a plug-and-play, appliance-like ease of use.

PHASE I: Demonstrate a plug-and-play concept that is viable for implementation in a radiation-hardened technology. The effort should clearly address detailed architecture(s) for reconfigurable and extensible interfaces over the widest possible classes of space electronics. If possible, the plug-and-play concepts should apply to all manner of spacecraft electronics subsystems, components, and even the cabling harnesses of the spacecraft itself. We believe this will permit an ala carte, Lego(TM)-like approach that will ultimately enable an extremely rapid putting together of even the most complex systems.

PHASE II: Implement the space-qualified architecture based on the Phase I demonstrated concept, possibly to include integrated circuit design and fabrication, multi-chip modules, flexible circuitry, etc. The offeror shall develop viable demonstration cases either in collaboration with the government or private sector. If successful, the project could be transitioned immediately to one or more advanced spacecraft insertions of direct interest to this organization.

PHASE III DUAL USE APPLICATIONS: Follow-on activities are expected to be aggressively pursued by the offeror, namely in seeking opportunities to integrate the hardware, software, and protocols of the developed plug-and-play approach into aerospace platforms. Commercial benefits include improved competitive opportunities for more providers of aerospace platform components and sub-systems, consistent with the open systems frameworks of terrestrial computers, workstations, and other systems.

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KEYWORDS: dynamic reconfiguration adaptive computing programmable electronics fault tolerance remote servicing advanced packaging, multichip modules

AF01-042 TITLE: Space Environment Detectors for Microsatellites

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop innovative and miniaturized particle and field detectors and techniques for microsatellites.

DESCRIPTION: In-situ measurement of the space environment, from LEO to GEO and beyond, including the solar wind, is one of the core missions of the Space Vehicle Directorate’s Battlespace Division. This division has requirements for data concerning those particles and fields that affect space weather and the survivability of DoD space assets, which include electric and magnetic fields, ions and electrons from thermal to relativistic energies, and thermal and energetic neutral atoms. This topic is primarily concerned with innovative and miniature instruments or techniques, with a strong emphasis on suitable designs for micro satellites. Enabling concepts are encouraged separately from complete detector designs. In addition, there is a requirement for laboratory hardware to support the design and calibration of such detectors.

PHASE I: Develop conceptual designs and/or bench-level devices that can establish feasibility. The Phase I products should be useful for estimating the scope and cost of an actual flight test experiment.

PHASE II: A working prototype of the device or technology is highly desired. This may or may not be a complete or flight-ready system depending on the complexity of the proposed effort. The AF desires the delivery of prototype equipment for our evaluation and may sponsor access to space for selected 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: Potential military applications will include expendable multi-mission payloads produced in large volumes. The overlap between DoD and civilian space weather missions make this effort inherently dual use. There should be significant commercial potential in supplying technology to those missions which include magnetospheric mapping and solar warning. In addition, miniaturization efforts are well known for unanticipated spin-offs.

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KEYWORDS: charged particle detectors neutral particle detectors magnetometers micro-satellites space detector calibration space weather

AF01-043 TITLE: Integration Concepts for Space IR Sensing Component Technologies

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a ground-based prototype of a space-based surveillance sensor, employing revolutionary approaches for interfacing advanced space infrared (IR) sensing component technologies.

DESCRIPTION: Opportunities exist to develop novel demonstration concepts for new-technology infrared sensor components—including focal plane arrays and space cryocoolers—through the development of revolutionary electrical, mechanical, and cryogenic interface concepts, as well as through innovative concepts for concomitant sensor fore-optics (e.g., spectroscopic or wide field imaging, cryogenically-cooled or ambient temperature). The latest IR focal plane array technology advancements of interest include (1) high operating temperature, MWIR HgCdTe, (2) dualband (MW & LWIR and dual-LWIR), and (3) low background, LWIR HgCdTe operating at 40 Kelvin. For example, a concept tailored to the newly-emerging dualband FPA technology might lead to improved hyperspectral imagery through use of overlapping grating orders dispersed over the dualband focal plane array, thereby providing for simultaneous acquisition of hyperspectral imagery over several wavebands of interest (e.g., MWIR and LWIR) and with high efficiency (due to the sharing of a common "blaze wavelength"). The offeror will formulate a proof-of-principle concept involving the component technologies and a sensor design leading to an economical, ground-based demonstration. The offeror will identify the associated space missions (e.g., space-based ground or space surveillance, planetary defense), their requirements, and the legacy of the proposed experiment to the mission requirements. The calculation of the signal and background photon rates corresponding to the proposed demonstration and the linked mission-viewing geometry would be used by the offeror to constrain the demonstration sensor design and component technology selection. The ground demonstration might make use of existing ground-based telescopes and narrow pixel fields of view in order to simulate the background levels for a space-based sensor in the mission context. Demonstration concepts that allow for collection of valuable target or background phenomenology data are of particular interest. The legacy between the proposed ground demonstration sensor and its space-based embodiment should be defined.

PHASE I: Formulate a proof-of-principle demonstration concept involving component technologies proposed for demonstration. Define the role of the demonstration in the context of the generic space missions mentioned above. A key aspect of this effort might be the definition and design of simplified infrared FPA and space cryocooler interfaces that facilitate and economize integration efforts in the spirit of "better, faster, and cheaper." Examples might include flight-qualifiable concepts for the integration of FPAs packaged with standard, leadless chip carrier interface (thereby saving costs and risks associated with the relocation of these FPAs to custom flight substrates) and universal cryocooler drive electronics that are both compact and economical. Consideration should also be given to the use of commercial off-the-shelf subsystems (e.g., IR FPA drive and data acquisition electronics) appropriately tailored to support the components identified for the technology demonstration.

PHASE II: Develop the prototype demonstration sensor in accordance with the Phase I design. The prototype sensor will be delivered to the government for evaluation, demonstration, and field data collection experiments.

PHASE III DUAL USE APPLICATIONS: Military applications of the proposed prototype sensor include efficient space-based surveillance. By qualifying the innovative interfacing concepts developed under this SBIR, these concepts will facilitate the transitioning of the advanced, infrared sensing component technologies. Commercial applications include both NASA remote sensing and space astronomy applications, as well as a commercial space surveillance proof-of-concept compatible with satellite anomaly diagnostics based on thermal imagery. This technology will be useful in troubleshooting anomalies associated with expensive commercial and military satellites.

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KEYWORDS: space cryocooler, focal plane array (FPA), infrared (IR), remote sensing, optics

AF01-044 TITLE: Control and Pointing of Very Flexible Large Space Structures

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop an approach to provide pointing and control capability for very flexible large space structures.

DESCRIPTION: Traditional attitude control (AC) views the space vehicle as a rigid body (i.e. having infinite stiffness). Excitation of spacecraft flexible modes is avoided by designing the AC algorithm such that the frequency response rolls off well ahead of the fundamental frequency of the structure. In some cases, structures are stiffened to facilitate this control approach, adding undesirable weight. In any case, this approach limits (sometimes severely) available AC bandwidth restricting maneuverability of the vehicle and, in turn, adversely affects control and pointing capability. Several recently proposed space structures possess such a high degree of flexibility that the traditional approach to AC will not be able to provide pointing capability for these structures. Examples include large inflatable structures or other extremely lightweight concepts. In fact, these structures may not even be controllable using the traditional AC approach. Innovative AC concepts are required for providing pointing capability for such large flexible space structures. A possible approach to the problem might use distributed integrated control modules (sensors/actuators) that provide local AC in support of a hierarchical AC system that determines and regulates the attitude of the overall structure. Other possible approaches might rely on advanced adaptive or neural control algorithms to compensate for structural modes in conjunction with high bandwidth AC authority. Proposed approaches should be able to provide pointing capability to structures with arbitrary levels of flexibility.

PHASE I: Develop an innovative attitude control approach for large, highly flexible space structures. Demonstrate feasibility of the proposed approach by analysis and simulation using a mathematical model of a representative space structure concept.

PHASE II: Finalize the Phase I conceptual design, and based on that design, build a prototype AC demonstrator system. Demonstrate the prototype via hardware-in-the-loop testing using dynamic model of an actual space structure concept.

PHASE III DUAL USE APPLICATIONS: Methods for controlling attitude and pointing of large, very flexible space structures represent enabling technology for several planned AF programs. The results of this effort will also provide enhanced attitude control capability for medium/large commercial satellites. A specific program this SBIR will support is the PowerSail program.

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KEYWORDS: autonomous fault recovery learning algorithms expert systems attitude control distributed integrated control module flexible space structures

AF01-045 TITLE: Serviceable Satellite Bus

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a spacecraft bus design that facilitates on-orbit servicing and allows reconfiguration via plug-n-play methodology.

DESCRIPTION: Recent advances in microsatellite technology make it feasible to provide low-cost autonomous on-orbit servicing. To utilize this approach, there is a need to design new satellite architectures that enable these microsatellite servicers to perform on-orbit maintenance, assembly, and repair. In addition, because it is now feasible to consider upgrading components during on-orbit operations, the architecture must be capable of autonomous reconfiguration and assimilation of new components via a standard interface in a manner similar to the acceptance of new cards/peripherals in a personal computer system. Identification of potential orbital replacement units (ORU) and standardized connectivity concepts for data, power, etc., are critical to the development of an on-orbit serviceable bus structure. Approaches and hardware concepts that facilitate docking with the servicing vehicle are also desirable. The contractor should also address how a standardized maintainable bus can be mass produced and then tailored to specific mission requirements. In addition to technical merit, considerations include potential for cost savings, manufacturability, and the likelihood of the proposed approach to be effectively transitioned to DoD and commercial space systems.

PHASE I: Develop a viable concept for a serviceable, reconfigurable, satellite architecture with standard interfaces. Develop a program plan that shall incorporate, but is not limited to, an implementation strategy/methodology for the new technologies, projected system and subsystem level payoffs, a detailed technical challenge breakdown, risk mitigation strategy, potential flight demonstration opportunities, proposed program schedule, and estimated costs. The primary result of Phase I shall be a well-defined development and demonstration plan for a technology with potentially high payoff for military and commercial spacecraft systems. Phase I would also identify the potential impact on critical parameters such as cost, reliability, serviceability, and performance. Proof-of-concept demonstrations are highly encouraged.

PHASE II: Develop and demonstrate prototype hardware for the concept identified in Phase I. Tasks shall include, but not be limited to, a detailed proof-of-concept demonstration of key technical parameters, which can be accomplished at a subscale level, although a full-scale demonstration is encouraged. A detailed performance analysis of the technology is also required. A strategy to transition the technologies developed for current and future spacecraft is strongly encouraged.

PHASE III DUAL USE APPLICATIONS: A serviceable satellite bus structure that enables autonomous on-orbit servicing in lieu of replacing a satellite will benefit both commercial and military spacecraft by dramatically reducing the operations cost of a satellite architecture. In addition, mass production of these “modular” bus structures would lower fabrication costs for both commercial and military users. This technology applies to various spacecraft systems, especially those that utilize satellite constellations to accomplish their mission, such as GPS and communication concepts.

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KEYWORDS: on-orbit servicing orbital replacement unit (ORU)docking modular bus structure plug-n-play spacecraft bus serviceable spacecraft bus

AF01-046 TITLE: Modular Miniature Satellite Subsystems

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Demonstrate the feasibility of “plug-and-play” interface between satellite subsystems through development of the necessary modular components, advanced packaging, and architecture technologies.

DESCRIPTION: The advent of advanced spacecraft technology, miniature electronics, adaptive architectures, novel packaging concepts, and Micro-Electro-Mechanical Systems (MEMS), can significantly reduce the size and cost of elements and components, and thus dramatically reduce the overall weight of satellites. Often, however, these technologies are not applied systematically to the entire vehicle or subsystem. In addition, satellite designs are generally “point solutions”, optimized to a single mission, thereby limiting the reuse of previously developed technology and significantly extending development timelines. Standardization has not yet been achieved since most reuse strategies are limted to ad-hoc combinations of a few existing standards and fall short of a truly open-system approach. We seek a synergistic approach to the open-system problem as it applies to space system electronics. With the combination of technologies such as advanced packaging, novel architectures, MEMS components, and other technologies, we believe novel approaches to modular miniature satellite subsystems are possible. Ideally, such components and subsystems would be easily interfaced to the widest possible number of spacecraft designs and missions. In some cases, it may even be possible to reconfigure such modular elements to new spacecraft without hardware modification, resulting in significant savings in cost, weight, and schedule. This would represent a paradigm shift in that spacecraft architecture could be assembled in an “a-la-carte” fashion, dramatically simplifying previously held notions of integration and systems engineering. An example of this concept might be a complete attitude determination and control module for a nano/micro-satellite. It is imagined that this unit is comprised of MEMS inertial measurement units, lightweight star cameras, embedded processors, and miniature reaction wheels. This complete package has all required sensors, actuators, and computation for attitude control. The unit requires a simple external interface—a physical, power, and command and telemetry (e.g., shared serial) interface. The attitude sensing capability is very accurate, and even though not required for all applications, comes at very little cost. The control torque capability is designed to be scalable, e.g., with interchangeable reaction wheel motors and rotors. Like modular personal computer systems, a single subsystem design can now be utilized for many applications. Similar highly integrated concepts for other subsystems are also possible.

PHASE I: Identify a novel candidate modular approach for miniature satellite subsystems and demonstrate its extension to various spacecraft architectures. Successful approaches would achieve this over a large number of variations of avionics designs without requiring significant modification. The approach should not become obsolete as the state-of-the-art in different aspects of space electronics improves (forward compatibility).

PHASE II: Complete a detailed design of a miniature modular subsystem to demonstrate the Phase I concept. Perform functional analyses. Build a space-qualifiable prototype of the integrated subsystem and perform functional tests. Demonstrate concept compatibility with at least 3 different bus architectures. If successful, the project could be transitioned immediately to one or more advanced spacecraft insertions of direct interest to this organization.

PHASE III DUAL USE APPLICATIONS: Considerable interest in modular subsystems has emerged within the commercial satellite industry. Modular subsystems will allow satellite primes to significantly reduce fabrication costs due to the elimination (or significant reduction) in NRE due to integration problems. In addition, this technology will allow manufacturers to integrate the latest performance-enhancing technology without compromising strict development timelines.

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KEYWORDS: microsatellites, plug-and-play, self-organizing networks, architectures, scalability, interface

AF01-047 TITLE: Novel Approaches to Optical Stand-off Detection

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop innovative space-based optical measurement techniques for intelligence preparation of the battlefield (surveillance and reconnaissance).

DESCRIPTION: The Air Force Research Laboratory's Battlespace Environment Division (AFRL/VSB) is interested in innovative techniques and approaches for optimal automated search, detection, identification and tracking of targets in structured environments. Examples include passive optical sensors which collect spectral, spatial and temporal data. Many commercial technologies are emerging that could be developed into innovative measurement techniques. The focus of the R&D tasks will be directed toward space-based applications.

PHASE I: Conduct analyses of candidate sensors and data analysis approaches with respect to sensitivity, contrast, spectral and/or spatial resolution, temporal resolution, et cetera. New measurement technologies will be defined and assessed in terms of contrast enhancement and/or clutter suppression, as well as for accuracy and speed. Techniques to identify materials will be a key part of this effort.

PHASE II: Conduct demonstration experiments to determine how effectively the proposed techniques address the requirements of intelligence preparation of the battlefield. An automated, near-real-time, target identification prototype will be developed and demonstrated using simulated and real data.

PHASE III DUAL USE APPLICATIONS: The techniques and methodologies developed under this effort potentially will be useful in military systems requiring autonomous threat recognition and identification under stressing conditions of cloud and haze cover, and sensor clutter induced by scene structure. It also potentially will be useful for non-military applications involving material/species identification under stressing real-world conditions of scene-induced clutter/noise and spectral interference. Examples include crop health assessment, precision agriculture (targeted applications of fertilizer and pesticides), mineral prospecting/mining, counterdrug, and assessment of natural disasters (actual or potential).

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KEYWORDS: sensors, multispectral, hyperspectral, remote sensing, imaging, non-imaging, data acquisition, data analysis, data processing, target detection, spectral signatures

AF01-048 TITLE: Autonomous Satellite Servicing to Increase Effective Mission Life

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Innovative and novel approaches are sought to dramatically increase effective mission life and maneuverability of existing or soon to be deployed satellite systems through on-orbit servicing.

DESCRIPTION: Many military and commercial satellite systems that are currently being developed or proposed consist of single or multiple spacecraft in reconfigurable constellations and close flying formations. These satellite systems will act in a coordinated fashion to achieve varying mission goals and requirements. In order to create a cost-effective means of continued use for these flexible systems, fully autonomous on-orbit servicing has been proposed for cooperative and uncooperative targets. Note, fully autonomous rendezvous and docking has not been achieved, especially with uncooperative targets. Research and development is needed to create the necessary technology for future applications, specifically a fully autonomous rendezvous and docking system. Several technologies must be developed, tailored, integrated and/or expanded to achieve autonomous inspection and/or on-orbit rendezvous and docking capabilities. This work must address one or more of the following specific issues to meet the unique needs of on-orbit servicing: novel approaches and mechanisms for autonomous micro-satellite docking, systems for target state identification and trajectory planning, control architectures for autonomous rendezvous, attitude and formation control. The servicing vehicle may be required to perform a close inspection of the satellite, either physically through the use of an on-board camera or through interrogation of the on-board software, to determine what servicing is required. The objective of this research is to examine and create viable on-board autonomous rendezvous and docking architectures and inspection systems, in terms of hardware, software, and algorithms, to meet these requirements. Proposals, which demonstrate an understanding of system level issues while emphasizing innovative technical solutions in one or more of the key technical risk areas are highly desirable.

PHASE I: Create a baseline architecture for the servicing concept to support, demonstrate feasibility of autonomous rendezvous docking of technical approach through simulation and/or prototyping. Sufficiently demonstrate that goals on increased mission life and/of lower life cycle cost can be achieved through further development.

PHASE II: Demonstrate the viability of the on-orbit servicing concept and technical approach for hardware demonstration and/or detailed simulations that will prove the concept and allow system level simulation of an on-orbit, multiple spacecraft environment that represents the proposed spacecraft philosophy. Highlight the reduced program costs and risks that are achieved through continued operation of serviceable vehicles.

PHASE III DUAL USE APPLICATIONS: The servicing approach selected can be applied to commercial satellite system to save costs and extend satellite lifetime for current and proposed ventures. Costs savings can come from replenishing on-board consumables such as fuel and replacing or repairing failed components, as well as upgrading computer and sensor subsystems. For commercial satellite systems, this capabilities means millions of dollars in additional revenue per year of extended operations. For military systems, this capability provides additional operational capability by extending the useable life of the system or providing significantly enhanced maneuverability. With satellite development and launch costs in the 100s of millions of dollars, technology that can cost effectively extend the useable service life of a satellite is of strategic value to the nation.

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KEYWORDS: proximity operations, operations autonomy, satellite servicing, GN&C, rendezvous & docking, on-orbit servicing

AF01-049 TITLE: New Launch Vehicle Fairing Concepts

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a new concept/low-cost/produceable spacecraft fairing, which reduces acoustic/vibration/ shock-related failures.

DESCRIPTION: Today's state-of-the-art launch vehicle fairings are typically constructed of a honeycomb sandwich structure with composite face sheets, which provide very weight efficient structures. However, this construction approach is labor intensive since it involves fitting the core and the skins to complex curvatures. Present day fairings also rely on heavy pyrotechnic release devices that transmit high shock loads to the payloads, as well as heavy acoustic insulation blankets. Recent advancements in multi-functional and lightweight composite structures, low cost fabrication techniques, vibration protection, acoustic suppression, and low-shock separation provide the potential to revolutionize next-generation payload fairings. For example, grid stiffened composite structures could provide dramatic fabrication cost savings at similar performance to sandwich structures. These structures could be combined with multi-functional layers that would provide vibration damping, low shock release, and acoustic suppression, and electric transmission pathways. In addition, epoxy materials have been developed that act as both structural components and releasable joints under an electric field that could be potentially used as a low shock separation device.This topic seeks innovative solutions for integrating these important technologies into a next-generation launch vehicle fairing. Concepts which can provide increased spacecraft protection and reduced integration times at a lower cost are highly desired. Modularity to enhance potential use on different launch vehicles would also be a consideration. For example, could multiple payloads be pre-integrated into a sub-structure that forms a protective fairing when assembled?

PHASE I: Investigate concepts for integrating these new material and structural technologies into a launch vehicle fairing. Through modeling, analysis, and/or experiments, demonstrate the feasibility of constructing, testing, and integrating the proposed fairing while maintaining compatibility with existing launch vehicle interfaces. The Phase I effort shall result in the design of the most promising option(s). The contractor shall work with government personnel to establish suitable performance criteria for the Phase II effort; however, a standard honeycomb sandwich payload fairing with standard release mechanisms and damping treatments will be used as the baseline for comparison purposes. The conceptual design shall serve as the basis for the prototype development in Phase II.

PHASE II: Based on the Phase I design, develop a full-scale prototype fairing. Characterize the fairing performance. Conduct demonstrations to establish compliance with DoD/commercial performance criteria determined during the Phase I effort. These may include both component level and systems level tests.

PHASE III DUAL USE APPLICATIONS: Successful fairing derived as a result of this development will have high potential for application to many DoD/NASA/commercial launches and their respective payloads. Because both commercial and military launches typically utilize the same launch vehicles (e.g., Taurus, Delta II, EELV, etc.), dual-use application of this technology will be the natural outcome.

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3. Sciulli, D., Denoyer, K.K., Fosness, E.R., "Program Development of Whole-Spacecraft Launch Isolation Systems at the U.S. Air Force Research Laboratory," 50th International Astronautical Congress, Amsterdam, The Netherlands, October 4-8, 1999.
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KEYWORDS: launch vehicle fairing, shock isolation, acoustic isolation, multi-functional structures, vibration isolation, low shock separation

AF01-053 TITLE: A Software Agent Advisor for Satellite Command Composition and Training

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a software agent for Satellite Ground Systems Operators to support the training and measurement of satellite command composition and operations.

DESCRIPTION: At the highest level, the actions of military satellites are based on commands sent by human operators from their ground stations. As satellites have become more complex with the passage of time, so also has the commanding process become more complicated. Currently, a typical satellite program uses a library of 500-1000 fragmentary commands (commandlets) that the operator must assemble into complete, composite commands to accomplish the desired purpose. As complexity increases, the number of commandlets increases, and consequently, the possible number of possible commands increases exponentially. A corollary is that there are many possible ways of accomplishing a given task, and some are significantly better than others. Thus, the complexity of the new Ground Systems Operator (GSO) position makes it increasingly difficult to master command languages of increasing richness. Innovative responses are sought to provide a software-based agent technology or an alternative approach that would advise, assist, and evaluate operators in building commands. Results of software agent or similar innovative research could be used to assist in the design of learner strategies to be applied to not only an advisor to operators on console, but also by providing innovative approaches to developing new training methodologies on coaching strategies. One possible scenario to be investigated would be to present a student with a script. After review of the script, the operator would be asked to build a command(s) with hints and guidance from the agent or an alternative technology, he or she could then possibly respond by executing symbolically the scenario advanced, the next command sought, and so forth. The performance measurement component of the coaching tool should be able to not only measure and score but also provide for the improvement of the agents developed. The system could be used in a Distributed Mission Training (DMT) environment for space with agents acting as proxies for other parts of the system or playing other roles.

PHASE I: Required Phase I deliverables will include; (1) a proof-of-concept and demonstration of an interactive coaching and measurement capability with potential to advise operators on command formulation, (2) a plan to implement Phase II including the design and architecture of the training environment, and (3) a technical report describing the research and results.

PHASE II: Required Phase II deliverables will include the prototype development, demonstration, and preliminary validation of an agent-based command coaching concept delivered in Phase I for satellite command composition assistance for human operators. The training effectiveness, evaluation, and assessment of the application of the training environment will be documented on the potential to support existing or developing system and expected commercial/dual-use platforms. The developed prototype technology will run in a platform-independent environment.

PHASE III DUAL USE APPLICATIONS: This effort will create a commercially doable capability that does not currently exist in any government or civilian research or development system. Results of this effort could transition the training environment to the SBIRS LOW training suite and/or other related military applications. At least one dual-use/commercial insertion of this technology will allow a significant contribution to the technology supporting the increasing reliance on satellite surveillance for assistance, including natural disaster assistance, border control and customs, air traffic control, and weather detection.

REFERENCES:

1. AFMC Training Systems Product Group Distributed Mission Training Homepage: http://tspg.wpafb.af.mil/programs/dmt/default.htm and http://tspg.wpafb.af.mil/programs/dmt/default.htm
2. SBIRS rds: Program Homepage : http://www.laafb.af.mil, follow the links to ORGANIZATION, MT.
3. Air Force Research Laboratory, Human Effectiveness Directorate, Roadrunner'98, http://www.williams.af.mil/html/roadrun.htm
4. Chairman, Joint Chiefs of Staff, Joint Vision 2010. (1997)

KEYWORDS: Software agent assistants, Human-agent interaction, Satellite command composition, Training environments, Satellite tasking,SBIRS LOW, Spaced-Based Infrared Systems Low

AF01-054 TITLE: A Decision Aid for a Surveillance Satellite Crew Shift Supervisor

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a measurably effective decision aid for a surveillance satellite crew shift supervisor

DESCRIPTION: As a result of the requirements for reduced manning and increased automation, the supervising of crews that operate constellations of surveillance satellites is becoming exceptionally challenging. In addition, the training of the individual operator as well as the crews has required implementation of such complex activities that it is often nearly indistinguishable from operations. Evolving military space programs, such as the Space Based Infrared Systems Low (SBIRS LOW) urgently need to incorporate software assistance for their crews in both operations and training. Crew shift supervisors will be required to advise, monitor, and assess crew performance with crew complements of up to 15-20 individuals. Research is needed to develop decision support assistance that will provide guidance, advice, and rationale for the assignment of tasks to individual operator and to assess an operator's performance. An innovative strategy is needed to apply this technology while incorporating transparent features that support individual operator training scores, use of estimated task times and levels of difficulty based on laboratory testing, workload balance among crewmembers, crew performance optimization in the presence of anomalies, malfunctions, and satellite re-tasking.

PHASE I: Phase I will result in a proof-of-concept for a decision support aid to assist surveillance satellite shift supervisors in both the training and operational environment of subordinate crewmembers. Initial effective measures for assessing the performance of crewmembers will be developed for the decision aid for both individual and crew tasks. In addition, Phase I documentation will provide an understanding of the Distributive Mission Training (DMT) concept for space and also provide a Development Plan for Phase II.

PHASE II: Deliverable for Phase II will include a full demonstration of the prototype decision aid to support a shift supervisor with a minimum of 15 subordinate crewmembers. Methods for assessing the decision aid features will be developed and applied to the insertion of an existing satellite systems simulator or prototype. Proposals should assume that the technology will run in a platform-independent environment.

PHASE III DUAL USE APPLICATIONS: Results of this effort will be applicable to military and commercial sectors of the satellite community. Potential outcomes of this research would assist in reducing the training time, error rate, and feedback time to satellite. At least one dual-use/commercial application of this technology will allow a significant contribution to the performance assessment and decision support technology for individual and crew surveillance satellite training as well as reduce the heavy workload and time constrained decision making requirements for the shift supervisor. This technology will also provide applications in the private sector and other government agencies to assist in commercial satellite constellation management, air traffic control, and intelligent manufacturing.

REFERENCES:

1. AFMC Training Systems Product Group Distributed Mission Training Homepage: http://tspg.wpafb.af.mil/programs/dmt/default.htm and http://tspg.wpafb.af.mil/programs/dmt/default.htm
2. SBIRS rds: Program Homepage : http://www.laafb.af.mil, follow the links to ORGANIZATION, MT.
3. Air Force Research Laboratory, Human Effectiveness Directorate, Roadrunner'98, http://www.williams.af.mil/html/roadrun.htm
4. Chairman, Joint Chiefs of Staff, Joint Vision 2010. (1997)

KEYWORDS: Software agent assistants, Human-agent interaction, Satellite command composition, Training environments, Satellite tasking, SBIRS LOW, Spaced-Based Infrared Systems Low

AF01-055 TITLE: A Satellite Pre-Pass Contact Support Aid

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a software agent for satellite pre-pass contact operations and support training.

DESCRIPTION: Military space systems are managed from one, or more, ground stations. For satellites on Low Earth Orbit (LEO), the interaction between space and ground is restricted to those times when a satellite passes near a ground communications node. Only at such times can a satellite downlink its health and status updates, and receive new uplink commands. A fully operational space-based infrared system is not subject to this limitation as it can use cross-links to communicate between any satellite and the ground station via intermediate satellites. However, during early constellation deployment, this limitation is critical as problems are most likely to occur at this time. Research is needed to train and support mission control station human operators to meet the challenge of planning satellite pre-pass contact operations. Assessing the mission control and pre-pass operations should provide an innovative approach to designing a technology aid to provide ground station mission personnel planning options for monitoring initial status and health of planned resources like remote tracking stations, communication networks, and operations center software and hardware for an impending space-based infrared low orbiting space vehicle pass. An agent planning tool that would provide mission and support operators the ability to determine real-time operations options of resource capabilities like data rates, communication and channel activity, and configuration; to monitor test results for commanding, telemetry and antenna slaving; and to monitor operator directives to resources for conflicting commands is required. An unique solution is needed to research and develop a mission control planning tool while integrating in-place operator training for contingencies such as negative test results from a resource or degraded operation. The innovative approach would provide customization to each operator's workstation and allow a single operator to assist the mission control team through a distributed set of agents interacting with the team to coordinate overall pre-pass operations.

PHASE I: Phase I will result in a proof-of-concept technology to reflect pre-pass operations, provide human mission control operators a rudimentary planning aid, and support training in a Distributive Mission Training (DMT) environment. Initial performance and assessment measures will be developed to support the satellite pre-pass contact effectiveness. Phase I documentation will include commercial application coordination and a Phase II Implementation Plan.

PHASE II: Required Phase II deliverables will include a full demonstration and validation of a prototype software planning aid for mission control operators to support satellite pre-pass contact. Preliminary performance assessment and training effectiveness measures will be developed and validated on an evolving space based infrared system with application recommendations for other satellite and training environments application. Potential commercial/dual-use applications will be documented. The developed technology will run in a platform-independent environment.

PHASE III DUAL USE APPLICATIONS: Results of this effort could transition the planning aid into the SBIRS LOW Mission Control Station or another developing system to support both mission control operators on consoles and training. At least one dual-use/commercial insertion of this technology will be applied that will allow a significant contribution to the technology supporting the increasing reliance on satellite surveillance for assistance, including natural disaster assistance, border control and customs, and air traffic control.

REFERENCES:
1. AFMC Training Systems Product Group Distributed Mission Training Homepage:
http://tspg.wpafb.af.mil/programs/dmt/default.htm and http://tspg.wpafb.af.mil/programs/dmt/default.htm
2. SBIRS rds: Program Homepage : http://www.laafb.af.mil, follow the links to ORGANIZATION, MT.
3. Air Force Research Laboratory, Human Effectiveness Directorate, Roadrunner'98,
http://www.williams.af.mil/html/roadrun.htm
4. Chairman, Joint Chiefs of Staff, Joint Vision 2010. (1997)

KEYWORDS: Software agent assistants, Human-agent interaction, Satellite pre-pass contact operations, Individual and team training, Satellite tasking, SBIRS LOW, Spaced-Based Infrared systems low

AF01-056 TITLE: A Satellite Operations Debrief Aid

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop an intelligent agent decision aid for SBIRS LOW post-pass debriefing to support training and operations.

DESCRIPTION: Military space systems are managed from one, or more, ground stations. For satellites on Low Earth Orbit (LEO), the interaction between space and ground is restricted to those times when a satellite passes near a ground communications node. Only at such times can a satellite downlink its health and status updates, and receive new uplink commands. A fully operational SBIRS LOW system is not subject to this limitation as it can use cross-links to communicate between any satellite and the ground station via intermediate satellites. However, during early constellation deployment, this limitation is critical as problems are most likely to occur at this time. A software agent to aid human operators to meet performance requirements during post-pass satellite operations debrief is needed. The aiding agent should provide real-time notification of pass-related problems with assigned support resources before the communications network is reconfigured. The aid should log resource response to identified problems and forecast next pass capabilities, opportunities and needs. Measures for operational performance and training effectiveness will demonstrate the efficiency of the debriefing aid.

PHASE I: Phase I will result in a proof-of-concept technology incorporating an intelligent software-based decision support aid to assist debrief of ground station operations and training. A Development Plan for Phase II will be documented to include the design and architecture of the software- training environment. A technical report will describe a limited set of the satellite interactions of LEO between space and ground training problem domains, the effectiveness of the decision debriefing aid, and the potential commercial applications.

PHASE II: Required Phase II deliverables will include a prototype intelligent decision support aid to assist ground station satellite operators in meeting performance requirements during the post-pass satellite operations debriefing. The prototype will be demonstrated with preliminary validation of capability. Training effectiveness, evaluation, and assessment of the application of the training environment will be documented to support an ongoing USAF system and potential commercial/dual-use platforms. The developed technology will run in a platform-independent environment.

PHASE III DUAL USE APPLICATIONS: Results of this effort will transition the software training decision aid to a current USAF satellite system. At least one dual-use/commercial application of this technology will allow advancement in performance assessment and training for post-pass satellite debriefing. This technology will also provide applications in the private sector and other government agencies to assist in commercial satellite constellation management, air traffic control, and intelligent software development, and natural disaster assistance.

REFERENCES:

1. AFMC Training Systems Product Group Distributed Mission Training Homepage: http://tspg.wpafb.af.mil/programs/dmt/default.htm and http://tspg.wpafb.af.mil/programs/dmt/default.htm
2. SBIRS rds: Program Homepage : http://www.laafb.af.mil, follow the links to ORGANIZATION, MT.
3. Air Force Research Laboratory, Human Effectiveness Directorate, Roadrunner'98, http://www.williams.af.mil/html/roadrun.htm
4. Chairman, Joint Chiefs of Staff, Joint Vision 2010. (1997)

KEYWORDS: Software agent assistants, Human-agent interaction, Satellite operations debriefing, Training environments, Individual and team training, SBIRS LOW, Space-Based Infrared Systems Low

AF01-058 TITLE: Improved Coatings for Helmet Mounted Display Visors

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop spectrally narrow, reflective coatings that can be applied to thin, curved, plastic substrates, such as helmet mounted display visors, that are durable or repairable and inexpensive to make.

DESCRIPTION: Helmet mounted display optical designs often use the visor as a final reflecting surface to superimpose display symbology over the scene on which the pilot concentrates. It is attractive to use the visor as an image combiner because doing so reduces the number of required optical elements, thus reducing total system weight. To improve the performance of these designs, a reflective coating is often placed on the visor to increase the amount of display light reflected towards the pilot. Unfortunately, these coatings reduce the amount of light transmitted through the visor, which the pilots need to accomplish their missions. The visual impact of this reduced transmission can easily be observed as a reduction in target detection distance or as errors in color perception. In addition, conventional multi-layer, thin film coatings can be difficult to apply to thin plastic pieces, can warp plastic parts, and can adhere poorly to the substrate. Acceptable visors produced using these methods are expensive and scratch easily. To overcome the shortcomings of current reflective coatings, a spectrally narrow coating that minimizes the impact on the human visual system (has high photopic transmission, does not affect color perception, causes no loss in visual acuity, etc.) is desired. Such a coating must be inexpensive to place on the current polycarbonate Air Force protective visor. The coating and visor combination must meet the requirements stated in MIL-V-43511C.

PHASE I: This research will result in an examination of potential coating designs and coating techniques. A theoretical analysis of the visual impact of the visor and coating is also required. Demonstration of the feasibility of the design and coating technique is highly desirable. Analysis of life cycle cost of visor and coating should be included. The contractor will provide a detailed technical report on the results of this effort.

PHASE II: Acceptable designs and coating techniques from Phase I will be refined. Prototype visors will be produced in sufficient numbers for testing to validate the theoretical visual impact analysis. The contractor is expected to receive feedback from the Air Force for a possible production version of the design.

PHASE III DUAL USE APPLICATIONS: Low-cost, rugged coatings that can be applied to thin plastic substrates will increase the potential for commercialization of helmet-mounted displays by lowering system cost and total lifecycle cost. This will speed the assimilation of helmet-mounted display technology into the medical, automotive, control systems, and entertainment industries. Improved inexpensive coatings would be a great advancement for optical engineering, increasing the availability of low cost, high quality, coated plastic optics for medical, research, and industrial applications.

REFERENCES:

1. Kang, R. N., LaPage, C. S., Cora, S. R., (1996) Effect of haze in advanced laser eye protection visors on contrast acuity, AL/OE-TR-1996-0002, Air Force Material Command, Brooks AFB, TX.
2. Maier, D. A., LaPage, C. S., (1996) Failure mechanisms in aircrew helmet visors, AL/OE-TR-1996-0117, Air Force Material Command, Brooks AFB, TX.

3. McGinniss, V. D., (1994) Advances in environmentally benign coatings and adhesives, Proceedings of the 1994 20th International Conference in Organic Conference in Organic Coatings Science and Technology, Athens, Greece, Vol. 27, Batelle Memorial Inst., Columbus, OH, pp. 331-346.
4. MIL-V-43511C, Military Specification Visors, Flyer's Helmet, Polycarbonate, 16 Jul 1990.
5. MIL-V-85374(AS), Military Specification, Visors, Shatter Resistant, 18 Sep 1996.

KEYWORDS: Crew Systems, Hemet Mounted Cueing System, Helmet Mounted Sight, Helmet Mounted Display, Human Effectiveness, Optical Coating, Scratch Resistance, Visor, Visually Coupled System

AF01-059 TITLE: Helmet-Mounted Display (HMD) Interface Design for Head-Up Display (HUD) Replacement

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Design a symbology mechanization and interface to replace the aircraft-fixed HUD with a HMD.

DESCRIPTION: There are compelling reasons to replace the aircraft fixed HUD hardware with an HMD-based virtual HUD capability. This technology strategy has the potential to save significant aircraft weight while simultaneously freeing up valuable display real estate in the cockpit. Removal or the reduction in size of the current HUD combiner may afford the installation of a windscreen that is both stealthy and bird strike safe. From a pilot performance standpoint, the use of the HMD as the sole transparent display media has the potential to provide a pilot/vehicle interface that is flexible, intuitive, and more capable compared to current technology. These benefits go toward the enhancement of Air Force mission effectiveness and aircrew survivability. Other applications include the ability to provide transparent display media to aircraft that do not currently have HUD capability. This is true both within the military inventory as well as in the private sector. The objective of this SBIR project is to investigate the viability of the no-HUD aircraft concept and design a performance optimized pilot/vehicle interface based on current and near-future HMD technology maturation.

PHASE I: The overall focus of this SBIR is symbology design and evaluation (human/machine interface) and the representation of that symbology in a HMD-based no-HUD aircraft. The R&D effort for Phase I is the determination of the best symbology format, functionality, and mechanization for an HMD-based no-HUD aircraft pilot interface. To accomplish this, define the human performance requirements of aircraft stabilized HUD utilization. Define the requirements for HMD use as a replacement for current HUD capability as well as for off-boresight utility. Produce a preliminary design of an HMD-based no-HUD aircraft pilot interface for air-to-air, air-to-ground, and navigation flight phases. The interface design should support operational mission scenarios across day, night, and in-weather visual conditions. Provide a detailed technical report.

PHASE II: The R&D effort for Phase II is to produce a prototype based on the design resulting from Phase I, and perform a comparative demonstration and evaluation of the HMD-based no-HUD aircraft interface for air-to-air, air-to-ground, and navigation flight phases. Current HUD equipped aircraft performance will be used as a baseline performance measure. Produce a detailed requirements definition document and deliver the refined interface design source code.

PHASE III DUAL USE APPLICATIONS: The commercial potential of this technology is high. Head-mounted display technology has direct application as a means of providing head-up transparent display information within commercial aviation cockpits. Use of the HMD will be a cheaper and easier way to provide transparent display capability in commercial aviation cockpits compared to dedicated aircraft fixed HUD hardware.

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1. Geiselman, E.E. (1999). Practical considerations for fixed wing helmet-mounted display symbology design. Proceedings of the Human Factors and Ergonomics Society 43rd Annual Meeting. Human Factors and Ergonomics Society, Santa Monica, CA., pp. 1187-1191.
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3. Meador, D.P., Geiselman, E.E., and Osgood, R.K. (1996). Helmet-display symbology development for the JAST/IHAVS flight demonstration. Head-Mounted Displays. Lewandowski, R.J., Haworth, L.A., Stephens, W., and Girolamo, H.J. (Eds.), The International Society for Optical Engineering. Bellingham, WA., pp. 39-49.

KEYWORDS: Helmet Mounted Display, Head-Up Display, Symbology, Visually Coupled Systems

AF01-060 TITLE: High-Resolution Visual System Development

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Development of advanced high-resolution visual system components for Distributed Mission Training (DMT) that provides eye-limiting resolution everywhere the eye looks, and can be inserted into any existing trainer facility with little or no trainer modifications.

DESCRIPTION: Particular interest to this solicitation will be concepts to develop (1) full-color, high-resolution light-engine technologies that can be tiled into a multi mega-pixel, wide field-of-view, out-the-window helmet-mounted display, (2) other high-resolution visual system technologies, or (3) efficient/automated database development tools for mission rehearsal.
One of the significant technologies being developed for DMT is ultra high-resolution image generation and display systems. The field-of-view, brightness, and contrast of practically every visual system available today is far less than what the pilot sees looking out of the real aircraft. Most importantly, the resolution of current out-the-window displays is at least an order-of-magnitude less than required. Because of this, current visual systems do not provide a pilot with adequate visual definition to identify other aircraft, ground vehicles, roads, and bridges at realistic tactical ranges or to properly assess their aspect angle. The focus of this solicitation is to support the development of reliable, easy to maintain visual system technologies with resolution, contrast, and fidelity required for realistic air-to-air and air-to-ground training in a DMT environment. While all concepts that address this focus are welcomed, special consideration will be given to proposals for development of lightweight, high-resolution, helmet-mounted display light engines, other high-resolution visual system display technologies, and efficient/automated database development tools.
(1) Helmet-mounted display light engines: Long-standing problems associated with head-mounted displays for ground-based simulator-training applications have been poor resolution, too much weight, poor center-of-gravity characteristics, and limited field-of-view (FOV). In attempt to resolve the resolution problems, and to improve the weight, balance, and rotational inertia burden on trainees head, neck, and shoulders, the USAF solicits industry to design and construct a miniaturized high-resolution, full-color light source, modulator, and scanner package for helmet-mounted applications. The concept is to capitalize on Micro-Electro-Mechanical Systems (MEMS) technology and miniaturize display components for an advanced, lightweight, wide FOV helmet-mounted display for pilot training.
(2) Other visual system technology: The Air Force is seeking innovative solutions for the development of high-fidelity visual system technology that implement the following requirements: Eye-limiting resolution everywhere the eye looks; full aspect field-of-view; sufficient target, background, and surround luminance to support eye-limited acuity; full color spectrum, low geometric and vergence distortion; built-in support for high resolution, readable HUD symbology, readable cockpit instruments, and viewable windscreen support structures; no anomalous peripheral view distractions, no distracting weight, balance, or rotational inertia burden on a trainees head, neck, and shoulders; no distracting image artifacts, i.e. jitter, blurring, jaggies, image lag, blending zones, noise, etc.; low production cost, and high reliability and maintainability.(3) Efficient/automated database development tools: Air Force users expect visual and sensor databases to be automatically generated from space and/or other high-resolution sensor data so they can fly over the same terrain in the simulator they will see during a real mission. This efficient, automated, database development philosophy is contrary to current database generation methods. Currently, database development is a slow, manually intensive effort that usually delivers less than realistic imagery. The Air Force is seeking innovative solutions for developing simulator visual and sensor databases efficiently from streaming, temporally–recent, geo-specific visual and sensor imagery. All terrain features, including vector features, terrain elevation, and textures are desired to be derived almost exclusively from live-feed, digital images.

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: 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: Laser, Collimated, 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

AF01-061 TITLE: Real-time Embedded Simulation Performance Monitoring and Analysis for Distributed Mission Training (DMT)

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: To develop an embedded monitoring and measurement tool that can be used to efficiently measure and optimize the interactive performance of entities within and across distributed mission training simulations. The Air Force is seeking development of innovative tools and techniques that can be used to efficiently gather and report data to permit diagnosis of performance latencies and deficits in the performance of networked real-time simulations, especially those that utilize DMSO High Level Architecture (HLA) technology.

DESCRIPTION: Current simulation network analysis tools allow the measurements to be made during real-time; but, collected data can only be analyzed after the data has been transferred and combined after the simulation run. An innovative tool is needed which will allow data to be gathered and problem areas to be identified for specific entities within DMT simulations. The developed tools must enable system and training evaluations to be displayed while the simulation is running so that real-time adjustments, where possible, can be made to the simulation. Additionally, having the data available as the simulation progresses will permit simulation designers and training researchers to better understand the potential negative aspects associated with delays in any contributing aspect of the simulation. The tool must not impact the quality or the interactivity of the simulation as data is transferred between data collection units. The tool should also be compatible with the current High Level Architecture (HLA) standards, and be able to display entity attributes. The desired system will display the information in a format that is easy to understand and pinpoint potential weaknesses in the quality of the simulation while the simulation is being conducted for diagnostic purposes. This tool will be used to determine the quality of the simulation while it is being conducted and identify problems and system bottlenecks that prevent effective Distributed Mission Training.

PHASE I: Phase I will develop a prototype measurement tool and provide a demonstration and report.

PHASE II: Phase II will result in a fully integrated performance monitoring and measurement capability which is MTA-complaint and which provides the capabilities outlined above. It will also result in test and evaluation of the developed tool and will provide documentation of results in a technical report. Developing, demonstrating, and testing the concept proposed under Phase I and provide a technical report.

PHASE III DUAL USE APPLICATIONS: The capability to provide real time performance monitoring, measurement and diagnosis of problem areas during an interactive simulation does not exist today. The military will realize a significant reduction in on-the-job training requirements while substantially increasing the capabilities of the operational forces in theater due to the improved training and performance transfer resulting from improved and more realistic training and rehearsal. Phase III Dual Use potential is significant since both the military and commercial sectors have devoted considerable resources to the development of highly complex operational systems. Reengineering systems to have these capabilities is cost prohibitive, whereas developing interfaces between these systems and performance support and training technologies is inexpensive and will result in substantial savings to units in the field.

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KEYWORDS: Interactive performance, Simulation Network Analysis Tools, High Level Architecture (HLA), Entity attributes, SNAPPY

AF01-062 TITLE: Distributed Crew Interface for Autonomous Satellite Operations

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop an interface for distributed satellite operations crews to maintain situation awareness of autonomous satellite missions.

DESCRIPTION: Current DoD satellite missions have dedicated, on-site crews who manually build, transmit, and monitor satellite command and control operations. Autonomous operations that use a reduced number of less experienced operators are starting to be investigated. However, the concept of operations still maintains dedicated, on-site crews. Satellite program officers are being driven to explore greater levels of computerization due to budgetary reductions, evolving ground system and range architectures, and the increased number and complexity of missions. This trend will likely lead to a concept of operations where spacecraft management will be conducted by dynamically configured crews, which, depending upon the status of a mission, may be geographically distributed. The crewmembers will act as on-demand supervisors at any time in any place. The supervisory tasks will take advantage of increased automation that would allow for the implementation of a proactive management-by-exception paradigm. During routine operations, standard process monitoring and management tasks will be performed autonomously using advanced automation, expert systems, and intelligent software agents. However, when a potential critical anomaly or emergency is detected, team collaboration tools allow the dynamic creation of a response team by identifying and assembling the appropriate personnel and resources from remote locations. This concept of operation requires new and novel crew system interfaces. When emergencies occur, the crew must be convened quickly; and must have immediate access to data regarding satellite health, history, and platform, so that they can correctly diagnose and correct the problem. In a distributed environment, the interface must electronically facilitate data communication, crew collaboration, and group coordination. Since the distributed crew may be assembled at any time in any place, the interface should support wireless communications and operate in a variety of workspaces, from laptops to palmtops.

PHASE I: Phase I efforts would provide a proof-of-concept crew interface that allows for crew interaction in a wireless environment to a simulated satellite anomaly. A technical report shall document how the new interface facilitates assembling a crew with special emphases on how the crew, which may have had minimal to no pass-to-pass interaction with the satellite, is made aware of the satellite's status and how communication and coordination with remote crew members are achieved.

PHASE II: Phase II efforts would build and demonstrate a wireless interaction interface for a distributed crew to monitor, diagnose, and correct satellite problems detected during autonomous operations.

PHASE III DUAL USE APPLICATIONS: Commercial applications of these technologies are possible for commanding and controlling equivalent commercial satellite constellations and may be applied to any remote monitoring application.

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KEYWORDS: Autonomous Operations, Management, Wireless Communication, Team Collaboration, Satellite Operations

AF01-063 TITLE: Surface Decontamination Using Electromagnetic Field/Laser Emitters

TECHNOLOGY AREAS: Chemical/Biological Defense

OBJECTIVE: Develop Technologies to Destroy Chemical and Biological Warfare Agents Using Electromagnetic Field/Laser Emitters.

DESCRIPTION: Our national defense against chemical and biological warfare agents (CBWAs) requires their rapid detection and destruction. Development of the scientific basis for detecting CBWAs and an electromagnetic field (EMF) and/or laser applicator capable of destroying CBWAs on surfaces such as clothing, buildings, grounds, and skin are desired. Chemical solutions might be applied to the surface to focus the energy from these emitters. Since CBWAs may readily enter the body through open wounds, decontamination of these surfaces should incorporate a protective covering to reduce chances of recontamination. The developed technologies should not damage the surface and should be environmentally friendly.

PHASE I: Determine the feasibility of detecting CBWAs and using an electromagnetic field and/or laser emitter to destroy CBWAs on surfaces. Identify means to: 1) detect a CBWA and 2) focus the energy from the emitter without damaging a surface, especially skin and mucous membranes.

PHASE II: Detect CBWAs and destroy them using an EMF and/or laser emitter. In vitro determinations should be made of the optimal exposure parameters required to destroy the CBWAs. These should be followed by additional evaluations of exposure parameters to prevent damage to skin and mucous membranes. The emitter should be portable for use on the battlefield or in the hospital environment.

PHASE III DUAL USE APPLICATIONS: Commercial applications of this technology are used by responders for suspected bioterrorism events and for identifying and destroying contamination of surfaces in hospitals and on clothing and skin.

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KEYWORDS: Anatomy/Physiology, Bioagents, Directed and Kinetic Energy, Sensor

AF01-064 TITLE: <u>Simulated Panoramic Night Vision Goggle Helmet-Mounted Display for Simulated NVG Imagery</u>

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: To develop a helmet-mounted display system that will support ground based training for the Panoramic Night Vision Goggle (PNVG) that will integrate with the physics based visual simulation of night vision goggle imagery currently in development. In order to support training requirements, this display must preserve the form fit and function of the new panoramic night vision goggle (PNVG). It also must be capable of supporting programmable video formats for the computer-generated imagery to support research objectives. This device will support training R&D in the transition to night operations using the PNVG and will allow an in-place training capability for the CAF. The goal is to be able to deliver a capability for a unit cost no greater than an actual PNVG.

DESCRIPTION: On-going research and development has resulted in a physics based capability to present a high fidelity simulation of the imagery presented by night vision goggles. Current NVG HMD simulation system technology displays a 40-degree field of view using high-resolution miniature CRTs mounted in an actual goggle shell. However, development of actual night vision goggle (NVG) technology has continued beyond the current 40-degree field of view in a new system called panoramic NVG which has a horizontal field of view of 100 degrees, maintaining a 40-degree vertical field of view. It has 35 degrees of overlap in the center of the display. The Air Force is seeking to develop a new HMD that mimics the new PNVG to support future training needs. The training HMD for the PNVG must incorporate all the adjustments and physical characteristics of the actual PNVG for use in training systems for platforms using PNVGS. Development of this system presents a significant technical challenge with considerable associated risk. Successful approaches will require creative and innovative design approaches, since it is clear that current CRT or LCD approaches will not be able to meet the “form, fit, and function” requirement. There is wide flexibility in approaches as long as the “form, fit, and function” requirements are met.

PHASE I: With guidance from the Air Force Research Laboratory’s Human Effectiveness Directorate, develop a proof of concept PNVG HMD for evaluation and user feedback.

PHASE II: Develop prototype PNVG HMDs for current PNVG models, incorporating lessons learned from the proof of concept design along with manufacturing, durability, and resolution improvements. Demonstrate integration with simulated NVG imagery.

PHASE III DUAL USE APPLICATIONS: The PNVG HMD could be used in a number of virtual reality applications requiring a wide field of view and high resolution. This could include educational and entertainment fields as well as commercial training services for non-military users of PNVG.

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KEYWORDS: Panoramic night vision goggle helmet-mounted display; panoramic night vision goggles; PNVGs; head-mounted displays; helmet-mounted displays; night vision goggles; computer-generated imagery

AF01-065 TITLE: Advanced Speech Production Models

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop advanced robust speech production models and estimation algorithms for use in military speech systems.

DESCRIPTION: There are many military applications of speech technology such as speech recognition (SR) for data entry in planning systems and for cockpit voice control, text-to-speech (TTS) for voice warnings, speaker identification (SID) for audio or multimedia information retrieval, and speaker verification (SV) for secure access to systems. However, current speech systems perform poorly in many military environments due to factors such as high noise levels, severe channel degradations, and speaker stress (both psychological and physical) on top of the natural variability found in normal speech. One factor that greatly contributes to the poor performance of many systems in military environments is the use of speech production models that do not adequately model natural speech. A second factor is the use of model parameter estimation algorithms that are not robust across speaker, noise, channel distortions, stress, speaking styles, and other factors. Proposals are sought for advanced speech production models (such as advanced glottal source, vocal tract, and prosody models) that better model natural speech as well as robust algorithms for estimating the model parameters. Proposals should address one or more target applications (e.g., SR, TTS, SID, or SV).

PHASE I: Develop speech production models and algorithms to estimate the model parameters from the speech signal. Demonstrate the robustness of the models and algorithms across a small set of clean, noisy, and channel-distorted speech from both male and female speakers. Provide software for estimating the model parameters and a detailed technical report.

PHASE II: Refine models, algorithms, and software to improve execution speed and robustness across an extensive database of clean, noisy, and channel-distorted speech from both male and female speakers. Using the refinements, implement a robust system for one or more of the application areas (e.g., SR, TTS, SID, or SV). Each implemented system should accept both prerecorded speech files and live speech input. Demonstrate the utility of each system by testing against standard systems in the chosen application area(s). Provide all software developed, any speech databases collected, and a detailed technical report.

PHASE III DUAL USE APPLICATIONS: Considerable potential exists for applying the developed models in commercial and military systems. Applications include (1) SR and TTS for data entry systems, wearable computers, and computer telephony applications; (2) SID for audio or multimedia information retrieval; (3) SV for secure access to computer accounts; and (4) noninvasive speech pathology assessment.

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KEYWORDS: Speech, Speech Production, Speech Recognition, Speech Synthesis, Speaker Identification, Speaker Verification, Glottal Source, Vocal Tract, Prosody

AF01-066 TITLE: Electromagnetic Field Overexposure Indicator

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: To develop a small, inexpensive portable alarm that will indicate overexposure to electromagnetic fields (3 KHz to 100 GHz).

DESCRIPTION: A personal alarm that has the ability to detect high levels of electromagnetic field exposure (near and far field) is essential for personnel to do their jobs without health hazards in the environments mandated by DoD global operations. Development of a small, inexpensive portable alarm to detect exposure to high intensity electromagnetic fields needs to be completed and brought to market. Currently available detectors/alarms generally cost several hundreds of dollars, making them impractical for mass distribution to military personnel who would wear this product on their clothing or equipment. The alarm should detect magnetic and electrical fields and each field will have separate audible and/or visible indicators. The alarm should be resistant to the extreme environmental conditions found on the battlefield. It is predicted that multiple alarms would be worn (e.g., front, back, or on helmet) to detect the millimeter wave frequencies. Alarm must reliably detect the incident electromagnetic field over a predetermined time period by some method that accounts for or is not affected by the presence of the person wearing the badge. Equipment to verify alarm activation (i.e., "read" the badge's history) needs to be accurate, inexpensive, and portable.

PHASE I: Survey existing electromagnetic field exposure meters and determine the feasibility of developing a small, inexpensive portable alarm. Complete computer modeling or laboratory testing to indicate sensitivity of prototype when electromagnetic field exposures are from the back or front, low around the knees, or high near the head.

PHASE II: Build a small, inexpensive, lightweight alarm that accurately detects exposure to high intensity electromagnetic fields. The alarm would be capable of emitting either an audible or visible signal to indicate overexposure. The alarm would have an internal mechanism to reset the time-averaging component of the alarm. Hardware and software to record the history of the alarm should be easily interfaced with a PC.

PHASE III DUAL USE APPLICATIONS: Individuals working in communication or medical enterprises utilizing high intensity emitters would wear the alarm to prevent accidental overexposures to high intensity electromagnetic fields.

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KEYWORDS: Anatomy/Physiology, Directed and Kinetic Energy, Modeling/Simulation

AF01-067 TITLE: <u>Human Orientation Model for Spatial Disorientation Countermeasures</u>

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a PC-based model of the human that characterizes spatial orientation (SO) in the maneuvering acceleration environment. The application is to aid pilots in situations where SO or situational awareness (SA) can be compromised.

DESCRIPTION: Spatial disorientation mishaps continue to plague the tactical Air Force. There have been over 150 Class A (pilot death and/or $ 1M damage to the aircraft) mishaps in the US Air Force since 1994 (Neubauer, 2000). 82% of these were in the fighter/attack community. The F-16 Viper accounted for 61% of the fighter/attack mishaps and 50% of all SD related mishaps. The current approach to reducing SD related mishaps is to improve cockpit display symbology, to train pilots to recognize and counter SD, and to continue to conduct research on human perception. What is needed is the concurrent development of a model of how the human perceives spatial orientation especially in the maneuvering environment. The difficult problem to solve is there are no physiological measures of SD; there are no objective measures of a pilot who has lost SO or SA. A model was partially developed in the late 1970s that can serve as a baseline for this effort. Borah, Young, and Curry (1988) at MIT developed a Kalman Filter based model of how the human senses motion and forces. The application of this model was for flight simulator development, however, Repperger, et al. (1990) describe a device that could be developed to mimic the linear and angular acceleration sensors of the vestibular system; such a device could report on the acceleration environment the pilot is exposed to but cannot describe how these accelerations are perceived. What is needed is a model that can eventually become a part of the flight control system of the aircraft, which can compare the system state of the aircraft with the perceptual state of the pilot. It will not necessarily assume control of the aircraft but would, for example, let the pilot know when a Type I or Type II SD situation arises. Perhaps a neural net approach could manage these types of occurrences. Since Type I SD (unrecognized) causes the most mishaps, the model would have to predict when the pilot can become distracted, or focus attention on a non-flying task, such as attending to a warning light. This means when a cockpit distraction occurs (light, warning, etc) the model would be alerted to a possible

Type I situation. Type II (recognized) can be modeled more precisely, as it involves the motion senses and is, the most studied.

PHASE I: Existing models for human orientation in space will be evaluated for their relevance to a more universal orientation 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 loss of SA, attention to distraction sources, and verification of linear and rotational accelerations as perceived by the human, 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 loss of SO or SA is considered a casual effect, and (2) an interactive program to predict pilot perception of orientation based on the maneuvering environment and the cognitive demands on the pilot.

PHASE III DUAL USE APPLICATIONS: A model of human orientation in the maneuvering environment may be adaptable to other flying environments, especially since many private and commercial aircraft are also lost each year to loss of SO and SA.
Because spatial disorientation mishaps account for nearly 35% of all private and commercial aircraft accidents, this model has great potential for being transferred to the non-military sector. The model could become an integral part of a warning and or recovery system for both light aircraft and commercial airlines. The FAA would be interested in this model in order to help reduce US airline CFIT or Controlled Flight into Terrain mishaps. Foreign governments and airline industries would also be interested in the model as a product. The model could be integrated with the flight computer in commercial aircraft and since many light, private aircraft are employing more sophisticated flight control systems, the model could be integrated into light, fixed wing aircraft. The model will also have great potential for the US Navy and Army aircraft.

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KEYWORDS: Spatial Orientation, Spatial Disorientation, Situational Awareness, Neural Networks, Human Operator Model, Maneuvering Acceleration, Dynamic Flight Simulation, Performance Measurement, Flying Mishaps, Vertigo, Vestibular System, Haptic System

AF01-068   TITLE: Work-Centered Interface Technology

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Improve the fusion, management, and utilization of information for Command and Control by developing work-centered interface technology.

DESCRIPTION: The ability to collect, integrate, synthesize, manage, and utilize information is critical to the success of military operations. Indeed, in modern warfare, information dominance is considered a critical strategic goal of Air Force operations. An important operational problem is information overload. End-users are provided a plethora of data, data sources, databases, and other information products. The challenge for users is how to extract the relevant critical information from all the “noise”. To help ameliorate this problem, the AFRL seeks innovative proposals to create work-centered interface technology.
A work-centered interface is a stand-alone application incorporating intelligent agents which mediate interactions between the user and the management information systems employed by the user in the course of his or her work. It is easiest to understand the concept by contrasting it with a traditional human-computer interface. A traditional human-computer interface usually has links to one system, while a work-centered interface may be linked to many diverse systems. Consider a user who has to access multiple databases to make a decision. With a traditional system, this requires several steps: The user must log onto the first system, retrieve data, log onto the next system, retrieve data, and then make the decision. In a work-centered interface, the interface serves as “middle-ware” that mediates between the user and the various databases. A menu structure is provided that reflects the tasks performed by the user. When making a decision, the user mouse clicks on

the appropriate menu item and the intelligent agents retrieve, fuse, format, and present all data relevant to the decision. These tasks are performed automatically by the agent application and require only one step or action from the user. In addition, application agents can automatically monitor the management information systems and notify the user when specified patterns of events occur. Such patterns may represent either potential problems or “targets of opportunities” of interest to the user.

The government seeks innovative proposals to develop work-centered interface application software. Such software will consist of a tool kit to develop front plane agents which manage the user’s graphical user interface widgets (i.e., the things the user sees and manipulates), mid-plane agents which embody the business rules of the work domain, and back-plane agents which are capable of interfacing with a variety of types of management information systems and/or command and control (C2) systems. Proposals, that address how coordinated work-centered interfaces can be developed for a whole domain, such as a specific C2 echelon, are of primary interest. The offeror should discuss commercial analogues of Air Force Command and Control situations, such as air freight scheduling/routing and aerial port facility planning, to highlight the dual use potential of this technology.

PHASE I: Develop and document a concept of how to create work-centered application software. The plan should include a concept of operations for the proposed tool, the projected payoff, and a commercialization strategy. In addition, the plan should discuss trade-offs between alternative interface agent architectures and task analytic techniques that can be used to characterize the application domain.

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 productivity of a wide range of commercial and military organizations. Work-centered interfaces have the potential to speed response time, improve decision-making, reduce operator training time, and reduce the number of personnel required to perform specific C2 jobs. Consequently, work-centered interfaces would be useful to most military or commercial command centers, particularly those that operate in information dense, time critical environments.

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KEYWORDS: HUMAN COMPUTER INTERFACE, INTELLIGENT AGENTS, WORK CENTERED DESIGN, COMMAND AND CONTROL

AF01-069 TITLE: Toxicity Evaluation Module

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop software techniques/tools based on artificial intelligence approaches to estimate the potential health risks to humans resulting from exposure to chemical hazards. The module should be able to evaluate a wide spectrum of toxicity endpoints that reflect the potential hazards encountered by DOD personnel in occupational and operational settings.

DESCRIPTION: The US Air Force is a high technology military force. To maintain leadership in military technology, the Air Force conducts research and development on a wide range of technologies and processes with the aim of fielding advanced weapons systems. These weapon systems utilize a diverse spectrum of exotic chemicals and materials to gain battlefield superiority. The health hazards of these materials must be evaluated to protect personnel and to minimize life cycle costs for the weapon systems. In this context, research is needed to develop new techniques and tools for predicting the potential health hazards associated with the incorporation of these chemicals and materials into sophisticated weapons systems. The tools sought under this request should utilize the latest developments in computer science and artificial intelligence to collect and evaluate diverse data sets and make rational decisions about the toxicity of novel chemicals in the face of significant uncertainties. Having formed a consensus decision as to health risks of candidate chemicals based on weight of evidence derived from diverse sources, the product should provide some measure of overall confidence in that decision and express the level of confidence in a meaningful manner. Toxicity endpoints that must be evaluated include: acute lethality, eye and skin irritation, skin sensitization, genotoxicity, developmental/reproductive toxicity, endocrine disruption, neurotoxicity, immunotoxicity, chronic target organ toxicity and carcinogenicity. This module will serve as a key tool in the assessment of chemical toxicity of new chemicals developed by the Air Force.

PHASE I: Phase I will provide a prototype software implementation that will demonstrate feasibility of the methodology for one of the toxicity endpoints listed above.

PHASE II: Phase II will result in a fully functional software prototype that will be used to validate the concept. The product required is a software implementation on high level PCs or work stations that will estimate health hazards over the full spectrum of toxicity endpoints.

PHASE III DUAL USE APPLICATIONS: PHASE III will result in an final integrated software-based tool that rapidly assesses chemical toxicity of novel chemicals in a user-friendly, graphically-based platform. The tool will be computer platform independent and function under diverse operating systems.
Evaluation of chemical hazards of new products is a regulatory requirement for various industries (industrial chemicals, drugs, consumer products) under the auspices of governmental regulatory agencies (the Environmental Protection Agency, the Food and Drug Administration, the Consumer Product Safety Commission). The software product of this SBIR, the Toxicity Assessment Module, will be marketed commercially to industry to provide rapid and reliable estimates of health risks to meet regulatory requirements. This product will be particularly valuable to small corporations that do not have the resources to conduct traditional toxicity testing which is expensive, time consuming and requires the use of live animals.

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KEYWORDS: Human Effectiveness, Toxicology, Health Risks, Chemical Hazards, Artificial Intelligence, Rules Based Decision Processes, High Performance Knowledge Bases

AF01-075 TITLE: <u>Remote Consolidated Data Loading</u>

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Design, develop, and demonstrate an aircraft consolidated data transfer device, wireless data communication link, and remote support system that can upload/download mission planning information, threats, intelligence data, weather, and other user-defined information from a remote centralized operations center to an aircraft.

