Air Force
SBIR 04.1 Proposal Submission 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 Program Manager is Mr. Steve Guilfoos, 1-800-222-0336. For general inquires or problems with the electronic submission, contact the DoD Help Desk at 1-866-724-7457 (1-866-SBIRHLP) (8am to 5pm EST). For technical questions about the topic during the pre-solicitation period (1 Oct through 30 Nov 03), contact the Topic Authors listed for each topic on the website. For information on obtaining answers to your technical questions during the formal solicitation period (1 Dec 03 through 15 Jan 04), go to **http://www.acq.osd.mil/sadbu/sbir/solicitations/sitis.htm.**

The Air Force SBIR Program is a mission-oriented program that integrates the needs and requirements of the Air Force through R&D topics that have military and commercial potential. Information can be found at the following website: **http://www.afrl.af.mil/sbir/index.htm.**

PHASE I PROPOSAL SUBMISSION:

Read the DoD program solicitation at www.dodsbir.net/solicitation **for detailed instructions on proposal format and program requirements.** When you prepare your proposal, keep in mind that Phase I should address the feasibility of a solution to the topic. For the Air Force, the contract period of performance for Phase I shall be nine (9) months, and the award shall not exceed $100,000. We will accept only one cost proposal per topic proposal and it must address the entire nine-month contract period of performance.

The Phase I award winners must accomplish the majority of their primary research during the first six months of the contract. This six month effort alone, based upon the evaluation of the technical results as reported in the interim report(s) and reviewed by the Air Force Technical point of contact utilizing the criteria in section 4.3, will be the baseline for determination on whether the Air Force will request a Phase II proposal. The last three months of the nine-month Phase I contract will provide project continuity for all Phase II award winners so no modification to the Phase I contract should be necessary. Phase I proposals have a 25 page-limit (excluding Company Commercialization Report). The Air Force will evaluate and select Phase I proposals using review criteria based upon technical merit, principal investigatior qualifications, and commercialization potential as discussed in this solicitation document.

NEW REQUIREMENT: ALL PROPOSAL SUBMISSIONS TO THE AIR FORCE PROGRAM MUST BE SUBMITTED ELECTRONICALLY.

It is mandatory that the complete proposal submission -- DoD Proposal Cover Sheet, **ENTIRE** Technical Proposal with any appendices, Cost Proposal, and the Company Commercialization Report -- be submitted electronically through the DoD SBIR website at http://www.dodsbir.net/submission. Each of these documents is to be submitted separately through the website. Your complete proposal **must** be submitted via the submissions site on or before the **6:00am EST, 15 January 2004 deadline.** A hardcopy **will not** be accepted. Signatures are not required at proposal submission when submitting electronically . If you have any questions or problems with electronic submission, contact the DoD SBIR Help Desk at 1-866-724-7457 (8am to 5pm EST).

Acceptable Format for On-Line Submission: All technical proposal files must be in Portable Document Format (PDF) for evaluation purposes. The Technical Proposal should include all graphics and attachments but should not include the Cover Sheet or Company Commercialization Report (as these items are completed separately). Cost Proposal information should be provided by completing the on-line Cost Proposal form and including the itemized listing (a-h) specified in the Cost Proposal section later in these instructions. This itemized listing should be placed as the last page(s) of the Technical Proposal Upload. (Note: Only one file can be uploaded to the DoD Submission Site. Ensure that this single file includes your complete Technical Proposal and the additional cost proposal information.)

Technical Proposals should conform to the limitations on margins and number of pages specified in the front section of this DoD solicitation. However, your cost proposal will only count as one page and your Cover Sheet will only count as two, no matter how they print out after being converted. Most proposals will be printed out on black and white printers so make sure all graphics are distinguishable in black and white. It is strongly encouraged that you perform a virus check on each submission to avoid complications or delays in submitting your Technical Proposal. To verify that your proposal has been received, click on the "Check Upload" icon to view your proposal. Typically, your uploaded file will be virus checked and converted to PDF within the hour. However, if your proposal does not appear after an hour, please contact the DoD Help Desk.

The Air Force recommends that you complete your submission early, as computer traffic gets heavy near the solicitation closing and could slow down the system. **Do not wait until the last minute.** The Air Force will not be responsible for proposals being denied due to servers being "down" or inaccessible. Please assure that your e-mail address listed in your proposal is current and accurate. By the end of January, you will receive an e-mail serving as our acknowledgement that we have received your proposal. The Air Force cannot be responsible for notifying companies that change their mailing address, their e-mail address, or company official after proposal submission.

PHASE I PROPOSAL SUBMISSION CHECKLIST

Failure to meet any of the criteria will result in your proposal being **REJECTED** and the Air Force will not evaluate your proposal.

1) The Air Force Phase I proposal shall be a nine month effort and the cost shall not exceed $100,000.

2) The Air Force will accept only those proposals submitted electronically via the DoD SBIR website (www.dodsbir.net/submission).

3) You must submit your Company Commercialization Report electronically via the DoD SBIR website (www.dodsbir.net/submission).

NOTE: Even if your company has had no previous Phase I or II awards, you must submit a Company Commercialization Report. Your proposal will not be penalized in the evaluation process if your company has never had any SBIR Phase Is or IIs in the past.

PROPOSAL/AWARD INQUIRIES

We anticipate having all the proposals evaluated and our Phase I contract decisions by mid-May. All questions concerning the evaluation and selection process should be directed to the local organizational SBIR managers. Organizations and their Topic numbers are listed later in this section (before the Air Force Topic desciptions).

KEY PERSONNEL:

Identify in the technical proposal key personnel who will be involved in this project, including information on directly related education and experience. A resume of the principle investigator, including a list of publications, if any, must be included. Resumes of proposed consultants, if any, are also useful. Consultant resumes may be abbreviated. **Please identify any foreign nationals you expect to be involved in this project, as a direct employee, subcontractor, or consultant. Please provide resumes, country of origin and an explanation of the individual's involvement.**

<u>COST PROPOSAL</u>:

The on-line cost proposal is part of your proposal's 25 page limit and must be at a level of detail that would enable Air Force personnel to determine the purpose, necessity and reasonability of each cost element. Provide sufficient information (a through h) on how funds will be used if the contract is awarded. Include any additional cost proposal information as an appendix in your technical proposal. The additional cost proposal information will <u>not</u> count against the 25 page limit.

a. Special Tooling and Test Equipment and Material: The inclusion of equipment and materials will be carefully reviewed relative to need and appropriateness of the work proposed. The purchase of special tooling and test equipment must, in the opinion of the Contracting Officer, be advantageous to the government and relate directly to the specific effort. They may include such items as innovative instrumentation and / or automatic test equipment.

b. Direct Cost Materials: Justify costs for materials, parts, and supplies with an itemized list containing types, quantities, price and where appropriate, purposes.

c. Other Direct Costs: This category of costs includes specialized services such as machining or milling, special testing or analysis, costs incurred in obtaining temporary use of specialized equipment. Proposals, which include leased hardware, must provide an adequate lease vs. purchase justification or rational.

d. Direct Labor: Identify key personnel by name if possible or by labor category if specific names are not available. The number of hours, labor overhead and / or fringe benefits and actual hourly rates for each individual are also necessary.

e. Travel: Travel costs must relate to the needs of the project. Break out travel cost by trip, with the number of travelers, airfare, per diem, lodging, etc. The number of trips required, as well as the destination and purpose of each trip. Recommend budgeting at least one (1) trip to the Air Force location managing the contract.

f. Cost Sharing: Cost sharing is permitted. However, cost sharing is not required, nor will it be an evaluation factor in the consideration of a proposal. Please note that cost share contracts do not allow fees.

g. Subcontracts: Involvement of university or other consultants in the planning and / or research stages of the project may be appropriate. If the offeror intends such involvement, described in detail and include information in the cost proposal. The proposed total of all consultant fees, facility leases or usage fees and other subcontract or purchase agreements may not exceed one-third of the total contract price or cost, unless otherwise approved in writing by the contracting officer.

<u>(NOTE): The Small Business Administration has issued the following guidance:</u>
" Agencies participating in the SBIR Program will not issue SBIR contracts to small business firms that include provisions for subcontracting any portion of that contract award back to the originating agency or any other Federal Government agency." See Section 2.6 of the program solicitation for more details.

Support subcontract costs with copies of the subcontract agreements. The supporting agreement documents must adequately describe the work to be performed (i.e. cost proposal). At the very least, a statement of work with a corresponding detailed cost proposal for each planned subcontract.

h. Consultants: Provide a separate agreement letter for each consultant. The letter should briefly state what service or assistance will be provided, the number of hours required and hourly rate.

<u>FAST TRACK</u>:

Detailed instructions on the Air Force Phase II program and notification of the opportunity to submit a FAST TRACK application will be forwarded to all Phase I awardees by the awarding Air Force organization at the time of the 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.

For FAST TRACK applicants, should the outside funding not become available by the time designated by the awarding Air Force activity, the offeror will not be considered for any Phase II award. FAST TRACK applicants may submit a Phase II proposal prior to receiving a formal invitation letter. The Air Force will select Phase II winners based solely upon the merits of the proposal submitted, including FAST TRACK applicants.

PHASE II PROPOSAL SUBMISSIONS:

Phase II is the demonstration of the technology that was found feasible in Phase I. Only those Phase I awardees that are **invited** to submit a Phase II proposal and all FAST TRACK applicants will be eligible to submit a Phase II proposal. The awarding Air Force organization will send detailed Phase II proposal instructions to the appropriate small businesses. Phase II efforts are typically two (2) years in duration and do not exceed $750,000. (NOTE) All Phase II awardees must have a Defense Contract Audit Agency (DCAA) approved accounting system.

All Phase II proposals must have a complete electronic submission. **COMPLETE** electronic submission includes the submission of the Cover Sheet, Cost Proposal, Company Commercialization Report, the **ENTIRE** technical proposal with any appendices via the DoD submission site. The DoD proposal submission site at http://www.dodsbir.net/submission will lead you through the process for submitting your technical proposal and all of the sections electronically. Your proposal **must** be submitted via the submission site on or before the Air Force activity specified deadline. Phase II Technical proposal is limited to 75 pages. Phase II Cost Proposal information should be provided by completing the on-line Cost Proposal form and including the itemized listing (a-h) specified in the Cost Proposal section earlier in these instructions. The commercialization report, any advocacy letters, and the additional cost proposal itemized listing (a through h) will not count against the 75 page limitation and should be placed as the last pages of the Technical Proposal file that is uploaded. (Note: Only one file can be uploaded to the DoD Submission Site. Ensure that this single file includes your complete Technical Proposal and the additional cost proposal information.)

AIR FORCE PHASE II ENHANCEMENT PROGRAM

On active Phase II awards, the Air Force will select a limited number of Phase II awardees for the Enhancement Program to address new unforeseen technology barriers that were discovered during the Phase II work. The selected enhancements will extend the existing Phase II contract award for up to one year and the Air Force will match dollar-for-dollar up to $500,000 of non-SBIR government matching funds. Contact the Air Force organizational SBIR Manager for more information.

AIR FORCE PROPOSAL EVALUATIONS

Evaluation of the primary research effort and the proposal will be based on the scientific review criteria factors (i.e., technical merit) and other criteria as discussed in this solicitation document. 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. The Air Force anticipates that pricing will be based on adequate price competition.

NOTICE: Only government personnel and technical personnel from Federally Funded Research and Development Center (FFRDC), Mitre Corporation and Aerospace Corporation, working under contract to provide technical support to Air Force product centers (Electronic Systems Center and Space and Missiles Center respectively), may evaluate proposals. All FFRDC employees at the product centers have non-disclosure requirements as part of their contracts with the centers. In addition, Air Force support contractors may be used to administratively process or monitor contract performance and testing. Contractors receiving awards where support contractors will be utilized for performance monitoring may be required to execute separate non-disclosure agreements with the support contractors.

AIR FORCE SBIR PROGRAM MANAGEMENT IMPROVEMENTS

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

AIR FORCE SUBMISSION OF FINAL REPORTS

All final reports will be submitted to the awarding Air Force organization in accordance with Contract Data Requirements List (CDRL). Companies **should not** submit final reports directly to the Defense Technical Information Center (DTIC).

Topic Number	Activity	Program Manager	Contracting Authority (for contract question only)
AF04-001 thru AF04-010	Directed Energy Directorate AFRL / DE 3600 Hamilton Ave. SE Kirtland AFB NM 87117-5776	Robert Hancock (505) 846-4418	Dave Tuttle (505) 846-8133
AF03-015 AF04-017 thru AF04-044	Space Vehicles Directorate AFRL / VS 3600 Hamilton Ave. SE Kirtland AFB NM 87117-5776	Robert Hancock (505) 846-4418	Francisco Tapia (505) 846-5021
AF04-051 thru AF04-064 AF04-066 thru AF04-074	Human Effectiveness Directorate AFRL / HE 2610 Seventh St. Bldg. 441 Rm 216 Wright-Patterson AFB, OH 45433-7901	Sabrina Davis (937) 255-2423, x226	Jeanette Snyder (937) 255-2527
AF04-085 thru AF04-091 AF04-094, AF04-097 AF04-100 thru AF04-107 AF04-109 thru AF04-0115 AF04-117 AF04-119 thru AF04-124	Information Directorate AFRL / IF 26 Electronic Parkway Rome, NY 13441-4514	Janis Norelli (315) 330-3311	Renee Arcuri (315) 330-4777
AF04-126 thru AF04-143 AF04-145 thru AF04-147 AF04-149, AF04-151 AF04-153, AF04-155	Materials & Mfg. Directorate AFRL / ML 2977 P St. Suite 13 Bldg. 653 Wright-Patterson AFB, OH 45433-7746	Marvin Gale (937) 255-4839	Terry Rogers (937) 656-9001
AF04-156 thru AF04-166 AF04-168 thru AF04-175 AF04-177	Munitions Directorate AFRL / MN 101 West Eglin Blvd. Suite 140 Eglin AFB, FL 32542-6810	Dick Bixby (850) 882-8591, x1281	Judi Jacobson (850) 882-4294, x3207

Topic Number	Activity	Program Manager	Contracting Authority (for contract question only)
AF04-181 thru AF04-194	Propulsion Directorate AFRL / PR 1950 Fifth St. Bldg. 18 Wright-Patterson AFB, OH 45433-7251	Laurie Regazzi (937) 255-1465	Susan Day (937) 255-5499
AF04-197 thru AF04-200	AFRL / PRO 5 Pollux Drive Edwards AFB, CA 93524-7033	Debbie Spotts (661) 275-5617	Theresea Weber (661) 277-3344
AF04-203 thru AF04-223	Sensors Directorate	Marleen Fannin	Sharma Wilkins
AF04-225 thru AF04-234 AF04-236	AFRL / SN 2241 Avionics Circle, Rm N2S24 Bldg. 620 Wright-Patterson AFB, OH 45433-7320	(9370 255-5285, x4117	(937) 255-4279
AF04-241 thru AF04-249	Air Vehicles Directorate AFRL / VA 2130 Eighth St. Bldg. 45 Wright-Patterson AFB, OH 45433-7542	Madie Tillman (937) 255-5066	Douglas Harris (937) 255-3427
AF04-255 thru AF04-258	Oklahoma City Air Logistic Center 3001 Staff Drive, Suite 2AG70A Tinker AFB, OK 73145-3040	Oscar Diaz-Valle (405) 736-5364	Joe Starzenski (405) 739-5510
AF04-264 thru AF04-271	Ogden Air Logistic Center 5851 F Avenue Bldg. 849, Rm A-15 Hill AFB, UT 84056-5713	Joseph Burns (801) 586-2721	Paulette Crowell (801) 775-2365
AF04-273 thru AF04-278	Warner Robins Air Logistic Center 420 Richard Ray Blvd., Suite 100	Jamie McClain (478) 926-6617	Nita Steinmetz (478) 926-3695

Robins AFB, GA 31098-1640

Topic Number	Activity	Program Manager	Contracting Authority (for contract question only)
AF04-279 thru AF04-280	Air Armament Center 46 TW / XPP 101 West D Ave. Suite 222 Bldg. 1 Eglin AFB, FL 32542-5492	Donna Self (850) 882-6766	Lorna Tedder (850) 882-4141, x4557
AF04-287 thru AF04-289 AF04-291 thru AF04-295	Arnold Engineering Dev. Center AEDC / DOT 1099 Avenue C Arnold AFB, TN 37389-9011	Ron Bishel (931) 454-7734	Kathy Swanson (931) 454-4409
AF04-296 AF04-298 thru AF04-299 AF04-302 thru AF04-303	Air Force Flight Test Center AFFTC / XPDT 307 East Popson Avenue Bldg.1400 Rm 107A Edwards AFB, CA 93524-6843	Abraham Atachbarian (661) 277-5946	Kim Davis (661) 277-9554

Air Force 04.1 Topic List

AF04-001*	Robust Single-Frequency Solid-State Seed Laser with Random Access of Wavelength
AF04-002*	Laser System for Space Control and Protection
AF04-003*	High Gain Panoramic Optical Power Amplifier
AF04-004	UV/X-Ray Bio-Decontamination
AF04-005	Automated Techniques for Extracting Four Dimensional Space-Time Data from Ground-Based Imagery of Space Objects
AF04-006	Conformal Impulse Receive Antenna Arrays
AF04-007	Optical Fibers for High-Power, Mid-Infrared Laser Diodes Emitting in the 2.0 Micron to 5.0 Micron Wavelength Range
AF04-008	Lightweight Optics for High Energy Applications
AF04-009	High Repetition Rate Pulsed Power Generators
AF04-010	High Brightness Mid-Infrared (2-6 Micron) Semiconductor Laser Development
AF04-015*	Advanced Algorithms for Exploitation of Space-Based Imagery to Detect Targets against Structured Earth Backgrounds
AF04-017*	Advanced Cost Model for Space Concepts Development
AF04-018*	Light Weight, Low Volume Deployable Antenna Structures
AF04-019*	Multiband Laser Communications
AF04-020*	Radiation Hardened, Low Power Digital Signal Processors
AF04-021*	Light Weight, High Density Space Qualified Bulk Memory
AF04-022*	Integrated Multi-Sensor System for Space Object Tracking, Imaging and Characterization
AF04-023*	High-Efficiency Phased -Array Antenna Power Amplifier Modules
AF04-024*	Multi-Beam Phased-Array Antenna Beamformers
AF04-025*	Novel Methods to Improve Efficiency of Copper-Indium-Gallium-diSelenide Solar Cells
AF04-026*	Multifunctional Phased Array Antenna Modules
AF04-027*	Encryption, Decryption Field Programmable Gate Array Using Specialized Software
AF04-028*	MicroElectroMechanical Systems Based Electronically Steerable Antenna
AF04-029*	Radiation-Resistant Solar Cell Coverglass
AF04-030*	Small Launch Vehicles (SLV) Technologies
AF04-031*	Thermal Protection System (TPS) for Agressive Reentry Trajectories of Space Vehicles

AF04-032* Programmable Satellite Transceiver (PST) for Dual Band Command and Control

AF04-033* Low-Cost Thermal Protection System (TPS) For Reentry Vehicles

AF04-034* Advanced Thermal Protection System (TPS) for Future Multiple Entry Vehicles

AF04-035* Energetic Polymeric Nanomaterials for Satellite Power Systems Design

AF04-036 Scene Generation for Simulations of Satellite-Based MTI Radars

AF04-037 Innovative Rapid Satellite Prototyping, Integration, and Manufacturing

AF04-038 Controlling Stability and Load Limits of Aerodynamically Induced Forces on Very Large Assymetric Fairing Designs

AF04-039 Advanced Technology Development Cost Estimation Methodology

AF04-040 Plasmaspheric and Enhanced Ionospheric Total Electron Content Monitoring

AF04-041 Distributed Optical Imaging of the Upper Atmosphere

AF04-042 Rad-Hard Reconfigurable Level Shifters

AF04-043* High Bandwidth Optoelectronic Data Interfaces for Satellites

AF04-044* Compact Vacuum Nanoelectronic Devices for Advanced Communication Devices

AF04-051 Pattern Recognition for Aircraft Maintainer Troubleshooting

AF04-052 Integrated Repair Level Analysis (RLA) Agent Technology

AF04-053 Quantification of Logistics Capabilities

AF04-054 Weapon System Design Simulation

AF04-055 Maintenance Mentoring

AF04-056 Optical Amplifier for Night Vision Imaging

AF04-057 Antireflection coatings for image intensifier tubes

AF04-058 Embedded Assessment Technology using Latent Semantic Analysis (LSA) Technology to Monitor Verbal Interactions

AF04-059 Determining Fidelity Requirements for Training and Certification on Maintenance Simulators

AF04-060 Collaberative Maintenance Support (CMS)

AF04-061 Future Night Vision System

AF04-062 Expanded Speech Recognition to Include Foreign Accents

AF04-063 New Decontamination for Aircraft Cargo Interior

AF04-064 Algorithms for Run-Time Terrain Deformation

AF04-066*	Next Generation Visualization Tools for Mission Planning, Briefing and After Action Review
AF04-067*	Achieving Decision Superiority in the Information Age
AF04-068*	Work-Centered Support System for Counterspace Operations
AF04-069	Enhancing Commanders' Cognitive Readiness at the Operational Level of War
AF04-070	Distributed Planning, Debriefing, and after-action-review Capability
AF04-071	Adaptive Levels of Automation for UAV Supervisory Control
AF04-072	Cultural Factors Influencing the Use of Non-Lethal Weapons
AF04-073	Focused Delivery of Laser Energy to the Eye Using Adaptive Optics
AF04-074	Real-time Bio-Sensors for Enhanced C2ISR Operator Performance
AF04-085	Military and Civilian Air Traffic Management Information Exchange and Visualization
AF04-086	ADS-B Data Integrity
AF04-087*	Expert Intelligent Match of Requirements and Solutions
AF04-088*	ISR Related Sensor Data and Ground-Station Associated Technologies for Integrating (QRC Basis) with State and Local Law Enforcement (LE) for Homelan
AF04-089*	Enhanced Gateway Interoperability Architectures for Legacy C3I Systems
AF04-090*	Improved Situational Awareness in the Cockpit
AF04-091*	Dynamic Replanning and Assessment
AF04-094*	XML Guard
AF04-097*	Metadata Generation
AF04-100*	Achieving Ubiquity: Technologies to Make Intelligence Available Everywhere on Demand
AF04-101	Data Compression
AF04-102	Sensor Resource Management for Improved Situational Assessment
AF04-103*	Enabling Technologies for Free Space Quantum Cryptography
AF04-104*	High Data Rate Error Correction
AF04-105*	Dynamically Sensing and Adapting Wireless Network
AF04-106*	Q/V/W-band High Powered Amplifiers
AF04-107*	A Family of Decision-Centric Software Applications for the Future ISR Network
AF04-109*	Disseminating ISR Products, Including Real-Time Moving Imagery, as a Multi-Service Enterprise

AF04-110	Campaign Level Adversarial Modeling System
AF04-111	An Integrated COA versus eCOA Tool
AF04-112	New Information Technologies for Crisis Operations
AF04-113	Information Management Staff Toolkit
AF04-114	Physical Layer Information Assurance for Wireless Networks
AF04-115	Innovative Approaches to Fusion 2+
AF04-117*	Coalition Shared Database Implementation
AF04-119*	Mentoring Software for the Warfighter
AF04-120*	Technologies for Injecting Targeting and Re-targeting Data in Precision-Guided Weapons in Flight
AF04-121	RA-2 Over the Horizon (OTH) Communications for Small UAV's
AF04-122*	Mixed Excitation Linear Prediction (MELP) algorithm development
AF04-123*	Improved Liveness Testing Techniques for Biometrics Applications
AF04-124	High Performance Biomolecular Computing Architectures for Information Technology
AF04-126	Development of On-line Fuel Tank Oxygen Sensor for Aircraft
AF04-127	Development of High-Temperature Aircraft Camouflage Coatings
AF04-128	Pilot Extraction Tool
AF04-129	Direct Manufacturing of Advanced Gas Turbine Engine Diffuser Cases
AF04-130	Ceramic Matrix Composites (CMCs) for Aircraft Brake Friction Materials
AF04-131	Erosion Protection Materials for High-Temperature Composites
AF04-132	Encapsulated Resin for Non-Autoclave Resin Film Infusion Composites Repair
AF04-133	Damage Detection in Composites via Passive Monitoring Techniques
AF04-134	Nondestructive Inspection (NDI) of Fastener Holes in Thick Multi-Layer Structure
AF04-135	Lean Techniques for Project Management in the Acquisition Environment
AF04-136	Waste Disposal/Waste Management System for Low Observable (LO) Composite Materials
AF04-137	Reusable Internal Mandrels For Composites Repair or Fabrication
AF04-138	Improved Processes for Joining of Polyetheretherketone (PEEK) Thermoplastic Components
AF04-139	Fatigue Life Enhancement of Fastener Holes Manufactured from High-Strength Aluminum Alloys

AF04-140	Enabling Materials Processing Technology for Low-Cost Fabrication of Integral Bladed Rotors (IBR)
AF04-141	Damage Identification Algorithms for Composite Structures
AF04-142	Robust Bearings and Gears
AF04-143	Shape Recovery Polymer Nanocomposites (PNCs)
AF04-145	Biologically Inspired Luminescent Technology
AF04-146	Biologically Inspired Thermal Detector Technology
AF04-147	Active Calorimetry Development for Testing of Active Thermal Control Coatings and Devices
AF04-149	Microelectromechanical Systems (MEMS) for Vehicle Health Monitoring
AF04-151	In-Flight Protective Transparency, and Personnel Armor
AF04-153	Wiring System In-Situ Health Monitoring Diagnostics
AF04-155	Modeling and Simulation for the Accelerated Development of Materials
AF04-156	Vertical Cavity Surface Emitting Lasers (VCSEL)
AF04-157	Innovative Technologies for Reducing Unexploded Ordnance (UXO)
AF04-158	Minimum RF Bandwidth Approaches to Human Interaction with Weapon Terminal Attack
AF04-159	Shock Hardened High Bandwidth Through Media Transmission Technology
AF04-160	Penetrator Trajectory Path Control
AF04-161	Ultra-High Speed Analog Lightwave Components For Ladar Scene Projection
AF04-162	Innovative Material Processing for Warhead Applications
AF04-163	Software Architecture for Universal Plug and Play of Weapons
AF04-164	Unitary Warhead Airburst Fuzing Capability
AF04-165	Visible/UV Image Projector for Sensor Testing
AF04-166	Plasma Aerodynamics for Munition Control
AF04-168	Global Positioning System (GPS) Jammer Threat Homing Munition Guidance System
AF04-169	Efficient High Power Amplification Technology for Munitions
AF04-170	Structure from Motion
AF04-171	Reaction Kinetics for Shock Driven Droplet Interactions
AF04-172	Processing Methodology for Reactives Enhanced Munitions
AF04-173	Digital Signal Processing in Radar Altimeters

AF04-174 Munition Sensor Electronics/Processor Integration

AF04-175 A Hydrodynamic-Stochastic Neutralization Model for Biological Agent Defeat

AF04-177 Multi-Mode Mobility

AF04-181 Development of Phenomenological Liquid Spray Design Tool for Augmentor Operability and Performance

AF04-182 Control of Fuel Atomization and Mixing for Emission Reduction in High Performance Gas Turbines

AF04-183 Thermal Barrier Coating (TBC) Durability

AF04-184 Genetic Algorithm Optimized Probabilistic Maintenance Scheduling

AF04-185* Nanomaterial-Based Lithium Ion Batteries

AF04-186 Thermal Battery with Low Internal Operating Temperatures for Missile Applications

AF04-187 Hypersonic Sensor Architecture Evaluation, Sensor Testing and Communication Needs

AF04-188 Aero Propulsion and Power Technology

AF04-189 Propulsion Health Management – Future, Legacy, and Integrated Power System Technology

AF04-190 MEMS Based Sulfur Detection for Logistic Fuel-Based Fuel Cell Power Generators

AF04-191 Analytical Diagnostic Tools for Heat Utilization Effects on High-Speed Aircraft

AF04-192 Self-Powered Wireless Micro Electro Mechanical Systems (MEMS) for Vibration Monitoring

AF04-193* Solid-State Electrolyte for High Pulse-Power Energy Sources

AF04-194* Fuel Cell Power System with Parallel-Connected Bi-directional DC-DC

AF04-197 Improved Jet Canopy Properties Through Hybrid Polymers

AF04-198* High Power Hall Thruster Technology Development

AF04-199 Advanced Rocket Propulsion Technologies

AF04-200 Nanomaterial Reinforcement for High Strength Solid Rocket Motor (SRM) Case Materials

AF04-203* Real Time Cueing and Identification – Coherent Combining

AF04-204* Innovative Filtering Techniques for Ground Target Tracking

AF04-205* Environmentally Driven Signal Processing Technology for Overland Height Finding

AF04-207* Adaptive Hyperspectral Sensor Designs

AF04-208 Improved Missile Launch Detection Techniques (IMLD)