DESCRIPTION: The contractor shall research, develop, and demonstrate innovative wireless remote data communication and information system technologies that support the overall concepts of a consolidated data loading system. The consolidated data loading system will be able to operate from a centralized operation center, support a remote high-speed high-bandwidth wireless transmission medium, and interface with an on-aircraft data transfer unit capable of remote operation. Research from this effort will play a critical role in the rapid and cost effective development of an operational consolidated data loading system. Commercial-off-the-shelf desktop, workstations, and remote data transfer device technologies will be employed to provide an early prototype system so that integrated information technologies and data management concepts can be evaluated in a realistic operational combat-like environment. Analysis will be performed and the results should provide characterizations, performance data, life-cycle cost information to assess mission benefits, generate designs and implementations, and/or generate Cost of Function and Measure of Effectiveness estimates. The following technical areas are of major concern:Type and size of databases to be transferredWireless data transfer of large blocks of dataData communication mediumCommunication security (COMSEC)Transmission time and latencyOn-aircraft mass memory storageOn-aircraft interfaces with avionics buses and networks.A proof-of-concept demonstration will be accomplished based on a user provided mission profile. The remote consolidated data support system located in the operation center shall be resident and operable on a commercial-off-the-shelf portable laptop or personal computer. This effort will use the Air Force Mission Support System (AFMSS), and/or Special Operations Forces Planning and Rehearsal System (SOFPARS) as the baseline mission planning systems. The consolidated data system will interface with and expand on the capabilities of the AFMSS/SOFPARS planning station to include many functions required for:Digital maps and digitized terrain elevation data (DTED)Mission planning and route replanningThreat, intelligence, imagery and sensor fusion database storageAircraft specialized data (maintenance built-in-test [BIT] reports, aircraft mission ready status, etc).The aircraft platform focus for this effort will be on Air Mobility Command and Special Operations assigned aircraft with research emphasis on global deployment operations and transmission of data from a centralized operation center. For many user mission scenarios, mission success depends on precise navigation, excellent situation awareness, and exact target/drop locations. The Command, Control, Computer, Communications, and Intelligence (C4I) nodes must provide threat/situation awareness information and targeting location/imagery to the operators in a format that is usable and easy to understand. Air Tasking Orders (ATO) usually define the top level mission tasking, and the mission planning system must transform the ATO and C4I information into a combat mission flight plan. Operating aircrews must have the ability to load, and verify loaded mission data via the data transfer system using both a commercially available medium (e.g., 3.5" disk, removal hard drive, PMCIA card etc.), and the newly developed remote consolidated data loader. In the event of an emergency the aircrew must have the ability to zeroize all mission data and COMSEC data with a single action. In addition, this effort must be aware of the Global Air Traffic Management (GATM) System. While the GATM system is not a direct response to C4ISR military requirements, it will implement C3I features which offer improvements to military aircraft positioning, communications, and mission control. The data link and voice communication requirements for GATM are being defined by international, regional, and national civil aviation authorities and are based on use of commercial communication systems. The commercial GATM communication systems will be capable of being used to support some C2 functions in addition to air traffic control. GATM communications in the future will provide data feeds to mission aircraft and could support many of the transmission concepts under this effort.

PHASE I: The desired products of Phase I are 1) identification of the enabling computer processing, remote data communications, and mass memory storage technologies, 2) conduct 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 remote data loading technology and demonstrate the proposed. 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 wireless remote data transfer and loading capability for use in defense and commercial global information technology developments. Significant laptop and desktop computing power is an enabling technology and a change in the way of doing business that will have major implications for the commercial and defense sector. Remote data terminals, data links, and networking technologies are exploding in commercial airline systems. The commercial marketplace is presently making greater use of generic planning tools, global networking infrastructures, and off-the-shelf embedded processing, mass storage and graphical components for applications in commercial aircraft industries, manufacturing, and information systems. The aircraft industries have demonstrated the success of integrated computer planning systems with supporting on-line maintenance systems. Advances in software, networking and computer technology are making remote input terminals possible and affordable for the small to medium business. High-speed data transmission to commercial aircraft remains a problem area. For the DoD user, consolidated and centralized planning of mission requirements, combat rehearsal, and generic planning tools are a future growth area in which desk top mission planning and remote data communication devices will be used to review completeness of mission plans and functionality for fusion of sensor information. DoD alone could modify up to 1000 aircraft with remote data loading devices. In addition, the airlines will have a need for the same remote data loading technologies that will be addressed under this effort.

REFERENCES:

KEYWORDS: Mission Planning, Data Transfer Device, Threat Data, Electronic Combat, Digital Maps, Wireless Data Transfer, Remote Data Loader, Imagery

AF01-078 TITLE: Artificial Intelligence (AI) Toolkit to Support Optimal Communications Network Configurations

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Provide an Artificial Intelligent (AI) interface to a commercial simulation engine to assist with network configuration and operations and make networks in the field easier to configure and operate.

DESCRIPTION: Rapid engineering of networks to process mission critical data is important in both military and commercial applications. Network engineering requires expert knowledge. It is context and environment specific and requires adherence to policies, such as those for security and other conventions. An artificial intelligence (AI) toolkit that interfaces with a commercial simulation engine would speed up this process. This toolkit could rapidly interface with the simulation engine to quickly design or fine tune communications networks without requiring the user to have programming skills or knowledge of the simulation engine. Minimal toolkit requirements are: application and user driven, intuitive and easy to use, include animation for instant visual analysis, provide speech capability, provide a way to create new network components, and come with a database of known devices. The AI toolkit would incorporate expert knowledge of device characteristics, goal oriented optimization and proof of adherence to the stated policies. The system should work with the user to develop network requirements such as projected network usage, end points, equipment, network cost, and network performance. The AI tool would provide an interactive session with the user, asking questions where more information is needed, and making recommendations with each question. Subject to a stated set of local network policies (configuration management, security, allowable services, connectivity, etc.), the AI rules-based tool would then create the optimal configuration based on the requirements. The user would be assumed to have a working knowledge of communications networks.

PHASE I: Design an AI toolkit to interface with commercially available simulation product. Identify goals, features, methodology, algorithms, user interface, and the network protocols/types to be supported.

PHASE II: Implement the AI toolkit for various types of military communications networks (i.e. ATM, ISDN) on a released version of a commercially available simulation product. Provide documentation for the toolkit. Demonstrate the ability to use this tool for exercises and joint communications networks.

PHASE III DUAL USE APPLICATIONS: This toolkit can be extended for use on all types of communications networks. The commercial industry needs a tool that enables them to determine a network design based on network utilization, cost, and performance. The toolkit can be used to compare various types of networks and to fine tune performance on existing networks. Programs which could use this technology: Combat Information Transport System (CITS), Theater Deployable Comm (TDC), Command and Control Information Processing System (C2IPS), and Theater Battle Management Core System (TBMCS).

REFERENCES:
Russel, Stuart J., Norvig, Peter, "Artificial Intelligence: A Modern Approach," Prentiss Hall Series in Artificial Intelligence, 1995

KEYWORDS: Artificial Intelligence (AI), Simulation, Networks

AF01-079 TITLE: <u>Network Common Data Link (CDL)</u>

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a Network Common Data Link (CDL) using an Omni-Directional Antenna for Airborne reception of Broadcast Communications

DESCRIPTION: A number of military aircraft require the capability to communicate the information generated onboard the aircraft to surface forces. In transferring this information, the system must provide for transmission to multiple locations simultaneously, thereby allowing surface forces to generate a situational awareness picture of the events happening around their location. The best technical approach for such a scenario is for the aircraft to transmit the information via an omni-directional broadcast, which implies the use of an omni-directional antenna. When you consider the impact or availability of suitable radio frequencies and the need for such a broadcast to be compliant with the Department of Defense (DoD) Common Data Link Program, use of the Ku-band or higher Ka-band portion of the frequency spectrum becomes a natural choice. The omni-directional antenna, therefore must support the desired operating frequency, be capable of operating on a large aircraft (707 type) at subsonic speeds, in a full duplex mode, while transmitting at high power levels (1000 watts). The antenna also needs to support circular polarization signaling to account for aircraft dynamics and varying antenna look angles between the airborne and surface antennas. Emphasis should be paid to the transmit and receive isolation requirements in development of the antenna system.

PHASE I: Evaluate the various implementation techniques (e.g., meander line polarizers, high temperature superconductive materials, etc) for developing a high power omni-directional antenna capable of operating at Ku-band or Ka-band frequencies. Develop an omni-directional antenna design(s) with low noise amplifier and diplexer capable of being qualified for flight on a 707 type aircraft. Note that small size, low RF conversion losses, circular polarization and low cost are desirable antenna attributes.

PHASE II: Fabricate, test, analyze, evaluate, demo, and document the performance of the prototype omni-directional antenna design(s) developed during Phase 1. The antenna design(s) should include the low noise amplifier and diplexer components associated with a full duplex communication system.

PHASE III DUAL USE APPLICATIONS: Develop a prototype omni-directional antenna with low noise amplifier and diplexer for integration and test with a high power CDL system. This technology can be readily adapted to high capacity data transfer between mobile users.

REFERENCES:

KEYWORDS: Omni-Directional Antenna, Wireless Communications, Wireless Networking, Common Data Link

AF01-080		TITLE: Common Data Access Models and Services

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Explore the feasibility of developing a common data access mechanism for a variety of data requestors.

DESCRIPTION: Multiple custom applications need to share data with each other regardless of the specific format of particular data storage schemata. In addition, the same data has to be made easily available to human consumers via a Web browser or by importing the data easily into an office automation (OA) product. This effort would explore the feasibility of developing a DBMS-independent and schema-independent mechanism that could easily support the data access requirements of shared applications, custom applications, Web pages, and OA products.This effort will also be tightly-coupled with the on-going work under the Joint Battlespace Infosphere (JBI) program. In particular, JBI is looking at procuring objects that are similar in nature to the Extensible Markup Language (XML) data structures that store meta-data in textual form [1]. This method can be used to represent object schemas and actual objects, and could be used as a starting point for this effort. These information objects are not true objects in the sense of object-oriented design and programming, rather they are object schema that defines and abstracts an entity using attributed value-pairs. This includes identity and inheritance, but not encapsulation, methods or polymorphism [1]. Once defined within an environment, or platform, these objects can form new relationships with each other and provide information on an entity or situation that wasn't readily apparent before the objects interacted. Client programs are able to query this cache of objects to discover the existence of an attribute-value that may satisfy their information needs.The objects and their relationships can form a representation of the current military situation. These object relationships are typically stored in a structured common representation (SCR), which describe hierarchical and/or informal relationships. The SCR supports presentation and tailoring of information. It also supports drill down through hierarchies of knowledge, so the user is able to examine evidence supporting presented information.[1][2].The objective of this effort, therefore, is to develop the common representation as "middleware" or "services" that are independent of data sources and that provide a common access for various clients running on multiple platforms. Pure object-oriented modeling and design techniques will be applied, initially, to provide a solid foundation for designing, and ultimately developing, objects that will support a JBI-like capability. The foundation-building effort will focus on analyzing subset schema of well-defined relational databases that serve as repositories for legacy systems, in an effort to understand the information from a systems engineering perspective. Once understood, object models will be designed and interface definition languages developed as a proof of concept. Next, the pure objects will be transformed to JBI-like objects in an effort to make them more usable in the JBI architecture. This transformation will be accomplished in the following phases.

PHASE I: Analyze existing data schema and structures utilized by the Theater Battle Management Cores Systems (TBMCS). Apply object modeling and object oriented principles to produce a logical design of Commander's guidance, apportionment/allocation guidance, common Air Battle Plan representation, and wing-level scheduling relationships. If time permits, apply the same activities to produce a common Combat Air Forces – Mobility Air Forces plan representation to facilitate the exchange of inter theater tanker and airlift assets and incorporation into the Air Battle Planning process. The final output of this design should be an interface definition language to the objects, that clearly identifies public and private variables, as well as "methods" or functions that manipulate those objects. The definition language could be very similar to the one defined for the Common Object Request Broker Architecture (CORBA) produced by the Object Modeling Group (OMG). Methods for using web-based protocols for accessing and generating the object schemas shall also be analyzed to the maximum extent possible.

PHASE II: Take the output from Phase I, and begin to implement the objects as real entities that access data from real repositories. To do this, software development and delivery should adhere to DII/COE standards, and any emerging standards dictated by industry via the JBI program. The object models, themselves, may go through revision at this stage to make them more like attribute-value pairs with methods, as opposed to pure object oriented definitions. This will make the implementation look more like objects that drive XML developments, thus making XML presentations of this data – as demonstrations – necessary.

PHASE III DUAL USE APPLICATIONS: Package or "shrink-wrap" the developed software in Phase II and integrate into existing COTS/GOTS enterprise level software infrastructures. By Phase III, TBMCS may well be employing a fully functional service layer, in which the common data service layer could easily integrate and become part of the substrate. Other applications could be made directly into the JBI program to act as major components or "glue" for the JBI platform. Links to the JBI Repository can be made directly from the developed software, rather than accessing disparate data sources directly.

REFERENCES:
[1] USAF Scientific Advisory Board (SAB), "Report on Building the Joint Battlespace Infosphere," Volume 1: Summary, SAB-TR-99-02, 17 December 1999
[2] USAF Scientific Advisory Board (SAB), "Report on Building the Joint Battlespace Infosphere," Volume 1: Interactive Information Technology, SAB-TR-99-02, 30 November 1999

KEYWORDS: Object Modeling, Distributed Computing, Enterprise Computing

AF01-081 TITLE: Power Aware Computing for AWACS

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop innovative Power Aware Computing applications, algorithms, and approaches to tailor power requirements of emerging Intelligence, Surveillance, Reconnaissance (ISR) platforms, particularly AWACS follow-ons, to dramatically increase the mission flexibility for next generation systems by allowing them to manage their power in the face of changing missions.

DESCRIPTION: Develop innovative power aware techniques in algorithm design, compilation, operating systems, and middleware, capitalizing on emerging technologies in architecture, novel CAD tools development, circuit design, clock gating, dynamic voltage/frequency scaling, etc. Various approaches can be explored, such as algorithm design, energy aware compilation, power aware architecture, energy efficient protocols, energy aware middleware, energy aware CAD tools and their use, and associated benchmarks. Power requirements of emerging ISR platforms, including AWACS follow-ons, are to be tailored to improve their capabilities to meet Air Force needs by increasing power capabilities through power adaptivity, up to three orders of magnitude over existing systems. This will enable the Air Force to add increased capabilities to existing missions, reduce costs, extend mission life, and perform new missions previously not possible due to power constraints.

PHASE I: Perform a feasibility study to define Power Aware Computing applications, algorithms, and approaches to tailor the power requirements of emerging ISR platforms, particularly those of AWACS follow-ons.

PHASE II: Build and test prototype Power Aware Computing applications, algorithms, and approaches for emerging ISR platforms; developed in Phase I, demonstrating their increased power capabilities over existing systems.

PHASE III DUAL USE APPLICATIONS: These computer architectures will be useful for military applications such as airborne and space surveillance, radios, missiles, satellites, and UAVs. Commercial applications include improving wireless and portable applications such as cell phones and Personal Digital Assistant (PDA) webservers, in addition to commercial satellites.

REFERENCES:
Stephan Ohr, "DARPA Funds Power-Aware Architecture Development", EETimes, August 17, 2000

KEYWORDS: Power Aware Computing, Computer Architecture, Algorithm Design, Energy Efficiency

AF01-082 TITLE: Improvement to Geo-Registration

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop algorithms and software tools for Ground Moving Target Indicator (GMTI) multiple-platform Geo-Registration.

DESCRIPTION: GMTI radar provides continuous wide area surveillance coverage of ground moving vehicles. Currently, GMTI platforms include Joint Stars, U2, and ARLM (Air Reconnaissance Low MTI). Planned GMTI platforms sensors include U2-AIP, Discoverer II, Joint Stars – RTIP, and Global Hawk. The ability to perform multiple platform tracking will improve target location, track association and track correlation. The problem is that each sensor platform uses a unique coordinate system for locating targets on the surface of the earth and each platform also has a platform location error. In order to fuse the GMTI detections from multiple GMTI sensors, a common reference point must be used to register the GMTI detections and remove the platform location error. Geo-registration is needed to accurately determine target location by reducing tracking errors from different sensors by, but not limited to, registering detections to RF tags and/or images of fixed sites for example. It is also important to accurately locate GMTI detections from a single platform. Single platform location errors need to be eliminated to provide accurate target location. Approaches and techniques for single-platform geo-registration may include but not limited to using RF Tags (GPS, Unattended Sensor) and Image registration to known fixed sites.

PHASE I: Develop novel approaches for Single and Multi-Platform Geo-Registration. The Phase I effort will conduct the research required to define the technologies needed to implement the desired geo-location techniques and algorithms. The Phase I research will identify the critical technology challenges and define the Phase II approach for developing/demonstrating the geo-location techniques and algorithms in Phase II. Phase I risk reduction experiments will be conducted to demonstrate the feasibility of the proposed Phase II approach.

PHASE II: Develop algorithms and software tools to implement the approach developed in Phase I. The Phase II effort will implement and demonstrate the geo-location technologies for single and multiple platforms. A commercialization plan will be developed.

PHASE III DUAL USE APPLICATIONS: Mature geo-location capabilities will be transitioned to operational systems. The commercialization plan will be executed and a "shrink wrapped" product will be developed. It is anticipated that commercial technologies will be used in the development of this SBIR. The algorithms that are developed could have application to the commercial shipping industry.

REFERENCES:
Kurien, T., “Issues in the Design of Practical Multitarget Tracking Algorithms,” In Multitarget-Multisensor Tracking: Advanced Applications, Y. Bar-Shalom (ed.), Artech House, Norwood, MA, 1990, pp. 43-83

KEYWORDS: GMTI, Geo-Registration, ISR, Platform

AF01-083 TITLE: Demonstrate Track Management Concepts for Exchange of GMTI Track Information

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop and demonstrate track management concepts to support the exchange and management of ground track information among networked military and commercial systems.

DESCRIPTION: Ground Moving Target Indication (GMTI) provides continuous wide area surveillance coverage of ground moving vehicles employing both radar and electro-optical systems. Currently, the military employs several airborne platforms with both electro-optical and radar sensors that will provide GMTI data. The commercial sector employs GMTI systems mostly to monitor traffic flow and patterns throughout many major cities. As part of the effort to extract information from this wealth of data, techniques are being developed to automatically generate and maintain tracks that represent these ground moving vehicles. A track database maintains history and heading information of the ground-moving vehicles allowing for an algorithm to exploit the information to determine items like traffic flow, density, and convoys. To accomplish the necessary resource management, these GMTI tracks must be exchanged and shared among a large number of nodes allowing for hand-off between systems and exploitation at various command nodes.The track management challenge is to develop techniques for the efficient, but non-ambiguous sharing of this GMTI track data among a large number of distributed users. In this distributed and potentially highly dense environment, it is critical to have only one track representing any given vehicle (or group of vehicles). As new information is obtained for a vehicle (or group of vehicles), this information needs to be associated with the track unique to that vehicle (or group of vehicles) and then shared among all interested users. Novel techniques in database management, data fusion and collaborative work environments need to be developed to ensure that only one unique track is generated and maintained for any given detected moving vehicle and that this same track in maintained over the entire life of the track. The generation and maintenance of these GMTI tracks can be accomplished at any of the management nodes that have access to the GMTI sensor data. As these tracking algorithms are evolving, techniques are also being developed to correlate and fuse this GMTI data, and the GMTI Tracks, with other data derived from other GMTI and non-GMTI sensors.

PHASE I: Develop novel approaches for real-time fusing of data from multiple sources in a distributed environment while maintaining the unique association of a fused element with its associated data. These approaches need to be applied to track management in a distributed theater architecture satisfying the unique challenges associated with GMTI tracking and track fusion on ground moving vehicles in realistic environments. The Phase I effort will conduct the research required to define the technologies needed to implement the desired track management techniques and algorithms. The Phase I research will identify the critical technology challenges and define Phase II. Phase I risk reduction experiments/simulations will be conducted to demonstrate the feasibility of the proposed Phase II approach.

PHASE II: Develop algorithms and software tools to implement the approach developed in Phase I. The Phase II effort will implement and demonstrate the track management techniques and algorithms defined in Phase I. A commercialization plan will be developed.

PHASE III DUAL USE APPLICATIONS: Military application of this technology is the exchange and management of ground track information among networked military command and control systems. The technology developed under this program will have application to any commercial activity that shares data generated from multiple sources over a distributed environment. The algorithms that are developed will have application to the commercial shipping industry, financial industry, environmental sensing, commercial aviation, and Intelligent Vehicle Highway Systems (IVHS). Currently, the Web has connected the traffic flow monitoring of major highways in most cities. Smart sensor Web activities have both military and commercial applications to the detection, identification and management of moving ground vehicles.

REFERENCES:

KEYWORDS: Track, GMTI, Radar, Database Management, Distributed Collaborative Environment, Data Fusion

AF01-084 TITLE: <u>FOPEN SAR Enhancements</u>

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Extend FOPEN SAR to detect, track, and identify camouflage, concealment and deception (CC&D) Ground Moving Targets.

DESCRIPTION: Airborne systems that use low frequency energy to map the earth have advantages over high frequency systems typically used in Synthetic Aperture Radar (SAR) imagery systems. These low frequency systems exhibit unique immunity to the challenges of a foliated environment. Targets that use camouflage, concealment and deception (CC&D) techniques by moving in forested areas are detectable with low frequency foliage-penetrating (FOPEN) radar. SAR modes of this radar allow mapping of these target locations and offer additional information about the targets. Using the advantages offered by low frequency, FOPEN-type SAR airborne systems, novel methods and software must be developed to exploit the information from the FOPEN SAR to track and identify CC&D targets. The problem space involves tracking and identifying both moving and stationary targets and should concentrate on techniques and technologies to improve the performance of Airborne FOPEN SAR systems.

PHASE I: In Phase I, various methods and initiatives will be analyzed to enhance detection, tracking, and identification capabilities in FOPEN SAR.

PHASE II: In Phase II, develop the advanced algorithms defined in Phase I. Perform modeling and simulation to prove that Airborne FOPEN SAR systems can feasibly detect, track, and identify ground-moving targets. Evaluate the algorithms developed with real data.

PHASE III DUAL USE APPLICATIONS: The military application is to successfully detect, track, and identify moving and stationary targets in foliage. Civilian applications of this technology include forestry monitoring by environmental services for compliance with logging restrictions as well as forest fire fighting. Counter drug units can use these technologies to monitor drug trafficking in heavily forested regions like South America.

REFERENCES:

KEYWORDS: Radar, FOPEN (Foliage Penetration), SAR (Synthetic Aperture Radar), Track, Identify

AF01-085 TITLE: <u>Exploratory Computer Architectures Which Mix Memory and Processing in Novel Ways</u>

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop computer architectures that mix memory and processing in novel ways to increase computer speed. Research objectives include demonstrating novel designs that hide or eliminate the memory latency, especially on complex, non-deterministic applications.

DESCRIPTION: To increase computer speed, novel architectures that overcome the increasing mismatch between processor performance and memory performance are of particular interest. Heterogeneous architectures and reconfigurable architectures are applicable to AWACS, JSTARS, and future space radars performing the AMTI, GMTI, and SAR applications and also of interest, especially in the area of dynamic databases. A dynamic database is used to search large amounts of unorganized data to obtain necessary information.

PHASE I: Define a computer architecture for an appropriate application, such as those mentioned above, mixing memory and processing in novel ways, such as Processor-in-Memory (PIM), to increase computer speed. Take into account data dependent processing.

PHASE II: Build and test the computer architecture. Take an advanced version of the chosen application and show why this architecture is applicable to the application.

PHASE III DUAL USE APPLICATIONS: These computer architectures will be useful for military applications such as air and space surveillance, using dynamic databases such as Space Time Adaptive Processing (STAP), Synthetic Aperture Radar (SAR), Automatic Target Recognition (ATR), and for Data Fusion and Method of Moments. For commercial applications, these exploratory computer architectures could be used to build a workstation that is more compute efficient because of the distributed manner of the processing as compared to today's hierarchical processor focused systems.

REFERENCES:

1. Mary W. Hall, Peter Kogge, Jeff Koller, Pedro Diniz, Jacqueline Chame, Jeff Draper, Jeff LaCoss, Jay Brockman, William Athas, Apoorv Srivastava, Vincent Freeh, Jaewook Shin and Joonseok Park, "Mapping Irregular Applications to DIVA, a PIM-based Data-Intensive Architecture," In Proceedings of the SuperComputing Conference (SC'99), November, 1999.
2. D Patterson et al. "A case for intelligent DRAM: IRAM", IEEE Micro, April 1997.

KEYWORDS: Computer Architecture, Processor in Memory, Reconfigurable Architecture

AF01-086 TITLE: <u>Dome Lens with Hemispherical Scan Coverage for Milstar Airborne Applications</u>

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Design a defractive dome lens that could be placed on top of a phased array antenna to increase scan capability to support airborne wideband GBS & MILSTAR satellite communications. An array that would normally scan a maximum of 60 degrees could be extended to scan beyond 80 degrees through the use of a lens.

DESCRIPTION: A recent system study conducted by the MITRE Corporation has indicated that antennas on MILSTAR airborne platforms would need to scan over the entire upper hemisphere to provide adequate communications coverage for U.S., Europe and Canada [1]. The analysis was conducted for straight and level flight only, assuming a hypothetical four-satellite MILSTAR constellation. Maintaining communications links with the satellite during aircraft maneuvers would require that the airborne antenna be capable of scanning even below the horizon. A serious deficiency of the phased array antennas that have so far been proposed is that they can provide scan coverage over only a portion of the upper hemisphere - from zenith down to a minimum elevation angle of only 20 to 30 degrees. Scanning down to the horizon with such an array would result in unacceptable penalties in antenna gain due to the reduced projected aperture and also increased impedance mismatch at the higher scan angles. One method that has been proposed for achieving wide angle coverage would be to use two (or more) planar array antennas, one on each side of the aircraft, oriented at an angle, to provide coverage over a portion of the upper hemisphere down to the horizon. However, such a system would be expensive because of the dual array arrangment and, more seriously, would also result in conical " blind zones " towards the front and rear of the aircraft in which no communications with the satellite would be possible. In 1973, the Sperry Rand Corporation (now UNISYS) proposed a new antenna concept [2] which allowed a single phased array antenna to achieve greater than hemispheric scan coverage by refracting the antenna beam through a passive dome shaped lens enclosing the array. The phased array is scanned over a 60 degree cone angle to keep the scan losses to a minimum. The dome lens collects the "near zone" collimated beam from the antenna and then refracts the beam in the desired scan direction acting much like the microwave analog of an optical prism. Appropriate "scan tailoring" of the refractive properties of the dome lens allows the phased array to scan over the entire upper hemisphere and slightly below if necessary. Various versions of the "dome lens" have been built and demonstrated by Sperry for radar applications; these include dome lenses built from ferrite phase shift elements [3] as well as multilayer dielectric domes [4, 5]. The dome lens array concept has also attracted attention both in the U.S. and

Russia since it affords a cost - effective approach to a wide range of radar and communications applications. In the case of the MILSTAR airborne terminal, the lens can also serve as a radome to provide weather protection for the phased array; by coating the outer layer of a suitably shaped lens with a frequency selective surface. The dome lens may also be used for reducing the RCS as well as providing camouflage for the IR signature of the phased array antenna, which can reach a relatively high temperature because of D.C. power dissipation from the solid-state transmitter modules in the array.

PHASE I: Study of the types of materials which would provide the greatest deflection of the RF energy at Ku, Ka and EHF-Bands. Ku and Ka Bands are used both by the DOD and commercial communications. Study of electronically scanned phased arrays and mechanically scanned antennas which could be used under the subject Dome Lens Radome. The study would also address cost and survivability to the airborne environment. Samples of each material would be fabricated and tested.

PHASE II: Develop flyable prototypes of multiple dome lenses that satisfy different frequency requirements. End products could be used for further testing of other government and commercial antennas.

PHASE III DUAL USE APPLICATIONS: Design and assembly of production process for actual high quantity fabrication and processing of radomes for the commercial and DoD market.

REFERENCES:
[1] D.V. Marsicano, R. A. Haberkorn "Specification for Minimum Elevation Angles for LCT Antennas" MITRE TIL 7690 - 94 -1204, D055 - L - 168; 3 May 1994
[2] J.J.Stangel, P. A. Valentino "Phased Array Fed Lens Antenna", U.S.Patent No. 3, 755, 815; 28 August 1973
[3] L.Schwartzman, P.M.Liebman "A Report on the Sperry Dome Radar" Proceedings 1978 Military Microwave Conference, London, England; 25-27 October 1978, pp 167 - 176
[4] P. A .Valentino, C. Rothenberg, J. J. Stangel "Design and Fabrication of Homogeneous Dielectric Lenses for Dome Antennas" Proceedings 1980 International Symposium on Antennas and Propagation, Vol. II, Universite Laval, Quebec, Canada, pp. 580 - 583
[5] P.A. Valentino , D.D. Donelin "Dielectric Dome Lens Experimental Model" Sperry Corp, Great Neck, N.Y., Report No. SG - 4253 - 1212, May 1981; AD # B057751L

KEYWORDS: Radome, Airborne Radome, Hemispherical Scan Coverage, Passive Refractive Radome

AF01-087 TITLE: <u>High Efficiency, Small Volume 44 GHz Transmitters</u>

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a high efficiency, small volume, 30 and 44 GHz transmitters for airborne wideband Global Broadcast Service (GBS) and MILSTAR satellite communications that considers solid state power amplifier (SSPA) solutions or Traveling Wave Tube Amplifiers (TWTA).

DESCRIPTION: Small efficient power amplifiers are needed for the transmission of 30 and 44 GHz frequencies to geostationary satellites.For SATCOM, the near term is governed by the schedule for Electronic Systems Command's (ESC) Airborne Wideband Terminal (AWT). The intent of the AWT program is to develop a wideband terminal that will provide a variety of services that will initially include Milstar Medium Data Rate (MDR) (44/20 GHz), Global Broadcast Service (GBS) receive (20 GHz), and 2-way Ka-band (30/20 GHz) communications capability. Other potential services include X-band and commercial Ka-band communications. AWT is slated for Engineering Manufacturing Development (EMD) in the 2002/2003 timeframe. Technology needs to be in place to support low risk development for the EMD effort. One possible approach would be to develop a novel, low cost method for combining an SSPA and TWTA for power levels greater than 80 Watts. An important goal is to develop an amplifier that could be placed external to the aircraft, with the antenna under the radome. The design concept of the amplifier needs to be flyable, in the sense that the end goal of the Phase III effort will be an amplifier that will meet commercial aircraft safety and performance requirements.

PHASE I: Study of the design of EHF-Band power amplifiers, which would be small enough to place under an antenna radome on the outside of an aircraft. This study would address RF power efficiency, > 20 watt RF output power at 44 GHz, and size < 50 cubic inches.

PHASE II: Design, fabricate, and test a 44 GHz RF power amplifier to meet the Phase I requirements. This design and test will be done with an end goal of producing an amplifier that will meet commercial aircraft standards.

PHASE III DUAL USE APPLICATIONS: Design and assembly of production process for actual high quantity fabrication and processing of high power RF amplifiers to meet airborne installation requirements, for the commercial and DoD market.

REFERENCES:

AFRL Technical Report: AFRL-IF-RS-TR-1999-70, "High Efficiency 44 GHz SSPA", Contract #F30602-95-C-0037, Contractor: TRW

KEYWORDS: EHF RF Power Amplifier, Ka-Band RF Power Amplifier, Airborne EHF/Ka RF Power Amplifier

AF01-088 TITLE: Low Cost, Low Volume Up Converter/Down Converter for Airborne Wideband SATCOM

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a low cost, low volume, up converter/down converter for Global Broadcast Service (GBS) and MILSTAR receive as well as MILSTAR transmit for airborne platform wideband GBS and MILSTAR satellite communications.

DESCRIPTION: Develop low cost, low volume, components for a hopping local oscillator (LO) up conversion to 43.5-45.5 GHz for transmit and a tunable down conversion from 20.2-21.2 GHz for receive.

PHASE I: The 20/44 GHz RF Milstar and GBS technology currently available is inadequate for airborne applications. Airborne antenna development work to date in the areas of phased arrays and Luneburg lenses for exterior aircraft mounting require extremely robust and small RF conversion components that must be collocated with the antenna. For example, in the Luneburg lens system currently under test, these components should optimally be placed under the low-profile radome of the antenna. The transition of the present 20/44 GHz RF up and down conversion functionality to a form which meets these space and robustness requirements will demand significant R&D in areas such as miniaturization of the frequency-agile LO sources and combination of stages to allow for direct baseband-to-RF conversion, for example. The goal of the Phase I design effort will be to identify and design the best technical approach to meet these requirements. Study of the design of 20/44 GHz, RF down/up converter, which would be small enough to place under an antenna radome on the outside of an aircraft. This study would address a MILSTAR type converter, at 44 GHz, and size. This design will be done with an end goal of producing a flyable RF converter that will meet commercial aircraft standards. Note, equipment installed on the president's executive fleet must meet commercial standards, unlike military aircraft.

PHASE II: Design, fabricate, and test a 44/20 GHz RF converter to meet the Phase I requirements. This design and test will be done with an end goal of producing a flyable up/down that will meet commercial aircraft standards.

PHASE III DUAL USE APPLICATIONS: Design and assembly of production process for actual high quantity fabrication and processing of an RF up/down converter to meet airborne installation requirements for the commercial and DoD market.

REFERENCES:

KEYWORDS: Airborne SATCOM Electronics, Airborne RF Up/Down Converters, 20 GHz RF Down Converter, 44 GHz RF Up Converter

AF01-089 TITLE: Agent-Based Algorithms to Search Multiple Databases for Spatial and Temporal Information

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop and demonstrate the feasibility of agent-based algorithms to search multiple databases for spatially and temporally related information, with a focus towards correlation and fusion of real time and near real time Ground Moving Target Indicator (GMTI) and Intelligence data.

DESCRIPTION: The current and expected capabilities in satellite imaging systems, airborne sensors, and ground-based systems, coupled with the continued growth in network and computing power, permit an operator to access unprecedented detail about a battlespace. To effectively exploit this information requires a set of decision support tools that are designed to exploit computational and networking power to support effective action within a complex and rapidly changing information environment. For example, consider the situation of an operator who must make decisions based on information that is gathered using several different resources and from a complex network of information and data sources. These decisions require the operator to search for relevant information and then mentally combine the relevant information to produce an instantaneous overall mental model of the current situation. In forming this mental model, subtle yet critical aspects of the information space may be missed, leading to incorrect decisions and a loss of information superiority. Therefore, one of the greatest challenges faced by an operator is assessing a situation in a complex information space and determining where to focus attention. As the volume of available data increases, operator information overload inevitably results. This basic problem of information overload cannot be adequately addressed solely through development of a better interface. Instead, a comprehensive approach to exploiting emerging intelligent agent technologies is required to significantly improve information timeliness, completeness, precision and to mitigate the effects of task and data overload.Intelligent agent technologies are based on software that is autonomous, adaptive, and cooperative. Technologies include mobile code, genetic algorithms, neural networks, and other machine learning and pattern recognition techniques. To satisfy the objectives of this topic, the intelligent agents must search static and real-time information sources, discover all relevant and available information, and correlate/fuse search products into a timely information product that is relevant to the tasks at hand and facilitates information understanding. This will require software that is adaptive to the needs of operators and can adjust to a changing network environment. Existing software tools do not provide the required flexibility. Operators must know the location of all data in advance and use brittle query languages to obtain it.

PHASE I: The Phase I effort will conduct the research required to define the technologies needed to implement the desired intelligent agents. The primary technologies include the following: learning based information presentation, knowledge discovery and acquisition techniques; design and development of intelligent associate systems, intelligent agents, information fusion algorithms, and multi-agent software architectures. The Phase I research will identify the critical technology challenges and define the Phase II approach for developing/demonstrating the intelligent agents in Phase II. 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 intelligent agent technologies for database search and information. A commercialization plan will be developed and commercial and other government partners will be identified. Potential partners include the Joint STARS SPO and geographic information system vendors, and government agencies responsible for traffic planning and management.PHASE III: Mature, agent based capabilities will be transitioned to operational systems. The commercialization plan will be executed and a "shrink wrapped" product will be developed.

PHASE III DUAL USE APPLICATIONS: Intelligent agent technologies for knowledge discovery, retrieval, fusion, and presentation have extensive applications in the personal and corporate exploitation of the world-wide web, audio, video, imagery, and text correlation, and law enforcement and financial service markets.

REFERENCES:

KEYWORDS: Software Agents, Spatial, Temporal, Retrieval, GMTI

AF01-090 TITLE: <u>3-D Display of Time Critical Targets on Joint STARS Operator Workstation</u>

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop concepts for the three dimensional (3-D) visualization and exploitation of large amounts of rapidly changing data. Apply the concepts developed to the ground moving vehicle situation awareness of the battlefield and ground moving time critical targets problems.

DESCRIPTION: GMTI (Ground Moving Target Indicator) radar provides continuous wide area surveillance coverage of ground moving vehicles. Thousands of vehicles can be detected and tracked with each sweep of the radar. Visualization techniques need to be developed to reduce the operator’s workload for performing GMTI system functions, such as Moving Target Exploitation (MTE). Current MTE tools provide traffic flow analysis, sources and sinks of GMTI, tripwire events and formation recognition in a two-dimensional display. The optimization of the information presented and how the information is presented to the user is key to this research. When looking at thousands to detections changing every 30 seconds over many square miles, it is not sufficient to just display the data in 3-D but determine what is the best utilization of 3-D to present the operator a clear understanding of the ground environment. The visualization includes looking at real-time data to looking at data over days, weeks and even months to extract information about changes in traffic patterns and behavior. Looking at GMTI data over time and looking for changes in traffic patterns can also extract information that is not currently exploited. 3-D visualization of GMTI data over time could provide important information of the enemy’s intent that is not currently exploited.

PHASE I: Investigate novel ways to visualize large amounts of data that is changing every 30 seconds or less. Investigate novel 3-D visualization techniques that can help the understanding of ground moving vehicles in a battlefield environment. The Phase I effort will conduct the research required to define the technologies needed to implement the desired 3-D visualization techniques and algorithms. The Phase I research will identify the critical technology challenges and define the Phase II approach for developing/demonstrating the 3-D visualization techniques and algorithms in Phase II. Phase I risk reduction experiments will be conducted to demonstrate the feasibility of the proposed Phase II approach.

PHASE II: Develop algorithms and software tools to implement the approach developed in Phase I. The Phase II effort will implement and demonstrate the 3-D of GMTI detections and tracks. A commercialization plan will be developed.

PHASE III DUAL USE APPLICATIONS: The military application is the increased understanding of the ground moving targets in the battlefield. The algorithms and visual techniques that are developed have applications to any commercial industry that evaluates large amounts of data from real-time to historical data to determine the current state of the environment, analyze trends and forecast the future. Applications include financial forecasting, traffic analysis in major cities, medical diagnostics, and weather forecasting.

REFERENCES:

KEYWORDS: GMTI, 3-D Visualization, JSTARS, ForecastingTrend Analysis

AF01-091 TITLE: Situation Awareness Information Fusion

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop and demonstrate interoperable situational awareness using multiple human machine interface modalities capable of fusing information into a consistent operational picture.

DESCRIPTION: New fighter/bomber aircrews encounter ever-increasing amounts and types of real-time information from both on-board and off-board information sources. The increasing number of off-board platforms providing situation awareness information on hundreds of different tracks/object complicates the problem. These growing demands place undue information processing requirements on the aircrew that can lead to spatial disorientation, loss of situational awareness, and cognitive overload during emergency or transient conditions. These potentially dangerous conditions underscore the need to supply operators with manageable amounts of high quality information. One method for accomplishing this goal is to address the requirement of providing a single situational awareness picture to the crew. This requires the development of the capability to fuse information in order to provide an integrated situation awareness picture to the crew. Recent advances in the areas of sensor fusion and display technology can be synergistically exploited to develop novel human-machine interfaces and control systems to reduce confusion on the part of aircrews of the future. The ability to incorporate large amounts of electronic flight information into control stations that can be managed with great ease and minimal training has the potential of revolutionizing the general aviation world. Safe and effective control has implications in other control room and control station scenarios including the operating room of a hospital, building management & safety, power plants, ambulances and the interactive workplace of the future. Information rich environments require a user-centered approach that adapts to heterogeneous changing connections of information sources and devices with multiple modalities. These multi-modal environments must possess the capability of being interoperable. Such environments may include such modalities as: gesture/speech recognition, eye gaze, lip reading and even biofeedback mechanisms attached to the crewmembers themselves.Traditional analog instruments and gauges would be replaced with large flat-panel multi-function displays that combine the functions of separate instruments into a multifunction workstation. A new digital cockpit would provide pilots and operators with equipment that is more intuitive, easier to use, and less expensive than avionics equipment is today. Much of this new technology could take maximum advantage of existing Commercial Off The Shelf (COTS) thus lowering the expense of development and making the resulting product more commercializable. Current Human Machine Interfaces (HMIs) are often the bottleneck in effectively and efficiently utilizing the available information flow. This is increasingly true with the advancements in processing speeds and throughput. The keyboard/mouse approach, though popular, can restrict information flow between the user and the computer system, and ultimately to the aircraft or plant under control. The integration of multi-modal inputs for human machine interaction can be approached from the viewpoint of multiple information source fusion. Different information sources can be related to different interface modalities. Selection of the appropriate modalities to integrate and at what level to integrate them is part of the process of developing an interoperable multidisciplinary situational awareness fusion system. Cross discipline applications include 3D displays for biologists, chemists, and other scientists, the virtual operating room, military simulation control, commercial aircraft, air traffic control, nuclear power plants, and life support and search and rescue management.This initiative will develop and demonstrate a real-time data fusion architecture with appropriate models and techniques, merging data from multiple sources, such as Link-16, intelligence data links and on-board sensors to form a single common situational awareness picture. It will involve combining knowledge of the application domain with the ability to express application specific actions, objectives, and qualifiers to improve the ability to conceptualize and visualize information. Improved conceptualization and visualization will add benefit by supporting collaborative decision making and the ability to continuously monitor and update present and future observation space (e.g. battlespace awareness). The focus will be on the development of a data fusion architecture within the context of an improved operator machine interface environment.

PHASE I: Develop a generalized architecture with appropriate models and techniques for situational awareness information fusion.

PHASE II: Apply the generalized model to specific aircraft and mission environments and analyze information fusion effectiveness.

PHASE III DUAL USE APPLICATIONS: Apply this architecture, model, and software to other large scale commercial aviation, medical, power systems, manufacturing, and operations research problems.

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KEYWORDS: Global Awareness, Situation Awareness, Situation Assessment, Information Fusion

AF01-092 TITLE: Estimation of Manufacturing Cost and Risks for Satellite Electro-Optical Sensors

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Development of improved computer code to estimate manufacturing costs and risks for satellite electro-optical sensors.

DESCRIPTION: In the last eight years, major progress has been made in understanding how manufacturing cost and cost risk arise in complex mechanical systems. A rigorous mathematical theory, Complexity Theory, has been developed [1]. It shows how the cost and risk of a mechanical part and an assembly of interconnected parts increases as the bits of information needed to describe the part and assembly increase. The theory has been tested on some 200 mechanical parts, and has been found to be as accurate as older, empirical, methods [2]. The theory offers three major advantages: 1) The cost estimating calculations are two orders of magnitude faster than traditional methods, and fewer coefficients are used; 2) The theory gives explicit estimates of the additional costs due to tighter tolerances - an important issue with high quality optical systems; 3) The theory gives explicit rules for calculating the probability distribution of cost, i.e., its risk. In the case of satellite electro-optical sensors, traditional cost data is not available in the format needed by the new theory. In order to realize the above benefits, innovative approaches are needed to remedy this difficulty. The objective of this project is to develop software to provide the necessary data format (and required Complexity Theory interface/modification) to allow timely electro-optical sensor system cost determination. In Complexity Theory, the bits of information are calculated as logarithms (base 2) of dimension/tolerance. A complete manufacturing description of a part consists of all its dimensions and tolerances, and all the processes used to fabricate and assemble it. The average value of the fabrication cost of a part made by a single manufacturing process is a coefficient times the part’s complexity (the sum of all the bits of information) plus raw material costs. To determine these coefficients, one needs several sets of similar parts, and their manufacturing processes (available from SMC/SBIRS Project Office, Los Angeles AFB). Prototype software incorporating these features has been previously developed for a radar system (under USAF funding). In that case, a commercial CAD system was linked to a commercial cost estimating shell. The time to retrieve a cost estimate for a precision machined part with several hundred dimensions was about one minute.

PHASE I: Collect manufacturing and design data for a set of AFSMC electro-optical sensors. Use this data to estimate the manufacturing cost coefficients. The main deliverable from Phase I is a prototype computer code that estimates nominal manufacturing costs for satellite electro-optical sensors.

PHASE II: A similar process will be used for a much larger sample of designs to determine the probability distribution for the cost coefficients. With this data, cost risk estimation for electro-optical sensors will be incorporated into the computer code and representative risks analyzed. The prototype software will be formally regression tested, brought under configuration control, and documented.

PHASE III DUAL USE APPLICATIONS: There are many dual use applications of this electro-optical system manufacturing cost software. Some include military and commercial space applications, others involve optical designs for non space use.

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KEYWORDS: Manufacturing Cost Estimation, Cost Risk Assessments, Satellite Electro-Optical Sensor System, Complexity Theory, Probability Distribution, Average Value of Fabrication Cost

AF01-093 TITLE: Spectral Filtering

TECHNOLOGY AREAS: Information Systems Technology

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 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 with the following specifications:Technology: 0.25 um CMOS (complimentary metal-oxide semiconductor) technology ASIC (application specific integrated circuit) chip;Points: 256 pointsVolt: 2.5 voltsPower Consumption: 100 mwBandwidth: 50 MHz bandwidthPrecision: 20 bit complex precision Clock: 50 MHz clock Interface: 16 bit A/D (analog-to-digital) interface, 5 Giga Operation Per Second (GOPS)

PHASE I: 1) Investigate technologies applicable to the design of a low power, low cost, small size FFT/IFFT meeting the requirements above. 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 agreed performance parameters. 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 production prototype FFT/IFFT capable of demonstrating all key performance features. 3) Conduct demonstrations to mutually agreed performance parameters to measure/verify FFT/IFFT performance. Provide final FFT/IFFT cost/power analysis.

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

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[3] R. J. Risk, "Efficient Hard-Wired Digital Fast-Fourier-Transform Processor," Electronics Letters, vol. 13, no. 16, p. 458-9, 4 August 1977, UK

KEYWORDS: Fast Fourier Transform, Spectral Analysis, Hardware Implementation, Adaptive Filters, Narrowband Jamming Waveforms, GPS Receiver, CMOS, ASIC

AF01-094 TITLE: A Software Cost Model Based on Software Architecture

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop an improved computer model to estimate software costs based on software architecture.

DESCRIPTION: Accurate cost estimation of new software can be very challenging. A measure of this difficulty is cost growth during development. According to the lore, the cost for a new satellite bus can be expected to grow 20% during design and development; the corresponding cost growth for the software orbiting in the same bus is expected to be 100%. Traditionally, industry has used estimated Source Lines of Code (SLOCs) as a basis for cost estimation while acknowledging that SLOC count is significantly dependent on the specific High Order Language (HOL) chosen. Research [1] has shown that there is a rigorous mathematical basis for measuring software by counting function points. While function Point theory [2] removes much of the dependence on HOL, it still cannot be fully implemented for two reasons. First, one needs a mathematically complete architectural diagram of what the software does. Reference [3] describes how one may construct such CAD drawings displaying all the mappings arising in a software application. Second, the effectiveness of various software engineering tools for management of databases, or for constructing input/output screens, has not yet been formally evaluated in the context of Function Point theory. In traditional function point methodology, tool effectiveness is lumped into a language factor, i.e., a “fifth level language.” It is now understood that a more rigorous and detailed effectiveness assessment method is needed. The rules for measuring tool effectiveness for a given language are defined by the mathematics [1]. The result is a set of coefficients relating the complexity of the various parts of a software application to the SLOC of each part. To study the application of this theory, actual case data are used to estimate these coefficients. Innovative approaches are sought to validate this new theory and to overcome traditional function point limitations. If the theory were validated, and if these new ideas were implemented, one should then be able to design the architecture of a new software application to minimize its complexity (and cost), and hence to achieve a greater chance of successful development.

PHASE I: The contractor will develop/build/deliver, prototype software to interface with commercial CAD software to automate the software architectural description process. Prototype software to post - process architectural descriptions to produce function point counts will also be written. Working with the SBIRS Low Program Office, the contractor will define the architecture/formal function point estimates for 5-8 Computer Software Configuration Items (CSCIs). Coefficient estimation will be based on the most complex part of each application.

PHASE II: Using the results of Phase I: 1) analyze the architecture of each chosen architecture; 2) identify/complete any obvious redesigns to simplify the application; and 3) identify/develop Automatic Code generating Tools (ACTs) that offer significant cost savings.

PHASE III DUAL USE APPLICATIONS: A graphic software development tool will be developed that will facilitate construction of graphic displays for new applications. This tool will develop code to calculate the complexity of a new application. These tools will assist the rapid design of low cost software in both military and civil software.

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KEYWORDS: Software Cost Estimation, Software Architecture, Computer Modeling, Source Lines of Code (SLOC), Software Engineering Tools, High Order Language (HOL), Function Point Theory (FPT)

AF01-097 TITLE: Voice Authentication

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop voice authentication algorithms for Personal Communication Systems (PCS). Demonstrate that logic chips based on commercial ASICS/FPGAs can implement in-terminal, local voice authentication algorithms.

DESCRIPTION: Current consumer products have implemented voice recognition with various degrees of success. Many voice mail systems provide voice recognition and other voice activated features. All of these systems perform the voice recognition on commercial computing platforms. The actual voice processing is accomplished with software hosted on commercial computers. A vast installed base of commercial voice processing software assures well-exercised algorithms and proven implementations. This same installed base assures user acceptance and optimization of the human /machine interface. However, local voice recognition processing at the remote location offers many advantages over central processing if the cost of hardware at the remote terminal can be brought down and if the performance of the voice authentication algorithm remains the same. Current results indicate a significant drop in performance of current voice authentication algorithms on decoded PCS audio signals. Local voice processing frees up valuable bandwidth on the over-air channels. It provides security since the terminal is available only to authorized users. Further, the time to send the clear text information is saved. Additionally, other users can not use lost or compromised terminals.

PHASE I: Evaluate/Design voice authentication algorithm using PCS decoded audio signals. Design algorithms for implementation into logic chip(s) using ASIC (Application Specific Integrated Circuits) or FPGA (Field Programmable Gate Arrays).

PHASE II: Develop software, fabricate the chips, and build prototype demonstration unit. Scale hardware to time and cost constraints. Analyze a full-scale model using the designed device. Compare size, weight, power, reliability, and other appropriate parameters with traditional approach.

PHASE III DUAL USE APPLICATIONS: The commercial viability of voice recognition has already been demonstrated. It is not widely used or accepted because of the cost. It is expensive because it requires processing on a general-purpose computer. With purpose-built hardware the price will drop substantially. It can be used in both DoD and commercial cell phones and in wire line phones, as well as in new applications. It can be used as voice locks for automobiles, both for doors and ignition. It can be used for ATM authentication instead of PIN numbers. With voice stress analysis, it can be used to determine if an "in use" ATM is being held up. It can be used for general access control.

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KEYWORDS: Voice Recognition, Voice Processing Software, Remote Terminal Processing, Central Processing, Authorized Users, Purpose-Built Logic Chip

AF01-098 TITLE: On-Board Reconfigurable Computing for Spaceborne Systems

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: To extend computing capability and enhance computing efficiency and flexibility for Spaceborne Systems.

DESCRIPTION: In adaptive or reconfigurable computing the processors, often FPGAs (Field Programmable Gate Arrays) can be reconfigured to be more efficient and to provide higher performance than traditional processors, as the environment changes, mission requirements evolve, and algorithms are enhanced. 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 aerospace application of RCs. Mapping algorithms onto fine-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 FPGA designer. Also, the existing RC programming and design tools are not seamlessly integrated into one design environment. Effective debug environments, which have the potential to significantly reduce design cycles, are not yet available for RCs. High level language and visual programming design for reconfigurable computing are needed to ease the transition of this technology. In addition, fault tolerance, especially important in the space environment, must be addressed by (not only radiation hardening) but also by a combination of a software-based approach and reconfiguration to bypass faults. Tools in all of these areas will make the adaptive/reconfigurable computing capability more accessible to a broad group of users, including scientists, engineers, and computer scientists. Industrial grade, radiation hardened, RC hardware for commercial and military aerospace equipment is not available. This topic is soliciting research and development of commercial products that will remove the barriers to widespread use of RC in both commercial and military aerospace systems which require signal processing equipment.

PHASE I: Develop a program concept as related to the topic description and perform technology feasibility demonstrations. Develop a high-level plan and preliminary design 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 aerospace application.

PHASE III DUAL USE APPLICATIONS: Advances/enhancements to reconfigurable computing technology coupled with advanced sensor technology has application in improved (military/commercial) satellite orbit stability, reconnaissance accuracy, communications reliability (military/commercial) facilities security systems, aircraft navigation/landing systems, missile launch/targeting, etc.. This effort could directly impact MILSATCOM.

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KEYWORDS: Device Level Code, Adaptive Computing, FPGA, Reconfigurable Computing, High Level Language, Fault Tolerance

AF01-099 TITLE: MEMS for Space Communication Systems

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop/apply MEMS-based RF switches, filters, oscillators and related components to new generation space communications systems.

DESCRIPTION: The advent of Microelectromechanical Systems (MEMS) has introduced new paradigms for microinstruments and microsystems. These new devices are complete micro-scale mechanical devices that can be produced by the silicon microprocessing infrastructure and can be integrated with various electronics to form sensors, actuators, resonators, filters, RF switches, tunable oscillators, and other kinds of components. One such component, MEMS-based RF switches, offer very low insertion loss, immunity to radiation damage that effects semiconductor switches, and attractive methods for mass production. The purpose of this project is to demonstrate how MEMS RF switches and other MEMS components can be innovatively integrated into a low frequency radio for space communications.

PHASE I: Demonstrate MEMS RF switches in a low frequency transmit/receive radio compatible with switch frequency requirements/capabilities. Demonstrate how such switches and other MEMS components can be readily integrated in a future-concept space radio, and made amenable to low cost replicate production. A fully functional brassboard demonstration is acceptable.

PHASE II: Carry forward the technology elements of Phase I to a truly integrated space based transmit/receive radio subsystem, and apply the MEMS elements in multiple capacities. Demonstrate a fully functional prototype. Develop plans for space qualification/validation of space operations, including possible exposure to enhanced radiation environments.

PHASE III DUAL USE APPLICATIONS: Radiation resistant communications system components are of great commercial interest, especially if they can be achieved at an affordable cost. MEMS-based components offer inherent radiation resistance and producibility (through the silicon microprocessing infrustructure) for use on commercial (and military) communication satellites. In addition, the enabling characteristics of MEMS and Microtechnology meet the needs for highly integrated/low cost/low power communications payloads in commercial (and military) micro/nano-satellite applications.

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KEYWORDS: MEMS, Space Communication Systems, RF Switches, Filters, Oscillators, Micro/Nano-Satellites

AF01-100 TITLE: Analog Arrays for Improved Spacecraft Telemetry and Data Acquisition

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Identify and develop a Field Programmable Analog Array (FPAA) for use in space.

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 orbits with high radiation environments. Radiation-hardened analog component types, in many instances, cannot be found. Instead, in many cases commercially produced components are screened on a lot by 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 for a universal 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 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 would have several analog components which can be internally connected together (or simply not used, as the application dictates), after most or all circuit fabrication steps have been completed. Some components in the module may have user-selectable options (such as gain). These resulting circuits are not necessarily 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. It is expected that the number of modules per array will be small, and the number of module types few. The user configuration may be volatile, non-volatile, or mixed. This effort will also create a design environment which allows the user to contrive the program-specific circuit within the array, accurately model its performance, and facilitate programming of the array.

PHASE I: Investigate and provide a design analysis for a Field Programmable Analog Array as described above. Provide a final design for a potential Phase II hardware implementation of the proposed Phase I design. The chosen design must be qualified for operation in the space environment, for both low Earth and geosynchronous orbit conditions.

PHASE II: Develop space-qualifiable hardware for the Phase I design for testing and validation in a simulated operational environment. Provide a terrestrial verification demonstration of the hardware with delivery to the Air Force for a possible flight on a Space Test Program satellite.

PHASE III DUAL USE APPLICATIONS: A rad-hard programmable analog array device, as described above, would benefit all types of satellite users including the Department of Defense, NASA, National Oceanographic and Atmospheric Administration, and the National Reconnaissance Office. This technology could also support the growing number of commercial satellite systems scheduled to be launched in the near future, especially the low Earth orbit constellations for wireless communications systems.

REFERENCES:

KEYWORDS: Rad-Hard Devices, Analog Components, Space-Qualified, Satellite Electronics

AF01-101 TITLE: Associative Retrieval for Sensor Data Exploitation

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop the concepts and techniques needed to demonstrate feasibility of an adaptive associative retrieval device.

DESCRIPTION: The Air Force requires enhanced methods and techniques to conduct high-speed sensor data recording while simultaneously processing these signals to accomplish unwanted signal filtering, signal-of-interest search, change detection, pattern matching and correlation functions. The adaptive feature will automatically adjust the associative retrieval device to search and identify patterns of interest. Large IMINT and ELINT databases will be searched using content-based techniques to identify relevant information in a timely fashion. Change detection techniques will be used to transmit only relevant information to the commander, thus reducing ISR communication bandwidth limitations. The operational payoff is to shorten sensor exploitation and dissemination times and improve warfighter decision-making. This device would reduce the amount of raw sensor data a C2 facility must process while insuring the commander has relevant battlespace awareness. Important technologies requiring investigation include: Processor/memory arrays, page oriented memories, dynamically programmable gate arrays (DPGA), field programmable gate arrays (FPGA), application specific integrated circuits (ASIC), digital signal processors (DSP), genetic algorithms, wavelet analysis, feature vectors analysis and neural networks.

PHASE I: Develop an overall system architecture and identify necessary sensor processing algorithms.

PHASE II: Implement and deliver a prototype device that performs pattern-matching operations on an unclassified, pre-assembled set of sensor data.

PHASE III DUAL USE APPLICATIONS: This device will prove useful for searching through relational data base systems to handle ad-hoc queries or as a tool for data-mining applications.

REFERENCES:
[1] WTEC Panel Report on the Future of Data Storage Technologies, S.C Esener, M.H. Kryder, dated Jun 99
[2] AFRL-IF-RS-TR-1999-117 Final Technical Report, Assessment of 2-Photon Optical Storage Potentials for the Years 2000-2010, Jun 99

KEYWORDS: Associative Retrieval, Content-Based Access, Pattern-Matching

AF01-102　　TITLE: Verification Technology for Integrated Operational/System C2 Architectures

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop information technologies to reduce the cost of verification of integrated operational and system architectures for command and control

DESCRIPTION: The contractor shall research, develop and demonstrate innovative information technologies supporting the specification, analysis, and verification of integrated operational and system architectures for command and control and other advanced information and communications systems. The contractor should consider technologies such as colored petrie nets, unified modeling language, or similar approaches for specifying architectures.   The developed methodologies should provide the user with key specification and verification capabilities, such as declaring rules to specify the operational and system architectures of a project; using architecture rules to generate project specific architecture palettes and employ them in a graphical editor; validating architecture models using architecture rules; storing and retrieving validated architecture models using a formal database schema such as the Command and Control Core Architecture Data Model (CADM); and displaying retrieved architecture models. The purpose of the architecture rules is to define building blocks and how they can be connected to make systems , defining entity types, architecture levels, association and containment relationships between architecture building blocks, and generating an integrated operational/system architecture. Rules should be stored in a formal database with database schema.   Proposed methodologies must be capable of executing on commercial-off-the-shelf desktops or workstations and be platform independent to support a substantial number of users. Graphical output should comply with industry or international standards such as HTML, VRML, and graphics metafile images . 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 verification system architecture should be open to support interfaces to other engineering and network simulation and modeling tools.

PHASE I: Phase I activity shall include: 1) specification of an innovative information systems architecture modeling methodology and rule based approach to specify and verify integrated operational and system architectures, 2) developing a verification tool system architecture and design concept, and 3) proof of concept demonstration.

PHASE II: The contractor shall accomplish a detailed design, develop, and demonstrate the system for command and control and advanced information systems applications. 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 architecture verification tool for use in defense and commercial automated information system development applications and discrete manufacturing applications.

REFERENCES:

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2. Jensen, Kurt, "Introduction to Coloured Petrie Nets," University of Aarhus, Denmark, http://www.daimi.au.dk/CPnets/intro/
3. Jensen, Kurt, "Coloured Petri Nets. Basic Concepts, Analysis Methods and Practical Use" 3 Volume set, Monographs in Theoretical Computer Science, Springer-Verlag, 1997.
4. Unified Modeling Language, http://www.rational.com/uml/index.jsp5. "Command, Control, Commmunications, Computer Intelligence Surveillance Reconnaisance (C4ISR) Core Architecture Data Model Version 2.0", http://www.c3i.osd.mil/org/cio/i3/AWG_Digital_Library/

KEYWORDS: Modeling and Simulation, Verification, Process Models, Product Models, Command and Control, System Architecture, Colored Petrie Nets

AF01-105 TITLE: Enabling Affordability in Science and Technology

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop and demonstrate affordability and cost estimation technologies and methodologies that support evaluations of the financial return on the Air Force science and technology investment.

DESCRIPTION: The contractor shall research, develop, and demonstrate innovative affordability and cost estimation technologies and methodologies that support the AFRL goal to make affordability an integral part of the laboratory technology development process. Proposed affordability and cost modeling shall be consistent with the AFRL Integrated Product and Process Development (IPPD) tenets and the approaches under development by the AFRL Affordability Council. Special emphasis shall be placed on return on investment methodologies for new technologies and the impact on weapon system life cycle costs. When appropriate, affordability methodologies should be able to consider how the use of commercial off-the-shelf (COTS) hardware/software will affect weapon system cost including COTS integration and operation and support. Approaches shall employ credible or validated cost data bases that are recognized by laboratory by laboratory customers. Classical cost tools such as PRICE, SEER, COCOMO, and others may be used in addition to innovative new approaches, such as the Constructive COTS (COCOTS) model and the Analogical Cost Estimation (ACE) model, for estimating the impact of new technologies on the cost of weapon systems. Affordability methodologies shall be consistent with the AFRL Collaborative Enterprise Environment (CEE) development and be integrated into the environment as resources.

PHASE I: The desired products of Phase I are 1) identification of the enabling affordability and cost estimation technologies and methodologies, 2) conduct of specific simulation 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 prototype demonstration designed and implemented by the contractor. 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 affordability and cost estimation capability for use in defense and commercial technology development. Affordability tools are crucial resources used in IPPD collaboration environments for the 21st century and are having major implications in how the commercial sector conducts business. 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. Affordability products quantify key trades including performance, producibility, sustainability, life-cycle cost, and risk.

REFERENCES:

[1] Rosenberg, Robert, "Using COTS in Real-Time Embedded Systems," Sabre Systems, Inc; Lexington Park MD; June 1998(AD-A-355329).

[2] Henderson, B.J., and B.J. Sullivan, "Management Aspects of SoftwareMaintenance," Monterrey CA, Naval Postgraduate School, 1984 (AD-A-152035)
[3] McQuay, William K., "Put a Virtual Prototype on Your Desktop," ProgramManager Magazine, 94-99, September-October 1998.
[4] Abts, Chris, COCOTS Research Web Page, University of Southern CaliforniaCenter for Software Engineering, 1999.(http://sunset.usc.edu/research/COCOTS/index.html)
[5] Walkerden, Fiona, and Ross, Jefferey, "An Empirical Study of AnalogyBased Software Cost Estimation," CAESAR Technical Report 98/8, University of New South Wales, Sydney, Australia, 1998.

KEYWORDS: Modeling and Simulation; Investment Strategy; Collaboration; Process, Product, and Cost Models; Affordability; Product Data Model

AF01-106 TITLE: Innovative Information Technologies

TECHNOLOGY AREAS: Information Systems Technology

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
  -- Information Fusion comprises situation assessment, impact assessment and process refinement. Innovative solutions to accurately perform situation assessment, identify current and future threats to blue forces, the ability to adapt to new patterns/environmental situations, as well as provide feedback to the data collection process are all highly desired.
- 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 ExecutionThis 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 ExchangeGlobal 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.

REFERENCES:

KEYWORDS: Information Technology, Command and Control, Communications, Computers, Intelligence, Global Awareness, Dynamic Planning and Execution, Global Information Exchange

AF01-107 TITLE: <u>Fuselet Concept Formulation and Retrieval</u>

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: To develop and demonstrate concepts, techniques and tools needed to improve the retrieval and discovery of information stored in large, geographically distributed databases. Develop and build a prototype capability to access, retrieve and aggregate a mix of document types (i.e. textual, graphics, web pages, and objects).

DESCRIPTION: Future information management systems will have access to more and better remote sensors, relational and object-oriented databases, automated analysis tools and collaborative planning and execution aides. A critical component of these new information management systems will be is a library of "fuselets" that covers a variety of anticipated decision-making situations. The concept of a fuselet is best understood as a program script that is created by information users to access and aggregate information in new ways from a variety of sources, redirect information flows, provide alerts and information updates, and control communication gateways to facilitate information sharing. Current state-of-the-art document and information retrieval systems are limited since they process a single key search term and idiom at a time and do not provide the necessary robustness and flexibility. There is a need for automated assistance in building and executing fuselets for control of information management operations. The primary goals for this effort are: (1) evaluate scripting languages for fuselet synthesis; (2) develop and implement necessary improvements; (3) search and retrieve fuselets as concepts as well as single term retrieval; (4) apply interactive dialog techniques to automatically generate fuselets; and (5) activate and monitor fuselet execution.

PHASE I: Apply a scripting language and demonstrate its application to fuselet concept formation and verification. Identify deficiencies of current scripting languages and areas requiring development. Implement enhancements. Build a sample database of fuselets to demonstrate these concepts. Develop a prototype system to first retrieve fuselets as keywords and then as concepts. Demonstrate a prototype and devise a plan for further advancement of these capabilities.

PHASE II: Extend the prototype developed in phase I to automatically create, store and categorize fuselets. Implement performance enhancements to the Phase I prototype. Conduct testing to verify feasibility within an operational environment.

PHASE III DUAL USE APPLICATIONS: An information management capability valuable to medical, law enforcement and Internet communities. System will prove useful for accessing and searching through large, diverse databases to handle user information queries and as a tool for data mining applications. Future military applications will include emerging information management systems, such as, the Air Force's Joint Battlespace Infosphere (JBI) which will provide individual user with specific information required for their functional responsibilities. The JBI system will integrate data from a variety of sources, aggregate the information and distribute the information in the appropriate form and level of detail.

REFERENCES:
United States Air Force Scientific Advisory Board Report on Building the Joint Battlespace Infosphere Volume 1: Summary SAB-TR-99-02 December 17, 2000. Internet document access: http://www.sab.hq.af.mil/Archives/index.htm

KEYWORDS: Concept Recognition and Synthesis, Information Retrieval, Information Extraction, Information Aggregation

AF01-108 TITLE: Practical Agent Construction/Deployment Environments

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: To create an integrated development environment (IDE) for creating intelligent software agents. The IDE will provide an interface that can be easily understood and used by non-computer scientists.

DESCRIPTION: Software agents are beginning to appear in many academic and commercial software products. These agents are usually handcrafted software entities created by computer scientists or engineers to serve some purpose or perform some specific function. Agents typically have a defined communications protocol for interactions with other agents and may or may not be created to interface with humans, databases, or other information stores. What is needed is a level of abstraction to be used during software agent construction that is intuitive to novice users. Such users should be able to visually construct their agents, task them, and give them the proper skill set so they can be deployed quickly. Agents could be designed to provide automated interaction with single or a small number of information sources, perhaps including humans. A simple metaphor is the construction of two-dimensional pictures of people where different heads, shoes, etc. Are placed on the picture to give it a different appearance. What is envisioned is a simple environment in which an AF staff member who needs information to complete a given task can construct agents. Just such a situation is found in the construction and launching of software agents in the Joint Battlespace Infosphere (JBI) or, more generally, the IDE described could be used whenever automated intelligent data extraction from a defined information source, perhaps from another agent, is required. Such an agent development environment must produce software that is executable on commercial hardware.

PHASE I: Develop an intuitive metaphor for agent construction that can be used by non-computer scientists. Develop an agent development environment model and prototype screens. Develop a prototype agent function library from which users can choose functionality. Determine and prove the feasibility of rapidly producing software agents for execution.

PHASE II: Develop a full-scale working prototype of the agent development environment. Demonstrate how this environment could create software agents. Demonstrate how this environment could rapidly deploy software agents in a relevant scenario. Demonstrate how this environment can quickly and intuitively construct and deploy agents that can interact with humans, the world wide web, and/or other data stores.

PHASE III DUAL USE APPLICATIONS: Such an environment could have numerous uses in the commercial and private sector. Individuals could rapidly construct their own agents to find/act on information on the world wide web (e.g. shopping or locating other persons), within their business (e.g. to help schedule meetings or collect data related to a specific topic), or other personal applications (e.g. gathering genealogical information). Such an environment should be readily downloadable from a web site for rapid and easy use.

REFERENCES:
SAB-TR-99-02, "Report on Building the Joint Battlespace Infosphere," December 1999.

KEYWORDS: Integrated Development Environment, Intelligent Software Agents, JATLite, KQMLAglets, D'Agents, Joint Battlespace Infosphere (JBI)

AF01-109 TITLE: Multicast Ontology-Based Object Repository Derivation/Dissemination for the Joint Battlespace Infosp

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Investigate new and innovative advanced distributed ontology infrastructures and layered-semantics-based schemes using network-centric mechanisms to support the efficient rapid access/dissemination of distributed knowledge base repositories.

DESCRIPTION: Knowledge intensive processing techniques are needed to rapidly disseminate and integrate distributed information/knowledge. Advanced computational models need to address processing of information/knowledge at very high speeds. Advanced representation techniques are needed to provide innovative ways to integrate, reason and disseminate various forms of knowledge. Ontology technology coupled with reasoning and machine learning techniques provide an opportunity for both adaptable and scalable innovations. Mobile computing designs, integrated with knowledge disseminators offer real potential for introducing new and reusable knowledge sources within local domains. Research innovations in these areas will help provide ways to support knowledge dissemination and assist intelligent Command and Control (C2) which focus on collection, intelligent analysis and course of action generation techniques to support operational decision-makers. The output will be advanced ontology infrastructure and layered-semantics-based schemes, possibly based on polymorphous computing architectures, which are capable of intelligently coordinating, cooperating, and negotiating to provide just-in-time services for customized information. Mechanisms to be investigated include: (1) intelligent multicast-based information dissemination techniques; (2) information/knowledge push-pull based on Event Condition Action (ECA) grammers; (3) publish, subscribe, and transform techniques; (4) multiple ontologies and repositories which can provide innovative mechanisms to rapidly reason and integrate distributed knowledge; (5) quality of service (QoS) for knowledge availability; and (6) cooperative query processing techniques. The technical risks include unique use of distributed data architectures using multicast, innovative reasoning and learning mechanisms, and dynamic knowledge bases integrated to rapidly disseminate knowledge in support of diverse command and control paradigms. This technology will also utilizre the ontology tools/techniques generated under the DARPA's Rapid Knowledge Formation (RKF) and Dynamic Agent Markup Language (DAML) programs.

PHASE I: Phase I will investigate new and innovative advanced distributed ontology infrastructures and layered-semantics-based schemes using network-centric mechanisms to support the efficient rapid access/dissemination of distributed knowledge bases.

PHASE II: Phase II will demonstrate rapid knowledge base derivation/dissemination in appropriate scalable information processing domains/platforms and focus on collection, intelligent analysis and course of action generation techniques to support decision-makers in various C2 scenarios.

PHASE III DUAL USE APPLICATIONS: This topic has broad dual use applicability. Phase III will test and evaluate tool(s) for rapid knowledge base derivation/dissemination 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 will support the tools/techniques generated under the Rapid Knowledge Formation program (RKF) with applicability to chemical/biological scenarios. This technology could also have a major impact on commercial 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.

REFERENCES:

[1] Lenat, D. et al, Build Large Knowledge-Based Systems: Representations and Inference in the Cyc Project, Addison-Wesley 1990

[2} Thuraisingham, B., Nwousu, K. C., and Berra, P.B. (editors) Multimedia Database Management Systems: Research Issues and Future Directions, Kluwer Academic Publishers, 1997

[3] Wiederhold, G. "Foreword: On the Barriers and Future of Knowledge Discovery",Advances in Knowledge Discovery and Data Mining, AAAI/MIT Press, 1996, pgs. VII-XI

[4] Knowledge-Based Techniques for Information Fusion and Discovery Session, Co-Chairs Liuzzi, R.A., and Anken C., Fusion 99 Conference, San Francisco, July 1999

[5] Emerging Knowledge Base Technology for the Next Decade , Chair: Liuzzi, R. A., The 2000 International Conference on Artificial Intelligence (IC-AI'2000) June, 2000, Las Vegas, NV

KEYWORDS: Intelligent Systems, Software, Polymorphous Computers, Knowledge Base, Dynamic Data Base, Agent-Based Tools, Joint Battlespace Infosphere, Cyber Command and Control

AF01-111 TITLE: <u>Mixed Resolution Modeling Issues for the Battlespace InfoSphere</u>

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop techniques for modeling Joint Battlespace InfoSphere (JBI) command and control scenarios composed of entities at various levels of detail/complexity.

DESCRIPTION: Inherent to the JBI basic design tenet is the need to fuse or aggregate data from multiple information objects; to reduce as necessary the "information fog of war" to a useful, manageable, volume of data - and ultimately, knowledge. But with that simple statement comes an enormous presumption: that the legacy applications to be "connected" are of the same level of model resolution. As has been well-documented, more often than not, this is not the case. Traditional synthesis efforts have taken a "locate and integrate" approach, whereby disparate models are coupled (for example, the outputs of a more detailed model are often passed as performance measures to broader-scope simulations) with little thought as to whether or not these couplings are "valid." There is much research required to validate -- or invalidate -- these traditional approaches (e.g., Lanchester Equations), and to set the stage for appropriate (i.e., logically/physically valid) reuse of legacy models and data. The purpose of this program then is to highlight some of the Mixed Resolution Modeling issues that must be addressed in order for the Joint Battlespace InfoSphere to be fully realized.

PHASE I: Perform preliminary investigations of the Joint Battlespace InfoSphere (JBI) initiative as it relates to Mixed-Resolution Modeling (MRM) and model/data interoperability. Develop an approach for improved MRM modeling for JBI; while maintaining compliance with the High Level Architecture (HLA).

PHASE II: The contractor shall accomplish a detailed design, develop a prototype mixed-resolution modeling formalism, and demonstrate the proposed technology in the appropriate Information Directorate facility. The contractor shall also detail his plan for his Phase III effort.

PHASE III DUAL USE APPLICATIONS: While this research initially supports the info-centric requirements of the Joint Battlespace Infosphere, it is by no means limited to that application. As discussed in "The Air Force Hierarchy of Models: A Look Inside the Great Pyramid" (see references), model interoperability -- especially so in cases involving applications of different levels of resolution -- has become a major focus of the M&S research community, with few prototype implementations beginning to show the way to a new generation of decision-support systems; in a wide variety of application domains. Some progress has been made in multiresolution modeling, abstraction techniques, interoperability protocols, and in hardware/software disciplines as well, but there is still much to be done. Research performed in this effort provides a sorely-needed foundation for increasing realism in large scale simulations/decision support systems in any domain.

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KEYWORDS: Mixed Resolution Modeling, Lanchester Equations, Variable Resolution Modeling, Command and Control, Aggregation, Model Abstraction

AF01-112 TITLE: Selective Encryption of Air to Ground Messages

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop selective encryption techniques for application to air-to-ground messages.

DESCRIPTION: In order to gain unlimited access to international civil airspace, the Air Force is evaluating the use of commercial data service providers to support the deployment of Aircraft Communications Addressing and Reporting System (ACARS) and the Aeronautical Telecommunications Network (ATN) as part of the Global Air Traffic Management (GATM) upgrades. A large segment of Air Force aircraft will be modified in the next several years with such data link communications in order to gain worldwide access to airspace otherwise restricted. An innovative research need exists for selective and dynamic encryption of certain sensitive message contents. The approach should accommodate both commercial and NSA approved software encryption algorithms and development of a rule-based technique for encryption. The resulting packets must be compatible with the commercial ground network, airborne communications management units and radios, ground based air traffic control, and military command and control centers.

PHASE I: Evaluate the various implementation techniques for encryption of air traffic data link messages, both civilian and military. Develop an encryption technique for both civilian and military air traffic data links.

PHASE II: Test and demonstrate evaluated and developed encryption techniques for civilian and military air traffic data links.

PHASE III DUAL USE APPLICATIONS: Develop a prototype encryptor for use in civilian air traffic data links. This technology can be readily adapted to commercial airline data links.

REFERENCES:

KEYWORDS: Data Link Communications, Secure Data Communications, Airborne Communications, Air Traffic Control

AF01-115 TITLE: Test Program Assessment Tool (TPAT)

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a tool to construct classic or tailored test programs that are efficient and give the best return for investment; thus saving program dollars on their test programs, assessing overall program health, and suggesting test program fixes.

DESCRIPTION: HQ Electronic Systems Center (ESC) Test and Evaluation Directorate provides Command and Control Test Managers (TMs) at ESC with functional guidance to construct robust test programs. Services provided to the TMs in the form of formal customer education - ESC C2 Test Managers Course, Test Concept Development Assistance, test and test-related document review and Test Program assistance. The TPAT tool will allow automation of test program assessments in an increased efficiency, reducing the time and manpower requirements. Currently, expert test advice is funneled through a few humans on a consultant team and a by a myriad of test guidance. The new tool is required in the wake of reduced manpower at ESC and the commercial world, a decrease in the availability of test expertise and an increased focus on test at ESC. These needs have led to the requirement for faster test program assessments. Thus, the available expert advice and test guidance must be harnessed and made available to less experienced test consultants. This effort will generate a force multiplier to enhance the effectiveness of a limited test consultant force. The tool must be user friendly enough to guide new test managers with limited experience through a simple test program construction exercise yet be able to support any ESC programs through any phase in the test planning process. Many rustic tools exist that provide parts of the requirements listed above that are not intuitive. Candidate technology areas are artificial intelligence with applications possibly in Cognitive Modeling, Complex Adaptive Systems, constructive learning algorithms for pattern classification, intelligent agents, intelligent diagnosis systems, knowledge-based systems, neural architectures for knowledge representation and inference. The tool must be able to take test program files or answers provided by human input and compare it to DoD, AF, and test organization guidance and lessons learned databases to rapidly perform the following functions: Identify test program resources,Assess level of test appropriateness and need (contractor, government development and operation); Identify the risks and suggest possible mitigation strategies; Assign risk ratings,Identify needed certifications; Identify and rate key test program elements; Identify and suggest required test procedure; Rate the test processes used and still needed; Rate the overall health of the test program; Calculate a cost range for the test program and investment return options; and Create and/or evaluate test schedules.

PHASE I: Demonstrate the feasibility of the underlying technologies and the basic strategies to be used. There should be a simple demonstration at the end of the phase I time line to show how the proposed technologies and their related methods will operate and interact. Innovative and creative approaches are highly encouraged. Any and all commercial implications/spin-offs should be examined and studied.

PHASE II: Building on the results of the phase I work; develop and demonstrate a prototype toolkit. The prototype toolkit will be technology based with broad dual use applications. The described need at ESC illustrates one possible use for the prototype toolkit but shall not limit the flexibility in regard to dual-use possibilities.

PHASE III DUAL USE APPLICATIONS: Phase III Air Force use is to build a fully functioning toolkit directed at the speific needs of installation at Air force Headquarters Electronic System Center (ESC) Test and Evaluation Directorate. This toolkit could be installed, verified and validated at ESC. Potential applications of this product can include but not limited to aircraft maintenance, training methodology, and other maintenance and repair operations. The information technology methods developed could also be used to access and verify data.

REFERENCES:

KEYWORDS: Artificial Intelligence with Applications in Cognitive Modeling, Complex Adaptive Systems, Constructive Learning Algorithms for Pattern Classification, Intelligent Agents, Intelligent Diagnosis Systems, Knowledge-Based Systems, Neural Architectures for Knowledge Representation and Inference

AF01-116 TITLE: Dynamic Situation Assessment and Prediction (DSAP)

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Design and demonstrate a Dynamic Situation Assessment and Prediction tool.

DESCRIPTION: This effort involves a faster-than-real-time predictive assessment of alternate courses of action and technologies to support on-the-fly "what if" scenarios. This system – a Dynamic Situation Assessment and Prediction (DSAP) tool – would involve research in modeling and simulation science, model abstraction/multiresolution modeling, intelligent agents, optimization and/or knowledge-based algorithms, and effects-based prediction; all technology areas that would support the ability to perform dynamic decision tradeoffs in mission planning and execution. Current Air Force execution monitoring is primarily a manual capability, and situation/battle damage assessment is generally relegated to after-action reviews, which results in the decision-maker being relegated to merely a bystander; unable to take advantage of new/unforeseen targets of opportunity, or even to abort a mission that is going badly. Allowing a decision-maker to interact with a running simulation to assess the effects of retasking opportunities (e.g., to prosecute a high-priority mobile target in lieu of an originally-planned target) provides the decision-maker with tremendous latitude to make time-critical, mid-course decisions. The DSAP system would, by definition, start at the current time and would look ahead in time; performing a faster-than-real-time simulation of mission outcome, as well as assessments of alternative courses of action and what-if scenarios. The modeling capability would determine the weaknesses in the plan and predict possible failures or recommend changes to the current mission tasking.

PHASE I: Develop an overall system design and concept of operations for achieving dynamic situation assessment and prediction.

PHASE II: Develop and demonstrate a prototype system in a realistic environment. Conduct testing to prove the feasibility over extended operating conditions.

PHASE III DUAL USE APPLICATIONS: This capability could be used in a broad range of military and civilian applications where dynamic planning and execution are required. Industry and Government budgets are based on a cycle of planning, virtual prototyping and replanning; and would improve significantly with modeling and prediction to make changes. Such a system would also support real-time situation assessment and retasking during military exercises. The basic research areas being pursued and applied (especially the complexity reduction approaches offered by model abstraction) allow for multiple Courses of Action and strategies to be assessed in faster-than-real time; which directly addresses stated requirements of the JWARS, JSIMS/NASM and JMASS program offices.

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[2] "A Methodology for Using Intelligent Agents to Apply Simulation Technologies to the Mission Operational Environment," J.R. Surdu and U.W. Pooch; Texas A&M.; Proc, Enabling Technology for Simulation Science III
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KEYWORDS: Course of Action, Decision-Making, Modeling and Simulation, Prediction, Visualization

AF01-119 TITLE: Battlespace Cyberforensics

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Investigate novel technology for distributed examination of battlespace infosphere transactions for data and information leading to summary identification, isolation, or circumvention of hostile activities (attacks) and hostile clients, thus contributing to the resiliency of battlespace networks.

DESCRIPTION: Investigate methods techniques and concepts that can be applied to collection and examination of cyber attack evidence gathered simultaneously within large distributed domains. Techniques such as advanced data mining, distributed network traffic pattern analysis, distributed network "health" sensing, may be useful for extracting cyberforensics information about potentially hostile activities, which are actions designed to limit or otherwise reduce the effectiveness of the battlespace infosphere. Any successful concepts must avoid reliance on large stores of network data collected for post attack analysis; and allow for examination and filtering in near "cybertime". This is a multilevel security environment. Robust ability to withstand multiple attacks, continue reliable services for designated clients. Employ diversionary tactics based on on-the-fly decisions regarding the severity of developing attacks. Cyberforensics can be employed as a trigger for auto launching of camouflage scenarios and decoys.

PHASE I: Select concepts and techniques which may be best for achieving cyberforensic objectives. Experiment with actual test cases, demonstrating the feasibility of the technology. Delineate the limitations of battlespace infosphere forensic mechanisms and generating a technology development roadmap/matrix.

PHASE II: Build cyberforensic mechanisms which can be applied to a variety of host platforms. In particular, focus on data products which may be used in the Joint Battlespace Infosphere concept.

PHASE III DUAL USE APPLICATIONS: The security of infosphere transactions is a prime concern in many commercial e-business entities for both customer based transactions and business to business transactions. The result can be the identification of network attack perpetrators made feasible through the use of cyberforensics techniques, as well as the ability to exercise proactive measures designed to mitigate the effects of malicious activities targeted at specific business sectors or even individual e-business entities. Deployed cyberforensic products once demonstrated effective can have a powerful deterrent effect on would be attackers in both the military and commercial domain.

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KEYWORDS: Cyber Forensics, Network Forensics, Computer Forensics

AF01-121 TITLE: Thermally and Electrically Conductive Adhesives for the F-22 Subarray Assembly

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop affordable novel high temperature, thermally and electrically conductive polymeric adhesives for bonding electronic structures.

DESCRIPTION: The thermal adhesive materials currently available to bond electronic components to dissimilar structural materials may require several hours of pressure and enclave cycle time to cure, thus making the bonding process time consuming. Improved property adhesive compositions are available commercially, but they are unsatisfactory for the subject bonding processes due to incompatibility with the automated assembly process of the subsystem and/or are difficult to handle. Furthermore, quick setting adhesive alternatives available today that are automatically dispensable are unable to withstand the repeated thermal cycles of –40 to +100 degrees C under operational conditions without premature failure. What is sought in this technical effort is a novel polymeric high use temperature adhesive composition of matter compatible with automated dispensing, and a process for non-autoclave cure. The results of the technical effort should afford a new high temperature adhesive product with excellent performance in the following criteria: flexibility under thermal cycle and subsystem assembly processes, dimensional stability upon cure and final component production, thermal conductivity, electrical conductivity at 106 S/cm, and adhesion even under hot/wet environmental and a variety of other environmental exposure conditions. Clean debonding and repair/rework of the adhesive bond for hardware component replacement on the subarray are also of prime interest. A simplification of the manufacturing and maintenance processes on a system such as the F-22 radar subarray just by incorporation of a novel high use temperature, rapid cure adhesive composition will result in a substantial reduction in production cycle and repair costs.

PHASE I: In Phase I of the effort the technical work shall require synthesis of the high use temperature and electrically conductive, polymeric adhesive composition of matter. Polymer properties to be evaluated include: polymer purity (including metal contaminants) by elemental analysis and molecular weight determination, full thermal analysis including, but not limited to thermal conductivity, 2-D and 3-D CTE, and rheological behavior. Thermomechanical and electrical conductivity performance at both room temperature and fabrication/ultimate use temperatures and elevated humidity conditions shall also be required using ASTM test methods appropriate for adhesive performance evaluation. All performance tests shall be conducted using currently used adhesives and preforms in the subarray for side-by-side comparison and to obtain figure of merit data for the proposed adhesive systems. More preferred approaches for adhesion tests proposed shall incorporate bonding schemes using dissimilar materials with varying CTEs and employment of imaging, spectroscopic and predictive methods to elucidate bond failure mechanisms. To prove bond repairability of the composition of matter, clean debond and rebond rework processes shall be demonstrated. Products of the subject Phase I effort are data and a proof-of-concept composition of matter and process.

PHASE II: In Phase II of the effort the technical work shall require scale-up of the Phase I candidate composition of matter to a minimum of five to ten (5-10) pounds (2.3-4.5 Kg). Basic chemical-physical, and ASTM standardized thermal, thermomechanical and conductivity evaluations shall be conducted again to assure reproducibility of performance properties in scale. In addition, isothermal aging characteristics up to 200 hours at ultimate use temperature shall be performed to evaluate the long term thermal aging characteristics of the adhesive composition. During this phase of the technical effort, additional environmental performance criteria for O and M, radiation and chemical-biological exposure shall be explored and evaluated with the candidate polymeric adhesive. Additional refinement of the imaging, spectroscopic, or predictive methods cursorily employed in the Phase I effort shall be applied to the Phase II effort. The final portion of the Phase II effort will involve the proof of improved ease of handling during manufacture and repair processes, and compatibility with automated dispensing, using components supplied by the Project Engineer in order to demonstrate and test the bonding capabilities of the new adhesive composition. Products of the Phase II effort are data and the final component assemblies provided that incorporate the improved adhesives.

PHASE III DUAL USE APPLICATIONS: The commercial electronic industries seek new thermally and electrically conductive, dimensionally stable adhesives for bonding electronic components to component substrates which also are environmentally durable and assembly process robust. Some of the current failures in interconnect technology bond integrity may involve the accelerated aging and resulting failure of the component adhesive bonds upon repeated exposure to thermal stability limits during thermal cycling.

REFERENCES:
1. C. E. Browning and J. M. Whitney, Adv. Chem. Ser. 1974, vol. 134 p. 137-148.
2. C. E. Morris, et al. “Off-Optimum Cure of Aerospace Epoxy Adhesives,” Journal of Adhesion 1994, vol. 47, p. 123-132.
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4. C. Ronnewinkel and E. Haberstroh, Ann. Tech. Conf. – Soc. Plast. Eng. 1999 57th, vol. 1, p. 539-544.
5. D. K. Shin and J. J. Lee, “Effective material properties and thermal stress analysis of epoxy molding compound in electronic packaging,” IEEE Trans. Compon., Packag. Manuf. Technol. – Pt. B 1998, vol. 21 (4) 413-421.

KEYWORDS: adhesives, thermoset (ting) adhesive, thermoplastic adhesives, antenna array, thermal conduction, thermal conductivity, non-autoclave cure, cure cycle

AF01-122 TITLE: Corrosion Prediction: Assessing the Effect of Corrosion Protection System Aging

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Understand and model Corrosion Protection System degradation to enable prediction of Corrosion onset and damage.

DESCRIPTION: Significant manpower is required to inspect for, find and fix corrosion damage. Corrosion maintenance is time consuming as well as costly, leading to a considerable lengthening of the time to service an aircraft in PDM, and a concomitant decrease in aircraft availability to support Air Force Mission Requirements. The ability to anticipate the onset of corrosion damage will help us to manage this aging fleet. Deterioration/breakdown of the corrosion protection system will provide the path for influx of the service environment to corrosion susceptible structure. Time and exposure dependent mechanisms contribute to the overall deterioration of the protection system (organic and/or inorganic coatings, sealants, suppression treatments). Research is sought to (1) model breakdown of the protection system, (2) anticipate the effect of continued service on the degraded system, (3) assesses the impact of the introduction of service environment to the onset of corrosion and its progression, and (4) conduct service and experimental verification of the model.

PHASE I: A program in this area should address the requirements and goals described above, and provide a demonstration of the viability of the technology developed as proof of concept. Viability of the technology will be quantified in terms the breadth of needs addressed and demonstration of utility: types of protection systems addressed, scope of structure addressed, completeness and utility of the demonstration provided, as well as the ease of model expansion into additional protection systems and structure. The phase one product for a successful effort is the development, demonstration, and limited experimental validation of a protection system degradation/effects model. It is expected that a single fielded protection system will be modeled, with emphasis on a particular, representative aircraft section or component for demonstration purposes. Experimental validation will be relevant to the system and component focus of the modeling effort.

PHASE II: The product from Phase I would be developed through optimization and scale-up efforts to establish a degradation model with application across a range of protection systems and structure. Identification of remaining gaps, accurate assessment of both the scope of application and limitations of application of the scaled up product are necessary deliverable in Phase II. Use of experimental and, ideally, service data for verification of the model developed is required in this phase of the effort. The product of this phase of the effort will need to be compatible with USAF structural integrity analysis capability.

PHASE III DUAL USE APPLICATIONS: Models developed under this effort will have benefit in extensive government and commercial applications. Protection of structural and non structural elements exposed to environment using protection systems similar to those used by the USAF is of key concern to any number of institutions, both in the private and government sector. Transportation industries, construction and electronics industries would be affected.

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KEYWORDS: Corrosion damage Polymeric Degradation, Corrosion Prediction

AF01-123 TITLE: <u>Removal Tools and Process for LO Materials</u>

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop Improved Tools and Removal Processes for Radar Absorbing Material on the F-117.

DESCRIPTION: Current Radar Absorbing Material (RAM) removal techniques used by the Air Force in the field and at depot are tedious, labor intense and inefficient. Most removal is performed by hand scrappers using care not to damage surrounding structures or materials. There is a need to develop removal processes that are more efficient and less labor intensive. Attributes to consider in order of importance are: substrate damage, health/safety (ergonomic effects), effectiveness/precision, field applicability, environmental impact, portability, removal rate, cost.

PHASE I: Develop proof-of-concept for RAM removal techniques using efficient new tools and/or processes. Determine the applicability of the proposed techniques to a field environment. Determine the environmental and health/safety impact. Demonstrate via small coupons the potential size, efficiency, removal rate, and substrate damage. Report findings, processes, costs and risks associated with the proposed removal techniques.

PHASE II: Procure/develop prototype tools and removal processes. Define equipment size, required support, and portability. Prepare process work descriptions. Demonstrate effectiveness and accuracy of processes via lab tests. Demonstrate strip rate and substrate damage via large panel tests. Work with Air Force Research Laboratory and Holloman AFB to field demo prototype tools and repair process and evaluate field performance.

PHASE III DUAL USE APPLICATIONS: Determine and refine the use of the removal techniques for use with aircraft sealants and coatings. Determine the effectiveness of the removal process for desesal/reseal applications.

REFERENCES:
1. UDR-TR-2000-00031, “Rapid Removal of Radar Absorbing Coatings.” University of Dayton Research Institute, February 2000
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3. T.O. 1-1-3, “Inspection and Repair of Aircraft Integral Fuel Tanks and Fuel Cells,” WR-ALC, Robins AFB, GA

KEYWORDS: Composites, UV Curing, Repair, Processing

AF01-124 TITLE: <u>Ice Phobic Materials</u>

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop and demonstrate ice phobic surface treatments that are compatible with low observable materials and coatings.

DESCRIPTION: Current aircraft utilize various methods to prevent ice formation on wing and engine inlet surfaces including pneumatic, electrostatic and thermal systems. Each of these applications has its own advantages, but are generally not applicable to low observable platforms. Ice formation on projections in engine inlets can lead to engine fan blade damage when accumulated ice becomes detached and goes down the inlet. Resultant damage typically requires engine removal to facilitate blade replacement. Surface treatments are required that will delay or prevent the onset of damaging ice accumulation in a high velocity environment. Long term durability of the surface treatment is desirable. Compatibility with crew-breathable air systems and typical gas turbine engine materials is required. The selected material should be compatible with low observables.

PHASE I: Evaluate current materials and application requirements to identify potential surface treatments and alternative approaches. Fabricate coupons of the chosen materials and evaluate properties including durability (e.g. abrasion resistance), surface reflectivity, application methods and removal methods. Determine the optimal material system using application method, removal method, frequency of reapplication, safety and especially overall life cycle affordability as considerations.

PHASE II: Further develop the proposed material system along with manufacturing processes/ methods. Demonstrate the capability of the selected material to eliminate/delay the development of ice formation (end product). Conduct an assessment of the compatibility of the material and it's products of decomposition with gas turbine engine materials and the human respiratory system. A small quantity of the material will be produced and tested at the end of the Phase II effort.

PHASE III DUAL USE APPLICATIONS: Operation in icing environments is common in the aviation industry, both military and civilian. Prevention of ice accumulation will enhance flight safety worldwide. Potential military application – B-2 program. Commercial application would be to helicopters or composite light passenger aircraft.

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KEYWORDS: Ice Control, Materials, Ice Phobic

AF01-125 TITLE: Nondestructive Inspection of Fastener Holes in Thick Multiple-Layer Structure

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop an NDI technique to detect cracking within the bore of installed Taper Lok fasteners

DESCRIPTION: A requirement exists to conduct nondestructive inspections on B-1B wing structure. Unfortunately, due to the thick, multi-layered nature of the structure, there is currently no means of inspecting this hardware without removing the Taper Lok fasteners and conducting bolt-hole eddy current inspection. Removal of the Taper Lok fasteners would cause damage to the fastener bore and result in cost prohibitive bore repair and fastener reinstallation.The two structural configurations of greatest concern are the wing carry through and the wing splice joint structures. The wing carry through (WCT) is a primary airframe component that serves as a bridge between the left and right wings and between the forward and aft fuselage. The worst case configuration consists of a four layer sandwich structure consisting of two center layers of titanium (approximately 0.9 inch thick each) and a top and bottom layer (bulkhead flanges) of 0.3 inch thick aluminum (or titanium depending on the location). The structure is fastened with stainless steel, protruding head, Taper Lok fasteners with a maximum diameter of 0.75 inch. Each interface of the sandwich is sealed with polysulfide fuel sealant.The wing splice joint attaches the upper and lower wing planks to the lug panels of the WCT structure. The lower wing splice (section of most concern) is constructed of a four-layer sandwich. This sandwich is comprised of two Ti-6Al-4V lug panels. At the splice zone, each titanium plate is machined to a taper to accommodate the tang from the aluminum wing plank that inserts into the lug panel assembly (tongue and groove configuration). In addition, the splice incorporates a fourth layer of aluminum rib flanges. The sandwich is fastened using three rows of flush-head, stainless steel, Taper-Lock shear bolts. Because of the tongue and groove configuration, the thickness of the titanium and aluminum layers varies inboard to outboard. The extreme case inboard, from top layer to bottom, consists of 0.64 inch of aluminum, 0.37 inches of titanium, 2.0 inches of aluminum, and 0.38 inches of titanium. The extreme case outboard consists of a 0.5 inch and 0.9 inch layers of titanium, 0.9 inch of aluminum, and 0.9 inch of titanium. Polysulfide sealant may not be present between each layer of the splice joint sandwich.For both the wing carry-through and wing-splice joints, the flaws of most concern are corner cracks initiating at the fastener bore at the interface of each layer. A 0.050 inch corner flaw detection sensitivity is the current goal.

PHASE I: Demonstrate concept feasibility. Demonstrate the ability to detect 0.050 inch corner flaws emanating from a holes with stainless steel Taper Lok shear bolts in the following layered structure: Layer Material Thickness 1 Aluminum 0.3" 2 Titanium 0.9" 3 Titanium 0.9" 4 Aluminum 0.3"The ability to detect corner flaws between layers 1 and 2, 2 and 3, and 3 and 4 is necessary. Design the prototype system will be proposed to be built in Phase II.

PHASE II: Develop and demonstrate the system prototype on a demonstration article representative of the actual B1B structure. Review prototype design with AF personnel for robustness, integration with existing practices and ability of AF personnel to have the prototype unit maintained and repaired. Build the prototype unit. Demonstrate the operability to AF personnel and provide a users/maintenance manual for expected operation. It is desired to have an integrated team approach to the development of the prototype that will incorporate user feedback.

PHASE III DUAL USE APPLICATIONS: Potential applications include inspection of metallic structures including commercial aircraft, naval vessels, automobiles, rail systems or building structures. Potential customers include aerospace, nuclear, marine, and automotive concerns, FAA, DoD and the DOE.

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KEYWORDS: Nondestructive inspection, Crack detection, Inspection

AF01-126 TITLE: CVD Process Control for Affordability and Repeatability

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Improved CVD fiber coating process control for cost reduction, improved repeatability, and enhanced performance.

DESCRIPTION: Most Ceramic Matrix Composites (CMCs) require the use of thin fiber/matrix interface coatings to achieve their desired mechanical properties. These coatings are generally applied by CVD. CVD coating deposition has been optimized in the electronics industry for selected chemistries and simple geometries. However, the complex and varied chemistries and complex substrate geometries (e.g. woven cloth) relevant to fiber/matrix interface coatings represents a significant increase in complexity. The process has not been optimized for these coatings. This represents a weak link in CMC processing and a hindrance to scale-up. Poor control results in poor coating reproducibility (too thin, off stoichiometry, etc) which leads to poor or inconsistent composite performance, and ultimately to increased cost. A survey of the process control literature and commercially available sensors will show that process control technology now exists which will allow significantly improved coatings. The goal of this effort is to implement appropriate sensor and/or process control technology, optimize the process for coating affordability and composite performance, and utilize the technology to promote CMC application to identified defense and commercial needs. The prior existence of an established composite system with identified defense and commercial applications, and a CVD system capable of coating significant quantities of woven cloth with some level of controllability is required.

PHASE I: Phase I will demonstrate the sensor and/or control technology, validate the payoff, and develop a detailed plan to implement it on line in Phase II. Suitable sensor(s) and/or control technologies should be evaluated on or off line to demonstrate proof of concept (i.e. proof that this approach will result in significantly improved process control as demonstrated by reduced cost, improved coating properties, or better composite performance).

PHASE II: Phase II will implement the process control technology identified in Phase I, optimize the process, and assess the coating improvement in terms of yield, cost, throughput, and composite fabrication, properties, and performance. The necessary reactor and software modifications to implement the technology on line should be made. The range of acceptable operating parameters should be defined and the deposition parameters optimized for coating affordability and performance through designed experiments. Sufficient fabric should be coated to allow fabrication of composite specimens and sub-elements or components and they should be tested to verify the material performance. An analysis of the cost and performance impact of the technology developed on the composite system/application component should be accomplished.

PHASE III DUAL USE APPLICATIONS: CMCs are being developed for a variety of commercial applications (e.g. combustors, seals, heat exchangers, radiant burners, etc). Cost is a major factor, and reduced costs associated with improved process control will facilitate the commercial application of CMCs. Reduced cost is also expected to result in the development of additional commercial applications.

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2. “In-situ Control of Chemical Vapor Deposition for Fiber Coating,” J. G. Jones, P. D. Jero, and P. H. Garrett, Engineering Applications of Artificial Intelligence, vol. 11, p 619-626 (1998).

KEYWORDS: Chemical vapor deposition, Process control, Sensors, Fiber coatings, Ceramic matrix composites

AF01-127 TITLE: <u>Non-Destructive Recognition/Prediction of Structural Corrosion Damage</u>

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Interpretation and Management of NDI Data for Corrosion Damage Assessment and Maintenance Management.

DESCRIPTION: The requirement exists to analyze the effect of present corrosion damage condition, as interrogated by an appropriate NDI technique or techniques, on the structural integrity of the component being examined. Further, we seek to analyze the effect of time on uninterrupted structure, as well as the effect of alternative repair options on current and future aircraft condition is needed. Key to the utility of this predictive capability is the interpretation and management of the NDI corrosion damage assessment. A “snapshot” of corrosion condition, which can be used to make current corrosion management decisions and can be archived for PDM planning and as baseline for future damage assessments, is desired. We need to recognize the significant corrosion feature from the “snapshot” provided by NDI assessment, convert it into a structural metric and utilize that metric in a predictive corrosion tool. That tool will ultimately support the aircraft maintainer as he makes structural integrity assessments, establishes inspection and PDM intervals, and evaluates the life cost impact of alternative repair decisions. This technology will enable safe, cost effective maintenance decisions to be made. After a repair action (if any) is made an additional NDI image would be attained and archived providing the documentation that is necessary for predictive tail number management. The structural consequence of the repair can then be assessed as this ‘post repair’ snapshot is fed into the predictive corrosion/structural integrity analytical tool.Effort is needed to map NDI interrogation of corrosion damage to representative corrosion damage features appropriate to feed the structural integrity code by structural detail. Emphasis should be placed on automated interpretation of the NDI output into metrics that can be recognized by the structural integrity code (e.g., initial discontinuity state, equivalent flaw size and topographical profile, as appropriate). Methodology for data management supporting tail number management is a supporting technology necessary for implementation of the product of this effort. Hidden structural features and multiple layer details are a priority and must be addressed as a part of this program.

PHASE I: Programs in this area should address the objective of the proposed effort described above, as well as initial demonstration, and experimental validation required for proof of concept. It is expected that automatic interpretation of NDI data created from analysis of complex or hidden structure using available NDI technology will be demonstrated on a limited number of aircraft structural components. The phase one product is a demonstration that will necessarily include: data intake from typical ndi spectra, image/data analysis to identify and quantify relevant damage features present in the structure, correlation of ndi damage analysis to direct damage measurement, and quantification of damage features in a metric(s) relevant to structural integrity analysis. Example sample NDI data sets can be made available to those receiving a Phase I award.

PHASE II: The methodology from Phase I would be developed through optimization and scale-up efforts. An accurate assessment of both the scope of application and limitations of application of the scaled up product are necessary deliverable in Phase II . The range of NDI technologies for which the methodology has application, the precision of the analysis, the level of correlation with actual damage, and the extent of complex structure that can be analyzed successfully will be identified as part of that assessment. Use of service damaged components for verification of the methodology developed is required in this phase of the effort. The ability to archive and recall NDI inspection files for future analysis and damage tracking will be required as a part of the phase II product. The product of this phase of the effort will need to be compatible with USAF structural integrity analysis capability and maintenance documentation procedures.

PHASE III DUAL USE APPLICATIONS: Technology developed under this effort will have benefit in extensive government and commercial applications. Protection of structure exposed to environment is of key concern to any number of institutions, both in the private and government sector. Evaluation of damage, without destruction of the article being interrogated All transportation industries, construction industries could benefit from the ability to understand and predict corrosion damage.

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2. M. P. Connolly, "A Review of Factor Influencing Defect Detection in Infrared Thermography: Applications to Coated Materials," Journal of Nondestructive Evaluation, Sep 01, 1991, vol. 10, n 3, p. 89-96.

KEYWORDS: Corrosion damage, Nondestructive inspection, Neural nets

AF01-128 TITLE: Up Conversion Photochemical Methods for Non-Autoclave Fabrication

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Nonlinear absorption processes (e.g. two-photon or sequential absorption) for photoinitiated cure of polymers.

DESCRIPTION: The goal of this program is to determine the feasibility of a new polymer processing/manufacturing technique: up-conversion photochemical methods for non-autoclave fabrication. This technique could potentially be utilized for flight line repair of Radar Absorbing Material (RAM), Radar Absorbing Structure (RAS) and gap treatment material. Significant advantages may be realized such as reduced Maintenance Man Hours per Flying Hour (MMH/FH) because of the advantages of this novel processing technology, which include the potential "portability" and spatial control, short cure times, as well as enhanced depth of cure relative to conventional photochemical processes.Two-photon chromophores undergo a process called two-photon absorption in which light is absorbed in the infrared wavelength range and initiates photochemistry using either the two-photon excited molecule or its up-converted visible/ultraviolet fluorescence emission. These processes are referred to as two-photon absorption or sequential absorption. One type of photochemistry for which the two-photon up-conversion process can be used is photopolymerization. The subsequent fluorescence or excited molecular state can be used to induce photopolymerization. Most organic systems have lower attenuation in the near-infrared (NIR) range therefore, NIR light can penetrate much deeper into organic materials and initiate photocuring throughout the resin. Thus, it is possible to photocure objects thicker than those fabricated with traditional ultraviolet curing. Novel 2-photon organic chromophores developed in the Air Force Research Laboratory (1) and other laboratories exhibit large effective two-photon cross-section values, which provide efficient excited molecular states or visible light fluorescence required to accomplish photocure. The utilization of up-conversion photochemical processing provides a relatively new processing method for fabrication of structures ranging from precisely patterned nanostructures to thick structures (>1cm). This study is intended to evaluate the advantages and limitations of this new polymer processing technique, as well as demonstrate the feasibility for Air Force applications.

PHASE I: Screening of materials candidates will be accomplished in Phase I. Potential up-conversion chromophore and resin systems will be evaluated. The candidate chromophores will include 1-2 Air Force 2-photon chromophores and, resin candidates must include at least one elastomeric system. A test matrix will be developed to identify the most promising formulations. The figures of merit to be used in the evaluation of the materials systems include: polymer thickness, extent of cure, homogeneity, laser power thresholds and integrity of the specimens, as well as a preliminary study of the feasibility of the technique especially in the presence of filler particles.

PHASE II: The expectation for Phase II is that the top 2-4 chromophore/resin candidates from Phase I will be developed to demonstrate the potential of the new technique. End products will include a feasibility study of the technology, analysis of the cure process, evaluation of polymers cured using this technique versus cured with traditional techniques and the production of a variety of polymeric structures. Figures of merit used to evaluate this program will be similar to those in Phase I. If feasible the technique will be used to produce a polymeric "gap sealant". The potential use of a portable laser system to accomplish cure will be explored to demonstrate minimum energy requirements. It is possible that the small business may partner with a commercial polymer manufacturing company to fully evaluate the potential of two-photon assisted photocure.

PHASE III DUAL USE APPLICATIONS: This a viable technology for flight-line repairs, where repairs of damaged structures could be accomplished virtually anywhere. Repairs could be accomplished by simply applying the resin system in the section of the plane requiring a "patch" and exposing the resin to a laser light beam to complete the cure and form a polymer bond. The polymer-manufacturing sector of the commercial industry could greatly benefit from the development of a new polymer processing technique. Polymer structures could be formed "on the fly" and polymer structures of any length and width could potentially be fabricated in place by applying resin to the desired area and curing with a laser light source. Polymer manufacturing applications can be envisioned as potential spin-offs.

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KEYWORDS: polymer, 2-photon absorption, 2-photon assisted photocure

AF01-129 TITLE: Application Techniques of Appliques for Aircraft Topcoats

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop and demonstrate application techniques of appliques to aircraft components.

DESCRIPTION: Traditional painting and stripping processes generate a tremendous amount of hazardous waste. The volatile organic compounds emitted in the painting and stripping process account for over 75% of all of the hazardous wastes generated by the Air Force. Advanced applique film materials have been developed that can eliminate a significant portion of these hazardous materials. One drawback of appliques is the lack of rapid, field and depot level applications techniques. Currently, all applique application to aircraft has been done with manual labor. Although the applique products are available in widths up to 48 inches, application has been limited to 24 inches due to limitation in manual application techniques. Although some simple tools have been used, specific techniques for applying appliques to complex contours, over fasteners, and methods for applying sealant to edge terminations must be developed and matured for reliable applications.

PHASE I: In Phase I the small business shall develop application techniques on representative sections or coupons representing aircraft components to demonstrate application techniques for applying appliques. The small business shall identify a commercially available applique film product for application technique development. The small business shall develop application procedures and techniques including methods for large area application, application over fasteners, around complex curvatures, and edge sealant application. The small business shall demonstrate at least two of these techniques on a small (roughly 10 ft2) sub-component to demonstrate feasibility in Phase I.

PHASE II: In Phase II the small business shall further develop and characterize the application techniques derived from Phase I. Development of improved designs for application tools and modifications to the applique film shall be performed to reduce the labor related cost and time associated with application of these materials. Characterization shall include evaluation of the applique performance after exposure to typical aircraft environment (ultraviolet radiation, hydraulic fluids, kerosene based fuels, cleaners, and damage). The small business shall demonstrate all of these techniques on a large sub-element representative of a military aircraft. The small business shall evaluate the application techniques demonstrated on the large sub-element in phase II for application time, cost, and performance.

PHASE III DUAL USE APPLICATIONS: The technology derived from this program is directly applicable to commercial applications. Reliable and repeatable application techniques will enable commercial airlines to adopt this process to significantly reduce their hazardous wastes associated with painting and repainting their fleet.

REFERENCES:
1. National Research Council (U.S.) Committee on Materials for the 21st Century, Materials research agenda for the automotive and aircraft industries: report of the Committee on Materials for the 21st Century, National Materials Advisory Board, Commission on Engineering and Technical Systems, National Research Council. IMPRINT: Washington, DC : National Academy Press, 1993.
2. Koleske, J. V., Paint and Coating Testing Manual: 14th Edition of the Gardner-Sward Handbook, American Society for Testing and Materials, 1995

KEYWORDS: Aircraft, Coatings, Applique

AF01-130 TITLE: Development of Low Weight Radar Absorbing Coatings

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop and demonstrate a lightweight, environmentally compliant binder system for radar absorbing materials.

DESCRIPTION: Radar Absorbing Materials (RAM) are used on some aircraft to reduce the radar return signal. A typical RAM is comprised of ferro-magnetic particles (or pigment) in a polymeric binder. These materials are applied either by spraying or as a prefabricated sheet. Spray RAM offers the flexibility to apply to a variety of complex shapes in a manufacturing environment but this material requires high levels of solvents for processability. Sheet RAM is processed outside of the aircraft manufacturing environment and is available adhesive backed or must be bonded onto the aircraft skin. While the environmental concerns are not as great with sheet RAM, both materials are relatively heavy (~1 lb/ft2 , ~5 Kg/m2) and this limits their application. Innovative approaches in binder formulation are sought to reduce the weight of conventional RAM by 50%. While the main contributor to the high weight of RAM is the ferro-magnetic particle, the binder system could be modified to reduce weight of the overall composite system. Additionally, new lightweight binder formulations that reduce hazardous materials and volatile organic compounds (typically solvents) would offer significant advantages in the manufacturing and field environments. Alternate ferro-magnetic particles/pigments or other radar absorbing concepts are not to be addressed!

PHASE I: In Phase I the small business shall select a commercially available RAM for use as a baseline system; this RAM may be either a spray or sheet product. The small business shall identify weight, hazardous materials (HAZMAT), and volatile organic compound (VOC) saving goals. The small business shall develop alternate binder formulations that address these goals; the highest priority is to address weight savings. Alternate ferro-magnetic particles/pigments or other radar absorbing concepts are not to be addressed! Formulation development trials with alternate binder chemistries, lightweight additives and innovative processing techniques shall lead to identification of several concepts for reducing the RAM weight by at least 50% through modification to the binder. The small business shall demonstrate at least two of these concepts through the formulation and processing of at least one square foot (~0.1 m2) of this lightweight RAM in Phase I.

PHASE II: In Phase II the small business shall develop and refine the concepts developed in Phase I; either a spray RAM or sheet RAM product shall be selected for further development. The small business shall perform additional formulation development to further reduce the weight, HAZMAT and VOC of the RAM. If the concept is a spray RAM product, the small business shall develop application techniques that incorporate the modifications developed in Phase I. The small business shall develop and refine spray techniques to apply the light weight spray RAM formulations. If the concept is a sheet RAM product, the small business shall investigate extrusion, roll forming, or other processing techniques to produce the light weight sheet RAM formulations. The small business shall characterize the selected concept formulation for resistance to humidity, water, heat, hydraulic fluid, and kerosene based jet fuel. The small business shall demonstrate the refined product on several large (~10 ft2, ~1 m2) complex shapes similar to aircraft structure (fuselage, wing roots, control surfaces). The small business shall deliver at least 5 gal (20 liters) of the spray RAM, or at least 50 ft2 (5 m2) of the sheet RAM to the Air Force for evaluation.

PHASE III DUAL USE APPLICATIONS: The technology derived from this program may be indirectly applicable to commercial applications such as electromagnetic noise shielding for electronics and avionics applications.

REFERENCES:
1. Jones, J., Stealth technology : the art of black magic, Blue Ridge Summit, PA : AERO, c1989.
2. K.J. Vinoy and R.M. Jha (Kalarickaparambil Joseph), Radar absorbing materials : from theory to design and characterization, Boston : Kluwer Academic Publishers, c1996.

KEYWORDS: Aircraft, Radar, Absorbing

AF01-131 TITLE: Ultraviolet Light Curing Materials for Field Level Composite Repair

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop processing techniques using ultraviolet energy for on-aircraft high quality repair of fiberglass composites.

DESCRIPTION: Field level repair of composite fiberglass aircraft structure generally requires an adhesively bonded approach to provide the load transfer and restore the original design strength of the composite laminate. These materials generally require freezer storage and have limited shelf life. Heat and pressure are required to cure the adhesive and patch materials and obtain a uniform, non-porous adhesive layer. The most common heating method for on-aircraft repair is using a heating blanket that is controlled by a programmable temperature controller. The heat blankets are a series of electrical resistance wires embedded in silicone rubber. There are several disadvantages to this heating method. Repair technical orders specify a curing temperature of adhesives and composites with a tolerance (e.g., ±10°F); however, due to thermally complex structures, achieving curing temperatures within the required parameters is often difficult. Also, heating large areas using heat blankets require large amounts of energy, which can easily exceed available power sources. Finally, time to repair aircraft structure can exceed 17 hours with up to 7 hour cure times depending on the materials cure requirements. Ultraviolet curing materials with high-quality high-strength bonds have advanced in recent years so that the repair time can be drastically reduced through a significant reduction in cure time (>50%). The method of heating does not require large amounts of power and should be adaptable to field level repair. With the advent of the Air Expeditionary Force concept within the Air Force, increased emphasis is being placed on quick reaction forces requiring minimal support equipment and materials not having short shelf lives or requiring environmentally controlled storage conditions. This technology appears to fit into this Air Force philosophy.

PHASE I: The contractor shall identify candidate prepregs and plain resin material systems and demonstrate processing procedures to achieve mechanical and physical properties with a decrease in repair cure time for fiberglass/epoxy and fiberglass/BMI laminates. The contractor shall demonstrate, at a laboratory scale, properties that are comparable to thermally cured prepregs and adhesives. Issues to consider include cure time, service temperature, shelf life, laminate thickness and power requirements. The repairs should be performable at temperatures between 40 and 120 degrees F.

PHASE II: The contractor shall refine and optimize the process investigated during Phase I. The repair process shall be demonstrated, and strength tested, on a US Air Force representative composite structure with equipment and skill level compatible to a field base location. The term process, when applied to the repair process is meant to include the basic repair procedures, any support equipment (i.e. UV lamps, vacuum bagging materials, etc.), and the environmental considerations they entail.

PHASE III DUAL USE APPLICATIONS: The process developed would be beneficial for repair of commercial aircraft radomes, engine cowlings, fuselage and composite flight control structures. Other uses include fabrication of and repair materials for automotive body repairs, fiberglass boats, electrical insulators, water softeners, connecting rods and spas/hot tubs.

REFERENCES:
1. Sennett, Michael S.; 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, ADA181256.
2. Smith, Novis; Livesay, Mark; and Castenada, Emiro, Field Repair of Composite Lightweight Armor, Sunrez Corporation, May 1988.
3. Miller, Kevin; and Walters, Kevin; Repair of Low Observable Composite Structures, Fourth DOD Composites Repair Technology Workshop Proceedings, 9-12 February 1998.

KEYWORDS: Composites, UV Curing, Repair, Processing

AF01-132 TITLE: Development of Improved Aircraft Thermal Protection Materials

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop thermal protection materials with improved durability, more reliable substructure attachment, and reduced thermal conductivity.

DESCRIPTION: Fibrous or foamed ceramic tile is used in certain military aircraft exhaust washed structure applications to protect the underlying polymeric or metallic structures from the high temperature (~850F and higher) exhaust flow. The tiles are very low density (porous) to reduce their thermal conductivity and typically employ a thin ceramic top coat to minimize moisture ingress and improve durability. The tiles are inherently fragile, leading to frequent damage and a significant maintenance burden. They are typically adhesively bonded to the substructure. Loss of a tile during engine operation can result in overheating of and significant damage to the substructure. Materials and processes are required which can survive the thermal and acoustic environment but are significantly more durable and can be more reliably attached to the substructure than current materials. The materials must be maintainable in the field. Reduced thermal conductivity is also desirable. Weight is an issue; the proposed approach should be comparable in weight to the tiles. The selected material should be low observables (LO) compatible.

PHASE I: Phase I will develop the proposed tile improvements or alternate approaches and test their physical and thermal properties in order to provide proof of concept. Coupons of the chosen material/structure should be fabricated and subjected to a suite of tests, to include durability assessment (e.g., impact resistance, abrasion resistance, etc), bond/attachment strength, and thermal conductivity. Material suitability should be evaluated based on the test results, as well as cost and scale-up issues.

PHASE II: Phase II will demonstrate the capability of the material/structure developed in Phase I by fabricating and testing complex parts representative of realistic components. The thermal and mechanical properties of the structure should be measured, and the shape capability, dimensional control, and process scalability quantified. Application issues such as attachment technique and moisture resistance (both effect of penetration on the structure [with regard to, for instance, bloating] and effect of exposure on mechanical properties) should be explored. Fabrication and testing (including attachment) should be iterated in order to optimize the materials and processes. One or more components should be tested in a hot acoustic environment to validate material capability.

PHASE III DUAL USE APPLICATIONS: Ceramic tile material is used in many commercial/industrial applications as thermal insulation. Poor durability is an issue. Improved durability will result in improved life and reduced cost. Also, ceramic tiles are currently used extensively on the space shuttle for thermal protection. Future military and commercial launch systems will require more durable thermal protection materials as well. Materials with improved durability are highly desirable for reduced maintenance cost and improved turn around time.

REFERENCES:
1. E. H. Moore and R. A. Smith, "Dust Erosion Testing of Coated AETB Tile for Aerospace Applications," Cer. Eng. Sci. Proc., vol. 19, [4], p 303-310 (1998).

KEYWORDS: Aircraft thermal protection materials, Ceramic tile, Thermal insulation4. Durable materials

AF01-133 TITLE: <u>Compliant Substrate for Compound Semiconductor Microelectronics</u>

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a silicon-based compliant substrate suitable for the epitaxialdeposition of compound semiconductors.

DESCRIPTION: Compound semiconductors offer a variety of material properties that enhance device performance over that provided by the elemental semiconductors, silicon and germanium. For example, integrated circuits based on GaAs and InP can operate at much higher frequencies and at lower power than those based on silicon. Also, photosensors and imaging arrays fabricated using HgCdTe and InSb are sensitive in portions of the infrared spectrum that are not covered by silicon. The problem with fabricating devices based on these compound semiconductors is that the substrates now used as a starting material are not only very expensive but also relatively poor in quality. For example, even GaAs substrates, which have been in production for many years have defect densities several orders of magnitude greater than silicon, cost at least ten times more. In addition, they are limited in size to 100-125 mm in diameter, whereas leading edge silicon wafers are 300 mm in diameter. Obviously, the very low cost and high quality of silicon wafers make them highly desirable as a starting wafer for compound semiconductor devices. Unfortunately, the mismatch between the crystal lattices of silicon and most compound semiconductors produce so much stress in the deposited device films that they fracture. Several attractive solutions to this problem have been proposed, including twist bonding [1], using a silicon-on-insulator (SOI) wafer in which the silicon film has been converted to SiC [2], and making the silicon film on the SOI wafer so thin (about 5 nm) that it can deform enough to accommodate the lattice mismatch. While the last approach would appear to provide the most universal solution to the problem, the challenge is to develop a method that is capable of producing a uniform, high quality SOI film as thin as required.

PHASE I: Demonstrate a method to produce a universal silicon-based compliant substrate suitable for the epitaxial deposition of device-quality, compound semiconductor films. Define a simple proof-of-principle device application for these compliant substrates, such as detectors, FET's or solar cells.

PHASE II: Develop the silicon-based compliant substrate fabrication method demonstrated in Phase I and use it to fabricate prototype substrates. Demonstrate the use of these compliant substrates for the epitaxial deposition of one or more compound semiconductors, such as GaAs or InP. Fabricate the simple devices proposed in Phase I. Characterize these devices to validate the compliant substrate as a starting material.

PHASE III DUAL USE APPLICATIONS: The availability of the compliant substrate will reduce the cost of compound semiconductor devices to the point that they would be used in a wide variety of DoD, commercial and industrial applications. High volume applications include terrestrial/space based high-speed communication circuits, infrared sensors, imaging arrays, and solar cells.

REFERENCES:
1. Ejeckam, F. E., et al., "Dislocation-free InSb grown on GaAs compliant universal substrates," Appl. Phys. Lett., vol. 71(6), p. 776, August 11, 1997.
2. Fathimulla, A., et al., "Growth and fabrication of InGaAs/InAlAs HEMTs on bonded-and-etch-back InP-on-Si," Second Int'l Conference On Indium Phosphide and Related Materials, p. 57, Denver, CO, 1990.
3. Steckl, A. J., et al., "The growth and characterization of GaN thin films on SiC SOI substrates," Journal of Electronic Materials, vol. 26, No. 3, p. 217, March 1997.

KEYWORDS: Microelectronics, IR sensors, III-V semiconductors, II-VI semiconductors, Microwave integrated circuits, Silicon-on Insulator.

AF01-134 TITLE: Improved Titanium Machining Process

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop innovative machining concepts to improve machining times and reduce the cost of machined components.

DESCRIPTION: Recent advances in the high speed machining of aluminum based materials have significantly reduced the cost of aluminum aerospace structure. However, titanium-based materials have inherently different machining characteristics which make high metal removal rates more difficult to achieve. Machining costs represent a major cost driver in the production of aerospace titanium components. Even with the drive towards the use of near net-shape processes such as castings and forgings, finish machining operations significantly impact finished part cost. In order to improve machining productivity and reduce finished product cost, new and innovative concepts are being sought which have the potential to significantly improve metal removal rates and machining efficiencies. In particular, specific opportunities are being sought in development of improved cutting tool and machining technologies that could significantly increase metal removal rates. Also there may be novel enhancements to other Ti machining methods including, but not limited to, laser and water jet machining processes. The Air Force is also interested in opportunities to develop machining processes concurrently with new net-shape fabrication processes such as castings and solid free form fabrication technologies to arrive at lowest final part costs.

PHASE I: The Phase I effort 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: The Phase II effort will be structured to develop and refine the concept developed in Phase I to the point where performance is physically demonstrated on a scale (i.e., a prototype component) to permit an evaluation of the improved machining process as compared to traditional machining in terms of cycle time, cost, repeatability, etc.

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.

REFERENCES:
1.De Lacalle et al. “Using High Pressure Coolant in the Drilling and Turning of Low Machinability Alloys”, International Journal of Advanced Manufacturing Technology 2000, vol. 16, no. 2, p. 85-91.

KEYWORDS: Titanium, Machining, Net-shape, Laser Machining, Water Jet Cutting

AF01-135 TITLE: Design of New Night Vision Goggle (NVG) Optics

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a form-fit-function replacement for the NVG lens assemblies that are optimized for the visible spectrum (400-700nm).

DESCRIPTION: Totally new helmet mounted device concepts have demonstrated the need for fast optical systems, f/1.2, optimized for performance in the visible spectrum (400-700nm). Typically NVG objective performance has been optimized for the near infrared (600-900nm) where these optical systems operate. Wide acceptability of the NVG format makes form-fit-function replacements ideal for any new helmet mounted device concepts. Some new helmet mounted device concepts require high transmission throughout the visible (400-700nm), well corrected optics throughout this wavelength range, and 40° field of view.

PHASE I: Develop and evaluate optical designs for optimized visible (400-700nm) performance that meet the requirements described above. Build prototype objective lens assemblies and characterize their optical performance. Deliver the final design optical prescription and at least four (4) objective lens assemblies built to this final design to AFRL/MLPJ for characterization and in-house testing. Develop and demonstrate a laboratory test system that incorporates these assemblies.

PHASE II: Develop and evaluate optical designs for both objective and eyepiece lens assemblies that minimize their weight. Build at least two (2) sets of the reduced weight assemblies, characterize them, and deliver them with the optical prescription to AFRL/MLPJ for characterization and in-house testing. Develop and demonstrate a field test system that incorporates these assemblies.

PHASE III DUAL USE APPLICATIONS: These optical lens systems could be used in a broad range of military and commercial applications where head mounted devices are used including next generation NVGs and direct view devices.

REFERENCES:
1. Military Specification MIL-L-49426 (CR), LENS ASSEMBLY, OBJECTIVE FOR AVIATOR'S NIGHT VISION IMAGING SYSTEM2. Military Specification MIL-L-49427 (CR), LENS ASSEMBLY, EYEPIECE FOR AVIATOR'S NIGHT VISION IMAGING SYSTEM

KEYWORDS: Night Vision Goggle, NVG, visible spectrum, optical system

AF01-136 TITLE: <u>Broadband LO NDE Sensor Technology (BLONDE)</u>

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop real-time broadband nondestructive evaluation technology to interrogate low observable materials and structures.

DESCRIPTION: With the advent of low observable (LO) radar technology and materials, it is becoming increasingly important to be able to perform fast, accurate evaluations and inspections of the low observable features on stealth aircraft structures. Thus as more and more low observable aircraft are fielded by the Air Force, new nondestructive evaluation techniques and tools will be required to keep these LO aircraft operational. The radar signature of low observable aircraft may be altered by any number of different types of damage occurring in flight or during routine maintenance and repair. A need exists to research and develop real-time broadband nondestructive evaluation technology to interrogate low observable materials and structures. As an LO maintainers NDE tool, the system must be easy to operate, hand-held, provide broadband (2-18 GHz) real-time, accurate and repeatable information, be flight-line operation compatible and simple to use. The system must be able to detect and locate damage to the low observable material and structure and quantify the electromagnetic materials properties of interest in the 2 - 18 GHz frequency range.

PHASE I: During Phase I, it is expected that a design for such a system as described above will be demonstrated in a laboratory, benchtop, prototype device. The subsystem level components of the nondestructive evaluation technology system must be functional and integrated to demonstrate the feasibility of the approach.

PHASE II: Once the basic approach and feasibility of the fully broadband system has been demonstrated, Phase II would focus on the integration and packaging of a benchtop prototype system to a system that could be evaluated in the field such as on real LO aircraft. The system software and hardware must be fully developed and tested. The system will be evaluated for its fidelity in measurements, repeatability, and accuracy of the measurements.

PHASE III DUAL USE APPLICATIONS: Due to the nature of the low observable technology limited to military purposes there are few identifiable dual use applications.

REFERENCES:

KEYWORDS: Low observable, Broadband microwave frequency, Stealth aircraft, Radar cross section

AF01-137 TITLE: <u>Strain Rate Effects in Ballistic Analyses of Bonded & Co-Cured Composite Structures</u>

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop methods for analyzing effects of ballistic and hydrodynamic loading on bonded/co-cured composite structures.

DESCRIPTION: Bonded structure relies on adhesive properties to transfer load, and is therefore susceptible to strain rate-dependent changes in stiffness and strength, especially in the adhesive. The effects on structural integrity of ballistic loading are not understood due to lack of tools capturing damage progression and failure mode behaviors of z-reinforced/non-z-reinforced bonded and co-cured materials in hydrodynamic ram analyses. An illustration of the importance of these issues to the Air Force is provided by the tens of millions of dollars per aircraft evaluation presently required by Live Fire Test &

Evaluation (LFT&E). A commercial software code (e.g., LS-DYNA3D, MSC/DYTRAN) can be modified to perform the required analyses, through an external module or vendor modification; in that case, a strategy for working with a software vendor should be documented in the proposal. A modest strain rate-dependent material property database (strengths and stiffnesses) over the range governing hydrodynamic ram (order of 100/sec) to direct ballistic impact (order of 10,000/sec) is required for the Phase II modeling; such data is extremely scarce, and its absence is thought to promote over-conservative designs. Z-reinforced and non-z-reinforced IM7/5250-4 and/or IM7/977-3 are the required materials systems; strain rate-dependent properties models, based on a modest database, for at least one of these systems (both z-reinforced and non-z-reinforced models are required) should be included in the Phase II product. Finally, validation is required for Phase II at a structural level.

PHASE I: Phase I shall develop software-based models for damage progression and failure of z-reinforced and non-z-reinforced material and structural concepts and demonstrate the suitabilities of the models for analyses of rate-dependent ballistic and hydrodynamic loadings. The resulting software and user's manual shall be contract deliverables. The offeror will demonstrate its present capabilities within the proposal. An ideal demonstration problem would feature composite materials, multiple sealed fluid-bearing cells, and hydrodynamic ram leading to failure; plots at critical locations of fluid pressure, displacements, and strains, vs. time, are suggested.

PHASE II: Phase II shall further develop the methods demonstrated in the Phase I contract, for the engineering design environment, and shall gather and/or generate strain rate-dependent test data as required for properly modeling the rate-dependence of both z-reinforced and non-z-reinforced IM7/5250-4 and/or IM7/977-3 materials. Test results from a structural level article incorporating z-reinforced joints, ballistic impact and hydrodynamic ram shall be required for model validation/modification purposes. The product should ideally be a software tool compatible with commercially available finite element codes. A software tool and user's manual shall be contract deliverables.

PHASE III DUAL USE APPLICATIONS: DoD applications are numerous (e.g., survivability of fixed-wing aircraft, rotorcraft, armored vehicles, surface marine craft and submarines, helmets, structure blast resistance; of course the hydrodynamic ram aspect of the work is not applicable to every example). This technology could also be applied to predict performances of: composites in automotive and commercial marine impact applications; composite body armor (e.g., improvements to Kevlar vests); composite reinforced armored vehicles (e.g., financial services, political figures and other dignitaries); law enforcement weapons to penetrate such protections; explosion survival of polymer and composite structures (e.g., automotive or marine fuel combustions, resistance of such or other structures to explosive devices).

REFERENCES:

1. Lewin, L. and Kari, S. E., "Simulation of Aircraft Wing Response to High-Energy Explosive Projectile", The ITEA Journal of Test and Evaluation, vol. 18, no. 3, September/October 1997.
2. Reid, John D., "Admissible Modeling Errors Or Modeling Simplifications?", Finite Elements In Analysis and Design, vol. 29 (1998) p. 49-63.

KEYWORDS: Ballistic impact, Hydrodynamic ram, Composite, Strain rate-dependent material properties, Bonded, Co-cured

AF01-138 TITLE: Development of Optical Host Materials with High Laser Damage Thresholds

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop dye compatible optical host materials that have high laser damage threshold.