AF04-209 Combat Identification for Difficult Targets

AF04-210	NCID
AF04-211*	Polarization Compensation for Phased Array
AF04-212*	Advanced Waveform Processing
AF04-213*	Global Position System (GPS) Control Segment Precision Estimation Techniques
AF04-214*	Revolutionary Photoreceivers Based on Combining Si-MOS Process with SiGe Nanotechnology
AF04-215*	Monolithic Microwave Integrated Circuit (MMIC) Beamforming Weights
AF04-216*	Multi-Band/Beam Module
AF04-217*	Synchronized Space Object Tracking
AF04-218*	Efficient High Frequency Electromagnetic Source for Communication Devices
AF04-219*	Signal Processing and Amplifier Design for Non-Constant-Envelope Modulation
AF04-220*	Manufacturing Technology for Conformal Arrays
AF04-221*	Advanced High Frequency Tunable Filters for Wide-Band Arrays
AF04-222*	High Speed Optical Limiter for Laser Communications Systems
AF04-223*	Optical Communication Turrets
AF04-225	RA-1 Multi-mode Collision Avoidance Technology for UAVs
AF04-226*	Multisource Data Registration Tools
AF04-227	Small Aircraft Self Protection
AF04-228	Compact, Lightweight, Low-Power Hyperspectral Sensor
AF04-229	Low Cost Electro-Optic Sensors for Mini/Micro UAV's
AF04-230	Machine Learning for Robust Automatic Target Recognition
AF04-231	Modeling and Simulation Technologies for Multi-Sensor Dynamic Targeting
AF04-232	Dual-Use Simulation Technologies for Advanced Technology Demonstrations in Synthetic Battlespace
AF04-233	Multisensor Time Synchronization
AF04-234*	Algorithms for Real Time Corrections of Multi-Path Errors using Modernized GPS Signals
AF04-236*	Digital Array Analog to Digital Converter
AF04-241	Verification of Coldworking and Interference Levels at Fastener Holes
AF04-242	Comprehensive Structural Health Monitoring (SHM) System

AF04-243	System Engineering -- Thermal/Power- Efficiency Assessments of Air Vehicles
AF04-244	Flow Control for Enhanced Sensor Beam/Directed-Energy (DE) Beam Quality
AF04-245	Exergy–Based Design and Analysis for Optimization of Aerospace Components and Systems
AF04-246	Technology for Affordable Validation and Verification (V&V) Software Design Processes and Safe Flight-Critical Software
AF04-247	Constraint Estimation for Aerospace Vehicle Trajectory Retargeting
AF04-248	Innovative Weight Efficient Combined Structural/Thermal Protection System (TPS) Concepts
AF04-249	Demonstration of Multiple Fiber Pre-forms for Local Property Tailoring
AF04-255	Next Generation, High Temperature Chip Based UV and IR Sensors
AF04-256	Streamlined Site Investigation Procedures
AF04-257	Next Generation Confined Space Monitoring & Inspection System
AF04-258	Chemical/Biological Decontamination
AF04-264	Chemical, Biological, or Radiological (CBR) Agent-Resistant Composite Materials For Tactical Shelters
AF04-265	Low Cost, High Tensile Strength Composite Materials
AF04-266	Self-Activate Corrosion Inhibitor
AF04-267	Advanced Composite Structural Members for Tall, Narrow Structures
AF04-268	Demonstrate Alternative Wear Coatings for Improvement of Landing Gear Performance
AF04-269	Thermo-Plastic Materials Replacement For Metal or Composite Shelters
AF04-270	Advanced Sacrificial Dense Metallic Coatings for Aircraft Components
AF04-271	Surface Protection of Aircraft Brake Pressure Plates
AF04-273	Aircraft Fatigue Damage Inspection
AF04-274	Aircraft Corrosion Inspection
AF04-275	Advanced Battery Modules for Vehicle and Support Equipment
AF04-276	Robotic Arm
AF04-277	Automatic Test Markup Language
AF04-278	JP8 Solid Oxide Fuel Cell to Power Existing Hybrid 25K Loader
AF04-279	Completely Integrated Jamming Test System (CIJTS)
AF04-280	Directed Energy Hardened Instrumentation (DEHI)

AF04-287	Arcjet Segment Development
AF04-288	Thermal Phosphor Based Heat Flux and Temperature Gauge
AF04-289	Dynamic Pressure Transducer Calibration Source
AF04-291	Measurement of Angular Valve Displacement in High Vibration Environments
AF04-292	Infrared Imaging Fiber Optic Bundles
AF04-293	CFD Design Tool for Fuel Injectors in Turbine Engines
AF04-294	Temperature Sensitive Paint for Wind Tunnel Models
AF04-295	Develop Plasma Radiation Source for >300 ns Simulators
AF04-296	Global positioning system Software Radio (GSR)
AF04-298	Data Acquisition Error Budget Analysis Tools
AF04-299	Multi-Object Radar Imaging Algorithms (MORIA)
AF04-302	Real-Time Process Control Sensor for Measuring Arsenic Concentration in Water
AF04-303	Instrumentation Support Systems Smart Transducer Plugins

* Proposals may be evaluated by non-government personnel working under government support contracts with Product Centers (SMC and/or ESC).

AirForce 04.1 Topic Descriptions

AF04-001 TITLE: Robust Single-Frequency Solid-State Seed Laser with Random Access of Wavelength

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace, Weapons

OBJECTIVE: Develop and demonstrate single-frequency, wavelength-agile, CW solid-state laser with controllable frequency.

DESCRIPTION: Active laser tracking of a remote, fast moving and maneuvering target or cluster of targets for space surveillance and control operations requires a wavelength-tunable, narrow linewidth laser with unique capability to meet the following requirements:

1. Output power no less than 100 milliwatts (mW) at or around 1.06 microns (um).
2. Monolithic construction to reduce components and alignment constraints.
3. Lightweight and compact.
4. Controllable frequency tunability over a range of 1/cm (one inverse-centimeter, or a frequency range of 30 GHz) in the vicinity of 1.06 um, with random access to lasing frequency.
5. Set-on accuracy of the output lasing frequency of 100 megahertz (MHz).
6. Lasing frequency tuning/switching time of less than 100 milliseconds (ms).

Conventional methods for laser wavelength tuning based on intra-cavity spectral selectors or an alteration of the optical length of the micro-cavity cannot provide the performance level as needed. Achieving fast-tunability over the specified frequency range will require novel concepts and designs. This solicitation seeks innovative research and generation of creative concepts and original designs leading to the development, demonstration, and evaluation of a laser system that can serve as a frequency-tunable seed laser for space/air surveillance and control. Modeling/simulation and analysis are encouraged to guide in the course of identifying novel solutions enabling the realization of a rapidly tunable solid-state laser source.

PHASE I: Develop a preliminary design for a tunable solid-state laser that meets the technical requirements for space surveillance and control. Demonstrate its feasibility and assess its practical applicability in a laboratory environment. Characterize the proposed laser system and establish its operation and performance envelope. The proposed system design must be realizable within the scope of a Phase II SBIR contract. Risk reduction tasks that support the design may be carried out. The Phase I products are the laser system design, the final report, and a Phase II proposal (if requested).

PHASE II: Further refine the Phase I preliminary design to fabricate, integrate and assemble a prototype laser system based on the final plan. Measurements to assess system performance such as tuning speed and range, output power as a function of lasing frequency, output frequency stability, linewidth, and beam quality (M-squared) should be carried out against realistic application scenario drivers. The products should include the laser system with any power supplies and chillers, test and demonstration drivers, measurement data of system performance, a plan for a full-scale space tracking application and demonstration, and the final report.

DUAL USE COMMERCIALIZATION: There are numerous applications that require or could benefit from the use of scalable, frequency-stable, fast-tunable laser sources. Potential military applications include remote sensing, active laser tracking of fast-moving targets including missiles, satellites, and cross-communication systems in military environments. One or more potential commercial applications of this technology include laser communications with wavelength division multiplexing, laser profilometry, vibrometry, high-density optical data storage, as well as range-finding applications and laser clocks.

REFERENCES: 1. W. Koechner, Solid-State Laser Engineering, Fourth Edition (New York: Springer-Verlag, 1996).

2. F. Duarte, Tunable lasers handbook, San Diego: Academic Press, 1995.

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KEYWORDS: Rapidly Tunable Laser, Narrow Linewidth, Wide Tuning Range, Stable Frequency, High Power, Wavelength-Agile Tunable Laser

AF04-002 TITLE: Laser System for Space Control and Protection

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace, Space Platforms, Weapons

OBJECTIVE: Develop phase-conjugate based laser systems for neutralizing surveillance and optical communication modules in space, air and ground targets.

DESCRIPTION: Space control and protection missions may be implemented by delivering a laser beam with sufficient energy onto a distant target. This is to suppress (or optically jam) space, air, or ground-based surveillance or optical communication modules placed on various platforms pointing toward the laser transmitter. The application demands a laser system that has maximal throughput efficiency and minimal losses. To be effective, such a laser system should compensate not only for a beam jitter caused by turbulent atmosphere, and rapid changes in the relative position between the transmitter and target, but also for decrease in the laser beam divergence and the spot size on the target.

It is widely accepted that adaptive optic systems are not capable of compensating for dynamic variations at rates higher than 1 kHz. An alternative solution for this problem is to use a laser system with optical phase conjugation (OPC) methods. It is essential that the system is self-steering to the target and does not require a high accuracy pointing mechanism for lightweight and low cost. It is a well-established fact that delivery of the laser energy onto the target can be achieved when this target serves as an output coupler of the resonator. This also satisfies the conditions of minimal losses for oscillation. The objective of this project is to develop and demonstrate a laser system with phase conjugate mirror (PCM) for delivery of laser energy to a distant target to jam or degrade the performance of optical sensor or transmission subsystem on board the target pointing toward the laser transmitter.

PHASE I: Develop a preliminary system design of a PCM-based laser energy delivering system with an extended cavity filled with a turbulent medium for long distance targeting. Assess its feasibility for practical application to space control and protection mission. Identify, analyze and estimate the key parameters that can determine and limit such a system's operations and performance. Evaluate the dynamic characteristics of the PCM laser capable to sustain the oscillation at realistic rates of change of turbulence, of switch between targets, and of the relative position between the transmitter and the target. Define an experimental plan and technology roadmap to demonstrate the operability and transferability of the system for space control and protection application.

PHASE II: Further refine the Phase I preliminary design to fabricate, integrate, and assemble a prototype of the laser system. Experiment and validate its operation and performance in a turbulent atmospheric environment and demonstrate the energy transfer onto multiple distance targets with high beam quality and optical jamming capability. Design an application and transition plan for a full-scale demonstration.

DUAL USE COMMERCIALIZATION: Many military and commercial systems require a high-energy transfer onto a remote object. In military sector such lasers can be used as a component of laser weapon module, when used to suppress ground-based or space-based surveillance systems, or as a component of the anti-missile defense system.

In the commercial sector such a laser can find applications for a long-range (satellite, air space) laser tracking and communication.

REFERENCES: 1. L. Weinstein, Open resonators and open waveguides, Boulder, Colo., Golem Press, 1969.

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KEYWORDS: Space Control and Protection, Phase Conjugation, Optical Jamming, Performance Degradation, Laser Cavity, Phase Conjugate Mirror.

AF04-003 TITLE: High Gain Panoramic Optical Power Amplifier

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop and demonstrate high gain, high efficiency, wide viewing angle optical power amplifier.

DESCRIPTION: Laser tracking and pointing of the remote targets for space/air surveillance and control applications require the development of compact, high electrical plug in efficiency, and high gain optical amplifiers. The desired operating characteristics include a sufficiently wide (panoramic) angle of view (better than 54 mrad), high output power (>17 dB), and high electrical plug in efficiency (>40%) in order to provide high quality amplification of an image. Several critical issues have to be solved in order to build the desired amplifiers, such as maximal suppression of the super luminescence and possibility of spurious oscillation. Both effects can result in a decrease of the level of inversion population in the gain medium and therefore decrease the gain coefficient. High level pumping of a gain medium creates thermal distortions in its volume, resulting in aberrations of the laser beam. Thus, the proposed design concepts should account for all these and related problems and minimize their effect on the quality of the output laser beam.

PHASE I: Develop candidate preliminary designs of "panoramic" optical power amplifier (POPA) for active tracking and pointing of multiple targets in space and air. Explore different laser material, fiber configuration, pump mechanisms and coupling techniques, and low loss pump laser filters to arrive at several promising design concepts. Identify, analyze and estimate the key parameters that can determine and limit POPA's operation and performance envelope. Assess feasibility and effectiveness of each candidate design for practical use in laser tracking and pointing systems. Define an experimental plan to demonstrate its operability and applicability for active laser tracking in space/air surveillance and control applications.

PHASE II: Fabricate and test several POPA devices based on the materials and design concepts developed in Phase I. Test the devices to determine output and efficiency over a range of operating conditions likely to be required for laser tracking and communications. Verify noise figure and bandwidth capability that can meet requirements for active laser tracking and pointing in real operating environment.

DUAL USE COMMERCIALIZATION: The developed amplifiers can be used for military space/air surveillance systems. They should find many dual use applications in image projection systems, medical and biomedical instrumentation, laser communication, etc. POPAs could also be used for fiber network communications, reducing thermal control requirements, increasing distance between repeaters, and permitting more bandwidth per fiber in wavelength division multiple access schemes.

REFERENCES: 1. V. Dominic, et al., "110W Fibre Laser", Electronic Letters, 35, 14, (1999).

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KEYWORDS: Laser Tracking and Pointing, Optical Power Amplifier, Wide-Angle of View, High Gain, High Efficient

AF04-004 TITLE: UV/X-Ray Bio-Decontamination

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors, Electronics

OBJECTIVE: Develop a compact source of ultra-violet and x-ray radiation to use for decontaminating aircraft, vehicles, and buildings subjected to a biological warfare attack.

DESCRIPTION: High intensity UV optical sources and x-ray sources are needed for decontamination of assets subjected to biological threats. Currently, most techniques to neutralize biological agents rely on either bulky equipment or gases and other materials corrosive or harmful to many objects. The combination of an x-ray and UV source in a relatively small package, has the potential for decontamination on the surface and sub-surface of assets. However, at the present time, UV sources have insufficient fluence and efficiency for this application and at best are difficult to combine with an x-ray source. At the present, new generations of nanoparticulate phosphors are being investigated as sources of electrically pumped UV radiation. The aim is to develop a UV and x-ray source, (electron beam driven) that utilizes new advances in nanoparticulate powders as UV phosphors. At the end of Phase I the potential phosphors will be specified and a design developed to combine the UV source and x-ray source in a single compact, electron-beam-driven device.

PHASE I: Develop a design for combined UV and x-ray source. The design shall include specifics of x-ray production as well as UV production. The design shall be sufficient enough to allow fabrication of a proto-type system in Phase II. Potential phosphors will be specified and a design developed to combine the UV source and x-ray source in a single compact, electron-beam-driven device.

PHASE II: The prototype article shall be fabricated and demonstrated during this phase. A prototype source will be delivered to AFRL/DE at the end of Phase II.

DUAL USE COMMERCIALIZATION: The source can be used for purification of equipment used in bio-technology areas as well as medical areas. These applications include cleaning of equipment that has been exposed to bio-materials that can be affected by UV and z-ray radiation. Viruses and other pathogens in the medical arena also constitute another area of interest.

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2. "Laser action in strongly scattering rare-earth-metal-doped dielectric nanophosphors" G. R. Williams, S. B. Bayram, S. C. Rand T. Hinklin and R. M. Laine, PHYSICAL REVIEW A 65 , 013807, 2001.

KEYWORDS: Electronic Devices, Environmental Effects, High Power Microwaves, Laser, Optics, and Power Systems, Nanotechnology

AF04-005 TITLE: Automated Techniques for Extracting Four Dimensional Space-Time Data from Ground-Based Imagery of Space Objects

TECHNOLOGY AREAS: Information Systems, Electronics, Space Platforms

OBJECTIVE: Develop automated techniques that extract four-dimensional space-time data from a sequence of ground-based imagery taken of a space object.

DESCRIPTION: The Air Force Research Laboratory’s Directed Energy Directorate (AFRL/DE) owns many of the world’s finest ground-based space sensors including those operated at the Starfire Optical Range (DES) and as a part of the Maui Space Surveillance System (DEBI). Further, DE’s Surveillance Technologies Branch (DEBS) conducts state of the art research to ensure the quality of imagery collected at these sites will continue to improve for years to come. The Satellite Assessment Center (SatAC, DEBE) is interested in innovative techniques for automating the analysis of this imagery. SatAC currently has processes in place to glean four dimensional space-time data from these images, but they require a great deal of human interaction and are very slow (on the order of months to complete). The output of these processes is a 3D model of the space object as well as parameters describing the object's position and orientation as a function of time. The goal of this SBIR is to develop and demonstrate algorithms/techniques that will produce this 4D information in near-real time (<20 minutes). The fidelity of the model will necessarily be a function of the image resolution and all discernible image artifacts should be modeled. The orientation of the space object should be determined for all image capture times and predictions of future and past motion should be calculated as well. The model reconstruction problem is mostly solved for cases where the imaged object is cooperative, but our objects of interest are not necessarily cooperative. Images can only be taken at certain times – governed by the laws of orbital mechanics -- and we usually have no control over the behavior of the space object at those times. These limitations make this problem much more complex and worthy of further research.

PHASE I: Investigate a number of algorithmic approaches to the problem. Required Phase I deliverables will include a prototype system that proves the concept and helps determine expectations for Phase II. Proof of the concept would entail successful 4D modeling from at least one real image sequence of a space object or a simulated sequence based on realistic imaging conditions.

PHASE II: Based on the findings from Phase I, develop, demonstrate and validate a more robust prototype system that incorporates a combination of the most promising approaches from Phase I. Exact expectations will be formulated during Phase I, but the Phase II prototype will be robust enough to handle real data under less than ideal conditions, and produce richer, more accurate representations of shape and motion as well as accommodate articulating components on the subject.

DUAL USE COMMERCIALIZATION: Many government agencies as well as private businesses are very interested in the field of automatic object recognition of uncooperative subjects. The most natural extension of this research would be to apply the same techniques to help the military paint a clearer picture of the air, ground and sea battlefields as well. Additionally, automated terrorist identification from surveillance video is another application that would directly benefit US intelligence agencies in the war against terrorism. Scene reconstruction for autonomous robot navigation during planetary exploration is yet another application that would support the country's space program. Similarly, automobile manufacturers could utilize this technology to equip their cars with sophisticated collision avoidance systems. Lastly, any industry that relies on robotic assembly lines could utilize this technology to automatically sort and separate items from an unorganized pile of parts.

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2. Alessando Chinso, Paolo Favaro, Hailin Jin, and Stefano Soatto, "Structure From Motion Causally Integrated Over Time." IEEE Transactions on Pattern Analysis and Machine Intelligence, April 2002.

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KEYWORDS: Space Situational Awareness, Space Superiority, Image Processing, Automatic Target Recognition

AF04-006 TITLE: Conformal Impulse Receive Antenna Arrays

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop co-planar conformal impulse receive antenna arrays that can be integrated into airborne platforms such as Unmanned Aerial Vehicles (UAVs) and aircraft.

DESCRIPTION: This effort will develop and demonstrate design concepts for electromagnetic impulse receive antenna arrays that are co-planar (minimum depth) capable of being conformably mounted on the body or wing of airborne platforms. It is expected that to achieve the co-planar and conformal requirements that the antenna design(s) will be a multi-element array approach. The received impulse signals will contain frequencies of interest from approximately 200 MHz to 2.0 GHz. The goal for the frequency response over this range is +/- 5 dB. To capture the lower frequencies, the antenna aperture must be large thereby requiring that the individual elements of the array be electrically bonded to form the larger aperture. The antenna gain should be as high as feasible. Additionally, antennas that can be fabricated of flexible conductive materials that can be bonded to inflatable structures are highly desirable. The output from each element of the array should be capable of being interconnected so as to allow a single analog output or individually connected to waveform digitizers.

PHASE I: Requires innovative research and concepts that can be modeled and feasibility demonstrated experimentally with a small scale antenna design. The modeling and experimental data should not only demonstrate the impulse response of the antenna design(s), but also show the potential to meet the mechanical and structural requirements for integration into airborne platforms.

PHASE II: Requires the development and demonstration of a full size antenna array(s) including full electromagnetic characterization and physical properties mounted on a mockup of a typical airborne platform structural element such as a fuselage or wing.

DUAL USE COMMERCIALIZATION: Military uses of this technology when combined with other elements of an impulse radar system include airborne identification of obscured and uncooperative targets. Civilian applications include land mine identification and mapping of underground utility lines and hazardous waste sites.

REFERENCES: 1. Carl E. Baum, “Transient Arrays”, pages 129-138, Ultra-Wideband, Short-Pulse Electromagnetics 3, Plenum Press, New York, 1997, ISBN 0-306-45593-5.

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KEYWORDS: Impulse Signals, Short-Pulse, Ultra-Wideband, Array Antennas, Receivers, Conformal, Co-planar, Airborne

AF04-007 TITLE: Optical Fibers for High-Power, Mid-Infrared Laser Diodes Emitting in the 2.0 Micron to 5.0 Micron Wavelength Range

TECHNOLOGY AREAS: Materials/Processes, Sensors, Weapons

OBJECTIVE: Develop optical fibers for the transmission of high-power, mid-IR wavelengths in the 2.0 to 5.0 micron range.

DESCRIPTION: High-power, mid-IR diode lasers are highly relevant to defense and commercial applications. It is desirable to connect these lasers to existing systems using small-core optical fibers. Optical fibers for high-power sources operating at wavelengths in the 2.0 to 5.0 micron range are required to provide system flexibility and reduced cost. These fibers must transmit multiple wavelengths with low loss and survive megawatts per square centimeter powers over a 3 to 10 meter distance. The output from the fiber should be near diffraction limited for the designed wavelength range. The fibers should have high thresholds for thermal, bending and tensile stress. A polarization maintaining capability is also of interest. There are many important applications for fiber-coupled, mid-IR lasers. These applications include infrared countermeasures (IRCM), infrared imaging, target designation, trace gas sensing, and medical applications.

PHASE I: Fabricate small-core diameter optical fiber samples and characterize the numerical aperture, losses and other optical characteristics.

PHASE II: Optimize and demonstrate an optical fiber that delivers multiple wavelengths in the 2.0 to 5.0 micron range. Demonstrate low-loss, high-strength and high power capability. Prototype optical fibers will be delivered at the end of Phase II.

DUAL USE COMMERCIALIZATION: Fiber-coupled, high-power, mid-IR diode lasers have several military and civilian applications. IRCM, illumination, targeting, secure communications and sensing are important military applications for fiber-coupled lasers. Civilian applications include remote sensing and medical applications.

REFERENCES: 1. Y. Raichlin, E. Shulzinger, A. Millo and A. Katzir, "Fiberoptic Evanescent Wave Spectroscopy (FEWS) System and Its Application in Science, Industry, Medicine and Environmental Protection," 5th International Conference on Mid-Infrared Optoelectronic Materials and Devices, September 8-11, 2002.

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KEYWORDS: Optically Coupled Mid-IR Lasers, Fiber Coupling Mid-IR Lasers, Mid-IR Transmitting Optical Fibers

AF04-008 TITLE: Lightweight Optics for High Energy Applications

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics

OBJECTIVE: Develop high stiffness, lightweight, low cost mirror fabrication technology for tactical airborne and relay mirror beam control of high energy lasers.

DESCRIPTION: Current conventional lightweight optics with areal densities of 15-20kg/m2 have been developed in the 1 meter diameter category and diameters of 1.5 meter may be possible in the near term, but the optics have not demonstrated performance under high laser-fluence levels. Even lighter weight mirror systems are possible in the 15kg/m2 range using membrane mirror technology but these usually require active wave front compensation to correct intrinsic deformation or other induced deformation of the mirror or support structure. Currently, lightweight optics development efforts are not concerned with thermal induced deformation or damage initiation resulting from High Energy Laser (HEL) irradiation. The overall goal of this project is to reduce the areal density of large diameter mirror components while maintaining high quality wave front control for HEL applications. Lightweight optics capable of handling HEL irradiation can potentially benefit airborne and relay mirror systems in tactical missions. While significant progress has been made in lightweight mirror technology under the Advanced Mirror System Demonstrator and other programs, development challenges still exist in many areas necessary to material procurement, fabrication, testing and scaling. Technologies proposed should consider the following performance criteria: optical figure, surface roughness, stiffness, faceplate print-through, actuator control, aberration correction and band-width, thermal conductivity and thermal manage-ment, thermal expansion, areal density, fabrication cost.

Performance issues with HEL-coated lightweight optics are absolute reflectivity, absorption, coating durability, laser-induced degradation, coating uniformity, large area reflectivity.

PHASE I: Investigate lightweight technologies by developing a fabrication and metrology plan. Analyze and estimate performance capabilities with the performance criteria listed above as a guideline. Develop scaling estimates correlating size, weight, stiffness and cost as critical parameters.

PHASE II: Develop a prototype component or system with primary mirror of approximately 75-100cm diameter. Design and conduct mechanical and optical metrology to demonstrate the performance criteria above.

DUAL USE COMMERCIALIZATION: Lightweight large diameter optics have been identified as a key technology for the AFRL/ARMS Relay Mirror program, the airborne tactical laser (ATL) and space-based laser (SBL) systems. The Lasers and Space Optical Systems (LASSOS) study of 1999 identified lightweight optics as one of four key technologies for the employment of space-based relay systems. The HEL Joint Technology Office (JTO) also identified lightweight, deployable optics as essential for a practical and affordable operational SBL and other HEL beam control applications. Laser transmitters based on large lightweight mirrors will enable increased operational range or enhanced lethality on target. Since the transmitted laser spot size and hence the fluence on target depends on the transmitter aperture diameter, doubling the transmitter diameter will result in four times increase in fluence with appropriate turbulence compensation techniques. Doubling the transmitter diameter would also allow four times the reduction in laser power for equivalent fluence on target. Since system weight is a linear combination of laser and beam control component weight, lightweight optics enable systems designers to balance component weight and cost for maximum laser performance. Lightweight optics and coatings capable of withstanding high power solid state laser fluence are important in tactical beam control systems such as the Mobile Active Tracking for Integrated Experiments (MATRIX) program which will develop advanced beam control for the C-130 gunship. Lightweight optics not only reduce the weight of the primary but this translates into weight reductions in the gimbal system. In addition a lightweight pointing and tracking system enables rapid repointing and targeting and jitter stabilization, extremely important in a target rich tactical environment. Potential commercial applications include lightweight structures for space-based and ground-based astronomical telescope employment.

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KEYWORDS: Lightweight Optics, High Energy Lasers, Tactical Systems, High Energy Laser Coatings

AF04-009 TITLE: High Repetition Rate Pulsed Power Generators

TECHNOLOGY AREAS: Materials/Processes, Electronics, Weapons

OBJECTIVE: Develop compact, lightweight, high voltage pulsed power generators capable of delivering pulse repetition frequencies (PRFs) of several kHz into an approximately 100 ohm load.

DESCRIPTION: This effort will develop and demonstrate design concepts for a compact, lightweight, pulsed power generator system capable of delivering PRFs of 1-10 kHz at voltages ranging from 100-1000kV into an approximately 100 ohm load. Present pulsed power generators are generally centered around two primary technologies: resonant transformers and Marx generators. Whereas resonant transformer technology is capable of producing voltages on the order of 1 MV and PRFs of several kHz, they are generally heavy due to the large volume of insulating oil required. Marx generators, on the other hand, can be made very compact and lightweight, especially when designed to drive impulsive sources. However, their performance is usually limited to <100 Hz. It is desirable to develop lightweight pulsed power technology that will deliver higher PRFs. Precision triggering is also a desirable feature (trigger jitter < 10% of pulse risetime, for example).

PHASE I: Phase I will build and test a working model capable of at least 30 kV and 1 second bursts of fast PRF pulses and develop an initial commercialization concept and plan.

PHASE II: Requires the development and demonstration of a prototype high-PRF Marx generator capable of delivering the required output.

DUAL USE COMMERCIALIZATION: Military uses of this technology include airborne and ground-based pulsed radar systems and high power microwave systems. Civilian sector applications include pulsed radar, counter mine and numerous manufacturing applications.

REFERENCES: 1. J.R Mayes and W.J. Carey, "Sub-nanosecond Jitter Operation of Marx Generators," Proc. International Pulsed Power Conference, 2001.

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3. C. E. Baum and J. M. Lehr, "Charging of Marx Generators," CESDN 43, Air Force Research Laboratory/DEHP, 1 September 2000.

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5. F.E. Peterkin, et al., "Modular Compact Marx Generator," Proc. AMEREM 2002 Conference, Annapolis MD, June 2002.

KEYWORDS: Marx Generator, Pulsed Power, High Voltage, High Repetition Rate, High Power Microwave

AF04-010 TITLE: <u>High Brightness Mid-Infrared (2-6 Micron) Semiconductor Laser Development</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop the next generation of high brightness two to six micron semiconductor laser diodes and laser diode arrays.