DESCRIPTION: Polymeric materials are widely used as optical materials for low power laser applications because of their low cost, light weight, and ease of processing. Unfortunately, the use of these materials has not expanded to high power laser applications because of their low laser damage threshold. In this topic we are interested in research to identify optical host materials with high single and multiple pulse laser damage thresholds, investigate material structure-property relationships, and understand the mechanisms that give rise to increased laser damage thresholds. In addition to high laser damage thresholds, these materials must be highly transparent with good optical quality and serve as host materials for a variety of dye chromophores. The basic research to establish structure-property relationships should include at minimum synthesis, formulation development, processing, spectroscopic analysis, laser damage threshold measurements, microscopy, rheological measurements, and thermal analysis (including DSC, DMA, and TMA).

PHASE I: Identify and develop optical host materials with high laser damage thresholds at least an order of magnitude greater than PMMA. Deliver representative samples to AFRL/MLPJ for evaluation using in-house capabilities. In addition, establish preliminary structure-property relationships and investigate the mechanisms that give rise to increased laser damaged thresholds.

PHASE II: Establish detailed structure-property relationships of materials demonstrated in Phase I. Incorporate chromophores into these high laser damage threshold materials and optimize dye/host compatibility. Develop and demonstrate prototype high laser damage threshold materials with dye concentrations of at least 1mM. Deliver representative samples to AFRL/MLPJ for evaluation using in-house capabilities.

PHASE III DUAL USE APPLICATIONS: This technology has broad commercial and DoD applications including advanced optical components for high power lasers, solid state tunable dye lasers, optical data storage, and laser safety eyewear

REFERENCES:
1. Robert M. O'Connell, Terrence F. Deaton, Theodore, T. Saito, Appl. Opt. vol. 23(5) p. 682-688 1 March 1984.
2. A. Manenkov, G. Matyushin, V. Nechitailo, A. Prokhorov and A. Tsaprilov, Opt. Eng. vol. 22(4) p. 400-404, July/August 1983.
3. A. Butenin and B. Kogan, Sov. J. Quantum Electronics, vol. 16(10) p. 1422-1424, October 1986.

KEYWORDS: Optical host material, High laser damage, Threshold optical host material, High laser damage threshold polymers

AF01-139 TITLE: Solar Photovoltaic for Air Expeditionary Force (AEF) Deployable Shelters

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Demonstrate the feasibility of an innovative highly efficient, lightweight, and flexible solar photovoltaic suitable for AEF operations.

DESCRIPTION: The evolution of thin film photovoltaic technology as a replacement for conventional silicon photovoltaic has provided a gateway to future efficient, flexible, and cost effective power generating systems using solar energy as primary fuel. Use of 20% efficient flexible photovoltaic as cover or integrated into deployable shelters skin can provide enough energy to meet deployed bases' needs during the day. The major drawback to the use of existing photovoltaic technologies is cost and efficiency. Existing thin film photovoltaic can be categorized into silicon and CISG technologies. Both technologies yield poor efficiency (up to 10%) with high cost (as low as $4.00 per watt). The molecular photocell technology of the Graetzel Cell has the potential of 33% efficiency and a 40-cent per watt cost. A new concept is sought to develop lightweight, flexible, cost-effective, and efficient photovoltaic suitable for deployable shelters.

PHASE I: Develop and test a viable prototype to demonstrate the feasibility of the concept.

PHASE II: Develop an optimized prototype and field-test it.

PHASE III DUAL USE APPLICATIONS: A successful, efficient, and flexible photovoltaic material will have a multitude of commercial applications in addition to the bare base solar electrical generation. Solar homes and buildings are two potential applications.

REFERENCES:
1. O'Regan, B.; Grätzel, M. "A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO/sub 2/ films". Nature 1991, vol. 335, p. 737-40.
2. Grätzel; M. "Properties and Applications of Nanocrystalline Electronic Junctions" in Handbook of Nanostructured Materials and Nanotechnology, Nalwa, H.S.; ed., Academic Press , New York, 2000, volume 3, chapter 10, p. 527-552.
3. Bach,U.; Lupo, D.; Comte,P.; Moser, J.E. Weissörtel, F.; Salbeck, J.; Spreitzert H.; Grätzel, M. "Solid-state dye-sensitized mesoporous TiO/sub 2/ solar cells with high photon-to-electron conversion efficiencies" Nature, 1998, vol. 395, p. 583-85.
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5. Pichot. F.; Ferrere, S.; Pitts, R.J.,; Gregg B.A . "Flexible solid-state photoelectrochromic windows." J.Electrochem.Soc. 1999, vol.146, p. 4324-26.

KEYWORDS: Graetzel Solar Cell, Thin Film Photovoltic, Solar Power

AF01-140 TITLE: Processing of Tough, Fracture and Puncture Resistant Thin Films for Space Deployable Reflectors

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop processing methods for polymeric thin films with improved tear resistance for deployable optics applications.

DESCRIPTION: AFRL has demonstrated the feasibility of using 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. While small high quality polymeric reflectors are 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. In addition, the thin film tear resistance is unsatisfactory due to pin holes, scratches, and contaminants acting as fracture initiation sites, or tear resistance is poor due to puncture during deployment of the toroidal structural components. The purpose of this SBIR topic is to develop polymer processing and fabrication techniques for the production of very tough and puncture resistant, precision optical quality thin films (10 - 100 microns +/- 1%) which are parabolic in shape and possess a relatively small focal number (f # < 2), such that deployment will unfold the packaged film to yield the optically satisfactory shape. The films should possess a uniformly glossy surface with surface roughness less than 0.5 micron. This effort should focus on the processing of the tough reflector thin film using homopolymer and copolymer compositions as physical or chemical blends, fabrication processes for neat or reinforced systems, and metallization techniques. Material selection should consider stability in low earth orbit (atomic oxygen, ultraviolet, thermal cycling in eclipse), resistance to creasing incurred on polymer film packaging, resistance to creep deformation and impact from micrometeorite episodes. Consideration must also be given to the ability to scale the proposed processing and fabrication methods to large diameters (D > 8 meters).

PHASE I: The contractor shall develop processing schemes for the parabolic reflector material which result in improved tear resistance and fracture toughness in comparison to state-of-the-art polymeric materials. For the use of novel polymeric materials, the characterization shall include, but not be limited to, basic physical properties of the polymer, such as molecular weight determination and solution viscosity. Secondly, accepted test methods to determine the performance of the material in low earth orbit shall be employed. Characterization of the thermal and thermal analytical properties of any of the polymers proposed shall be conducted as well as profiling of the optical quality surface for planarity and surface roughness. Third, accepted test methods shall be invoked which evaluate the tear resistance, puncture resistance, and fracture toughness of thin films at low and high test velocities, similar in process to the deployment of the reflector structural supports at varying rates. Characterization of the perfection of the reflector’s parabolic shape shall be demonstrated on the prototype deployable parabolic reflector using precision optical test methods and computational analysis. Products of this Phase I effort shall be data and a proof of concept deliverable with a diameter between 10-25 cm.

PHASE II: Based on the results of Phase I research, the contractor should further develop the reflector processing methods to be implemented for the production of a mirror with a diameter of greater than one meter. The process model should be modified, as needed, to account for scale-up issues. The process should be altered, with guidance from the process model and characterization results, to yield the desired precision. Products of this Phase II effort shall be data and one deliverable with a diameter greater than one meter.

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, fracture toughness, parabolic films, tear resistance

AF01-141 TITLE: Life Cycle Performance Screening Methodologies for Composite Cryogenic Tankage

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop accelerated aging methods of advanced organic matrix composites for LH2 and LOX tankage applications.

DESCRIPTION: Lightweight advanced organic matrix fiber reinforced composite (OMC) cryogenic tanks for liquid hydrogen (LH2) and liquid oxygen (LOX) will be system-enabling in many future spacecraft applications. Space vehicles such as NASA's Reusable Launch Vehicle (RLV) and the US Air Force Space Operations Vehicle (SOV) will require very large cryogenic fuel and oxidizer tanks that must be fabricated from advanced composites in order to meet system performance objectives. A primary system requirement for these systems will be a long service life (> 20 years) with many cycles (> 100). No rational methodologies currently exist for experimentally investigating or validating the performance of OMCs in these severe thermal and fluid environments for the expected service life of the space vehicles. Material developers require a hierarchical approach to screening and lifetime evaluation that can be accomplished on various scales of material quantities.

PHASE I: Develop a hierarchical screening/exposure methodology for high performance structural composite materials exposed to fluid environment. Demonstration of expected service cycling methodology using a high performance structural composite material for non-mechanically stressed materials.

PHASE II: Extension of Phase I methodology to include applied mechanical stresses as well thermo-mechanical and chemical. Definition of critical evaluation methodology and demonstration using a variety of classes of candidate high performance structural composite materials.

PHASE III DUAL USE APPLICATIONS: Potential commercial space launch programs will all require a lifetime performance screening methodology for reusable vehicles.

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KEYWORDS: Composites, Accelerated Testing, LOX,. LH2, Cryogenic, Space Launch, Reusable Launch Vehicle

AF01-142 TITLE: Advanced Optical Coatings for Space Applications

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Design and develop more affordable optical coating processes.

DESCRIPTION: Space applications for optical coatings is very broad and diverse ranging from space-based deployable mirrors to antireflection (AR) coatings and optical limiters. AR coatings are used to optimize transmission of light between two dissimilar mediums, e.g., AR coatings improves quantum efficiency for silicon detectors in air as well as a vacuum (in space). Currently, single layer AR coatings are used, but while patterned multilayer coatings will improve quantum efficiency, the challenge is to develop processes to reduce costs. Multilayer/composite material systems are vital to protecting optical sensors in Air Force systems from jamming or laser radiation. Optical limiters and filters are the devices being developed for obtaining such protection. Many improvements over the current state-of-the-art limiter materials are necessary for practical use in systems, especially, space sensor systems. Of interest is the discovery of new processes to enable more cost-effective thermochromic materials which have improved optical switching and transmission performance for space sensor hardening applications. These materials undergo a metallic to semiconductor phase transition at a certain temperature (Tp) such that below Tp the material is transparent and above Tp it becomes opaque. The potential of thermochromic materials such as oxides of vanadium to provide infrared optical limiting has been demonstrated, but improved process yield and lower costs of materials with precise phase transition capability will enable more widespread application. The goal of this SBIR topic is to design and develop technologies for more affordable deposition of optical coatings to address the above identified applications.

PHASE I: Demonstrate the feasibility of enabling optical coating process technologies to enable processing cost reductions and more widespread use of deployable mirrors, AR coatings and optical limiters for space application. Processing results of one or more of the above optical coating specimens on various substrate materials will be necessary. Although stress caused by varying thermal expansion coefficients is usually of secondary importance, in space coating stress may be significant, and thus in situ process control of film-substrate interface stress and adhesion will be assessed.

PHASE II: Develop a prototype of an advanced optical coating process to demonstrate scale-up and validate more affordable optical coatings. Focus will be one of the above applications: deployable mirrors, AR coatings, or optical limiters. Thin face-sheet substrates should be first investigated to demonstrate the prototype's ability to accommodate precise monitoring and control of optical coating adhesion and stress. In addition, the objective in Phase II is to demonstrate the application of conformal coatings, e.g., optical coatings of polymeric deformable surfaces involving varying radii of curvature.

PHASE III DUAL USE APPLICATIONS: Space Mirror 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 large area deposition processing capability to produce more affordable optical coatings with high reflectivity, low absorption, low stress optical coating is key to enable longer life from space mirrors.

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KEYWORDS: Thin Film Optical Coatings, Adaptive Process Design/Control Technologies, Deployable Mirrors

AF01-143 TITLE: Engine Component Life Management Technology

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Create engine life management technology for a geographically distributed pattern-driven information system.

DESCRIPTION: To extend engine life via knowledge/data management technology, data must be collected and organized to elicit patterns, anomalies and trends which may extend or curtail operating life. To enable such a capability, three types of data must be collected and analyzed: Process design data - which addresses processing conditions and results; in-use data - which contains the information relative to in-flight behavior and engine profiles; and lastly, test data which contains the component inspection results. If any of these types of data is missing, it is not possible to obtain a complete description of component life and impairs our ability to effectively manage component life.About 20% of all data generation processes are repeated due to a lack of data retention and analysis. To retain the value of the data there needs to be descriptive knowledge management capability for relating data from multiple sources, involving various methods of recovering patterns from the data which enable prediction of component life. This system would need to store the three types of data (manufacturing, in-use conditions and post process inspection) across production and multiple depot/field inspections and invoke feature saliency and pattern identification algorithms. This synthesized component life and life extension information would allow future field, depot and researcher personnel an opportunity to collaboratively determine where improvements could be made in the component manufacture and/or inspection.The goal of this SBIR is the development of web-based knowledge management technology. This technology would enable users to easily: 1) create new agents to extract information and knowledge from the data archive, 2) modify knowledge presentation, and 3) evolve both methods and presentation information to support component life extension decisions .

PHASE I: Demonstrate the feasibility of a descriptive web-based knowledge management system to provide the ability for users to access large datasets (up to 100,000 patterns comprised of over 1000 variables) using a web browser for data retrieval and visualization. Demonstrate autonomous access to the data archive by intelligent agents. Design an architecture for an evolving agent-based system for engine life management.

PHASE II: Create a web-based engine life management system that will enable users from various Government and Industry functional organizations (laboratory researchers, original equipment manufacturers, and logistics personnel) to invoke agents to analyze archived data to support their respective missions.

PHASE III DUAL USE APPLICATIONS: Engine life management technology can be utilized by manufacturing, research and operational personnel in managing large datasets. The research field can benefit from remote collaboration between research and manufacturing and/or operational facilities, i.e., in the future it will be far more cost effective to avoid duplicative data gathering and merge data to better design, operate and maintain high performance engine components. For example, researchers can use in-flight and inspection data to validate crack initiation and propagation theories as well as methods of materials processing. In the future collected data will be used to construct a virtual process and focus experimental research toward alternative or enhanced materials. In addition the intelligent agents may be designed to discover new methods of production and possible new processes. For manufacturing, the same problems apply. The time required to test new processing methods relate directly to down time on production machines. When the machine is not producing parts it is losing money. By using this knowledge management technology it will be possible to test out new upgrades to a process before actually taking that machine out of service.

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KEYWORDS: Intelligent Agent, Knowledge extraction, Process Discovery

AF01-144 TITLE: Qualifying Light, High-Performance Materials for Airborne Space-Based Laser Systems

TECHNOLOGY AREAS: Materials / Processes

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.Problem: 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:

KEYWORDS: chemical oxygen iodine laser (COIL), basic hydrogen peroxide (BHP), chemical decomposition

AF01-145 TITLE: Computational Materials Science

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop and commercialize, simulation and experimental techniques for reducing the time to implement new materials.

DESCRIPTION: The Air Force depends upon the timely development and insertion of materials to deliver technically advanced systems. However, materials development is time consuming and evolutionary. Modification and insertion of known materials into systems spans seven to fifteen years. New materials require even longer times for first use. Development and insertion proceeds by a protracted iterative sequence of processing materials or components, and experimental characterization and evaluation. Although new DoD systems historically drove materials evolution, for the foreseeable future fewer DoD systems are being built. A challenge for the 21st century is to shorten the materials maturation time and to insert materials earlier into systems. Use of a material stems from an aggregate of information making up a distributed ‘knowledge base’ describing the material’s performance benefits to a specific component, potential for affordable use over the component life cycle, and reliability when configured as a component. The knowledge base supports decisions in risk/payoff assessments, and currently exists largely through test and evaluation.Continuum modeling leads much of material processing research. Further, improvements in computational chemistry and materials science are beginning to impact material selections, structure description, and predicting mechanical-behavior. There is reason to believe that the time required to mature materials for use can be reduced through advances in theory, modeling and simulation. Therefore, new approaches are requested to establish material properties and processes through simulations and experiments explicitly linked in an engineering knowledge base required for use. Methods should not be solely ‘multi-scale modeling’; but rather, consist of modules which are generally applicable, robust, and linkable to an engineering knowledge base. Approaches may target integration of information across materials science disciplines forming a knowledge base; growth of fundamental capability for reliable simulations within or across disciplines; the architecture and representation of materials in a knowledge base; or, combinations of these. Proposed methods must allow linking to other models or to experiments, and be accessible in an industrial environment. Proposed efforts should focus on the following needs: Representing material performance, affordability and reliability information in an accessible knowledge base, irrespective of its origin in experiment or simulation.Commercialization of techniques which better capture key physics of material performance or processing, and accomplish linking of that information to other models and portions of the knowledge base.Commercial methods that validate simulation results through efficient key links to experiment, and quantitative descriptions of accuracy and uncertainty in the knowledge base.Given the evolutionary nature of materials and simulation methods, proposers may want to critically interrogate existing commercial capabilities, or gaps in existing capabilities, to define new approaches for the accelerated insertion objective.

PHASE I: This will focus on 1 or 2 well defined critical issues or uncertainties, which when successfully addressed, provide a deliverable proof of concept for the new simulation or experimental tool. This must include an early software/hardware demonstration, or a complete detailed description of how the new tool will be constructed, implemented, and affect shortening materials insertion time. This may also include working drawings, critical software modules or other tangible, proposer-defined proof of concept. Proposal should demonstrate reasonable expectation that proof of principle can be attained within Phase I, and that both commercial potential and commercialization paths exists.

PHASE II: This will be structured to develop and test the simulation/experimental method from the Phase I effort, such that a commercial simulation/experimental tool or object is made available. Proposers should expect that Phase II may result in delivering a commercialization plan and a working version of the tool, with documentation, to AFRL for use in the laboratory.

PHASE III DUAL USE APPLICATIONS: The developed approaches would have broad commercial applicability due to the large number of commercial air, space, and engine systems that have materials requirements of a very similar nature to those faced by the DoD. These methods are critical to affordable access to space for both the military and commercial sectors, where their use in development and transition of light-weight, high-temperature, durable propulsion, structural, and thermal-protection systems is critical, and continued advances in materials are anticipated.

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KEYWORDS: Materials Simulation, Materials Representation, Materials Insertion, Development Time, Computational Materials Science, Materials Performance Prediction, Materials Affordability

AF01-146 TITLE: Low-Loss, Environmentally-Rugged Fiber-Optic Blind Connector for the F-22 High-Speed Data Bus

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Achieve affordable, reliable fiber-optic backplane connections in harsh military environments.

DESCRIPTION: F-22 avionics employs a modular physical design wherein standard SEM-E modules plug into a backplane. At the rear of the module and hidden from view, three types of connections are made simultaneously: (1) an array of electrical pins, (2) a pair of hydraulic couplers for the passage of coolant fluid and (3) a "Robust Optical Connector" (ROC?) for the fiber optic interface. This modular approach using SEM-E's with blind connectors that snap into place supports a modern avionics maintenance philosophy. However, the ROC® used for the F-22 high speed data bus interface connection is failing when exposed to adverse environments. Signal loss events causing the failures are most likely attributed to some instability in the mechanical configuration of the "Robust Optical Connector" (ROC?) and/or chemical contamination. These losses are greatly aggravated by exposure to low temperatures. Possible factors contributing to the losses include: (1) mechanical misalignment of the sapphire lenses within the ROC, possibly induced by other system components, and (2) presence of stray Poly-Alpha Olefin (PAO) coolant fluid that attenuates light within the ROC?. There are no other connectors of this nature available that claim the environmental ruggedness necessary for the F-22. Developing innovative ideas on alternative means of accomplishing reliable optical connections would greatly benefit the F-22 and future systems requiring high speed data bus interfacing.

PHASE I: Identify and validate alternative optical connector configurations that will withstand harsh military environments. The Phase I technical work shall require that the present configuration be investigated and possible root causes identified. Alternatives may include redesign of the ROC connector itself, or other interface concepts and strategies—such as module-seating methods or use of active connectors. Alternatives shall be validated for their suitability in harsh military environments (such as airborne avionics) and their compatibility with modern maintenance approaches. Technical investigations shall be conducted to evaluate the merits of each approach. The most promising candidate shall be downselected, and a prototype configuration shall be demonstrated at the end of Phase I.

PHASE II: The prototype approach shall be developed further into a production worthy design and prototype. The effectiveness, reliability, reproducibility and affordability of the design shall be demonstrated in an environment equivalent to that of a military avionics system. These demonstrations shall include simulated cold start and combat conditions.

PHASE III DUAL USE APPLICATIONS: Produce affordable and reliable connector components for military and other commercial harsh environment applications. For example, commercial aircraft, like military aircraft, have sophisticated electronics systems, are deployed in almost all climates, experience similar altitude and temperature extremes, and require timely maintenance.

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KEYWORDS: Fiber Optics, High-speed Connectors, High-speed Optical Data Bus, Fiber Optic Cable, Optical Attenuation, Optical Efficiency, Index-matching Materials, Sapphire Lenses, Pigtailing

AF01-152 TITLE: Target Detection and Orientation with Advanced Short Pulsed Optical Components

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Adapt light-in-flight Techniques, diffractive optics, and high speed detectors for target detection and orientation determination

DESCRIPTION: Target detection and classification through the use of active imaging techniques is required for the next generation of short-range, high-resolution, high-speed fuzes. Active systems provide a high probability of detection and excellent countermeasure resistance against advanced surface and air targets. Component technology in the past has limited the ability to weaponize a practical active imaging target detection device that would be size, power, and cost compatible with fuzing applications. The particular interest is determining the exact orientation of the weapon relative to the surface of the target for terminal attitude sensing and aimpoint selection for electrically aimed kill mechanisms. A 2-pi steradian field of view is required with a complete volume update at > 1 kilohertz frame rate and a detection range >75 meters. There have been numerous recent advances in diffractive optics, high-power diode lasers and other technologies that may be applied to this problem. For example, flight techniques coupled with single photon noise equivalent high speed detectors might be used to provide a hybrid target detection and orientation determination capability in a small, rugged, low-cost package. Contributing technologies may include sub-nanosecond Q-switch components for picosecond laser and detectors with 100Khz and higher frame rates that have also become available. Depending on the technique chosen, the size and orientation of targets may be mapped by changes in the contours and converted into a 3D representation. Countermeasure resistance would be high with the ability to rapidly discriminate 2D from 3D surface elements. Aerosol penetration is another key feature of very short pulse active optical systems. High-speed detectors can also be used to investigate range binning versus frequency modulated ranging techniques. The effort will address both detection and classification of targets in the field-of-view and perform target orientation extraction.

PHASE I: The Phase I effort will be a thorough system feasibility study that may include limited proof-of-principle experimentation.

PHASE II: The Phase II effort will demonstrate a hemispherical detection and orientation determination concept for fixed objects (vehicles/buildings/storage tanks) with clutter and simulated multiple air vehicle objects in closing trajectory at up to 75 meter range.

PHASE III DUAL USE APPLICATIONS: This application has high use in the, navigation, mapping, landing assistance avionics, modeling/gaming/entertainment community, CAD, medical-surgical, collision avoidance, material handling, and automated manufacturing industries.

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KEYWORDS: Active Imaging, Fuzing, Contour Mapping, Active Sensors, Diffractive Optics, Target Classifications

AF01-153 TITLE: Micro Weapons

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Determine MicroElectro/Mechanical Systems capable of attacking components of Hard and Deeply Buried Targets

DESCRIPTION: MicroElectro/Mechanical Systems (MEMS) are making rapid technical advances despite being a relatively new technology. Defense related applications already include inertial navigation units, signal processing, sensors, weapon fuzing, integrated micro-optomechanical components, and radio frequency detectors. MEMS technology can provide several avenues (surveillance, detection, guidance and control, communications, transportation, etc.) to place at risk hard and deeply buried targets which conventional weapons cannot accomplish at this time. This effort would examine the state-of-the-art MEMS technology and identify an optimal method for developmental approaches of micro weapons for a variety of missions. Evaluation of approaches whose mission objectives are to survey, deny, disrupt, disable, destroy, provide intelligence, etc. of these deeply buried, high value targets. This effort would identify available MEMS technology to accomplish such mission objectives, technology gaps, and approaches to fill those gaps. Additionally, insertion and disbursement methods, perspective costs, risk, reliability, and effectiveness will be evaluated.

PHASE I: The Phase I effort would conclude with a final report evaluating 1) technologies capable of being currently weaponized, 2) technology areas for future focus, and 3) what combination of micro technologies would provide the most productive first demonstration with the ultimate goal to hold deeply buried targets at risk.

PHASE II: A Phase II effort would conduct this demonstration in a realistic operational scenario.

PHASE III DUAL USE APPLICATIONS: MEMS sensors could be injected or swallowed in humans or animals to monitor vital organ health indicators, track medication performance throughout the body, or even perform micro surgery. MEMS guidance and communications systems could navigate these systems to precise locations in the body and communicate performance data back to medical specialists. Additionally, miniaturizing electronics has reduced the size of computers from large rooms to desk tops whereas MEMS could reduce it from desk tops to wallet sizes and reduce the cost of each computer.

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KEYWORDS: micro, MEMS, deny, disrupt, degrade, destroy, hard targets, deeply buried targets

AF01-154 TITLE: <u>Performance Assessment of Penetrator Weapons</u>

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Non-invasive techniques to assess effectiveness of penetrator weapons on buried targets in various geologic systems.

DESCRIPTION: An innovative and cost-effective technique, based on physical scale-model testing at 1-g, is needed to evaluate the performance of the next generation penetrator weapons designed to destroy or neutralize underground structures. The sub-scale target, an engineered system, can be considered equivalent to an underground facility built using tunneling or cut-and-cover construction techniques in geologic systems with varying characteristics. The engineered system can be designed as a complex multi-level facility or simply a system of tunnels excavated at the same depth or elevation. The overburden thickness above a potential target can vary from only a few meters to several tens of meters. The objective of the mission is defined by the launched weapon penetrating to a desired depth, detonating or impacting, and producing shock waves impinging on the engineered system (tunnel). The success of the mission is defined by the ability of the penetrator weapon to generate ground shocks of large enough magnitude to cause structural damage. Similitude laws should be used to determine the relevant characteristics of the scaled-model geologic and engineered systems and those defining the size and type of weapons. Ground shock propagations may be able to be realistically simulated by matching the impedance characteristics of the material model and those of the natural ground in which the test beds have been constructed. The proposed effort is directed towards the development of experimental and analytical methods followed by a field test program for actual performance assessment and design optimization of conventional penetrator weapons for “sure kill” scenarios. Direct hit, near misses, and side-on loading resulting from penetrator attack scenarios need to be considered. Impingement may occur either sideways or towards the centerline of the underground facility to cause structural damage such as internal spalling of concrete support lining material. Damage assessment could be made using existing sensor technology such as ground penetrating radar integrated with differential GPS giving the resolution capability necessary to evaluate the shock wave propagation in a variety of geologic and engineered systems.

PHASE I: Define scaling relationship principals for physical modeling under normal gravity. Lay out procedures for scaling rigid body and kinetic energy penetrators’ size and characteristics. Define the lithology and stratigraphic columns through which the ground shocks from surface or near surface propagates. Define localized rockmass (fracture properties) to be modeled and saturation state. Develop procedure for test bed preparation and identification of instrumentation requirements. Define a simulation of the dynamic characteristics of the penetrator weapon-induced ground shocks with emphasis on penetration into the geologic system, reproducibility of load-rise times, duration, and intensity. Define scenarios for Phase II. Propose the sensor technology for geologic system characterization and damage assessment. Prepare a technical report describing the findings in the feasibility effort described above.

PHASE II: In this phase, findings from Phase I are to be used to conduct field scale experiments and analysis. Proposed sensors would be used to determine the degree of damage to the underground targets and establish the threshold for "sure kill" defining the objective of the mission. The final product should be a predictive empirical tool which describes mission success based on the site-specific characteristics of the geologic and engineered systems and for each type of the weapon used. The Phase II program should consist of, but not limited to, the following tasks: Identification of test bed locations at a US Air Force designated site with the desired geologic system characteristics. Formulation of specifics, mix proportion, for the material model with impedance properties similar to those of the host geologic system and with overall characteristics representing those of full-scale at geometric and strength scale factors of 20:1. Identification of the engineered systems, i.e., design drawings and specifications of the underground structures of interest for physical modeling. Construction of test beds with associated and embedded instrumentation scheme. Fabrication of the penetrator weapons (rigid body and kinetic energy units) based on findings from Phase I. Assessment tests for concept validation, performance evaluation of instrumentation schemes, and overall system response evaluation. Preparation of a technical report describing the findings and preparation of a field-test plan.

PHASE III DUAL USE APPLICATIONS: Understanding the ground and penetrator interaction will provide a cost-effective approach for development and performance prediction of weapons which can benefit the commercial sectors (manufacturers) and the Air Force. The use of non-invasive sensors for sub-surface exploration can benefit the military and also the construction industry in determining both existing and required strength of underground civilian structures with respect to natural forces such as earthquakes.

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2. DTRA (DNA) Publications on scale-Model Testing.
3. Three-Dimensional Analysis of Penetration into Geological Media. ADA318759
4. Ito, Y.M., et al., "Influence of Models on Ground Shock Environments," Technical Report SL-86-47, U.S. Army Engineer, Waterways Experiment Station, Vicksburg, MS, December 1986.
5. Ito, Y.M., England, R.H., and Nelson, R.B., "Computational Method for Soil Structure Interaction Problems," Computer and Structures, Vol. 13, No. 1-3, pp. 157-162, 1981

KEYWORDS: Penetrator Weapons, Geologic Features, Underground Targets, Bomb Damage Indications, Battle Damage Assessment, Ground Penetrating Radar, Differential GPS

AF01-155 TITLE: <u>Innovative Methods for Bonding Large Scale Sections of Tungsten Alloys</u>

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop innovative bonding materials, concepts and processes for production of large tungsten hard target penetrators.

DESCRIPTION: New and innovative large-scale tungsten alloy bonding methods, concepts and processes are required in the area of air delivered non-nuclear munitions. Additionally, the bonding development should have a high commercialization potential. Current methods for tungsten alloy manufacturing are generally limited by part length, height, weight requirements placed on it by the "Liquid Phase Sintering" processing furnace. These restrictions limit the production of tungsten penetrators to only small-scale units. In order to obtain full-scale penetrators, creative bonding processes must be investigated and devised so tungsten can be utilized to it's fullest potential. Alternative bonding methods include but not limited to interface bonding material and bond interface zone melting. Once instituted, the tungsten penetrator should be capable of up to 3X increase in penetration performance over steel penetrators. The newly developed concepts and processes must consider cost reduction and improved performance. Additional areas of manufacturing research that must be considered along with bonding are control of slump, porosity, tungsten particle "settling" and quality control.

The necessity for improvements is apparent as hard target penetrator production costs continue escalating and targets are further hardened. Military uses include bombs, penetrators, sub-munitions, warheads, projectiles, etc. Commercialization applications include ballast for aircraft and x-ray shields.

PHASE I: Investigate new and innovative bonding methods, concepts and processes for producing full-scale tungsten penetrators. Develop methodology for the proposed processes and establish control parameters. Demonstrate that procedures are reproducible, flexible and yield anticipated results.

PHASE II: Develop and demonstrate that the proposed bonding methods, concepts and processes are valid and that the results are equal or better than currently produced tungsten parts. Develop mechanical properties database for development and production of one-quarter to one-half scaled prototype penetrators. These prototypes will be used to verify that the bonds have sufficient strength and ductility and that the bonding process is robust enough to justify further developmental testing.

PHASE III DUAL USE APPLICATIONS: This exploratory development program has extremely high utility for both the military as well as the commercial sector. Military tactical program objectives of increased penetration and reduced costs will benefit from the improved mechanical properties. Military aircraft developers will have greater latitude in design of weapon bays and deployment options by utilizing smaller, more efficient weapons. Commercial tungsten users such as aircraft manufactures and producers of x-ray shields will have new bonding processes available for new designs that are more efficient and cost effective.

REFERENCES:
1. German, R.M., "Liquid Phase Sintering", 1985 Plenum Press, New York.
2. Penrice, T. W., "Developments in Materials for Use as Kinetic Energy Penetrators", Powder Metallurgy, Defense Technology, Vol. 5.
3. German, R. M. and Hanafee, J. E., "Processing Effects on Toughness for Liquid Phase Sintered W-Ni-Fe", Processing of Metal and Ceramic Powders, German, R. M. and Lay, K. W., (eds), The Metallurgical Society, Warrendale, Pa., 1982.
4. "Warhead Penetrator Materials", (AED-91-012), Army Armament Research Development and Engineering Center, Picatinny, NJ.
5. "Properties of Tungsten Base Alloys for Penetrators", DAOBOO41, Frankford Arsenal, Philadelphia, PA.

KEYWORDS: Liquid Phase Sintered (LPS) Tungsten, Bonding, Eutectic Alloys, Induction Bonding

AF01-156 TITLE: Munitions Research

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop innovative concepts in areas associated with air-deliverable munitions and armaments.

DESCRIPTION: The Air Force Research Laboratory Munitions Directorate's mission is to develop, integrate, and transition science and technology for air-launched munitions for defeating ground-fixed, mobile/re-locatable, air and space targets to assure the preeminence of US air and space forces.
a. The Assessment and Demonstrations Division is seeking new and innovative ideas for future weapon integrating concepts, such as urban combat weapon, close air support weapon, low cost miniature cruise missile, counterproliferation weapon, time-critical target defeat, functional defeat of hard targets, limited collateral damage weapons, and Bomb Damage Indication/Battle Damage Assessment (BDI/BDA) systems. Technologies under consideration include weapon design, innovative flight controls and range extension technologies, compressed carriage and dispense technologies, micro technologies, munition borne and munition deployed BDI/BDA sensor, processor, and transmitter technologies, and integrated subsystem techniques. 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 system-level

analysis for theater- level modeling. New concept and innovative tools are sought for system-level 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
b. The Advanced Guidance Division seeks new concepts in areas associated with closed-loop guidance of autonomous munitions including inertial sensors, antijam GPS, and terminal seekers, including electro-optical (I2R and LADAR), millimeter-wave, and synthetic aperture radar seeker technology, and the components thereof, and the signal/image/data processing used in such areas. Algorithm/software concepts of interest include (1) guidance software, including guidance laws, estimators, autopilots, and AJGPS software, (2) innovative signal and image processing algorithms for use within autonomous target acquisition (ATA) applications, and (3) operations/functions associated with the ATA process involving noise elimination, detection, segmentation, feature extraction, classification, and identification. Algorithms capable of processing/fusing multi-sensor data are of interest. Fundamentally new approaches to closed-loop autonomous guidance based on biomimetic principles are of particular interest.
c. The Ordnance Division is seeking new and innovative ideas/concepts to support the development of advanced warheads, fuzes, and explosives for use in air-delivered conventional munitions to defeat ground, mobile, air targets, as well as above-ground and buried structures. Technologies developed should ultimately result in new and innovative components which are needed to meet the complex future munitions requirements for general-purpose bombs, penetrating warheads, submunitions, safe-arm-fire devices, explosive detonators, explosives and advanced energetic materials, and devices for collecting data to be used in warhead design and analysis. Technologies for defeating weapons of mass destruction, including biological and chemical agents, and/or access denial to stored weapons, are of interest.

PHASE I: Determine the technological or scientific merit and the feasibility of the innovative concept.

PHASE II: Produce a well-defined prototype product or process.

PHASE III DUAL USE APPLICATIONS: a. 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.

b. Commercial dual use applications for these guidance technologies include sensors, processors algorithms applicable to medical imaging, commercial aviation (adverse weather penetration), remote sensing and surveillance.

c. Commercial dual use application for these ordnance technologies include facility/plant security and monitoring, high speed wireless data transmission, micro-electrical mechanical devices for controls and collision avoidance, high powered energy storage devices (capacitors and batteries) and environmentally responsible recycling of energetics and other materials.

REFERENCES:
1. AFRL/MN Home Page: http://www.mn.afrl.af.mil

KEYWORDS: (a) demonstration, assessment, airframe, munition, simulation, weapon(b) terminal guidance, autonomous guidance, automatic target recognition, precision guided munitions, sensor technology, seeker technology, autonomous target acquisition, signal and image processing, pattern recognition/classification, image understanding, artificial neural networks, fuzzy logic, superresolution, knowledge- and model-based vision, data fusion, biomimetics(c) target detection; hard target defeat; warheads; explosives; fuzes; safe, arm, fire devices; nanoparticles; simulation; chemical neutralization.

AF01-157 TITLE: Advanced Laser Research for LADAR Munition Seekers

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop new lasers for use in imaging LADAR systems for munition seekers

DESCRIPTION: Increasing emphasis is being placed on the use of two dimensional focal plane array (FPA) detectors 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. Lasers in the near to mid-IR atmospheric windows (between 1-5 micron) with 10 to 100 Hz PRF, greater than 10 MW peak power, and pulse width in the neighborhood of 1 to 15 ns are needed. We are primarily interested in low cost, high efficiency, compact laser designs. Efficient, high peak power lasers at eye-safe wavelengths (1.5 to 5 micron) are of particular interest. Laser systems should be capable of implementation in seekers for small autonomously guided airdropped munitions where space and available power are severely limited. Proposals should address low-cost, low-maintenance thermal management techniques suitable for munitions. Systems that allow stable lasing for up to 30 minutes before shutdown are needed. However, 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 modeling, construction, and experimentation with critical elements of the proposed design. The investigation results will 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 transmitter based upon the design developed in Phase I. The laser should be appropriate for use in a breadboard LADAR system in a research laboratory environment.

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.

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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. 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.
6. AFRL/MN Home Page: http://www.mn.afrl.af.mil

KEYWORDS: Laser, Laser Radar, LADAR, Munitions, Imaging, Laser Ranging

AF01-158 TITLE: Lattice Fin Manufacturing

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop and evaluate affordable lattice fin manufacturing processes.

DESCRIPTION: Increasing weapon loadout on current and future weapon delivery platforms remains a key focus area. While there have been many attempts to produce a compressed tailkit with reliable fin deployment, it remains a challenging problems. Although the planar fin design have been the primary candidate for compressed carriage, the lattice fin design is a revolutionary concept with benefits that far exceed the planar fin technologies. With the first U.S. lattice fin demonstration scheduled for 3QFY00, the lattice fin will become a leading contender for future compressed carriage weapon configurations. Some of the unique benefits provided by the lattice fin include very low hinge moments that reduce power requirements an packaging size, robust find deployment based on the forward fin-fold design, and excellent high alpha characteristics.

The manufacturing cost of lattice fins remains an issue. To minimize the lattice find drag the internal web thickness must be on the order of 0.008” for a 250lb-class weapon. The current manufacturing process, Electrical Discharge Machining (EDM), results in fin cost of $1200. The lattice fin material and the manufacturing process must both be evaluate to make the lattice fin an affordable option. The affordability of the lattice fin should be baselined against the planar fin on both a fin-to-fin cost basis, as well as on the cost of an integrated Control Actuation Systems (CAS). Although the actual lattice fin cost may be higher, the cost of a CAS with lattice fins may be less due to reduced actuator sizes and smaller systems battery requirements.

PHASE I: Phase I would include the evaluation of various materials including composites, as well as alternatives to the current EDM manufacturing process. Affordability should be a primary consideration.

PHASE II: Phase II, if awarded, would include lattice fin fabrication using the manufacturing techniques identified under Phase I and testing to evaluate the resulting fin structural integrity and performance.

PHASE III DUAL USE APPLICATIONS: Information gathered could extend to high-strength honeycomb composites with unique applications to light weight-low cost aerodynamic control surfaces. The manufacturing technology generated from this effort may be applicable to reducing the costs of fabricating the complex airframe structural pieces that depend on honeycomb design. Significant manufacturing cost reductions could also make the strength-to-weight benefits of composite honeycomb structure widely available to the automobile and pleasure boat industries.

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3. AFRL/MN Home Page: http://www.mn.afrl.af.mil

KEYWORDS: Lattice Fins, Missile Fins, Control Actuator System, Honeycomb Composites, Electrical Discharge Machining, Aerodynamic Control Systems

AF01-160 TITLE: Micro Electro Mechanical System (MEMS) Scale Deposited Energetic

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Determine the feasibility of constructing an energetic material integral to MEMS and demonstrate usable devices

DESCRIPTION: Many existing MEMS developments are underway that propose to combine some type of energetics materials that would eventually deflagrate (burn) to provide work (pressure, thrust, etc.) or to initiate a detonation train. Current methods of manufacturing ignitionable energetics (e.g., slurring, pressing) are not compatible with MEMS fabrication methods. The goal of this effort is to determine the feasibility of constructing energetic material(s) integral to MEMS devices such that sustained ignition by low energy heat or light stimuli is achieved. When ignited, the output must be capable of being contained by the MEMS scale device sufficiently to perform its function.

PHASE I: Develop and investigate the feasibility of proposed concept(s). The investigation should include construction/fabrication techniques, initiation techniques and associated energy levels and proposed work output (thrust, detonation, etc.).

PHASE II: This phase would consist of design, fabrication and test of a sufficient number of devices to demonstrate its applicability to military usage. The test must include functioning and output measurements over the temperature range of -65F to +160F.

PHASE III DUAL USE APPLICATIONS: Next generation automobile airbags, blasting caps, detonators, and explowively driven piston motor applications would benefit.

REFERENCES:
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2. "Behavior and Utilization of Explosives in Engineer Design" Proceeding of 12th Symposium March 1972 - Sponsored by New Mexico Section, American Society of Mechanical Engineers and the University of New Mexico College of Engineering.
3. AFRL/MN Home Page: http://www.mn.afrl.af.mil

KEYWORDS: Initiators, detonators, explosive loading, MEMS, primary explosives, secondary explosives

AF01-161 TITLE: Novel LADAR Signature Exploitation for Obscured Target Environments

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Iinvestigate LADAR signature properties that can be exploited to detect targets in obscured environments.

DESCRIPTION: Laser Radar (LADAR) autonomous target acquisition (ATA) research has focused on the range channel. This is because of the predictable and invariant signature. However, in a highly obscured environment, the shape signature will be less reliable as a discriminant. Targets hiding behind opaque objects such as buildings will be detectable by LADAR seekers only to the extent that they may only be partially occluded. In these situations, the shape-based ATA algorithms can be trained to detect partially occluded targets. However, there are other obscurants that are only partially opaque to the LADAR sensor, e.g. targets hiding behind or under trees or other natural clutter. In these environments, the target signature will be occluded in a statistically random fashion depending on the density of the occluding foliage. In this environment, some pixel returns may be completely obscured by foliage, some only partially obscured, and some pixels entirely unobscured. In areas of very dense foliage, the shape-based ATA algorithms may become ineffective due to the occlusion. In these situations, a LADAR seeker may have to exploit other target signature constituents that provide additional discriminating capabilities. Obvious candidates are return intensity and texture. Less obvious signature constituents may also be available for exploitation. The purpose of this topic is to solicit proposals outlining innovative ideas for solving this problem. The eventual military use for this concept is for real-time, autonomous target acquisition using a relatively small and inexpensive autonomous weapon system. Overall volume for the operational seeker system (LADAR sensor, optics, electronics, processor, etc) will be less than one cubic foot. The contractor is expected to understand the significant constraints this places upon the architecture of any fielded system. For this reason, the proposed concept must be consistent with the prospect for eventual packaging in such a confined volume.

PHASE I: The contractor will investigate his proposed concept(s) for suitability in detecting obscured targets. A program schedule and plan will be generated to outline the research approach and to identify milestones and decision points. The contractor will develop a preliminary design for his concept(s) and will propose and conduct analyses, simulations, and / or basic laboratory tests to confirm the concept viability. A preliminary concept of operation will be developed to describe how the concept(s) might be utilized in the commercial sector as well as in a weapon system. The contractor will generate an initial component development roadmap outlining the technological improvements that might be necessary to develop the concept(s) for integration into an autonomous weapon system. The end product of this effort will be a report documenting the research activities, test results, and conclusions. Favorable research results will justify development of a Phase II proposal.

PHASE II: During Phase II, the contractor will continue to develop and refine his concept(s) and demonstrate its capabilities. A demonstration system will be built to collect data to demonstrate the utility of the concept. The system need not be tactically sized nor operate in real-time, but the concept must be compatible with eventual arrival at these goals. The contractor will update and revise, as appropriate, his preliminary design, preliminary concept of operation, and initial component development roadmap. The end products of this effort will be: (1) a report documenting the research activities, test results, and conclusions; and (2) copies of collected data.

PHASE III DUAL USE APPLICATIONS: A contractor's concept could possibly prove useful in government and commercial remote sensing applications, in law enforcement applications, in medical imaging and diagnosis applications, in robotics, and in other "computer vision" applications.

REFERENCES:

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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. C. G. Bachman, "Laser Radar Systems and Techniques", Artech House, Boston, 1979.
4. AFRL/MN Internet Web Site – http://www.mn.afrl.af.mil
5. Eglin Air Force Base Internet Web Site – http://www.eglin.af.mil

KEYWORDS: LADAR, laser radar, ATR, automatic target recognition, ATA, automatic target acquisition, target detection, occluded target, sensor fusion, obscured target, signature, range, intensity, amplitude, sensor, target, munition, smart munition, algorithm, laser ranging, laser applications

AF01-166 TITLE: Munition Bomb Damage Indication (BDI)/Battle Damage Assessment (BDA) Technologies

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop technologies for munition borne and munition deployed sensors for BDI/BDA

DESCRIPTION: Today's autonomous munitions are providing to be an effective means for prosecuting an air war. Standoff cruise missiles are used to opening days of the war and short time duration contingencies. INS/GPS guided bombs have the potential to be the general purpose workhorse for future air campaigns. As a result of these autonomous munitions, direct overflight of the target is not required and aircraft loss rates have dropped dramatically. However, BDI is becoming more difficult with autonomous munitions. “Gun camera” imagery is not available from the delivery platform. High overhead imagery is either not available or is unable to discern target damage, especially for buried targets. The recent Kosovo operations demonstrated increasing need for BDI/BDA associated with INS/GPS munitions. The percentage of unknown results for INS/GPS munitions was three times that for traditional laser guided bombs. The prospects for the future could be even worse with the advent of miniature munitions which will provide even less visible damage to the target. Without improved BDI, targets will be reattacked unnecessarily requiring more sorties, munitions, etc. This may limit our ability to become a true expeditionary air and space force.Munition borne and deployed sensors can provide valuable data for BDI/BDA without overflight by valuable manned aircraft or UAVs. Weapon impact location, function, pre- and post-impact imagery are examples of information that could be made available. Retarded/loitering munitions could provide long duration imagery and/or sensing for BDA. Target characteristics and contents may be discernable for buried targets. Probabilistic and/or statistical algorithms could be used to support restrike decisions. Future munition concepts could be BDA information “in the loop” for attack decisions. Additional technology investments are necessary to realize BDI/BDA potential. To date only small investments have been made in fuze function recovery and munition deployed cameras. Further research is required for sensor, munition integration, assessments, and data links/data processing. For this effort, the focus will be placed on Bomb Damage Indication of Hard Target defeat.

PHASE I: In Phase I feasibility concept designs for munition borne sensors shall be explored. The concepts should be examined in sufficient detail to insure survivability of munition’s impact, penetration and detonation/explosive events. The feasibility concepts should address the ability to record fuze function and parameters associated with determining weapon effectiveness for Hard Target defeat. In addition, the feasibility concepts should address techniques for transmitting information from target to surface and/or air receivers.

PHASE II: Phase II, if awarded, will be a prototype demonstration of one or more feasibility concepts examined in Phase I. This will consist of test hardware fabrication, bench testing of sub-system components, and system level testing.

PHASE III DUAL USE APPLICATIONS: Application, integration, and test and evaluation (T&E) for remotely gathering information on fortification layout, criminal/friendly disposition, etc. for use by law enforcement agencies in a terrorist or hostage situation.

REFERENCES:
1. Meade, Tony E., BDA, The Road to Victory, Military Intelligence, 1 Apr 98.
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KEYWORDS: sensors, video, surveillance, tacking, vision systems, pattern analysis

AF01-168 TITLE: Directed Energy Weapon Power Conditioning Technology

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop electrical power conditioning and pulsed power conditioning for potential directed energy weapon systems concepts for application on airborne platforms. Develop the modeling and simulation tools to predict component and system performance.

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 to 10’s MW power. The voltages in these systems range up to 100’s kV for microwave and radio frequency based systems. Current state-of-the-art power electronics would require a 10 to 100 fold increase in voltage and current levels to meet these requirements. The power electronic technologies of interest in this effort include cryogenically cooled and ambient temperature components, high voltage semiconductors (10’s kV), high voltage pulsed power switches (100’s kV), high voltage connectors (100’s kV), and high-energy capacitors/inductors (10’s kJ). 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 Windows operating systems on personal computers. The development of high density and high voltage power conditioning is an enabling technology need to build a practical directed energy weapon system that will be used in any airborne tactical defense system or on any DEW missile defense system.

PHASE I: Develop innovative conceptual designs of components, experimentally demonstrate the feasibility of materials, and 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: In addition to military directed energy weapons, the 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:
Cohen, H., Lehr, F., Engel, T. Spear II: High Power Space Insulation, Texas Tech University Press, 1995.

KEYWORDS: Electric power, directed energy weapons, semiconductors, power electronics, high voltage pulsed power, pulse forming networks

AF01-169 TITLE: <u>High Efficiency Power Electronics for Aircraft and Pulse Power Weapons</u>

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop high efficiency switching and rectifying components for power conditioning, distribution, electric actuation, weapons, and surveillance systems for moderate (10's of kW) to high power (1000 kW range) systems. In addition, technology solutions for switch and rectifier components to be used in fast rise-time pulse power networks are also being solicited.

DESCRIPTION: High efficiency power electronics will improve reliability, environmental hardness, switching speed, and power density for future aircraft, spacecraft, and pulsed power weapons. Reductions in volume and weight may be achieved through reduced requirements for active cooling and magnetic mass commensurate with higher switching speeds and higher frequency operation. Component developments shall focus on improvements in efficiency, switching speed, high temperature operation, reliability, with objective reductions in weight, volume, dI/dt stresses, power dissipation (switching and conduction), and cost. Innovations in power electronic component technologies for solid state laser diodes and free electron lasers are also of interest. Specifications for these power electronic components include both high voltage (1 kV to 100 kV) and moderate (600 –100V) device classes, high power density (up to 2 KW/lb), high efficiency (up to 98 %), and high temperature (200 to 350 oC). Component technologies should include a consideration of wide bandgap (SiC, GaN, AlN, etc.) power semiconductor devices (Field Effect Transistors, Diodes--both Schottky and pn, and Thyristors, etc.) and their packaging. Packaging may include integration of multiple components into efficient "Power Modules." Integration of thermal management with device development should be considered for component designs and packages. The proposed efforts must also consider space environmental power issues such as surface charge build up and corona/arcing. Technologies should show a mutual benefit for these space based systems as well as commercial applications such as medical electronics, automotive electronics, electric utilities, aircraft engine ignition systems, electrical actuation, and deep well instrumentation.

PHASE I: Demonstrate innovative device and component approaches with substantial improvement in breakdown voltage, conduction and switching losses, switching speed, and high temperature operating limits. Laboratory devices and/or components (motor drives, converters/inverters, power controllers, etc.) should be fabricated and tested to demonstrate the feasibility of the technology.

PHASE II: Demonstrate development of prototype power electronic devices and/or components using innovative materials, device designs, component topologies, packaging schemes, or a combination of these. Component level testing should be performed including electrical, thermal, radiation performance quantified. In addition, lifetime analysis should be performed.

PHASE III DUAL USE APPLICATIONS: Military unique materials/devices will provide commercially viable products for the high-end commercial sector. Potential applications include electric utilities, aircraft systems, and deep oil/well drilling.

REFERENCES:
"Wide Bandgap Power Electronics for the More Electric Aircraft", K.C. Reinhardt, M.A. Marciniak, In proceedings of the 31st Intersociety Engergy Conversion Engineering Conference, Pg 127-132. 1996

KEYWORDS: Pulse power, power conditioning, dielectrics, electrical switches, rectifiers, pulse forming networks

AF01-170 TITLE: Thermal Control of Future Phased-Array Antenna Systems – An Integrated Thermal/Electronics Packaging

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Design and develop an innovative light weight thermal control concept which is integrated directly with the transmit/receive electronics required for the future phased-array antenna system such that the antenna array will maintain thermal and structural stability during orbital and operational duty cycles.

DESCRIPTION: Air Force is developing low and medium earth orbit (LEO/MEO) space based radar (SBR) concepts which require a large structure containing modularized phased-array antenna system such as the DICOVERER II and Space Bistatic Illuminator for tracking and surveillance in space. If the antenna system does not remain isothermal and structurally stable, out-of phase conditions will result causing performance deterioration. Electronic calibration and steering means are tedious and may not fully correct for the out-of-phase conditions resulting from the thermal oscillations. Once deployed in orbit, the antenna will receive heat inputs from solar, earth IR and albedo radiation in addition to the heat loads generated from the losses of electrical and RF power. Typically, the temperature excursion from shadow to full sun case can be from –100 to +100°C in LEO/MEO. The phased-array antenna structure (with its built-in temperature sensitive transmitter/receiver and amplifier units) has to be isothermal within plus or minus 3°C and controlled near the safe range of –34 to 29°C. Current conventional thermal control technologies such as passive thermal control coatings are limited in capability. Heat pipes and heat pump systems, and capillary pump loops (CPLs)/loop heat pipes are expensive, bulky and require deployable radiators adding more complexity to the system. Energy storage (phase change material- PCM concept) is also bulky and limited on the choice of material availability. Thus, it is desired to develop an innovative thermal control technology that will solve this problem with a new approach. Potential solution methods could include, but are not limited to, an integrated structural-thermal/electronics composite packaging concept such as a printed wiring board (PWB) that houses the electronics, be light in weight (less than or equal to 5.67kg/m2), and possess the required thermal spreading capability and mechanical strength and eliminate intermediate coupling thermal resistance. A concept not requiring separate deployable radiators, heat transfer loops and pumps, etc. is sought. Variable emissivity/absorptivity coatings with or without energy storage concept, keeping the area weight density within limits, may also be considered. A proposed thermal management system for the cooling of future space-based phased-array system should provide the following capabilities: (1) Transmit/receive (T/R) module's design temperature must range from -34°C to 29°C during all phases and modes of operation; (2) Mass density of the phased array is less than or equal to 5.67 kg/m2; (3) Heat dissipation levels and duty cycle for transmit, receive and idle modes are 1076W/m2 at 30%, 32.3 W/m2 at 60% and 18.3 W/m2 at 10% respectively; (4) Operation time per orbit is 30 minutes; (5) Able to rotate less than or equal to 40° about either planar axis during operational scenarios; and (6) Earth pointing during non-operational scenarios. Additionally, the thermal management system should be designed to operate in the following environments: LEO altitude; Beginning-of-life and end-of-life optical properties; Hot and cold environments; and All beta regimes. To maintain satisfactory system performance, the thermal management system should involve the following but not limited to: Any means of thermal management technology; Orbital maneuvers for "thermal conditioning"; Considerations for better, faster, and cheaper system.

PHASE I: Develop a clear technical definition of the problem, identify possible solutions, and down-select the optimum solution and demonstrate the key technologies by designing and building a sub-scale phased array radar thermal test module. Computer modeling of the selected thermal management technology as applied to the future phased array radar and the development of a plan for operational prototype development/demonstration in phase II are also expected in the Phase I effort.

PHASE II: Develop scaled version of prototype components of the thermal management concept integral with an electrically functional radar system and conduct a prototype demonstration of the technology under simulated load conditions. Also, check for radio frequency(RF) interference caused by the thermal system on the radar performance.

PHASE III DUAL USE APPLICATIONS: Dual-use commercialization will be considered in all phases of this effort. Potential applications include military and commercial high power spacecraft, ground radar and electronics cooling.

REFERENCES:

1. Jonas, Fred M. "Thermal management Approaches for Large Planar Phased Array Space Antennas," Space Technology Applications International Forum(STAIF 2000), Albuquerque, NM. Jan/Feb 2000. http://www-chne.unm.edu/isnps/
2. Cantafio, L. J., Editor, Space-based Radar Handbook, Archtech House, Inc., Norwood, MA 1989.
3. Yeh, L.T. "Thermal Design of a Multiple-Channel Bidirectional-Flow Coldplate for Solid-State Phased-Array Radars," Proc of the International Symposium on Cooling Technology for Electronics Equipment, Honolulu, HI(1987) pp149-160.
4. Lage, J. L., Weinert, A. K., Price, D. C., and Weber, R. M., "Numerical Study of a Low Permeability Microporous Heat Sink for Cooling Phased-Array Radar Systems," International Journal of Heat and Mass Transfer, Vol. 39, No. 17, pp. 3633-3647 (1996).

KEYWORDS: Space based radar, heat transfer, phased array radar cooling, light weight material, thermal control, passive thermal control

AF01-171 TITLE: Prognosis/Diagnostics for improved Gas Turbine Engine reliability and maintainability

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Evaluate, modify/design, real-time, in and on line diagnostics for gas turbine engines

DESCRIPTION: Gas turbine engine condition monitoring for the prognosis of the oil-wetted component's health is an elusive technology. Engine health information is currently derived post-flight from visual examination of chip detectors, elemental analysis from wear and environmental contamination, and detecting changes in the lubricant. These analyses, along with other data, are used to determine engine health and engine flight-worthiness. There are numerous other diagnostic approaches, and associated instrumentation currently available that have potential for in-line and on-line prognosis and/or diagnosis of engine health. Requirements for a robust, flight-weight system will include data transfer and interpretation by either the pilot or ground crew. Data generated in-flight can be used for trending and diagnosis of normal and abnormal wear, environmental contamination detection, and oil degradation. Application of such technology will improve system reliability and play a critical role in real-time diagnostics of the mechanical components minimizing down time and avoidance of catastrophic component failures.

PHASE I: In phase I the small business shall work with a U.S. gas turbine engine manufacturer to identify engine oil wetted component failure modes and viable means for on-line and in-line prognosis and diagnosis of engine health before a significant event occurs. Modifications of existing diagnostic techniques and/or new diagnostic techniques shall be identified. Current problems occurring with bearings and/or gears, in operational systems, shall be used as models for evaluating each diagnostic technique and how these techniques can be used to prognose and/or diagnose future problems before becoming major events. Recommendations, supported by test and evaluation data, of innovative prognostic and diagnostic techniques to be pursued in Phase II for use on and in-line shall be made for current and future gas turbine engines.

PHASE II: All condition monitoring diagnostic techniques determined to have significant potential for prognostics and/or diagnostics shall be further investigated. Bench top evaluations should be used only for applications requiring further development. Selected techniques shall be evaluated in real time using gas turbine engines or simulators possessing the required environments of current and/or advanced mechanical component systems from turbine engines. All diagnostic and prognostic capabilities shall be demonstrated with known quantities of wear debris introduced into the system as well as wear generated in-situ from bearings and/or gears.

PHASE III DUAL USE APPLICATIONS: Improved condition monitoring of gas turbine engine lubrication systems, including on-line and in-line prognostics/diagnostics, will greatly benefit the militaries ability to maintain fleet readiness, improve commercial airlines engine reliability and maintainability, extend maintenance on ship power generators and ground based power generator turbines. Condition monitoring accomplished in real time will increase reliability, maintainability, and prevent costly down time by diagnosing impending problems before a catastrophic event can occur in all of the above applications.

REFERENCES:
Tribology Data Handbook, Wear Metal and Metal Analysis, Edited by Brown, R. E., CRC Press, 1997, p.p. 875-1018.

KEYWORDS: Turbine engines, turbine engine health monitoring, turbine engine prognosis, oil analysis, tribology, turbine engine lubrication monitoring.

AF01-172 TITLE: Actively Cooled Power Converter Technology

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Design and build innovative high voltage power converters that supply power to radio frequency (rf) sources that are used in Directed Energy (DE) weapon power systems.

DESCRIPTION: Innovative, lightweight, high voltage power converters are required to successfully implement DE weapons on tactical aircraft. Emphasis is on high voltage (10's of kV to over 100kV) power converter technology that optimizes size, weight, efficiency and reliability. Input power will be supplied from sources such as superconducting generators supplying power on the order of 10kV. The load may be continuous or pulsed for an rf source depending on the DE application. The efficiency of the high voltage power converter determines the extent of the thermal problems that need to be addressed and past experience has shown that cooling is effective for improving efficiency.

PHASE I: Clearly identify the problem or opportunity to be addressed by the proposed research. Define the conceptual solution and predict the performance of the proposed design through analysis, modeling, and simulation. Explore the feasibility of new concepts through analysis and/or small scale testing. All concepts should be scaleable or flexible designs, which can support various mission applications.

PHASE II: Provide detailed analytical derivations and prototypical device or hardware demonstrations. Models and/or simulations, validated by demonstrations that fully capture the relevant physics, are typically expected.

PHASE III DUAL USE APPLICATIONS: Research sought under this topic has widespread application in multiple aerospace power systems, residential power generation, and power for critical production facilities.

REFERENCES:
1. Blanchard, R. "Designing Switch-Mode Power Converters for Very Low Temperature Operation", Proceedings Powercon 10 (1983) D2, p. 1-11.
2. Mueller, O. "Properties of High Power Cryo – MOS-FETs", Proceedings of the 27th Power Electronics Specialists Conference (PESC-96), 24-27 June 1996, Baveno, Italy.
3. Severns, R. "Superconductivity and Low-temperature Power Converters", Powertechnics (1988) 4, p. 32-34.

KEYWORDS: power converters, actively cooled power converters, high voltage power converters, directed energy weapons, low temperature power converters, superconducting power converters.

AF01-173 TITLE: Cryogenic Electrical Machines

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Provide multi-megawatt power for Directed Energy (DE) weapons.

DESCRIPTION: Superconducting generators and superconducting radio frequency (rf) source magnets are enabling technologies for DE weapons with the potential for significant weight and size reductions compared to conventional technology. Proposed uses of DE weapons include lethal, non-lethal and self-protection on aircraft, spacecraft and ground based systems. Innovative cryogenic electric machines using High Temperature Superconductors (HTS) will enable multi-megawatt power systems. Multi-megawatt power levels present challenging problems for power system design. HTS conductors enable power system designers to meet the challenge of designing lightweight, compact, efficient and reliable systems by using high critical current density conductors, low loss AC conductors and cryogenic refrigerators. Proposed work for cryogenic electric machines should be overall system development or major component development such as rotor, stator, magnet and thermal components.

PHASE I: Clearly identify the problem or opportunity to be addressed by the proposed research. Define the innovative conceptual solution and predict the performance of the proposed design through analysis, modeling, and simulation. Explore the feasibility of new concepts through analysis and/or small scale testing. All concepts should be scaleable or flexible designs, which can support various mission applications.

PHASE II: Provide detailed analytical derivations and prototypical device or hardware demonstrations. Models and/or simulations, validated by demonstrations that fully capture the relevant physics, are typically expected.

PHASE III DUAL USE APPLICATIONS: Research sought under this topic has widespread application in multiple aerospace power systems, residential power generation, and power for critical production facilities.

REFERENCES:
1. Rodenbush and Young, S. "Performance of High Temperature Superconducting Coils for Implementation into Megawatt Class Generators", IEEE Transactions on Applied Superconductivity, Vol. 9, n. 2, p.1233 (June 1999).
2. Oberly, C.E., Joshi, C., Long, L.J. and Kozlowski, G. "Progress Toward Megawatt Class Superconducting Generators which Operate at Greater than 20 Kelvin", Advances in Cryogenic Engineering, Vol. 39A, 1994, pg. 949.
3. Gamble, T. Keim, "A Superconducting Generator Design for Airborne Applications", Advances in Cryogenic Engineering, Vol. 25, 1980, pg. 127.

KEYWORDS: Superconducting generators, superconducting magnets, high temperature superconductors, cryogenic electrical machines, directed energy weapons, multi-megawatt power.

AF01-174 TITLE: High Energy Density Dielectrics for Pulse Power Capacitors

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop state-of-the-art, high performance capacitor dielectrics, impregnants, foils, conductors and/or advanced packaging concepts to enable leading-edge, pulse power, high energy density (>15 J/g) capability with nanosecond delivery rates (burst mode).

DESCRIPTION: Compact, high energy density, pulse power capacitors will be a key enabling technology for many future weapon systems. These capacitors will be used in pulse forming networks (PFNs) or Marx bank configurations for the conversion of available prime electrical energy into the necessary short and very fast pulses of energy needed to energize military loads. Such loads may be directed energy weapons, kinetic energy weapons, electromagnetic guns/launchers, high power microwaves, etc. Repetitive energy pulses could easily go into the megajoule per pulse regime. The need for compact, lightweight, pulse power capacitor devices is a necessity for airborne applications and particularly crucial for spaceborne. Therefore, research objectives include special emphasis on thin dielectrics with an extremely high voltage breakdown strength (> 20kV/mil), a dielectric constant greater than 3, and low loss (<1%). Attention to thermal management issues due to a need for increased life (>10,000 shots), increased pulse repetition rates to > 500 pulses per second (pps), and high voltage reversal tolerance (>80%) will be required; interconnects, aging analysis and manufacturability are also to be highlighted. The proposed research should provide a substantial reduction in size, weight and volume of the capacitor component over state-of-the art devices while delivering superior electrical and thermal performance.

PHASE I: Demonstrate innovative capacitor approaches with substantial improvement in increased capacity, dielectric constant, voltage breakdown strength, and decreased dissipation factor. Prototype laboratory capacitors should be fabricated and tested to demonstrate the feasibility of the proposed technology.

PHASE II: Demonstrate the optimized development of prototype capacitor components using innovative dielectric material/impregnant, metallization, advanced high density packaging, manufacturing technology or a combination thereof. System issues such as safety, maintainability, supportability, reliability, and mechanical robustness (shock, vibration, etc) should be also addressed.

PHASE III DUAL USE APPLICATIONS: Military unique materials/capacitors will provide excellent margins for the high-end commercial sector. Potential applications include electric utilities, aircraft engine ignition systems, medical defibrillators, mobile power systems, solid state switch snubbers and deep oil/well drilling to name a few.

REFERENCES:
1. Metzger, T. L. “From Dreamworld to Real world: Electromagnetic Guns”, Aerospace Defense News, Nov/Dec. 1990.
2. MacDougall, F.W., Howe, D.C. and Winsor, P. “High Energy Density Pulsed Power Capacitors,” in Proc. IEEE Pulsed Power Conf., Albuquerque, MN, July 28-Aug. 1, 1991,pp. 79-83.
3. Cygan, P. and Laghari, J.R. “Models for Insulation Aging Under Electrical and Thermal Multistress,” IEEE Trans. Dielectrics Electrical Insulation, vol. 25, no. 5, pp. 923-934, Oct. 1990.

KEYWORDS: pulse power, capacitors, dielectrics, energy storage, pulse forming networks, high energy density dielectrics.