DESCRIPTION: High power mid-IR diode arrays have recently been demonstrated and play a key role as pump sources for longer-wavelength optically pumped lasers (e.g,- 3 to 6 micron lasers). However, since the primary interest of the commercial diode industry is in telecommunication lasers, which operate in the near-IR (below 1.5 micron), there are no commercial vendors for high power mid-IR laser diodes or laser diode arrays. In fact, companies that recently were able to provide mid-IR diodes and diode arrays no longer do so. Consequently, the next generation of this important class of diode lasers is not being developed. Further, research and development of near-IR semiconductor lasers has not "jump-started" progress in mid-IR semiconductor lasers since the materials are, often, entirely different. The aim of this SBIR effort will be to encourage the development and manufacture of high power laser diodes, laser diode arrays, and advanced high power architectures that emit in the 2 to 6 micron region. There are many important applications for intense, coherent, mid-infrared, diode laser sources including infrared countermeasures, secure communications, infrared imaging, target designation, trace gas sensing and identify friend or foe (IFF). A major military application, that requires relatively high power, is infrared-countermeasures (IRCM). In recent military conflicts, about 85% of the air-combat losses were from surface-to-air-missiles (SAMs). The effective-ness of SAMS, coupled with their low cost, indicates the necessity of equally effective IRCM systems. The urgency for developing cost effective IRCM systems has been compounded by the potential for attacks against commercial aviation. Certainly, IRCM systems based on high power, compact, and rugged mid-IR diodes or diode arrays are top candidates to fill this role.

PHASE I: Investigate and specify epitaxial materials to be used for the crystal growth of high power mid-infrared (2-6 um)laser material. Fabricate and test a mid-IR laser diode, laser diode array or other high power semiconductor diode.

PHASE II: Grow and optimize 2-6 micron materials for inclusion in high-power 2-6 um linear diode arrays and other high brightness architectures. Several prototype laser diodes, laser diode arrays or other high power diode architectures, to include fast-axis collimation optics, shall be developed and characterized.

DUAL USE COMMERCIALIZATION: High power mid-IR diode lasers have several military and civilian applications. The military applications include infrared countermeasures (IRCM), illumination, targeting, collision avoidance, IFF, secure communication, and Weapons of Mass Destruction detection. The civilian applications include optical pumps for mid-IR lasers, sources for long-baseline remote sensing, marking, and medical applications.

REFERENCES: 1. R. Kaspi, et.al. "High power and high brightness from an optically pumped InAs/InGaSb type-II midinfrared laser with low confinement", Appl. Phys. Lett., 81(3), 406, 2002.

2. C. Felix, et. al. “Near room-temperature midinfrared interband cascade laser”, Appl. Phys. Lett., 74(4), 628, 1999.

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4. B. Lane, et. al., “High Power InAsSb/InAsSbP electrical injection laser diodes emitting between 3 and 5 microns”, Materials Sci. and Engin. B-Solid State Materials for Advanced Technology, 74(1-3), 52, 2000.

KEYWORDS: Mid-Infrared Semiconductor Laser, Optically Pumped Semiconductor Laser, W Laser, Gallium Antimonide, IRCM

AF04-015 TITLE: Advanced Algorithms for Exploitation of Space-Based Imagery to Detect Targets against Structured Earth Backgrounds

TECHNOLOGY AREAS: Information Systems, Space Platforms

OBJECTIVE: Develop innovative algorithms to optimize techniques for detection, identification and tracking of objects in images taken from space-based sensors of targets against structured Earth backgrounds.

DESCRIPTION: The Air Force Research Laboratory's Advanced Optical Technologies Branch (AFRL/VSBT) is interested in innovative, effective and computationally efficient techniques to optimize the performance of space-based optical (ultraviolet/visible/infrared) imaging systems to detect targets against structured Earth backgrounds. 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 proposals will exploit these databases to explore potential space-based techniques for clutter-mitigation/contrast-enhancement techniques to develop, validate and optimize signature-based object-detection algorithms. 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 object detection in structured backgrounds and reduced false-alarm rates.

PHASE I: Conduct analyses, using real data, to develop algorithms for clutter-mitigation/contrast-enhancement techniques to optimize object detection, search and track capabilities in imagery collected from space-based sensors of targets viewed against structured Earth backgrounds. Compare and contrast the candidate algorithms.

PHASE II: Perform detailed analyses and demonstrate the efficacy of algorithms for target detection, search and track in structured Earth backgrounds. 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.

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

REFERENCES: 1. Algorithms for multispectral and hyperspectral imagery, SPIE Conference Proceedings, Orlando, FL, Apr 1994, A.E. Iverson, ed.

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3. Thermal imagery spectral analysis, B.H. Collins et al.., Proceedings of the SPIE Meeting, San Diego, CA, 28-30 Jul 1997, "Imaging spectrometry III", p. 94-105.

4. Target detection in a forest environment using. spectral imagery, R.C. Olsen et al., Proceedings of the SPIE Meeting, San Diego, CA, 28 -30 Jul. 1997, "Imaging Spectrometry III", pp. 46-56.

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KEYWORDS: Multi-Spectral, Hyper-Spectral, Ultra-Spectral, Ultraviolet, Visible, Infrared, Data Analysis, Data Processing, Algorithms

AF04-017 TITLE: Advanced Cost Model for Space Concepts Development

TECHNOLOGY AREAS: Materials/Processes, Space Platforms, Weapons

OBJECTIVE: Develop and demonstrate an advanced life cycle cost model for transformational space concepts development.

DESCRIPTION: An advanced cost prediction model, not based on extrapolation of current technology trends, is needed to reflect the technology readiness level (TRL) of new space technologies required to enable future space concepts and ultimately operational space systems. Innovative cost estimating techniques are required because existing, traditional cost modeling techniques do not provide adequate insight into the impacts of the application of emerging or maturing technologies to the transformational space concepts. Typically, current cost models estimate the cost benefits or penalties of an emerging technology by using prediction methods based on component weight, power, or other parameters extrapolated from current state- of-the -art. Such techniques may be adequate for the continued advancement of evolving technologies but generally miss the mark for low TRL or immature technologies, resulting in under estimating the Life Cycle Cost (LCC) for transformational space concepts due to the non linear TRL evolution relationship. Long range planning dictates that the Air Force Space Command planners prioritize the development of space technologies very early in their maturation cycle; as early as during conceptual or preliminary design to forecast future space system LCC as much as 18 to 25 years into the future. The advanced cost estimating model should address the cost impact of the TRL progression required to support future space concepts. An advanced cost-estimating model addressing the cost impacts for the various TRLs is required to support transformational space concepts in cost effectiveness assessments, AOAS, concept selection, investment analysis and other key decisions points.

PHASE I: Perform in-depth case studies analysis to identify the cost assessment problems of space programs that have experienced major cost growth. The AF will provide case study material based on current and historical Program Office estimates and actual costs. Focusing on Responsive Spacelift and Advanced Space Sensors, assess the impact of TRLs at the inception of these programs and determine the level of system cost growth attributed to the maturity and applicability factors. Based on the findings, define and document a strategy to develop an advanced LCC estimating model for transformational space concepts.

PHASE II: Develop a prototype advanced cost-estimating software tool to support the LCC planning and budgeting of future space concepts and operational system architectures while accounting for the cost of technology investment required to evolve the TRL. Demonstrate the feasibility and applicability to an ongoing space program. Further refine the advanced cost-estimating model through prototype iterations. Demonstrate the utility and effectiveness of the cost estimating methodology/model by applying it to two AF provided cases, Responsive Spacelift and Advanced Space Sensors. Evaluate the demonstration results and document.

DUAL USE COMMERCIALIZATION: The tool developed under this effort has diverse military and commercial applications. Military and commercial planning and budgeting activities that need to forecast the LCC of future systems that depend on technology development could benefit from this cost-estimating tool. Target areas include military and non-military satellite programs, ground systems, communication, aircraft, as well as non-aerospace applications.

REFERENCES: 1. DoDD 5000.1 “The Defense Acquisition System,” 12 May 2003.

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KEYWORDS: Advanced Cost Model, Technology Readiness Level, Transformational Space Concepts, Subsystems, Cost Estimating, Cost Analysis

AF04-018 TITLE: Light Weight, Low Volume Deployable Antenna Structures

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop lightweight, low cost, and low volume deployable antenna structures for use with an Electronically Scanned Array (ESA) and other large aperture space applications.

DESCRIPTION: Future space-borne Intelligence, Surveillance, and Reconnaissance (ISR) systems, such as the Space Based Radar (SBR) system, will require larger apertures as the demand for high-resolution imagery and tracking products increases. Critical to meeting this need is the effective power-aperture placed on orbit. As spacecraft are severely power limited, aperture is the obvious trade space for increasing performance. Needed is a lightweight and low volume antenna structure that will enable an effective stowage capability. This capability will allow volume savings, thereby possibly allowing more spacecraft per launch vehicle. Thus, not only is increased spacecraft performance acquired, but also reduced mission cost as more spacecraft may be launched per launch vehicle. The antenna structure must be simple in design to increase reliability while deploying and must take advantage of “new age” materials for maximal strength and minimal weight and volume.

PHASE I: Develop designs and technologies for lightweight, low cost, and low volume deployable space antennas. The following factors should be considered: 1. materials effects in the space environment, 2. ability to simulate structural integrity throughout mission phases, 3. ability to model launch, deployment, and operations phases of spacecraft at multiple altitudes. The design should ensure performance of antenna (deformation, jittering, relaxation time) given realistic space environmental and materials factors. Recommend materials, structural components and design, and deployment methodology to ensure mission success.

PHASE II: Use engineering model and simulation data to build and test a subscale antenna. The test should characterize the performance of the antenna system throughout its mission phases.

DUAL USE COMMERCIALIZATION: Improvements in space-qualified antenna structures will serve the DoD, intelligence community, National Aeronautics and Space, and commercial ventures by allowing more effective power apertures to be placed on orbit. Specifically, these technologies have great benefit to space-based radar systems, communication satellites, space-based missile defense systems, and space-based surveillance systems.

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KEYWORDS: Antenna Structures, Materials, Deployment

AF04-019 TITLE: Multiband Laser Communications

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop capability for wavelength division multiplexing and multiband optical communications.

DESCRIPTION: Military Satellite Communications is currently pursuing laser communications as a means of meeting the projected bandwidth requirements of tomorrow's warfighters. Laser communications are being considered for a wide range of applications including UAV (unmanned air vehicles) satellite links and satellite-to-satellite crosslinks. Single wavelength laser communications have several disadvantages (when compared to multiband communications) including susceptibility to jamming and reduced data transfer rate. Advantages of multi-wavelength laser communications transmissions include separating data and increasing the data transfer rate. Multiband laser communications might also enable "wavelength hopping" in which the wavelength is periodically changed during transmissions to improve transmission security. The purpose of this topic is to develop and demonstrate a laser communications link capable of operating on two or more wavelengths, wherein continuous (on-going) communication is maintained when the transmission wavelengths are altered from one to another.

PHASE I: Design/develop a multiband laser communications link. Provide a sub-scale demonstration of the innovative technique/device to prove operational feasibility of the concept. Document operational results and address future issues as to (among others) scalability, fault tolerance, control systems capable of random change of transmission wavelength during communication, and security reliability.

PHASE II: Fabricate a complete, operationally functional, 'multiband laser communications link' device (based upon selected Phase I technologies) capable of (laboratory based) military lasercom operation. Performance test this device under a full suite of environmental extremes, in addition to (among others) communications capacity, operational life, fault tolerance and security reliability. Document results.

DUAL USE COMMERCIALIZATION: Results from this project will apply to military missions requiring high security, high capacity communications and civilian applications such as mobile telephony, secure business/government communications, etc.

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KEYWORDS: Lasercom, Secure Communications, Multiband, Wavelength, Electro-Optical, Detectors

AF04-020 TITLE: Radiation Hardened, Low Power Digital Signal Processors

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

OBJECTIVE: Develop a low cost and low power Digital Signal Processor (DSP) architecture for use with high performance space applications.

DESCRIPTION: Future space-borne Intelligence, Surveillance, and Reconnaissance (ISR) systems, such as the Space Based Radar (SBR) system, will require space qualified, radiation hardened, high throughput DSPs to ensure data latency to the user. A critical component of space-borne systems' heterogeneous on-board processors will be the high throughput processing elements. Given the size, weight, and, especially, power constraints, these processing elements must be highly efficient while also radiation hardened. Both Single Event Effects (SEEs) and Total Ionization Dose (TID) requirements must be met by these operational systems. This SBIR will focus on the definition, development, and performance verification of a high performance, programmable DSP architecture that will enable future transformational space systems. Results will include the simulation of hardware and algorithms, development and fabrication of integrated circuit hardware, and verification of performance. This DSP is the first attempt at providing a scalable, embeddable and design hardened processor portable to evolvable electronic device processing technology.

PHASE I: Identify a highly efficient, hardened architecture. Simulate and model performance effects of the processor in different environments. Model the efficiency and throughput characteristics with radar processing algorithms, including Space Time Adaptive Processing (STAP) and Space Frequency Adaptive Processing (SFAP). Using state-of-the-art, space qualified (or qualifiable) integrated circuit processors, develop a scalable and programmable DSP element architecture. A large amount of on-chip memory is desirable for achieving highly efficient, backend signal processing (e.g., radar signal processing). Future ISR systems will require in excess of 5 GFLOPS/s (32-bit floating point arithmetic) per Watt for functions like STAP, Doppler processing, image formation, Constant False Alarm Rate (CFAR), and target position estimation.

PHASE II: Using a Very Large Scale Integration Computer Aided Design tool suite with Very High speed Integrated Circuit Hardware Description Language modeling, fabricate the programmable DSP element in a space qualified integrated circuit process. Use MATLAB software like a tool to develop and verify the radar processing algorithms and performance. Use software development tools to code the programmable DSP element radar signal processing functions. Verify the programmable DSP element performance by using simulated and actual data (if available), executing various radar signal processing functions on prototype hardware.

DUAL USE COMMERCIALIZATION: Improvements in hardened DSP architectures will serve the DoD, NASA, and commercial space ventures. As examples for National Aeronautics and Space Administration and commercial purposes, high throughput DSP architectures are needed for communications systems (channelizers, etc.). NASA may use the DSP architecture for Earth Observing (EO) program or Deep Space Program satellites as a method to reduce required throughput and bandwidth through Tracking and Data Relay Satellite System. Radiation hardened DSP migration to support floating point software applications needs to exceed a billion operations per second. This device architecture must scale to apply for future military or commercial space missions that include space based radar or ultra wide band communications. The benefits will reduce power, weight and size while improving performance and reducing cost for these space processing intensive applications."communications systems (channelizers, etc.). NASA may use the DSP architecture for Earth Observing (EO) program or Deep Space Program satellites as a method to reduce required throughput and bandwidth through Tracking and Data Relay Satellite System.

REFERENCES: 1. Prado, E. R. and Prewitt, J. P., "A High Performance COTS Based Vector Processor for Space," 2000 IEEE Aerospace Conference Proceedings, 18-25 March 2000, Big Sky MT, USA, vol. 5 pp. 227-233.

2. Belasic, M., Bezerra, F. and Rouxel, G., "Evaluation of the Digital Signal Processor TSC21020F from the Manufacturer TEMIC Semiconductors MHS for Space Applications," European Space Components Conference, ESCCON 2000, 21-23 March 2000, Noordwijk, Netherlands, pp. 239-245.

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KEYWORDS: DSP, High Performance Processing, High Throughput, Radar Signal Processing Algorithms, Radiation Hardened

AF04-021 TITLE: Light Weight, High Density Space Qualified Bulk Memory

TECHNOLOGY AREAS: Information Systems, Space Platforms

OBJECTIVE: Develop an on-board mass storage memory product that focuses on reducing weight, power, volume and cost of existing solutions. Advanced packaging solutions, innovative chip or memory system architectures, or incorporation of emerging technologies may be used to meet this objective for high memory requirement space applications.

DESCRIPTION: Future space-borne Intelligence, Surveillance, and Reconnaissance (ISR) systems, such as the Space Based Radar (SBR) system, will have large On-Board storage requirements. The ability to store and process data on-board will enable near real time dissemination to the user and reach-back to Continental United States for enhanced mission processing. Further, storage will allow longer operational periods without required down-linking, thereby increasing mission effectiveness. Critical to meeting this need is low-power, low-volume, lightweight bulk memory. Write/read speed and volatility will directly affect the overall system usefulness of the bulk memory system. Finally, these memory systems must be able to either resist or efficiently correct for radiation effects, such as ionizing dose and single event effects. Proposals must describe the variety of tradeoffs that are possible for memory solutions, and provide an innovative approach to meet system memory needs. In addition, while the focus of this topic is on performance and not radiation hardening, proposals must show an understanding of space radiation environments on electronics.

PHASE I: With a target of 10 TBytes or greater, research the most effective and reliable memory system. Analyze memory stack technologies and architectures. Evaluate most effective chip technologies (Static Random Access Memory (SRAM), Dynamic Random Access Memory (DRAM); volatile, nonvolatile; solid-state, hard disk). Research sources for memory and advanced packaging technologies. Recommend architecture, technologies, designed support electronics, size, weight and power estimates. Develop a modular Mass Data Storage (MDS) system architecture to support a range of input data rates, memory capacities and size, weight power allocations. For memory system single event effects mitigation beyond chip-level Single Event Upset hardness, there is a preference for fault tolerance using efficient error detection and correction coding techniques such as Reed Solomon rather than expensive block redundancy schemes. Also, redundant Input/Output and controller shall be explored. Target goals of 200 watts of power dissipation per Terabyte of memory storage should be evaluated. High density packaging techniques such as 3-D memory die stacking, wafer scale integration, or multichip packages shall also be explored. Target input data rates are on the order of 20 Gbits per second.

PHASE II: Based on Phase I results, fabricate mass memory elements (stacks, multichip modules, etc.) and evaluate all key components in a relative environment. Demonstrate an integrated system to at least 500 Gbytes and a input date rate of at least 10 Gbits per second. Verify power and volume requirements to meet 1Tbyte memory needs through analysis or modeling.

DUAL USE COMMERCIALIZATION: Improvements in space qualified memory systems are a pervasive need for satellite systems and will serve the DoD, Intelligence Community, National Aeronautics and Space Administration, and commercial ventures by allowing more data to be collected and maximizing operational efficiency of the collecting space system.

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KEYWORDS: SRAM, DRAM, Solid-State, Storage, On-Board Storage

AF04-022 TITLE: Integrated Multi-Sensor System for Space Object Tracking, Imaging and Characterization

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

OBJECTIVE: Develop and demonstrate an integrated multi-sensor system concept for high-resolution tracking, imaging and characterization of long-range space/air objects.

DESCRIPTION: Tracking and characterization of space objects from ground, or airplane, based sensor several thousands kilometers away are difficult technical challenges for any space/air surveillance and control mission. This is due to the great distances involved, the high speed of the object, and the variations in its trajectory. Available radar techniques provide a tracking resolution much below the required accuracy. Thus optical sensors are often employed to meet the performance requirements. The objective of this solicitation is to develop an innovative system concept of ground/air-based surveillance system with integrated laser tracking and multi-spectral infrared sensing that would provide high-resolution tracking, three-dimensional imaging and characterization of space/air objects with down range resolution of 1 cm and velocity measurement accuracy of 1-10 cm/sec. It will allow for high-accuracy measurements of temporal variations of spatial and spectral parameters in terms of object velocity, shape and temperature to characterize and assess the nature and intent of the object. Both passive and active discrimination techniques could be employed to achieve maximum synergy between spatial and spectral measurements. The system is used to support precise aiming point determination and other space/air control/protection functions. Because there may be several dozens of space targets with different orbital parameters in engagement concurrently, the sensor should be able to switch between multiple targets very rapidly. Thus adaptive optics may not be applicable or cost effective in this operating environment. Nonlinear optics using phase conjugation method that can lock onto a space target with self-steering capability may simplify the system substantially with smaller form factors at much lower cost and make it suitable for airborne platform application.

PHASE I: A broad range of candidate design concepts with non-linear optical phase conjugation to integrate active and passive sensors shall be exploited and assessed. Key system parameters are analyzed and characterized. Operational limits and constraints against various space/air control and protection scenarios will be identified and the projected performance envelop is estimated. System architecture and design trades will be conducted to synthesize an optimal system concept to be recommended for more detailed Phase II design, prototyping and demonstration. A detailed technical report and a briefing on the proposed system architecture, preliminary design, concept of operations, enabling technologies and development roadmap, and a transition plan to space/air control system implementation will be provided.

PHASE II: Fabricate, integrate, and assemble a prototype of the integrated multi-sensor prototype to demonstrate its operating principle and validate its performance in a turbulent atmospheric environment. Define an application and transition plan for a full-scale system level demonstration of its operability and transferability for space control and protection application will be provided.

DUAL USE COMMERCIALIZATION: Successful demonstration and validation of the concept in Phase II will be transitioned to a series of system level demonstrations for eventual incorporation into a future space/air control system to interrupt or degrade space/air threats in defending our space/air services. This integrated multi-sensor system can improve the accuracy and efficiency of commercial satellite launch and operations, air traffic control and laser communication.

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KEYWORDS: Space Control and Protection, Integrated Multi-Sensor System, Three-Dimensional Imaging Phase Conjugation, Tracking and Characterization of Space Objects, Nonlinear Optics, Phase Conjugation.

AF04-023 TITLE: <u>High-Efficiency Phased -Array Antenna Power Amplifier Modules</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop high efficiency solid-state power amplifier modules for application in multi-carrier components for spaceborne phased-array transmit antennas.

DESCRIPTION: This program addresses the need for simultaneous transmission of multiple carriers in Radio Frequency power amplifier chains through the development and implementation of discrete power amplifier modules. Discrete power amplifier modules (PAM), suitable for being implanted in microwave integrated circuit (MIC) structures, will be used to demonstrate the desired performance enhancement. The power output of interest is between 0.1 and 1.0 watts with an input power of approximately ten milliwatts. Future applications will include military satellites such as Transformational Communications program and future surveillance systems such as Space-Based Radar, as well as commercial satellites operating in the 20 GHz transmit (downlink) band. Since multiple modulated carriers will be applied to the modules, the reduction of inter-modulation products is thought to be one of the key issues and should be considered. Potential voltage peaks that could cause device degradation as a consequence of beat frequencies should also be considered a one of the reliability issues. Compensation techniques may be required to meet performance goals. The compensation techniques to be considered include, but are not limited to, the following: 1) automatic gain and level control to maximize efficiency with minimum intermodulation products, 2) a predistortion network to improve linearity and phase matching, 3) wideband characteristics to enhance phase matching, and 4) temperature compensation circuits.

PHASE I: Develop innovative approaches to enable high efficiency solid-state amplifier modules for future spaceborne phased-array transmit antennas. Demonstrate feasibility of developed approaches via modeling, simulation and/or brass-board experimental techniques. Conduct system analysis to "qualify" potential benefit to both military and commercial communication systems.

PHASE II: Validate proposed approaches via appropriate design, simulation and fabrication of prototype components to demonstrate performance capabilities of new approaches. Build the necessary PAM/MIC hardware and perform adequate demonstrations/testing to show that the contractor has achieved a significant improvement in amplifier performance with regard to efficiency, linearity, phase matching, temperature stability, and reliability through the use of compensating circuitry. Transition of program results to Monolithic Microwave Integrated Circuit (MMIC) technology to show compatibility with current module developments may be described and considered if appropriate within the scope of a phase II effort.

DUAL USE COMMERCIALIZATION: Phased arrays are receiving considerable attention in both the military and commercial space communications communities. The downlink transmit band at approximately 20 GHz is allocated to both types of service. Accordingly, the effort proposed is directly applicable to many systems under serious consideration for future deployment that involve multiple carrier transmission and in which the reduction of inter-modulation products is a key requirement.

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KEYWORDS: Solid-State Amplifiers, Linearizers, Phased Arrays, Antennas, Inter-Modulation Products, Microwave

AF04-024 TITLE: Multi-Beam Phased-Array Antenna Beamformers

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop phased-array antenna beamformer architectures that enable multiple/simultaneous beams of moderate to high bandwidth.

DESCRIPTION: Phased-array antennas offer significant advantages to communications systems. For example, since the power-aperture product determines performance, a communications system with a large antenna may transmit low radio frequency (RF) power. If the large antenna is a phased-array antenna, design of the receive beamformer (and transmit RF signal distribution) presents several challenges. First, the phased-array antenna must maintain a minimum bandwidth at large off-broadside scanning angles. Second, the beamformer weight per square meter of aperture must be relatively low so that the weight of the large antenna does not exceed specified limitations. Third, the beamformer must support the use of multiple simultaneous search beams. Since the beamwidth is very narrow, communications with a very large antenna requires multiple simultaneous search beams in order to fully search a sector within a specified time. The Air Force is interested in the research and development of innovative phased-array antenna beamformer architecture. In addition to the receive beamformer, all approaches must also consider the transmit signal distribution and the distribution of control signals for beamsteering and calibration. Space feeds are of particular interest due to their potentially minimal weight. Optical beamformers, digital beamformers, and hybrid approaches are also of interest. It should be assumed that the antenna is an active array, operating in the L, S, or X communications bands. The antenna sizes of interest are 40,000 to 400,000 elements. The minimum desired bandwidth is 10 MHz, when scanned 60° off broadsides, to support normal search and track operations. Approaches supporting bandwidths close to 600 MHz at S- band or 1,500 MHz at X-band are desirable (but not required) to support target identification. Average radiated power should be assumed to be in the range of 3 to 30 Watts per square meter of antenna, with roughly a 0.10 duty factor. The multi-beam approaches may utilize a spoiled transmit beam, and should support from 4 to 16 simultaneous beams.

PHASE I: Develop one or more beamformer architectures, including identification of the types of components recommended. Use analysis and simulation to illustrate and quantify performance of the proposed approaches. Produce a transmit loss budget, a receive G/T (Gain/Temperature) budget, and directivity patterns. Quantify the bandwidth, and estimate the weight. Address other performance issues that are unique to the architecture.

PHASE II: Fabricate and demonstrate samples of the critical components of the selected Phase I beamformer. Combine demonstrated results with analysis and simulation to illustrate large array beamsteering, transmit loss, receive G/T, directivity patterns, and bandwidth. Validate that the beamsteering timing and control supports typical communications track functions

DUAL USE COMMERCIALIZATION: The technology developed under this effort is directly applicable to phased-array antennas used for communications, in both commercial and military applications. Use of large antennas in a communications link increases the transmit gain and the receive power-collecting area. This enables increased data rates; decreased error rates; lower transmit power; and higher receive noise temperature.

REFERENCES:

KEYWORDS: Communications, Radar, Antenna, Phased-Array, Beamformer, Space Feeds, Beamsteering

AF04-025 TITLE: Novel Methods to Improve Efficiency of Copper-Indium-Gallium-diSelenide Solar Cells

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: Increase the efficiency of Copper-Indium-Gallium-diSelemnide thin-film solar cells through novel processing schemes or materials.

DESCRIPTION: Flexible Thin-Film Photovoltaics (FTFPV) are a revolutionary new solar power generation technology that, combined with lightweight array support structures being designed, promises a 5X reduction in solar array cost, a 5X reduction in stowed volume, and increased radiation resistance compared to state-of-the-art rigid panel solar arrays. In trade studies for a 20 kW GEO (Geosynchronous Earth Orbit) mission, these advantages have been found to hold despite the 2.5-times larger size of FTFPV arrays. These conservative calculations show that rigid panel arrays are limited to <110 W/kg, even with 35% efficient solar cells, while thin-film solar arrays on metal foil substrates will yield >160 W/kg, at end-of-life. FTFPV on reduced mass substrates will result in even higher specific power levels, but maximum specific power requires both lightweight substrates and increases in efficiency beyond the 8-10% AM0 (Air Mass Zero) efficiency typically found currently for large area FTFPV. Opportunities for increased efficiency of FTFPV remain. Copper-Indium-Gallium-diSelenide (CIGS) thin-film solar cells (and other alloys of Copper-Indium-Gallium-diSelemnide) show promise for efficiencies of 15-20%, and laboratory-scale 15% AM0 efficiency cells have been demonstrated. However, efficiencies typically decline as cell size increases, and innovative designs are needed to boost performance. The bandgap of CIGS cells has not increased substantially above 1 eV, far from optimal for the solar spectrum. Ga (Gallium) has been added to CIS (Copper-Indium-diSelenide) but this has increased open circuit voltages less than expected. Partial replacement of Se (diSelenide) with S (Sulfide) to increase the bandgap has been achieved with some success. CIGS multijunction cells have not yet been successfully fabricated.

Potential methods of achieving increased efficiency are alloying to increase the material bandgap or novel processing schemes that avoid undesirable compositional changes at the CIGS/CdS (Copper-Indium-Gallium-diSelenide/Cadmium Sulfide) interface. Other innovative methods expected to result in large area CIGS solar cells with efficiencies >15% AM0 are also sought. The processing methods proposed must be capable of depositing the cells on high temperature polymers or lightweight metal foils for space FTFPV arrays of high specific power.

PHASE I: Develop innovative methods for increasing the efficiency of CIGS cells by increasing the cell bandgap, producing a multijunction cell or, improving processing. Phase I will demonstrate the feasibility of the proposed design/processing scheme. The method should be economical with respect to processing conditions and material use and must be capable of production scale-up.

PHASE II: Finalize development of all deposition processes necessary to demonstrate the feasibility of the design developed during Phase I (in a laboratory environment). Demonstrate the feasibility of using the resultant process for fabrication of a candidate thin- film solar cell array. Large area CIGS solar cells will be provided to the Air Force Research Laboratory for evaluation.

DUAL USE COMMERCIALIZATION: Dual use commercialization would occur through the development of the technology, and the process must yield a competitive cost per watt, watt per kilogram, and long-lived solar arrays available for DoD and commercial space systems. The demand for DoD space systems is strong.

REFERENCES: 1. K. Kushiya, "Improvement of electrical yield in the fabrication of CIGS-based thin-film modules," Thin Solid Films, vol. 387, 2001, pp. 257-261.

2. T. Negami, Y. Hashimoto, S. Nishiwaki, "Cu(In,Ga)Se2 thin-film solar cells with an efficiency of 18%," Solar Energy Materials & Solar Cells, vol. 67, 2001, pp. 331-335.

KEYWORDS: Satellite Electrical Power, Power Generation, Solar Cells, Thin-Film Photovoltaics, Conversion Efficiency, Photovoltaics, CIS, CIGS

AF04-026 TITLE: Multifunctional Phased Array Antenna Modules

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop and demonstrate high efficiency, phased-array antenna with integrated energy storage and enhanced array pointing precision.

DESCRIPTION: Current spaceborne communication and surveillance spacecraft employ sophisticated, single purpose phased-array antennae for transmission (and/or reception) of RF (Radio Frequency) energy. Integral to the performance of these devices are the separate power and thermal management subsystems, typically developed independently as part of the spacecraft bus. Precise pointing requirements for both communications and surveillance require precise knowledge and control of dimensional tolerances that are adversely affected by thermal distortions induced by waste heat from RF components. Because phased array antennas typically occupy large areas that tend to radiate heat rapidly in space, keeping transmit/receive modules warm enough is usually of more concern than keeping them cool. Power distribution for large phased-array antennas may entail power transmission over relatively large distances that in turn lead to high power distribution losses and inefficient spacecraft operation. The combined effect of pointing requirements, thermal management and power distribution tend to increase the overall weight of the "assembled" spacecraft. Significant reductions in spacecraft weight may be enabled by direct integration of power and thermal management functions at the component level of the phased array. The objective of this project is to develop technology that enables energy storage and thermal management at the components level of transmit/receive antenna modules. Potential system level benefits of this technology would be mass reduction and/or affordability improvement through higher level integration of payload with supporting technologies.

PHASE I: Develop and demonstrate innovative electronic packaging concepts to enable the integration of energy storage and thermal management is conventional phased- array transmit/receive antenna subsystems that will provide significant overall spacecraft mass reduction. Invent, develop, and demonstrate of proof-of-principle breadboard designs that enable integration of energy storage and thermal management into transmit/receive antenna module (TRAM) devices. Conduct concept designs, thermal analysis and energy management/thermal vacuum experiments (if appropriate and as needed) to 1) demonstrate applicability of the multifunctional phased-array antenna architecture to communications and surveillance systems of interest to the Air Force and DoD, 2) validate concept feability in representative operating environments through appropriate modeling and/or experiments, and 3) demonstrate system level benefit in terms of antenna mass/unit area of the proposed multifunctional phased- array antenna.

PHASE II: Develop and demonstrate sub-scale RF transmit/receive phased-array antenna incorporating integrated energy storage and thermal management modules. Validate RF performance using appropriate ground simulation and testing.

DUAL USE COMMERCIALIZATION: Application of this technology would permit next generation commercial satellite communication systems to display higher efficiency RF operation and higher transmitted output with existing energy generation technologies.

REFERENCES: 1. Harvey, Tim, "The Use of Neural Networks in A Smart Battery Charger," University of Missouri-Rolla, 1995.

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KEYWORDS: Phased Array Antennas, Multifunctional Structures, Energy Storage, Power Distribution, TRAM, Thermal Management

AF04-027 TITLE: <u>Encryption, Decryption Field Programmable Gate Array Using Specialized Software</u>

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

OBJECTIVE: Develop reconfigurable hardware and software tools to support FPGAs optimized for advanced encryption/decryption algorithms.

DESCRIPTION: Communications security (COMSEC) is essential to commercial and military satellite communications links. As encryption/decryption computer platforms such as supercomputers and quantum computers become more capable and exhibit greater computing speed, existing encryption/decryption algorithms can become obsolete. This opens opportunity for more sophisticated algorithms and integrated circuits to commensurate with increased computer capability and greater computing speed. Continuing developments in reconfigurable computing and Field Programmable Gate Array (FPGA) technology advance the potential for application of FPGA-supported, reconfigurable logic as a replacement for spacecraft-based, hardwired Application Specific Integrated Circuit (ASIC) chip systems. The purpose of this topic is to exploit advances in FPGAs and associated software tools to develop advanced encryption/decryption algorithms. The primary goal is maximize throughput (parallelism is possible), while maintaining flexibility in protocols for encryption/decryption with maximum growth in the future. If possible, the SBIR seeks a breakthrough domain-specific FPGA technology that is rad-hard. It is also possible to consider a wider range of possibilities, such as using high-density FPGAs that are commercially available by using a combination of supplemental circuitry, design techniques, and programming tools. Approaches that maintain capability while ensuring resilience to radiation effects, including total dose, latch-up, single event upset and dose rate are most highly sought after.

PHASE I: Develop a feasible basis for an FPGA architecture and approach for efficient identification and migration of encryption / decryption algorithms. If a domain-specific architecture is proposed, identify the process technology and steps taken to ensure radiation hardness (through design and/or process).

PHASE II: Extend Phase I results to develop a feasibility demonstration, capable of implementing extremely high-throughput encryption / decryption algorithms (plural). Demonstrate ability to perform in the presence of single event effects. Also demonstrate the ability to easily up-grade algorithms within system. Plan and conduct a demonstration of a mutually agreed-upon, government-furnished unclassified encryption and decryption algorithm using the prototype FPGA. Demonstration must include throughput and implementation of a government/contractor agreed, government supplied encryption and decryption algorithm.

DUAL USE COMMERCIALIZATION: Commercial applications of encryption technology include banking transactions, transfers of data containing proprietary information, and medical records, or, in general, digital rights management and privacy protection. Military applications include encryption for satellite and terrestrial communications systems. In design, the protection of intellectual property is an important common concern.

REFERENCES: 1. Mosanya, E et.al. "CryptoBooster: A Reconfigurable and Modular Crytptographic Coprocesor," Crytopgraphic Hardware and Embedded Systems, 1999, v. 1717,p.246-256.

2. Karri, R.et.al. "Fault-Based Side-Channel Cryptanalysis Tolerant Rijndael Symmetric Block Cipher Architecture," IEEE International Workshop on Defect and Fault Tolerance in VLSI Systems; 2001; p. 427-435.

3. Kean, Tom, "Crytographic Rights Management of FPGA Intellectual Property Cores," Algotronix Ltd, 2002.

4. Kean, Tom, "Secure Configuration of Field Programmable Gate Arrays," Proceedings of IPL 2001, Belfast, UK.

KEYWORDS: Encryption, Algorithm, Applications Specific Integrated Circuit, Microcomputer, Communications Security, Field Programmable Gate Array

AF04-028 TITLE: MicroElectroMechanical Systems Based Electronically Steerable Antenna

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop and demonstrate a MicroElectroMechanical Systems based electronically steerable antenna.

DESCRIPTION: Phased array antennas have several advantages over mechanically steered antennas. They are lighter in weight, more agile, and induce no angular momentum to the satellite when redirecting the beam. Phased array antennas have traditionally used MMIC (Monolithic Microwave Integrated Circuit) phase shifters, which have two key weaknesses. They can contribute substantially to the cost of fabrication and tend to introduce a relatively high insertion loss, reducing the phased array antenna's effective EIRP (Effective Isotropic Radiated Power. Multibit MEMS (MicroElectroMechanical Systems) controlled phase shifters have recently been demonstrated that show promise in lowering cost and insertion loss. The purpose of this topic is to develop and demonstrate MEMS controlled phase shifters in a subarray design with a minimum of two elements that are capable of space qualification.

PHASE I: Design a multibit MEMS phase shifter. In concert with the Air Force, select an operating frequency band and simulate operation including phase delay and insertion loss across the frequency band. Develop a manufacturing plan to build a working subarray. Describe the production approach and provide projected costs.

PHASE II: Manufacture and integrate a minimum of 10 multibit MEMS phase shifters into a phased array antenna subarray. Characterize their performance over the operating frequency band and compare against theoretical performance. Describe next generation modifications for improved performance. Document the results.

DUAL USE COMMERCIALIZATION: Commercial communications satellites in LEO (Low Earth Orbit) and MEO (Medium Earth Orbit) could benefit from this technology by reducing costs and insertion losses. Military communications systems could also use this technology to produce lighter weight and thus cheaper satellite systems.

REFERENCES: 1. C. Goldsmith, T.H. Lin, B. Powers, W.R. Wu, and B. Norvell, "Micromechanical Membrane Switches for Microwave Applications," 1995 IEEE MTT-S Dig., pp. 91-94.

2. Y. Liu, A. Borgioli, A. Nagra, R. York, "K-Band 3-Bit Low-Loss Distributed MEMS Phase Shifter", 2000, IEEE M&GW Letters.

3. Brown, Elliott, "On the Gain of a Reconfigurable-Aperture Antenna" IEEE Transactions on Antennas and Propagation", Oct. 2001.

KEYWORDS: MEMS, Antenna, Phase Shifter, Phase Delay, Transmission Line, Phased Array

AF04-029 TITLE: Radiation-Resistant Solar Cell Coverglass

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: Develop innovative solar cell coverglass materials and coatings with increased radiation resistance.

DESCRIPTION: The end-of-life (EOL) power generation performance of satellite solar arrays would be improved by the use of coverglass materials and coatings with an increased resistance to radiation-induced darkening, especially in higher radiation orbits such as Half-Geo (geosynchronous earth orbit). Today's high performance multijunction solar cells require equally high performance broadband coatings and coverglass materials. Ceria and other dopants are typically incorporated into solar cell coverglasses in order to decrease the darkening effects of radiation and to protect the coverglass adhesive from UV (ultraviolet) exposure. The coverglass can incorporate antireflective, conductive, and UV and near IR (infrared) reflector coatings. Commercially available solar cell coverglasses are capable of withstanding 15 years in GEO and 10 years in LEO (low earth orbit) without darkening. New materials and innovative solutions are sought to obtain similar lifetimes for coverglass in high radiation (Half-Geo) orbits, and the materials must demonstrate resistance to electron and proton radiation profiles found in the half-GEO orbit. These new materials must maintain a high degree of spectral broadband transmissivity, withstand UV exposure, have high thermal emissivity, and possess a high index of refraction.

PHASE I: Develop and validate innovative technologies for the fabrication of solar cell coverglasses with increased radiation resistance combined with broadband transmission and high emissivity. Provide demonstration of coverglass material.

PHASE II: Optimize one or more materials developed in Phase I and demonstrate radiation resistance on prototype coverglass samples.

DUAL USE COMMERCIALIZATION: This technology is applicable to both military and commercial satellite solar arrays and is enabling for higher radiation orbits. The improved EOL power generation capabilities of this technology will have broad application in future military space systems.

REFERENCES: 1. Aiken, D. J., High Performance Anti-Reflection Coatings for Broadband Multi-Junction Solar Cells, Solar Energy Materials & Solar Cells, 64 (2000), 393-404.

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KEYWORDS: Solar Cell Coverglass, Coating Deposition Technologies, Solar Arrays, Optical Properties, Radiation Environments, Multijunction Solar Cells.

AF04-030 TITLE: Small Launch Vehicles (SLV) Technologies

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace, Weapons

OBJECTIVE: Develop innovative Small Launch Vehicle (SLV) technologies that provide responsive, cost effective spacelift solutions for Small-Sat and Common Aero Vehicle (CAV) architectures.

DESCRIPTION: Both Small-Sat and CAV payloads are showing increasing promise in improved mission capability. Small-Sat and CAV payloads will need a complementary responsive, cost-effective SLV capability. Innovative technologies are being sought that address SLV responsiveness and cost reduction in the areas of avionics, propulsion, airframe and structures, manufacturing, integration, and/or operations. A vehicle focus identifies enabling SLV technologies using a SBIR time-phased, risk reduction approach. Development of these technologies will make possible the eventual acquisition and operation of a responsive and cost-effective SLV-based system capable of rapidly deploying small satellites (200-1000lbs) and CAVs (under 2000lbs.) to low earth orbit (LEO). At the end of Phase I and II, the contractor is expected to have developed and tested technologies that are enabling to their SLV design in terms of addressing proposed SLV responsiveness and affordability goals. The result of these technology demonstrations will determine whether they are feasible to warrant consideration for a Phase III flight test program.

PHASE I: Conduct sub-orbital booster design analysis with proposed component technology requirements. All proposed sub-orbital booster technologies shall be traceable to an orbit capable SLV, whereby specific technologies are identified for Phase II development/test. Specifically, proposed Phase II SLV technology demonstrations must address a unique combination of improved launch responsiveness and cost reduction technologies. This will require technology risk mitigation plans that addresses identification, rationale, and test exit criteria of proposed high-risk component(s) in meeting advertised improvements to SLV launch responsiveness and cost.

PHASE II: Develop prototype sub-orbital booster components identified under Phase I. Refine the design of the sub-orbital booster as knowledge is gained through the critical component development process. The prototype hardware shall emphasize launch responsiveness and cost reduction technologies, and possess sufficient design information to fabricate, integrate, and operate the selected high-risk component(s) for demonstration. The contractor shall perform prototype ground test and evaluation of the enabling components per the Phase I technology risk mitigation plan. Phase II shall demonstrate critical booster component technologies that address launch responsiveness and/or cost reduction, which sufficiently meet required subsystem performance and reliability requirements.

DUAL USE COMMERCIALIZATION: Based on an in-depth USAF evaluation of Phase II results, a non-SBIR funded Phase III sub-orbital flight program will be considered. Dual use applications include target vehicles, sounding rockets, Ballistic Missile Replacement (BMR) and strap-on boosters. Enabling technologies that evolve from this program are directly traceable to a new responsive and low cost SLV for both commercial and military applications. A responsive SLV would enhance the launching of military tactical satellites for theater Intelligence and/or Surveillance and Reconnaissance (ISR). A low cost SLV would enhance the deployment of commercial LEO Communications Constellations (e.g., Store and forward paging communication systems). Other dual use variants of this technology include booster and/or upper stages systems for larger launch vehicles. If Phase II technical exit criteria are met and commercial and/or government (non-SBIR) program funds are identified for Phase III, the contractor shall design, fabricate, integrate, and flight-test the sub-orbital vehicle as defined under Phases I-II.

REFERENCES: 1. Steven J. Isakowitz, "International Reference To Space Launch Systems," AIAA, Second Edition, 1991.

2. George P. Sutton, Rocket Propulsion Elements, John Wiley & Sons, Sixth Edition, 1992.

3. James R. Wertz and Wiley J. Larson (editors), "Reducing Space Mission Cost," Microcosm/Kluwer, 1996.

KEYWORDS: Launch Vehicle Design, Sub-Orbital Vehicle, Satellite Micro-Miniaturization, Common Aero Vehicle, Technology Risk Mitigation, Flight Test and Evaluation, Small Launch Vehicle

AF04-031 TITLE: Thermal Protection System (TPS) for Agressive Reentry Trajectories of Space Vehicles

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: Develop innovative lightweight TPS for vehicles with agressive reentry trajectories.

DESCRIPTION: The need for hypersonic vehicles to meet emerging Department of Defense (DoD) requirements has necessitated the development of a new generation of robust TPS systems. Extended mission times in areas of high reentry heat loads have exceeded the current limits of the state-of-the-practice TPS designs. Current TPS designs and materials are incapable of providing the level of protection required by these mission scenarios without significant increases in allocated TPS weight and volume. The combination of large integrated heat loads, large surface heat fluxes, and long duration flights (time > 4100 seconds) for emerging DoD, National Aeronautics and Space Administration, and commercial vehicles; requires new TPS designs and materials to accommodate quantum leaps in demands exerted by new missions. Also, hypersonic vehicles such as the Common Aero Vehicle (CAV) will have flight trajectories that make the utilization of high temperature coatings difficult due to the high shear experienced during extreme maneuvers employed during the terminal portion of the vehicle's trajectory.

An integrated hot structure with an integral thermal protection system offers significant promise in meeting the restrictive weight and volume goals already envisioned by several DoD programs. However, developing such structures requires characterization of these systems in areas of thermal insulation, ablation, and structural integrity. Additional development issues that need investigation are component attachment, vehicle integration, manufacturing techniques, and cost. Proposing entities are encouraged to develop a working relationship with TPS system integrators and supporting government offices for future demonstration efforts. A strategy to incorporate selected technologies in current and future spacecraft is encouraged.

PHASE I: Develop conceptual designs or techniques that provide significant TPS improvements compared to current state-of-the-practice techniques. As part of Phase I, a program plan for risk mitigation strategies is required. A proof of concept subscale hardware demonstration is encouraged.

PHASE II: Demonstrate the feasibility of technology identified in Phase I. Tasks shall include, but are not limited to, a detailed demonstration of key technical parameters that can be accomplished at a subscale level, although a full-scale demonstration is encouraged if feasible. A detailed performance analysis of the technology is also required.

DUAL USE COMMERCIALIZATION: There are numerous and far-ranging possibilities of commercial applications for a heavy-duty yet ultra-lightweight, durable, and reliable TPS system in commercial launch vehicles such as the next generation shuttle and other NASA vehicles. Also an innovative integrated TPS technique, that integrates hot structure and thermal components into one unit, may have potential applications in the hot parts of automobile engines and autoclaves.

REFERENCES: 1. Air Force Space Command Strategic Master Plan for FY2025 and Beyond, 9 February 2000.

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KEYWORDS: Thermal Control, Thermal Insulation, Shock Resistance, Vibration Resistance, G Tolerance, Lightweight, Low Density, Thermal Management

AF04-032 TITLE: Programmable Satellite Transceiver (PST) for Dual Band Command and Control

TECHNOLOGY AREAS: Electronics, Space Platforms

OBJECTIVE: Design, build, and test a miniaturized programmable satellite transceiver (PST) for command and control (C2) that operates in both the Space Ground Link Subsystem (SGLS) and Unified S-Band (USB) frequency bands.

DESCRIPTION: The Department of Defense, National Aeronautics and Space Administration, and National Oceanic and Atmospheric Administration jointly developed a transition plan for implementing an integrated architecture for satellite operations (SATOPS) with the goals of reducing SATOPS costs and increasing interoperability between military and civil space and ground systems. Currently, military space systems use the SGLS frequency band consisting of 1755 – 1850 MHz, whereas civil space systems use the USB frequency band between 2025 – 2110 MHz. Ongoing discussions between the DoD, National Telecommunications and Information Administration, and the Federal Communications Commission may allow for military space systems to use both the SGLS frequency spectrum as well as USB. While the AF Satellite Control Network (AFSCN) Remote Tracking Stations are being upgraded to operate in both SGLS and USB, many of the military satellites are prevented from hosting both SGLS and USB capabilities due to size, power, weight, interface, and cost concerns of the existing available transponders. As a result, the integrated SATOPS architecture will be difficult to attain unless both the military and civil space systems as well as the related ground systems used for command and control can use both frequency bands.

The goal of this initiative is to develop a miniature Programmable Satellite Transceiver (PST) that will enable DoD satellite C2 interoperability with NASA and NOAA. Capable of operating in both SGLS and USB, the PST will have the ability to change frequency bands, waveforms, and protocols on-orbit. In addition to offering jam-resistant command and control of the satellite, its size, power consumption, and weight will be much less than today's transponders.

PHASE I: Develop a PST subscale demonstration unit for identifying technical limitations, evaluating technology options, and demonstrating potential capabilities. Based upon completed designs and experimental tests, define PST performance goals and provide a blueprint for developing a space-qualified demonstration unit. Work with Space and Missile Center to address integration issues to support future space validation activities.

PHASE II: Further refine the Phase I PST design, and based on that final design, develop a space-qualified PST demonstration unit. Provide a preliminary plan for the PST flight demonstration and validation.

DUAL USE COMMERCIALIZATION: Upon successful development and flight validation of the Programmable Satellite Transceiver (PST), it is anticipated that the PST will enter production and be used on military and civil satellites. Potential military users include the many DoD, AF and Navy space programs. Civil applications include NASA and NOAA earth observing, meteorological, and science missions.

REFERENCES: 1. Singer, J., Defense Dept to Keep Radio Spectrum, Space News, July 29, 2002.

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KEYWORDS: Integrated Satellite Control, Satellite Command and Control (C2), Transceiver/Transponder, Air Force Satellite Control Network (AFSCN), Space Ground Link Subsystem (SGLS), Unified S-Band (USB)

AF04-033 TITLE: Low-Cost Thermal Protection System (TPS) For Reentry Vehicles

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: Develop low-cost innovative reusable Thermal Protection System (TPS) for future reentry spacecraft.

DESCRIPTION: Over the past few years, Air Force strategists have envisioned the Air Force migrating into an Air and Space Force. Consequently, the Air Force is developing an aircraft-like spacecraft that has a 25% to 35% payload mass fraction, and a 48 to 72 hour turn-around cycle (~ 120 launches/year) to provide quick turn-around to replenish/deploy new space assets. The vehicle must have a significantly lower TPS-mass contribution to the total dry vehicle mass to achieve greater than 25% payload mass fraction. Hence, an innovative low-cost TPS system, unlike any current system that attaches to the vehicle's outside structure, is envisioned to be integrated/woven into the structure to achieve the volume and mass savings needed. In essence, a revolutionary change in both the TPS design approach, the use of innovative materials that can survive long durations in a hypersonic environment without significant ablation, and low maintenance are needed to yield a low-cost TPS system. All proposing entities are encouraged to develop a working relationship with TPS system integrators and supporting government offices for future demonstration efforts. A strategy to incorporate selected technologies in current and future spacecraft is encouraged. Additionally the envisioned low-cost TPS system has to be:

· Ultra safe and reliable – the new system has to increase the durability of TPS surfaces and system and be resistant to space micrometeoroid impacts.

· Significant capability increase – integrated TPS structure system must have higher temperature tolerance to support quick turn-around.

· Little or no ablation of TPS system surfaces – due to its mass fraction requirement, the leading hot surfaces should not shed as a way to control heat flux into the spacecraft and its contents.

· Significant decrease in operational cost – increase the time between overhauls, repairs, replacement of components, and required inspections.

PHASE I: Develop conceptual designs or techniques that provide significant TPS improvements compared to current state-of-the-practice techniques. As part of Phase I, a program plan for risk mitigation strategies is required. A proof of concept subscale hardware demonstration is encouraged.

PHASE II: Demonstrate the feasibility of technology identified in Phase I. Tasks shall include, but not be limited to, a detailed demonstration of low cost production and key technical parameters, which can be accomplished at a subscale level, although a full-scale demonstration is encouraged if feasible. A detailed performance analysis of the technology is also required.

DUAL USE COMMERCIALIZATION: There are numerous and far-ranging possibilities of commercial applications for an ultra-lightweight, durable, and reliable TPS system in commercial launch vehicles and National Aeronautics and Space Administration in addition to military reusable space vehicles such as the Common Aero Vehicle, Small Maneuverable Vehicle, and Solar Orbit Vehicle. Also an integrated TPS technique, which integrates structural and thermal components into one unit, may have potential applications in the hot parts of an automobile engine such as pistons and rods and autoclaves.

REFERENCES: 1. Lt Col Henry Baird; Maj Steven Acenbrak; Maj William Harding; LCDR Mark Hellstern; Maj Bruce Juselis; "Spacelift 2025, The Supporting Pillar for Space Superiority", Aug 1996.

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KEYWORDS: Thermal Control, Thermal Insulation, Lightweight, Shock Resistance, Vibration Resistance, and G Tolerance Thermal Management System

AF04-034 TITLE: Advanced Thermal Protection System (TPS) for Future Multiple Entry Vehicles

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: Develop an innovative Thermal Protection System (TPS) for future reusable spacecraft with aircraft-like reliability and duty cycle.

DESCRIPTION: In recent years, the need to develop flight vehicles and systems with the capability to operate for extended periods in a hypersonic environment has necessitated the development of a revolutionary TPS concept that is lightweight, robust, and maintainable. And are state-of-the-practice TPS systems are not robust, require too many hours to refurbish, heavy, fragile, moisture sensitive, and burdensome to maintain. As an example, TPS waterproofing is currently a time consuming, toxic, serial procedure, seriously affecting turn times. The TPS system currently planned for the X-37 requires all other work be stopped while waterproofing is accomplished. The waterproofing coating is toxic and must be done in a sealed facility to prevent toxic fumes from escaping. Bunny suits are required while personnel apply the coating and the X-37 must then be dried in the sealed facility for 28-32 hours before any other work can be accomplished. Another example is the amount of manpower required to inspect, replace, and waterproof the TPS on the shuttle. Over 18,000 maintenance man-hours (MMH) per sortie are required for TPS alone. This compares to the 20-50 MMH required to completely turn a modern fighter for its next sortie (shuttle 100,000 MMH/sortie total).

Future military space vehicles have flight profiles that require a long duration hypersonic flight. Currently planned Reusable Launch Vehicle systems are designed to maximum instantaneous heating rate of 50 BTU/ft2-s with integrated heating of 850 Btu/ft2 with zero ablation because of TPS limitations. While these rates are not severe, the requirements for these vehicles demand the vehicle achieve several successful flights through this environment before refurbishment of the TPS due to a low system maintenance requirement (40 MMH per sortie). Even at relatively low heat rates and loads, this level of reusability and rapid refurbishment time cannot be accomplished with any contemporary TPS design. To remain within these relatively low heating limits, current TPS systems require flight at angles of attack (AOA) which are compromised toward heat survivability and not toward generating maximum cross-range. To maximize cross-range, the vehicle needs to be flown at its maximum hypersonic lift to drag (L/D) ratio. Current TPS systems would burn up if flown at max L/D, especially leading edges and nose tips. Reusability factors mandate that these vehicles cannot accommodate TPS erosion common in most typical TPS designs for expendable reentry vehicles. In addition, mass fractions of reusable launch vehicles are critical, and TPS can make up as much as 25% of total vehicle dry weight. To improve mass fraction, the TPS must not only provide minimal levels of ablation, but also be exceedingly lightweight. A revolutionary change in both the TPS design approach and the use of innovative materials that can survive long durations in a hypersonic environment without significant ablation is needed. Lightweight, low erosion, fine edge shapeable, low conductivity materials coupled with an integrated hot-structure design that eliminates the bond line and the substructure would result in a revolutionary technology allowing a program such as the Space Maneuver Vehicle (SMV) to attain its objectives. All proposing entities are encouraged to develop a working relationship with TPS system integrators and supporting government offices for future demonstration efforts. A strategy to incorporate selected technologies in current and future spacecraft is encouraged.

PHASE I: Develop conceptual designs or techniques that provide significant TPS improvements compared to current state-of-the-practice techniques. As part of Phase I, a program plan for risk mitigation strategies is required. Goals could be TPS materials and systems that could be waterproof, low maintenance, machineable to fine edges, mechanically attached, eliminate support structure, or tolerate extremely high temperatures repeatedly. A proof of concept subscale hardware demonstration is encouraged.

PHASE II: Demonstrate the feasibility of technology identified in Phase I. Tasks shall include, but are not limited to, a detailed demonstration of key technical parameters that can be accomplished at a subscale level, although a full-scale demonstration is encouraged if feasible. Initial testing would include coupon samples followed by subscale structures and eventual flight test. A detailed performance analysis of the technology is also required.

DUAL USE COMMERCIALIZATION: Commercial applications for an ultra-lightweight, durable, and reliable TPS system may have applications in the next National Aeronautics and Space Adinistration generation NASA shuttle. Also an integrated heavy duty TPS technique, which integrates hot structure and thermal components into one unit, may have potential applications in the autoclave business and hot parts of an automobile engine such as pistons and rods.

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KEYWORDS: Thermal Control, Insulation, Heat Sinks, Thermal Management

AF04-035 TITLE: <u>Energetic Polymeric Nanomaterials for Satellite Power Systems Design</u>

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

OBJECTIVE: Develop biomimetic energetic polymer-based nanomaterials for photonic energy transduction to space-based satellite power needs.