AF01-175 TITLE: High Power Microwave Source Cooling to Enable Compact Directed Energy Weapons

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Design, build, and integrate an advanced cooling subsystem for a high power microwave source (excluding any cryogenic components like a superconducting magnet) enabling a more compact and less massive directed energy weapon for airborne applications.

DESCRIPTION: Recent advances in high power microwave (HPM) source technologies have fostered the current focus on directed energy (DE) weapons in airborne applications. HPM sources now exist with high enough output powers and repetition-rates to be useful in aircraft military offensive/defensive situations. The major obstacle to the practical application of these types of DE weapons is the size/mass of the HPM, and in particular the collector structure. The practical limitation to the reduction in size of these HPM sources is commonly related to the cooling/heat flux limitation (at or above 300 K). An advanced/innovative high heat flux cooling technique that can be integrated into a HPM source could enable its practical operation in an airborne DE weapon application. The cooling challenges will vary with the DE application, from short duration (10 - 100 seconds) while the aircraft is performing evasive maneuvers (high-g) to long duration (5 - 50 minutes) during steady level flight (one-g).

PHASE I: Develop overall cooling system design and perform preliminary proof-of-concept experiments.

PHASE II: Develop and demonstrate a prototype system in a realistic environment. Conduct testing to prove feasibility over extended operating conditions.

PHASE III DUAL USE APPLICATIONS: The cooling system could be used in a broad range of up-and-coming military DE application. As power requirements for private sector communication applications rise, there is reasonable potential for the use of this cooling system in many of these commercial communication applications.

REFERENCES:
1. Benford, J., "Making HPM practical", Conference: International Conference on Plasma Science, 5-8 June 1995, Madison, WI, p. 241
2. Pevler, A.E., "Security implications of high-power microwave technology", 1997 International Symposium on Technology and Society Technology and Society at a Time of Sweeping Change. Proceedings (IEEE Cat. No.97CH36081), 20-21 June 1997, Glasgow, UK. pp.107-11

KEYWORDS: High power microwave, directed energy weapons, cooling, high heat flux cooling, thermal energy storage, high power microwave source cooling.

AF01-176 TITLE: Oil-Free Bearings for Mid-Size Uninhabited Air Vehicle Gas Turbine Engines

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop innovative oil-free bearings for shaft support in 5,000 to 15,000 lbs. thrust class gas turbine engines.

DESCRIPTION: Oil-free bearing concepts offer great benefits for future gas turbine engines. Specifically, by eliminating the gearbox, oil-tank, and other mechanical equipment, engine cost and weight savings up to 30% can be achieved. Additionally, improved storability can be realized by eliminating rolling element bearings that are susceptible to corrosion. Also, improved specific fuel consumption can be realized by eliminating the friction losses from the gear box. Oil-free concepts include magnetic and air-foil bearings. For the mid-size engines, magnetic bearings are thought to be the most promising approach due to load carrying, loss of damping, and scalability issues with air-foil bearings. However, other innovative concepts, including air-foil bearings, will be considered.

PHASE I: In Phase I the small business shall work with a US gas turbine engine manufacturer to address viable, innovative oil-free bearing concepts for specific uninhabited air vehicle (UAV) applications. Prototype designs, rotor dynamic analyses, and bench top testing will be performed based on the operating conditions for a 5,000 to 15,000 lbs. thrust class UAV engine(s).

PHASE II: In Phase II the small business shall manufacture and test, promising concepts derived from Phase I. The bearings shall be tested at engine conditions (load, speed, temperature, and simulated rotordynamic conditions).

PHASE III DUAL USE APPLICATIONS: Oil-free bearings are being developed for remote natural gas pumping stations, electrical power turbines, combustion engine turbochargers, and others. The technology derived from this program is directly applicable to these commercial applications. Additionally, the gas turbine technology can be used in commercial aviation and marine applications, as well as other military applications. The goal of a future Phase III effort will include transitioning this technology to a US engine manufacturer for the mid-size UAV application.

REFERENCES:
Numerous papers on magnetic bearings are published in: Proceedings of Mag ’95 – Magnetic Bearings, Magnetic Drives, and Dry Gas Seals Conference & Exhibition. Published by: Technomic Publishing Co. Inc, 851 New Holland Av., Box 3535, Lancaster, PA, 17604.

KEYWORDS: Gas turbine engine bearings, oil-free bearings, magnetic bearings, air-foil bearings, air-film bearings, air bearings

AF01-177 TITLE: Electrochemical Systems for Micro Electro Mechanical Systems (MEMS) Applications on Microsatellites

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop electrochemical power systems to provide and store power for MEMS applications

DESCRIPTION: This topic seeks proposals with innovative concepts related to electrochemical power generation and storage for MEMS. Micro-batteries have recently been demonstrated as documented in the reference material. One of the largest challenges for successfully implementing MEMS technology into an application is the lack of an autonomous power supply suitable for MEMS. Electrochemical propulsive power and energy storage systems can provide lightweight, small footprint, cost-effective solutions to the power/energy storage needs for MEMS applications. The power requirements can range form hundreds for joules to millijoules or even microjoules. The mission times can range from a few hours, which might only require a primary battery, to days or weeks which would require a secondary battery coupled with some means (solar, motion, mechanical stresses, thermal) of recharging the battery. These batteries or battery/charger systems could provide power for a MEMS device, a micro sensor or for some other device such as a microsatellite. Microbatteries might also be considered whenever or wherever a small, isolated, autonomous power system is needed to prevent "crosstalk" between individual and separate electronic control systems. Microbatteries could also be considered as a standard potential for miniature analytical devices. This topic will provide the warfighter with a light-weight, dependable, safe, renewable power source for all of the portable electronic equipment that increases his readiness, make his mission more likely to succeed and increases his lifetime. Satellites, particularly microsatellites, would benefit from the available of miniaturized electrochemical power sources. The technology developed under this topic will be useful for computer equipment, sensors, communications equipment, land, sea and air vehicles (manned and unmanned), and for advanced electronic weapons.

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 energy and power requirements in a package compatible for a MEMS device.

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 would be utilized in civilian MEMS applications, microelectronic applications, and microsensors as well the military satellite application described above.

REFERENCES:
1. Ryan, David M., LaFollette, Rod, Salmon, Linton. "Microscopic Batteries for Micro ElectroMechanical Systems (MEMS)", Proceedings of 32nd Intersociety Energy Conversion Engineering Conference IECEC, 97-8, 97136, Honolulu, HI, (1997).
2. Bates,J.B., Lubben, D. and Dudney, N.J. "Thin Film Li-LiMn2O4 Batteries", Proceedings of the Tenth Annual Battery Conference on Applications and Advances, Chem Abstr 1995, 122, 19238h, (1995).

KEYWORDS: Micro Electro Mechanical Systems, MEMS, Microsatellites, batteries, Micro-batteries, electrochemical power

AF01-178 TITLE: Advanced Electrical Power Generation (High Power Non-Super-Conducting)

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop advanced multi-megawatt (1-5 Mw desired) non super-conducting generating systems for high energy/high power directed energy applications.

DESCRIPTION: Innovative and creative solutions to provide high power, lightweight, compact power systems are needed for aerospace applications; large aircraft operating from sea level to 20,000 ft. are the initial platforms for consideration. Emphasis will be on multi-megawatt generator designs (1 to 5 megawatt, which may include modular packaging that can address scaling) that are optimized for size, weight, and efficiency with close coupling to a power source such as a gas turbine. The duty cycles for consideration should include continuous to 10% duty cycle (with up to 10 second on operation). Cooling for the power generation system must be considered from an aircraft integration aspect; the power generation and thermal cooling power may be included as part of an integrated power (electrical and cooling) package. While cooling of a high power load is not the focus of this effort, it is recognized that there may be synergistic solutions for load cooling that may be incorporated into the power generation package. For the purposes of consistency, the power generation system should include components necessary to achieve 10 to 40 kV DC output, so that any proposed component efforts are easily evaluated for importance to the overall system. Hybridized systems may be an important consideration as the duty cycle tends further away from continuous operation. As part of an overall power package, a candidate prime power source should be identified for power system evaluation (nearer term and far term). Since operation may entail significant amounts of fuel for missions extending for hours, the fuel requirements for the power system should be assessed as an hourly rate of consumption. Also, power system readiness availability (hence, how long till operational readiness from initial notification; i.e. 2 minutes) should be addressed. Weight, volume, supportability, and operability are important issues to be addressed when compared against advanced systems employing super-conducting power generation.

PHASE I: Develop sufficiently detailed technical definition of problem, identify proposed solution(s), and demonstrate the benefits of the proposed solution(s) through modeling and simulation, trade-offs, and/or through key experiments.

PHASE II: Concentrate on exploratory power generation development by implementing solutions identified in Phase I. Effort will focus on thorough understanding and verification of the machine high power capability through fabrication and test.

PHASE III DUAL USE APPLICATIONS: Dual use application may pertain to military and commercial ground and ground mobile/transportable power systems for standby and emergency power.

REFERENCES:
1. Colegrove, P.G., “Integrated Power Unit For A More Electric Airplane”, American Institute of Aeronautics and Astronautics AIAA Paper 93-1188, Feb. 16-19, 1993
2. Klaass, R.M., McFadden, B.B., “More-Electric Integrated Power Unit Designed For Dual-Use”, Society of Automotive Engineers SAE Paper No. 94115, 1994
3. Smith G., Halsey D., Hoffman E., “Integrated Power Unit - Advanced Development”, Society of Automotive Engineers SAE Paper No. 981281, 1998

KEYWORDS: power systems, electrical generators, power generation, multi-megawatt generators, non-superconducting power generation, aircraft power generation

AF01-179 TITLE: Aero Propulsion and Power Technology

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop innovative technologies which provide major improvements in gas turbine engines, advanced propulsion systems, electrical power systems, and advanced fuels for manned and unmanned applications.

DESCRIPTION: The Propulsion Directorate aggressively pursues and solicits innovative ideas offering major performance advances in all areas of airbreathing propulsion including turbine engines, advanced and combined cycle engines, fuels, and electrical power. Payoffs include increased aircraft and weapon system effectiveness, survivability, reliability and affordability. Turbine engine technology development is focused on delivering higher thrust-to-weight ratios, reduced cost, improved efficiency, and increased reliability. Advanced and combined cycle engine efforts are focused on developing innovative and high Mach airbreathing engines for future manned and unmanned applications. Fuel technologies are currently focused on improving the performance (thermal stability, low temperature properties, etc) of JP-8 through the use of additives. Finally, electrical power efforts (non-propulsive) are focused on advanced techniques for power generation, storage, and distribution for aircraft, spacecraft, and weapons with a particular emphasis on directed energy weapons. Subsets of these technologies include innovative combustion measurement techniques, diagnostics, control techniques, microelectromechanical machines (MEMS), and engine related materials technologies. Offerors are strongly encouraged to establish relationships with suppliers of the aerospace systems relevant to their research in order to facilitate technology transition. Proposed efforts shall emphasize dual-use technologies that clearly offer commercial as well as military applications. Proposals emphasizing “spin-on” technology transfer from the commercial sector to military applications are also encouraged. Proposals also submitted for any other Air Force FY01 Small Business Innovative Research (SBIR) topic shall not be considered for this topic.

PHASE I: Develop the concept and perform analyses and subscale testing to demonstrate the feasibility of the proposed technology.

PHASE II: Provide detailed analytical derivations and prototypical device or hardware demonstrations. Develop a technology transition and/or insertion plan for future systems and commercial ventures.

PHASE III DUAL USE APPLICATIONS: New and innovative propulsion and power technology is equally applicable to both military and commercial aircraft engines and power generation and distribution systems.

REFERENCES:
Air Force Research Laboratory Propulsion Directorate website address: http://www.pr.wpafb.af.mil

KEYWORDS: Turbine engines, high speed propulsion, scramjets, fuels, lubrication, power systems

AF01-180 TITLE: Pulsed Power Technology for Aerospace Applications

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Explore innovative approaches for pulsed power electrical networks and the components of these networks.

DESCRIPTION: The Power Division of the Propulsion Directorate aggressively pursues power generation, power distribution, and energy storage technologies. Applications include manned and unmanned aerospace vehicles, directed energy weapons, gun and tube propulsion systems, next generation fusion, weapon effects simulators, and in commercial power conditioning systems for motor drives, inverters, down-hole drilling, uninterruptible power supplies, power quality systems, and mobile power systems. Mission requirements are dictating development of pulsed power networks capable of high repetition rates (up to 1000 pps), high efficiency (>90%), and high power capacity (>2000 KW). Particular technologies of interest for these networks are reliable capacitor dielectrics, compact Marx generators, and high rate batteries. It is expected that the dielectric materials will require innovative polymers, polymer-polymer composites, polymer-ceramic composites, or diamond-like carbon formulations for application in pulse forming networks and Marx generators. Dielectric materials with very high voltage breakdown strength and low loss factors are imperative to reduce size, weight and volume while increasing electrical performance. Marx generators that are physically compact but offer high voltage, fast risetime peak pulse outputs and which utilize reliable high power density capacitor charging systems and reliable switches (spark gaps or solid state) are of interest. Simultaneously pushing the power and energy density of rechargeable/refuelable electrochemical technology is desired (>10 kW/kg and >70 Whr/kg, respectively). High power/energy density rechargeable lithium, lithium-ion, and metal/air (oxygen) batteries, as well as hybrid combinations of batteries, ultracapacitors, and fuel cells, are likely electrochemical candidates for further development to achieve these goals. Offerors are strongly encouraged to establish relationships with suppliers of the aerospace systems relevant to their research in order to facilitate technology transition. An element of risk is expected in the proposals due to their innovative nature.

PHASE I: Clearly identify the problem or opportunity to be addressed by the proposed research. Define the conceptual solution and predict the performance of the proposed design through analysis, modeling, and/or simulation. Explore the feasibility of new concepts through analysis and/or small scale testing. All concepts should be scaleable or flexible designs that support various mission applications.

PHASE II: Provide detailed analytical derivations and prototypical device or hardware demonstrations. Models and/or simulations, validated by demonstrations and which fully capture the relevant physics, are typically expected to accompany hardware.

PHASE III DUAL USE APPLICATIONS: Research sought under this topic has wide-spread application in multiple aerospace systems, residential power generation systems, and power for critical production facilities. Much of the work in space systems could directly transition to commercial communications satellites.

REFERENCES:
1. Air Force Research Laboratory, Propulsion Directorate, Power Division website: http://www.pr.afrl.af.mil/divisions/prp
2. D. G. Ball and T. R. Burkes, "PFN design for time varying load," in Proc. 1976 IEEE Power Modulator Symp., New York, Feb. 4-5, 1976, pp.156-162.
3. D.W. Larson, F.W. MacDougall, X.H. Yang, and P.E. Hardy, "The impact of high energy density capacitors with metallized electrodes in large capacitor banks for nuclear fusion applications," in Proc. 9th IEEE Pulsed Power Conf. Albuquerque, NM, June 22-25, 1993, pp.735-738.
4. D.L. Loree and James P. O'Loughlin, "Regulated Capacitor Charging Circuit Using a High Reactance Transformer", in Proc. 12th IEEE Pulsed Power Conf. Monterey, CA, June 27-30, 1999, pp. 433-436.
5. J.C. Kellogg, "A Laser-Triggered Mini-Marx for Low-Jitter, High Voltage Applications", in Proc. 12th IEEE Pulsed Power Conf. Monterey, CA, June 27-30, 1999, pp. 1175-1178.

KEYWORDS: Batteries, capacitors, fuel cells, pulsed power, pulse forming networks, Marx generators.

AF01-181 TITLE: High-Temperature Advanced Instrumentation for Gas Turbine Engines

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Advanced instrumentation concepts are desired to measure high-temperature parameters in a gas turbine engine. Ideally, the innovative concept would be useful in the design and test phases of the engine and have a potential of being transitioned into robust flight-weight units for continued engine health monitoring.

DESCRIPTION: Conventional instrumentation techniques are currently limited to applications under ~250 C. There is a significant need to develop robust, high-temperature instrumentation to measure a variety of high-temperature parameters in gas turbine engines. Such applications include, but are not limited to, surface temperature measurement of combustor liners and turbine airfoils, gas path temperature profiles for the combustor (pattern factor monitoring and T4 measurement), augmentor emissions (component wear) and acoustics (screech and rumble), compressor and turbine tip clearance and blade stress/vibration, bearing temperature and vibration, and component damage detection (e.g. disk crack detection, FOD, etc.). Measurements on both stationary and rotational components are desired. Minimally intrusive sensing schemes are also desired. One enabling technology is the area of micro-electro-mechanical systems (MEMS). Recent advances have created a base for the next-generation engine-sensing systems. The miniaturization of a suite of sensors (pressure, temperature, vibration) will enable sensor implementation to fielded engines and enable the Air Force to effectively monitor engine performance and health. Miniaturization will also afford integrated sensor arrays to simultaneously measure multiple parameters or to measure surface areas. Advances in telemetry combined with sensor robustness will afford new measurement capabilities in rotating components. The development of micro-sensing systems with feedback control will also enable the Air Force's vision of a truly "intelligent" engine that can sense a problem (such as stall) and automatically take measures to avoid the problem. However, it is recognized that MEMS may not be the appropriate solution to the variety of measurement applications mentioned above. Thus, other innovative sensing techniques are welcome under this topic.

PHASE I: Under Phase I a prototype sensor should be developed and tested in a laboratory environment. Theoretical performance limitations should be established and potential applications should be identified.

PHASE II: In phase II a sensor should be developed and tested in a laboratory in preparation for an actual component test. Calibration techniques and equipment should be developed along with data acquisition and processing techniques. Test chambers should be developed and used to experimentally determine physical sensor limitations.

PHASE III DUAL USE APPLICATIONS: The development and application of micro-sensors in turbine engines will afford engine health monitoring and active control capabilities useful for both military and commercial customers. Effective use of engine health monitoring could save millions in maintenance costs for all users and can potentially reduce fighter mishaps which result in loss-of-aircraft (LOA).

REFERENCES:
1. Wood, Kristin L., et al, "MEMS Hydrodynamic Bearings: Applications to and Implications for Machine Failure Prevention," TriboTest, Vol. 4, No. 3, 3 MAR 1998, pp. 275-288.
2. Kobayashi, Hiroshi, et al, "Experimental and Theoretical Frequency Response of Pressure Transducers for High-Speed Turbomachinery," 34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Cleveland, OH, July 13-15, 1998, AIAA Paper 98-3745, 9 p.
3. Air Force Research Laboratory Propulsion Directorate website address: http://www.pr.afrl.af.mil.
KEYWORDS: Micro-Electrical-Mechanical Systems (MEMS), Micro-Optical-Mechanical Systems (MOMS), Telemetry, Gas Turbine Engines, Engine Health Monitoring, Instrumentation.

AF01-182 TITLE: Energetic Solid Rocket Nozzle / Throat Insulator Concept

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: The objective of this program is to reduce throat erosion of solid rocket motors, thus enabling increased payload to orbit or reduced cost for a given payload.

DESCRIPTION: Erosion of solid rocket motor nozzles is a problem that currently costs several seconds of specific impulse and hence, payload delivered to orbit. As the nozzle erodes, the throat diameter increases, resulting in a reduced expansion ratio and reduced thrust. The current state-of-the-art employs advanced coatings which reduce, but do not eliminate throat erosion. Innovative solutions are sought to address reduced rocket nozzle throat erosion. The offeror should establish a baseline erosion rate and the associated performance decrement on some of today's current space launch systems. Innovative solutions should be identified and should assess structural integrity, material bonding and computability, affect on propellant loading, weight, cost, and of course erosion rate, specific impulse, and total delivered impulse. Potential erosion reducing concepts to be evaluated, such as film cooling the throat with a low temperature-low burn rate aft closure propellant, using new erosion resistant materials, or other innovative ideas shall be compared to today's baseline. Concepts which minimize aluminum oxide build-up may offer a gain of an additional several seconds of delivered specific impulse.

PHASE I: Establish conceptual designs and perform analysis to determine the feasibility and payoffs of each concept. Perform subscale screening tests of the critical elements (such as material testing and/or 2x4 motor firings). Establish a sub-scale prototype design based on the results of the preliminary screening tests and predict anticipated performance.

PHASE II: The small business should manufacture and demonstrate the feasibility of the concept with a reasonably sized sub-scale prototype under realistic conditions. Demonstration results should be used to assess projected full scale performance.

PHASE III DUAL USE APPLICATIONS: This technology has application to many commercial and military space launch systems. Specifically, this could be used on the commercial Delta and Atlas families of space launch boosters as well as the Stage 1 motors of the commercial Athena family of boosters. The military applications would be the strap-on boosters for the Titan and the first stage motors of Inter-Continental Ballistic Missiles.

REFERENCES:
Sutton, G. P., Rocket Propulsion Elements, John Wiley & Sons, Inc., New York, 1992 AIAA 97-2721 "Supersonic Splitline (SSSL) Flexseal Nozzle Technology Evaluation Program" presented at the 33rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, July 6-9, 1997.

KEYWORDS: Solid rocket motors, rocket throat erosion, rocket nozzle erosion, rocket throat inserts, low burn rate propellants, low temperature propellants.

AF01-183 TITLE: <u>Develop and Demonstrate Inflatable Reflector Technology</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and evaluate inflatable parabolic or spherical reflector technology.

DESCRIPTION: Thin-film inflatable reflector technology offers the potential to reduce the packaged weight and volume of today's current "precision rigid" parabolic reflectors by an order of magnitude. Successfully developing and demonstrating the operation and reliability of these innovative inflatable reflectors in actual space flight is needed to ensure this technology is viable for military and commercial use. Uses for these reflectors include collecting electromagnetic, solar and/or radio waves for power generation, solar thermal propulsion, reconnaissance and communications. Additionally, an innovative new class of satellites, called pico-satellites, may become available for flights of opportunity. Innovative proposals are sought to develop and demonstrate subscale prototype inflatable parabolic or spherical reflectors (package size of 1"x3"x5"). Thinner materials and innovative packaging are encouraged. Issues that should be addressed in the development include leakage rates, makeup gas requirements, rigidization performance, reflector surface accuracy, film degradation from space environmental effects, pointing and tracking performance. Concentrating reflectors should produce a peak intensity of around 800 watts/cm^2. Power systems should have a specific mass competitive with the state of the art for this scale. Surface accuracy for antenna applications should be on the order of 0.2 mm. Mass density should be less than 2kg per meter squared of reflector area. This technology directly supports the DoD Key Technology Area of Space Platform Propulsion in that it helps to meet the Integrated High Payoff Rocket Propulsion Technology mass fraction goals for Solar-Thermal Propulsion.

PHASE I: Establish performance goals based on the issues discussed above. Design and develop an innovative concept which to meet the established goals. Limited testing of material properties and structural concepts are desirable.

PHASE II: Phase II should build on and extend the Phase I work and produce sub-scale prototype hardware. This hardware should be sufficient to undergo testing under terrestrial sunlight and in a simulated space environment to demonstrate the feasibility of the technology.

PHASE III DUAL USE APPLICATIONS: This technology would be a strong candidate for flight testing funded by the Space Experiments Review Board and/or Space and Missile Command and subsequent commercialization into many applications. This technology can be used as a solar concentrator power source, antenna, or propulsive system for small military and commercial satellites.

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1. Lichodziejewski, D., Cassapakis, C., “Inflatable Power Antenna Technology,” 37th AIAA Aerospace Sciences Meeting and Exhibit, AIAA 99-1074.
2. Paxton, J. P., Holmes, M. R., “A Performance Evaluation of an Inflatable Concentrator for Solar Thermal Propulsion,” Proceedsings of the 1996 JANNAF conference, CPIA 650, Vol. 1, Dec. 96, pp. 153-162.
3. Clayton, W. R., Gierow, P. A., “Inflatable Concentrators for Solar Thermal Propulsion”, Solar Engineering, Proceedings of the ASME International Solar Energy Conference, 1992.
4. Kennedy, F., Jacox, M., “Mission Applications of an Integrated Solar Upperstage (ISUS)”, Solar Engineering, Proceedings of the 1995 ASME International Solar Energy Conference, Paper AP0401.

KEYWORDS: Concentrators, Inflatable Reflector, Antenna, Bimodal, Solar Thermal Propulsion, Thin-Film

AF01-184 TITLE: Addition of Photovoltaic Cells on Solar-Thermal Propulsion Concentrators

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop innovative technologies to add photovoltaic cells to thin-film parabolic concentrators/antennas, thus enabling direct generation of electrical power.

DESCRIPTION: Combining photovoltaic (PV) cells with parabolic reflectors allows a single support structure, pointing, and tracking mechanism to serve more than one satellite function. Inflatable antennas and concentrators consist of large area, reflectorized thin films that are used to focus either solar energy or Radio Frequency energy into a small area. These same structures could be used to support thin film PV cells for generating spacecraft power while not being used for their primary function. For example, a concentrator used for propulsion would normally go unused after finishing an orbit transfer. If the backside of this concentrator were covered with thin-film PV cells, then power could also be generated without increased support structure weight. For another example, an antenna’s surface could be made with thin-film PV cells and the metal substrate of these cells would double as the Radio Frequency reflective surface. We are looking for proposals that put forward this sort of innovative approach to doubling the benefit of using inflatable structures. Development of thin-film, foldable PV and power distribution materials is critical to the success of this concept. Combining thin-film inflatable reflector technology with PV cells for power generation offers the potential to significantly reduce the packaged weight and volume of today’s “precision rigid” parabolic reflectors and PV arrays.

PHASE I: Determine the primary issues to be addressed and establish photovoltaic material requirements. An initial design should be developed. The resulting concept should be implemented into demonstration hardware to show its feasibility.

PHASE II: Phase II should build on and extend the Phase I work and produce a scale concentrator integrated with photovoltaic conversion cells. This hardware should be sufficient to undergo testing under terrestrial sunlight and in a simulated space environment.

PHASE III DUAL USE APPLICATIONS: Military and commercial spacecraft with limited volume could utilize these inflatable thin-film PV cells to allow for much tighter packaging in spacecraft farings. Also, it is expected that there would be several terrestrial applications for this technology, such as inflatable structures, tents, or deployable film or cloth structures could utilize this technology to provide electrical power in remote or mobile applications. Simultaneously, forced convective flow over the same PV array would cool the array and provide heating capability.

REFERENCES:
1. Lichodziejewski, D., Cassapakis, C., “Inflatable Power Antenna Technology,” 37th AIAA Aerospace Sciences Meeting and Exhibit, American Institute of Aeronautics and Astronautics AIAA 99-1074.
2. Paxton, J. P., Holmes, M. R., “A Performance Evaluation of an Inflatable Concentrator for Solar Thermal Propulsion,” Proceedings of the 1996 JANNAF conference, CPIA 650, Vol. 1, Dec. 96, pp. 153-162.
3. Clayton, William. R., Gierow, Paul. A., “Inflatable Concentrators for Solar Thermal Propulsion”, Solar Engineering, Proceedings of the ASME International Solar Energy Conference, 1992, American Society of Mechanical Engineers, pp 795-800.
4. Kennedy, F., Jacox, M., “Mission Applications of an Integrated Solar Upperstage (ISUS)”, Solar Engineering, Proceedings of the 1995 ASME International Solar Energy Conference, American Society of Mechanical Engineers Paper AP0401.

KEYWORDS: Concentrators, Inflatable Reflector, Photovoltaic, Bimodal, Solar Thermal Propulsion, Thin-Film

AF01-185 TITLE: High Power Hall Thruster Technology Development

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Design, develop, validate innovative “high power” Hall thruster technologies that significantly improve thruster operating characteristics and/or reduce thruster life cycle cost.

DESCRIPTION: The application of electric propulsion (EP) systems for orbit transfer of satellites will deliver larger payloads and provide greater mission capability when compared to chemical propulsion systems. Due to its high efficiency and appropriate specific impulse range, the Hall Effect Thruster (HET) is a strong candidate technology for stationkeeping, repositioning, and orbit transfer missions. Over 100 Russian Hall thrusters operating up to 1.35 kW have flown in space. Development of Hall propulsion systems with powers up to 10 kW is proceeding internationally, and on-orbit application of several 4.5 kW systems is projected within the next few years. To support future orbit transfer missions, multiple Hall systems operating at powers exceeding 20 kW are envisioned. The development of innovative Hall thruster technologies that can significantly improve thruster operating characteristics and/or reduce thruster life cycle cost is expected to provide greatly increased mission capability and system application. Topics of interest include, but are not limited to: thrust to thruster mass ratio; thrust to thruster power ratio; efficiency; total impulse; thruster production cost; electromagnetic and contamination output and measurement; ground test cost. Research may focus on one or more improvement objectives. Since these characteristics are both interrelated and power dependent, it is necessary that such effects be accounted for when investigating technology improvements. Innovations may include, but are not limited to: thruster magnetic system; thruster geometry; thruster materials; thruster fabrication techniques; propellant type; ground test pumping system; thruster diagnostics. Research may focus on one or more innovations. Evaluation of technology improvements with respect to state of the art should occur throughout the effort. Government and commercial test and evaluation facilities may be utilized if proper documentation of efforts to secure these facilities is provided. Government facilities can be sought at no cost to the contractor or SBIR office. Information regarding government test facilities may be obtained from the technical point of contact.

PHASE I: The objectives of phase I are the following: (1) identify and evaluate candidate technology improvements applicable to 10 kW and greater thruster power; (2) perform initial validation of high payoff concepts through analysis and test(sub-scale is acceptable); (3) develop preliminary designs implementing the selected technologies.

PHASE II: The objectives of phase II are the following: (1) demonstrate the feasibility of the design concepts created during Phase I by fabricating and testing hardware (sub-scale is acceptable); (2) as a result of the testing, incorporate changes and improvements as necessary to scale-up and demonstrate a full size prototype 10-20kW Hall Thruster; (3) fabricate and deliver a duplicate prototype demonstrator for evaluation by the Air Force.

PHASE III DUAL USE APPLICATIONS: Dual use commercialization would occur through the development of a flight quality Hall thruster for orbit transfer vehicle and space experiment applications. Both mission capability and profitability will increase through the introduction of this technology into both the military and commercial satellite marketplaces.

REFERENCES:

1. Jankovsky, R. S., McLean, C., McVey, J., ”Preliminary evaluation of a 10 kW Hall thruster”, American Institute of Aeronautics and Astronautics AIAA Paper 99-0456, Aerospace Sciences Meeting and Exhibit, 37th, Reno, NV, Jan 1999.
2. Oleson, S. R.; Myers, R. M., “Launch Vehicle and Power Level Impacts on Electric GEO Insertion”, American Institute of Aeronautics and Astronautics AIAA-PAPER-96-2978, Joint Propulsion Conference, 32nd, Lake Buena Vista, FL, July 1996.
3. Kim, V., “Main physical features and processes determining the performance of stationary plasma thrusters”, Journal of Propulsion and Power, v. 14 no. 5, Sep-Oct 1998. p 736-743.
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5. Tchuyan, R. K., Bagdasaryan, V. V., Belousov, A. P. Mosesov, S. K., “Estimation of possibilities of electric propulsion application for space Missions”, IAF Paper 98-S407, International Astronautical Congress, 49th, Melbourne, Australia, Sept. 28-Oct. 2, 1998.

KEYWORDS: Electric Propulsion, Hall Effect Thruster, Anode Layer Thruster, Stationary Plasma Thruster, Orbit Transfer, Total Impulse

AF01-186 TITLE: Micropropulsion Thruster for Low Power Satellites

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and validate innovative design concepts for “low power” electric propulsion thrusters for station keeping and orbit maneuvering of small satellites. Identify and validate means of improving small satellite thruster performance.

DESCRIPTION: Small satellites are extremely mass and power limited (500 lbm down to 10 lbm with satellite specific powers from 1 to 4 W/kg). Propulsion system requirements for this class of satellite are high due to larger maneuvering requirements, higher precision attitude control, increased stationkeeping life, and higher drag make-up for low orbit satellites. Substantial improvements in both thruster performance and specific power are needed to provide this increased propulsion system capability while constrained by large mass and power limitations. The objective of this effort is to radically push the technological envelope in the field of electric propulsion. Proposed concepts must show promise of more efficiently utilizing the on-board electrical energy while maintaining high specific impulse operation. Primary interests are performance, thrust-to-weight ratio, minimal impact on spacecraft operations and systems, minimal spacecraft contamination, environmental compatibility, and lifetime. Projects proposing significant enhancements to existing systems will also be considered. 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 if proper documentation of efforts to secure these facilities is provided. Based on the results of these tests, thruster performance should be estimated and improvements quantified. Evaluation of technology improvements with respect to state-of-the-art should occur throughout the effort. Use of Government facilities may be requested. Government facilities can be sought at no cost to the contractor or SBIR office. Please contact the technical point of contact for more information regarding government facilities.

PHASE I: Develop and assess the feasibility of innovative electric propulsion thruster concepts for small satellite applications.

PHASE II: Apply the results of Phase I to the design, fabrication, experimental validation, and optimization of Electric Propulsion thruster performance capabilities. The design process is expected to be iterative with the thruster with the best overall performance being reproduced and be deliverable to the Air Force at the end of the phase II period.

PHASE III DUAL USE APPLICATIONS: Dual use commercialization would occur through the development of flight quality electric propulsion systems for small satellite and space experiment applications. The development of small satellites, and their propulsion systems, is one avenue for reducing satellite launch costs. The higher performance thrusters will result in greater mission capability including both satellite life and maneuverability, which are areas of interest to military 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.

REFERENCES:
1. Stephenson, R.R., "Electric Propulsion Development and Application in the United States"
2. International Electric Propulsion Conference IEPC Paper 95-1, Sept. 1995.
3. Antropov, N.N. et al., "Preliminary Results on Service Life Development of PPT Scale Model", International Electric Propulsion Conference IEPC Paper 95-114, Sept. 1995.
4. McLean, C.H. el al., "Life Demonstration of a 600-Second Mission Average Arcjet", American Institute of Aeronautics and Astronautics AIAA Paper 94-2866, June 1994.
5. Garner, C.E. et al., "Cyclic Endurance Test of a SPT-100 Stationary Plasma Thruster", American Institute of Aeronautics and Astronautics AIAA Paper 94-2856, June 1994.

KEYWORDS: Electric propulsion, Arcjet engines, Ion engines, Electromagnetic propulsion, Electrothermal engines, stationkeeping, service life, performance tests, specific impulse

AF01-187 TITLE: Advanced Rocket Motor Case Design and Development

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Design and develop innovative lightweight rocket motor cases.

DESCRIPTION: Innovative rocket motor case designs and materials selection offer the potential to improve performance, supportability, cost and weight of today's current rocket motors. Although rocket motor materials have evolved over quite some time, advancements in both composites and metals have left much room for innovation and improvement. The Air Force is interested in pursuing advanced rocket motor cases that can be utilized both in a United States Navy shipboard, and United States Air Force land-based environment. Hence, water absorption, strength of materials over long term use, storage, uniformity of materials, corrosion resistance and quality of materials are critical. In addition to the need for lighter weight and additional propellant loading (longer burn times), tactical air-to-air missiles require a case which supports propellant fills which when viewed as a system comply with Insensitive Munition Requirements (DOD-Std-2105). Affordability is absolutely critical. Exotic materials are possible…but often expensive and difficult to manufacture. The challenge is to develop a rocket motor design which meets high dynamic structural, storage, employment, environmental performance, Insensitive Munitions compliance, and is affordable and manufacturable. This effort should characterize innovative materials and design concepts, as well as provide tests, data, and analyses to support military commercialization of an advanced rocket motor case. In addition to the motor case, application of the technology to the missile forebody, fuze, warhead, and the aft sections should also be assessed. The idea is to improve performance and supportability over a 20 year lifetime of storage and use. The relatively small, advanced Sidewinder missile should be used as the baseline for assessing different approaches and anticipated payoffs.

PHASE I: Determine the feasibility of using innovative case designs and materials to meet the criteria discussed above. Limited material testing desired.

PHASE II: Further develop and demonstrate the feasibility of the concept in prototype hardware.

PHASE III DUAL USE APPLICATIONS: This technology is applicable to both military and commercial launch vehicles, drive shafts, and airframe structures. Other commercial applications include tennis rackets, golf clubs, & bicycles.

REFERENCES:
Sutton, G. P., Rocket Propulsion Elements, John Wiley & Sons, Inc., New York, 1992

KEYWORDS: Solid rocket motor, structural dynamics, affordability, stiffness, fatigue, composite motor case, material properties

AF01-188 TITLE: Develop and Demonstrate a Hybrid Powered Missile Motor

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop and demonstrate innovative hybrid propulsion systems for tactical missile applications.

DESCRIPTION: A recent Air Force Research Laboratory study and subsequent subscale testing demonstrated that missiles employing hybrid propulsion have the potential to make significant gains in performance over conventional solid rocket motors. Motor performance improvements translate directly to improved launch aircraft survivability and missile lethality via increased missile range and reduced flight time-to-target. Hybrid propulsion systems, unlike solid rocket motors, keep the fuel and oxidizer separate until they are mixed in the combustion chamber. This enables higher fuel loading since less volume is required for the relatively high-density liquid or gelled oxidizer. Innovative approaches are needed to develop and demonstrate the feasibility of this new technology in a 7” diameter, 86” long motor (i.e. similar to current state-of-the-art air-to-air missile motors). Proposed designs will be compatible with the internal weapons bays of future USAF aircraft such as the F-22 and JSF while also meeting load and vibrational requirements of externally carried munitions. Issues which may ultimately reduce the total fuel and oxidizer loading, such as thermal insulation to protect the motor from aerodynamic heating and placement of launch hook reinforcements and fin actuation systems should be addressed. The final goal will consist of the integrating propulsion system components into a 7” diameter flight-like engine and conducting a full-scale engine demonstration. Demonstration of flight-weight hardware is desired.

PHASE I: Establish motor requirements (with assistance from the Air Force program manager) which include but are not limited to physical dimensions, captive carry and launch loads, thermal environments and delivered performance. Establish conceptual motor designs, which meet the established requirements. Demonstration of critical technologies is desired.

PHASE II: Fabricate and demonstrate full-scale hybrid rocket motor performance in static ground tests. Lightweight and/or flightweight hardware of critical components is desired.

PHASE III DUAL USE APPLICATIONS: The results of a successful Phase II program would demonstrate technologies that would find a wide variety of commercial uses. Automobile airbags and other safety devices represent a large market that require a similar ability to deploy gases quickly and efficiency. Other commercial products include various combustion devices such as torches, welders, and emergency generators. Direct application to heavy launch booster vehicles is also anticipated.

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1. Altman, D. “Hybrid Rocket Development History,” American Institute of Aeronautics and Astronautics AIAA Paper 91-2515, June 1991

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4. Sutton, G. P., Rocket Propulsion Elements, John Wiley & Sons, Inc., New York, 1992.

KEYWORDS: Rocket, Hybrid Rocket, Oxidizer, Propellants, Expulsion System, liquid oxidizer

AF01-189 TITLE: Develop Mechanical Aging Criterion for Energetic Materials

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a criterion for determining failure properties of energetic materials based on mechanical aging phenomena.

DESCRIPTION: Solid rocket motor systems, and in particular, tactical motor systems are exposed to a wide range of mechanical loading environments including cyclic storage, vibration, and transport. As a result, mechanical aging, also referred to as cumulative damage, is often the major cause of failure in tactical motors. There is no standard model for assessing cumulative damage and predicting failure. The models that do exist have varying applicability depending on particular loads or environments to which the motor is exposed. An ideal cumulative damage model would be able to handle the entire range of inputs a tactical motor experiences and accurately give failure criteria for use in motor analysis.

PHASE I: Develop an innovative theoretical model for damaged energetic materials capable of dealing with cyclic loading, vibration, and handling.

PHASE II: Verify the model for a variety of energetic materials through mechanical testing and prediction.

PHASE III DUAL USE APPLICATIONS: A mechanical aging/damage criterion would have broad applicability to solid rocket motors of all types, including military (strategic and tactical), civilian, and commercial rocket motors. Constitutive models for damage in multi-component (composite) materials would be useful for civil engineering applications such as modeling of cements and filled rubbers and could have a much wider application to materials in general such as metals and alloys.

REFERENCES:
Liu, C.T., Cumulative Damage and Crack Growth in Solid Propellant. Final Report, Mar. 1988 - Dec. 1996; CASI HC A03/MF A01; AD-A323684; PL-TR-96-3033; NIPS-97-25146; AN: N97-23916

KEYWORDS: Mechanical aging, Damage models, Cumulative damage, Constitutive models, Solid rocket motors, Propellant

AF01-190 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 that can double existing rocket propulsion capabilities by the year 2010, and for bold, new, nonconventional aerospace propulsion-related technologies that 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 while 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. 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, storage of antimatter in chemical matrices, 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 FY01 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: 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:

1. “Selected Bibliographies, Handbooks, Manuals, and Reviews,” CPIA SB-94, Nov 1994.
2. Air Force Research Laboratory Propulsion Directorate website address: http://www.pr.afrl.af.mil

KEYWORDS: Rocket Plume, Rocket Engine, Rocket Propellants, Satellite Propulsion, Boost Transfer, Orbit Transfer.

AF01-191 TITLE: Advanced Aluminum Materials for Rocket Turbopump Rotors

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Identify and demonstrate the feasibility of using advanced aluminum materials for rocket engine turbopump rotor applications. Document and demonstrate cost and/or weight advantages over conventional titanium.

DESCRIPTION: Titanium is the typical material used for rocket engine liquid hydrogen turbopump rotors. This strategic material has a high cost associated with raw materials, processing, and machining. Additionally, hydrogen embrittlement requires material property debits against the titanium during design. Higher specific strength materials at a lower cost are desired. Ideally, a widely used, commercially available material would provide significant raw material, material processing, and machining cost advantages. Alternately, new materials with similar widespread commercial applicability would provide similar advantages. Advanced aluminum materials are seeing greater use in non-rocket applications and may be suitable for application as liquid hydrogen turbopump rotors. Innovative application of these advanced aluminum materials to turbopump rotors is desired.

PHASE I: a) Consult with rocket engine, launch vehicle and aerospace vehicle manufacturers to identify material property requirements for liquid hydrogen turbopump rotors. b) Identify potential advanced aluminum materials with cost and/or performance advantages over titanium. Identify the processes required to prove this material system is acceptable in this application. c) Formulate several conceptual designs incorporating the advanced aluminum material for either a direct replacement for a fielded component or as a component for a planned system. d) From among the various conceptual designs select and justify the component with the greatest cost and/or performance advantage for further development. e) Initiate a preliminary design and test plan for this material and component. Conduct subscale testing to demonstrate material properties.

PHASE II: 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 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. h) Re-accomplish testing as required and create manufacturing plan.

PHASE III DUAL USE APPLICATIONS: The commercial aerospace industry to include both aircraft, combined cycle vehicles, and launch vehicles would have widespread use of such a material. Additionally, the transportation industry as a whole will benefit from the availability of high specific strength low cost aluminum material systems.

REFERENCES:
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3. “Aluminum Composite Reduces Cost, Improves Performance,” Advanced Materials & Processes, Vol. 152 (Oct. 1997) p. 7.
4. “Smarter Methods Allow Aluminides To Improve Engines,” Advanced Materials & Processes, Vol. 152 (Oct. 1997) p. 14.
5. “Aluminum Beryllium Alloys,” Advanced Materials & Processes, Vol. 152 (Oct. 1997) pp. 37-40.

KEYWORDS: Turbopump, cryogenic turbopump, aluminum composites, aluminum alloys, hydrogen embrittlement, low temperature aluminum.

AF01-192 TITLE: Rapid Cost Estimates of Military Aerospace Vehicles (MAV’s)

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop a life cycle cost estimation tool for MAV’s with emphasis on propulsion elements.

DESCRIPTION: Air Force researchers are engaged in the development of propulsion system technologies for MAV’s, via activities such as the Reusable Military Launch Vehicle 2000 study. The researchers have many credible tools for synthesizing vehicle and propulsion concepts. They need innovative tools suitable for estimating the costs associated with vehicle life cycle cost with significant detail in propulsion. The product of this effort will be a tool that can be used to estimate the development, acquisition, operations, and maintenance cost of the aerospace vehicles and their propulsionsystems. The tool will be developed employing innovative data mining, data analysis, and adaptive intelligence techniques. The tool should be able to differentiate between horizontal versus vertical take-off vehicles. Anchors to representative expendable systems would be useful to compare missions. The tool should be able to extract subsystem costs: landing gear, avionics, thermal protection system, vehicle main structure, tanks, feed system plumbing, reaction control propulsion, and main propulsion. Operability cost model should contain sufficient detail to distinguish between storable and cryogenic propellants. Tool should scale from 3,000 lb hypersonic missiles to 2 Mlb single stage to orbit vehicles. The Propulsion Directorate is interested in a tool that will address the following propulsion systems: highly reusable rocket engines, rocket and turbine-based combined cycle engines. Propulsion flowpath (e.g. inlets, combustors, nozzles, compressors, and turbines), propellant feed systems (e.g. tanks, pumps, valves, and injectors), and consumables (e.g. fuels, oxidizers, and igniters) should be included in the cost tool.

PHASE I: Define a cost estimation technique for Military Aerospace Vehicles. Develop a detailed Phase II plan to create the cost tool and create a “look and feel” demonstration of the tool.

PHASE II: Execute the Phase II plan to develop the cost tool for MAV’s. Plan should include extensive user feedback during development to answer on-going vehicle and propulsion cost questions.

PHASE III DUAL USE APPLICATIONS: The cost estimating tool will most likely be used by USAF and NASA researchers and technology planners. It is also likely to be useful throughout the aerospace industry including commercial spacelift ventures. Phase III will provide baseline cost estimates that cover the scope of vehicle concepts that are of interest to the commercial market.

REFERENCES:
1. Koelle, D.E., “Launch Cost Analyses for Reusable Space Transportation Systems,” IAA-87-61, available from AIAA, Report Number: MBB-UR-1006/87-PUB; IAF-87-618 , 1987 , 6p.
2. Production/Cost Analysis of Ramjet Engines, AFAPL-TR-77-50-VOL-1. Available from NTIS, ADA 056 856.
3. Ramjet Cost Estimating Handbook, AFAPL-TR-77-50-VOL-2, CPIA-PUB-288. Available from NTIS, ADA 056 991.

4. Air Force Research Laboratory Propulsion Directorate website address: http://www.pr.afrl.af.mil

KEYWORDS: Acquisition Life-cycle cost, vehicle cost modeling, rocket, ramjet, turbojet, propulsion

AF01-193 TITLE: Sensors to Determine Composite Motor Case Damage

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Design/verify a sensor system capable of accurately detecting damage to solid rocket motor composite cases.

DESCRIPTION: Composites are excellent materials for solid rocket motor cases due to their high strength and low weight. However, because they are fibrous, damage may occur during manufacture or transport that is not easily detectable and may significantly weaken the case. Breaking of fibers and delamination are two possible types of damage. A sensing technique/device capable of detecting the location and type of damage that may have occurred, and reporting it with sufficient detail such that one could simulate the damaged case to determine its usability, is needed for commercial and military solid rocket motors.

PHASE I: Develop and demonstrate a prototype sensor system capable of locating and assessing damage to the type of composite materials used in rocket motors.

PHASE II: Design and manufacture a subscale composite motor case design on which to demonstrate the prototype case damage system. Verification articles should be damaged or manufactured with known flaws similar to those in large motor cases and the accuracy of the damage detection system verified by comparison with current (e.g. destructive) means of testing.

PHASE III DUAL USE APPLICATIONS: Composite materials are becoming more prevalent in industry, particularly in various aerospace applications due to their low weight, high strength, and good thermal properties. A sensor such as this would find many applications in the manufacture, maintenance, and repair of commercial and military aircraft, as well as spacecraft/launch vehicle applications.

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1. Ward D. Rummel, P.E., Solid Rocket Booster Initiatives for the Inspection of Composite Cases, D&W Enterprises, LTD., Report No. DW98-401, Sept 1998.
2. Wang, X., Wang, S., Chung, D. "Sensing Damage in Carbon Fiber and Its Polymer-Matrix and Carbon-Matrix Composites by Electrical Resistance Measurement," Journal of Material Science, vol. 34, no. 11, 1 June 1999.

KEYWORDS: Composite materials, Delaminations, Composite fibers, Composite material damage sensors, Composite material damage, Rocket motor cases

AF01-200 TITLE: Ultra Wide Band RF Antenna Element

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: The USAF is seeking new ideas and technology to support the reception/transmission of ultra wideband radio signals. Application areas include very wide band RF phased arrays for space-based as well as air based and terrestrial platforms.

DESCRIPTION: This effort is directed toward the development of an ultra wideband antenna element for both receive and transmit functions. The element shall be integratable into a planar RF phased array antenna and is capable of being integrated into RF beam formation and beam steering subsystems including the use of true time delay. The element shall have fixed polarization across the bands of interest. These frequencies include - but are not limited to - HF through 100 Ghz. The element shall be designed to provide the maximum frequency range as possible. These ultrawide elements - integrated into RF phased arrays - shall be used in diverse areas such as multifunctional antennas systems and in ultra wide band receivers for ELINT. The ultra wide antenna will reduce the total number of antennas on a platform including both military and commercial aircraft thereby reducing the required number of skin penetrations and maintaining fuselage integrity. Expected RF signal distribution from the output of the antenna element/RF phased array will be to RF photonics wide band links. Issues to be addressed are one or more of the following: (1) Integratable element into a planar RF phased array; (2) wideband / ultra wideband performance; (3) gain either as a single element or integrated into a RF phased array; (4) fixed polarization over the frequency range. Implementation of this technology can provide light weight, multifunctional RF phased array for numerous applications in both the military and commercial areas.

PHASE I: Provide a report and an initial laboratory technology demonstration of the proposed approach describing one the antenna element addressed above.

PHASE II: Fabricate and demonstrate a device which demonstrates the technical goals of the program.

PHASE III DUAL USE APPLICATIONS: Single antennas which can cover multiple frequencies such as cellular/PCS phones, new frequency usage, etc.

REFERENCES:
M. W. Nurnberger, etal., "Analysis of the log-periodic folded slot array," University of MI, IEEE Antennas and Propagation Society International Symposium, vol. 2, pp1282-5,1994.

KEYWORDS: Antenna Systems, RF Phased Arrays, Broadband Antennas, RF Sensors

AF01-201 TITLE: Ultra Wide Band High Performance RF Links

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: The USAF is seeking new ideas and technology to support the distribution of Radio Frequency (RF) signals. Application areas include space-based as well as air based and terrestrial platforms.

DESCRIPTION: This effort is directed to the development of enabling technologies for ultra wideband, high performance, RF links which are critical to the distribution of RF signals for such diverse applications such as antenna remoting, RF interconnects, Local Oscillator (LO) distribution, true time delay beam formation and beamsteering. Ultra wideband, high performance RF links will be initially designed as point to point transmission media but, through the application of other technologies such as optical switches and Bragg gratings, will be of use to other system and subsystem applications. Such ultra wide, high performance RF links will be designed to be transparent to the users and to the equipment which will be used with the interconnects. The dynamic range (even and odd orders), frequency of operation and gain shall be maximized, and required prime power, system noise, differential propagation delay, phase variation, frequency dispersion, and cooling requirements shall be minimized. It is anticipated that photonics will be critical to the performance of such Ultra wide band, high performance RF links including implementation into true time delay beam steering subsystems for RF phased array antennas. Issues to be addressed are one or more of the following: (1) high efficiency conversions from RF to optical and/or optical to RF; (2) minimization of throughput losses (3) transparency of the photonic RF interconnect to the RF signal by (a) low noise, (b) high dynamic range - goal of 140 dB/Hz2/3 , (c) small size, (d) light weight, (e) reduced prime power requirements; and (4) low loss, high speed, high isolation photonic switching. Frequencies of interest range are from 30 Mhz to 100 Ghz. Implementation of this technology can provide light weight, low loss, interference resistant - EMI(Electromagnetic Interference), EMP (Electromagnetic Pulse), and SGEMP (Surface Generated EMP) - RF (and data) signal distribution as compared to current technology all metallic electronic systems.Devices of special concern are both broadband and narrow band high frequency, low Vpi modulators with high dynamic range; high efficiency, high frequency, high dynamic range optical detectors with high power handling capability; and low loss, high speed, all optical switches. These device technologies must be capable of operation in both low and high altitude orbits in polar and in equatorial planes.

PHASE I: Provide a report and an initial laboratory technology demonstration of the proposed approach describing one of the photonic components addressed above.

PHASE II: Fabricate and demonstrate a device which demonstrates the technical goals of the program.

PHASE III DUAL USE APPLICATIONS: Reduced weight and interference for more maneuvering fuel and longer lifetime of commercial and military satellites. Applications areas include airborne platforms in the military and civilian usage along with potential applications to the cellular and personal radio communications sites.

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1. W. Ng, A Narayanan, R. R. Hayes, D. Persechini, D. Yap, "High Efficiency Waveguide Coupled = 1.3 µm InXInXGa1-XAS/GaAs MSM Detector Exhibiting LargeExtinction Radios at L and X Band," IEEE Photonic Letters, vol. 5. pp. 514 - 517, May1993
2. W. B. Bridges, L. J. Burrows, U. V. Cummings, R. E. Johnson, F. T. Sheehy, "60 and 94 Ghz Coupled Electro-Optic Modulators," DTIC ADA318136
3. R. Logan, "High Fidelity Microwave Remoting," Oct 1998, DTIC ADA358462, AFRL-SN-RS-TR-1998-195

KEYWORDS: Electrooptics, Command, Control, Communications, Antenna Remoting, RF Signal Distribution, Optical Switching, Photonics, Lasers, Photodetectors, Space

AF01-202 TITLE: Fusion of GMTI Reports from Multiple Sensors in Clutter

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop tracking algorithms for fusing ground moving target indications reports in clutter from sensors on multiple platforms.

DESCRIPTION: War fighters need a consistent shared view of the battlefield so they can operate most effectively. Fusion of ground moving target indications (GMTI) data from multiple platforms with overlapping fields of regard can improve tracking of moving ground targets. For this reason, the services are working to develop techniques that can be used by multiple systems to fuse GMTI reports from air and space platforms. The primary goal of this effort is to develop and demonstrate innovative tracking algorithms that fuse GMTI data from multiple platforms with overlapping fields of regard in the presence of clutter. An idealized thermal noise with Gaussian statistics assumption is often used for system design. This assumption results in optimistic performance predictions in the presence of clutter, since clutter is not white noise, but a persistent physical phenomenon. For small slow targets and for targets sensed at reduced signal levels, clutter will degrade target detection, raise false alarm rates, and increase measurement errors from GMTI sensors. These factors can lead to additional problems in report registration, report to report and report to track association, and false and redundant track formation. This effort seeks to develop a model that illustrates the effects of residual ground clutter and quantifies the seriousness of these problems for typical GMTI scenarios, and to develop multiple platform tracking and fusion concepts that ameliorate these problems. Implementing these concepts should result in improvement in the following parameters: improved target detection and localization, reduced false tracks, and improved report-to-track association.

PHASE I: The effort seeks to establish a basic understanding of the effects of clutter for fusing multiple platform GMTI reports and to quantify this problem for typical GMTI scenarios. The main goal is to develop concepts for tracking algorithms and data fusion techniques that mitigate disparities of tracks developed from GMTI sensors on multiple platforms in the presence of clutter. An evaluation methodology and a multi-platform fusion model that includes a realistic ground residual clutter model should be developed. Feasibility of the concepts developed needs to be established through engineering analysis and simulation in Phase I. Improvements in target detection and localization, reduction of false tracks and report-to-track association errors should be quantified as a part of this feasibility demonstration. As a minimum the effects of an appropriate clutter model should be compared to an idealized Gaussian noise model to estimate the impact on tracking and targeting. Significant issues should be identified and tradeoffs analyzed. In order to facilitate transition to Phases II and III, the methods developed should be consistent with typical multi-platform GMTI concepts of operation. It is anticipated that data from GMTI collections will become available. A secret facility clearance will be required to acquire, store and process this data.

PHASE II: The major goal of Phase II is prototype development and demonstration of the concepts developed in Phase I through more realistic simulations and on actual data from GMTI collections. This phase of the effort is likely to include further refinement of the tracking algorithms, the clutter model, and the fusion techniques to better address issues identified in Phase I.

PHASE III DUAL USE APPLICATIONS: Commercial applications include traffic pattern monitoring and intrusion alarms. Military applications include detection and tracking of low velocity targets for intelligence, surveillance and reconnaissance (ISR) or tactical missions.

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2. White, R.G. and Coe, D.J.; “Detection Limits for Sideways Looking MTI Radars”, Proceedings of the 1997 Radar Edinburgh International Conference. IEEE Conference Publication. (ISSN 0537-9989) p.434-438

KEYWORDS: GMTI Tracking, Clutter, Distributed Sensing, Multiple Targets.

AF01-203 TITLE: Dynamic Operational Re-Tasking of ISR Sensors

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop techniques for real-time or near real-time dynamic re-tasking of Intelligence, Surveillance, and Reconnaissance (ISR) sensors under realistic operational conditions.

DESCRIPTION: Information superiority is crucial to achieving the operational goals of Joint Vision 2010 involving precision engagement and rapid response. In this context the agility of the information-gathering activities to support intelligence, surveillance, and reconnaissance (ISR) is a key concern. The real-time moding, pointing, and directing of ISR sensors, commonly known as Dynamic Re-tasking, is a principle tenet within the envisioned information-gathering architecture; Yet it is unclear how well this goal may be achieved. Factors such as the diversity of ISR assets, limited communication bandwidth, volatile situation dynamics, computational/organizational limitations in absorbing and processing the glut of information, and the evolutionary nature of the information-gathering architecture itself present serious technical challenges. This research effort seeks to develop, test, and demonstrate algorithmic methods for managing diverse ISR assets under real-time operational conditions. The solution methods shall be firmly based in relevant scientific theory and must be extendible into current and future information-gathering architectures.The challenge here is fundamentally a multi-objective optimization problem: A diverse set of ISR assets (Joint Stars, U2, Rivet Joint, various UAVs, Discoverer II) fitted with various sensors (GMTI, SAR, electro-optic and infrared sensors, SIGINT) must satisfy the multiple objectives of detecting, classifying, and tracking ground targets as well as performing various miscellaneous tasks (Battle Damage Assessment, etc.) within appropriate time constraints. Each asset may be assumed to be operating according to some pre-mission plan. It is unclear whether or not the ISR resource manager can dynamically allocate resources to satisfy new information needs in a timely manner while minimizing perturbations to pre-existing collection plans for individual assets. Part of the challenge here is to derive a global objective function which yields desirable system behavior in a realistic demonstration. This objective function may include technical performance parameters to be optimized such as probability of detection, probability of correct classification, kinematic tracking error, probability of maintaining track and other performance measures which may be defined during the course of this effort. Other parameters of interest include the computational complexity of the solution algorithm and its ability to use the ISR resources in an efficient and adaptive manner. The challenge of optimal scheduling of multiple assets to satisfy or optimize multiple objectives has been studied in numerous application areas (such as management of power/communication networks, traffic control) and within the scientific disciplines of Operations Research, Systems Engineering, and Computer Science. It has often been found to be NP-complete even under modestly complex conditions. Here, the problem contains many complicating factors (harsh time limitations, large number of targets and sensors, and uncertainties associated with their movement and articulation) which may only worsen in the future. We are particularly interested in novel methods which may overcome explosive combinatorics, cope with the ubiquitous uncertainties, and provide an adaptive, robust solution for the management of future ISR systems.

PHASE I: Examine theory and pertinent resource management methods; identify their limitations while suggesting means to circumvent these. Establish current baseline capabilities and architecture for managing ISR assets. Develop sensor tasking performance analysis and identify appropriate performance metrics. Synthesize an ISR resource manager with dynamic re-tasking capability for a suitable example problem, preferably involving dynamic cross-cueing of GMTI sensors and other sensors (i.e., video, SIGINT, Electro-Optic/Infrared, etc.) which can provide a capability for multiple platform tracking and identification of ground targets. Develop feasibility analysis of solution concepts. Achieving desired results requires scenario development, mathematical modeling, algorithm formation, simulation development, algorithm evaluation, and analysis. Review available simulation tools for evaluating resource management algorithms and if cost-effective, modify them to fit this problem. The Government shall help to identify and obtain background information that can be used to support the research effort.

PHASE II: Refine integrated resource management methods based on findings in Phase I. Characterize system performance via simulation for an assortment of mission scenarios involving an enlarged set of sensors and platforms (relative to Phase I work) and more realistic operational conditions. Phase II efforts shall culminate in a prototype demonstration. The approaches developed must take into account the current or planned information-gathering architectures (including nature and flow of information, decision-making structure, communication links, etc.) and must develop a draft concept of operations to show how the developed approach would be applied. Use simulation results to evaluate Phase II methods against the baseline established in Phase I. Identify limitations of the designed system and cite avenues for future research.

PHASE III DUAL USE APPLICATIONS: The development of robust and dynamic resource management methods for ISR assets has application to many commercial fusion domains. Management of power and communication networks may require intelligent re-routing of process resources (e.g., resource management). Intelligent vehicle control systems (e.g., air-traffic control, intelligent vehicle highway system, etc.) can also benefit from sound resource management methodologies.

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KEYWORDS: Dynamic Replanning, Scheduling, Cross-cueing GMTI Sensors, Multi-sensor Fusion, Resource Management, Automatic Target Recognition, Distributed Tracking, Intelligence, Surveillance, and Reconnaissance (ISR) Missions

AF01-204 TITLE: Standard Image Compression for Data Link Transmission

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a standard complex Synthetic Aperture Radar (SAR) image compression algorithm that retains original exploitation capabilities on ground targets.

DESCRIPTION: The DoD has been investing in several Synthetic Aperture Radar (SAR) systems that produce very large quantities of data that must be transmitted and stored. The amount of data is such that 'standard' communications systems will be overwhelmed and storage capability will be stressed. One solution is to compress the data to reduced required communications bandwidth and storage capacities. The challenge is to find an algorithm that will provide sufficient compression without degrading data to the point that is unusable for exploitation and intelligence extraction. SAR imagery provides a particular challenge in that it has characteristics that differ from Electro-Optical (EO) imagery. In particular, the dynamic range of SAR is much greater that other types of imagery. The construction of the SAR imagery from coherent radar pulses introduces speckle that is essentially randomly distributed. Neither of these effects can be adequately dealt with by standard image compression techniques e.g. JPEG. Modern SAR systems transmit data in a complex image format. The usual complex format used is phase and magnitude samples. The presence of the phase component has at least 2 implications. First, the compress phase data vice image data. Phase data is more sensitive to reconstruction errors than is imagery. There has been limited research in this area. Secondly the presence of phase information allows the data to be used to support Materials and Signature Intelligence (MASINT) exploitation. Therefore, reconstructed phase data must be of sufficient quality to support MASINT exploitation algorithms. Another issue is the automation of the exploitation process is the number of analysts available to exploit the huge amounts of data that must be processed. In order to deal with this large amount of data automatic techniques such as Automatic Target Detection/Recognition (ATD/R) and Automatic Change Detection (ACD) for SAR imagery must be employed. At the same time the human analyst will remain a key element of the exploitation process. The challenge is to develop a compression algorithm that will support compression of complex SAR imagery and not significantly impact ATD/R, ACD and MASINT exploitation algorithms or human interpretability of the imagery.

PHASE I: The offeror will develop an innovative approach to SAR data compression algorithms that will be sufficiently robust to satisfy the requirements above.

PHASE II: The major goal of Phase II is the demonstration of the compression algorithm on a DOD simulated and/or on real data from SAR collections. Testing will be conducted to show the capability of operation over a wide range of operating conditions. Efforts likely include further developments to meet operational requirements

PHASE III DUAL USE APPLICATIONS: The standard algorithm would be incorporated as part of the National Image Transmission format (NITF) and become part of the Joint MASINT Architecture. As such, this algorithm would be used by all of the services and other agencies. A standard SAR compression algorithm would be useful in commercial ventures that have similar problems and requirements.

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2. The Affect of Image Compression on a Synthetic Aperture Radar Automatic Target Recognition Prescreener and the Relation to SAR Image Statistics, Final rept. Jan 95-Jun 97, Withman, Raymond, Cates, Donnie, Kotz, Bob, Aug 1997, WL-TR-97-1162
3. Assessing the impact of image compression on SAR automatic target detection and cueing Gorman, John D.; Werness, Susan A. S.; Wei, Susan C. (Michigan, Environmental Research Inst., Ann Arbor) 1996 IEEE National Radar Conference, Univ. of Michigan, Ann Arbor, May 13-16, 1996, Proceedings (A96-38901 10-32), Piscataway, NJ, Institute of Electrical and Electronics Engineers, Inc., 1996, p. 118-123.1996
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KEYWORDS: SAR Image, Compression, Complex Imagery, Image Quality, Phase Quality

AF01-206 TITLE: Mitigating Data Order Effects in Multi-Platform GMTI Tracking

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Investigate fusing out-of-order GMTI radar data.

DESCRIPTION: The issue of fusing out-of-order detections received from a network of sensors at a central fusion center needs to be studied to allow development of solutions for various military and commercial applications. A basic question is when to insert the old data and quantify what "old" means. This question is highly related to the particular application. While simple for a small set of targets, this effort will consider this question in the challenging environment of tracking several thousands targets. A basic research question is which out-of-order reports are relevant and how can these reports be incorporated in real-time.The focusing military application for this effort is surveillance of moving ground targets by multiple airborne platforms using Ground Moving Targeting Indication (GMTI) radar modes. Platforms include J-STARS, U-2, Global Hawk, and space assets. A central ground station uses detections from these platforms. A highly related application is surveillance of U.S. borders in order to detect and track vehicles transporting illegal aliens or drugs while another is real-time analysis of transportation networks. For all these applications, data can be received out-of-order as a result of asynchronous operations, and delays in transmission initiation and communication network execution. In surveillance applications, the potential exists for different tracking systems to produce different results because they receive and process reports in different sequences. This could potentially cause miscommunication between assets reacting to these different views of the situation. The simple solution is to re-process the entire history of reports but this is computationally intractable given large numbers of targets over a long period of time. Even within a particular application, the mode of operation could drive how and when out-of-order data is inserted. For a military example, directing assets to destroy a target requires maintaining high accuracy in terms of the target's identity as well as position. This is similar to the needs of a distributed transportation network flow analysis used to control traffic light sequences in real-time. Given all the detections cannot be re-processed in real-time, only relevant detections should be included. For this effort, the emphasis will be on rapid targeting applications where precision tracks on tens of targets must be maintained and passed to weapon systems while simultaneously maintaining surveillance tracks on thousands of other targets.Related programs include ASC/RA's Joint Multi-Platform Tracking Exploitation (MPTE) and DARPA's Affordable Moving Surface Target Engagement (AMSTE) and Moving Target Exploitation (MTE). Scenarios and classified data will be available from these efforts.