DESCRIPTION: Materials design at the nanomolecular level could have a significant beneficial impact on polymer-based photonic energy transduction devices for use in space-based satellite power systems. One particularly interesting area of materials design at the nanomolecular level is the development of biomimetic transduction polymers that transduce radiation and photonic energy into electronic energy, particularly when doped with heavy metal chiral centers. Effective models for synthetic modification of nitrosylated quasi-phenolic and orthoquinone-based for catechol/diol-based polymer architectures, such as those originally derived from thermophilic, aquatic or insect environments, hold promise in meeting photonic to electronic energy transduction goals for future space systems hardware. Incorporation of molecular rotor components within such polymeric architectures may significantly enhance their inherent potential for power generation and its efficiency. Regenerating nanomaterial assemblies of such electronic acceptor/donor biomimetic polymer systems could be incorporated within or laminated onto satellite surface materials to enhance power generation and optimization performance characteristics of entire satellite architecture scaffolds or even of specialized micorocircuity and on-board extendable or activatable robotic microdevices. Innovative ideas that have the potential to increase the conversion efficiency of photonic energy to current through design at the nanomolecular level are sought.

PHASE I: Develop advanced polymer-based photonic energy transduction proof-of-concept devices. This activity could include developing modular organic and recombinant synthetic pathways for candidate biomimetic energetic nitrosylated polymer architectures, displaying rare earth and other metal chelation and electron acceptor or donor behavior. Using natural source and synthetic derived energetic polymer nanomaterials, demonstrate Radio Frequency and photonic to current transduction behavior, output, and efficiency. Develop a laboratory model for initial proof-of-concept.

PHASE II: Refine and scale-up organic and/or recombinant synthesis of energetic polymers and assemble into nanomaterial arrays suitable for enveloping complex structures or developing outer energetic polymer sheaths for microelectronics and robotic devices. Optimize molecular design for maximum photonic to electronic transduction and high current electrical power output using more extensive molecular rotor constructs mounted on the polymer-based nanomolecular array. Demonstrate commercial and production feasibility of proposed polymer-based energetic nanomaterials systems.

DUAL USE COMMERCIALIZATION: Advances in biomimetic polymer-based energetic nanomaterials have the potential to yield revolutionary advances in military aviation and robotic designs of the future, and to have a significant impact on the design and innovation of space technology. Of even greater commercial significance, the development of highly efficient energetic polymeric nanomaterials could offer a rich and fertile potential for exploitation in the photoconductive sensor, radiofrequency sensor and solar energy technology market, particularly in the efficiency/cost context. Development of versatile energetic materials will offer substantive promise for their incorporation in energetic bionanomaterials and implantable bionic devices.

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KEYWORDS: Energetic Materials, Nitrosylated Biomimetic Polymers, Nanomolecular Assemblies, Rare Earth Chelation, Solar Power, Satellite Design, Photovoltaics, Renewable Energy Sources

AF04-036 TITLE: Scene Generation for Simulations of Satellite-Based MTI Radars

TECHNOLOGY AREAS: Information Systems, Space Platforms

OBJECTIVE: Develop an inexpensive capability to rapidly create simulated, global radar scenes to support space based air and ground moving target indication modeling, simulation, and analysis.

DESCRIPTION: Current military and political affairs require a reliable and global capability to track air and ground moving targets. Using radar Doppler is an effective method of tracking moving targets of interest. Unfortunately, air-borne Moving Target Indication (MTI) assets are limited in coverage and access. Space based radar promises greater coverage and is not limited by airspace constraints. However, space based MTI is hindered by the vast amount of clutter data that must be processed in order to track the Doppler effect of the air and ground moving targets of interest. The current approach to clutter modeling relies heavily on statistically based background clutter on a geo-specific location. This approach to building radar clutter scenes has proven inefficient, costly and provides less than desired MTI results. There is a need for the capability to rapidly generate radar clutter scenes for any area of interest on the Earth's surface such that reliable space based moving target indication can be performed. It is recommended to leverage the extensive geodetic data owned by the National Imagery and Mapping Agency

(NIMA). Common commercially available software should be used when possible to support data management and exploitation.

PHASE I: Develop an approach to rapidly generate global radar clutter scenes to support space-based air and ground moving target indication. Identify the necessary scene data required to support reliable space based air and ground MTI . Demonstrate this methodology by developing a preliminary prototype system that provides necessary radar background clutter over a limited area resulting in reliable space based air and ground MTI.

PHASE II: Upon completion of Phase I, expand the area of interest and the associated geodetic database to support rapid, global radar clutter scene generation. Develop a flexible Graphical User Interface (GUI) that supports an interface to known space based MTI radar system(s) and the capability to support autonomous radar scene generation. Emphasis is placed on the ability to generate radar scenes quickly at minimal cost while limiting fidelity to the level necessary to support reliable air and ground MTI, not image quality.

DUAL USE COMMERCIALIZATION: Reliable MTI of enemy and civilian items of interest is necessary to support precision targeting. This capability should limit collateral damage and optimize warfare resources. This capability also gives our diplomatic assets the early warning and evidence needed to diplomatically stymie enemy intent. This capability has significant role in peacetime also by providing realistic data to support war gaming and training exercises. The spin-off to support commercial applications and homeland security concerns is significant. Search and rescue and traffic analysis are only a few practical applications of MTI.

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KEYWORDS: radar, space-based, moving target indication (MTI), background, clutter, modeling, simulation

AF04-037 TITLE: <u>Innovative Rapid Satellite Prototyping, Integration, and Manufacturing</u>

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: Develop and implement new methods to design, manufacture, and test satellites that will enable rapid production, simplified integration and significantly reduced manufacturing costs.

DESCRIPTION: The Air Force has an operational need to be able to launch satellites on demand for a variety of missions. One critical capability that is required to achieve this goal is the rapid fabrication of satellites and integration onto the launch vehicle. Currently, satellites are built using a "design from scratch" methodology where the spacecraft and launch are specifically tailored for the individual mission. Not only are wiring harness and software totally customized for each satellite/mission combination, but often the combination of "commodity" components (defined as spacecraft subsystems and components that are largely reusable) requires the development of many custom interfaces. This approach has been very successful in producing highly capable satellites with minimized mass. Unfortunately, it is also the most costly way to produce a satellite. While these maximum capability satellites will always be required for some space missions, this solicitation is designed to explore advances in satellite design and manufacture that will produce a product with slightly reduced capability, slightly increased mass, and major decreases in cost and fabrication time. There are several avenues whereby small relaxations in the satellite capability and mass requirements can afford large decreases in development, time and cost. Using commercial-off-the-shelf (COTS) components might result in additional mass or in unnecessary excess capacity but will greatly reduce the cost and fabrication time. The development of standardized satellite sub-systems (e.g., power, avionics, telemetry, attitude determination and control, bus) could enable a modular architecture of components that would be rapidly integrated to produce a satellite for a selected mission. These are felt as necessary, but not sufficient conditions for ultra-rapid development of flight systems. It is necessary to investigate creative solutions to avoid the need to develop custom hardware, software, and interfaces. Ideally, complex interactions can be managed by script-driven interface concepts, blending a number of software and hardware concepts together. More primitive implementations of this concept have been referred to as “plug-and-play." More advanced embodiments can dramatically reduce the time to create a complex spacecraft system by reducing many complicated interface decisions to simpler ones. Self-organizing networking protocols (wireless examples include the Bluetooth standard) can potentially simplify not only interface design but reduce the burden of complex software development. Proposed concepts should strive for techniques that can eventually achieve a fabrication and integration time of a few days. In the near term, these techniques should cut fabrication time in half and decrease cost to about $2M for a small satellite. Rapid, cost-effective methods to test and prototype new satellites will greatly enhance the entire satellite community. However, proposed concepts should focus on small satellites attractive for technology demonstration, in-theatre support, and on-orbit mobility. Proposals can address the entire spacecraft, selected sub-systems of the spacecraft bus, individual payloads, or focus on the rapid integration of the components onto the spacecraft bus or the spacecraft onto the launch vehicle. In either case, proposers should seek approaches that can deliver low-cost and rapid prototyping, design, fabrication and/or integration over the widest range of relevant capability.

PHASE I: Develop and mature a technique for rapid fabrication of small satellite at low cost. Perform analysis to identify AF and commercial missions that could benefit using the proposed concept. If appropriate, develop engineering designs for the proposed concept. Where appropriate, work with Air Force technical personnel to define specifications, performance, manufacturability, and cost guidelines.

PHASE II: Demonstrate the feasibility of technologies identified in the Phase I. Specific processes and designs will be perfected and tested. Prototype level (or higher) hardware will be built for testing and demonstration.

DUAL USE COMMERCIALIZATION: The successful development of a low-cost, rapid fabrication, small satellite will realize high commercialization potential from DoD, NASA, and industry.

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KEYWORDS: Manufacturability, Bus, Spacecraft, Payload, Satellite, Structures, Modular

AF04-038 TITLE: Controlling Stability and Load Limits of Aerodynamically Induced Forces on Very Large Assymetric Fairing Designs

TECHNOLOGY AREAS: Air Platform, Space Platforms, Weapons

OBJECTIVE: Evaluate and develop means of providing stabilization, control, and structural structure load mitigation resulting from launch forces on large fairings with asymmetric profiles.

DESCRIPTION: DOD is interested in developing new large diameter fairings to support launch of very large diameter optics experiments (greater than 6 meters in at least one cross-axis dimension). The intent is to provide accommodations for precision dish-shaped structures at the limit of lift capacity for the Evolved Expendable Launch Vehicle heavy launch vehicles. One means of delivery for payloads is to develop asymmetric fairing designs presenting a reduce profile to aerodynamic loading. In the past such designs have presented severe constrains on primary launch vehicle control systems. Very large peak bending moments have also results at the fairing attachment to the launch vehicle.

The objective of this project is to develop novel structural fairing design concepts that minimize in-flight instability conditions and reduce lateral force induced peak stresses in the fairing. The systems or features developed must provide these control features in a manner that minimize the need for additional requirements of the launch vehicle guidance, navigation, and control (GNC) system.

The proposed effort should address issues such as reliability, safety, weight, manufacturing/integration, acoustic and structural vibration mitigation, configuration flexibility, and aerodynamic loading. The use of manufacturing technology that will allow inclusion of multi-functional features into the overall structure design such as integral acoustic mitigation, connection features for separation systems, structural vibration mitigation systems, or thermal mitigation systems is advantageous.

PHASE I: Develop system level conceptual structural design addressing stability and failure criteria in a fairing with at most two planes of symmetry. The fairing design must attempt to optimize containment of large dish-shaped payloads to be specified by the Air Force. Demonstrate the potential range of capability of the concept by analysis. The effort can include the production of a sub-scale engineering model for use in model/concept validation.

PHASE II: Develop, with the Air Force, a mutually agreed upon sub-scale prototype fairing manufacturing and test plan. Design, fabricate, and test a sub-scale fairing shell per an agreed-on test plan under wind tunnel load conditions. Air Force facilities for these efforts may be available as Government Funded Equipment for these efforts.

DUAL USE COMMERCIALIZATION: Currently, there is a growing interest in satellite launch missions requiring fairings suitable to support larger payloads consisting of mirror or dish-shape precision alignment structures. The development of fairing designs that support pre-launch final assembly and precision alignment can greatly reduce the cost of satellite development costs and can result in dramatic improvements in DOD surveillance activities and commercial investigation and management of natural resources.

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Author: Dotson, K. W.; Baker, R. L.; Sako, B. H. Affiliation: Aerospace Corporation, Los Angeles, CA 90009-2957, United States
Journal: AIAA Journal ; November 2002; v.40, no.11, p.2197-2205 Journal Abbr.

2. Title: Aeroelastic vehicle dynamics of a proposed Delta II 7920-10L launch vehicle
Author: Ericsson, L. E.; Pavish, D.
Affiliation: Boeing Co, Huntington Beach, CA, USA
Journal: Journal of Spacecraft and Rockets ; Jan-Feb 2000; v.37, no.1, p.28-38.

KEYWORDS: Fairing, Multi-Functional, Spacecraft, Controls, Mechanism, Stability, Separation, Composites

AF04-039 TITLE: Advanced Technology Development Cost Estimation Methodology

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: Develop capability to derive accurate cost estimates for space technology development projects.

DESCRIPTION: The advancement of technologies for space concepts or system applications is a high risk, high payoff investment that enhances national security and war-fighting capabilities. The ability to accurately estimate cost and risk associated with Technology Readiness Level (TRL) progression is key to effective project management of space technology programs. Historically, the use of parametric cost analysis techniques proved adequate for estimating project costs, however, future space concepts will integrate non-traditional and new technologies like reconfigurability, miniaturization, autonomy and system of systems constructs. These new design domains lack a well-defined and valid cost estimation methodology. The inability to accurately assess technical risk and the associated costs has resulted in significant program cost over-runs and even project cancellations. The capability to provide more reliable technology cost information will also help Air Force Space Command plan and budget for the Life Cycle Cost (LCC) of future operational space systems. The Air Force is seeking innovative technology investment cost estimating methodologies and tools that will give the space technology project manager reliable cost projection and risk insight into the complex space technology being managed.

PHASE I: Research AF costing methodologies and cost analysis tools used to support space technology programs. The AF will provide limited, relevant project data to support case study analysis and access to existing AF cost tools. The SBIR contractor will identify the deficiencies of the current cost/risk analysis tools and develop an improved methodology that remedies these deficiencies and provides a better forecast of costs associated with a technology program's TRL progression. Results from this phase should be clearly documented and presented to the AF with a recommendation, rationale and plan for phase II refinement and implementation.

PHASE II: The innovative cost methodologies developed in phase 1 will be further refined and implemented through the development of a cost management capability. This capability will help government project officers analytically understand cost implications associated with programmatic and technical options presented in their technology program. This capability should leverage innovative and intuitive user interfaces and be easily adaptable to the dynamic circumstances of modern space technology programs. This capability should be parameterized to handle a wide range of variations (programmatic, risk, cost, schedule, performance, system, etc.) and present a reliable cost forecast to the project manager. This capability will be validated by comparing its output to actual Air Force Research Laboratory experience.

DUAL USE COMMERCIALIZATION: positive contribution to space technology development by giving the project manager analytical insight into the cost implications of management decisions. Project risk will be better mitigated through the ability to forecast technology investment costs and build in an analytically grounded management reserve that better handles the unknowns associated with space technology development. This capability could then be marketed to the Air Force as a proven technology cost management tool. The problem of understanding cost with respect to technology investment is not limited to space programs, in fact, all industries that rely on Research & Development and innovation to compete will benefit from the reliable cost estimating capability defined in this SBIR.

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2. Disselkoen, A; "Adv. Tech/Cost Assessment," Accession Number DF081153.

3. Technology Readiness Levels and their Definitions

4. http://www.jsc.nasa.gov/bu2/resources.html.

KEYWORDS: Advanced Cost Model, Technology Readiness Level, Advanced Space Concepts, Subsystems, Cost Estimating, Cost Analysis

AF04-040 TITLE: Plasmaspheric and Enhanced Ionospheric Total Electron Content Monitoring

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

OBJECTIVE: Develop a ground-based methodology and instrumentation for monitoring contributions to the Total Electron Content (TEC) from the ionosphere and plasmasphere.

DESCRIPTION: The ionosphere critically affects the operation of numerous surveillance, navigation, geolocation, and other Radio Frequency systems. Ionospheric TEC (I-TEC) is a key measured parameter that is either exploited directly or used to drive real-time ionospheric models in order to assess system impacts or to support correction/mitigation. Increasing accuracy of ionospheric TEC is needed to support current and future system requirements. Today's leading source of ionospheric TEC (I-TEC) measurement is dual-frequency GPS receiver monitor systems. However, since Global Positioning System satellites operate at altitudes of ~20,200 km the GPS TEC measurement combines electron content from both the ionosphere (approximately 100 - 1000 km altitude) and the plasmasphere (altitudes greater than 1,000 km). Although the plasmaspheric TEC (P-TEC) is typically a relatively low value, representing less than 10% of the GPS TEC, when the ionospheric TEC is itself low P-TEC can be of comparable size. For example, nighttime GPS TEC is often 50% P-TEC for wide regions of the globe. In absolute terms, existing I-TEC accuracy requirements have an objective of ~1 'TEC unit', and plasmaspheric contributions to GPS TEC can vary from <1 to ~10 TEC units. Thus P-TEC is a serious source of error in using GPS TEC to meet ionospheric TEC monitoring requirements. As an example of the objective of this SBIR, development of a methodology to separate the P-TEC and I-TEC portions of GPS TEC would significantly improve the accuracy of ionospheric TEC monitoring to specify ionospheric effects on RF systems. However, the P-TEC data would also be an entirely new source of valuable space weather data. Specifying the near-Earth space environment is becoming increasingly important in order to specify and forecast effects on space vehicles. There is currently no ground-based means of wide-scale monitoring of the plasmasphere. Thus there is a critical lack of observational data to establish better climatological models and develop/validate real-time models. A methodology to accurately separate P-TEC from GPS TEC could open up vast existing data sets of GPS observations for extraction of plasmaspheric data, and provide means to obtain real-time data to drive specification models.

PHASE I: Design a methodology and instrumentation for accurate separation of the P-TEC and I-TEC portions of ground-based measurements of columnar TEC. Provide evidence or analysis supporting both the feasibility of the methodology and the expected accuracy of the data.

PHASE II: Develop and test instrumentation and software that implements the Phase I design and methodology. Validate the accuracy of resulting data by studies and experimental measurements providing comparison with other sensing techniques such as incoherent scatter radar measurements or Topex satellite TEC data. If the methodology supports it, develop algorithms applying the methodology to "mine" existing GPS TEC data archives to obtain both P-TEC data and more accurate I-TEC.

DUAL USE COMMERCIALIZATION: An inexpensive, highly-accurate, ground-based sensing methodology/instrument that can achieve significantly improved I-TEC monitoring (by removing P-TEC) would support both dedicated monitoring for DoD RF systems and would significantly advance scientific research. A software methodology would have potential to be retrofitted into existing GPS monitors, enhancing their performance and improving AF system support. P-TEC measurements/monitoring would provide an entirely new source of valuable Space Weather data to support specification and forecast of space environment effects on space vehicles. A software P-TEC separation methodology could mine existing data sets of GPS TEC for production of possibly an entire solar cycle of globally-observed plasmasphere data.

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KEYWORDS: Ionosphere, Plasmasphere, Total Electron Content, TEC, Monitoring, Protonosphere, Global Positioning System, Ground-Based, Beacon Satellite

AF04-041 TITLE: Distributed Optical Imaging of the Upper Atmosphere

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace, Space Platforms

OBJECTIVE: Develop and demonstrate low-cost automated weatherproof low-light optical imaging sensors for ground-based space weather monitoring networks.

DESCRIPTION: Imaging of sub-visual optical emissions is one of the few means available to determine upper atmospheric conditions over large regions for purposes of monitoring, modeling, and forecasting space weather phenomena including equatorial plumes, auroral arcs, or polar cap patches. Ground-based imaging systems are affordable, flexible, and accessible compared to space-based instruments, but are limited in operational utility primarily by tropospheric weather conditions. However, as the field of view of a ground-based upper atmospheric imaging system is typically greater than the decorrelation distance for terrestrial cloud cover, a network of multiple imaging systems distributed up to hundreds of kilometer apart but with overlapping fields of view could provide high-quality real-time, space environment information even under adverse weather conditions at many of the individual sites. When favorable conditions allow for multiple overlapping observations, such a network could also provide additional high-value products including tomographic reconstructions, ionospheric drift measurements, unambiguous emission heights, and neutral density determinations. Typical low-light imagers are custom-built research units that operate in a controlled observatory environment and often require significant maintenance or operator attention. Establishment of a practical distributed imaging system, however, requires development of sensitive low-light imagers that can be manufactured in quantity for an order of magnitude smaller cost than traditional research-type instruments; can be easily transported to and installed in remote locations without specialized training; can operate reliably and autonomously when exposed to the weather for many months at a time; and can feed data directly to a network without any inputs other than electrical power, i.e., a sensor that provides the plug-and-play functionality of a weatherproof digital web-cam combined with the sensitivity needed to detect and image faint emissions from the upper atmosphere. Software algorithms, infrared observations, or other automated means of identifying image regions affected by clouds are also expected to be an important part of such a sensor network. We seek innovative solutions taking advantage of modern digital imaging and computer technologies to create a practical and effective automated imaging sensor system for distributed monitoring of the upper atmosphere. Innovations allowing simultaneous imaging at multiple wavelengths and elimination of moving parts while remaining within the constraints of a low-cost ruggedized sensor concept are especially desired.

PHASE I: Design a fully automated all-sky imaging sensor and demonstrate its capability to detect sub-visual upper atmospheric emissions by constructing a working laboratory demonstrator unit that can deliver live sky images to a network in real time without human intervention. The design should be capable of being produced in quantity for costs on the order of $10,000; be compatible with portability, weatherproofing, and reliability considerations; and be able to be reconfigured for observations at other wavelengths if multi-wavelength capability is not inherent.

PHASE II: Further refine the Phase I design, incorporating necessary changes identified through testing of the initial demonstration unit. Develop a prototype portable, ruggedized, weatherproof sensor based on the final design. Construct at least three prototype units and operate them exposed to the weather at multiple ground sites to demonstrate capability to form a distributed sensor network automatically acquiring and feeding live sky data to a central location in real time. Develop, implement, and demonstrate image processing algorithms or other means to automatically determine which image regions are free from clouds and to create mosaic images combining cloud-free data from multiple sites.

DUAL USE COMMERCIALIZATION: A successful distributed imaging system could be expected to generate orders for hundreds or thousands of individual units for positioning at military facilities, research sites, tactical deployments, or even aboard ships or aircraft. Affordable, automated, durable optical imagers needing no observatory infrastructure or expert operator can be expected to greatly expand the civilian market for upper atmospheric monitoring, which already results in demand for hundreds of imaging systems around the world. Many weather stations or educational institutions might purchase inexpensive imagers to monitor aurora or other upper atmospheric phenomena. Possible spin-offs include a potentially huge commercial market in applications such as automated determination of night-time cloud cover for meteorological stations and civil aviation. Additional niche markets for specialized military applications such as optical space surveillance support are also likely.

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KEYWORDS: All-Sky Imaging, Airglow, Ruggedized Instruments, Ionospheric Structures, Optical Tomography, Cloud Detection

AF04-042 TITLE: Rad-Hard Reconfigurable Level Shifters

TECHNOLOGY AREAS: Information Systems, Electronics, Space Platforms

OBJECTIVE: Improve co-integrating legacy and new system components by developing practical approaches for reconfigurable, rad-hard level shifters.

DESCRIPTION: It is given as a generic requirement that all space electronics must be radiation-hardened through process or design or a combination of those methods. This topic addresses a very narrowly focused “sub-problem” that invites creative exploitation, and it is one that seems well-suited for small businesses to address: level shifters, i.e., circuits that are able to translate the binary signaling levels of one circuit to those required by another circuit. The problem is not unique to rad-hard systems, but the application environment imposes unique constraints. For example, almost all new terrestrial digital electronics use primary voltages below 5V. Many space systems, however, still use 5V in some or all of the digital electronics, which suggests an obvious incompatibility that will get worse in time as more microelectronics migrate to lower voltages. This problem was dealt with long ago in terrestrial systems through the use of level shifters. These level shifters interface different, discrete and logical signals between space subsystems that operate from different voltage baselines (e.g., 5V, 3.3V, 3.0V, 2.5V, 1.8V). With these level shifters, it is possible to much more readily integrate components built to dissimilar voltage signalling standards. These continue to be popular for terrestrial systems that require "legacy" interfaces. Such level shifters would undoubtedly find widespread use in space systems as they make the eventual migration to 3.3V and lower supplies. Unfortunately, the Commercial Off-the-Shelf level shifters are not radiation-hardened. This topic has a single, simple, but very practical goal: develop low-cost, radiation- hardened voltage level shifters. We seek creative approaches, such as very tiny, and multi-level (programmable)/(reconfigurable), but above all, very efficient (low-power) and affordable chips.Rad-hard level shifters represent an important trend in modern systems: reconfigurability. When systems are designed with reconfigurable components such as level shifters, they are easier to develop and integrate.

PHASE I: Devise a strategy for compact and programmable level shifters that are effective in a radiation environment. Requirements include density (100's per sq.cm., for example, suggesting chip-scale approaches), extremely low-power, high-speed, and, most importantly, bidirectionality and the ability to independently configure each side of each channel for different signalling standards. Galvanic isolation is a plus. The ability to exploit redundancy to create bidirectional "firewalls" is not necessary but highly desirable. The phase 1 must: (1) establish target configurability objectives, voltage spans, power, speed, form factor, etc.; (2) identify candidate fabrication approaches; (3) demonstrate the feasibility of the concept in some effective way, through a combination of simulation/modeling, breadboarding, or other methods. Address also the approach through which the level shifters can be made to withstand the various space environment concerns.

PHASE II: The offeror is expected to demonstrate prototype level shifter assemblies. Tasks include: (1) test-cell design; (2) fabrication, characterization, and radiation-performance assessment; (3) finalized design; (4) fabrication of at least one "production-like" configuration; (5) test and evaluation of those components.

DUAL USE COMMERCIALIZATION: Dual-use opportunities for these components exist, particularly with commercial spacecraft manufacturers who employ standard bus designs. These components would ease the burden of retrofitting new digital hardware into other parts of a legacy platform.

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KEYWORDS: Level-Shifter, Rad-Hard, Electronics, Space, Reconfigurable, Bidirectional Transceivers, Legacy Bridge

AF04-043 TITLE: High Bandwidth Optoelectronic Data Interfaces for Satellites

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

OBJECTIVE: Develop and validate innovative designs for transponders.

DESCRIPTION: Next generation transponders for 40GB/s datacom systems require several critical circuit blocks that become impossible to achieve with conventional integrated circuits, even when pushed to the state-of-the-art in lithography. The critical building blocks in the deserializer are the receiver, the clock and data recovery (CDR), the clock divider and the demux. At these data rates, the conventional circuit approach of the transverse impedance amplifier (TIA) and decision circuit for the receiver, a phase locked loop (PLL) for the CDR, and a 1x16 clock divider with a demux consume inordinate levels of power and clearly demand performance that cannot be met with scaled electronics. Required to meet these needs are new architectures based upon new device capabilities. This topic seeks new approaches to the basic functions by introducing novel devices with nonlinear characteristics and thresholding features. Thresholding devices can eliminate transimpedance designs and may combine detection, waveshaping, amplification, and gain into a single element with speed and power improvements. Most important they may offer scalability to next generation bit rates. Thresholding devices may also offer unique approaches to waveform generators, which can perform phase and frequency realignment and thus eliminate the conventional PLL by using intrinsic device properties to adjust loop delay. With such innovations the discriminator function is performed internally to the device and conventional bounds on circuit performance no longer apply. The basic flip flop on which the clock divider is based can be substantially simplified to provide correspondingly higher bit rates by using thresholding to implement the comparator with a fraction of the components required in conventional flip flop design. Optically activated thresholding devices when integrated with complementary pairs are particularly interesting as interfaces between high bit rate optical transport and lower speed electrical outputs. Similar advantages are possible on the serializer side. Here also the opportunities are for simplified flip flop designs to implement compact counters for clock synthesis, multiplexers based upon device-thresholding flip flops, and optoelectronic oscillators with electrical phase control to provide the speed and timing flexibility for > 40Gb/s electro-optical interfaces.

PHASE I: Develop innovative low power, high speed optical interface solutions based upon devices with nonlinear properties and thresholding features to resolve the fundamental limitations of conventional integrated circuits. Validate and provide proof-of-concept for a final design to be implemented under Phase II.

PHASE II: Fabricate and demonstrate a prototype for the concept developed under Phase I. This should include, but not be limited to, a detailed proof-of-principle demonstration and a detailed performance analysis of the technology.

DUAL USE COMMERCIALIZATION: Successful demonstration of the technology will benefit both military and commercial applications in meeting demand for 10-40 Gb Ethernet transceivers in next generation servers/routers with a III-V digital alternative to Complimentary Metal-Oxide Semiconductor. The technology is ideally suited for application in high speed data transfer via optical crosslinks in satellites.

REFERENCES: 1. Behzad Razavi, "Challenges in the Design of High-Speed Clock and Data Recovery Circuits," IEEE Communications Magazine, pp 94-101, August 2002.

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KEYWORDS: Transponders, Serializer Deserializer, Mux-Demux, Clock and Data Recovery, Optoelectronics, Phased Arrays, Data Interfaces

AF04-044 TITLE: Compact Vacuum Nanoelectronic Devices for Advanced Communication Devices

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Manufacture efficient/compact vacuum nanoelectronic devices based on recent advances in cold cathode nanostructure material technology.