PHASE I: Efforts should address at least two goals. The first is to establish a basic understanding of the effect of data ordering and quantify the problem for a typical scenario. A model, a set of scenarios, and an evaluation method can be developed as necessary and then used to study the problem. Tradeoff studies and analyses may be used to identify and understand significant parameters. The second goal is to develop concepts or procedures for detecting when and how to incorporate detections. Feasibility of the concepts or procedures needs to be established through simulation or engineering analysis. While a mature tracker is desirable, the developed method does not have to demonstrate mature tracking on real GMTI radar data. However, the method underlying the concept must be consistent with typical harsh surveillance operating conditions such as tracking thousands of targets with reports lost due to obscuration and line-of-sight velocities that are less than minimum detectable velocities while rejecting false alarms. In particular, projected computing and bandwidth requirements should not greatly exceed projected capabilities of airborne ground surveillance systems and related ground-based processing. The result of Phase I should be a rough design with enough analysis to establish feasibility of meeting Phase II goals.

PHASE II: Demonstrate and assess the method on Air Force GMTI simulations and/or on real data from GMTI collections. Efforts will include further developments to meet operational requirements such as scenario enrichment, algorithm enhancement, and sizing for operational implementation. Based on these studies, maturity assessment will be performed to determine where the technology needs further development before transition may occur.

PHASE III DUAL USE APPLICATIONS: Known application areas include commercial aviation, Intelligent Vehicle Highway Systems (IVHS), and border surveillance by Drug Enforcement Agency and the Immigration and Naturalization Service. Military applications include surveillance of the battle space with an improved and integrated picture of the battle space among platforms.

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KEYWORDS: GMTI, Tracking, Multi-Platform, Surveillance

AF01-207 TITLE: Optimally Fuse Multiple Source SAR Images to Improve Combat ID

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop algorithms to optimally use multiple SAR images creating an "enhanced" image or fused information for automatic target recognition and combat identification of ground targets.

DESCRIPTION: High resolution synthetic aperture radar (SAR) imagery is used for target recognition, either automatically or by an image analyst, providing a level of confidence for target identification. Experiments have shown the utility of multiple aspect "looks" for increasing the probably of identification. This effort will develop algorithms to optimally use multiple SAR images to create an "enhanced" image or fused information, which can be multi-dimensional. Multiple users can receive multiple SAR images from multiple airborne platforms in a netted architecture. If the information from these multiple sources of SAR data can be optimally used the potential exists to improve the identification and/or classification of the target. For instance, viewing more target scatterers may provide better separability between target classes. The algorithms should be robust in the dimensionally of the parameter space of a SAR radar. Hence neural network or other innovative robust techniques may be investigated. From these and integrated with them, ATR classification and discrimination algorithms that take advantage and exploit the fused information will be developed. These may be new or use existing ATR algorithms (e.g., Moving and Stationary Target Acquisition and Recognition (MSTAR)).

PHASE I: Analyze existing algorithm approaches for using multiple SAR images of the same target. The algorithm and analysis may consider features that are prevalent across multiple angles and provide target class separability. Alternatively, an innovative approach to fusing information from multiple images can be used to provide class separability. Depending on the approach, image registration and alignment issues may need to be considered. Develop benchmarks to identify the improvement in classification of the target.

PHASE II: Develop and test the algorithm. Develop benchmarks to identify the improvement in classification and identification in the new algorithms as compared to a provided baseline of algorithms.

PHASE III DUAL USE APPLICATIONS: Technology is applicable to all applications where a high degree of classification/recognition or identification is required; e.g., law enforcement and transportation.

REFERENCES:

KEYWORDS: Automatic Target Recognition (ATR), Fusion, Synthetic Aperture Radar (SAR), Combat Identification

AF01-208 TITLE: Tracking Densely Spaced Ground Targets with Data Fused from Moving Target Indication Radar

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Iinvestigate fusing GMTI radar and EO data from disparate sources.

DESCRIPTION: The problem addressed in this SBIR is how to fuse detections from air and space assets at a central processing station e.g. a JSTARS ground station when target density is great, the report data may have gaps and latencies, sensors contain uncompensated biases, and collection platforms have imperfect navigation solutions. We assume that the collection platforms view a common region and carry radar that are geographically separated and able to make ground moving target indication (GMTI) measurements and EO devices that are able to measure instantaneous angular location against moving targets. The users of this system need the capability to process a large number of targets and/or groups (on the order of 5000 to 10000) in ground clutter. Payoffs include improved target localization and an improved integrated picture of the battle-space. When GMTI radar is employed against densely spaced targets, there exists an association problem of assigning reports with initiated tracks. In addition to report-to-track association, the track processor must also initiate and terminate, and link track fragments in appropriate ways. These problems are made more difficult due to sensor errors resulting from platform flexure, sensor misalignments, and platform navigation errors. Further, it is important to determine computational complexity as the number of targets and sensors increase. We must also size the computer load required and latency associated with undersized computers.

PHASE I: The offeror will develop and implement optimal or near optimal probabilistic methods to perform track initiation, termination, association, and track maintenance to fuse data from dispersed sensors and will develop a residual ground clutter model to support the effort. The offeror will develop and implement in group-and-out of group logic for group tracking. The algorithm must be capable of processing a several thousand real targets in clutter, given data latencies, data gaps, and false alarms. Further, the offeror will calculate the sensitivity of changes in various parameters to probability of mis-association. The offeror will determine the size of the required computer load for an approved scenario and estimate the potential of future computers to meet the requirement. Further, the offeror will identify the latency associated with processing task parametrically as a function of an undersized computer. Finally, the offeror will identify the computational complexity of this problem as the number of targets and sensors grow and classify as to its type; e.g. polynomial or exponential.

PHASE II: The major goal of Phase II is demonstration of the method on Air Force GMTI simulations and/or on real data from GMTI collections. Efforts likely include further developments to meet operational requirements.

PHASE III DUAL USE APPLICATIONS: Known civilian application areas include commercial aviation, Intelligent Vehicle Highway Systems (IVHS) drug enforcement, and transportation system. Military applications include surveillance of the battle space with an improved and integrated picture of the battle-space among platforms.

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C. Chong, S. Mori, and K. Chang, "Distributed multitarget multisensor tracking", in Multitarget Multisensor Tracking (Y. Bar-Shalom, eds.), Artech House, Inc, 1990.

KEYWORDS: GMTI, EO Multi-Target Tracking, Multi-Sensor Tracking, Distributed Sensor, Sensor Fusion

AF01-209 TITLE: Evolving Onboard/Offboard Electronic Warfare Technology

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a rapid prototyping capability for evolving onboard/offboard sensor and electronic warfare technology

DESCRIPTION: Advanced sensor and electronic warfare technologies are being applied to both airborne and space assets. Current research and development methodologies that evolve these technologies are time-consuming and require extensive/costly testing on open air ranges. Open air ranges cannot generate the dense threat emitter environments that would be experienced in actual combat situations. Flight test productivity is low due to the fact that there are so many uncontrolled variables and the inability to make changes during the actual flight test. Approaches leading to the creation of innovative simulation concepts/technologies that enable the affordable rapid prototyping of onboard/offboard sensor and electronic warfare technologies in a controlled laboratory environment are sought. The goal of this research is to evolve dual use high fidelity simulation concepts/technologies that reduce the cost and time required to develop sensor and electronic warfare technologies. This research is intended to reduce the development and implementation time/cost for onboard/offboard sensor/electronic warfare capabilities through the creation of innovative synthetic battlespace simulation concepts/technologies that enable early insight/visibility into the maturity of these capabilities. The current simulation technologies do not have the required fidelity and real-time DoD High Level Architecture (HLA) simulation support environment for rapid prototyping of onboard/offboard sensor and electronic warfare capabilities. These limitations must be overcome if the DoD HLA concepts/requirements being sponsored by the Defense Modeling and Simulation Office are to become a reality in the defense community. This research addresses the incorporation of HLA standards per the DMSO M&S Master Plan.

PHASE I: The Phase I effort will conduct the research required to define affordable simulation concepts/technologies for rapidly evolving onboard/offboard sensor/electronic warfare capabilities. These simulation approaches/technologies will 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 create innovative dual use simulation concepts/technologies that enable offboard/onboard sensor/electronic warfare technologies to be evolved in the laboratory minimizing the need for open air range research/evaluation. The Phase I research will identify the critical technology challenges and define the Phase II approach for developing/demonstrating in the Sensors Directorate Integrated Demonstrations and Applications Laboratory (IDAL), the critical simulation concepts/technologies required for the rapid prototyping of onboard/offboard sensor/electronic warfare capabilities. 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 rapid prototyping simulation concepts/technologies 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: Simulation concepts/technologies that enable rapid prototyping of sensors are dual-use technologies that also have extensive commercial applications for markets such as the telecommunications industry. These concepts/technologies can be utilized to develop/evolve/mature commercial telecommunications equipment in a controlled laboratory environment. This approach will reduce development costs and accelerate product movement to the market place through rapid prototyping in a laboratory development environment that incorporates realistic real-world effects. These same simulation concepts/technologies can be implemented in government laboratories and test ranges for the rapid development/evaluation of onboard/offboard sensor and electronic warfare capabilities.

REFERENCES:
Jerry Black, “Data Collection in an High Level Architecture Federation,” Dec 1998 AD A359374/XAG

KEYWORDS: Battlespace, Electronic Warfare, RF Threat, Simulation, HLA, High Level Architecture.

AF01-210 TITLE: GPS/IMU Ultra-Tightly Coupled Integrity Monitoring

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a GPS Integrity Monitoring method that exploits the benefits of IMU/Ultra-tight GPS coupling

DESCRIPTION: Global Positioning System (GPS) applications involving safety-of-flight operations (e.g. precision and non-precision instrument landing) require integrity monitoring. Integrity monitoring can involve either on-board resources (Receiver Autonomous Integrity Monitoring or RAIM) or off board resources such as wide area or local area augmentation. Since measurements to only four GPS satellites are required for a GPS navigation fix and there are normally many more in simultaneous view, most RAIM approaches traditionally rely on algorithms that use redundant satellite measurements. If there is inconsistency, outside allowable tolerances, between the measurements to all satellites (caused by a problem with one or more measurements) the user is alerted to the possible error. With six or more satellites in view, it is normally possible to isolate the bad satellite. Experimental GPS landing systems have used a combination of inertial and radar altimeter measurements to implement the RAIM function. Several researchers have recently been investigating novel GPS-inertial integration techniques (deep-integration or ultra-tight coupling) that may yield markedly improved performance in the presence of signal interference. These techniques may be incompatible with conventional RAIM algorithms, but conversely may allow the implementation of even more effective integrity monitoring techniques. The purpose of this project is to identify, select, implement, and characterize the most effective RAIM techniques that exploit these new GPS-IMU, (inertial measurement unit) integration architectures to obtain more robustness and greater reliability under all practical types of GPS and IMU failure modes.

PHASE I: Phase I shall: 1) Identify/characterize the selected RAIM technique. 2) Provide simulation results to verify applicability of the selected technique. The simulation shall include the necessary levels of fidelity to test the contractor’s approach with realistic degraded GPS and IMU performance parameters. 3) Provide detailed description of the selected technique including software documentation. 4) Develop a plan for Phase II demonstration/test/verification.

PHASE II: Phase II shall: 1) Finalize the test plan/procedures(to mutually agreed performance characteristics). The test shall be conducted using a real GPS receiver ultra-tightly coupled with an IMU. The test program shall simulate various failure modes of GPS and the IMU, including soft failures. 2) The contractor shall perform the mutually agreed test and evaluate results. 3) The detailed test plan, procedures and test data/results/evaluation/recommendations shall be contained in the Final Report.

PHASE III DUAL USE APPLICATIONS: In Phase III the contractor shall assist the government in the application of this technology to the military Joint Precision Approach and Landing System (JPALS). The resulting GPS technology is equally applicable to civil airlines landing procedures.

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KEYWORDS: GPS Integrity Monitoring, GPS/IMU Coupling, RAIM, Precision Landing, GPS-Inertial Integration, Signal Interference

AF01-211 TITLE: Adaptive Array Processing for Targeting Radar Application

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop novel, improved algorithms for direction of arrival estimation in severe clutter and interference environments, thereby enhancing the performance of targeting radar. Furthermore, investigate the potential for incorporating adaptive combat identification techniques within the simultaneous process of detection and angle estimation.

DESCRIPTION: Targeting radar must detect, locate and positively identify moving targets in severe clutter and interference environments. To enable detection in strong clutter and interference, it is desirable to employ the class of space-time adaptive processing (STAP) algorithms. However, the process of adapting the space-time response to detect targets leads to complication in estimating target direction of arrival. Thus, it is imperative that adaptive array algorithms seamlessly perform the simultaneous operations of target detection and target direction of arrival estimation. The goal of this topic is to develop sensor and/or signal processing techniques that simultaneously allow accurate target location in severe clutter and interference, with potential for incorporating adaptive combat identification techniques. Techniques should include considerations for radome reflections and wideband operation, along with the means for practical evaluation and implementation for use on the radar platform.

PHASE I: Develop approaches for target detection and direction of arrival estimation in severe clutter and interference environments based on the principles of adaptive array processing. Perform modeling and simulation to predict the performance of the chosen approach. Include radome effects and wideband operation in the development. Provide a detailed plan for the practical deployment of the proposed techniques on targeting radar platforms.

PHASE II: Develop, test and demonstrate the adaptive array processing techniques. Provide practical implementations of the developed techniques and evaluate the performance impact for targeting radar platforms. Provide a detailed plan discussing the practical deployment of the simultaneous adaptive detection, direction of arrival estimation and identification algorithms.

PHASE III DUAL USE APPLICATIONS: Adaptive array techniques have important applications in communications, sonar and industrial problems. Techniques developed under this topic would enable weak target signal detection and location of the signal source, with the potential for identifying the particular features of the target source. Potential military applications include targeting and attack radar functions and emitter location. Potential commercial applications include wireless communications, emitter location for law enforcement applications and medical imaging.

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KEYWORDS: GPS Anti-Jam Environment, Multi-Carrier Wave, Multi-Path, Space Time Adaptive Processors (STAP), Multi-Broadband Jammers, Antenna Element Mismatch

AF01-213 TITLE: Analysis of Measurements on Resident Space Objects (RSO)

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Demonstrate the utility of fusing visible and infrared observables for characterizing RSO signature characteristics.

DESCRIPTION: Part of Space Surveillance is monitoring resident space objects (RSO) for the purpose of characterizing satellites and their optical signatures. It has been limited in the past to ground based radar and visible sensors. Because of the broad range of satellite geometries and operating characteristics, these ground sensors may provide only limited data for object characterization. Exploring the utility of multi-spectral and multi-viewing aspect Space Based Optical Sensors promises enhancement of our ability to understand the mission capabilities of satellites. Innovative approaches are sought to develop math models that incorporate the thermal and geometrical characteristics of spacecraft, and that permit the space control analyst to exploit the utility of multicolor longwave infrared and visible spectral signatures, to estimate satellite observable characteristics. It is envisioned that these models would include the geometric and thermal characteristics of spacecraft to generate predictive signature patterns, as components reorient and experience variable solar irradiation. The products would be signature math models for a family of satellites to include GPS (Global Positioning System) Shuttle Orbiter and Hubble Telescope, for which an extensive collection of optical measurements have been made and are available for analysis.

PHASE I: Required Phase I deliverables will include: 1) a demonstration illustrating the understanding of the key target/environment. 2) Phenomenologies and characteristics of a specific satellite 3) the results of an analysis of the measurements (data to be provided by AFSMC) 4) a plan for extending the models to other spacecraft and 5) recommendations for future collections.

PHASE II: Required Phase II deliverables will include: 1) software showing the above models incorporated into a small size simulation depicting the specific satellite characteristics 2) a plan for incorporating such methods into surveillance systems operating software will also be delivered.

PHASE III DUAL USE APPLICATIONS: In Phase III the contractor may explore additional techniques and methodologies for transitioning the concepts used to develop math models for other related military applications such as ballistic missile defense. Many civilian and commercial applications of this technology include (among others) remote sensing astronomical sensor calibration, law-enforcement surveillance, rescue missions, etc.

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0724179 NTIS Accession Number: AD-A058 709/7/XAB "On the Development of Space Object Optical and LWIR Cross Section Population Distributions," UHF Cross Sections Journal Announcement: GRAI7825. Order this product from NTIS by: phone at 1-800-553-NTIS (U.S. customers); (703)605-6000 (other countries); fax at (703)321-8547; and email at orders@ntis.fedworld.gov. NTIS is located at 5285 Port Royal Road, Springfield, VA, 22161, USA. Report No.: AFAL-TR-77-193

KEYWORDS: Resident Space Objects, Space Surveillance, Space Object Characteristics, Optical Measurements, Optical Signatures, Sensor Fusion

AF01-214 TITLE: Tunable Superconducting Filters

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop high-performance, magnetically tunable superconducting filters for K- and Ka-band space applications.

DESCRIPTION: Superconducting filters can achieve very high Q, thus very low insertion loss. They are smaller and lighter than those made of conventional metals. One critical application is a tunable filter that may be placed in front of the low noise amplifier (LNA) of a communications satellite payload to reduce noise and jamming possibility. Future DoD and commercial communication satellites require RF (Radio Frequency) front-end filters capable of operating at K (l8-27 GHz) and Ka bands (27-40 GHz). The superconducting filters should have a 100 MHz passband at the 1dB points with at least 40dB of out band rejection 300 MHz from the center frequency in the K/Ka bands. The center frequency of the passband should be continuously tunable over the 1GHz bandwidth in the K and Ka band. A minimum number of filters should be used to cover the 1 GHz bandwidth. No space qualified, production capable, compact K/Ka band superconducting filters are currently available. The purpose of this project is to determine the challenges confronting the design/manufacture of K/Ka band superconducting filters. Include choices of tuning technique, resonator type, power handling, tunability range, tuning speed, and intermodulation distortion. One high potential, innovative approach, utilizing magnetization as the tuning mechanism, promises a compact, low loss filter with a useful tuning range. DC power, weight and elimination/reduction of shorted-turn effects are directly impacted by the design of the magnetics.

PHASE I: Determine technical feasibility of known superconducting filter technologies. Examine challenges/solutions. Establish performance requirements (e.g., bandwidth, tuning range, roll off, insertion less, and intermodulation distortion) in prescribed frequency band and application. Develop/compare conceptual designs. Provide tradeoff data comparing: current, weight, tuning speed, temperature stability/compensation means, etc. Verify selected design via computer models or electromagnetic simulation and provide documentation on the models and/or simulator.

PHASE II: Finalize/validate tunable superconducting filter designs to meet challenges and achieve performance requirements defined in Phase I at both K- and Ka-bands. Fabricate and demonstrate selected prototype filter design(s).

PHASE III DUAL USE APPLICATIONS: Tunable K- and Ka bands superconducting RF filters will have wide application in future DoD and commercial communication satellites.

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KEYWORDS: Tunable Filters, Superconducting Filters, Millimeterwave Integrated Circuits, YIG Filters, EHF Space Applications, Magnetic Microwave Devices

AF01-215 TITLE: Fast Polarization-Insensitive Optical Switches for Photonic Phased Array Control

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a fast, polarization-insensitive optical switch for fiber optic true-time-delay photonic control of phased array antennas.

DESCRIPTION: Phased array antennas (PAAs) are very well suited for use in space communication systems when transmit/receive beam directionality is required. PAAs are lighter and more reliable than mechanically-steered antennas (MSAs). Furthermore, a PAA beam will be more agile than that of a MSA, since the steering time constant (determined by how fast the array element phases can be changed) may be of the order of microseconds, regardless of the amplitude of the beam swing. True-time-delay (TTD) implementation of array phasing avoids changes of beam direction with frequency (“squinting”), but it is hard to implement in the RF domain. Photonic implementation of TTD beam forming, where RF signals are superimposed on an optical carrier, is highly attractive. Suitable lengths of optical fiber connected through a switching matrix can provide the required selectable delays. Appropriate optical switches are essential components for this beam-forming concept. Some switch performance requirements are: short switching times, low insertion losses, high extinction ratios and high switch-state stability. The optomechanical switches used in commercial fiberoptic communication systems are unacceptably slow; they are also relatively bulky and heavy. Electro-optic switches are fast, but they have large insertion losses, and their extinction ratios are sub-optimal (and temperature-sensitive!). Furthermore, they are polarization-selective, requiring the use of polarization-maintaining optical fiber for the delay lines. Novel optical single-pole, doublethrow (SPDT) switches are desired, having switching times of the order of a microsecond, insertion losses below 1 dB and extinction ratios of 50 dB or better. The switching technology should be polarization-independent and temperature-insensitive. Ultimately, fully engineered switches should be small, light, and suitable for space qualification. Better than 10E6 switching cycles during the device lifetime should be achievable.

PHASE I: Explore possible novel optical switching technologies with the potential to satisfy the above objectives. Perform analytical and experimental work to select best approach. Build breadboard switch prototype using the selected technology, and demonstrate speed and polarization independence. Demonstrate achievability of low insertion loss, high extinction ratio, lifetime and temperature insensitivity by a combination of analysis and laboratory experimentation.

PHASE II: Develop, design and build fully engineered prototype of basic SPDT optical switch unit and command interface. Demonstrate compliance with the objectives listed above, following mutually acceptable test plan.

PHASE III DUAL USE APPLICATIONS: PAAs using the Phase II switch technology for selectable fiberoptic delays could be widely used in DoD and commercial space communications systems. The same PAA beam forming technology could be used with very little modification for radar applications, both space and ground-based. Furthermore, fast, reliable optical switches could have wide applicability in fiberoptic-based ground communication systems.

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KEYWORDS: Optical Switches, Phased Arrays, True Time Delay, Photonic Beam Forming Network, RF-Photonics, Polarization-Insensitive.

AF01-216 TITLE: Tactical User Antenna
TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop suitably packaged, cost effective antenna for tactical users.

DESCRIPTION: Tactical users require lightweight, rugged, appropriately packaged antenna systems that are inexpensive and easy to transport and deploy. Integration of the antenna with system electronics is an important requirement so that the total antenna package requires only power and an interface with the control terminal for operation. An urgent need exists for two different innovative designs. The first design is a small, manpack size single package, offset reflector. The antenna is required to provide mission readout and low data rate services from the DMSP (Defense Meteorological Satellite Program) polar satellites for meteorological data, and for communications with GBS (Global Broadcast System) and the MILSTAR MDR (Medium Data Rate) Satellites. The aperture for this application is on the order of 1 meter and should operate at S-band and at 20/44 GHz with Linear/RHCP/LHCP polarization diversity capability. The purpose of the single package is to reduce logistics and costs. The second larger aperture design is for higher data rate applications . An aperture size of about 3 meters is needed for high resolution meteorological data and DSP (Defense Satellite Program) information at S and L bands. The antenna should be easily deployed and collapsible for ease of transportation. Antennas of this size are quite visible targets and disassembly of these antennas can indicate changing military strategies. The cost of this design is envisioned to be sufficiently low to consider the antenna as being expendable. If damaged or if the tactical location changes, another antenna would be used. The inexpensive satellite TV antennas are an existing technology, and with innovative modification, might be developed for this application.

PHASE I: Phase I activities should include design/development to satisfy mutually (AF/Contractor) agreed RF requirements/integration with typical Air Force system electronics. Additional efforts should include assessing existing technology to obtain cost effective designs, developing packaging concepts and modifications to COTS items. Appropriate demonstrations of selected design candidates shall be provided, leading to selected operational prototype demonstrations in Phase II. Development issues to control cost and improve effectiveness to users is an important aspect of this phase.

PHASE II: Operational prototype demonstration/evaluation of selected Phase I development models (based on mutually agreed specifications) are the principal objectives of this phase. Both RF and mechanical performance of the prototype designs shall be evaluated.

PHASE III DUAL USE APPLICATIONS: Several military tactical applications are envisioned for such terminals including manpack tactical weather/communication terminals and mobile tactical command center weather/communications facilities.

Commercial applications include small, lightweight, highly portable, direct weather satellite access for use in-connection with sporting events, installation on fishing boats/yachts, remote centers of population and other mobile applications.

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KEYWORDS: Tactical User Antennas, Reflector/dish Antennas, Multiple Frequency Antennas, Expendable Antennas, Tactical Weather Terminal, Tactical Communication Terminal

AF01-217 TITLE: Space Qualified GaN Communication Technology

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop innovative linear high-power amplifiers, based on developing GaN device technology, for space applications.

DESCRIPTION: Space communications require high-power, solid-state microwave amplifiers as small, lightweight replacements for traveling-wave tube amplifiers. GaN/AlGaN heterojunction field effect devices have been shown to perform in the microwave spectrum with many advantages due to its wide bandgap, high thermal conductivity and radiation tolerance. These devices offer high power and high temperature operation for space applications. A developmental effort is needed to transition amplifiers, based on this new material system, to satellite communication systems. This program will benefit both military and civilian space communication systems up to 40GHz.This developmental effort will focus on the demonstration of GaN linear power amplifiers for downlink transmitter applications. Therefore, this effort will address solid-state sources with improved power-added efficiency and linearity at high output powers. Assessment of this technology for environmental challenges in space, potentially large temperature variations due to limited environmental control, and high radiation tolerance will also be necessary.Device process improvements for efficient, linear power, as well as preliminary power amplifier demonstrations, shall be performed during Phase I. The linear power amplifier meeting program performance goals and space requirements shall be demonstrated in Phase II. Further, it is expected that manufacturing capability of commercial and military amplifiers will be demonstrated by the end of Phase II.

PHASE I: K-band amplifier performance goals for the initial amplifier demonstration: @Peak PAE: >2 watt output power, >50% PAE @ 6dB backoff from Peak PAE drive: >40% PAE, better than 25dBc Carrier/IMD3

PHASE II: K-band amplifier performance goals for the initial amplifier demonstration: @Peak PAE:>4 watt output power, >60% PAE@ 6dB backoff from Peak PAE drive: >50% PAE, better than 30dBc Carrier/IMD3

PHASE III DUAL USE APPLICATIONS: Commercial applications include Local Multipoint Distribution Systems, commercial satellite communications, and portable electronics (i.e. Digital Radio).

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KEYWORDS: Gallium Nitride, RF Materials, RF Amplifiers

AF01-218 TITLE: GaN FET Based Re-Configurable Multiple Frequency Band Systems

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop innovative high-power wide bandgap switches for space-based re-configurable multiple frequency antenna systems.

DESCRIPTION: The re-configurable antenna can potentially reduce cost and weight in the space communications systems. The reconfiguration needs high isolation and low resistance switching circuits. The circuits can be used to configure elements of the antenna for multiple frequency band applications. FET devices, based on wide bandgap materials such as SiC and GaN, have the potential of providing high breakdown voltage and high isolation. High isolation of the two dimensional electron gas, in excess of 1013 cm-2 , is induced, in part, from the presence of a high piezolelectric field at the interface. Wide bandgap devices perform in the microwave spectrum with many advantages due to their material properties, high thermal conductivity and radiation tolerance. The resulting high power handling switches support compact size required for space applications. A developmental program is needed to determine how to implement RF switches based on new materials, such as GaN, for reconfiguration of different communication antennas. The results of the program will benefit both defense and civilian satellite space communication systems.The research will explore revolutionary new device and/or circuit concepts and conduct feasibility demonstration efforts on devices with potential for enhanced functionality to support space-based applications. This effort will address switches with high-power handling and isolation, fast switching time and low insertion loss. The technology must be assessed for the environmental challenges in space, potentially large temperature variations due to limited environmental control and high radiation tolerance.This program shall be divided into two phases. Device and switching circuit feasibility, shall be demonstrated during Phase I. Phase II will focus on the higher power, higher performance switch demonstration. Initial space qualification will be performed. It is expected that fabrication capability of commercial and military products will be established by end of Phase II.

PHASE I: DC – 40 GHz switching circuit demonstration goals: 1-5 watt CW input power, isolation 25 dB minimum, switching time less than 100 nano seconds and insertion loss 1 dB maximum.

PHASE II: DC – 40 GHz switching circuit demonstration goals: 5-10 watts CW input power, isolation 30 dB minimum, switching time less than 30 nano seconds and insertion loss 0.2 dB maximum.

PHASE III DUAL USE APPLICATIONS: Commercial applications include portable electronics, wearable electronics, space-based systems, automotive electronics, and RF tags.

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KEYWORDS: Gallium Nitride, RF Materials, RF Amplifiers

AF01-219 TITLE: Power Limiter for Anti-Jamming at K-Band and EHF

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop high-performance power selective limiter for anti-jamming at K-band and EHF space applications.

DESCRIPTION: The heightened awareness of vulnerability of satellite communication systems to even low levels of intentional and unintentional interference has resulted in diverse proposed solutions. One of the techniques proposed is the Yttrium Iron Garnet (YIG) filter, also known as the Power Selective Limiter (PSL). The YIG filter is a bandpass filter utilizing magnetically tunable YIG ferri-magnetic resonators. As a PSL device, the YIG filter has a nonlinear amplitude-discriminating phenomenon. It develops a limiting amplitude threshold above which jammer signals are limited. Current high-performance YIG PSLs operate in the lower frequency bands. Future DoD and commercial communication satellites require PSLs capable of operating at K-band and extremely high frequencies (EHF), such as 20-45 GHz. No space qualified, production capable, K-band/EHF PSLs are currently available. A critical need exists to design manufacturable, space competent K-band/EHF PSLs capable of operating in an anti-jamming system. Challenges confronting design include (among others) optimizing performance for: different waveforms, lowered capture threshold power levels, highest number of jammers in prescribed scenarios, and minimum insertion loss.

PHASE I: Determine the feasibility of microwave filters based on ferrimagnetic substrates as a Power Selective Limiter (PSL) at K-Band/EHF. Examine the challenges, formulate solutions, and discuss alternative approaches to providing the PSL function at the subject frequencies. Establish PSL performance requirements (e.g., bandwidth, insertion loss, intermodulation distortion, temperature stability/compensation and suppression level) for prescribed waveforms, capture threshold level, jamming scenarios. Develop/compare innovative conceptual designs. Provide tradeoff data comparing various ferrimagnetic substrate filter technologies. Select/develop a producible design and validate the concept via computer simulation.

PHASE II: Finalize/validate production capable designs of the PSL to meet challenges and achieve performance requirements defined in Phase I. Fabricate/demonstrate selected PSL prototype in a variety of jamming scenarios .

PHASE III DUAL USE APPLICATIONS: The PSL will have wide application in future DoD/Commercial communications satellites at K-band/EHF due to the increased use of the higher frequency spectrum in various applications. Use of a PSL could mitigate jamming of a desired signal from the ever greater saturation from undesireable signals in the same frequency band.

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KEYWORDS: YIG Filters, Nulling Antenna, Adaptive Antenna, Anti-Jamming, EHF Space Applications, Satellite Communication

AF01-220 TITLE: MEMS-Switched Reconfigurable Antenna

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a reconfigurable antenna for spaceborne K-band and EHF application.

DESCRIPTION: The concept of a reconfigurable antenna is currently being investigated for potential spaceborne applications. Reconfiguring the contour beam, for example, can provide coverage for different geographical service areas from different satellite positions and orientations. Another application is to reconfigure the antenna to operate in a different frequency band reducing the number of deployed antennas. Future DOD and commercial communication satellites will benefit from the application of this new concept specially with changing military strategy, theater tactics, commercial markets, user demographics, etc. The primary challenge confronting the design and manufacture of reconfigurable antennas is the maturity level of the switching technology employed to control the antenna characteristics (gain, radiation efficiency, pattern, bandwidth, EIRP, etc). Such technologies include MEMS switches, conventional switches, PIN diodes, piezoelectric actuators, optical switching, etc. The objective of this project is to select/demonstrate a reconfigurable antenna for spaceborne applications.

PHASE I: 1) Determine scientific merit and technical feasibility of known reconfigurable antennas, e.g., the dipole array and the array-fed dual reflector. Concurrently, determine which type is more realizable and will provide more reconfiguration efficiency. 2) Establish technical and commercial feasibility of the selected antenna type and switching technology. 3) Validate the above with a conceptual multi-band design suitable for space applications at K-band and EHF. Determine feasibility of multi-band design through demonstrations/simulations/analysis of results.

PHASE II: 1) Simulate and design the appropriate switched reconfigurable antenna for a particular space application. Optimize design for maximum radiation efficiency at all frequency bands of interest. 2) Fabricate and demonstrate a prototype (suitable for space qualification) by employing the appropriate technology determined in Phase I.

PHASE III DUAL USE APPLICATIONS: Reconfigurable antennas will have wide application in future DOD and commercial communications satellites specially with changing military strategy, theater tactics, commercial markets, user demographics, etc. The concept and technology will also be applicable to airborne (commercial/private aircraft and associated ground traffic control) and terrestrial (wide area security systems, radar systems, police activity) communications.

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KEYWORDS: Reconfigurable Antennas, Switches, Micromachined Antennas, Microwave RF Devices, MEMS RF Devices.

AF01-221 TITLE: Hyperspectral Resolution Enhancement

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop novel sensor and/or signal processing techniques for enhancing the spatial resolution content of hyperspectral imagery.

DESCRIPTION: Hyperspectral remote sensor technology is being pursued in both the commercial, defense, and civil communities to support a broad range of applications. An important attribute of hyperspectral sensors is the inherent ability to detect and/or identify materials of interest without the need to spatially sample the object of interest at a finer level than the object dimension. The design of hyperspectral sensors, however, is often limited by practical constraints (e.g., aperture diameter, focal plane array size) such that the spatial sampling at the scene is substantially coarser than objects of interest. In these situations, there are significant challenges in extracting the scene content of interest. The objective of this topic is to develop sensor and/or signal processing techniques that allow the enhancement of hyperspectral imagery for constrained sensor designs such that higher resolution scene content can be extracted. Techniques should incorporate a priori knowledge of the spectral characteristics of the scene, objects of interest, and/or environment as well as the sensor design characteristics to optimally extract desired information for sub-pixel objects and high frequency scene content.

PHASE I: Develop the technical underpinnings of sensor and/or signal processing techniques for the resolution enhancement of hyperspectral imagery. Perform modeling and simulation based on available hyperspectral imagery to predict the expected performance for both commercial and military applications. Provide a detailed plan for the development and demonstration of the techniques and for applying them to planned hyperspectral systems for both commercial and military applications.

PHASE II: Develop, test, and demonstrate the hyperspectral resolution enhancement techniques. Evaluate the performance impact for the targeted systems and applications. Package a demonstration prototype in a user-friendly form for delivery to the government for independent evaluation.

PHASE III DUAL USE APPLICATIONS: Techniques developed under this topic would allow the extraction of enhanced information from a range of planned commercial hyperspectral remote sensing systems for both commercial and military applications. Potential military applications include target detection and terrain/trafficability analysis. Potential commercial applications include remote sensing for geological, land use monitoring, agricultural, and mineral exploration purposes.

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KEYWORDS: Remote Sensing, Hyperspectral

AF01-222 TITLE: Silicon Carbide Power Transistors for High Power Transmitter

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop Silicon Carbide power transistors that will enable high power pulsed transmitters to achieve a stable output signal.

DESCRIPTION: Silicon Carbide power transistors are being used in the design of high power, high temperature applications. Current Silicon power transistors have a maximum operating temperature of below 150 degrees C and a maximum power of 300 Watts. Silicon Carbide power transistors on the other hand, can operate at temperatures on the order of 400 degrees C and amaximum power of 650 Watts. Therefore, Silicon Carbide power transistors can develop about twice the power of Silicon power transistors. Additionally, Silicon Carbide transistors are more efficient, which means that more power can be generated for the same cooling and power requirements as Silicon power transistors. When these power transistors are used in pulsed transmitter operations, output signal stability becomes an issue. In order to obtain a stable output signal, particular attention must be paid todesign of both the power supply and the pulsed transmitter. The services seek a design over the frequency range from 100 MHz to 3,000 MHz. The process development of SiC devices and circuits is evolving. Although the SiC materials have excellent high temperature operation, additional work remains to be completed on developing compatible metal contact systems and packaging/interconnect technologies that efficiently operate at high temperatures. These process and packaging issues should be addressed as part of the subject effort.

PHASE I: This topic focuses on the design of Silicon Carbide power transistors. The design should lead to improved device fabrication processes and packaging techniques. To optimize high temperature operation, compatible metal contact systems and packaging/interconnect techniques should be considered.

PHASE II: Construct and demonstrate the operation of a prototype pulsed transmitter with Silicon Carbide power transistors.

PHASE III DUAL USE APPLICATIONS: In both airborne and space applications where space is limited, pulsed transmitters using Silicon Carbide transistors will allow for smaller transmitter designs with high output power.

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KEYWORDS: Silicon Carbide, Power Transistors, Pulsed Transmitter, High Temperatures, Output Signal Stability, Airborne and Space Applications

AF01-223 TITLE: Adaptive Multispectral Signal Aperture

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Demonstrate the feasibility of automated aperture reconfiguration to support multiple signal collection and transmission requirements.

DESCRIPTION: There is a growing demand for multispectral sensing and communication to support the Expeditionary Aerospace Force. Ranging from threat alerting to real-time intelligence updates to target location and positive combat identification, more portions of the electromagnetic spectrum are being used to ensure mission success. While electronic generation and processing of such signals have been developed for a wide variety of military radar and radio equipment, a significant difficulty still exists in transitioning free-space signals of different wavelengths into and out of the electronics. A different aperture or antenna is typically needed for each different section of the spectrum (Radio frequency, Microwave, Millimeter, Optical) to efficiently capture or broadcast signals. This leads to multiple apertures for satellites, command posts, mobile units, weapon platforms and missiles to take advantage of multi-band sensing and communications. On aircraft and uninhabited air vehicles, the numerous antennas increase drag and radar returns; both of which detract from mission performance. The static nature of these apertures also limits their effectiveness when confronted with jamming, interference, or unexpected field conditions during various phases of an operational mission. Proposed research would establish the feasibility of low-cost apertures whose receiving/transmitting elements can be changed in near-real time to match a variety of operating wavelengths. Payoffs from the technology would include: lighter weight for satellite and UAV platforms; lower RCS (radar cross-section) military aircraft, vehicles, and command posts; greater wavelength diversity to enhance target detection, increase data transmission, resist jamming/interference, and respond to hostile emanations; reduced logistics base for sensor, communication, intelligence, and avionics apertures.

PHASE I: Design a concept for reconfigurable apertures, and simulate key missionaspects of their multifunction capability.

PHASE II: Establish adaptive aperture performance parameters through laboratory breadboard experiments and prototype fabrication.

PHASE III DUAL USE APPLICATIONS: Continue development with a manufacturing partner, leading to field testing of affordable “smart” apertures for aerospace applications. High market potential in medical diagnosis/treatment, law enforcement, industrial process control, mobile communication, and space exploration.

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KEYWORDS: Reconfigurable Antenna, Automated (SMART) Antenna/Aperatures, Multi-Function Operations.

AF01-224 TITLE: Synthetic Spectral Scene Simulator

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a cost effective, high fidelity spectral scene simulator for military targets and their background environments to support the development and evaluation of sensor system concepts and processing algorithms.

DESCRIPTION: Spectral remote sensing is being actively pursued by both the DoD and commercial sectors to provide enhanced information for detecting and identifying materials in an imaged scene. Applications range from military target detection and recognition to land use and environmental studies. The design optimization and performance assessment of proposed sensor system concepts and processing algorithms, however, has been somewhat limited by the lack of an adequately extensive empirical database of remotely sensed imagery to support rigorous performance predictions over the breadth of target, background, and environmental conditions of interest. Collection of such an extensive empirical database is prohibitively expensive. The objective of this project is to develop a cost effective, high fidelity spectral scene simulator for both military and non-military targets and their background environment to support the development and evaluation of sensor system concepts and processing algorithms. The simulator should support the generation of realistic imagery at visible through longwave infrared wavelengths (nominally 0.4 to 14 microns). For the purposes of this project, “realistic” is defined in the sense that it captures the essential target and background spatial and spectral statistical properties to support confident estimates of exploitation algorithm performance. “Cost effective” refers to its inherent ability to efficiently generate simulated scenes with minimal trained operator effort based on available descriptions of areas of interest, such as from Global Information Systems (GIS) data.

PHASE I: Develop the approach for spectral scene simulation, and perform initial demonstrations of the critical components to support its viability. The realism of the approach shall be demonstrated by comparing, either via analysis or numerical results, the expected simulator performance to statistical (spatial and spectral) properties of relevant empirical data collected from current airborne hyperspectral data collection instruments.

PHASE II: Build, test, and demonstrate the synthetic spectral scene simulator. The testing and demonstration shall include validation experiments against relevant empirical data over a sufficiently broad range of target, background, and environmental conditions. The synthetic image generator shall also be delivered to the government for independent evaluation.

PHASE III DUAL USE APPLICATIONS: A low cost synthetic spectral scene simulator would greatly enhance the design process for both military and commercial sensor development. Potential commercial applications include remote sensing for geological, land use monitoring, agricultural, and mineral exploration purposes.

REFERENCES:
Algorithms for Multispectral and Hyperspectral Imagery V, Proceedings of the 1999 SPIE AeroSense Conference, Orlando, Florida (April 1999), VOL. 3717.

KEYWORDS: Passive Imaging, Modeling and Simulation

AF01-225 TITLE: RF Synthesis for Wireless Communication, Intellience, Surveillance, and Reconnaissance (ISR) Systems

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Design and build a Computer Aided Design tool capable of synthesizing analog/RF designs, thus reducing both the high cost of analog electronics as well as the time required to complete the design.

DESCRIPTION: Radio Frequency (RF) electronics is an important cross-cutting technology which is vital to sustain the U.S. competitive edge in a battle environment. RF components are essential to generate, control, radiate, receive, and process VHF, UHF, microwave and millimeter-wave signals. AFRL's Core Strategy A includes "pursuing affordability technologies to reduce the cost of ownership by at least 50% of the four major AF product lines (spacecraft, aircraft, weapons, and C2)". The Defense Technology Area Plan clearly defines an obstacle associated with the front end of military systems to be the production of "affordable and compact" solid-state RF electronics to meet the sensitivity, bandwidth, dynamic range, and frequency range requirements while producing a high output power with high efficiency, small volume, acceptable dynamic range and linearity and low power consumption. Wireless communication systems make up a large segment of the command and control backbone, which we refer to as the "information grid". RF electronics are also essential for ISR systems to create their images of battlespace. RF electronics are currently found on as many as one-third of the circuit card assemblies embedded in our current airborne surveillance, command and control systems. Advances in RF electronic design ability have not kept pace with that of digital electronic design, and RF electronics currently account for 70% of the cost of communication and ISR systems. Furthermore, the complexity of analog/RF design requires months longer to design than digital electronics, thus designers often have to settle on marginal designs to meet schedule and budget constraints. Ongoing research to attempt to "optimize" existing analog/RF designs, has currently been able to reduce the optimization process of an amplifier from one week to a few hours. These results have aroused much interest from commercial RF design contractors. This optimization tool amounts to only a small portion of the automation that we must develop to seriously reduce the cost of RF electronics. Academia has demonstrated success in automatically synthesizing lower frequency analog systems. For these low frequency systems, the synthesized designs often had better performance than the manually developed designs and in much less time. Complexity of analog/RF design increases as we strive for higher operating frequencies and smaller feature sizes. Synthesis, or the ability to transfer our desired transfer function, specifications, and constraints to a specific electronic design is a complex, difficult task which will greatly reduce the cost of developing government and civilian electronic systems and will reduce the design time from months to days.

PHASE I: The preliminary design of the synthesis design tool will be performed. The functionality, user interface, look and feel, and interfaces to other products will be completely specified.

PHASE II: The synthesis design tool prototype will be designed, constructed, evaluated and demonstrated. Documentation and user guides will be developed.

PHASE III DUAL USE APPLICATIONS: This tool could be used in the design of a broad range of military and civilian analog/RF front-ends, wireless communication systems, radar, and sensor systems.

REFERENCES:

KEYWORDS: RF Design, Design Automation, Wireless, Amplifiers, Receivers, Transmitters, Sensors.

AF01-226 TITLE: Requirements Modeling Technologies for Affordable C2 Systems

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Research technology for creating and using requirements models to improve cost, cycle-time, and quality of complex C4ISR systems.

DESCRIPTION: This topic solicits innovative computer automation technologies that make it easier and more productive to create and use the new Rosetta System Level Design Language (SLDL) for requirements modeling. Such technologies could include a) techniques for making it faster and easier to capture and view requirements models, b) automated analysis techniques for checking the requirements models for properties such as correct syntax, consistency, completeness, redundancy etc., c) Rosetta-based requirements tracking and management tools, d) techniques for converting from more "human friendly" graphical representations (e.g. block diagrams, state charts, data flow diagrams, etc.) to the more "computer friendly" Rosetta language, and f) other innovative productivity solutions.Complex command, control, computer, communication, intelligence, surveillance, and reconnaissance (C4ISR) systems and their embedded hardware and software are very expensive, take years to implement, often encounter large cost and schedule growths, frequently contain errors or don't meet the user's requirements, and are costly to sustain and modernize. Relatively recent studies show that overruns are by no means unique to defense systems and are more extensive than most people realize. According to findings by the Standish Group International, Inc., on a survey of 8,000 information technology companies, 46% percent of projects were "challenged" – that means that they were completed over budget, past the original deadline, or failed to meet some requirements. Also 28% of projects "failed" – meaning that they were either canceled or did not meet enough requirements to be usable. Therefore, only 26% of information technology programs were completely successful! This survey also showed that the average project exceeded its planned budget by 90% and its schedule by 120%. Therefore, neither the defense-sector nor the private-sector can claim a very impressive track record. The DoD spends billions of dollars every year developing systems with heavy electronic and software content. The private-sector has a huge demand for electronic products and information technologies, with millions of dollars at stake if new products are late to market. Semiconductor companies need products developed faster and cheaper to keep their fabrication lines full or they also stand to lose billions in the next decade. Large program overruns are eating away both DoD and private-sector budgets and delaying availability of much needed products and systems. Numerous tools are available to aid the developer of individual circuits or software programs, but they do not support "systems engineering" and are insufficient for large and complex systems. Thus, solutions must be found for making complex systems better, faster, and cheaper.Several DoD organizations, industry consortia, and industry standards bodies are currently collaborating to develop, promote, and start standardization activities on an "affordability technology" solution called "requirements modeling". Requirements modeling is an emerging technique for describing a system's engineering requirements (e.g. intended functionality, architecture specification, verification requirements, modeling requirements, and implementation constraints) in a form that is both human and computer readable. Requirements modeling technology is important because problems with incomplete, inconsistent, ambiguous, overlooked, ignored, changing, unverified, or unvalidated requirements, or simply an overwhelming number of engineering requirements, are the major cause of system development problems. These problems frequently lead to rework that can cost as much as the original budget of the program. A typical reduction in cost and schedule resulting from requirements modeling will be about 20% and the probability of overruns should also drop significantly. Requirements models replace the traditional natural language requirements specifications, that are notorious for being verbose, inconsistent, and ambiguous, with a format that is suitable for computer processing. Requirements models help handle the thousands of hierarchical, multi-domain, and interrelated requirements for a complex system. Requirements models also lend themselves to further computer aided design assistance to system engineers. Requirements models explicitly specify interactions between various parts of the system. Thus they support collaboration between multiple application domains (e.g. analog, digital, software, electromechanical, etc.) – something we don't have any way to do now. Requirements models support collaboration between multiple engineering disciplines (e.g. design, test, manufacturing, human factors, modeling and simulation, 'ilities, etc.). In an era where specialists find it difficult to communicate outside of their specialty area, this is a problem that needs fixing. Requirements models support system quality improvement because quality is defined as a system's conformance to its requirements. The requirements models stay with the systems and reduce the costs of sustaining and upgrading them throughout their life-cycle.The following are examples of groups that are active in researching and supporting requirements modeling. AFRL Information Directorate is developing the Rosetta System Level Design Language (SLDL), which is the base technology for requirements modeling. AFRL/IF is also researching the application of Rosetta to specifying the "Joint Battlespace Infosphere". AFRL Materials and Manufacturing Directorate is researching the application of Rosetta to obsolete electronic parts, mechanical, electromechanical, and manufacturing systems. AFRL Sensors Directorate is researching Rosetta's application to the "systems-on-a-chip" that contain both radio frequency and digital circuitry. Individual DARPA projects are researching Rosetta's application to formal methods software and micro-electromechanical systems. AFRL Air Vehicles is researching Rosetta's application to adaptive control systems. Naval Air Warfare Center is researching Rosetta's application to electronic parts obsolescence. NASA is currently reviewing proposals to apply requirements modeling to some of their major problem areas. Requirements modeling with Rosetta SLDL also has strong ties to commercial industry. Rosetta is being developed to address needs created by the Electronic Design Automation Industry Council. The need for an SLDL is documented in the "International Semiconductor Roadmap". There is an Institute of Electrical and Electronic Engineers (IEEE) working group forming to begin industry standardization of Rosetta. Rosetta has been adopted as part of the European Chips and Systems Initiative (ECSI) and Accellera industry consortium has announced that it will promote Rosetta SLDL to the industry. What are not being developed elsewhere are the technologies that make Rosetta users productive at creating and applying requirements models. Such technologies would be proposed and researched by this topic.

PHASE I: The feasibility concept will be developed and preliminary design created for Rosetta-based product(s) that support requirements modeling of electronic and software systems. The functionality, user interface, look-and-feel, and interfaces to other products will be completely specified.

PHASE II: Commercially viable, prototype, requirements modeling product(s) will be constructed, evaluated, and demonstrated.

PHASE III DUAL USE APPLICATIONS: Because all systems have engineering requirements, there are no limitations on the types of systems that Rosetta SLDL can be used to specify. Rosetta is applicable to any kind of commercial or military system and there is significant interest for both. Commercial interest to date has been from the electronics industry, including semiconductor, communications, computer, automotive, and industrial control companies. Requirements modeling will provide the most benefit to large and/or complex product developments and especially those that have multiple domains, disciplines, and interfaces; that have more than three people involved with the product development; or that are being developed by geographically dispersed development teams. The technologies developed under this SBIR will be applicable anywhere requirements modeling is used.

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5. http://www.eda.org

KEYWORDS: Requirements Modeling, SLDL, Rosetta, Affordability Technology, Quality Improvement, Systems Engineering, Computer-Aided Engineering

AF01-227 TITLE: Miniature Sensor forAircrew Laser Warning

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop miniaturized cost-effective technology to detect, identify and characterize pulsed and continuous-wave (CW) lasers that are a threat to US military aircrew.

DESCRIPTION: This program will focus on the development of cost-effective miniaturized laser warning technology for use in aircrew protection from laser blinders and dazzlers. The objective is to develop low false-alarm laser detection with high resolution wavelength determination while also miniaturizing the technology to reduce the weight and power requirements. This technology should be suitable for use in a sensor unit that will be used for protecting tactical aircrews from laser blinders and dazzlers. This laser sensor technology will initially be demonstrated in the laboratory with eventual demonstration in an aircraft. The laser sensor should perform three main functions: 1) separate lasers from false alarm light sources (natural or manmade) based on the laser spatial or temporal coherency features; 2) determine the wavelength of the laser; and 3) determine and log the pertinent laser event characteristics for both CW and pulsed lasers (down to pulses <= 10nsec). The sensor must have a wide field of view (>=90 degrees) and have wide dynamic range as well as be sensitive to energy levels many orders of magnitude lower than those which are dangerous to vision. Additional warning information that would be useful for aircrew protection is direction of arrival of the laser energy, but this is not the primary focus of this program. This effort deals with multiple system issues, including determining performance requirements, evaluating the effects of the operational environment limitations such as atmospheric turbulence, optimizing performance of the candidate design, formulating efficient detection and signal characterization algorithms, and evaluating the sensor packaging technique. This sensor is intended for personnel protection which places the design emphasis not only on performance, but on small, light weight and low power devices, eg. cell phone size or smaller. It is expected that at least two detector technologies would be necessary to cover all threat bands. Uncooled detectors would be preferred over cooled sensors in order to meet the size and weight goals. The following types of technologies are thought to have potential: etalons, interferometers, diffractive elements, tunable filters, filter interpolation schemes and hyperspectral staring imagers; however, these are only examples and are in no way meant to constrain a solution to meet the above requirements.

PHASE I: Design and characterize the performance of the laser sensor concept. The end products will be a final report and a final presentation. Breadboard hardware as an end product is desirable, but not mandatory.

PHASE II: Develop a hardware prototype of the laser sensor and test it under appropriate conditions of operation for aircrew protection (e.g. on helmet, cockpit dash, etc.). The end products will be a final report, a final presentation, and the prototype hardware.

PHASE III DUAL USE APPLICATIONS: The laser sensor technology developed in Phase I and II will be transitioned to the production of sensor systems suitable for both aircrew protection laser warning and similar systems for aircraft and tactical sensors. This type of laser sensor should also be transitioned to commercial laser-aided manufacturing operations, clandestine law enforcement, optical communication receivers, and laser safety use in laboratories or in the medical field.

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KEYWORDS: Aircrew Laser Warning, Spatial Coherence, Temporal Coherence, Wavelength, Miniaturization, Threat Characterization, Laser Eye-Safety

AF01-228 TITLE: Automatic Target Recognition Characterization for Electro-Optical Sensors

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a methodology for determining the robustness of new ATR systems designed for electro-optical sensors.

DESCRIPTION: The Air Force Research Laboratory (AFRL) is investigating technologies that could provide the Air Force with an improved capability to find, identify, and engage mobile targets deployed in "deep hide." The effort, called Tanks Under Trees (TUT), is looking at several emerging sensor technologies and associated automatic target recognition (ATR) algorithms to identify those suitable to move from research and development into the field. The emerging sensor technologies under consideration include hyperspectral imaging, active laser sensing, unattended ground sensors (UGS), and foliage penetration (FOPEN) radar. Maturing ATR for these new sensor technologies will present challenges in data adequacy, modeling, and demonstrated performance. Of particular interest here is the ability to characterize the variability in electro-optical sensor parameters, environmental factors, and target features to determine level of difficulty for ATR systems. The ATR system should be characterized by measuring its performance over as many operating scenarios as possible. AFRL has developed a methodology for describing ATR performance over a variety of missions by defining extended operating conditions (EOCs) as a measure of the difficulty of a particular scenario. For example, uncamouflaged targets in the open generally present an easy operating condition (EOC) for all ATR systems, adding radar camouflage increases the difficulty for radar ATRs as expected, but may also impact ATR systems designed for EO systems. Characterizing the extending operating conditions for a particular sensor and mission is an essential part of the ATR evaluation process. EOC definitions are used to drive experimental design and are critical when putting the results into context within the desired mission scenario. AFRL is currently employing the EOC methodology for the Moving and Stationary Target Acquisition and Recognition (MSTAR) program and Hyperspectral Imagery (HSI) algorithm evaluation.

PHASE I: Develop a qualitative description of the EOC space for a candidate sensor and ATR system. Candidate sensors for this effort include: 1, 2, &3 Dimensional Laser and Laser vibrometry. Map existing sensor data to the EOC description highlighting missing data for future data collection requirements. Design algorithm experiments and report baseline algorithm performance over samples of the EOC space.

PHASE II: Execute experiments to quantify the EOC sensitivities of a baseline algorithm. Recommend options for filling in missing data with collected or simulated data. Generate simulated data or perform data collections to populate a more complete and standard database for future evaluation activities. Demonstrate and quantify system performance by using the database in executing experiments and reporting on EOC sensitivities for commercial and/or military applications.

PHASE III DUAL USE APPLICATIONS: Evaluation of emerging sensors will be necessary in order to determine their readiness and applicability for commercial applications. In particular, use of HSI and 3-D laser data in automated manufacturing will require quantified performance estimates as a function of sensor quality, illumination, and manufacturing tolerances.

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2. T. Ross, J. Bradley, L. Hudson, M. O'Connor, "SAR ATR - So What's the Problem? An MSTAR Perspective", Algorithms for Synthetic Aperture Radar Imagery VI, Proc. SPIE Vol 3721.
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KEYWORDS: Electro-Optical Sensors, Modeling, Simulation and Analysis, Lasers Detection.

AF01-230 TITLE: Enhanced RF Device Functionality for Space Antennas

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop innovative electronic device and/or circuit technologies for increased functionality to reduce parts count, power consumption, signal loss, mass, and cost for large, lightweight apertures for space-based radar.

DESCRIPTION: The research will explore revolutionary new device and/or circuit concepts and conduct feasibility demonstration efforts on devices with potential for enhanced functionality to support space-based radar. This effort will not address system-on-a-chip type approaches, but it will focus on enhanced electronics for the components at the radar element or subarray level. The effort will examine new devices, device concepts or circuits for use on large, lightweight apertures for space. The effort will consider ideas for laying out the device cell structure (gate stripe) as a circuit which may be partitioned into miniature circuit elements for enhanced functionality. Technology must be assessed for the environmental challenges in space, potentially large temperature variations due to limited environmental control and/or high radiation. This program will examine new electronic approaches using a large, lightweight aperture for space as the application. These apertures could potentially contain up to 500,000 elements and millions of components. Increased functionality components could substantially reduce the parts count, power requirements, mass, and increase reliability. Examples of increasing the functionality of a single active device include: 1) combining the LNA and phase shift function; 2) dual gate FETs; 3) balanced quadrature hybrids, and 4) a reconfigurable bank of device cells connected in series or parallel with multiple outputs (phase path lengths). Other concepts of interest can be aimed at reconfiguring the set of active device cells to meet specific mission needs such as the ability to time vary LNA bias points and device cell combining to achieve a dynamic/selectable dynamic range vs DC power drain. Limited hardware breadboards will be fabricated to verify simulation/modeling results as required. Selection of the demonstration vehicles shall be based on customer's future needs and the availability of suppliers transferring these technologies from a research to a production environment. This program shall be divided into two phases. Concepts, including device or circuit feasibility, shall be demonstrated during Phase I. Functional demonstration vehicles and design of potential products shall be completed at the end of Phase II. It is expected that fabrication capability of commercial and military products will be established by end of Phase II.

PHASE I: Device and circuit development shall be completed.

PHASE II: Functional demonstration vehicles and design of potential products shall be completed, such as enhanced functionality active devices and components.

PHASE III DUAL USE APPLICATIONS: Commercial applications include portable electronics, wearable electronics, space-based systems, automotive electronics, and RF tags.

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[1] Edelstein, W. N., Kim, Y., Freeman, A., Jordan, R., "Next Generation SAR Demonstration on Space Station", Space Technology and Applications International Forum-1999, AIP Conference Proceedings 458, pp. 352-357, Albuquerque, NM, February 1999.
[2] Huang, J., Lou, M. C., and Caro, E., "Super Low Mass Spaceborne SAR Array Concepts," presented at the IEEE Antennas and Propagation International Symposium, Montreal, Canada, Vol. 2, pp 1288-91, July 1997.
[3] Huang, L., Lou, M., Feria, A., and Kim, Y., "An Inflatable L-Band Microstrip SAR Array," IEEE AP-S/URSI Symposium, Atlanta, GA, June 1998, pp. 2100-2103.
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KEYWORDS: RF Electronic Devices, Functionality, Space Based Radar, Aperture

AF01-231 TITLE: <u>Short-Pulse Target Ranging Laser Transmitter</u>

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a short-pulse, high-repetition-rate, laser source for high resolution ranging of targets.

DESCRIPTION: Laser transmitters are needed for target identification in laser radar systems capable of efficiently performing target ranging with spatial resolution < 20 cm. A target with spatial depth will reflect a pulse of laser light with a pulse shape characteristic of the spatial features of the target. Resolution is limited by the pulse width of the laser. Useful resolution requires a laser pulse less than 1 nsec. Q-switched solid-state lasers typically have pulses too long. Modelocked lasers have the required short pulses but pulse energies are very low and very high repetition rates cause aliasing problems in interpreting return signals. Source technology is desired which provides eye-safe (~1.5 microns) laser pulses with mJ pulse energies and repetition rates in the 1 kHz to 1 MHz range. The device must also be compact and robust for use in military environments.

PHASE I: Demonstrate the feasibility of an innovative technique, concept, or device which would lead to a major improvement in short pulse width, high energy per pulse laser operation at 1.5 microns.

PHASE II: Demonstrate a complete device which incorporates the innovation demonstrated in Phase I. Demonstrate spatial resolution < 20 cm of distant targets. 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 technology developed to make a short pulse laser with pulse widths in the 1-10 psec range is also of strong interest for commercial drilling and cutting applications. The short pulses have been shown to ablate materials without any heating damage to adjacent material (an important feature for medical applications).

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2. E. A. Watson, M. P. Dierking, and R. D. Richmond, “Laser Radar Systems for Multi-Dimensional Imaging and Information Gathering,” Invited Paper, presented at the 1998 11th Annual Meeting of the IEEE Lasers and Electro-Optics Society, Orlando, FL (Dec 1998), vol. 2 pp 269-270.
3. P. F. McManamon, E. A. Watson, and D. D. Smith, “Multidiscriminant imaging with active sensors,” presented at the Annual Meeting of the Optical Society of America, Baltimore (1998).

KEYWORDS: Optics, Infrared, Laser, High-Resolution Ranging, Q-Switched, Mode-Locked, Eye-Safe

AF01-232 TITLE: Multi-Mission Waveform Design

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop an integrated waveform design for a multichannel airborne/spaceborn radar system that is capable of performing multiple missions.

DESCRIPTION: With the ever decreasing resources available to develop and build specialized airborne platforms for specific surveillance missions, there is a need to develop cost effective waveform design changes to improve the utility of current surveillance assets. There is a need to perform multiple missions from a single multi-channel airborne platform without massive, costly, hardware changes. One desirable solution is to use an integrated waveform design capable of performing a multitude of tasks using the same platform. The tasks include airborne moving target indication (AMTI), ground moving target indication (GMTI), imaging, automatic target recognition (ATR), and weather/environmental assesement.For the AMTI mission the detection of low radar cross section (RCS) targets in the presence of sever clutter environments is of concern. For the GMTI mission, the aim is to detect slow moving targets with a large RCS. For the imaging/ATR aspect, multiple bands should be considered to employ target detection/classification under a host of conditions including open fields and areas with large amounts of foliage (foliage penetration). Weather radar should also be considered in terms of providing environmental assessment over the battlefield within some time period. In an integrated approach to threat target detection as discussed above, adaptivity on transmit will permit optimization of interleaved waveforms best suited to the scene specific mission.

PHASE I: Develop an integrated adaptive (interleaved) waveform design that will accomplish the tasks listed above. Perform preliminary experiments and simulations that indicate how well the concept addresses the desired tasks. Design an experiment for demonstration in the AFRL Surveillance Facility. Recommend existing airborne surveillance platforms that would accommodate the mature adaptive transmit algorithm.

PHASE II: Implement the adaptive (interleaved) waveforms selected/developed under Phase 1 in the AFRL Surveillance Facility for flight test demonstrations. Develop a plan for integration of mature adaptive waveform algorithms aboard a candidate platform for field testing.

PHASE III DUAL USE APPLICATIONS: The development of this type of waveform has benefit across all aspects of government military and civilian, as well as commercial users of communications, navigation and remote sensing technologies. This technology is extremely critical as demands on bandwidth increase. Waveform diversity will permit more efficient use of available and allocated spectrum.An application plan for transition (to a myriad of military users) should be produced in Phase 2 for continuation of this work in Phase III.

REFERENCES:
See DTIC search #AKK05I

KEYWORDS: Integrated Waveform Design, Multi-Function Waveform Design, Adaptive Waveforms

AF01-237 TITLE: Hyperspectral and Low Frequency Radar Target Modeling Technologies for TUT Intelligence Suveillance

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop innovative Hyperspectral and FOPEN modeling technologies for targets in tree region settings.

DESCRIPTION: The Air Force Research Laboratory (AFRL) is investigating technologies which could provide the Air Force with an improved capability to find, identify, and engage mobile targets deployed in "deep hide." The effort, called Tanks Under Trees (TUT), is looking at several emerging sensor technologies and associated automatic target recognition (ATR) algorithms to identify those suitable to move from research and development into the field. The emerging sensor technologies under consideration include hyperspectral imaging, active laser sensing, unattended ground sensors (UGS), and foliage penetration (FOPEN) radar. Maturing ATR for these new sensor technologies will present challenges in data adequacy, modeling, and demonstrated performance. This topic solicits innovative solutions in following technology areas: 1. Hyperspectral Target Signature Modeling 2. FOPEN Target Signature Modeling 3. CAD target modeling technologies to support FOPEN and Hyperspectral signature prediction techniques and 4. Background Clutter Modeling Techniques to support FOPEN and/or Hyperspectral target in terrain predictions. Proposals that address one or a combination of the technology areas 1-4 will be considered. Innovative physics-based phenomenology modeling techniques that will support the prediction of low frequency RF or Hyperspectral sensor observables from targets are needed. Existing target geometry and material collection techniques for CAD modeling of complex targets are equipment and time intensive. Novel techniques that use hand portable equipment to efficiently collect target geometry and material information on tactical targets to support high fidelity target model builds for Hyperspectral and low frequency RF predictions are needed. Once the target CAD geometry model is constructed, customizing a CAD model for low frequency RF and Hyperspectral predictions is man-intensive. Efficient CAD discretization, translator and surface healing methods that can be used to generate the input target geometry from a high-fidelity geometric and material common CAD model to support multi-sensor physics-based prediction methods are needed. For example, a high-fidelity CAD geometry and material model built for radar predictions must be manually re-gridded to support thermal predictions. CAD tools that automate this process are needed to speed target insertion. Clutter modeling techniques that address low frequency RF or hyperspectral prediction for background terrain including tree regions are also sought. Target and clutter signature modeling techniques should allow the prediction of a sensed observable such that sensor specific processing models can be applied as post-processing step to allow sensor parameter trade studies.

PHASE I: Address at least one of the following: Prototype low frequency RF or hyperspectral physics based modeling technique for complex targets. Design or limited proof of concept of a target geometry and material collection system. Proof of concept CAD geometry healer or CAD translator. Prototype low frequency RF or hyperspectral modeling technique for background clutter.

PHASE II: Address at least one of the following: Development of low frequency RF or hyperspectral radar physics based modeling techniques for complex targets and/or targets in tree region. CAD geometry and material collection system. CAD geometry healer or CAD translator. Development of a low frequency RF or hyperspectral modeling technique for background clutter.

PHASE III DUAL USE APPLICATIONS: CAD data collection techniques and target and scene prediction techniques developed on this effort have applications to large area site modeling for communication system design.

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2. J. M. Song, C. C. Lu, W. C. Chew, and S. W. Lee, "Fast Illinois solver code (FISC) solves problems of unprecedented size at the Center for Computational Electromagnetics, University of Illinois," IEEE Antennas Propag. Magazine, (invited), vol. 40, no. 3, pp. 27-34, June 1998.