DESCRIPTION: The ability to develop and manufacture next generation space-hardened, temperature independent electronics derived from non-solid state/non-semiconductor approaches such as nano-vacuum emitter devices will have numerous applications in military and commercial systems. These nanoelectronic devices will replace transistors, providing electronic functions that are radiation and temperature insensitive, eliminating cooling infrastructure and significantly reducing power requirements. Electron [cold cathode] sources may include nanotubes, nanotips and edges, vertical or horizontal configurations and molecular level design material content and morphology. This SBIR topic seeks to develop the technology for the manufacture of vacuum nanoelectronic devices based on the recent advances in the areas of innovative nanostructure and low electron affinity materials. The goals are to develop the technology and scientific underpinning that is required to fabricate such vacuum nanoelectronic devices and to provide the infrastructure for their manufacture and insertion into military and commercial applications.

PHASE I: Design/fabricate prototype and demonstrate the concept of vacuum nanoelectronic devices. Target performance characteristics for the prototype vacuum nanoelectronic devices is performance of conventional electronic functions. The prototype devices should demonstrate speed and power characteristics equivalent to state of art silicon without temperature sensitivity. Gather and analyze performance data on prototype vacuum nanoelectronic devices. Refine theoretical model to improve the efficiency of the device.

PHASE II: Refine the design and materials system to enhance the efficiency, reliability and performance of vacuum nanoelectronic devices. Using model predictions and actual Phase I prototype data, design/fabricate/demonstrate an engineering model device in a practical package. Prepare a manufacturing and commercialization roadmap to market the technology.

DUAL USE COMMERCIALIZATION: Vacuum nanoelectronic devices offer numerous opportunities for enhancement in both military and commercial applications where a temperature or radiation insensitive electronic function is needed with a better speed-power product than present solid state technology. This would be very advantageous in mobile communications (laptops, cell phones) situations vastly increasing battery life and collapsing weight and volume limitations.

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KEYWORDS: Cold Cathode, Vacuum Field Effect Transistors, Nanostructures, Field Emission, Field Emitters, Nano-vacuum Emitter.

AF04-051 TITLE: Pattern Recognition for Aircraft Maintainer Troubleshooting

TECHNOLOGY AREAS: Information Systems, Materials/Processes

OBJECTIVE: Intelligently decipher text strings and determine when one is related to another even if they aren't exact to reduce troubleshooting time.

DESCRIPTION: When an aircraft maintainer enters a discrepancy into their CAMS/GO81 (maintenance) database, the system should automatically search past similar discrepancies and present suggested courses of corrective action based on past corrective actions. The system should always use as much data as available to assist the maintainer with the troubleshooting process. Discrepancies are not always written up the same way although they may be the exact same problem. Same thing goes for corrective action. There must be some way to recognize certain text patterns, perhaps with the addition of sorting by work unit code (WUC). Over time the system should get "smarter", either with a neural network or some other kind of feedback comparison mechanism. There is significant flexibility in developing an innovative approach to meet the technical objectives.

PHASE I: Required Phase I deliverables would include a software package to determine the best course of action for an aircraft maintainer based on past corrective actions in the specific problem area. It should also present several alternatives based on a probability of success.

PHASE II: In theory, the exact same discrepancy should have the exact same corrective action. Each of these two sections will have a slightly different text string to describe the problem and the algorithm should be able to determine when maintenance actions are related. Access to CAMS/GO81 will be needed to perform the data mining and collect as much information as possible. The focus should be tested on a few WUC's first before being expanded to every system on an aircraft. Personal interviews should be conducted with maintenance personnel to determine how one's thought process works from discovering the discrepancy to eventually signing it off in CAMS/GO81 with the corrective action.

DUAL USE COMMERCIALIZATION: Commercial applications could include any industry that determines a problem and then must determine what to do to fix it. Airline industry, telephone industry, any company that receives calls from customers to try and help them troubleshoot on their own before using a more expensive method of sending a technician to the site, heavy equipment industry, etc...
Military applications could include retrieving information from the maintenance information system database to compare with your current problem and suggest a course of corrective action.

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KEYWORDS: Maintenance mentors, diagnostics, interactive electronic technical data, decision support, text recognition algorithms, neural networks, advanced troubleshooting

AF04-052 TITLE: Integrated Repair Level Analysis (RLA) Agent Technology

TECHNOLOGY AREAS: Materials/Processes, Human Systems

OBJECTIVE: Develop a robust repair level analysis agent based technology advancing avionics support

DESCRIPTION: It is the function of the logistic support management team to ensure support for aircraft avionics through assessment of proper spares, technical orders, support equipment, and by maintaining that all other support issues are in place and correct. It is also a primary function of the logistic support team to make decisions on the maintenance repair level (concept), whether it is 2-or 3-level repair. A 2-level maintenance action indicates on aircraft (O-level) maintenance (removal and replacement of the Line Replaceable Units (LRUs) and the depot (D-level) where major overhaul takes place. A 3-level maintenance action involves the aforementioned levels plus an additional intermediate (I-level). With 2-level maintenance, the LRU is removed from the aircraft and sent directly to the depot (whether it be an organic Air Force depot) or a civilian original equipment manufacturer. With 3-level maintenance, the LRU is removed from the aircraft and sent to the I-level back-shop. The back-shop is typically located on the base itself and managed by Air Force organic personnel. Personnel troubleshoot the LRU and determine specific faulty Shop Replaceable Units (SRUs), primarily circuit cards. The I-level personnel remove and replace the faulty SRU and return the LRU to service. The efficiency and effectiveness of an I-level shop requires adequate supplies and purchase power to maintain support equipment, facilities, etc. The maintenance concept relies on these requirements to support Air Force aircraft.

Currently, in order to determine the repair level (2 vs. 3-level), an outdated model called the NRLA (Network Repair Level Analysis) is performed. This NRLA model takes into account the different costs to set up facilities, the costs to repair various components, the projected mean time between failures of the different components, and does a cost benefit analysis to determine the optimum repair level. This model is inadequate to handle the rate of turnover, is difficult for personnel to run, and harder still to interpret the results. In addition, the NRLA does not take into account other influencing factors such as manufacturers warranties and manufacturers obsolescence mitigation efforts. This model is not robust enough to support current and future Air Force requirements and is consistently flawed in performance. As a result, personnel are not able to rely on the model's validity.

PHASE I: Asses current and developing RLA models across the government services that have a partial capability to support the C-17 mission. Design a robust RLA model integrating agent technology and concepts derived from the assessment. Demonstrate an intelligent driven prototype concept that will provide reliable and robust levels of support and analysis for aircraft maintenance.

PHASE II: Phase II will result in a fully integrated, easily managed and understood, model that accounts for all factors mentioned above and includes other factors such as manufacturer warranties, manufacturer obsolescence, technology turnover, etc. Results of Phase I will be incorporated I to Phase II as determined by the user community.

A full demonstration of the model will be applied to support both 2-and 3-level maintenance criteria. Potential commercial use/dual-use applications will be documented.

DUAL USE COMMERCIALIZATION: Development and ownership of government service repair level analysis technology that is shown to be cost effective should provide the small business with an increased advantage for other DOD participants in aircraft maintenance. The results of this effort have high value for commercialization as real-time performance technologies. Real data generation and decision support tools to support the aircraft maintenenace area are a critical issue. The technology will support government aircraft maintenance for heavy aircraft such as the C-17 and C-5, and mid-size aircraft like the C-130. In addition, the commecial potential to enhance performance and streamline the maintenance process for cargo aircraft (FedEx, etc.)is significant. There is also a direct dual-use relationship for enhancing the robustness of commercial airline maintenance both nationally and internationally.

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KEYWORDS: Repair level analysis, maintenance repair level, aircraft maintenance, avionics maintenance, maintenance-concept

AF04-053 TITLE: Quantification of Logistics Capabilities

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Lay the groundwork for an established and accepted system of measurement that assigns value to logistics capabilities based upon that capability's contribution to the success of operational Air Force combat missions.

DESCRIPTION: This project is in response to the top logistic need as defined by a panel of Air Force logistics experts/leaders in a Strategic Planning Workshop conducted in Sep 02. The ultimate goal or purpose of this effort is to create an accepted set of conversion factors to provide theatre and headquarters level Air Force “logistics leaders/planners” with a method of communicating critical logistics requirements to theatre and headquarters level “operational leaders/planners” using a common vocabulary. The operational leaders typically have little or no background in logistics support requirements, but instead think of war time tasks solely in terms of operational capability. The specific objective of this effort is to conduct innovative research into the area of value-focused thinking to create units of measurement and conversion factors that will accurately translate and describe logistics capabilities (maintenance, transportation, supply, mobility) into quantities of direct combat effects such as fighter-bomber sorties, bombs on target or air mobility missions using a common vocabulary. Currently, the theater/headquarters-level operational communities will construct operational plans based solely on the outcome without considering the logistics investment required to support these operations. While current value-focused techniques exist, they are somewhat limiting in their application to this particular domain. Once specific logistics impact requirements are determined, the decision support foundations must be laid. How to specifically weigh the logistics requirements against the operational objectives is the critical area of research required. Additionally, this technology has the potential to be used by the acquisition community by providing policy makers with significant information on the impact of investment decisions. By providing information on logistics/operational tradeoffs, limited fiscal resources would be more accurately allocated to the more critical needs.

PHASE I: Deliverables will include a final report defining the derivation of a common vocabulary between the operational and the logistics communities. The report will also include the approach of how to specifically weigh the logistics requirements against the operational objectives. In addition, a concept prototype that demonstrates the feasibility of the vocabulary and weighting standards developed.

PHASE II: Deliverables include a prototype software model that demonstrates the use of business rules and algorithms developed by the contractor for component two of the Phase I final report. The contractor must show validation of the prototype software using the real-world case scenarios reported in component one of the Phase I final report, in coordination with the Air Force Research Laboratory and Headquarters AF/ ILM.

DUAL USE COMMERCIALIZATION POTENTIAL: Such a proposed standard could be adapted to any civilian organization that is concerned with acquisition of new systems. With such a similar standard, a civilian organization could optimize their logistics acquisitions (equipment, manpower, consumables, major systems) by proving the value of these key logistics systems in terms of operational output. The primary potential military application of such an accepted system is the enhancement of logistics tools, materials, people, and processes to support combat weapon systems.

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KEYWORDS: Value-Focused Thinking, Value assignment, Likert models, Logistics Measures of Effectiveness, Logistics, Logistics Capabilities, Algorithms, Business Rules, Logistics Business Rules

AF04-054 TITLE: Weapon System Design Simulation

TECHNOLOGY AREAS: Information Systems, Materials/Processes, Weapons

OBJECTIVE: Develop a simulation module that will evaluate the effectiveness/affordability/performance of different design characteristics of a weapon system, specifically related to logistics/maintenance support and life cycle sustainment requirements and costs.

DESCRIPTION: This tool would be created by modifying existing software already in use or creating new software to develop a simulation tool designed to quantify design decisions throughout the weapon system development process. The end result is more cost efficient supportability and operability

PHASE I: Identify all requirements for a design prediction model of this type across the Air Force and other DOD agencies. The Phase I final report would identify all these requirements and determine the parameters the model needs to predict and/or measure, such as cost of sustainment, maintenance down time,time to generate sorties, etc.
The proposing company would have significant flexibility in determining the details and approach for meeting the technical objective of a design simulation tool, and innovative or creative approaches would be encouraged.

PHASE II: Phase II would result in two specific deliverables:
First, a demonstration of the tool's ability to predict effects such as cost, maintenance sortie generation time, and other key supportability and operability measures resulting from design changes, using existing weapon systems with known costs and maintenance data as a gage.
Second, a final report would be provided describing the simulation tool in detail and providing data from the demonstration and other sources showing the validity of the simulation tool.

DUAL USE COMMERCIALIZATION: A system design simulation tool such as this would be a highly valuable method for any civilian aviation industry to determine aircraft system or support equiment life-cycle costs and optimal design charateristics to minimize those costs. Additionally, such a tool could be easily modified to reflect specific operating conditions and would allow civilian designers and users of aerospace systems to optimize performance characteristics before final production or modification of an aircraft system or aircraft support system. The primary military application of this technology would be the optimization of life-cycle logistics costs and efforts through the "logistics- smart" design that this tool would allow.

REFERENCES: 1. DTIC report titled “Simulation and Logistics Support Technologies for Logistics Managers” DTIC number AD-B244995

KEYWORDS: Simulation, Supportability, Design Cost, Analysis, Maintenance, Sortie Generation, Life Cycle Cost, Return on Investment, Logistics, Support

AF04-055 TITLE: Maintenance Mentoring

TECHNOLOGY AREAS: Information Systems, Materials/Processes

OBJECTIVE: Develop initial concept design and model key elements of an enhanced interactive technical data display format enhancements to known interactive diagnostic technical data will include mentoring functions designed to adapt to the user's skill and experience level.

DESCRIPTION: This project will develop initial concept design and model key elements of an enhanced aircraft maintenance job guide format. The enhanced format will utilize cognitive engineering technologies to increase the efficiency and effectiveness of aircraft maintenance technicians through its dynamic interactive mentoring capabilities that enhance existing diagnostic aiding technologies. The proposing company would have significant flexibility in determining the details, approach and medium for meeting the technical objective of the interactive technical data, and innovative or creative approaches would be encouraged.

PHASE I: Required phase I deliverables will include a report detailing the requirements and potential solutions for extending basic diagnostic aiding designs such as the Maintenance Diagnostic Aiding System (MDAS) diagnostic capabilities to include mentoring capabilities. Phase I would document the concepts, methods and requirements of a dynamic interactive electronic maintenance mentoring job aid system.

PHASE II: Phase II deliverables include working software models that demonstrate key elements of maintenance mentoring technologies. These key elements include dynamic interactive pictorial directions for specific maintenance processes or tasks and the ability to automatically filter and adapt the technical data to the skill level of the user, specific fault code and specific aircraft condition. Key elements also include dynamic fault trees with decision support. The dynamic fault tree deliverable will show how advanced interactive technical data can recommend courses of action for the aircraft maintainer based on past performance, time required to complete the action, availability of parts and equipment, and other environmental factors.

DUAL USE COMMERCIALIZATION: This technology can be transitioned to any civilian or military industry where training or detailed instructions or technical data is required to perform complex tasks. A system described above can ideally be used as a stand-alone training device for inexperienced personnel or an electronic mentor for experienced technicians on the most difficult problems. The primary military application of this technology would be to allow generalist maintainers to perform as seasoned specialist without assistance when performing complex aircraft maintenance tasks.

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KEYWORDS: Interactive, maintenance mentoring, enhanced diagnostics, diagnostics, interactive electronic technical data, interactive electronic technical manuals, decision support tools, mentoring

AF04-056 TITLE: Optical Amplifier for Night Vision Imaging

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics, Human Systems

OBJECTIVE: Develop a device capable of amplifying light by optical means for vision under low-illumination conditions.

DESCRIPTION: Image intensifier tubes, as part of night vision devices, have been the primary devices for the detection and amplification of near infrared light for night military operations. In an image intensifier tube, light is converted to electrons by its photocathode. The electrons are then amplified using a microchannel plate. Finally, electrons leaving the microchannel plate excite a phosphor screen, converting the electrons back into visible light. The use of a microchannel plate limits the resolution of image intensifier tube based night vision goggles and gives rise to a number of unwanted visual effects, including halos around bright point sources. In addition, the photocathode, essential to the conversion of near infrared light to electrons, is sensitive to both near infrared light and much visible cockpit light, therefore restricting the kinds of lighting permissible in the modern cockpit. The use of optical amplification could eliminate the negative visual artifacts from using a microchannel plate while tailoring the overall spectral response to be more sensitive to infrared light and less sensitive to visible light, yielding a device that is more easily integrated into the modern cockpit. This program is intended to develop a method of amplifying red and near infrared light optically, in such a manner to allow for the formation of images, without the use of a conventional photocathode and microchannel plate.

PHASE I: This phase will provide an examination and selection of applicable technologies and concepts for image amplification. Work in this phase should also address system size, weight, power requirements, and functional concepts. The potential image quality benefits inherent to proposed amplification schemes should also be identified in a detailed technical report, written at the end of this phase.

PHASE II: This phase will involve the construction of a prototype system using an appropriate approach as determined by the Phase I effort. The Phase II prototype will be robust enough to undergo laboratory and limited field-testing and function as a concept demonstrator.

DUAL USE COMMERCIALIZATION: Optical image amplification will significantly improve the quality of low light and infrared imagery and eliminate several problems inherent in image intensifier tube based systems. The resulting improved image quality and capability will lead to advances not only in the military and law enforcement communities, but also in other fields where high quality low light images are required, such as astronomy and medicine. This technology will be a great advancement over current methods for imaging as it is adaptable to a broad range of wavelengths in the electromagnetic spectrum.

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KEYWORDS: Night Vision Goggle, Optical Amplification, Imaging, Near Infrared

AF04-057 TITLE: Antireflection coatings for image intensifier tubes

TECHNOLOGY AREAS: Materials/Processes, Electronics, Human Systems

OBJECTIVE: Develop an antireflection coating for image intensifier tube faceplates.

DESCRIPTION: Image intensifier tubes, as part of night vision devices, have been the primary devices for the detection and amplification of near infrared light for night military operations. In an image intensifier tube, light is converted to electrons by its photocathode. The electrons are then amplified using a microchannel plate. Finally, electrons leaving the microchannel plate excite a phosphor screen, converting the electrons back into visible light. To reach the photocathode in an assembled tube, light must first pass through a transparent glass window, or faceplate, which reflects a percentage of light incident on it. This reflected light is then scattered by the night vision device objective lens and reflected back to the photocathode where it is amplified, causing a noticeable veiling luminance and reducing visual performance through the night vision device. Antireflection coatings are commonly used in the optics industry to reduce or eliminate unwanted reflections. However, the image intensifier tube assembly process makes the use of antireflection coatings on the glass window in front of the photocathode difficult. This effort is intended to find a cost-effective method for placing antireflection coatings on image intensifier tube faceplates.

PHASE I: Examine potential coating designs and techniques suited to placing antireflection coatings on image intensifier tube faceplates. A theoretical analysis of the optical and visual impact of the coating on image intensifier tube performance is also required. Demonstration of the feasibility of the design and coating technique is highly desirable. Analysis of life cycle cost of the coating should be included as part of the Phase I effort. 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. The best concept resulting from Phase I will be used to produce antireflection coated image intensifier tubes 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.

DUAL USE COMMERCIALIZATION: Low-cost, rugged coatings will increase the potential for commercialization of image intensifier tubes and night vision devices by improving their performance with minimal impact on system cost, making them more attractive to the law enforcement community and to civil aviation. This will speed the assimilation of image intensification technology into the 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 optics for medical, research, and industrial applications.

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KEYWORDS: Night Vision Goggle, Image Intensifier Tube, Thin Film Coatings, Antireflection Coatings

AF04-058 TITLE: Embedded Assessment Technology using Latent Semantic Analysis (LSA) Technology to Monitor Verbal Interactions

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop an LSA-based intelligent software agent for embedding analysis of verbal interactions in learning and performance environments such as Distributed Mission Training

DESCRIPTION: Rapidly changing global environments for expeditionary operations create a need for new tools to enhance cognitive readiness by rapid training and selection of individuals and teams for mission-critical assignments. Embedding automatic, continuous, and cumulative assessment and feedback for individual and group knowledge and performance in individual, crew, and team rehearsal and simulation training environments will greatly improve the effectiveness of these learning modes. Latent Semantic Analysis (LSA) is a new technology that can instantly evaluate free-form verbal contributions of students and instructors during training or operational flights, briefs or debriefs, and match content to stored doctrine and procedure documents and prior recorded after-action or after-training reports. A requirement exists to develop automated methods for capturing, representing, and assessing individual pilot and aircrew knowledge and interaction for use in rehearsal, training, and performance support. Individuals and teams must be quickly trained or retrained for new systems and new missions; mission teams must often be rapidly selected, assembled, and trained for group operations. Advanced Distributed Learning (ADL) will enable sophisticated computer support for local or remotely stationed teams, or potential teams of geographically dispersed individuals, training in group discussion, problem solving, and mission scenario, simulation and rehearsal exercises. The intelligent software agent will keep track of each team member's knowledge levels and of a team's total cognitive readiness by monitoring and analysis of verbal interactions, either in speech or keyboarded. The analysis will provide feedback and automatic retrieval/insertion of relevant information. This technology development will help government and private sector organizations to timely, effectively, and economically meet the needs of rapidly changing operations, technologies, and labor forces.

PHASE I: Phase I will result in a proof-of-concept technology for embedded performance assessment in a distributed, collaborative environment. Also, exemplar, psychometrically sound criterion measures and data collection methods will be developed for two content domains. For Phase I the domain should be related to military team performance such as JSF combat operations.

PHASE II: Develop, apply, and validate an embedded and distributed, collaborative performance assessment technology and criterion measures. Methods for assessment item development, warehousing and management will also be developed. The technology must ensure that the item warehousing cannot be compromised and that learner assessment security and verification is addressed. Proposals should assume that the technology will run in a platform independent environment.

DUAL USE COMMERCIALIZATION: This effort will produce a cost-effective capability to evaluate individuals and teams. The results from this effort are of considerable interest to the private sector as a means of gathering team productivity and performance assessments from dispersed workgroups for use in identifying areas of high performance, areas of potential problems, and additional education, training, or management requirements. Phase III Dual use potential is significant as no assessment capability such as the one described herein exists. The benefits from such a capability to government and private sector agencies could help organizations save considerable time and expenditures by targeting measurement to address specific areas of performance and productivity.

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KEYWORDS: Intelligent software; Training; Communication assessment; Latent semantic analysis; Advanced distributed learning

AF04-059 TITLE: Determining Fidelity Requirements for Training and Certification on Maintenance Simulators

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop an intelligent maintenance tool to reduce fidelity, cost, and learning time while minimizing the overall aircraft downtime for maintenance training

DESCRIPTION: Training and certification of maintenance technicians through the use of simulators requires an individual to not only possess the skills and level of abilities of the maintenance requirements but also to demonstrate those requirements at a predetermined level. Continual reduction in aircraft availability for training from the operational command requires intervention on behalf of Air Education and Training Command (AETC) to design and develop alternative methods to train and certify C3 level maintenance technicians. As the AETC continues to be limited in aircraft access, requirements for maintainers to competently perform the tasks on the flightline without supervision has driven the development of costly and complex high fidelity simulators. To date, the use of high fidelity simulators for training and certification to the C3 level has not been assessed to determine the best media mix for optimal performance for either the maintainer or the simulator. Reliance on high fidelity simulators for training and certification of many skills may not be required which would alleviate some of the cost, complexity, time delay, and burden to provide high fidelity maintenance simulators. It is critical that performance assessment of maintenance technician requirements is performed to determine the short and long term needs of AETC. Valid strategies need to be developed for training, certification and remediation of instruction to support the skills requirement and training standards of AETC. Technology today provides many alternative low cost and rapid development tools that could support this effort. Essential research and development intervention is needed to support the training and certification requirements of C3 level maintenance technicians.

PHASE I: Phase I will result in the identification of training and certification fidelity requirements for the C3 level maintenance technician, the performance requirements required by current certification techniques, and the development of alternative models to support certification in an off aircraft environment using innovative approaches to develop certification methodology. This effort will demonstrate proof-of-concept technology(ies) to support maintenance training and certification.

PHASE II: Develop and demonstrate an alternative integrated set of technologies to support the streamlining of training and certification of a C3 level maintenance technician. Other alternative models will be documented with an analysis as to the best approach based on cost, complexity, time, reduction in remediation, applicability across aircraft systems.

DUAL USE COMMERCIALIZATION: This innovative effort will provide an integrated and seamless set of cost effective and uniquely capable certification tools and technologies to support AETC training requirements across several aircraft systems. Results of this effort will have high commercial value across all training systems based on equipment and aircraft certification within the military as well as in the civil aviation community.

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KEYWORDS: 1. Maintenance training; fidelity requirements; instructional strategies; advanced maintenance technologies; certification requirements

AF04-060 TITLE: Collaberative Maintenance Support (CMS)

TECHNOLOGY AREAS: Information Systems, Materials/Processes

OBJECTIVE: Develop initial concept design and model key elements of a collaborative aircraft maintenance support system.

DESCRIPTION: Produce a concept for harnessing digital photography, wireless internet messaging, cellular and satellite communication technologies and other electronic equipment/tools including portable maintenance aids (PMAs)/hand-held computers to offer maintenance collaboration and synergetic solutions to technicians positioned in austere environments. Solutions will be provided by harnessing advanced communication, digital photography and display technology between technicians at the aircraft and various technical experts.

PHASE I: Required phase I deliverables will include a report detailing the concepts, methods, requirements, processes, required technology integration, secure transmission requirements and concept of operations for an advanced communication system integrating digital photography and image display, wireless internet messaging, bar code reading, and other selected advanced communication technologies. The purpose of integration of these technologies will be for communicating technical questions, photographs illustrations, interactive electronic technical manuals (IETMs) and other required media to guide inexperienced technicians through detailed troubleshooting and repair of remotely located aircraft. The proposing company would have significant flexibility in determining the details and approach for meeting the technical objective of a collaborative tool, and innovative or creative approaches would be encouraged.

PHASE II: Using commercial off the shelf (COTS) and government off the shelf (GOTS) technology develop and demonstrate a prototype communication and display system capable of capturing, editing, displaying, sending and receiving digital photographs and video, voice over IP, bar coding, and interactive electronic technical manual display on portable devices. The purpose of these devices is to communicate technical information/questions and solutions in an unambiguous format between engineers and technicians at remote locations in real time. This system could be used to guide an inexperienced or untrained technician through advanced troubleshooting or maintenance actions by an expert located elsewhere. Deliverables include the hardware and software designated for application of this system, and a final report outlining the conceptual design and detailed analysis of predicted performance including cost/benefit analysis. Other deliverables include initial concept design details and modeling and demonstration of key elements including interactive voice communication and digital video and photography feeds.

DUAL USE COMMERCIALIZATION: This technology can be transitioned to any field where technical or detailed procedures need to be performed where highly qualified civilian or military personnel are not readily available. Examples include but are not limited to medicine, security, vehicle maintenance, and many other technical fields. The primary military application of this technology would be to enable generalist maintainers to perform aircraft repairs through the guidance and direct support of a specialist with more extensive and encompassing training.

REFERENCES:

KEYWORDS: Advanced communication, interactive, maintenance mentoring, enhanced diagnostics, diagnostics, interactive electronic technical data, interactive electronic technical manuals, decision support tools, mentoring, digital photography, collaborative maintenance

AF04-061 TITLE: Future Night Vision System

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop an ultra-lightweight future night vision spectacle-size system that has the potential to provide information fusion.

DESCRIPTION: To support night combat missions throughout the world and meet the requirements for warfighter readiness and mission performance a new generation of night vision technology is envisioned. This future night vision system will utilize new sensor technology and leading edge flat panel display technology to provide the warfighter a tremendous nighttime capability that currently does not exist. This approach will provide the warfighters with a lightweight new generation night vision system that can be a standalone device and accept onboard sensor imagery for information fusion to successfully accomplish their mission. This approach has broad joint warfighting applicability in particular the Joint Strike Fighter. In order to support a variety of warfighter applications a family of night vision systems is desired. Specific requirements include the following: >80 degree horizontal field of view by 40 degree vertical field of view, low light resolution >1.0 cy/mrad at 1.0 e-4 fL target luminance. Good human factors principles should be adhered to such as user-friendly adjustments to accommodate anthropometric differences, lightweight, and minimal impact on head center of gravity. Desired spectral sensitivity range should be longer (up to 2 microns) than current image intensification night vision systems.

PHASE I: This phase will include a trade study to evaluate candidate sensor and display approaches, a recommendation of an optimized approach, and a detailed design based on the selected technologies. The detailed design will include one, two, and four channel systems.

PHASE II: Prototype hardware for the one, two, and four channel designs shall be fabricated and demonstrated for laboratory and field evaluation.

DUAL USE COMMERCIALIZATION POTENTIAL: Prototype hardware for the one, two, and four channel designs shall be fabricated and each approach integrated and demonstrated for possible use with other government, commercial and civilian applications such as law enforcement, border patrol, fire-fighting, night aviation business operations, etc.

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KEYWORDS: Night vision, image intensification, flat panel display, miniature camera, CCD, CMOS

AF04-062 TITLE: Expanded Speech Recognition to Include Foreign Accents

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a speech processing system for speech recognition, speech coding, and/or speaker recognition by identifying specific foreign speech and speaker characteristics

DESCRIPTION: The key technical challenges are: (1) to gain a better understanding of the key features and processes used by biological systems to robustly process speech signals; and (2) the incorporation of those key features and processes into computationally efficient algorithms. Key potential applications include: 1)

Improved control input into a computer / weapon system; 2) means of individual human identification / verification; and 3) improved real-time communication across foreign languages.

PHASE I: Candidate speech processing algorithms will be researched to identify viable approaches to mitigate the effects of various foreign accented english speech on system performance. This Phase I effort will demonstrate a proof-of-concept of the selected approach on one foreign accented speech source.

PHASE II: Fully develop, integrate and evaluate the product using speech from several targeted foreign accented english speakers. Phase II will also demonstrate a computationally efficient and modular approach that can be easily ported to a variety of computing platforms.

DUAL USE COMMERCIALIZATION: Improved speech processing of foreign accented speech has significant potential across a broad range of military applications in coalition operations to improve human-computer interface. Commercial applications include improvements to automatic telephone transaction processing and access to information services in a large variety of domains.

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KEYWORDS: Speech and Speaker Recognition; Speech Coding; Foreign Accent

AF04-063 TITLE: New Decontamination for Aircraft Cargo Interior

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: Develop a novel chem-bio decontamination process that can be used in aircraft cargo interiors without affecting the interior or its contents, and that can be applied in 15 minutes or less and not require reapplication.

DESCRIPTION: Innovative and creative solutions are needed to address the lack of a decontamination system that can decontaminate aircraft cargo interiors without affecting the aircraft, its equipment, the crew, or any cargo. Equipment and materials placed in cargo interiors span from delicate plastics to porous aluminum, all of which need to be decontaminated for continued worldwide use. This includes weapons, electronics and medical equipment. The host countries, where the aircraft may land, define the worldwide use of decontaminated materials differently. Therefore, all decontaminated materials from this process shall not off-gas chem-bio agents faster than a rate of 0.0018 mg-min-m3 (GD), 0.018 mg-min-m3 (HD) and 0.00061 mg-min-m3 (VX). Aircraft cargo interiors have numerous structural cavities that do not allow for standard aqueous-based decontamination processes. Also, the user community requires a decontamination system that can be applied in one single application and not require any additional support such as additional washing or vacuuming.

PHASE I: Produce a novel decontamination process to be used in aircraft cargo interiors. The proposed process will be tested to prove the efficacy and the results documented in the final report.

PHASE II: Develop a system prototype, fully tested, to demonstrate that the application can be accomplished in 30 minutes or less and that reapplication is unnecessary

DUAL USE COMMERCIALIZATION: Phase III military applications include expansion of application to decontaminate sensitive equipment for the joint service community. Sensitive equipment involves equipment such as aircraft pitot tubes, optics, aircraft electronics ground equipment electro-mechanics and electronics, and composite materials. Commercial uses include decontamination of chemical spills during transport of hazardous materials via aircraft or commercial vehicles. More importantly, this solution can be used to decontaminate aircraft from other countries plagued with outbreaks of Foot and Mouth Disease or any other contagious disease where contamination of various types of surface materials is problematic.

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KEYWORDS: Decontamination, Treatment, Toxic Industrial Material, Toxic Industrial Chemical, chemical, chemical warfare agent.

AF04-064 TITLE: Algorithms for Run-Time Terrain Deformation

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop algorithms and prototype minimum hardware and system requirements for implementation of run-time deformation of terrain based on elevation of topographic features in real-time visual simulations.

DESCRIPTION: Current image generator architectures force topographic features to conform to an underlying terrain model. This IG technique is backwards in terms of training value, because the three-dimensional position accuracy of topographic features is of greater interest to pilots versus the general accuracy of a featureless terrain skin. A superior IG architecture should necessarily deform terrain in accordance with the elevation values of topographic features. The ideal architecture would perform deformation at run-time. The run-time deformation of terrain controlled by the z elevation of topographic features should dramatically reduce the cost and time to produce terrain databases for training and simulation. The cost of generating terrain databases is steadily becoming a larger percentage of the total cost of procuring training devices. This technique could help alleviate the cost growth problem of terrain databases, as well as help reduce the time it takes to generate databases for mission rehearsal purposes.

PHASE I: Identify existing and develop new algorithms/techniques to perform the real-time terrain deformation function. It will establish the minimum hardware and system requirements for implementation of each algorithm/technique. Finally, the associated performance strengths, weaknesses, risks and performance/cost tradeoffs associated with each algorithm/technique will be evaluated.

PHASE II: Select and prototype one or more of the most promising candidate algorithms/techniques to work with commercial IG hardware.

DUAL USE COMMERCIALIZATION: The following are a few of many potential Dual Use applications of this technology:
1. Mission planning visualization.
2. Embedded, counter-measure resistant, stealth navigation for UAV's, RPV's and piloted vehicles.
3. Virtual landscaping.
4. Visualization for large scale, cultural construction projects.

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KEYWORDS: Training Simulation, Visual Simulation, Image Generation

AF04-066 TITLE: Next Generation Visualization Tools for Mission Planning, Briefing and After Action Review

TECHNOLOGY AREAS: Air Platform, Information Systems

OBJECTIVE: To develop a demonstrable visualization environment and data creation toolset for mission preplanning, execution and after-action review.

DESCRIPTION: This effort will develop high fidelity visualization technologies and tools for critical mission preplanning, execution evaluation, and battle damage assessment and after action review. At the present time, warfighters are severely limited in their ability to effectively preplan and evaluate combat mission plans and scenarios in real time and with the level of fidelity necessary to visualize the expected combat battlespace for mission execution evaluation and after action reviewing and debriefing and to learn appropriate mission planning and debriefing techniques and methods. Lessons learned from Desert Storm and Kosovo point to the fact that many of our operational aircrew did not have an opportunity to preplan, evaluate and assess mission strategy and execution prior to their actual missions. Moreover, there was no capability for tactical combat teams to adequately evaluate and debrief previous missions in a high fidelity environment that facilitates learning and future mission preparedness. This effort will develop and demonstrate a deployable high-fidelity visualization environment for advanced combat tactical mission planning and evaluation. Where appropriate, the proposed environment will necessarily integrate virtual and constructive entities to support a variety of instructional strategies and a variety of scenarios and missions.

PHASE I: Phase I will result in an analysis of visualization needs and mission parameters that will drive the development of the mission planning, evaluation and debriefing environment specifically for tactical combat missions. In addition, the Phase I effort will develop and demonstrate a proof-of-concept technology to support mission planning, training and rehearsal.

PHASE II: Phase II will build upon Phase I to fully develop, refine, test and evaluate visualization needs and mission parameters for the battlespace visualization environment. Additional activities in Phase II include a demonstration of instructionally-rich and integrated mission preplanning, execution, evaluation and debriefing environment that will leverage virtual and constructive assets to provide high fidelity mission analysis capabilities. Phase II will also provide initial data on mission readiness and effectiveness and data on improved mission visualization, planning and analysis on combat exercise performance.

PHASE III DUAL USE COMMERCIALIZATION: This effort will provide a uniquely capable and cost-effective, deployable high fidelity, interactive planning and evaluation capability that does not exist today for any operational air combat system. The results of this effort have high value for commercialization as visualization tools for many complex and difficult tasks that will challenge the state-of the art in PC-image generation and display technologies for high fidelity visualization as well as mission development tools and modeling and simulation capabilities. Dual Use potential is significant as no other technology exists that provides a common approach to mission planning and evaluation that integrates advanced organizers, data management tools, instructional agents and strategies and permits a high fidelity representation of the current battlespace and the planning activity.

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KEYWORDS: Advanced organizers, Brief and debrief systems; distributed collaborative systems; instructional coaches, data management

AF04-067 TITLE: Achieving Decision Superiority in the Information Age

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Design and develop interactive training for C2 INFO-SYS and efficient decision- processes.

DESCRIPTION: A critical capability of focus in Joint Vision 2020 is "information superiority," defined as the ability to collect, process, synthesize, and share vital information to a far greater extent than an adversary can. Information, information processing, and communications are at the heart of any military operation. And information superiority is a key enabler ensuring victory. Information superiority provides our forces a competitive advantage only when it is effectively translated into superior knowledge and decisions. Future effectiveness in warfare will be increasingly dependent on the relative capabilities of opponents to use advanced information systems (INFO-SYS) and efficient decision processes to efficiently integrate political-military functions such as C2. Within C2 information is collected to make good situational and battle space decisions and in turn to communicate those decisions to the forces. The force must be able to take advantage of superior information converted to superior knowledge to achieve "decision superiority" which is defined as better decisions arrived at and implemented faster than an opponent can react to changes and accomplish the mission. Decision superiority is achieved by possessing knowledge of how the decision-making process works and how it is applied. Key to this process is how to properly collect and fuse information from a variety of sources to reduce uncertainty inherent in the pursuit of innovation. It is envisioned that greater focus on education and training in decision-making will lead to greater information superiority as well as effective information warfare as we move to achieve the objective of Joint Vision 2020.

PHASE I: Demonstrate the feasibility of designing and developing an interactive scenario-based process training system: (a) to depict INFO-SYS and efficient decision processes as related to the C2 political-military function. (b) instructional strategies to teach these processes, (c) preliminary system architectural specifications, and (d) development of a technical report documenting the Phase I effort.

PHASE II: Design and develop a functional and operationally evaluated training prototype to demonstrate the information systems and decision process related to information operations with the objective to produce fully functional product to commercialize in Phase III. The system will be implemented via an internet/intranet environment allowing ease of access.

DUAL USE COMMERCIALIZATION: This technology will benefit current/future military and civilian programs requiring training in Information Operations. Examples include: First Responder Rescue Teams operating in disaster and crisis environments to make better use of information sources to improve their decision-making ability; Aerospace Operations Center (AOC) Process Training; and Homeland Security decision making processes in the corporate classified and non-classified environment.

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KEYWORDS: Decision making; information superiority; Joint Vision 2020; information processing; communications

AF04-068 TITLE: <u>Work-Centered Support System for Counterspace Operations</u>

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a work-centered support system that facilitates a human analyst in the detection and identification of threats to space assets.

DESCRIPTION: Space assets are critical to our military superiority thus making them targets for attacks. These attacks may be difficult to detect using current tools available at Space Operations Squadrons (SOPS) because the degradation effects may be gradual and appear to be isolated. Improved user work-centered technologies are needed to assist the operator in detecting otherwise imperceptible trends and to rapidly gather the information needed to report the incident. Neural networks that are being refined for counterspace operations can detect some trends but this technology lacks the flexibility needed for warfighters to perform their own analyses. To address this problem, AFRL seeks innovative proposals to develop a Work-Centered Support System (WCSS) [2,5] that bridges the gap between the analyst and the numerous information sources available.

A WCSS differs from traditional human-computer interface development in that it is focused on the user's problem workspace and provides multiple forms of work aids within a unified cognitive support framework. In addition to improved user interfaces, the WCSS would benefit from intelligent agents that work cooperatively with humans and other agents in the gathering and fusing of information [3]. At the request of the analyst, the WCSS should be able to intelligently survey the historic and current data of individual satellites, entire constellations and other relevant sources. In addition to recognizing threats and attacks, the system should help operators identify non-intentional system degradation that may have otherwise been difficult to identify.

PHASE I: This phase will include surveying existing task analyses on counterspace operations providing a detailed architecture and initial design of a WCSS, and documenting the results in a WCSS preliminary design report. Results of these analyses will be used in Phase II for the development of the intelligent agents.

PHASE II: Prototype WCSS software – including functional intelligent agents – with the intent to tested at an operational facility such as the Space Warfare Center.

DUAL USE COMMERCIALIZATION POTENTIAL: The prototype WCSS and its software components will be equally applicable to commercial satellite operations as well as to other military and commercial systems where it is important to distinguish between intentionally-induced and normal/accidental degradations in performance. Certain homeland defense systems fall in this latter category.

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KEYWORDS: Counterspace, work-centered support system, intelligent agents.

AF04-069 TITLE: Enhancing Commanders' Cognitive Readiness at the Operational Level of War

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop scenario-based training capability for operational-level leaders using advanced archiving/retrieval of contextualized developmental experiences.

DESCRIPTION: Operations Desert Storm and Allied Force brought to light shortfalls in the training programs for senior leaders in critical command and control (C2) positions. Traditionally these leaders are brought in from a rated position to fill a C2 leadership position without having gone through a formal training program for their specific role in the operation. After Operation Allied Force, the Air Force leadership made clear the lack of training at senior levels of operations, leaving our C2 warriors in the unacceptable position of learning, to a large degree, on-the-job. Gen John P. Jumper said of Kosovo: "LGen Michael Short, the JFACC of Operation Allied Force, trained himself in the operational level of warfare… [Most of us in Air Force leadership] trained ourselves, because our system did not train us." (Air Force Magazine, April 2000). Currently, senior-level C2 leader training is accomplished through mentoring by senior leaders from prior warfighting operations. This type of approach is highly sensitive to the scheduling and availability of the mentors, limited by their memory of specific actions and reactions during critical incidents, and is not always in context for the current conflict. This effort would "warehouse" knowledge and lessons learned from these senior leaders' experiences from warfighting operations such as Desert Storm, Joint Endeavor, Allied Force, Enduring Freedom, and Iraqi Freedom. The decision-making process at the operational level of war can be modeled through a cognitive task analysis (CTA) of the senior leaders' actions during critical incidents. The warehoused information and decision-making model(s) would be organized through a process such as latent semantic analysis to develop contextually valid relationships between operational conditions and appropriate actions. This knowledge base will provide a deep corpus of contextualized experiential knowledge to serve as content to develop scenario-appropriate training and rehearsal experiences for senior C2 leaders in modern operational scenarios.

PHASE I: This effort will develop an instructional strategy, proposed architecture for data warehousing and contextualized retrieval, and an initial training simulation proof of concept. This effort will also develop an initial high-level cognitive model of JFACC operations based on past research efforts in JFACC cognitive analysis to determine requirements for further analysis in the second phase.

PHASE II: This effort will develop a prototype training system which will integrate the contextualized knowledge warehousing capability and the scenario-based training tool to provide instructionally principled training for senior Air and Space Operations Center (AOC) decision makers. This will require the refinement of the expert model of the JFACC from Phase I and the development of models for other key AOC positions. This prototype will be demonstrated at operational AOC training locations such as the C2TIG or the CAOC-Nellis.

DUAL USE COMMERCIALIZATION: This effort could be expanded to demonstrate dual-use capabilities. The proposed effort will provide an opportunity to develop a commercially viable capability that is not currently available. Dual use potential is significant because many commercial scenarios exist in which leadership decision making in crisis operations could be improved (triage staffs, commercial air crew training, civil emergency response teams).

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KEYWORDS: Aerospace operations, command and control training, distributed mission operation, readiness evaluation, team effectiveness, knowledge warehousing, contextualized training, senior leader training.

AF04-070 TITLE: Distributed Planning, Debriefing, and after-action-review Capability

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop, demonstrate, and evaluate a distributed planning, debriefing, and after-action review capability for long-haul, distributed, computer-driven simulations in support of team coordination training.

DESCRIPTION: Team coordination skills are critical to ensure all team members and groups of teams function in an integrated and effective way. This is true of military and civilian teams including: fighter and multi-crew aircraft, command and control, force protection, firefighters, civil emergency, and other types of rapid-response teams. Base and homeland defense cannot be guaranteed simply by the existence of rapid-response teams. Highly trained teams must be capable of making individual decisions under extreme time pressures and effectively coordinating actions among individual team members and functionally distinct teams. Obstacles to training rapid-response teams include geographic and organizational separation. One approach to overcoming these obstacles is to supplement standard training with long-haul, distributed, computer-driven simulations in support of team coordination training. Such an approach would allow trainees and instructors at geographically-separated locations to participate in training over a long-haul network and therefore avoid the costs of travel to a centralized location. Such an approach would provide an opportunity for functionally-distinct teams to interact in realistic virtual environments and coordinate actions in support of overall team effectiveness. Although long-haul, distributed simulation training offers promise as an economical approach, it does not include an effective capability for trainee collaboration in support of mission planning or trainee / instructor interaction for debriefing and after-action review. Research has shown when trainees learn and rehearse the same mission in the same simulation in co-located and in geographically-separated locations, training is less effective for geographically-separated trainees (Singer, Grant, Commarford, Kring, & Zavod, 2001). In co-located or centralized simulation training exercises, trainees can collaborate in the development of mission plans prior to the exercise and instructors have the opportunity to directly observe trainee performance during the exercise, identify performance inadequacies, and provide feedback. The purpose of this effort is to develop a distributed planning, debriefing, and after-action-review capability for long-haul, distributed, computer-driven, simulations in support of team coordination training.

PHASE I: Develop a proof-of-concept capability for distributed planning, debriefing, and after-action review for long-haul, distributed, computer-driven, training simulations. The proof-of-concept capability should include: tools for trainee collaboration during distributed mission planning, simultaneous replay of simulation exercise at geographically-separated sites including both the simulation visual display and trainee/instructor communications occurring during the exercise, an option for simulation replay control originating from geographically-separated trainee and instructor sites, and trainee/instructor communications. Interactivity between the instructor and multiple trainees should include illustrations of the functionality for jointly viewing live/simulation snap shots, timelines, and tables or graphs illustrating outcomes of mission planning and simulation training exercise.

PHASE II: Develop, demonstrate, and evaluate a prototype distributed planning, debriefing, and after-action-review capability to support long-haul, distributed, computer-driven, training simulations. Demonstrations will consist of military/civilian teams and live/simulation exercises at geographically-separated sites to include deployed military locations, trainee collaboration for distributed mission planning, long-haul, distributed replay of computer-driven simulation exercises, and replay control by both trainee and instructor. The prototype should demonstrate interactivity between instructor and students in the form of communications and joint viewing of exercise snap shots, exercise timelines, and tables or graphs illustrating outcomes of mission planning and simulation training exercises.

DUAL USE COMMERCIALIZATION POTENTIAL: Phase III activities will result in demonstration of dual use applications. The effort should provide an opportunity to apply the technology to long-haul simulation training for civil agency (Homeland Defense, airport authority), military (wing battle staff, Battle Control Center), or commercial airlines. Phase III proposals must include a detailed market survey and letters of interest / commitment from potential commercial partners for evaluation and Phase III consideration.

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KEYWORDS: Computer-driven, training simulations, long-haul distributed training, distributed mission planning, debriefing tools, after-action-review capability, team coordination training

AF04-071 TITLE: Adaptive Levels of Automation for UAV Supervisory Control

TECHNOLOGY AREAS: Information Systems, Battlespace, Human Systems

OBJECTIVE: Develop a robust architecture for implementing and evaluating mission phase-specific levels of automation and contingency-specific adaptive automation for future UAV systems.

DESCRIPTION: Unmanned Air Vehicles (UAVs) are at the forefront of current battles and future thinking (OSD UAV Roadmap, 2002). Several projects are underway to increase the level of autonomy for future unmanned systems, so as to increase the number of UAVs that one crew (or one operator) can 'control'. Global Hawk, AF-UCAV, and N-UCAV all have goals of reducing the operator-to-vehicle ratio in order to reduce life-cycle costs and serve as force multipliers. However, it is well known that increasing autonomy and number of supervised semi-autonomous vehicles can cause rapid and significant fluctuations in operator workload and can result in loss of operator situation awareness. Thus innovative methods are required to keep the operator 'in the loop' for optimal situation awareness, workload, and decision-making. Two methods that have shown significant promise in enhancing operator performance in supervisory control include mission phase-specific application of a broad range of Levels of Automation (LOA)(Parasuraman, Sheridan, & Wickens, 2000) and Adaptive Automation in response to mission contingencies (Bonner, Taylor, Fletcher, & Miller, 2000). This SBIR seeks to develop an innovative system architecture and accompanying multi-UAV simulation testbed that would enable the implementation and evaluation of task-specific LOA and situation-specific adaptive automation for future UAV systems. This product will provide a unique research testbed for generating guidelines that ensure a more relevant coupling of human and autonomy throughout the entire supervisory control work domain.

PHASE I: Develop and demonstrate a prototype system architecture for manipulating a range of feasible adaptive LOAs for supervisory control, using a multi-UAV control station simulator testbed.

PHASE II: Perform spiral iterations of design, test, and refinement to expand the system, culminating in a full evaluation in a representative high-fidelity UAV simulation environment.

DUAL USE COMMERCIALIZATION: This effort directly supports the goals of the UCAV-AF, UCAV-N, and Global Hawk programs. This architecture and research also will be generalizable to unmanned ground and sea systems as well as numerous civilian supervisory work domains.

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KEYWORDS: Human factors, human computer interface, UAV, unmanned system, supervisory control, level of automation, adaptive automation, automation architecture, autonomy, situation awareness

AF04-072 TITLE: Cultural Factors Influencing the Use of Non-Lethal Weapons

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop training courses and methods to collect information that would provide the war fighter with enhanced understanding of how cultural differences would influence the manner in which individuals or crowds would respond to the use of non-lethal weapons, including directed energy systems (e.g., active denial system).

DESCRIPTION: Understanding the cultural identity of an individual or group is important in determining the optimal military use of non-lethal weapons. Cultures with flat horizontal hierarchies may respond differently than those with vertical hierarchies. Rapidly changing emerging leadership within the group may be more prevalent in one of these hierarchies. The integrity of the civilian law enforcement agencies with which an individual has experience may influence the manner in which that individual responds to the military use of non-lethal weapons. The difficulty in these types of situations is providing the war fighter with accurate knowledge of the culture (e.g., beliefs, attitudes, religion). Simply providing the war fighter with a review of the general culture may be inadequate, due to possibility of minority cultures within the society. The sub-cultures might respond to the military use of non-lethal weapons in a manner that is very different from that which would be predicted for the general culture. It may be critical to provide the war fighter with the tools to collect the most pertinent information regarding the culture with which they are interacting.

PHASE I: Emphasis is on the decision-making process of the war fighter in the global theater. Conduct research to determine cultural influences on the potential responses of an individual or group to civilian law enforcement and military activities. Develop strategies to identify the potentially changing leadership within a crowd. Conduct studies (e.g., interviews, focus groups) to identify the crowd control techniques used by civilian and military law enforcement agencies within and outside of the United States. Develop an understanding of which crowd control techniques are the most effective and whether these techniques are limited by the culture in which they are used. Use the results from the above research efforts to determine the extent to which culture will influence an individual or group response to the military use of non-lethal weapons. The methodology and findings will be documented in a technical report.

PHASE II: Develop training that provides the war fighter with a solid understanding of the cultures with which they will be interacting. Conduct research to develop guidelines or instructions for the war fighter to collect information pertinent to the cultures with which they are interacting. Provide training as to the optimal methods to influence the individual or group when using non-lethal weapons. Addressing these topics would aid the war fighter in determining the relevance, pertinence, and applicability of lethal and non-lethal weapons. Training effectiveness assessments would be conducted.

DUAL USE COMMERCIALIZATION POTENTIAL: The developed training and procedures might be taught on a contract basis to military, government, and commercial customers. As an example, the developed course might be incorporated into broader courses, such as the Interservice NLWs Instructor Course (INLWIC) in Fort Leonard Wood, Missouri. In addition, the developed course would be applicable to numerous security forces that provide security in diverse cultural regions. In addition, the developed training and procedures would be applicable to humanitarian and crisis response teams situated in potentially hostile environments.

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4. "Joint Vision 2020: America's Military Preparing For Tomorrow"http://www.dtic.mil/jv2020/jvpub2.htm
5. Joint Non-Lethal Weapons Program homepagehttp://iis.marcorsyscom.usmc.mil/jnlwd/

KEYWORDS: Cognitive Science, Human Factors, Non Lethal Weapons, Sociology, Psychology

AF04-073 TITLE: <u>Focused Delivery of Laser Energy to the Eye Using Adaptive Optics</u>

TECHNOLOGY AREAS: Biomedical, Sensors, Human Systems

OBJECTIVE: Create the ability to deliver laser energy to the retina through an aberration-corrected optical system.

DESCRIPTION: The Air Force desires to evaluate the damage thresholds and mechanisms for retinal exposure to laser exposure. One of the most challenging pieces of this evaluation is estimation of retinal spot size in the living eye. To allow for evaluation of retinal damage mechanisms, a means to deliver a laser beam with a diffraction-limited spot size is desired. The device would take the output from several lasers across the 400 nm to 1400 nm wavelength range, and deliver the smallest spot size possible to the retina. This will allow for assessment of the damage mechanism to the retina and will have ophthalmic application in the treatment and assessment of ocular diseases.

PHASE I: The methodology and design of a prototype delivery system for diffraction-limited laser delivery to the retina of a living eye will be accomplished in Phase I of this effort. The solution will provide a means to deliver a laser beam through an aberrated optical system with a predictable spot size. This solution may be validated in a mock-up system with random aberrations to allow evaluation of the efficacy of the solution proposed.

PHASE II: A prototype delivery system for diffraction-limited laser delivery to the retina of a living eye will be accomplished in Phase II of this effort. The solution will provide a means to deliver a high-energy laser beam through an aberrated optical system with a predictable spot size. The prototype will be evaluated for real-time laser delivery with dynamic aberrations. The ability to deliver a high-energy beam through a robust aberration correction is essential. The ability to also image the retinal structures through this system is a desired offshoot.

DUAL USE COMMERCIALIZATION POTENTIAL: Novel retinal imaging capabilities will allow for battlefield assessment of retinal damage. This technology can also be used by both DoD and civilian physicians the ability to assess retinal disease progression with unprecedented fidelity.

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KEYWORDS: Laser, Eye, Adaptive Optics, Aberrations, Retina, Surgery, Ophthalmoscope

AF04-074 TITLE: Real-time Bio-Sensors for Enhanced C2ISR Operator Performance

TECHNOLOGY AREAS: Information Systems, Sensors, Human Systems

OBJECTIVE: Develop a real-time, unobtrusive, biological sensors and monitoring technology for evaluating C2ISR warfighter cognitive readiness.

DESCRIPTION: A variety of environmental and/or mission-related stressors threaten to adversely impact the operational readiness of C2, ISR, and other console operators and teams. For instance, sleep deprivation (a common operational stressor) has been shown to substantially reduce performance accuracy while slowing reaction times and adversely affecting psychological mood. In addition, high workload demands (commonly encountered by C2 operators, battle management staff and others) can overwhelm a human’s capacity to effectively process information and manage complex systems and subsystems under the time pressures typically found in operational settings. The extent to which fatigue and cognitive overload interact to degrade operator performance has not been determined. Early detection of degradations attributable to the combined effects of insufficient sleep and cognitive overload (factors typically encountered in operational settings) would provide an opportunity to implement countermeasures that could ultimately prevent serious performance failures. Unfortunately, at present, it is difficult to make such predictions in C2 and other settings with any degree of accuracy. This is in part due to the fact that unobtrusive subjective assessments are unreliable and the administration of proven, objective diagnostic tests requires interruption of the operator’s primary task (flying the aircraft, making command decisions, operating a UCAV, etc.).

Furthermore, continuous, objective physiological monitoring/status assessments have not been developed/validated to the extent that accurate real-time feedback on alertness and cognitive load can be made immediately available to the operators and commanders involved in demanding work settings. Properly processed, objective, real-time, continuous, and non-invasive monitoring of warfighter psycho-physiological data (heart rate, EEG, eye blinks, voice, etc.), cognitive load, and performance data (task and team indicators) will enable immediate identification of increased performance vulnerabilities without interfering with the operator's primary task. This development/validation effort will produce an individualized status monitoring system for C2, ISR, Information Operations, UCAV, and space operators and teams. The system will consist of a collection of bio-sensing technologies and processing/feedback algorithms which will guide the effective "fusing" of fatigue/adaptive-workload interventions with weapon systems to mitigate the currently unpredictable episodes of cognitive overload and the lapses in operator attention that often result in missed signals and catastrophic failures.

PHASE I: Determine what electro-physiological and other indicators of compromised operator states are most amendable for unobtrusive monitoring of psycho-physiological and warfighter performance data. Propose a multi-sensor platform of bio-sensing technologies (i.e., continuously-wearable, high-impedance sensors, or off-body physiological sensors that do not require complicated and uncomfortable scalp/skin preparation) for development under Phase II.

PHASE II: Develop an individualized operator-state-assessment model capable of predicting actual real-world-relevant performance and an integrated suite of unobtrusive bio-sensing technologies (psycho-physiological monitoring sensors).

AF Phase III applications include "fusion" of these warfighter system data with C2, ISR, AC2ISR (MC2A), UCAV, Intelligence, Information, and Space systems. Real-time, bio-sensor technologies could also enhance aviator performance through fusion with JSF tactical and weapon system data.

DUAL USE COMMERCIALIZATION: Unobtrusive, bio-sensing operator monitoring systems will enhance cognitive performance in a variety of commercial applications including: aviation, transportation, security, nuclear power, and other vigilance demanding applications.

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KEYWORDS: biosensors, psycho-physiological measurement devices, real-time feedback systems, alertness, cognitive load, fatigue, workload

AF04-085 TITLE: Military and Civilian Air Traffic Management Information Exchange and Visualization

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Improve overall interoperability among military components operating in civil airspace by abstracting information from the data available in the Department of Defense (DoD) Air Traffic Management (ATM) system and provide increased situational awareness and flight safety to combat/mobility forces and their civilian counterparts, subject to appropriate operations security (OPSEC) restrictions.

WARFIGHTER IMPACT: Enhanced situational awareness and flight safety in military operations conducted in civilian airspace. Seamless sharing of information among mobility, combat and civil aviation communities enhancing overall military and civilian mission effectiveness.

KEY TECHNOLOGY AREA: Situational Awareness, Common Information Representation, and Extensible Markup Language (XML).