KEYWORDS: Hyperspectral Prediction, Low Frequency Radar Prediction, Hyperspectral Clutter Modeling, Clutter Modeling, Scene Modeling, Target Modeling.

AF01-239 TITLE: Aerospace Vehicle Structural Certification by Analysis

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: To replace tests performed for certification of aircraft structures with analyses.

DESCRIPTION: Advances in computer and computational technologies have developed to the point where more confidence can be placed in analyses. Currently aircraft and aircraft parts/components are certified through expensive tests. In order to replace testing with more affordable analyses, confidence in the analysis methods, their implementation (computer codes) and their associated models needs to be increased. The current effort is to develop an analytical certification process by increasing confidence in the analytical methods through research into the limits of applicability of the code, enhancing the code to include risk/confidence assessments or to expand the limits of applicability, and/or research into proper modeling techniques. A means of determining the criteria of certification (e.g. quantification of error, probability of failure, etc.) is needed. In order to keep the effort within a reasonable scope, it is recommended that the effort target certification tests for which analytical methods are sufficiently advanced to be considered for replacing the test or reducing the number of tests that need to be performed for a certification. Of particular interest in this effort are analytical methods to replace structural and structural load certification tests (fatigue, buckling static strength, flutter, air loads, etc) for any aircraft structural component (ribs/spars, bulkheads, skins, etc.) or assemblies (wings, fuselages, etc). It is anticipated that some analytical tools may be used for certification of multiple classes of components and/or assemblies, that the guidelines for using the code for certification may differ from component to component or assembly to assembly, but these differences should be rather small. This topic is open to certifications for all types of aerospace vehicles, including future vehicles and re-certification on existing vehicles.

PHASE I: Develop overall analytical method concept that includes test to be replaced, all software to be used, a detailed plan for certifying the software and issues to be addressed in creating models (software input) for certification.

PHASE II: Implement concept developed in Phase I through the development of guidelines (input/output parameter limits, areas of applicability, modeling techniques, etc) for using analysis tools and of other tools (software enhancements, etc) necessary for analytical certification of a given class of structural components or assemblies.

PHASE III DUAL USE APPLICATIONS: A broad range of analytical certification methods may be developed. The primary application of the method would be for military aircraft. The method may also be used either directly or with minor modifications for civilian aircraft, other classes of transportation vehicles and other structures.

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2. Millwater, H., K. Griffin, D. Wieland, A. West, H. Smith, M. Holly, R. Holzwarth, "Probabilistic Analysis of an Advanced Fighter/Attack Aircraft Composite Wing Structure," Proceedings of the 41st AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, Atlanta, GA, 3-6 April, 2000, AIAA 2000-1567.
3. FAA Advisory Circulars; AC 20-107A, "Composite Aircraft Structures" and AC 23-13, "Fatigue and Fail-Safe Evaluation of Flight Structure and Pressurized Cabin for Part 23 Airplanes."
4. Advisory Group for Aerospace Research and Development, Corporate Author, Loads and Requirements for Military Aircraft, FEB 1997, AGARD-R-815 or ADA 324348.

KEYWORDS: Aircraft, Structures, Certification by analysis , Loads, Multidisciplinary. Analytical certification

AF01-240 TITLE: Visual Crack Measurements of Vibrating Structures Compared with AFGROW

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Visual crack measurement system to measure crack growth on vibrating structures.

DESCRIPTION: Structural damage occurs in aging aircraft (e.g., B1, F-15, E-3A, C-5, F-18 and C-130) and spacecraft due to vibration and acoustic fatigue. DOD needs experimental and analytical crack growth data to explore concepts to extend secondary structure lifetimes to improve aircraft life cycle costs and mission performance. These new concepts may not only extend the useful lives of our aging aircraft but could significantly extend the period of performance of our newer aircraft (e.g., C-17, F-22, etc.). This effort will develop an innovative visual crack measurement system (VCMS) to measure crack growth rates of vibrating structures during out-of-plane vibration or acoustic excitation. The VCMS should view crack initiation and crack length on vibrating structures. Empirical crack growth data, measured by the VCMS, are needed to validate analytical crack growth life predictions from software programs such as AFGROW. One possible approach is to research and develop a VCMS using temperature sensitive paint (TSP) as described in references 1 and 2. The VCMS should view a specimen while vibrating on a shaker to measure crack length versus fatigue cycles. The system will be designed for laboratory or field environments (e.g., at modification centers) to measure cracks with minimal aircraft mission impacts. This system will help engineers to design and evaluate bonded durability patches on structures to extend lifetimes at a lower cost than replacing aircraft skins. A working knowledge of vibrations, acoustics, fatigue, test controls, imaging, thermal sensitive paint, materials and structures are required. The VCMS will automate crack growth measurement to allow characterization of aircraft material. This previously unobtainable data will increase reliability and maintainability of aircraft secondary structures.

PHASE I: Perform design and feasibility investigations of VCMS concepts. Using design of experiments (DOE), demonstrate the VCMS using aircraft material mounted on an electrodynamics shaker to validate crack growth length measurements for out-of-plane excitation. Finite element analysis is required to obtain stress intensities at the crack tips of vibrating structures. During Phase I a design of a detailed experiment for phase II will be produced.

PHASE II: Fabricate and deliver visual crack measurement systems based on the design and experiments demonstrated and validated in Phase I. A Phase II system shall view and measure crack growth rates in more complex, multi-dimensional aircraft structures. The system will be usable in a laboratory or field environment. Conduct a designed experiment to compare experimental crack growth curves using the VCMS with analytical curves using AFGROW.

PHASE III DUAL USE APPLICATIONS: Crack length measurement for out-of-plane excitation is required by the aviation industry, gas pipeline industry, materials industry, automotive industry and any commercial application where acoustic or vibration fatigue impact a product's lifetime. The visual crack measurement system will be useful in numerous military applications including spacecraft, aircraft, naval vessels, wind tunnels and ground vehicles.

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KEYWORDS: Dynamic Fatigue, Shakers, Video, Crack Length Measurements, Temperature Sensitive Paint, Instrumentation

AF01-241 TITLE: <u>Rapid Characterization of Tactical & Special Mission Precision Approach Flight Inspection Techniques</u>

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Provide rapid, safe, accurate characterization of the readiness of tactical landing systems for operations.

DESCRIPTION: This research shall be focused on rapid determination of safety of landing system readiness for operations when using Global Positioning System (GPS) or other precision landing aids. Utilization of emerging technologies and sensors for improving these processes are paramount. This work will focus on using innovative Information Systems technologies coupled with new survey tools to ensure safety of flight. Verification technologies must also be employed to assure the integrity of the GPS signals in the final approach segment to Category II and III environments.

PHASE I: Identify most promising concepts. Propose a design that demonstrates the feasibility of rapidly confirming that GPS instrument approach procedures are safe to fly to category II and III minima in less than four hours. The tool shall identify changes required to the instrument approach procedure to make it useable if the planned procedure is not acceptable. Products will include a brief proposal for a candidate SBIR design approach for Phase II.

PHASE II: Develop and demonstrate proof of concept prototype.

PHASE III DUAL USE APPLICATIONS: Enable use of newly developed procedures by documenting the: Required changes to Terminal Instrument Procedures (TERPS) for GPS landing to CAT II and CAT III, and the required changes to the United States Flight Inspection Manual. Dual Use Applications: The development of this capability is required to meet military Operational Requirements Document (ORD) timelines for the DOD Systems but also, once developed, would be widely applicable to other programs. The FAA Local Area Augmentation System (LAAS) program employs augmented GPS for its category I and II systems and such innovative research would greatly assist FAA efforts to support contingencies by providing an ability to rapidly respond to national emergencies. This technology could likewise provide rapid site selection and evaluation of alternative sites to support worldwide contingencies.

REFERENCES:
1. Flight Inspection TM 95-225, NAVAIR 16-1-250, AFMAN 11-225, FAA Order 8200.1A.
2. TERPS TM 95-226, OPNAV Inst. 3722.16C, AFJM 11-226, CG 318, FAA Handbook 8260.3B.
3. RTCA/DO-245 Local Area Augmentation System (LAAS) Minimum Aviation System Performance Specification.
4. Joint Precision Approach and Landing System ORD USAF 002-94-I, AFSSA/XR, 4 MAR 98.

KEYWORDS: Expeditionary Airfield, Survey Tools, Flight Operations, Safety, Flight Inspections
Global Positioning System (GPS)

AF01-242 TITLE: Aerosol & Diamond Substrate Cooling for Airborne Platform Computers & Radomes

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop concepts for aerosol & diamond substrate cooling for airborne platform computers & radomes.

DESCRIPTION: The insertion of the new high power sensor, transmission antennas and high performance computer requires efficient means of radome and hardware cooling. As the utilization of high powered computers and electronics (and for example the insertion of the new high power Advanced Extremely High Frequency transmission antenna on Joint Surveillance Target Attack Radar System) become common, easily adaptable and inexpensive high conductivity substrates become a necessity. These systems require highly effective cooling techniques. Of those presently being considered, aerosol & diamond substrate cooling appear extremely attractive but are in need of development.

PHASE I: Analysis, conceptual design work, and optional simple experiments shall be performed to evaluate the feasibility of developing the selected techniques. Analysis shall include the relative merit of the new, innovate approach in comparison to current cooling technologies. The analysis and conceptual design will also address the compatibility of technique with the vehicle and its subsystem. The design shall show sufficient technology maturity, practicality, and payoff benefit for orderly development in the next phase of effort. The Phase I work shall produce a competent technical report and plans for experimental development in a proposed Phase II effort.

PHASE II: This phase continues the necessary analytical work and provides experimental verification of predicted cooling capabilities of the techniques developed. Laboratory simulation, demonstration, and verification of typical operating conditions will evaluate performance at various heat loads. Environmental impacts shall be identified and assessed. Benefits to be gained from the use of the new approach will be quantitatively established for different potential applications to prepare for possible commercial development of the system. A comprehensive technical report shall document all of the work conducted. A final optimized design shall be completed, and a demonstration device will be fabricated and tested.

PHASE III DUAL USE APPLICATIONS: Dual-use commercialization will be considered in all phases of this effort. Potential applications include space operation vehicles, commercial space launch vehicles, satellites, fleet sustainment and commercial computer and electronic industries.

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5. Steinberg, DS, 1991, Cooling Techniques for Electronic Equipment, 2nd Edition, by, John Wiley & Sons, NY.

KEYWORDS: Heat transfer, Cooling, High conductivity material, Diamond, Aerosol

AF01-243 TITLE: Evaluation of Vehicle Fiber Optic Wiring Systems

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop methodology and equipment for remote sensing capability of optical wiring systems health.

DESCRIPTION: Wiring is found in nearly every part of an aging aircraft (40 miles of wiring in an F16). Metallic wiring can be diagnosed using Time Domain Reflectometry (TDR) techniques. The move to optical cable to replace metallic wiring systems is increasing in use across systems in both old and new aircraft. The Fly-by-Light Advanced System Hardware (FLASH) Program developed flight control components using multimode optical fibers to transmit control data and sensor signals. The emphasis was on demonstrating fiber optics in general, as a key element of reliable flight control systems architecture. The Advanced Vehicle Management Technology (AVMT) Program has developed Photonic Vehicle Management System Architectures that utilizes Wavelength Division Multiplexing (WDM) on both singlemode and multimode optical fibers. The technology of diagnosis and troubleshooting fiber optic systems in aerospace vehicles has not kept pace with optical technology developments. One of the few places that weight can be trimmed from high performance aircraft is the wiring system. When technological improvements are made on aircraft this usually results in a weight increase. The use of optical technology can increase the performance of the transmission of signals as well as reduce weight. In order to integrate this technology to the aircraft fleet, development of prognostic and diagnostic technology must be accomplished. This technology must provide field technicians with prognostic information that tells where the degradation in the system is located, predict when the performance will degrade below the minimum required, and provides a means to schedule the repair. This system will eliminate numerous pieces of expensive, user sensitive test equipment, which require additional logistics resources to support and provide a real-time health management system for the aircraft for control and data signals.

PHASE I: Develop a sensory and prognostic system design and methodology that includes sensor specifications and software support for prognosis and diagnosis for optical wiring. The prognostic and diagnostic system must account for fiber performance, connector interface performance, and signal attenuation. The prognostic algorithms must also estimate the time element for future performance degradation. The prognostic/diagnostic system should demonstrate a proof-of-principal prototype incorporating selected sensors. Demonstrate detection and prognosis capability with near location of suspected fault indication, connector or fiber.

PHASE II: Building on the success of Phase I, the Phase II objective should be to develop diagnostic equipment and procedures necessary to assess the integrity and residual life of the optical wiring. Build an optical test system to demonstrate portable field and or space application inspection capability of the system.

PHASE III DUAL USE APPLICATIONS: 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 ability to easily replace metallic wiring systems with optical systems is needed in the aerospace, automotive and construction industries. The diagnostic tools developed under this SBIR will have widespread use.

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KEYWORDS: Optics, Prognostics, Diagnostics, Sensors, Wavelength Division Multiplexing, Portable/miniaturized

AF01-244 TITLE: Enroute Mission Planning Rehearsal (EMPAR)

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: To provide aircrews with a portable, real-time mission rehearsal capability.

DESCRIPTION: There is an outstanding and immediate need for a portable, real-time mission rehearsal system that allows the warfighter to plan and practice all aspects of a planned mission prior to mission departure (e.g., mission planning and coordination, takeoff, enroute, ingress, find potential target area, egress, return to base). Currently, no mission rehearsal system exists that offers portability, man-in-the-loop functionality (from the pilot's out-the-window perspective), real-time processing, and the ability to incorporate additional data regarding weather, threat, and other situational awareness related data that may become available after the initial mission planning was conducted. The challenge in developing the EMPAR system is to create a real-time, low-cost, portable computer system with a network capable architecture and software suite that combines the fidelity and speed of high-end ground simulation models and databases with the detailed, non-real-time mission planning systems. A particular challenge will be the development of a real-time computer architecture with sufficient memory, speed, and data buffering that is also small enough and light enough to make the system portable and practical to use. To date, flight simulators that use accurate flight models and generate detailed 3-D terrain graphics have been limited to large computer systems housed in simulation facilities. Today's existing mission planning systems take hours of pre-flight set-up and do not allow crewmembers the opportunity to fly through all aspects of the mission to gain valuable insight into performance measures. This new system needs to seamlessly process aircraft modeling, flight characteristics, detailed terrain (including the out-the-window 3-D visual scene), weather information, and threat information in a real-time mode. It should have the capability to incorporate remote updates to mission tasking, threat laydowns and imagery information via satellite uplink or any DOD established secure communication link using DOD connectivity architectures. In addition, the system should incorporate existing imagery data, in a Digital Terrain Elevation Data (DTED) format, currently maintained by the National Intelligence Mapping Agency (NIMA). With all these details combined, the system should then allow pilots to perform a fly-through mission from their perspective in order to familiarize themselves with all aspects of the mission.

PHASE I: Provide a feasibility analysis for the development of a low-cost computation platform based mission rehearsal system.

PHASE II: Develop, test, and operationally demonstrate the mission rehearsal system studied in Phase I SBIR effort.

PHASE III DUAL USE APPLICATIONS: This EMPAR will be useful as a deployable limited training and mission rehearsal system. In addition, commercial pilot programs and civilian pilot training programs can use this technology to train.

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KEYWORDS: Simulation, Planning , Computer, Graphics

AF01-245 TITLE: Effect of Parameter Accuracy and Variance on Structural Life Prediction and Life-cycle Costs

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Link the inaccuracy and variance in life prediction for different designs of the same detail to operations/support costs and aircraft availability.

DESCRIPTION: Analytical qualification of structural components is an exciting and innovative endeavor. Ultimately, analytical qualification will morph itself into a process that spans aircraft component design through retirement and provide the user with information required to make trades between aircraft performance, acquisition costs, life-cycle costs and availability. For example, the designer would select a component design and yield component fabrication costs versus total life cycle costs and iterate until the desired balance was achieved.In order to assess the degree of analytical qualification that is possible, the contribution of error associated with each step of the qualification process must be determined. Additionally, in order to determine the magnitude of current deficient life prediction and cost models, the statistical distributions associated with the various parameters must be determined and then analyzed using innovative processes. The process to achieve this (required data, analysis methodology and models) is far from clear and will be addressed under this effort.The proposed effort will begin the process of tying current and anticipated life prediction models, and their deficiencies, to costs incurred and aircraft availability. Successful achievement of the goal will require, at a minimum, innovative analysis techniques and the application and development of science and technology in probabilistic/stochastic methods. Cost models will need to be evaluated and developed, if necessary. Finally, an innovative method for combining life analysis methodology must be integrated with cost and availability models.The reason for this effort is a continually increasing focus on reducing fixed-wing vehicle operations and support (O&S) costs and increasing aircraft availability. A portion of an aircraft's availability and operations and support costs are due to inspections. Additionally, some components are replaced after a specified period of usage based, in part, on analysis methods used to derive the component's life. For a given structural detail, a change in the accuracy and variance associated with each parameter perturbs the structural life prediction which, in turn, perturbs the cost (inspection, repair, replacement with like or new design) and aircraft availability. To achieve the goal of linking the structural life prediction to cost and availability, it will be necessary to quantify the accuracy and variance of the parameters used to predict structural fatigue life. A determination of how much the parameter variance could be altered also needs to be quantified. By selecting various detail configurations for a given environment, and performing a structural life prediction using appropriate parameter distributions, the drivers of fatigue life for that detail can be determined. An assessment can then be made to change detail design, processes or materials to provide the most appropriate life. This assessment could also be used to help identify parameters where the variance could be altered. This, in-turn, would help determine cost/benefit ratio associated with the variance alteration. For example, controlled riveting with a specific squeeze force versus standard rivet installation techniques. Cost and aircraft availability, rather than life, become the primary output as a function of detail design, usage, material, initial quality, stress, stress intensity and many other parameters. This type of analysis will form the basis for analytical certification of aircraft structure.For commercial use, the original equipment manufactures (OEMs) and aircraft operators can also make use of this information in the same manner as the military. By examining the affect of the parameters on both prediction accuracy and life cycle cost estimates, it would be possible to perform trade studies that will maximize the value of the funding used in research (for existing aircraft and new aircraft designs). Unmistakably, there is considerable excitement from the aircraft OEMs, and all OEMs want to see technology development in this area.

PHASE I: Identify the models and parameters used in structural life prediction and estimate the accuracy and variance associated with those parameters. Develop and/or refine probabilistic/stochastic methods to model life prediction that includes parameter variance. Link the life prediction parameters to cost and availability model parameters. Establish statistical confidence in analysis results.

PHASE II: Further define the accuracy and variance of the various parameters. Quantify the confidence associated with the parameter's accuracy and variance. Further refine life prediction and cost/availability models. Use the analysis results to identify the drivers for inspections and component repair/replacement. Demonstrate process that links the structural life prediction analysis to O&S costs and aircraft availability.

PHASE III DUAL USE APPLICATIONS: Parameters are used as part of various models used to predict the modeled system's response. The process established under Phase II could be applied to any system that includes life prediction or response modeling and linked to the appropriate cost or availability metric. This could be used by the commercial aviation industry such as Boeing, Lockheed or Cessna. It could also be used by the Air Logistics Centers (ALCs) to help identify the optimal solution to various problems.

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KEYWORDS: Modeling and Simulation, Structural Fatigue Life, Total Ownership Cost, Detail Design, Probabilistic Methods

AF01-246 TITLE: Electro-Mechanical Actuation for Reusable Space Vehicle Flight Systems

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Demonstrate an innovative lightweight electro-mechanical actuator (EMA) suitable for reusable launch vehicle control performance and operational requirements.

DESCRIPTION: Air Force and NASA studies have identified up to 20% operation and support cost savings for reusable launch systems by eliminating hydraulic and pneumatic systems and replacing them with electrically driven systems, such as electro-mechanical actuators (EMA) for aero-surface and thrust vector controls. However, current EMA subsystems (electric motor, motor controller, gear train transmission, clutches and braking devices) have traditional designs that result in a weight penalty when compared to hydraulic and pneumatic actuation equivalents. The need exists for incremental and revolutionary technological change in EMA component and subsystem designs that will enable order of magnitude improvements in EMA performance-to-weight (approaching .5 to .65 horsepower per pound) and power density (EMA HP per cubic inch > .04 HP/c.u.i.). These performance characterizations are equivalent to or better than current EMA, hydraulic and pneumatic actuation equivalents.

In an effort to improve performance-to-weight and power density attributes, the innovative EMA design could for example, attempt to attain the following goals.

No fluids to be used as a source of power transition to maintain a true electrical to mechanical transition of power and avoid the use of fluidic components.

No rotational-to-linear power translation to eliminate performance impedance (frequency response and bandwidth) from typical EMA rotating group inertia. Also provides means to minimize/eliminate bulky gear train, clutch and brake impacts to EMA weight and volume.

No jammed failure modes to eliminate single point failure attributes and improve vehicle probability of loss of control (PLOC).

PHASE I: Will involve exploration and analysis of potential innovations with potential to increase performance-to-weight and maximize power density while maintaining design constraints for a pre-determined set of actuation performance requirements. The Phase I deliverables will include a report describing the innovations analyzed for each EMA subsystem and results of trade analyses conducted between like sets of innovations, and an EMA preliminary design. The EMA design will include an artist's conception and engineer drawings.

PHASE II: Will detail the innovative EMA design for development, fabrication, test and evaluation. It is desired to fabricate and test an EMA system in Phase II. However, based on a clear definition that a limitation of funding exists, it may of best interest to the project to develop one or more of the EMA subsystem innovations for test and evaluation.

PHASE III DUAL USE APPLICATIONS: - EMA applicable to AF Space Operations Vehicle (SOV) and NASA Space Shuttle (STS)
- EMA derivative applicable to AFRL/DARPA/Boeing Unmanned Combat Air Vehicle (UCAV) and future DoD Unmanned Air Vehicle (UAV) platforms
- EMA applicable to commercially funded launch vehicles

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KEYWORDS: Electro-Mechanical Actuator, DC Motor Control, Jam Proof/Resistant, Thrust Vector Control, Electric Actuation, Power-By-Wire

AF01-247 TITLE: <u>Aeromechanics Technology for Mini Aerospace Vehicles</u>

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop aeromechanics, stability and control technologies for Mini Air Vehicles for tactical Air Force missions.

DESCRIPTION: Tactical Mini Air Vehicles, with largest characteristic dimension between five and fifteen feet, are expected to conduct militarily significant Air Force missions in the next 10-20 years. Some current examples of mini air vehicles are AeroVironment's Pointer, Aerial Robot Corp.'s Freewing, and the AAI Shadow 200. For low observability, drag, and weight, it is desirable to reduce or eliminate the number of traditional aerodynamic control surfaces on these air vehicles. The use of active, adaptive 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, Shaped Memory Alloy (SMA) devices, steady or pulsating jets, deployable vortex generators, 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). Areas of interest include: integration of existing devices into mini air vehicle concepts, 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. These innovations can be realized through the simultaneous consideration of multiple design disciplines as well as through highly efficient aerodynamic, aerothermodynamic, and integration concepts.

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 OR demonstration under simulated flight conditions.

PHASE III DUAL USE APPLICATIONS: High-payoff military applications include flow control in low-signature compact inlets for mini air vehicles, separation and acoustic control for integrating Small Smart Weapons, low-cost, low weight fluidic (vs. mechanical) thrust vectoring, cruise drag reduction for both transport and combat aircraft, combat maneuver enhancement, and reduced runway requirement for transports. Virtually every commercial market that deals with some aspect of flow control could stand 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.

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KEYWORDS: Flow Control, MEMS - Micro Electromechanical Systems, Weapons Bay, Inlet, Nozzle, Mini Air Vehicle

AF01-248 TITLE: Adaptive Mesh Controller for Computational Analysis

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop software product that performs adaptation of computational grids used in physics-based modeling and simulation.

DESCRIPTION: Recent emphasis in physics-based modeling and simulation has exposed a need for more effective and efficient uses of computational resources, as well as higher fidelity in numerical results. Optimal redistribution of existing points in the discrete numerical model is often needed to achieve sufficient resolution of physical phenomena. Problems related to multiple bodies in relative motion, such as weapons separation and rotating engine components, require stretching and deformation of the numerical mesh elements to accommodate movement of the boundaries. Such applications have experienced limited success at the expense of highly specialized adaptation techniques tailored to each simulation. Existing software has limited potential in terms of generalized identification and improvement of regions of a computational mesh that require relatively inexpensive modifications such as coarsening and refinement. These modifications further need to be incorporated in a controlled manner to ensure effective utilization of computer resources, especially in a distributed (parallel) processing environment. In addition to effectiveness, solution accuracy is a concern for meshes that are adapting during the solution process, in real time, especially if the mesh becomes too distorted and remeshing must be performed. General, conservation-preserving approaches are needed in these situations. The technology that is required consists of an automated process to adapt unstructured computational meshes to capture relevant physics and account for moving boundaries. Solution error identification and reduction strategies are considered essential features. All of the required capabilities should be incorporated in a single software product, and the product should be interoperable with existing computational analysis software, including (but not limited to) geometry/mesh modelers, grid generators and iterative solvers for equations governing physical phenomena.

PHASE I: Define and determine the feasibility of the proposed adaptive mesh control concept(s). Present example(s) of the enhanced capabilities that will result from the proposed technology. Determine the risk and extent of improvement over existing methods.

PHASE II: Develop, demonstrate and validate the proposed concept(s) for realistic applications in the aerospace industry.

PHASE III DUAL USE APPLICATIONS: This product could be used in any industry that uses physics-based modeling and simulation to conduct design and analysis of complex systems or components. Highest payoffs could be realized for applications involving large mesh deformations due to movement of model boundaries. Some examples include air and ground vehicles, turbomachinery, heating and cooling systems and medical devices such as pumps.

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KEYWORDS: Modeling and Simulation, Numerical Analysis, Computational Analysis, Grid/Mesh Adaptation, Grid/Mesh Refinement, Mesh Modeling

AF01-249 TITLE: Affordable Control/Trajectory Management Systems for Unmanned Air or Space Vehicles

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop affordable control/trajectory techniques for autonomous vehicle operations throughout the spectrum of aerospace military environments.

DESCRIPTION: The Air Force is exploring the development and deployment of unmanned air and launch space vehicles that can act more autonomously than previous generation of such vehicles. These vehicles may be operated in isolation, in multi-vehicle groups, swarms, or as part of a cooperative force structure involving large numbers and varieties of both manned and unmanned vehicles. Current unmanned vehicle control approaches require a high level of real time human supervision/interaction. Achieving the full potential of the next generation of unmanned vehicle weapon systems will require unprecedented use of “intelligent” highly automated and “mission flexible” autonomous trajectory management/control systems to reduce the level of human interaction and associated infrastructure costs. To accomplish this vehicle control concepts will incorporate additional levels of high integrity automation for decision making, situation awareness, mission replanning, trajectory generation/flight path management, and vehicle health assessment. The reduction of real time human interaction necessitates that the verification and validation of vehicle control system behavior in response to anticipated, and/or unanticipated events or threats must be more extensive than commonly used on current unmanned vehicles while still being affordable.The Air Force is seeking innovative affordable techniques or concepts that can make a significant difference in affordability, reliability and mission capability for the next generation of unmanned air or space launch vehicles. Of specific interest are those control techniques which address the following goals: (1) Significant reduction in human real time interaction; (2) vehicle situational behavior response to anticipated and unanticipated events or threats that is appropriate to mission segment needs; (3) implementation supports rapid and affordable verification and validation of vehicle behavior for initial vehicle development and subsequent mission or operational planning for both actual deployment and force structure tactics development using simulations; and (4) achieve at least equivalent mission effectiveness of manned vehicles for the same mission.

PHASE I: Identify and define promising control concepts, system mechanization schemes, evaluation metrics and V&V methods consistent with mission application. Accomplish preliminary analysis and studies that support feasibility of proposed concept. Propose a development and demonstration program that would accomplish risk reduction technology maturation for key technical issues.

PHASE II: Develop autonomous system concept, including primary control algorithms and evaluate mission feasibility using high fidelity simulation methods. Accomplish experiments on a test bed to accomplish risk reduction for the key risk issues associated with autonomous vehicle operations for typical aircraft, missile and space vehicle scenarios.

PHASE III DUAL USE APPLICATIONS: The technology developed under this effort will be applicable to a wide variety of autonomous vehicles including air, space, land and sea vehicles that have to work in multi-vehicle groups or swarms. Applications range from wild fire fighting aircraft appropriate for remote hard to get to forest fires, autonomous cargo carrying aircraft, autonomous harbor protection under or above water vessels, and autonomous vehicles to mop up residual pollution left over from conventional bulk protection methods.

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KEYWORDS: Autonomous Air Vehicles, Unmanned Aircraft, Automated Control, Verification & Validation, Affordability, Control Techniques

AF01-250 TITLE: <u>Control Techniques for Distributed Systems</u>

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop decentralized feedback control techniques for groups of similar, independent, distributed entities.

DESCRIPTION: Active feedback control techniques are well developed for independent systems such as aircraft, spacecraft, and ground vehicles. In this case, a single, centralized control law is used to obtain optimal performance from a dynamical system. Of increasing interest to the United States Air Force is the ability to design decentralized feedback control systems for large numbers of independent, similar, autonomous entities such as groups of unmanned air vehicles, clusters of microsatellites, or groups of ground vehicles. Similar interest lies in modeling and control design techniques for distributed systems such as micro-electromechanical systems to control global flow phenomena using distributed systems of sensors and actuators on aerodynamic surfaces. These are examples of multi-agent systems in which many independent systems interact in a common environment; each can be autonomous or arranged in a hierarchy. Such systems have the advantages of simplicity, robustness, and flexibility. The primary challenge is to design a decentralized control system for these multi-agent systems. The individual elements of such a system are nominally interchangeable, and are more limited when used individually. A decentralized control theory is desired that describes how the system performance is to be achieved with distributed components. This includes a hierarchical structure if needed, system performance decomposition, coordination strategy, local sensor vs global sensor information, stability, and complete or restricted communication. System tasks will focus on formation management, reconfiguration, collision avoidance, cooperative attack, cooperative search, and rendezvous. Potential applications for flow control include drag reduction and separation control. In each case, the goal is to achieve the desired group behavior using a large number of basically identical, decentralized control systems that cannot be achieved though a large centralized control system because of the impracticality and inflexibility of such a system. The control concepts must be sufficiently generic so that they are applicable to a wide variety of distributed systems.

PHASE I: Define the proposed decentralized control concept and/or modeling technique, outline the basic principles, and establish a method of solution. Choose at least one particular distributed application that is to be used for analytic development of the control technique and experimental validation.

PHASE II: Develop the modeling technique and/or decentralized control concept, perform control law design to the application test bed, and show numerical simulation and/or experimental results for the distributed control system.

PHASE III DUAL USE APPLICATIONS: The methods and tools developed under this effort will be applicable to a wide variety of air vehicles, space vehicles, ground vehicles and sea vehicles. In addition, the methods and tools will be applicable to distributed parameter systems such as controlled fluid systems. The methods would enable many groups of systems to interact in an autonomous, cooperative fashion.

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KEYWORDS: Distributed System, Distributed Parameter System, Multi-agent System, Decentralized Control, Cooperative Control, Swarms, Reduced Order Modeling, Coordination Strategy, Hierarchical Decomposition

AF01-251 TITLE: Aerospace Structures Technology

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop structural technologies for conventional and high-speed manned and unmanned platforms.

DESCRIPTION: There are three primary research areas of interest. The first area is Structural Technology Integration. Within this area, research in innovative design concepts and analysis methods for three-dimensionally reinforced composites are needed to extend the use of composites in new systems or as substitutes into existing systems. In addition, multi-functional and adaptive structural concepts that provide for structural usage beyond the mere reaction of loads are needed for manned and unmanned systems along with methods to insure reliability and safety of bonded structure. A recent example of a successful multi-functional concept is conformal load-bearing antenna structures. The next research area of interest is Extreme Environment Structures. This area requires innovative design concepts for integrated thermal protection and propellant tank structure, integrated thermal protection and dry bay structure, and actively cooled structures. These concepts are needed to achieve weight, cost, and operability goals for advanced systems such as the space operations vehicle or future strike aircraft. Low observable-compatible integrated structure/thermal management design concepts are sought for use in high temperature areas such as airframe nozzles/exhaust washed decks. In both cases within extreme environments, life prediction techniques are required for both thermal/acoustic and thermal/mechanical load environments. The final area of interest is Structural Sustainment. Within Structural Sustainment life extension techniques such as repair, structural integrity analysis methods, and vibration suppression techniques are needed for reduced operations and maintenance costs, retrofit of fail-safety, and to provide increased system capability.

PHASE I: Synthesize the proposed design concepts, outline analytical tool requirements for concept verification, and determine development risks and benefits.

PHASE II: Refine design concepts with scale models and analysis tools. Validate design concept using a building-block development approach including elements, sub-components, and eventual component-level verification testing. Validate analytical tools with experimental correlation. Demonstrate and quantify advanced technology function and performance.

PHASE III DUAL USE APPLICATIONS: A broad range of commercial applications exists in each research area. For example, Multifunctional Structurally Integrated Apertures and electronics can be applied to commercial aircraft, reducing the installation cost and weight by eliminating cutouts and reinforcing structure required to protect antenna apertures from flight. Adaptive structural concepts can be applied to both commercial and military aircraft to improve aerodynamic efficiency. Extreme Environments technologies will be equally useful to both military and commercial space operations. Structural Sustainment technologies should apply to both military and commercial transport industries.

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KEYWORDS: Structures, Multi-functional Adaptive Structure, Analysis Methods, Thermal Structure, Unitized , Structure. Composites, Metallics, Sustainment

AF01-252 TITLE: Aerothermoelastic Optimization Methods for Reusable Launch Vehicles

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop a system for coupled aerothermoelastic design, analysis, optimization and thermal protection system trade studies.

DESCRIPTION: Aerothermoelastic analysis is a major discipline required for Space Access and Future Strike Vehicle (SA-FSV) design. Aerothermoelastic analysis provides detailed knowledge of a design's flutter, divergence, structure, and gas heating properties is required to determine the flight characteristics of a vehicle. Additionally Thermal Protection System (TPS) sizing and selection based on a vehicle trajectory are critical steps during the design process. Aerothermoelastic analysis and TPS sizing work together for defining a vehicle configuration and structural layout. Applying optimization in the design cycle is required to discover the best design and possibly a workable vehicle design based on a set of user constraints. Currently Aerothermoelastic analysis and TPS sizing are only performed stand-alone and not coupled with other analysis disciplines. The optimization process, if it is performed today, is currently performed by manually passing data. A single design environment eliminates manual data exchange and allows for reduced design cycle times, which is essential for producing workable Future Strike Vehicle design configurations. This topic will seek to develop a system for coupled aerothermoelastic design, analysis, and optimization of aerospace vehicle structures. The system should consider both conceptual and preliminary-level analysis methods. For instance, the system could use conceptual-level methods to get a trajectory that is optimized for heating and then use preliminary-level analysis methods to validate (or optimize) the thermal characteristics of the vehicle and determine if another pass through the conceptual-level design is needed. TPS sizing and material selection is then required for a final solution. The system developed by this effort should automate this design process for use with numerical optimization routines.

PHASE I: Develop an innovative toolset for conducting a limited aerothermoelastic analysis. The analysis tool must be validated using a general FSV design before transition to Phase II. Demonstrate the feasibility of expanding this integration to include trajectory analysis, TPS sizing, and design optimization, needed for vehicle closure.

PHASE II: Integrate trajectory analysis, TPS sizing, structural design, optimization, and leverage Phase I work to allow complete aerothermoelastic design optimization. Demonstrate reduced design cycle time with validated codes and validate optimization/integration techniques through a complete high-fidelity FSV design.

PHASE III DUAL USE APPLICATIONS: Both the US Air Force and NASA have indicated that next-generation reusable launch systems will be built. The innovative software tools developed in phase II are essential for the design of reusable launch vehicle concepts and Future Strike Vehicle designs. Other applications include any structural interface where aerothermoelastic analysis and thermal protection is required. Examples include foundry and oil refinery design, internal combustion engine applications, turbine design, and exhaust systems.

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KEYWORDS: Thermal Protection System, Space Access, Future Strike Vehicle, Optimization, Aerothermoelastic, Engineering Modeling

AF01-253 TITLE: Multifunction Wind Measurement Sensor

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and demonstrate a multifunctional optical sensor to measure atmospheric winds and air data.

DESCRIPTION: Real time wind data is pertinent for launch and recovery of reusable launch systems. Profiling winds aloft can minimize uncertainty for guidance/control, effectively broadening the available launch window. Measurement of winds for re-entry/landing can eliminate uncertainty in the energy management/ guidance/control to increase vehicle performance and range (especially for un-powered recovery). Additionally, air data is needed for the vehicle's flight control system during atmospheric flight.Advances in solid state laser technology have made laser Doppler velocimetry measurements feasible for the derivation of wind and air data. Air Force, Navy and NASA technology maturation and demonstration programs are proceeding to develop and demonstrate the viability of single function atmospheric sensing technology for the short range air data application and the long range wind sensing application. The air data application is short range and is focused near the aircraft. The wind sensing application is much longer range and uses a collimated laser beam. The technology being developed for fixed wing air vehicle air data can be adapted to also provide long range wind profiling, such as for gust compensation or derivation of winds aloft. Research and development is needed to overcome technical challenges to increase the power, use of adaptive optics to dynamically change how far away the measurement is being made, and packaging a multifunction sensor for the air/space vehicle.This effort will develop a multifunctional sensor to measure winds and air data for representative reusable launch vehicles. Effective range requirements, vehicle environmental factors, and sensor system weight will be considerations. It is expected that the near field measurement capability will have update rate and accuracy consistent with air data needs of the inner loop vehicle flight control system and multi-axis capability to provide a complete air data solution. It is expected that the far field measurement capability will have field of measurement flexibility to provide the vehicle information on wind fields, gust and air turbulence ahead of the vehicles flight path.

PHASE I: The product of Phase I will be a preliminary design of the sensor system.

PHASE II: The product of Phase II will be a brassboard demonstration of performance for both wind (greater than 1 kilometer range, 10 km desired) and air data (less than 50 meters range) measurement. Ground tests will be conducted at a minimum, flight data collection and analysis as feasible.

PHASE III DUAL USE APPLICATIONS: A multifunctional sensor will have wide applicability to commercial uses. Airliners currently do not have on-board sensors that can detect air turbulence ahead of the aircraft to provide warnings of imminent air turbulence. The primary application of air turbulence detection will provide the necessary incentive to install the system. Then the secondary air data function will almost certainly be utilized to obtain air data in place of conventional pitot static probes.

REFERENCES:
1. G. F. Rouse, H. R. Bagley, et al., "Development of a Laser Wind and Hazard Profiler", Proceeding (SPIE) - The International Society of Optical Engineers, Fly-by-Light III, Volume 2840, 1996, pp. 157-167.
2. Stephen M. Hannon, et al, "Autonoumous Lidar Wind Field Sensor: Performance Predictions", Proceedings (SPIE) – The International Society of Optical Engineers, Optical Instruments, Vol 2832, 1996, pp. 76-91.
3. James T. McKenna, "Rallying For Attack on Turbulence," Aviation Week & Space Technology, July 27, 1998, pp. 40-42.

KEYWORDS: Winds Aloft, Air Data, Laser Velocimetry, LIDAR, Turbulence, Guidance, Navigation, and Control

AF01-257 TITLE: Long Range, High Altitude, Offshore Tracking and Scoring System

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a tracking system for the measurement of overwater trajectory parameters for munitions.

DESCRIPTION: Current trends in weapon systems development are for longer range weapons having safety footprints that extend many miles when released from aircraft at operational altitudes. These safety footprints are too large for most land based testing. As a result, many DoD weapon systems are not tested over their full operational envelope. The need exists to be able to test these weapons over a large water based range such as the 80,000 square mile Eglin AFB Gulf (of Mexico) Range. The problem is that an instrumentation system does not exist that is capable of providing the required time-space-position-information (TSPI) for a water based test range.

PHASE I: Develop an innovative design for an overwater, over-the-horizon, object tracking system. This system must be capable of providing sub-meter accuracy/resolution TSPI throughout the entire envelope from launch to impact for objects traveling at velocities from subsonic to Mach 10, at altitudes from 50 to 100,000 feet, and ranges up to 100 miles.

PHASE II: Develop and demonstrate a prototype system that performs to the specified levels. Document and validate the method of operation to include software algorithms, source code, software operating system and licenses, input/output data requirements, et cetera.

PHASE III DUAL USE APPLICATIONS: Within the DoD and the weapons development community, there will be a continuing need to be able to track/score weapons and targets at longer standoff ranges and higher altitudes. This same technology could have commercial applicability in any area that requires the ability to track objects in an overwater environment such as Coast Guard activities, commercial aviation, air traffic control, and space research.

REFERENCES:
1. "Wide Area Global Positioning System (GPS) Time-Space-Position Information (TSPI) (WAGT) Demonstration"; Lindegrin, John E. & Hammond, Martin J.; June 1999; AD-B245 725/XAG.
2. "Aerial Target Scoring Systems Technology Review"; Plonski, Frank E. & Lehman, Eugene W.; 07 October 1997; AD-B231 037/XAG."Miss Distance Vector Scoring System"; Bradley, Joseph L. & Whiteman, Don & Mills, George T.; 25 March 1997; AD-D018 482/XAG.

KEYWORDS: Optics, radio frequency, TSPI, hazard footprint, miss distance, scoring, trajectory, imaging.

AF01-258 TITLE: Conformal Scene Generation Display System

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a scene generation capability for total weapons system integration testing within an installed systems test facility.

DESCRIPTION: Installed System Test Facility (ISTF) testing involves stimulating a full-up weapons system (i.e., an F-22 or Joint Strike Fighter aircraft with munitions and aircrew) with a realistic electromagnetic or weather environment. In order to accomplish operationally realistic Human-in-the-Loop total weapons system testing in an ISTF facility there is a need to develop a scene generation capability that will interface with the actual system under test and not interfere (physically or electromagnetically) with the simulated environment. Current Human-in-the-Loop simulators use either cathode ray tube (CRT) or liquid crystal display (LCD) projection techniques, either by emitting light onto a screen from the front, backside, or through a monitor device; or through virtual reality head mounted displays. These existing techniques are not suitable for ISTF total weapons system testing. Projection techniques require large support infrastructures and electronics that interfere with the simulated environments, and head mounted displays cause problems for the air crew and usually are not operationally realistic. Newer LCD technologies are introducing flat panel monitors to the commercial market, but these monitors are limited in size and shape. A material that can conform to a curvilinear shape (such as an aircraft canopy) while supporting computer controlled LCD emissions that would provide visual projection over a controllable geometry while maintaining a non-intrusive environment is needed. The technical challenges are to advance LCD or a similar technology from small flat panels to large conformable materials and to advance software algorithms to address the variable geometry of this material on a pixel level such that correct spatial and color rendering occur. Additionally, the new display material and supporting infrastructure must not interfere with an electromagnetic or weather environment created within an ISTF; therefore, metallic or any RF reflective material is not acceptable.

PHASE I: Identify an innovative scene generation concept that will satisfy the requirements of this project. In addition, a plan is required to address a plausible approach, schedule, and cost breakdown for identified components. An interactive, spatially correct visual rendering demonstration of a small (desktop) size curved LCD panel, which is controlled by a computer, also is desired. This interactive (fly mode) demo would present a side-by-side comparison of the curved LCD rendering and a standard monitor rendering using typical 3D visual simulation terrain data and models.

PHASE II: The end product for this phase will be an interactive, spatially correct, visual rendering demonstration of a full-size curved LCD canopy, such as an F-15 canopy shape, controlled by a real time computer. The canopy and supporting resources must not interfere with or reflect RF emissions. As a minimum, the projected environment will cover at least 2 Pi steradian coverage at a radius agreeable with human effects requirements established at the US Air Force Research Laboratory, Mesa, AZ. The range of this radius is approximately 0.5 to 5 meters. The final product will also include a technical report, including trade-off evaluations of material, parallel computers, geometry coverage and radius optimization contrast and brightness.

PHASE III DUAL USE APPLICATIONS: If this technology develops, it is anticipated that other military training applications such as vehicle operation, ordnance disposal, fire control, part task trainers, and commercial applications in interactive training simulators (such as emergency rehearsals, driving, sports, and entertainment simulators) will evolve.

REFERENCES:
1. "Polymer diodes," Physics World, June 1999.
2. "Electroluminescence in conjugated polymers," Nature, January 1999

KEYWORDS: Visual, LCD, curvilinear, displays, pixel, spatial, light emitting plastics (LEPs)

AF01-259 TITLE: Automated Surface Mapping and 3-D Model Generation

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a system for automated generation of 3-D models of aircraft and stores.

DESCRIPTION: A system is needed to allow the creation of 3-D, solid body models to support current and projected fit check analysis of aircraft and associated equipment. The need to measure and model physical items is critical when accurate documentation and configurations are either out of date or unavailable. These models are required to replicate existing physical items accurately and in detail. Current measurement systems require extensive operator involvement in the areas of setup and teardown, measurement collection, and data manipulation to create 3-D solid body models. The desired system would automate this process through non-contact collection of the surface coordinates of the 3-D physical item and the direct conversion of this data into a 3-D, solid body model in standard file formats such as IGES, STEP, CATIA, or UNIGRAPHICS. The minimization of post data collection manipulation is a requirement. This system is also required to be portable and capable of rapid calibration for use in both indoor and outdoor environments.

PHASE I: Develop a conceptual design for a non-contact measurement system to provide rapid and accurate generation of digital 3-D models. Desired model tolerances are to be within plus or minus ¼ inch. Estimated system costs should be identified.

PHASE II: The Phase II effort would finalize the design and develop and test the most viable measurement/model generation system. The end product would be a system requiring minimal system operator re-working of generated models.

PHASE III DUAL USE APPLICATIONS: There are numerous applications for automated measurement/model generation systems. Applications include measurement of manufacturing fixtures and production assemblies, reverse engineering of prototypes, facility modeling, product development, and mould making.

REFERENCES:
1. WWW.3DSCANNERS.COM, Demonstrated commercial application of automated surface mapping.
2. Moring, I.; Heikkinen, T,; Myllyla, R,; Kilpela, A. "ACQUISITION OF THREE-DIMENSIONAL IMAGE BY A SCANNING LASER RANGE FINDER," Aug 89 (DTIC AD:ADD329629) Unclassified.
3. Advisory Group for Aerospace Research and Development Neuilly-Sur-Seine (France). "3-D Surface Anthropometry: Review of Technologies, " Dec 97 (DTIC AD:ADA339120) Unclassified.
4. National Technical Information Service. "Dimensional Measurement by Laser Beam. 1975-November 1985," Nov 85 (DTIC AD:ADD80174) Unclassified.

KEYWORDS: measurement, models, modeling, scanning, three dimensional, reverse engineering, computer aided design, CAD, computer aided manufacturing, CAM.

AF01-262 TITLE: Integrated Communications Module for Global Positioning System (GPS) Simulations

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a module to generate data link signals compatible with current Global Positioning System (GPS) navigation and signal interference simulators.

DESCRIPTION: GPS receivers are used extensively for precise timing as well as determining positions. In battlefield operations, timing is critical for synchronizing maneuvers to ensure all operations are conducted as planned. Air and ground assets communicate information to each other, and to a field controller, concerning where they are and what is happening. However, several different communication links are used in this process. The objective of this project is to develop a module that can be configured to simulate the various communication data link signals including Link 16, the Joint Tactical Information Distribution System (JTIDS), Joint Precision Approach and Landing System (JPALS), and Local Area Augmentation System (LAAS). In addition, the design must incorporate the capability to generate interference to the signals and corruption of the data themselves.

PHASE I: Develop a feasibility concept for a communications module that is capable of generating the data link signals that are used in field operations. This module must be able to be reconfigured to simulate the different types of data links currently in use, as well as be upgraded to support those that are in development for future use. In addition, this module must have the capability to be connected directly with satellite simulator equipment, as well as GPS receivers, in order to work with laboratory simulations and testing in the field using live transmissions. The module must also have features to handle local control at the unit and remote control through a standard interface (e.g., GPIB protocol).

PHASE II: Design and demonstrate a prototype Integrated Communications Module based upon the Phase I work.

PHASE III DUAL USE APPLICATIONS: Potential users (in addition to the Air Armament Center's Navigation Test & Evaluation Laboratory) of this communications module within the military will probably include the Air Force Research Laboratory (AFRL), Space Warfare (SPAWAR) Systems Center, and the Electronic Proving Grounds. In addition, commercial manufactures of GPS receivers and communications equipment will also want access to this communications module for various applications

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. 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.
3. Gateway TADIL-J Host Simulator (TJHS) http://gateway.nosc.mil/tadilj.html, 1 Sep 1998.

KEYWORDS: Global Positioning System, GPS, Joint Tactical Information Distribution System, JTIDS, Joint Precision Approach Landing System, JPALS, Local Area Augmentation System, LAAS, battlefield communications, battlefield operations.

AF01-263 TITLE: Rapid Assessment System for Flutter Configurations and Ejection Loads

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a store/weapon software system for rapid assessment of flutter and ejection loads.

DESCRIPTION: Aircraft/store-weapon compatibility requires rapid flutter clearance and ejection loads of massive numbers of different store/weapon combinations for designated aircraft. This requires intensive engineering effort, computer resources, and long computing time. In the time when the military responds to world regional crises, this task becomes an urgent one where flight clearance solutions must result within a short time frame. Current systems use the extended doublet lattice method (DLM) to account for selection of the large quantities of critical cases. Although computationally efficient, the current system needs further improvement in solution accuracy, algorithm robustness, modeling fidelity, extended flight regimes, computing speed, and more effective solution methodology to achieve a rapid selection procedure of the critical flutter cases, and limit cycle oscillations (LCO). Innovative approaches are sought to improve the current system in rapid selection of flutter/ejection loads in the subsonic/transonic/supersonic flight regimes and the current flutter and aeroelastic instability solution methodology, while achieving both solution accuracy and algorithm robustness, with increased computing efficiency. As a result, such an improved system should effectively identify all possible linear and nonlinear critical flutter cases thereby substantially reducing the number of flight test cases and test costs. The proposed system must be capable of analyzing and processing approximately 2000 flutter configurations in a two-week period.

PHASE I: Develop a conceptual design and formulate an efficient and comprehensive screening software system with an improved flutter solution methodology. Perform a feasibility analysis to demonstrate the capability of the formulated system in an effective, massive, flutter screening procedure, while maintaining solution accuracy and computation efficiency. The end product should be a detailed report of the feasibility analysis describing the flutter software capability, the massive flutter screening procedure, and the prioritization of the resultant flutter loads. The preliminary software source code must also be delivered. Estimated system costs should be included.

PHASE II: The Phase II effort will finalize the design and fully develop the comprehensive screening software (and a compatible computing environment) with a user-friendly Graphical User Interface (GUI) and rapid flutter-mode tracking capability. The developed system must be fully validated by various massive flutter solutions with all available test cases. The end product will be a system developed to provide a cost efficient, robust assessment procedure for rapid screening of various linear and nonlinear critical flutter cases according to different aircraft-store configurations. In addition, the system should include the capability of providing store-released scheduling for minimum ejection dynamic loads.

PHASE III DUAL USE APPLICATIONS: The developed system could be used in aircraft design/analysis with or without stores/nacelles for multidisciplinary design optimization (MDO) or for flutter/dynamic aeroelastic instability analysis. Potential air vehicles for application include military, commercial, general-aviation aircraft, unmanned vehicles including missiles, UAV/UCAV's, and trans-atmospheric vehicles (TAV). Potential customers include DoD and aerospace/defense industry in the private sector.

REFERENCES:

1. "Subsonic Unsteady Aerodynamics for General Configurations: Part I, Vol. I - Direct Application of the Nonplanar Doublet-Lattice Method; Part I, Vol. II - Computer Program H7WC," AFFDL-TR-71-5, November 1971.
2. "An Automated Procedure for Computing Flutter Eigenvalues," Robert N. Desmarais and Robert M. Bennett, Journal of Aircraft, Vol. 11, No. 2, February 1974, pp. 75-80.
3. "Limit Cycle Oscillation Prediction Using Artificial Neural Networks," Charles M. Denegri, Jr. and Michael R. Johnson, CEAS International Forum on Aeroelasticity and Structural Dynamics, Williamsburg, VA, June 1999.

KEYWORDS: Aircraft/store compatibility, flutter clearance, improved flutter solution methodology, flutter mode tracking, massive critical flutter screening, limit cycle oscillation (LCO), ejection loads scheduling, efficient software system, user-friendly computing environment.

AF01-267 TITLE: Robust Affordable Flight Termination (RAFT) System

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Research and develop robust affordable flight termination (RAFT) system for improving use of radio frequency spectrum.

DESCRIPTION: Research and develop a new flight termination system (FTS) with the following features: The new FTS must make better use of the radio frequency spectrum and minimize unintended/failed terminations reducing unintended/failed terminations, increasing security and positive control of high altitude endurance (HAE) unmanned air vehicles (UAVs). The airborne segment must be airworthy, lightweight, low power, and low cost. The new FTS must be capable of commanding multiple UAVs (threshold 8, objective 16) in large-footprint/extended-range environments. The new FTS must be capable of operation without interfering with current FTS systems. The numbers and types of (UAVs) are growing dramatically. Future UAVs will span a large performance/cost envelope. High-altitude endurance UAVs will perform reconnaissance, surveillance, radio-relay, and navigation missions. Unmanned combat air-vehicles (UCAVs) will provide performance capabilities unmatched by manned fighters. Access to space (ATS) vehicles will be used for autonomous launch, orbital insertion, and crew return. Recent successes by DoD and NASA, coupled with technological advances, will drive further exploitation of UAVs. Range Safety Officers are tasked with the enormous responsibility of minimizing risks to the general public while managing increased UAV traffic. Flight termination systems (FTS) provide Range Safety Officers with a crucial resource in maintaining positive control over the UAV's. However, limitations of the current analog tone-based systems have resulted in increased risk of unintended termination and loss of FTS link (by receiver capture). The innovation should address the major technological shortfalls of the current analog tone-based signaling technique. The main thrust of the innovation should aim at finding a better modulation method; one that improves utilization of the radio frequency spectrum and minimizes unintended flight termination and receiver capture by trusted sources (other FTS ground stations). The proposal should demonstrate the researcher's knowledge of the end-to-end flight termination link, which includes both airborne and ground segments. The proposal should also address the reusability issue for current FTS ground stations.

PHASE I: Conduct a feasibility analysis and prepare a recommended system design. Submit a final report covering analysis results, findings, and recommendations.

PHASE II: Build/integrate a proof of concept system and demonstrate its operation. Submit a final report covering results, findings, and recommendations.

PHASE III DUAL USE APPLICATIONS: Remote command/control of unmanned test vehicles in automobile, railroad, farming, communications and boating industries. Potential commercialization also exists in the remote detonation/handling of explosives and toxic chemicals.

REFERENCES:

1. RCC Standard 319-99, Flight Termination Systems Commonality Standard (RSG) AD-A255349
2. RCC Standard 313-94, Design, Performance, and Test Standards for Flight Termination Receivers/Decoders, Volume 2, Test Standards (RSG) AD-277263

KEYWORDS: flight termination system, FTS, unmanned air vehicle, UAV

AF01-268 TITLE: Air Toxic Chemical Monitoring During Open Burn/Open Detonation

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop remote sensing technologies to measure and monitor toxic chemicals released as air pollutants during open-burn/open-detonation events.

DESCRIPTION: Weapon system testing at Edwards AFB, California, includes the use of a Precision Impact Range for ordnance and targeting systems testing. As a result of these activities, hazardous waste propellants, munitions, and pyrotechnics (PEP) are generated. In addition, Air Force Research Laboratory/Propulsion Directorate research activities at Edwards AFB generate waste PEP. The current disposal process for PEP is open burn/open detonation (OB/OD). However, because of the significant environmental impacts caused by OB/OD operations, Edwards AFB is required to obtain a Resource Conservation and Recovery Act (RCRA) Part B subpart X permit modification to its existing Part B permit for hazardous waste operations.One of the key requirements of the RCRA Part B permit modification will be to accomplish monitoring of toxic chemical air pollution releases from OB/OD events. Examples of toxic chemicals of concern are, but not limited to, benzene, benzo(a)pyrene, formaldehyde, and tetrachlorodibenzo-p-dioxins. The typical concentration levels for these chemicals are in the range of gram per liter (g/l) to microgram per liter (ìg/l). During an OB/OD event, a plume is released from the OB/OD source. Over time, the plume will disperse along the prevailing wind direction and deposit toxic chemical air pollutants into the biosphere (air, land, water, etc.). The traditional method used to monitor toxic chemical deposition is to place multiple ground-level air samplers along the plume dispersion axis. However, plume direction can be highly variable and changeable due to meteorological conditions. Therefore a large number of samplers are required to ensure that plume deposition is adequately sampled. The requirement of this SBIR project is to develop remote sensing technologies to measure and monitor toxic chemicals released as air pollutants during OB/OD events and negate the need for multiple sampling points. The proposed technologies should be able to quantify target chemicals at concentration ranges of g/l to ìg/l. The proposed technologies should be able to quantify target chemicals through direct line-of-sight measurement of an OB/OD plume, and in all three dimensions (plume length, width, and height). The proposed technologies should be portable and self-powered such that a single individual can use and operate in a field environment.

PHASE I: Research and develop a proposed system design to achieve project goals.

PHASE II: Build the proposed system and demonstrate at Edwards AFB, California, during an OB/OD event.

PHASE III DUAL USE APPLICATIONS: Technologies developed to accomplish this work can be applied to all DoD activities associated with OB/OD, and other DoD activities that produce toxic air pollutants that require monitoring for regulatory requirements. Technologies developed to accomplish this work can also be applied by commercial industries whose activities produce toxic air pollutants that require monitoring for regulatory requirements.

REFERENCES:
None

KEYWORDS: Remote Sensing, Toxic Air Pollutants, Open Burn, Open Detonation, Sampling.

AF01-271 TITLE: Advanced Data Link Simulator (ADLS)

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Research/develop a programmable real time Advanced Data Link Simulators (ADLS) for testing interactive data link communications /networks in a realistic environment.

DESCRIPTION: The trend in military and civilian avionics is ever increasing use of data links and networked systems. Testing these systems is currently accomplished with actual transceiver equipment which has limited availability, high cost, requires excessive integration into the simulation, limited evolution, and no growth to other links. An ADLS is needed to provide this growth through easily programmable waveforms, spread spectrum techniques, protocols, networking methods, and message sets for new or developmental links. The signals can be emulated but nothing accomplishes that function. Innovative and creative approaches - hardware, software, or both - are needed to define the mechanism to easily program and produce the signals. Approaches are desired to be scalable or modular to ultimately provide an environment of multiple links simulating data exchange and information flow through networks and across links for a system under test. This signal programming and generation capability satisfies several DOD Technology Areas such as Information Systems Technology and Electronic Warfare, but primarily Sensors, Electronics and Battlespace Environment. It has applicability to lab, anechoic facility, or range evaluations of systems and the links themselves. This applied research will develop the requirements, architecture concepts, design, and prototype of an ADLS. Signal density, data and information coherency (signals produced by the ADLS must be consistent in time, space, and informational content from each of the players), multiple links, multiple types of links, system simulations, behaviors, and interfaces to existing simulators shall be considered.

PHASE I: Review current and planned data links (military and civilian) to define requirements and architecture concepts, for the ADLS signal programming and generation capability. The selected approach must provide waveform, protocol, and network structure programmability for multiple links. Diagnostics should be included to assess performance of the link and components. The ADLS must also be capable of interfacing with other simulators for radar, EW, CNI, and IFF for integrated tests and may draw on their attributes. The architecture and supporting design will address the issues of signal programmability and density. The final product will be a report identifying alternative architectures, design information, and cost and technical tradeoffs associated with candidate implementations. It shall also include a recommended development approach with implementation plan including cost estimates, and risk mitigations.

PHASE II: Implement the architecture selected and develop a prototype system for installation and demonstration. Tests will be conducted in an anechoic chamber, and in the open-air to evaluate performance capabilities. The demonstrations will address: waveform, signal, and network programmability as well as signal generation and transmission. Signal density, data and information coherency, data correlation with a real-time scenario, and operation with other radar, EW, CNI, and IFF simulators will be considered. A final report covering all pertinent events and activities will be provided.

PHASE III DUAL USE APPLICATIONS: This will be a new product that has as its potential customer every advanced avionics laboratory, avionics system integration lab, and installed system test facility. The system developed by this effort could also be used in the design, development, and evaluation of commercial communication networks for industry customers.

REFERENCES:

1. http://www.dtic.mil/jcs/j6/education/warfare.html
2. http://www.rtca.org
3. http://www.arinc.com
4. http://www.icao.org

KEYWORDS: communications networks, data links, CNI, free-space, coherency, correlation

AF01-272 TITLE: Data Display Description Conversions to eXtensible Markup Language (XML)

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Research and develop translators to convert data displays between vendor specific formats and XML.

DESCRIPTION: Display of data is a generic requirement for test and evaluation (T&E) of aircraft and space systems. The use of graphical displays (such as line graphs, scrolling line graphs, x-y plots, bar charts, and text boxes, etc.) is a normal part of real-time monitoring and post-test analysis. These data displays can be relatively complicated with a variety of graphics components and hundreds of linked measurands. For example, one part of a display screen may be a scrolling line graph that displays test aircraft altitude and airspeed using different scales (e.g., feet for altitude, feet/second for airspeed), in different colors. Many of these displays are hand-tailored to specific program's, test's, or engineer's requirements. Users of T&E data systems have identified the ability to transport data displays across proprietary and government-developed display software as a requirement for support of these activities.Commercial and government-developed data display software packages have their own 'meta-file' language, binary or human-readable, that is used to describe and store data displays internally (e.g., DataViews, BBN Probe, SBS DataXpress, etc.). Whenever users require transfer of a display from one system to another, displays are recreated manually by an experienced data display programmer. This process can take weeks or months, causing unnecessary delay in test programs and undesirable costs. An automatic process could be built to satisfy this requirement without delays and at a greatly reduced lifecycle cost. This unsatisfied requirement becomes very high priority for joint service programs, like the Joint Air-to-Surface Standoff Missile (JASSM) and Joint Strike Fighter (JSF), where common data displays are required for flight testing, regardless of testing location or data acquisition and display system.Standard approaches for solving such data transfer problems are known and in use. For example, telemetered and recorded data formats, and the methods needed to process them can be generically described by a standard set of attributes (e.g. IRIG 106-98, Chapter 9, Telemetry Attributes Standard). Conversion programs exist which translate these attributes into and out of specific, customized databases and other file formats. A language to generically describe data displays and their processing should also be possible. In fact, such a language is emerging in the form of XML. [1,2]. Any markup language (such as HTML) is fundamentally a language for describing the display of information. The XML can be considered an extension of HTML that targets the transfer and display of data. It is also a flexible extension since it allows self-definition of markup tags. Thus, XML provides an infrastructure for developing a universal data display description language. Such a universal language does not exist while many disparate, proprietary languages are in use. The risk in this project is that there may be no standard description hierarchy that does not require unduly convoluted mappings of display objects from existing languages to the standard. That is, developing a standard that is easily mapped to one existing language may inherently make the mapping into another language extremely complicated.

PHASE I: Research existing data display languages and develop a universal description language to be implemented in XML. Any existing proprietary display languages may require agreements or contracts with various companies. A detailed draft of the description language should be provided. Mappings between existing data description languages and the developed extension to XML should be provided in enough detail to demonstrate that the mappings exist and are not unduly complicated. An initial software design of the translators should also be provided.

PHASE II: Develop core translation software that will allow the addition of new formats through the reuse of core modules. The delivered prototype software should be used to demonstrate that the developed data description language unambiguously implements all necessary display objects. This should be done by converting data displays currently used at AFFTC between disparate platforms via the XML extension.

PHASE III DUAL USE APPLICATIONS: The XML is a growing standard already in used by industry and academia. There exists a host of software to support XML [1]. For example, there are a variety of translators available for converting data between database engines (e.g., ORACLE, MS Access) and XML. The XML is the expected successor to HTML. This means that support software for XML will be at the heart of internet activity. The additional ability to convert data displays into XML will find a ready market amongst a variety of scientists and analysts.

REFERENCES:
[1] For a general overview of XML (This includes a software list):http://www.oasis-open.org/cover/xml.html - overview/
[2] The main website for the group developing the XML standards: http://www.w3.org/TR

KEYWORDS: Data Acquisition System Interoperability, Interoperability Standards, Commonality of Operation, Data Display, XML, Format Conversion, Language Theory

AF01-273 TITLE: Integrated Anechoic Chamber Simulation

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Research and develop an integrated simulation capability to accurately predict the electromagnetic environment in an anechoic chamber.

DESCRIPTION: Integrated testing of electronic systems involves generating a complex electromagnetic (EM) environment in an anechoic chamber into which one or more test articles are placed. The perturbation of the EM field due to the presence of the test articles in close proximity to one another can reduce the accuracy of the test results. Current anechoic chamber simulation capability accurately computes the radiated field of many types of antennas, estimates the reflectively of some radio frequency absorber geometries, and provides limited calculations of the effects of scattering from a single test article. A more accurate and detailed EM simulation of anechoic chambers is required to enhance user confidence, to reduce pre-test set-up time and to speed EM environment verification of integrated electronic testing. This shall require the integration of present simulation capability with other EM modeling techniques (such as finite element, finite difference, and ray tracing techniques). The integrated simulation capability should produce accurate simulation of the EM scattering from test assets, and other electrically large equipment in the chamber, and provide details of the scattering mechanisms (such as locations of major scattering centers).   In addition, the integrated simulation should allow the user the ability to describe the effect of any object (size, location, orientation, and material) on the EM environment. The output of the simulation should be detailed enough to compute and display complex EM field accurately anywhere in the chamber and to compute statistical bounds on the field for determination of test configuration and anechoic chamber performance.

PHASE I: Research and define methods and procedures required to provide accurate computation of the EM field in an anechoic chamber. This shall include the identification of third party software (EM and mechanical CAD software), and a description of the manner in which these capabilities can be seamlessly integrated with capabilities. Also, due to the computationally intensive nature of the tasks associated with the simulation, explore the possibility of multiprocessor and/or distributed computing. Develop a simulation requirement document, and show how the proposed plan meets these requirements.

PHASE II: Implement essential features of the proposed approach, and demonstrate the operation of an integrated EM simulation capability. Verify simulation results with measurements of the electromagnetic environment in an anechoic chamber.

PHASE III DUAL USE APPLICATIONS: Fully implement and integrate all components of the anechoic simulation capability. Explore the possibilities of extending the simulation capability to other military and commercial applications, and implement where possible.Issues associated with electromagnetic compatibility (EMC) and electromagnetic interference (EMI) are major concerns in the health, transportation and consumer electronics industries. Testing of electronic emissions and susceptibility are now required for all new products. Accurate anechoic chamber and test facility simulation capability would greatly reduce costs associated with certification testing.

REFERENCES:
Reference to Anechoic Chamber Modeling, NEC-BSC Manual, Electromagnetic Scattering Codes: http://imperator.cip-iw1.uni-bremen.de/~fg01/codes2.html and BAC-SIM Final Report

KEYWORDS: avionic systems, plane wave, free space, anechoic chamber, radar testing, scanned array, radio frequency absorber, electromagnetic scattering

AF01-274 TITLE: Wide Band Radio Frequency (RF) Infiltration Detection/Tracker (WAVES)

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Research and develop an ultra wide band system for radio frequency spectrum monitoring.

DESCRIPTION: This effort will address concept exploration and advanced development of a system for identifying, locating, and racking spectrum activity. This system will be used to monitor spectrum activity for background use, unauthorized use, channel utilization, emergency use, and unused or open frequencies. This data will be used to determine if these transmissions affect authorized test area transmissions to avoid possible interference to government and civil systems. The proposed system will have specialized software to alert spectrum managers in real time of potential interference or conflicting scenarios based upon daily schedules in near real time. The software would be capable of learning the signature of signals. A database of past scheduling, current daily schedule and all authorized users and frequencies in the area will be provided to the system. The proposed system needs to compare the database with current use and identify unauthorized use and potential interference scenarios using intelligent computation and processing. Inputs to the system will be from an integrated database of authorized users and range schedules including authorized past, present, and future usage. The system will detect unauthorized users and authorized users who are not in their allotted RF spectrum/time slot. System reports will include: the frequency and the RF spectrum used, the geographic location using precision direction finding from multiple sensors in the geographic area of potential interference, and times of transmission. With the current and ongoing reallocation of spectrum the amount of RF spectrum for use in testing has decreased and the chances of interference from other users has increased dramatically. The transition of spectrum from government to civilian use has an extremely high potential to cause interference to flight test operations and civilian systems. In the future, an increasisng number of users will be accessing the same frequencies (government and civil) on multiple test ranges in close geographical areas. With this increased use within a smaller RF spectrum, a need has developed for an increase in monitoring of the usable RF spectrum and the detection of unauthorized users. Authorized users should remain in the RF spectrum authorized and time allotted for transmission. The information shall enable test engineers and spectrum managers to make near real-time decisions on when and where to perform test missions. This will minimize DoD and civilian conflicts, and ease tensions associated with the reallocation of the spectrum. The approach should be innovative. It is acceptable to use a state of the art receiver and innovate with algorithms that accomplish the goals.

PHASE I: Research and analyze development methods, propose a system design and make a recommendation. Submit a final report covering the analysis results, the design and recommended approach. Include feasibility and cost analysis.

PHASE II: Develop and demonstrate prototype system.

PHASE III DUAL USE APPLICATIONS: Potential commercial applications include airport monitoring, commercial communication systems monitoring, civilian FDMA radio systems, search and rescue.

REFERENCES:

None

KEYWORDS: RF, RF Spectrum, RF Communications, RF detection, Spectrum Allocation, RF tracking, automated RF monitoring

AF01-275 TITLE: Real-Time Monitoring of Turbine Engine Data

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop an advanced real-time model-based software that can be “economically” deployed to reduce the time, cost and risk of aircraft propulsion test development, and improve data quality.

DESCRIPTION: Recent advances in computer hardware and algorithmic advances in model-based computer techniques are making possible a new generation of health monitoring, data validation, and diagnostic systems for aircraft propulsion research, development, test, and evaluation. The current effort would use a combination of existing technologies, innovation, and creativity to meeting technical goals that necessarily include development of “economically deployable” model-based computer techniques to (a) calibrate a generic computer model (such as a compressible fluid flow system) in real- or near-real time using available test instrumentation and (b) enable real- or near-real-time health monitoring, data validation, and system diagnostics. Implementation of the proposed technologies, methodology, and associated software must also enable (1) real-time validation of engine gas path and test facility measurements including facility fuel flow, airflow, and thrust measurements, (2) real-time calibration of non-linear aerothermodynamic engine models for diagnostics, and (3) real-time monitoring of critical engine and test facility components. Significant flexibility will be allowed in formulating an economically deployable approach.

PHASE I: Develop and demonstrate the concept software to accomplish the following: (1) real-time validation of engine gas path, fuel flow, airflow, and thrust measurements, (2) real-time calibration of non-linear aerothermodynamic engine models for diagnostics, and (3) real-time monitoring of critical engine and test facility components.

PHASE II: Develop and demonstrate prototype model-based software system that will calibrate a generic computer model (such as a compressible fluid flow system) in real- or near-real time using available test instrumentation and enable real- or near-real-time health monitoring, data validation, and system diagnostics. The prototype system should be capable of calibrating a generic model to within +/- 1% of truth, validating test data to within the stated uncertainty, and detecting changes in component performance on the order of 1%.

PHASE III DUAL USE APPLICATIONS: These technologies have commercial potential in DoD, NASA, and commercial research, development, and production test facilities. Follow-on work will mature key technologies and expand potential propulsion applications to include test facility component data validation and diagnostics and flight test and production test facilities (logistics centers). In addition, critical technologies necessary to expand the applicability of this technology to aircraft and space ground test, flight test, and production transportation systems will also be developed.

REFERENCES:
(1) Bickmore, T.W., Real-Time Sensor Data Validation, NASA CR-195295, March 1994
(2) Bickford, R. L., T. W. Bickmore, C.M. Meyer, J.F., Zakrajsek, Real-Time Sensor Data Validation for Space Shuttle Main Engine Telemetry Monitoring, AIAA 99-2531, 35th Join Propulsion Conf, L.A. Calif., 1999.
(3) Bickford, R.L., T.W. Bickmore, C.M. Meyer, J.F., Zakrajsek, "Real-Time Flight Data Validation for Rocket Engines", AIAA 96-2827, 32nd Joint Propulsion Conference, Lake Buena Vista, Florida 1996.

KEYWORDS: Turbine engine, test techniques, data validation, condition based monitoring.

AF01-277 TITLE: On-Board Model Data Acquisition Systems to Operate in a Wind Tunnel Environment

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a prototype model with an on-board integral instrumentation system, which allows for both conventional and advanced MicroElectroMechanical Systems (MEMS).

DESCRIPTION: A number of non-intrusive, optically based measurement techniques are being developed for wind tunnel applications. The state of maturity of these techniques requires a known reference to be measured within the field of view of the instrument. To avoid the costly installation of conventional instrumentation to provide the necessary reference data, a suite of inexpensive, easily installed sensors that can be remotely interrogated is required. The goal is to develop and demonstrate advanced sensors capable of measuring pressure and temperature data on the surface of a model mounted in a wind tunnel, and transmitting the result to the facility computer. The integration of MicroElectroMechanical Systems (MEMS), integrated circuit design, and wireless communication technologies is anticipated.The pressure sensors should be capable of measuring steady-state pressures in the range from approximately 200 psf to 4000 psf with an uncertainty of ± 3 psf. The temperature sensors should be capable of measuring temperatures from approximately 40 °F to 140 °F with an uncertainty of ±1 °F. The thickness of the sensors should not exceed the criteria for roughness height that can trip a laminar boundary layer. For conditions typical of a conventional wind tunnel, the thickness should not exceed 0.004-in. The sensors will be required to operate within the metal shell of a the wind tunnel in an environment that contains electrical interference; therefore, the analog signals from the sensors should be digitized prior to transmission to the facility computer to minimize the effect of background noise. The sensors should be capable of operating independent of each other or in groups, and the output from any particular sensor should be easily identified.

PHASE I: Conduct a feasibility demonstration of a on-board integral instrumentation and data acquisition system for pressure and temperature sensors. The demonstration will address those critical elements and the basic components of the technologies to meet the operational and measurement requirements described. Demonstrate the most reliable and beneficial instrumentation technologies that will provide a significant reduction in model installation cycle time, utilizing standardized, quick-disconnect interfaces and on-board data acquisition and conversion electronics packages.

PHASE II: Developed and demonstrated a prototype of the data acquisition on-board integral instrumentation data acquisition system which will handle a minimum of 24 pressure sensors and 24 temperature sensors. The new data acquisition and sensor system will be validated by performing measurements on a wind tunnel test and comparing the results from conventional wind tunnel instrumentation.

PHASE III DUAL USE APPLICATIONS: Numerous commercial applications exist for a stand alone sensor and data acquisition system that is inexpensive, can be easily installed, and can be remotely interrogated. Examples include the flight testing of aircraft, health monitoring of mobile as well as stationary equipment, and troubleshooting large, complex mechanical systems.

REFERENCES:
1. Mehregury, Mehran; DeAnna, Russell G.; Reshotko, Eli "Microelectromechanical Systems for Aerodynamic Applications", NASA-E-10417, ADA314332.
2. Bult, K.; Burstein, A.; Chang, D.; Dong, M.; M.; Fielding, M. "A Distributed, Wireless MEMS Technology for Condition Based Maintenance", ADP010211.
3. Hosom, David S. "Feasibility of Wireless Data Transmission on Ships", ADA334163.

KEYWORDS: Sensors, Standardized Instrumentation, Data Acquisition, Microelectromechanical systems (MEMS), Wireless Data Transmission, Pressure and Temperature Sensors, Measurement, Wind Tunnels.

AF01-278 TITLE: Advanced Hyperspectral Imager and Analysis System

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop and demonstrate a fully functional multi-color infrared focal plane array and associated hyperspectral analysis tools.

DESCRIPTION: Develop a multi-wavelength focal plane array (FPA) imager system or hyper-spectral imager from the shortwave to longwave infrared (SWIR to LWIR) that would allow for optical signatures measurements over at least two spectral regions of interest with the same imager head and data system. This would create multiple registered images and reduce the number of instruments and optics needed to characterize a signature. Innovative concepts leading to advanced capabilities in the area of hyperspectral imagery data analysis are solicited. The evolution of sensors suitable for hyperspectral imaging applications from x-ray wavelengths through the infrared continues to advance at a rapid pace. Unfortunately, traditional approaches to data reduction and analysis, such as static in-band imagery and plots of spatially integrated in-band energy over time, are inadequate for effective human interpretation of results. Specific problem areas are the huge volume and high dimensionality of data generated by these sensors, which provide spatially (in two dimensions), temporally, and spectrally resolved intensity data.The proposed solution must provide analysis tools and presentation techniques that enable human operators to effectively assimilate these data sets. Spectral and spatial analysis tools, (e.g., radial and axial spectral characterization of the near-field of rocket plumes, image ratioing, …) as well as error analysis and calibration capability must be provided, in addition to the ability to integrate both sensor and ancillary data into a structured database. The package must be flexible such that it can be applied and used with diverse data sets, including imaging x-ray spectrometer data, multi-spectral UV imagery, hyperspectral IR imagery.

PHASE I: Demonstrate on a limited scale the ability to produce a focal plane array working over the desired bandpasses (SWIR to LWIR). Define a set of innovative data analysis and presentation tools for hyperspectral data sets. Demonstrate the critical components of the system.

PHASE II: Demonstrate the prototype dual-wavelength IR imaging system and a comprehensive set of analysis tools.

PHASE III DUAL USE APPLICATIONS: Commercial applications in all aspects of infrared imagery such as maintenance, condition, and control monitoring, surveillance, nondestructive testing, law enforcement, and public safety. Military uses of hyperspectral imaging include concealed target detection, materials properties analysis, counter-proliferation and counter-terrorist operations. Commercial applications include medical imaging, radiation therapy (or other areas where x-ray dose as a function of spatial location and time is desired), exploration for petroleum and minerals, land-use quantification, crop surveys, law enforcement, and pollution and environmental monitoring.

REFERENCES:
1) Dual-wavelength response in double-barrier quantum well infrared photodetectors; Osotchan, T.; Zhang, DaoHua; Shi, W.; (Nanyang Technological Univ.)Publication: Proc. SPIE Vol. 3896.
2) LWIR/MWIR imaging hyperspectral sensor for airborne and ground-based remote sensing; Hackwell, John A.; Warren, David W.; Bongiovi, Robert P.; Hansel, Steven J.; Hayhurst, Thomas L.; Mabry, Dan J.; Sivjee, M

KEYWORDS: signatures, hyper-spectral, imaging, focal plane array, surveillance, image enhancement.

AF01-279 TITLE: Computational Aero-Optic Simulation System Development

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a computational simulation to prediction the aero-optic performance of DoD aero-optical systems.

DESCRIPTION: Aero-optic phenomena affect the performance of a wide range of optical systems. These include actively cooled IR seekers, optical systems mounted in aircraft, as well as ground-based sensors viewing through atmospheric turbulence. AEDC is currently improving on a capability to test the performance of these systems in the presence of atmospheric phenomenon such as supersonic flow, atmospheric turbulence and cooling gasses. A complementary aero-optic computational simulation capability is needed to completely evaluate the system optical performance. For complicated flow fields, and aero-optic computation is typically performed by first computing the flow field with a computational fluid mechanics (CFD) code and then using those results to estimate statistical parameters for use in calculating the optical performance of a beam propagated through the flow field. Most models used to date are anchored primarily with classical shear layer data without much of the physics present in a typical seeker flow field.

PHASE I: Demonstration the feasibility of critical components. A review of the existing techniques for aero-optic predictions and highlighting any deficiencies of the methods as well as the salient parameters required (i.e. Strelh ratio, blur, boresight error, etc.) to measure aero-optic performance of IR seeker systems need to be addressed. Identify the aerodynamic and physical system properties (i.e. window curvature) needed to assess the overall aero-optic performance. Coupling to a stand-alone CFD package is acceptable since this would allow the use of several existing commercial & government CFD packages. Identified a set of improvements necessary for improving the prediction accuracy.

PHASE II: Demonstrate the computational simulation ability to predict aero-optic performance in the presence of complex flow fields. The computational simulation should be fast and accurate aero-optic system that is capable of addressing many different types of DoD aero-optic problems (including those mentioned above). The software should be capable of running on typical High Performance Computing platform with a Unix workstation as a user interface Coupling to a stand-alone CFD package is acceptable since this would allow the use of several existing commercial & government CFD packages. The predictions will be validated against available test data in the Mach range of 2.0 to 10.1.

PHASE III DUAL USE APPLICATIONS: An aero-optic computational simulation system has applications in many governmental and commercial areas. Phase III activities could include refining this system and marketing it to the developers of advanced seekers as well as commercial companies needing prediction of aero-optic performance in such areas as point-to-point optical communications and ground based telescope image improvement.

REFERENCES:
1. Clark, R. et al. "Fundamentals of Aero-optical Phenomena" AIAA-94-2545 18th AIAA Ground Testing Conference, June 1994.
2. Chew, L. "Coherent Structure Effects on Shear Layer Optics" AIAA 90-0185 28th Aerospace Sciences Meeting.

3. Fivel, H.J., C.A. Hinrichs, "Effect of Turbulent Boundary Layer Flow on Optical Transmission", AIAA-83-1524, AIAA 18th Thermophysics Conference.

KEYWORDS: Aero-optics, seeker performance, shear layers, CFD, turbulence

AF01-280 TITLE: Real-time Corrections to Multiple Channel Response Functions for Time-Correlating Transient Data

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop methodology to adjust in real-time phase between data channels resulting from differing processing and filtering in test data.

DESCRIPTION: Develop methodology to adjust in real-time phase between data channels resulting from differing processing and filtering. The methodology is needed to provide proper time correlation between data channels, e.g., force, moment, temperature, and pressure data time correlated with roll or pitch sensor output. Wind tunnel data acquisition cycle time is currently limited by the requirement to time-correlate transient data signals from various sensors, including electrical, pneumatic, and mechanical. A methodology is needed to provide either appropriate time scale corrections to multi-channel data streams or equivalent processing for simultaneous data from different sources.

PHASE I: Demonstrate the ability of the critical components of the system to time correlate to within 10% of the sample interval.

PHASE II: Demonstration the prototype system ability to time correlate to within 2% of the sample interval (e.g., 1 millisec for a sample rate of 100 samples/sec).

PHASE III DUAL USE APPLICATIONS: Applications of the technology include test environments such as automotive, wind tunnel, engine-stand devices, flight test systems (essentially all transient data systems requiring real-time correlation of multiple data channels).

REFERENCES:
1) Allen H. McCoy, Flight Testing and Real-Time System Identification Analysis of a UH-60A Black Hawk Helicopter with an Instrumented External Sling Load, NASA CR-1998-196710, June 1998.
2) Robert W. Moses and Gautam H. Shah, "Spatial Characteristics of F/A-18 Vertical Tail Buffet Pressures Measured in Flight," 39th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Long Beach, California, AIAA 98-1956, April 20-23, 1998.
3) Joey White, "Using Dataflow Architecture to Solve The Transport Lag Problem When Interfacing With An Engineering Model Flight Computer In A Telemetry Simulation" Proceedings of the International Telemetering Conference, Las Vegas, NV, Nov. 4-7, 1991.

KEYWORDS: Real-Time Data Systems, Time Correlation, Data Processing

AF01-281 TITLE: Solar Panel Designed for ESD Protection

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop a Electrostatic Discharge Immune High Power/Voltage Solar Array.

DESCRIPTION: The development of high power, high voltage solar arrays for spacecraft has increased the risk of damage by electrostatic discharge (ESD) mechanisms. Examples already exist of recently launched 10 kW+ spacecraft which have experienced solar array damage in their first year of operation. While recent analysis coupled with space and ground-based experiments has produced further insight into the problem, unresolved issues continue to exist. To date investigations on high voltage solar arrays indicate that ESD triggered arcs that induce sustained/long-duration sequential plasma arcs lead to permanent array damage. The purpose of this solicitation is to initiate an objective analysis to understand and evaluate this potential ESD power degradation phenomenon (as applied specifically to geosynscronous satellites) and to design/demonstrate an "ESD Free" prototype solar array. As a first step, an innovative investigation needs to define the high voltage solar panel array design characteristics/materials that are vulnerable to environmentally stimulated ESD triggered discharge arcs. This would be followed by evaluating new design features based on modeling/experimentation, where by damaging effects (electrical performance degradation from [literature documented] resultant plasma arc discharges) would be mitigated by innovative design/materials changes. Solar panel and/or high voltage solar cell circuits from 70 to 130 volts should be investigated.

PHASE I: Investigate design features/elements of high voltage solar array panels for ESD mitigation. Suggested areas for investigation include (but are not limited to) solar cell type, cover-glass type/conductivity, solar cell size/separation, dielectric materials/adhesive chemistry, circuit termination geometry, feed-throughs on the substrate front and backside, diode board configuration, substrate material type/edge effects, and grounding schemes. 2) Based upon investigation results, produce a preliminary high voltage solar cell array design impervious to ESD-induced failure. First order designs should be substantiated by a space charge analyzer program, e.g. , the NASA Charging Analyzer Program (NASCAP) or a similar field effect spacecraft charging analyzer program.

PHASE II: 1) Based upon Phase I results, fabricate selected high voltage solar cell coupon/panel designs. Evaluate the candidate designs (and the prototype array at a later date) in an ESD facility, capable of simulating the space charging environment of a satellite in geosynchronous orbit. Evaluate the design enhancements, for ESD mitigation/control against a set of controlled and unmodified coupon/panel designs. A second set of evaluations may be necessary to verify both the sensitivity to the design variations and the modifications made toward more optimized designs. 2) Based upon the results in (1) a high voltage solar panel array design matrix is to be established with effectiveness ratings. Favorable designs shall be fabricated to demonstrate, establish, and validate resistance to environmentally induced ESD effects.

PHASE III DUAL USE APPLICATIONS: The solar array advances made in this project can be directly applied to all high voltage/ high power geosynschronous DoD, commercial and civilian communications spacecraft.

REFERENCES:

1. Crofton, M.W., Francis, R.W., "Electrostatic Discharge Measurements on Solar Cell Coupons in a Simulated GEO Environment," IECEC Paper 1999-01-2634, 1999.
2. Hoeber, C.F., Katz, I., Davis, V.A., and Snyder, D.B., "Solar Array Augmented Electrostatic Discharge in GEO," AIAA Paper 98-1401, 1998.
3. Herron, B.G., Bayless, J.R., and Worden, J.D., "High Voltage Solar Array Technology," J. Spacecraft and Rockets, Vol. 10, No. 7, 1973, pp. 457-462.
4. Thiemann, H., and Bogus, K., "Anomalous Current Collection and Arcing of Solar-Cell Modules in a simulated high-Density Low-Earth-Orbit Plasma," ESA Journal, Vol. 10, No. 1, 1986, pp. 43-57.
5. Hastings, D.E., Cho, M., and Kuninaka, H., "Arcing Rates for High Voltage Solar Arrays: Theory, Experiment, and Predictions," J. Spacecraft and Rockets, Vol. 29, No. 4, 1992, pp. 538-554.

KEYWORDS: Electrostatic Discharge (ESD), Solar Panels, Solar Arrays, High Voltage, High Power, Arcs, Plasma, Geosynchronous

AF01-282 TITLE: Validation and Numerical Testing of Turbine Augmentors Combustion Computational Modeling

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop and validate numerical simulation methodology for turbine engine augmentor combustion modeling.

DESCRIPTION: Turbine augmentor testing at all power levels is a necessary yet expensive and technically challenging component of military jet engine development programs. Due to strong coupling of the augmentor flow with upstream (turbine) and downstream (nozzle) flows, and the need to control the combustion dynamics at all altitudes and Mach numbers in the flight envelope, augmentors cannot be tested in isolation, and require full engine testing. The complex phenomena of rumble, screech, and longitudinal and tangential acoustic modes leads to performance degradation.Numerical modeling and prediction of the augmentor performance is highly desirable. Such numerical modeling capability would ideally include the following augmentor flow physics: high swirl rate turbulent inflow with profile, spray droplet injection and combustion, interaction of film cooling and core flow, ignition and flame stability, and transonic flow. For accurate predictions applicable to real engine hardware, augmentor geometry representation must integrate complex cooling hole patterns, circular-to-square duct transition, and variable nozzle jet area. The code would preferably include complex geometry capability through close coupling of CAD and grid generators to the flow solver using unstructured grids and an unstructured, scalable database. The code must also include aerodynamics and combustion features necessary for augmentor flow models. Development of the augmentor code will require experience in benchmark experimental measurement and validation, and experience in related computational development, modifications, and application of combustion codes and experience in the application of CFD to gas turbine combustors and augmentors.The benefits to the Air Force include: 1) rapid augmentor performance prediction, 2) diagnostic tool for analyzing combustion and flow physics phenomena.

PHASE I: Research the methodology to predict unsteady combustion instabilities and conduct a feasibility study to develop a new code (or modify an existing code) for augmentor combustion simulation. Develop and demonstrate a new computer code which represents the augmentor flow field of a military engine (i.e. F100, F110, F119).

PHASE II: Demonstrate the critical components of the computational augmentor simulation package using actual augmentor geometries. Design an experimental test matrix to generate critical data to anchor numerical models for augmentor aerodynamics and combustion modeling development and validation. Perform benchmark measurements to facilitate and advance the development of the numerical algorithms.Phase III: Develop post-processing approaches for direct comparison of test stand measurements such as thrust, combustion efficiency, pollutant emissions, and overall engine pressure ratio with the predictions. Integrate the numerical simulation methodology into an augmentor test process to support advanced augmentor development.

PHASE III DUAL USE APPLICATIONS: The augmentor combustion code will be applicable for both commercial as well as military applications. The code will be useful in the gas turbine engine industry, combustion applications in power generation and automotive industries that is as a test bed for computing pollutant emissions in local airports.

REFERENCES:
1) Brankovic, A. Ryder, R.C., Syed, S.A., "Mixing and combustion modeling for gas turbine combustors using unstructured CFD technology," AIAA Paper 98-3854, 1998.
2) Ebrahimi, H.B., "Validation Database for Propulsion Computational Fluid Dynamics," Journal of Spacecraft and Rockets, Vol. 34, Sept.-Oct. 1997, pp. 642-650.
3) Munir M. Sindir and E. Douglas Lynch., "Overview of the State-of-the-practice of computational Fluid Dynamics in Advanced Propulsion System Design", AIAA 97-2124 July 2, 1997.
4) Richard T.C. Harman, "Gas Turbine Engineering" John Wiley & Sonsn N.Y N.Y 1984.5) Jack D. Mattingly, "Element of Gas Turbine Propulsion" October 1999 Mcgraw-hill.

KEYWORDS: Gas Turbine Engines, Augmentor, CFD, Combustion, Turbulence, Modeling, Unstructured Grid

AF01-285 TITLE: Enterprise-wide Strategic Planning and Management System

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a web-based capability to facilitate data collection across an enterprise (one to many depots, industry, and academia) for Strategic Planning, Program Planning, requirements collaboration, data collection, tracking, analysis, and control.

DESCRIPTION: Strategic Planning and managing large programs remains much more of an art than a science. The difficulty is magnified over an enterprise wide group due to geographics, the increased number of view points, and the ease of access. Formulating a correct set of goals is encumbered because of the difficulty in formulating a set of goals and objectives to program requirements. Another problem is that goals are not properly translated into a measureable set of objectives having a well defined set of metrics that can be tracked and used to control program requirements. Neither are objectives evaluated and justified by assessing their impact on the problems or opportunities the program was formulated to address. The data collection infrastructure needs to be addressed as well for establishing ease of access with hand held devices and utilization of wireless technology.Therefore, a requirement exists for the development of a web-based wireless data collection enterprise wide capability. The resulting application will collect, prioritize, coordinate among multiple views/users, manage, and analyze the enterprise wide planning information. The challenges for an enterprise wireless web based collection tool are the following:1) User Interface: Applications must be simple and be able to accomplish specific tasks quickly and easily using input devices like voice commands, microbrowsers, and open standards such as extensible Markup Language (XML).2) Performance and Portability: Applications deployed on wireless devices must be compact and efficient without compromising performance with limitations of power, memory, disk size, screen size, and mobility.3) Process Connectivity: Application should provide framework for push and pull data collection, be accessible at any time and from any device.4) Security: Provide for data encryption, ensure data integrity, privacy, authentication and denial-of-service protection.

PHASE I: Research the four technology challenges above and formulate a high level design concept.

PHASE II: Develop a pilot implemenation of the design concept formulated in Phase I that will demonstrate an enterprise wide data collection and hand held wireless access that address all of the four technical areas address above.

PHASE III DUAL USE APPLICATIONS: IDE software tool providers such as Structural Dynamics Research Corporation (SDRC) are very interested in the potential use of this SBIR development for applying it as a front end to their own requirements gathering group ware product.

REFERENCES:
The Air Force Instruction 37-102, "Strategic Management Planning, Implementation, and Control Guidance and Procedures". SDRC suite of tools descriptions may be found at www.sdrc.com.

KEYWORDS: Strategic Planning, Enterprise Planning, Management Planning, Wireless Networking

AF01-286 TITLE: Mid-Infrared Laser Development for Environmental Monitoring Systems

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop mid-infrared semiconductor lasers and laser systems for in situ and 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 3 to 10 microns. For example, toluene and phenol have strong absorption lines near 6.7 microns. It is important to demonstrate that the proposed semiconductor lasers have sufficient tunability to scan across absorption bands of these and other molecules. Individual lasers that can measure multiple molecules are desired for designing versatile environmental monitoring 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

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 chemcial system capable of detecting, identifying, quantifying, and warning personnel of the presence of chemical weapons.

REFERENCES:
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3. P. J. McCann, K. Namjou, and I-Na Chao, "Using Mid-IR Lasers in Semiconductor Manufacturing", MICRO 71, 93 (1999). (www.micromagazine.com/archive/99/07/mccann.html)

KEYWORDS: Mid-Infrared Lasers, Molecular Spectroscopy, Environmental Monitoring

AF01-287 TITLE: Fuel Additives For Improved Turbine Engine Performance Under Extremely Cold Temperatures

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop fuel additives that enhance the operation and ground starting capabilities of aircraft engines.

DESCRIPTION: Engine starting at extremes of cold ambient and fuel temperatures as well as engine relight at high altitudes are of concern for both military and commercial aircraft operators. Particularly for military applications, reliable engine start is vital for time critical operations in the battlefield. The conversion to JP-8 from JP-4 from JP-4 compromises the ability of older engines to start reliably at low temperatures due mainly to the lower volatility and higher viscosity of JP-8. These properties impact both fuel spray droplet size and fuel-air mixing at startup resulting in unburned fuel exiting the engine, high smoke exhaust and consequent aborted starts in cold climates. The B-52, for example, is one aircraft that has been experiencing enormous difficulties starting reliably at temperatures below -20°F. At temperatures below 32°F, the TF-33 engines in the B-52 produce torching (flames exhausting through the engine nozzle) due to the inefficient atomization, mixing and burning of JP-8. Fuel system hardware modifications have provided moderate improvement, however, further work is needed for reliable engine startup and operation at temperatures as low as -40°F. JP-8 has been optimized based on performance, cost and availability, and contains additives that address fuel lubricity, fuel static discharge, prevention of water in fuel from freezing, and thermal stability to reduce engine fouling. A fuel additive that can enhance the cold start capability and operation of older and future aircraft is needed to ensure reliable cold ground start and high altitude relight. The fuel additive should be non-toxic, stable and compatible with aircraft fuel system materials. Also, the additive should be such that when added to JP-8 the resultant fuel is within JP-8 fuel military specifications. The Air Force can provide JP-8 fuel as Government Furnished Property (GFP) if necessary.

PHASE I: Identify additives that when added to JP-8 (at ppm levels) will improve fuel atomization, reduce fuel droplet size and enhance fuel-air mixing at temperatures down to -40°F to enhance engine startup reliability and increase relight envelope.

PHASE II: Continue development of fuel additives and assess the performance of the most promising additives in a prototype combustor at conditions of interest to the Air Force. Perform additive stability and material compatibility studies. Quantify the performance and operational payoffs for both military and commercial applications, and conduct a cost benefit assessment to determine affordability.

PHASE III DUAL USE APPLICATIONS: This technology could be used in a broad range of military and civilian applications such as: a) improving the starting reliability at low temperatures of jet fuel operated aircraft and ground-based turbine engines, and b) as an ignition enhancer for diesel engines operating in extremely cold climates. Technology will ensure reliable engine start for time critical operations, reduce sooty emissions due to aborted engine starts and may improve engine overall efficiency (i.e., cleaner emissions) of engines operating at low temperatures.

REFERENCES:
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3. Karpovich, P.A., Masters, A.I., "Fuel Effects on the TF30 Engine," Journal of Engineering for Gas Turbines and Power, Vol. 107, n. 3, July 1985.

KEYWORDS: Fuel Additives, low temperature ignition, JP-8 ignition, high altitude relight, ignition enhancers, subfreezing fuel properties.

AF01-290 TITLE: Tube Hydroforming Simulation

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: To model and simulate tube hydroforming process, and then optimize process variables by using closed-loop control schemes.

DESCRIPTION: Tube hydroforming is a relatively old metal forming process which has come back to industry with many new applications. The key to its new usage in metal forming industry is the availability and rapid increase in popularity of closed-loop control techniques using microprocessors. Many structural components which are traditionally manufactured by stamping and joining operations, have potential to be replaced hydroformed tubes. The most significant advantage of this process over conventional stamping is a marked design flexibility offered by this process. Such flexibility results in considerable weight savings and part quality improvement, as demonstrated in the initial applications of this process in auto industry. The weight saving advantage achieved by this process becomes even more important for airborne products. Because of its very development there is not a knowledge base available for this process. Most of the current data is generated by auto industry on hydroforming of tubes made by welded steel sheet. The real advantage of tube hydroforming, in both design flexibility and weight savings, surfaces when extruded aluminum tubes are used, for which very little data is available. Material and process parameters such as formability of aluminum alloy (affected by extrusion parameters and heat treatment), initial cross sectional geometry of the tube, location of extrusion welds, internal pressure profile, and axial (end) feed profile are important factors that affect the quality of the part and the manufacturing cycle time. In current applications these parameters are selected by trial and error for each part geometry, a very inefficient technique. A systematic analysis of this process, and development of closed-loop control of the process parameters are needed. In aircraft industry the number of each manufactured component is relatively small, and therefore the advantage of a closed-loop controlled process over trial and error method may be even more significant.

PHASE I: Develop a proof of concept analytical model of tube hydroforming. Such process model will be used later during the development of control models. Also develop a computer simulation of the process for simple geometry and process parameters.

PHASE II: The concept simulation in phase I will further be developed for complex geometries and tools. Also, a tube hydroforming apparatus will be constructed. The formability of selected aluminum alloys under this forming condition will be established. Then, closed-loop control of some of the key process parameters such as internal pressure and axial feed will be performed. The simulation results will be verified by testing.

PHASE III DUAL USE APPLICATIONS: The potential for this application is very high in the commercial manufacturing industry. Aerospace manufacturing firms to smaller manufacturing shops that specialize in tube manufacturing would benefit from this developed application.

REFERENCES:
1. Process Control for Hydroforming of Aluminum Extrusions, S. Prasoody, S.A. Majlessi, G. Subhash, J. Pilling and M. Ahmetoglu, Proceedings of the Int. Conference on Hydroforming Technology, Detroit, Michigan, June 2000.
2. Hydroforming of BIW Structural Parts and Exhaust Components, M. Schroeder, Hydroforming of Tubes, Extrusions and Sheet Metal, Ed. Klaus Siegert, 1999, pp. 335-351.
3. Hydroforming of Structural Parts for Personal Cars, C. J. Bruggemann, Hydroforming of Tubes, Extrusions and Sheet Metal, Ed. Klaus Siegert, 1999, pp. 353-371.

KEYWORDS: Tube Hydroforming, Simulation, Metal Forming.

AF01-291 TITLE: Three-dimensional real-time Visualization of Air Quality Modeling Data

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Develop a three dimensional real-time visualization method to analyze and interpret air quality data.

DESCRIPTION: Use of three dimensional visualization has been adapted since the early 1990's to environmental restoration activities. Recent emphasis on environmental air quality and long range transport of pollutants has generated a need for adaptation of this technology for air quality data analysis purposes.

PHASE I: Demonstrate proof of concept. Incorporate data for up to ten major air emission sources. Develop a promising application for three-dimensional visualization of real time data output from an EPA-endorsed air dispersion model that will allow the user to perform predictive air emission / dispersion modeling of future air emission chemical concentrations.

PHASE II: Develop and optimize the real time application for use in a CAVE (Computer Aided Visualization Environment) or related technology. Investigate the use and enhancement of the technology for other Air Force applications.

PHASE III DUAL USE APPLICATIONS: With the increasing pressure for industry to monitor its environmental impacts, the commercial market for three-dimensional visualization of real time emission / dispersion data output is tremendous. This technology will be useful for other military applications including illustrating complex air data for users and regulating agencies, predicting air emission levels potentially associated with expected workload increases, and characterizing atmospheric dispersion of hazardous chemical releases into the environment.

REFERENCES:
1. N. I. Durlach and A. Mavor, Virtual Reality: Scientific and Technological Challenges, National Academy of Science Press, Washington, D.C., pp. 35-36, 1995.
2. C. Cruz-Neira, D. J. Sandin, and T. A. Defanti, "Surround-screen projection based virtual reality: The design and implementation of the CAVE, "Comp. Graph., vol. 27, pp. 135-142, 1993.
3. Executive Order 13111, Using Technology to improve training opportunities for Federal Government Employees, signed 12 Jan 99.
4. S. K. Isabelle, R. H. Gilkey, R. V. Kenyon, G. Valentino, J. M. Flach, C. H. Spenny, and T. R. Anderson, "Defense applications of the CAVEä (CAVE Automatic Virtual Environment)", The University of Illinois at Chicago Department of Electrical Engineering and Computer Science, http://www.eecs.uic.edu/~kenyon/GILKY/CAVE DOD.html

KEYWORDS: Virtual environment, Computer Aided Visualization Environment (CAVE), Real time Air Quality monitoring

AF01-292 TITLE: Trichlorcethylene Treatment via In-Situ Microbial and Chemical Oxidation Technologies

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a cost effective reliable process for degrading Perchloroethylene (PCE) Trichloroethylene (TCE), and all toxic daughter products.

DESCRIPTION: Anaerobic dehalogenation and chemical oxidation processes have been utilized for the remediation of dilute PCE/TCE plumes but the optimal approach varies due to site specific variables. The project proposes that a combination of anaerobic dehalogenation followed by aerobic biodegradation can be used for the complete remediation of PCE/TCE. It has also recently been shown that chemical oxidation of TCE with potassium permanganate can be an effective remedial approach. Thus, there are a variety of in-situ approaches and combinations thereof that have high potential for remediating dilute TCE plumes. The question is which process will work the best at any given site. The focus of this proposal is to identify an optimal process for remediating dissolved TCE from the groundwater. The approaches that will be evaluated include (1) anaerobic dehalogenation alone, (2) anaerobic dehalogenation followed by anaerobic biodegradation, (3) anaerobic dehalogenation followed by chemical oxidation, (4) and chemical oxidation only.

PHASE I: Demonstrate proof of concept. Select a promising application using an effective combination of technologies, and perform a preliminary investigation to determine optimum 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 reliable process for degrading PCE / TCE, and all toxic daughter products, from subsurface soil and groundwater structures.

PHASE III DUAL USE APPLICATIONS: With the increasing pressure for governmental agencies to minimize its environmental impact, the commercial market for technologies that will clean up contaminated subsurface soil and groundwater structures is tremendous. Military applications will extend DOD wide.

REFERENCES:
1. Sims, J. L.., J. M. Suflita, and H. H. Russell, Reductive Dehalogenation: A subsurface bioremediation Process, Remediation, Volume 1, Winter 90/91, pp. 75-93, 1991.
2. Townsend, G. T., and J. M. Suflita, Influence of Sulfur Oxyanions on Reductive Dehalogenation Activities in Desulfomonile tiedjei, Appl. Environ. Microbiol., 63:3594-3599, 1997.
3. Nelson, C. H. and C. S. Barker, Treatment of TCE-impacted groundwater using in situ chemical oxidation, The fifth international In Situ and On-site Bioremediation Symposium, Volume 5(2), pp 199-204, 1999.

KEYWORDS: Anaerobic dehalogenation, chemical oxidation, perchloroethylene / trichlorethylene remediation, PCE / TCE remediation.

AF01-294 TITLE: Functional and Diagnostic Analysis of Circuits using Laser or Electron Beam Scanning Technology

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Develop hardware and software methods for analyzing component defects using laser or electron beam technology.

DESCRIPTION: Focus on using laser and electron beam technology for testing and diagnosing failures in printed circuit board components. Optical technologies using lasers with a short wavelength and/or electron beam is maturing, thus providing a wide variety of methods to approach a test and diagnosis of printed circuit boards. Laser and electron beam components to fabricate unique applications are vast and widely available. To optimize the usage of these technologies will require new computer aided tools and new testing methods. A laser or electron beam can scan circuits, and a functional or diagnostic analysis can be performed by analyzing the scanned image. New software allows the stacking of multiple images for multi-dimensional surface analysis. Software analysis tests can be structured to a specific set of tests depending on circuit complexity. Employing these test methods can significantly enhance test and diagnosis of complex circuitry and furnish an excellent method to determine aging problems. A 3-Dimensional display measurement system is preferable so dynamically controlled motion is favored. A transparent view of the circuit structure is expected and approaches to developing software methods for test and diagnosis can be creative. The technology can improve the understanding of circuit failures and provide answers as to how and why circuits fail. Circuit weaknesses can be perceived, so design problems can be corrected and previously unknown circuit deficiencies plotted. This topic shall focus on using laser or electron beam technology hardware and software methods to test printed circuit board components for defects.

PHASE I: Conduct research and development and determine feasibility of focusing on innovative hardware and software methods to analyze component defects using Laser or electron beam Technology.

PHASE II: Create a detailed design and develop a working prototype.

PHASE III DUAL USE APPLICATIONS: This new technology is particularly relevant to aircraft and plant maintenance, industrial process control, medical, and other applications where system performance is critical and repair should be precise and quick.

REFERENCES:
None

KEYWORDS: Test & Diagnosis Electron Beam Laser Technology Hardware and Software

AF01-296 TITLE: Tracking Current Flow through Units Under Test (UUT)

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop and implement methods for analyzing current flow deviations in units under test.

DESCRIPTION: Develop a creative ability to monitor current readings from Power Supplies and other instruments during testing, and then make a UUT defective part determination based on that current flow needs to be developed. Excessive currents drawn by UUTs diminish reliability and contribute to aircraft aging problems. Current drawn by avionics hardware is critical to aircraft flight safety since aging components can fail arbitrarily and contribute to other aircraft hardware failures. Sensors in a Power Source can accurately and repeatedly monitor the current draw of a UUT and various instruments in Automatic Test Equipment (ATE) can monitor current. The current drawn by a UUT under-going test can be plotted against time. A defective component in a circuit can cause a change in the current drawn from a power supply or other instruments by a UUT. This change in current can be plotted with good verses bad boards. Concise repeatable test results have plagued the ATE testing world since its conception. Using quality power source's, internal sensor, or an instrument's internal sensor for UUT current can provide concise repeatable results. These results can be used to accurately diagnose UUT faults. As a circuit is tested, the current drawn can vary as different functions are invoked by the test. The current draw can be plotted against time, showing a characteristic trace for the test performed. Sensors in the ATE power source can be used to monitor the current flow during test execution. Deviations from the trace of a "good" card can be identified, and the fault causing the deviation can be identified. Software routines with associated hardware functions need to be developed to use current draw deviations to determine UUT functionality and reliability, and perform UUT diagnostics.

PHASE I: Conduct research and development and determine feasibility of focusing on software methods to analyze current draw and hardware settings to perform testing.

PHASE II: Develop a prototype design that will create and demonstrate the objectives of the topic description.

PHASE III DUAL USE APPLICATIONS: The new technology from this project is applicable to a wide variety of applications and processes. It is particularly relevant to aircraft and plant maintenance, industrial process control, medical, and other applications where large numbers of diverse signals are monitored, and overall system performance is characterized through the interpretation of the combination of signals, in addition to the discrete interpretation of individual signals.

REFERENCES:
Kirkland, L.V., "Monitoring Power Supply Current and using a Neural Network to determine UUT Functionality", AUTOTESTCON 94' Anaheim, California, 21-24 September, 1994.

KEYWORDS: Automatic Test Equipment Neural Networks Current draw Fuzzy Logic Sensors Genetic Algorithms

AF01-297 TITLE: Remote Support via Multi-Terabit Networks

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Facilitate remote testing of equipment through a high-speed network.

DESCRIPTION: This topic seeks innovation in the development of test and support scenarios that can facilitate remote testing of equipment through a high-speed (terabit-level) network where ATE and UUT can be physically separated by thousands of miles. Test technology requires the use of automatic test equipment (ATE) that is geographically co-located with the unit under test (UUT) due to limitations in signal propagation and data exchange requirements. As new generation digital avionics become more prevalent, interface requirements become more suitable for direct connection to computers and the Internet. Likewise, as network centric operations become more prevalent throughout the DOD coincident with networking technology that supports tens to hundreds of Terabits data transfer, operating environments for remote test and diagnosis of aircraft avionics and other devices becomes more feasible. Current technology limits data transfer rates to a few megabits per second. This capability can provide unprecedented flexibility in operational support scenarios, enabling new mission and support capabilities.

PHASE I: Conduct research and development and determine feasibility of focusing on scenarios that can facilitate remote testing of equipment.

PHASE II: Create a detailed design and develop, implement and evaluate a working prototype.

PHASE III DUAL USE APPLICATIONS: The technology underlying this topic is quite generic, and is applicable to a wide variety of applications and technologies. It is particularly relevant to aircraft and plant maintenance, industrial process control, medical, and other applications where large numbers of diverse signals are monitored, and overall system performance is evaluated.

REFERENCES:
No references available.

KEYWORDS: Automatic Test Equipment Networks Sensors

AF01-298 TITLE: Imagery Manipulation for Simulator Database

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop tools to automatically remove time specific artifacts and create 3D cultural features from overhead imagery.

DESCRIPTION: This innovative software program will investigate technologies and develop a tool to, (starting with overhead imagery usable as source data for simulator database development and modification), automatically recognize objectionable time specific artifacts within the imagery, automatically remove these artifacts and replace them with appropriate non time specific data, and automatically generate accurate 3D cultural models based on the resulting modified imagery. Numerous numbers and types of image data covering simulated areas will be merged, orthorectified, and tone / color balanced. Objectionable time specific imagery artifacts such as aircraft parked on airport tarmacs, automobiles parked in parking lots, and all cast shadows will be automatically recognized, deleted from the image data, and replaced with appropriate information. This tool should allow for programmable options for how many and what types of artifacts should be considered, allowing for cases when it will be desirable for certain artifacts to be retained as they were collected in the source image. Resulting treated imagery will be saved in Tagged Imagery File Format (.tif) and in National Imagery Transmission Format, version 2.1 (NITF 2.1). Various 3D cultural items of potential value to later real-time simulations will be "tagged". Once the image data is cleared of objectionable artifacts, 3D cultural models of the previously identified and tagged items (such as buildings, clumps of trees, individual trees, etc.) will then be automatically generated directly above their location on the treated image. Height of the 3D models will be accurate based on information attainable from the image(s). All vertical sides of the resulting 3D models will be filled in with realistic data and saved in OpenFlight format (.flt). Resulting 3D models will posses accompanying information correctly positioning them on the resulting merged, orthorectified, and treated imagery. This technology will not be imagery format / media dependent or limited by camera / image collection hardware type. Automation of this capability will be maximized.

PHASE I: Conduct research and development and determine feasibility of developing a single tool to merge and orthorectify various numbers and types of images. Develop a capability to automatically recognize objectionable time specific image attributes and items of potential value to later simulations. Develop a capability to remove program tool selectable attributes and replace them with realistic and believable non time specific data. Develop a preliminary capability to generate 3D OpenFlight models of selectable items identified in the imagery and position them properly. Document the results. Deliver highly documented source code for the tools as developed at this level of completion.

PHASE II: Develop a prototype single robust automated tool and demonstrate the result using a variety of combinations of source imagery data. Document and deliver a detailed users manual in both hard copy and soft copy (Word document). Deliver highly documented source code for the completed tool.

PHASE III DUAL USE APPLICATIONS: This tool will benefit current and future military and civilian commercial programs that require extensive use imagery based simulator databases with a high degree of specific 3D cultural content. Results will provide a higher fidelity product with reduced resources.

REFERENCES:
None

KEYWORDS: 3D models Simulator databases time specific artifacts merge and ortho rectify notional database scenario generation tools

AF01-299 TITLE: <u>High Speed Digital Timing Sets and Pattern Generator</u>

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Conduct research and design software to automatically develop high-speed stimulus patterns and timing sets for LASAR software.

DESCRIPTION: Digital circuits are tested on Automatic Test Equipment using a LASAR generated software routine. Engineers develop the circuit model, stimulus patterns and timing sets then LASAR processes this information into a test routine. The engineering task required to figure out the timing set and proper pattern routine for a complex digital unit could be prodigious. 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. When subtle timing problems exist within a timing set, the guided probe and fault dictionary routines can and will identify good parts as bad. Even-though, the go/nogo path might be stable, a diagnostic routine, which is used to detect defective parts, can miss changes in the node state logic when a trigger or input timing sequence is slightly inexact. Software is needed to automatically develop high-speed timing sets and stimulus patterns for LASAR based on component primitives, circuit models, and I/O factors. The dynamic software package is needed to augment the engineer's skill and accomplish the proper fix to critical timing problems.

PHASE I: Conduct research and determine feasibility of focusing on developing one or more approaches that will demonstrate new technology to solve the objectives in the topic description.

PHASE II: Develop and demonstrate a software prototype of the approach(es) designed during Phase I.

PHASE III DUAL USE APPLICATIONS: Significant commercial markets exist for this technology in industrial process control and medical process applications. Aids 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.

REFERENCES:
Kirkland, L.V., "ATE Enabling Technologies", AUTOTESTCON 94' Anaheim, California, 21-24 September, 1994.

KEYWORDS: Automatic Test Equipment LASER V6Digital Circuit Testing

AF01-300 TITLE: <u>Long Term Non-Interrupted Power Device (LTNPD)</u>

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Provide battery-less and non-diesel power source to provide continuous power after commercial power is lost.

DESCRIPTION: There are increasing environmental and safety concerns on the combined use of batteries and diesel generators to provide power support for critical mission loads when commercial power fails. This project seeks an innovative method of providing "instantaneous" and extended "ride-through" power without the use of batteries or the need to start diesel generators. Inherent in the LTNPD goal is: (a) the switching from commercial to standby power so the power loss is transparent to the critical load, (b) provide sustained support for a minimum of one hour or longer before "refueling", (c) output harmonically correct power, require minimal environmental controls (A/C), (d) be unaffected by elevation, (e) be situated in either indoor or outdoor settings, (f) comply with Air Quality regulations, (g) operate at 75dB or less measured at 6 feet if installed indoors. Combinations of technologies to operate are acceptable and (h) provide 18 months warranty to unit after installation.

PHASE I: Conduct research and development and determine feasibility of a non-interrupted field functional power device with the following capabilities: (i) Provide for 37.5 KVA or greater power support, (ii) provide power for one hour without disturbance to critical load.

PHASE II: Turn prototype device into a deliverable unit for in-place testing and evaluation. Test prototype to determine mean time between failure (MTBF), and operational costs and abilities.

PHASE III DUAL USE APPLICATIONS: This device will have multiple benefits for military and industrial communities. Benefits include: potential drastic reduction in hazardous waste, potential improved Air Quality, improved quality of electrical power delivery.

REFERENCES:
None

KEYWORDS: Un-interruptible power supply Battery-less Diesel generator Ultra-capacitor Flywheel Turbine Micro-turbine Fuel Cell Battery

AF01-303 TITLE: Enhanced Digital Corrosion Detection System

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a device, for aircraft use, to detect and quantify corrosion.

DESCRIPTION: Field repair of corrosion is increasing as forces continue to age in service. However, corrosion inspection techniques have in general not kept pace with ever growing corrosion inspection and repair requirements. Field-level visual inspection is the first and earliest opportunity to catch corrosion before it adversely degrades the structure or component. But, visual identification of corrosion is usually difficult in internal aircraft locations due to poor lighting, constrained spaces, etc. Yet, current visual inspection systems lack adequate detail and resolution, and are very subjective at best. Corrosion could be much better identified if visual inspection could be digitally enhanced to improve resolution and inspection reliability. Current operational systems include borescopes and portable video inspection systems to identify corrosion. Furthermore, these visual inspection systems are not true detection tools, in that they only allow subjective visual inspection and provide no ability to actually detect corrosion nor quantify the result. Currently available miniaturized electronics along with developments in photonics and digital processing indicate that a portable enhanced visual inspection system or device could be developed to actually detect, and quantify aircraft corrosion during field-level inspection activities. In this regard, this topic is intended to support an acknowledged Air Mobility Command Technical Need (see related references below).The intent of the SBIR is to develop a digital visual imaging system that allows detection of corrosion. In this context, detection implies quantitative ability. On the other hand, current video-based visual corrosion inspection systems are not quantitative, but are at best qualitative, i.e., subjective. The viewer observes the condition of the structure being inspected and based upon subjective reasoning determines if corrosion is present. This technique is not objective, nor does it allow for observation, much less quantitative detection of corrosion hidden under paint and coatings. The enhanced detection system described by this topic will employ digital techniques to acquire images at very high resolution, hardware and software processors to evaluate the images and convert them to numerical data as in image analysis, and an intelligent image attribute database to quantify the results. The system may require lighting or lasers that operate with closed-loop control as in machine vision, etc. This technique should eliminate the user's subjectivity to result in absolute determination or detection of corrosion either on the surface or hidden below the surface finishes.

PHASE I: Assess feasibility and evaluate and test candidate concepts and technologies to identify the conceptual technologies to be applied to the non-invasive, digitally enhanced visual detection of corrosion. This entails the identification of electro-magnetic frequencies required, development of the evaluation algorithm, developing test standards, and the evaluation of the cost to produce a final working product. Phase I would be complete with the development of a conceptual prototype.

PHASE II: Refining the detection algorithms, testing the output against standards and evaluating the results in comparison with current techniques. The device will be field-tested for applicability and reliability.

PHASE III DUAL USE APPLICATIONS: The signal processing technologies along with the associated processing power have become practical for miniaturization and can now be applied to field use. The commercialization of an enhanced digital method to visually detect corrosion would benefit from an increasing market since this capability, in its general sense, is not only needed by other DoD services and governmental agencies, such as the FAA and NASA, but also by the commercial aviation industry and the airlines. There is a substantial potential for commercialization if this effort is successful due to the expanding governmental and commercial aerospace markets.

REFERENCES:

United States Air Force Air Mobility Command Technical Need "Improved Visual Corrosion Detection Tool".Typical commercially available imaging and/or image analysis systems that operate in purely subjective applications for inspection: www.olympus.com http://www.mediacy.com   Related references whose techniques may be applicable to the topic with respect to digitization of images, and intelligent digital archival and databases: www.microimages.com, http://www.npaci.edu/Thrusts/DI/index.html, http://ncmir.ucsd.edu/abstracts.html, http://google.yahoo.com/bin/query?p=%2bmicroscope%2bmicroscopy%2bmetallurgical%2bimaging&hc=0&hs=0

KEYWORDS: Corrosion, detection, visual, digital, enhanced, field-level

AF01-304 TITLE: Measurement of Residual Stresses in Difficult Locations

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop an x-ray diffraction system for measuring residual stresses in difficult locations.

DESCRIPTION: Residual stress states in aircraft structures and systems play an important role in structural integrity and affect life-cycle costs. In general terms, with regard to fatigue and stress corrosion crack initiation, compressive residual stresses are typically beneficial, while tensile residual stresses can severely degrade structural integrity and adversely affect safety and airworthiness. Most areas of concern to the Air Force are in cases of multi-site damage and widespread fatigue damage, are those where stress concentrations take place, such as through-thickness holes, blind holes, sharp corners and re-entrant corners. Therefore, to quantitatively determine the residual stress states in these difficult to access locations, a system designed intently for these difficult to access locations is required. In this sense, the required system is deemed to operate in a micro mode to allow the measurement of residual stress in micro or difficult to access locations such as hole walls, blind hole bottoms, reentrant corners, etc. This capability will resolve a void in technical capability and allow improved force-management actions since heretofore unknown but assumed conditions will now be quantifiable. Furthermore, this new quantification ability should decrease inspection and replacement costs since in the absence of quantifiable solutions, engineering solutions such as damage tolerance analysis and risk assessment must relay on overly conservative estimates which actually increase life-cycle and inspection and repair costs.

PHASE I: This technological maturity will be leveraged in Phase I to identify the conceptual efforts and technologies that are required to miniaturize the measurement systems and allow targeting the difficult area. Leveraging in this manner ensures a high degree of success and minimum risk. The phase one goal would be to assess the feasibility of micro measurement in difficult to access locations and evaluate candidate concepts and technologies. This entails the identification of miniaturized sources and detectors, miniaturized manipulation and control systems, and innovative data processing and analysis to account for the small surface areas and excitation volumes. The concept will be developed to full conceptual capability to include a conceptual prototype and cost analysis representing operational systems.

PHASE II: As a result of the Phase I effort, the design of the conceptual system shall be refined and validated. The miniaturized detector system design shall be refined and validated as well. The appropriate software and users interface shall b e interfaced and integrated with the system and detector design to complete the final design. An operational pre-production prototype shall be manufactured for demonstration of the capabilities. The prototype shall be fully tested and evaluated to demonstrate the ability to produce accurate and quantifiable residual stress measurements in the difficult to access locations. Manufacture of test specimens and standards to include various materials/alloys such as high strength aluminum, titanium, and steel, various thickness, various through thickness hole diameters, various blind hole geometries, reentrant corners, etc will be required as the basis for the demonstration of the abilities of the prototype system.

PHASE III DUAL USE APPLICATIONS: Several companies and contractors manufacture residual stress measurement systems or provide services with respect to residual stress management. This is evidence that an already strong commercialization base exists for residual stress management. Since this effort to introduce the opportunity to discern residual stress states quantitatively at discrete, hard to access locations, which is not currently available, an even larger market for proven commercialization will exist. Moreover, this capability is not only needed by other DoD services and governmental agencies, such as the FAA and NASA, but also by the commercial aviation industry, and the airlines. There is a substantial potential for commercialization if this effort is successful in developing viable technological improvements in many other applications that rely upon residual stress measurement, such as the automotive industry, heavy manufacturing, the oil and gas pipelines, etc.

REFERENCES:

"X-Ray Residual Stress Analysis - The Potential for Locating precursors to Component Failures," NTIAC Conference, San Antonio, Texas, April 1987.

"Assessment of Component Condition From X-Ray Diffraction Data Employing the Sin 2Æ Stress Measurement Techniques", ASM Conference on Residual Stress, Indianapolis, Indiana, May 1991.

KEYWORDS: Residual stress management, x-ray diffraction, difficult to access locations

AF01-305 TITLE: Smart Fuels Injection for the U-2

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop "smart" fuel injection through the development of "smart" nozzles and fuel "cocktails" to enhance the operation of air and space platforms.

DESCRIPTION: The future Air and Space Force will need a new generation of hydrocarbon fuels. Stringent operational requirements have been met in the past by using costly specialty fuels such as JP-7 (SR-71) or JP-TS (U-2). Regrettably, the cost of these specialty fuels is a factor of three higher than conventional JP-8 (military) or Jet-A (commercial) fuels and are not readily available. Furthermore, many contingency locations will also not have ready access to JP-8 fuel, but will have access to commercial jet fuels. Since the demands placed on the fuel will change as the fuel flows through the fuel system and into the combustor, the most efficient military and commercial fuels should have enhanced properties only when required. Such "smart" fuels will feature components which can be selectively "controlled" by temperature or shear, for example, to react in the fuel system service life, reduce aircraft, helicopter, UAV and support equipment time-phase interval inspections, and reduce detection susceptibility.Under the present program, innovative fuel additives (or an additive "cocktail" package) are sought 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. Additives should include reduced combustion times and pollutant emissions, enhanced low properties at sub-freezing temperatures, and enhanced cooling capacity. Advanced additive injection techniques such as "fizzy" tablets, pre-mixed additive balls, or heat (or shear) activated microcoatings of tablets could be explored.

PHASE I: Identify suitable additives or diagnostic concepts, demonstrate the feasibility of the technology, and quantify the payoffs for both military and commercial applications. A financial assessment to determine affordability must be considered.

PHASE II: Demonstrate the application of the technology, demonstrate a prototype of the technology, validate performance at true operating conditions, and refine payoff predictions for both military and commercial applications.

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).

REFERENCES:

Coordinating Research Council, "Handbook of Aviation Fuel Properties," CRC Report No. 530, 1983, pp 113, Society of Automotive Engineers, 400 Commonwealth Drive, Wattendale, PA 15096-001.

KEYWORDS: Smart fuels, smart nozzles, additive cocktials, fuel additives, emissions, sub-freezing properties.

AF01-306 TITLE: Helicopter Obstacle Guidance System

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop a helicopter Obstacle Guidance Warning System.

DESCRIPTION: The Air Force and Army annually experience fatal helicopter accidents from collision with towers, power lines, structures, and terrain. The problem is not limited to flying during poor visibility conditions of darkness, dust, or weather. Many fatal helicopter crashes occur during daylight operations. Current sensors do not provide adequate warning of obstacles nor guidance around the obstacles. Existing ground proximity warning systems designed to prevent crashes are effective only when used during flight along planned routes. Military helicopters typically do not follow normal flight routes or land at commercial airports. They fly low level, nap-of-the-earth missions. Modern terrain following radar capable of identifying obstacles are cost prohibitive at $ 300,000 or more apiece. A low cost obstacle warning sensor with a guidance capability is needed to lead pilots around obstacles. The sensor and guidance system is also needed to direct helicopters in and out of austere airfields and landing pads located in remote desert, mountain, and forested areas. Modern aircraft have sophisticated navigation sensors and guidance systems. The majority of the systems have reserve or growth capability. Recently developed millimeter wave and laser sensors are potential low cost, obstacle warning sensors. Integrating a new sensor into the existing navigation systems would result in an affordable obstacle warning and guidance system. A helicopter fitted with such a system would be able to avoid the towers, power lines, structures, and trees that contribute to the annual loss of valuable aircraft and lives.

PHASE I: Develop obstacle warning and guidance system concept and aircraft integration architecture. Compare the flight safety margins, cost, functionality, and utility of the proposed obstacle warning and guidance system with existing terrain following and avoidance radar and navigation systems.

PHASE II: Develop and demonstrate an obstacle warning and guidance system that operates in realistic desert, mountain, and forested environments.

PHASE III DUAL USE APPLICATIONS: Commercial tour helicopters and light aircraft operating in Hawaii and Arizona have recently experienced fatal crashes similar to the Air Force and Army helicopters. Crashes of small aircraft at remote Alaskan and South American airfields have also been reported in the newspapers. Although they have maintained an excellent safety record, police and rescue helicopters operating in urban areas are vulnerable to collisions with power lines and towers. There is not an off-the-shelf ground proximity warning system or radar system capable of meeting the flight characteristics or supporting the flight routes of tour helicopters, light aircraft, or police/rescue helicopters. The installation of a low cost, obstacle warning and guidance system would prevent commercial aircraft crashes and save lives by providing early warning of and guidance around unexpected and unseen towers, power lines, structures, and terrain.

REFERENCES:
Flight Test of 35GHz MMW Radar, Forward Sensor for Collision Avoidance, presented at the First World Aviation Congress, October 22-24, 1996, Los Angeles, CA by Richard E. Zelenka, NASA Ames Research Center, Moffet Field, CA and Larry D. Almsted, Honeywell Military Avionics, Minneapolis, MN.

KEYWORDS: Obstacle Warning, Terrain Following, Ground Prximity Warning, Terrain Avoidance, Nap-of-the-Earth

AF01-307 TITLE: <u>Compressed Natural Gas (CNG) Reformer to Supply Hydrogen to Fuel Cell</u>

TECHNOLOGY AREAS: Ground and Sea Vehicles

OBJECTIVE: Research and develop reformer to generate hydrogen from natural gas for flight line fuel-cell applications.

DESCRIPTION: Fuel-cell powered electric drives are the future for highly mobile, military aerospace ground equipment (AGE). Proton exchange membrane (PEM) fuel cells are the best way to provide efficient and environmentally safe mobile electrical energy for flight line applications. However, there is no infrastructure at US Air Force bases or forward deployed areas to supply the hydrogen needed for fuel cells. The final goal for military applications is a JP-8 reformer (thus using a fuel that is widely available world-wide); the CNG reformer provides a stepping-stone that helps to mature the technology needed. In addition, 38 US Air Force bases in the continental United States already have CNG supply systems in place. The environmental enhancements provided by fuel cells will ensure their use in a variety of applications at these bases in the future.This project will focus on developing a reformer that will supply the hydrogen to fuel a 30 kW PEM fuel cells (which requires approximately 5000 psi at 150 cubic feet per minute of hydrogen production). CNG supplied will come from a 150 cubic feet per minute commercial-type CNG station.

PHASE I: Research, develop and test a CNG reformer to provide hydrogen to the fuel cell as mentioned above.

PHASE II: Fully research and develop the CNG reformer and integrate it into and existing PEM fuel cell in a flight line environment. Reliability, maintainability, environmental impact and cost effectiveness shall be addressed/evaluated in this phase.

PHASE III DUAL USE APPLICATIONS: Successful application of a CNG reformer, coupled with fuel cells would have numerous potential commercial applications, including commercial flightline vehicles and support equipment that operate under various specifications for energy. This application will also accelerate the commercialization for fuel cell vehicles and generators (fixed and skid).

REFERENCES:
1. DoD Fuel Cell Demonstration Program - www.dodfuelcell.com
2. DARPA Mobile Electric Power Technology Thrust - www.darpa.mil/dso/thrust/md/ees 1c.htm

KEYWORDS: Fuel Cell Energy, Reformate, Fuel Cell Power, Vehicles, Equipment

AF01-308 TITLE: Detection of Hydrogen Embrittlement in High-Strength Steel Aircraft

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop a robust, reliable system for detection of hydrogen embrittlement effects in high-strength steel aircraft components.

DESCRIPTION: Reliable detection of hydrogen embrittlement effects in aircraft components and structures manufactured from high-strength steels is critical for Air Force aircraft readiness. Hydrogen ingress in some of the observed cases of hydrogen embrittlement in aircraft components results from cleaning, pickling, and plating processes. Furthermore, many of the environmentally mandated cleaning processes employ citric acid-based solutions, which when employed at elevated temperatures, may also cause hydrogen embrittlement, and these solutions are routinely used during repair and programmed maintenance. Unfortunately, there is still no reliable and simple system or techniques to nondestructively detect and quantify hydrogen embrittlement effects. Therefore, a technique and system are required that are capable of detecting hydrogen embrittlement effects early enough to avoid the insidious delayed failures caused by hydrogen embrittlement cracking. The required method should be implemented in a portable system intended for laboratory, production, and field-level use. Alternatively, this technique might be developed to also allow detection of microcracks early enough to provide a viable damage tolerance-based inspection program.

PHASE I: Investigate the specific issues related to hydrogen embrittlement of high-strength steels used in Air Force aircraft components. Investigate the capability of a sensory system to detect hydrogen embrittlement effects in a high-strength steel typical of critical Air Force aircraft components using prototypical samples and/or relevant components. Explore the possibility of correlating the results from the examinations using the sensor with the data from currently performed tests, i.e. constant-load ("stress rupture") test data.

PHASE II: Expand investigation of the capability to detect hydrogen embrittlement effects to a wider range of high-strength steels. Develop a fieldable portable method for in-situ inspection of high-strength steel aircraft components using the method proven in Phase I.

PHASE III DUAL USE APPLICATIONS: Advanced sensors currently used for detection of microcracks and characterization of magnetizable and/or conductive materials have a great potential for detection of hydrogen embrittlement effects. Hydrogen embrittlement is an insidious problem that has resulted in numerous failures in a range of components used in military and civil applications, e.g. in the power and petrochemical industries as well as in civil transportation. Implementation of a fieldable system for in-situ detection of hydrogen embrittlement effects in high-strength steels will have a significant commercialization potential.

REFERENCES:
1. Metals Handbook, Ninth Edition, Volume 13, pp. 283-290, 1087-1091; Current Solutions to Hydrogen Problems in Steels, ASM, 1983.
2. Goldfine, N., Materials Evaluation, March 1993, 396-405; Weiss, V., et al., ASTM STP 1360, 2000, pp. 427-438
3. Goldfine, N. et. Al., The 38th Annual British Conf. NDT (NDT '99 and UK Corrosion '99, pp. 315-320

KEYWORDS: hydrogen embrittlement, inspection