DESCRIPTION: The United States Air Force (USAF) is undergoing the process of integrating the components of its Command and Control (C2) System. The product of this integration is referred to as the Integrated C2 System (IC2S) while the process to achieve this goal is referred to as C2 Enterprise Integration (C2EI).

Critical to this process is the concept of publishing data of interest to components of the IC2S and subscribing to data of interest published by other components of the IC2S. Key to accomplishing this information exchange is the use of the XML to represent the data. Publishing the data in the XML format will provide the information to the IC2S in a common format that can be accessed by any interested party. This will provide the decision-makers and the warfighters with timely information upon which they can act to make better informed choices.

While providing a common format for members of the IC2S, this will also provide information in the same common format for other members of the DoD, as well as other agencies that perform air traffic management, such as the Federal Aviation Administration (FAA) and foreign Civil Aviation Administrations (CAAs). Additionally, where applicable, data of interest can be made available to commercial airlines and other interested parties.

In addition, the USAF conducts substantial flight and tactics training activity in civilian airspace designated as "special use airspace" (restricted areas, military operating areas, etc.) where conventional surveillance may be disadvantaged by mountainous terrain. Since the events of 9/11, military operations in "open" civilian airspace has increased in frequency and in operations not necessarily related to training. This requires greater surveillance coverage from non-conventional (civilian) sources; however sharing of data from military systems with civilian control centers is impeded by concerns such as data security classification and OPSEC. Opportunities are emerging to improve the situational awareness from a surveillance perspective when ADS-B is deployed in the surveillance infrastructure and aircraft are equipped. But, these advantages are not fully realized without a method to visualize and distribute the information without compromise. The purpose of this activity is to investigate and identify approaches to visualize the integrated multi-source surveillance data to produce a single fused operational picture, and to explore ways to distribute the resulting composite picture to other facilities including both military and civil aircraft for improved situational awareness and flight safety while addressing fundamental issues involving the preservation of military security and OPSEC.

Key issues to be addressed include preservation of operations security while providing data useful for improving flight safety for both military and civilian aircraft. This activity will address novel data distillation and visualization concepts that enable useful yet unclassified representations of the air picture to be distributed to military and civilian participants.

PHASE I: Phase I activity shall include: 1) Gathering of the information available within the DoD realm of ATM. 2) Determination the applicability of representing that information in XML. 3) Development of an ATM registry within the DoD XML registry to track the DoD representation of ATM information in XML format. 4) Identify approaches and concepts for multi-source data aggregation and visualization that preserve military security and OPSEC.

PHASE II: Phase II activity will focus on demonstration the publishing of ATM information on the web and the benefits that publishing of this information provide to decision-makers and warfighters. Demonstrate the feasibility and validating the utility of the visualization concepts, as well as identify and resolve issues.

DUAL USE COMMERCIALIZATION: The USAF performs ATM throughout the world. Positive control of both commercial and civil aircraft is performed. By exchanging appropriate ATM information in a common format with the FAA, CAAs, commercial airlines and other interested parties, safer, more efficient flight can be achieved worldwide. Visualization of fused multi-source surveillance data is expected to have immediate benefit to military mission effectiveness by providing military aircraft enhanced situational awareness of civil aircraft in the operations area. Visualization of military aircraft in the civil air traffic control environment, while preserving military security and OPSEC, will enhance civil air safety and traffic flow in the vicinity of military operations.

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KEYWORDS: Situational Awareness, Air Traffic Management

AF04-086 TITLE: ADS-B Data Integrity

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics, Battlespace

OBJECTIVE: Develop and demonstrate encoding algorithms, error correction methods, fusion algorithms, correlation algorithms, etc. to verify and validate aircraft data transmission message authenticity, (i.e., Automatic Dependent Surveillance-Broadcast (ADS-B) and its data signal), despite their vulnerability to both accidental and deliberate contamination. The effort should include the identification and evaluation of the various enabling technologies, an architecture that considers the constraints imposed by ADS-B, simulation models to provide an evaluation of the various design trade-offs for ensuring the integrity of the data, a notional terminal and system design, and a spiral schedule describing the development and enabling technology insertion points.

WARFIGHTER IMPACT: Allows warfighter to use ADS-B surveillance data provided by Civil Aviation Authorities for enhanced situation awareness and flight safety while testing every data element for spoofing. Allows warfighter access to ADS-B controlled airspace without being deflected by spoofed signals.

DESCRIPTION: The DoD would benefit from if it could rely on data derived from the various communications, navigation and surveillance elements of the civil Air Traffic Control infrastructure, the National Airspace System

(NAS), to meet the needs of its aircraft for enhanced situational awareness and flight safety. This reliance cannot be complete unless the DoD can depend on the integrity and accuracy of that data. A critical component of proposed enhancements to the NAS (Free Flight for Air Traffic Management) is Automatic Dependent Surveillance – Broadcast (ADS-B). The value of ADS-B is that it can provide surveillance data to both the Air Traffic Control (ATC) System and to other aircraft in the vicinity, allowing for a shared view of the ATC situation in real time and increases airspace capacity. However, ADS-B as currently structured is highly vulnerable to spoofing.

A discussion with FAA sources indicated that the most likely FAA defense from spoofing is a comparison of ADS-B position reports and secondary radar reports. However, the greatest value of this data would be in areas/altitudes where there is no such conventional surveillance coverage. That is the case today, for example, in Alaskan airspace where obtaining and using ADS-B data from the FAA's Capstone project is currently being considered. This effort would allow USAF aircraft access to civil airspace abutting and crossing low altitude training routes in Alaska with no increase in the potential for collision with civil aircraft.

PHASE I: The enabling technologies to be developed will encompass processing/correlation of the physical/observable characteristics of the ADS-B message transmission and this information to the data in the ADS-B datagram. In addition the effort will analyze the options for incorporation of advanced encoding, error correction, fusion, and/or correlation algorithms in the ADS-B system which enhances message authenticity. In this phase, the contractor will identify and select the key physical characteristics of the ADS-B transmission that will provide the best source of integrity data. The options to be considered for laboratory demonstration/simulation will include, but not be limited to:
• Consistency between signal doppler shift and velocity information in the datagram.
• Signal-to-signal correlation for single aircraft; comparing information to datagram information.
• Correlation of signal direction with self-reported position.
• Correlation of time of flight to receiving antenna with reported position.
Simulations will be used to determine data authenticity relative effectiveness based on pre-processing the existing ADS-B system and a proposed enhanced ADS-B system. Estimates of the feasibility of implementing each approach will be made based on both technical and institutional issues.

PHASE II: The most promising enabling technologies identified in Phase I will be designed, developed and demonstrated in the laboratory. The laboratory simulation will identify the reliability and stability of the data being extracted from the physical characteristics of the transmissions and when new algorithms are included in the ADS-B system. This phase will also include the development of a conceptual operational architecture to make this integrity verification data available to DoD aircraft. Among the alternative data delivery architectures to be analyzed are on-board ADS-B equipment changes, ground based data receipt with transfer to the aircraft by tactical data links, and satellite systems.

DUAL USE COMMERCIALIZATION: Airspace management is a key area of research identified by the FAA as having great potential for improved NAS efficiency and safety. Once developed, the technology could be used as a preprocessor for airborne ADS-B transceivers by both military and civil aircraft operating in areas where there is no conventional radar coverage. International Civil Aviation Authorities, the FAA and DoD could also adopt it as a preprocessor for the ground based ADS-B receivers providing data to the Air Traffic Controllers. Changes proposed by this effort could also, via spiral development, be included by the FAA and civil agencies in their future ADS-B upgrade plan.

REFERENCES: 1. Skylar. Digital Communications, Fundamentals and Applications, Prentice Hall publishers, Englewood Cliffs, NJ. 1988.

KEYWORDS: Coding algorithms, fusion algorithms, correlation, jam resistance, data integrity, information assurance

AF04-087 TITLE: Expert Intelligent Match of Requirements and Solutions

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop the ability to match textual descriptions of Warfighter requirements (needs) to relevant textual descriptions of proposed solutions.

DESCRIPTION: The Information Warfare Solution Analysis Integrated Product Team (IWSAIPT) is developing a database that houses both Information Warfare (IW) Warfighter requirements and IW solutions. The IWSAIPT database uses a set of multifaceted IW requirements that cut across these 11 distinct IW areas: Counterintelligence, Computer Network Attack, Computer Network Defense, Electronic Warfare, Information Assurance, Integration, Military Deception, Operations Security, Physical Attack, Public Affairs Operations, and Psychological Operations. The total number of requirements at any one time is usually between 100 and 150. Complex IW solutions that number in the hundreds will also be housed within a database. Proposed IW solutions can be relevant to multiple requirements in multiple IW areas. Matching a requirement to solutions can be a daunting, time-consuming affair when done by human review. A computer-based means of comparing IW requirements to the database collection of solutions to find those that are relevant to the requirements is needed. Simple, literal, word-based searches are inadequate for this task because the keywords used may not be present in every IW solution document.

PHASE I: 1) Investigate emerging and existing relevant methods of intelligent search, 2) Define the approach that will be used to intelligently search for matches between requirements and solutions, 3) Define a method of measuring performance of the search, and 4) Develop an interface prototype.

PHASE II: 1) Develop the software that matches Warfighter requirements to relevant solutions, 2) Evaluate the search performance, and 3) Provide a demonstration and training on the use of the software.

DUAL USE COMMERCIALIZATION: The proposed technology has wide commercial applicability, including use by information specialists (those who assist others in finding information), and use by end users such as physicians, lawyers, and teachers. Other applications include automatic matching of open job positions to individual resumes and matching user needs to vendor-offered computer components and systems.

REFERENCES: 1. Losee, Robert M., Text Retrieval and Filtering: Analytic Models of Performance, Kluwer Academic Publishers, Boston, MA, 1998.

2. Meadow, Charles T., Bert R. Boyce, and Donald H. Kraft, Text Information Retrieval Systems, Academic Press, San Diego, CA, 2000.

3. Salton and McGill, Introduction to Modern Information Retrieval, McGraw-Hill, New York, NY, 1983.

KEYWORDS: Information Retrieval, Text Retrieval, Text Filtering, Topic Classification

AF04-088 TITLE: ISR Related Sensor Data and Ground-Station Associated Technologies for Integrating (QRC Basis) with State and Local Law Enforcement (LE) for Homelan

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop the means of delivering one or more candidate Intelligence Surveillance Reconnaissance (ISR) sensor data streams to local law enforcement to support Homeland Defense while encouraging the development of a taxonomy for data handling across the federal-state-local-commercial domains.

WARFIGHTER IMPACT: Warfighters, civilian disaster response and counter-terror organizations, and local law enforcement will all be enhanced by the sharing of data, information and knowledge on a continuous basis. Ensuring that the necessary protocols and relationships are in place in the event of a major incident (e.g., weapons of mass destruction within the continental United States), along with the continuous exchange and validation of data within an accepted and secure environment, will provide an immediate impact for the warfighter and the entire Homeland Defense community.

DESCRIPTION: Air Operations Center sites within the continental United States form the de facto regional framework for Homeland Defense. Information sharing across complex organizational boundaries requires not only a flexible and accommodating data encyclopedia, but also the provision for integration without violating laws and customs, including the Privacy Act, Proprietary Information, Posse Comitatus and Military security. Intelligence Surveillance Reconnaissance sensor data will be part of the multifarious Homeland Defense intelligence and response information resources. Some investigations into the interplay of ISR and Homeland Defense have been conducted, but a comprehensive enterprise data and data transfer model, including time/date stamping and geo-location, is required to guide development of collaborative tools and fusion.

PHASE I: Develop an innovative approach to a subset of the Homeland Defense area that directly supports data and information sharing across organizational boundaries.

PHASE II: Develop a prototype system including the enterprise data model and a set of aliases to link data from a typical selection of military (particularly Intelligence Surveillance Reconnaissance related), domestic transportation, law enforcement and emergency response information systems and data feeds.

DUAL USE COMMERCIALIZATION: Productized technology developed under this program will be directly applicable to delivering advanced sensor capabilities to Homeland Defense related organizations, but it will redound with benefits to military ground Intelligence Surveillance Reconnaissance users and providers and to operational end-users generally in the Air Operations Centers and Theaters. Commercially viable spin-off capabilities may be discovered for tailorable police, fire, emergency rescue and other state and local threat analysis and response organizations.

RELATED REFERENCES:
1. E. Waltz and J. Llinas, "Multisensor Data Fusion", Artech House, 1990.
2. R. Antony, "Principles of Data Fusion Automation", Artech House, 1995.
3. M. R. Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems", Human Factors Journal, 37(1), pages 32-64, March 1995.

KEYWORDS: ISR, Homeland Defense, Law Enforcement, Data Handling Taxonomy.

AF04-089 TITLE: Enhanced Gateway Interoperability Architectures for Legacy C3I Systems

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Provide Enhanced Gateway Architectures for a Seamless Interoperability Transition to the Future C3I System of Systems. The new gateway architecture connects disparate stove-piped legacy C3I systems to the Future Interoperable C3I System of Systems without requiring all systems to be replaced at the same time.

DESCRIPTION: The primary goal of this SBIR is to develop an architectural gateway approach that provides transitional interoperability as newer C4I systems are introduced to the battlefield. One of the most significant problems that will face Joint operations in the near future is the introduction of newer systems which we will have no way to “totally” transition to the field immediately. The use of Gateways must ease this transition. This new gateway architecture will be required in any evolutionary plan since replacing systems across the battlefield all at the same time is impractical. An evolutionary gateway architecture will begin to simplify the certification, testing, and fielding of interoperability solutions. The ideal architecture will allow a toolbox of gateway functions to be assembled in one domain. This domain will provide gateway products that connect the new systems to the older stove-piped systems. The USAF Tactical Data Links System Program Office (SPO) has realized that gateways have become a critical portion of the infrastructure and continues to focus on gateway systems. These Gateways provide communications connectivity. The real key to this SBIR is that it will allow a “more complete” set of tested and certified functions to populate the gateway toolbox under the Enhanced Gateway Architecture. This SBIR effort will immediately provide positive impact for the warfighter by creating more standardized architectures for gateways that are the key to system interoperability today. Existing gateways are mostly designed as "one time" applications or stove-pipes. These stove-pipe gateways are very focused on the particular connection that must be made and do not focus on testability, expansion, re-use, etc. A more standardized architecture will allow the gateways to be built from gateway building block components. This will immediately open the gates for more efficient testing and re-use of the gateway components in development. Interoperability is the key to the information race, and improved gateway architectures will provide our warfighters tested and proven interoperability sooner.

PHASE I: Develop alternatives for an Enhanced Gateway Architecture that will provide simple modification, certification, and reuse of gateway functional modules. Phase I will compare alternative architectures and prototype a gateway application designed upon the leading architecture. The final architecture alternatives will be thoroughly described and documented.

PHASE II: Design, build, and optimize a Gateway system based on the Enhanced Gateway Architecture. This system will be used to create new and improved gateway instances to cover the evolving needs of the battlefield. It will provide a demonstration showing the enhanced interoperability provided by these new gateway architectures.

DUAL USE COMMERCIALIZATION: The benefits of this Enhanced Gateway Architecture will be measured by the continued improved interoperability on the battlefield. The approved, tested, certified, and documented gateway functions will be plugged into the C3I architecture and provide evolving interoperability. The commercial and civil sectors are struggling with many of these same interoperability issues, and advances in gateway architectures & standardization have direct applicability to applications such as emergency response and aeronautical communications. The Enhanced Gateway Architecture will allow better re-use of certified interoperability functions that many lives depend upon.

REFERENCES: References:
1. Gateways, A Necessary Evil? David S. Dodge, The MITRE Corporation. Published for the Simulation Interoperability Workshop, September, 2000

2. Federal Standard – 1037C, Telecommunications: Glossary of Telecommunications Terms, dated 7 August 1996

3.Joint Chiefs of Staff Publication 1-02

4. Open Applications Group White Paper: Plug and Play Business Software Integration, The Compelling Value of the Open Applications Group

5.Open Financial Exchange web site, http://www.ofx.net

KEYWORDS: tactical data link; gateway; interoperability; C3I

AF04-090 TITLE: Improved Situational Awareness in the Cockpit

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Currently, Systems involved in the sensor-to-shooter process do not operate effectively together.

DESCRIPTION: USAF Chief of Staff General Jumper underscored this in his keynote address at the first Command Control Intelligence Surveillance Reconnaissance (C2ISR) Summit, by saying that "time has come to stop concentrating on individual systems and to start focusing on the information they provide and on automating processing (…)".

Issues: These separate systems have limited ability to interoperate, both technically (such as incompatible data formats) and operationally. As a result, they cannot easily and quickly exchange data; communication systems must be patched together to make this happen.

Solution: Real-Time Information into the Cockpit (RTIC) is a key enabler technology for streamlining the sensor-to-shooter Kill chain, since it can be leveraged to dynamically retask the ongoing mission from external sources such as the Air Operations Center (AOC) or even another aircraft working the mission in tandem, and thus reduce the timeline to find, fix, track, target, and engage time-sensitive targets with limited windows of vulnerability or opportunity (dynamic retasking refers to the logic required to generate a new mission profile in flight, based on external unpredicted tasking: For example, a higher priority mission may arise during the course of the original mission and the vehicle is thus signaled to address the new mission). Command/Control (C2) Systems that interface with Avionics and Tactical communication buses in combat aircraft in order to improve situational awareness in the cockpit are a key enabler technology to the DoD. For an RTIC equipped weapons platform to be successful, the information must be more than merely transferred. It must be usable in both a timely and efficient manner. Providing a large increase in raw data to an already task-saturated crew does not solve the problem. Simply put, the information must be integrated, not merely added. This SBIR seeks to tackle that problem by developing an “RTIC-to-Avionics Gateway” (RTAG) that will provide the machine-to-machine connectivity needed. RTAG is essentially an integrated “RTIC Server” for the weapons platform.

PHASE I: Define an RTIC-to-Avionics Gateway system. First, available RTIC information will be identified and evaluated to determine its utility to the crew of a weapons platform. Particular attention will be given to information needed to shorten the kill chain of the “Sensor to Decision Maker to Shooter” (S-DM-S) paradigm and the associated campaign scenarios. Once the set of key information is defined, any required additional or “supplemental” information must be identified. Supplemental information is defined as what is needed to make the RTIC usable particularly within an S-DM-S timeline. Next, an RTAG architecture and baseline design will be developed. This task will begin with an assessment of the state of the art and a review of on-going research that may be applicable. Several technologies are involved with the RTAG concept including: command & control, distributed robust network centric connectivity for both air and ground based nodes, open system architectures, machine to machine direct communications, communication systems (e.g Link16) and integrated avionics architecture. The focus of the RTAG effort is on the weapons platform end, but all elements of the information transfer must be considered. The key element of the RTAG system is the “Server” concept. RTAG must be able to interface to the avionics, providing needed information in the time and format required, yet never alter or disrupt the avionics system. RTAG on the platform must be fail-safe. This is critical to overall system validation and certification. The final step of Phase I is to prototype and demonstrate key elements of the RTAG architecture.

PHASE II: Develop and demonstrate a nearly complete prototype of the Phase I design. The demonstration will show the RTAG functionality, and will prove that the system design can safely and efficiently interoperate with modern-day avionics. The system operation will be evaluated using representative S-DM-S scenarios to characterize RTAG utility.

DUAL USE COMMERCIALIZATION: This phase will concentrate on the flight test certification of the RTAG concept and prototype developed in phase II, as well as validation of benefits provided in dynamic retasking scenarios and demonstrating streamlining of the Kill Chain. The RTAG concept also has a potential application to the commercial airline industry particularly in high traffic terminal areas where Air Traffic Control (ATC) rerouting can occur. An austere version of the RTAG could be of great benefit to civil aviation as well. Ground based applications are also conceivable.

REFERENCES:
Aerospace & High Technology Database:

1) “Real Time Information into the Cockpit: A Conceptual Overview”, B. Bishop, 1998
2) “Evaluation of airborne data link communication”, Mueller, Giesa, Anders, 2001
3) “Priorities, Organization, and Sources of Information Accessed by Pilots in Various Phases of Flight”, Schvaneveldt, Beringer, Lamonica, Tucker, Nance, 2000
4) “Situational awareness in the tactical air environment; Proceedings of the 4th Annual Symposium, Piney Point, MD, June 8, 9, 1999” AIAA

KEYWORDS: Awareness, Real time Information Cockpit (RTIC), Sensor to Shooter.

AF04-091 TITLE: Dynamic Replanning and Assessment

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Investigate methods of applying the new science of complex adaptive systems theory to the problem of dynamically planning, executing, and assessing effects-based operations.

WARFIGHTER IMPACT: Better forecast of effects achievable for a given Course of Action (COA) through a more accurate and dynamic simulation of the action-reaction interplay of Blue and Adversary COA.

DESCRIPTION: Effects-based operations (EBO) depends heavily upon the ability to predict, that is, to trace and understand direct, indirect, cumulative and cascading effects as they course throughout an enemy-as-a-system. Unfortunately, as the pace, uncertainty, and diversity of military operations increase; the ability of current or planned systems (comprised of human and machine elements) to keep up is falling short. The battlespace exhibits all the characteristics of a complex and adaptive system. The number and diversity of the elements means the ability to predict dynamic structural behavior through the detailed analysis of individual elements is low. Conflict is characterized by the interaction of intelligent human beings that react and adaptive to changes in the battlespace. Finally, the Blue, adversary, neutral and unknown elements in the battlespace react and change to each other and the environment—the classic definition of a system. Complex adaptive systems theory has been applied to a wide range of disciplines such as economics, biology, and even military decision making. The goal of this SBIR is to move the theory into algorithm and software development with an eye towards developing decision support tools that allow commanders to model, simulate, and analyze how their proposed COA “plays out” in a dynamic and complex battlespace. For example, when facing a time-sensitive or emerging target situation, commanders may wish to evaluate various options and know which attain the desired effects matched against various evaluative criteria such as probability of attrition or probability of collateral damage.

PHASE I: Develop and demonstrate the application of complex adaptive systems (cas) theory and techniques to the unique information and decision support requirements of EBO.

PHASE II: Continue algorithm development and characterize the operational and system architectural views of an effects-driven, cas-based decision support tool that enhances COA development, analysis, comparison, and selection through the incorporation and simulation of adversary COA.

DUAL USE COMMERCIALIZATION: The new algorithm developed under this effort will be directly applicable to effects-based training, mission rehearsal, contingency planning, execution and assessment, and force structure analysis. Effects based operations can also be applied to commercial industry. The technology developed by this effort can model a market as a complex adaptive system and perform predictive analysis of product entry in to that market.

REFERENCES: 1. Effects Based Operations A Grand Challenge for the Analytical Community, Paul K. Davis, RAND

2. Effects Based Operations Applying Network Centric Warfare in Peace, Crisis and War, Edward A. Smith, CCRP

3. Identifying, Understanding, and analyzing Critical Infrastructure Interdependencies, Steven Rinaldi, James Peerenboom, Terrence Kelly, IEEE Control Systems Magazine, 2001

4. From Physics to Finances: Complex Adaptive Systems Representation and Infrastructure, Naval Surface Warfare Center Technical digest, In press

5. Implementation of battlespace agents for network-centric electronic warfare, J.C. Sciortino, J. F. Smith, et al, SPIE Int. Society of Optical Enginnering, April 2001

KEYWORDS: Effects-based operations, uncertainty, complex adaptive systems, algorithm and software development, decision support, adversarial modeling

AF04-094 TITLE: XML Guard

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Investigate cross-domain guarding advancement opportunities made possible by the rapid growth of XML technologies.

DESCRIPTION: As the AF and DoD move towards network centric warfare and information superiority structure, web-based access to secure data is a critical support feature for the warfighter, all without compromising Information Assurance (IA). The provision of effective network access controls and security mechanisms which help to maintain the integrity of mission data flow processes is a cornerstone element of efforts like the Joint Battlespace Infosphere (JBI) and Network Centric Enterprise Services (NCES) programs. In many cases, these mission data flows occur across security domains (top secret->secret, US secret->coalition , etc.). The rapid adoption of XML technologies by commercial and Government systems, which is helping accelerate the web-enabling of both commerce and military, is driving the need for cross-domain guarding solutions to further leverage XML capabilities. Existing solutions have the capability to process and filter XML files using basic parsing and regular expression matching techniques and tools. As more and more systems "XMLize" their data, this capability will have an increasing impact. However, this is not enough. XML related technologies, such as Extensible Stylesheet Language Transformations (XSLT), presents an opportunity to transform XML documents to a lower classification for release through a guard. The use of XML for establishing content filtering rules and the use of XSL as a means of presenting these rules for security review and approval could significantly improve the flexibility of guarding solutions. The use of XML extensions accommodating digital signatures postures guards for being able to auto filter (no human reviewer-in-loop) high-to-low dissemination of signed XML products (e.g. web server data). The combination of pre-approved signed XML files with IPv6 and fiber link technologies could result in realization of high-speed guards capable of moving releasable imagery of gigabyte sizes between domains with a latency of single digit seconds. These examples illustrate the untapped potential of XML-related technologies to rapidly advance the information sharing capabilities offered by cross-domain guarding solutions. This technology area is a growth market which is ripe for innovation as information sharing and information access are fundamental components of the Air Force Transformation and our Nation's vigilant transformation towards improved homeland security.

PHASE I: Investigate cross-domain guarding advancement opportunities made possible by maturing and emerging XML technologies and deliver an innovative prototype guarding solution which includes at least one of the following features:
- use of XML transformation techniques (such as XSLT) for product sanitization and cross-domain dissemination
- XML-based rules for content filtering
- auto dissemination of signed XML
- support for IPv6

PHASE II: Perform a second phase investigation based on findings from Phase I and emergence of new XML related capabilities. Conduct a downselect of advancement opportunities to a short list of high-payoff items and produce/demonstrate a prototype guarding solution which is compliant with DCID 6/3 requirements.

DUAL USE COMMERCIALIZATION: Military - enhancement to existing cross-domain guarding solutions implemented throughout the DOD, US Intelligence Community, and Coalition forces. Commercial – information sharing solutions which enable bridging of intranets within a single company (financial<>legal) or between companies which are part of a consortium.

REFERENCES: 1. Director Central Intelligence Directive (DCID) 6/3 - Protecting Sensitive Compartmented Information within Information Systems, 12 Apr 2002

2. IETF/W3C XML-DSig Working Group - http://www.ietf.org/rfc/rfc3275.txt

KEYWORDS: XML, XSLT, cross-domain guarding, MLS, IPv6, information sharing, digital signatures, PKI

AF04-097 TITLE: Metadata Generation

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Automatically Index and tag all multimedia intelligence documents, for storage, web based retrieval, and summarization, providing "quick look" global awareness of all available Homeland Security information.

DESCRIPTION: The major complaint that is being heard from the Intelligence and Homeland Defense user communities is the inability to quickly, and easily find items of interest across the Government's web based systems. Furthermore, these same communities complain about the time and expense of generating metadata to alleviate their problems. Metadata is generated manually making timely intelligence information very expensive or simply non-existent. Metadata, XML, and Document tags are intended to provide greater insight into the content and structure of information and, thereby, to facilitate discovery by query and retrieval tools. The problem is that today only humans generate metadata creating a situation that is error prone, time consuming and labor intensive for both those who generate the information and those that use it. Information indexes, should be developed by the computer, retrieved by the computer, and graphically summarized by the computer. Computer generated metadata should use a signature analysis technique describing text and multimedia data as a compressed "image" in the web based library index. Furthermore, every entry in the library should be zoned, parsed, and geospatially tagged so that information can be summarized with a timeline/ temporal analysis displays (icons on an image, geographic map background, or timeline), Indications and Warning (I&W) display or some other graphic. Information users should not be forced to actually read the entire web holdings in order to get a sense of what information is stored on all of its servers.

PHASE I: Perform feasibility study with initial implementation and experimentation on the proposed approach, and provide initial results potential proving the validity of the approach and use as an information management system

PHASE II: The second phase develops a fully functional prototype to support a broad range of intelligence and surveillance web users.

DUAL USE COMMERCIALIZATION: This technology is directly applicable to a broad range of military applications. Known commercial application areas include general internet search engines and specialized search engines for medical, bioinformatics, drug discovery, financial, and leagal applications.

COMMERCIAL POTENTIAL: Recent Internet markets indicate the growing need to manage large complex web based libraries.). Dual Use Potential is enormous since all industries that will use Web based communications have requirements for automated metadata generation.

REFERENCES: Related References:
1. Tannenbaum, A. (2001). Metadata Solutions: Using Metamodels, Repositories, XML, and Enterprise Portals to Generate Information on Demand. Addison Wesley Professional, Reading, MA.

2. Berry, M. W., Browne, M. (1999). Understanding Search Engines: Mathematical Modeling and Text Retrieval (Software, Environments, Tools). Society for Industrial & Applied Mathematics, Philadelphia, PA.

3. Baeza-Yates, R., Ribeiro-Neto, B., Baeza-Yates, R. (1999). Modern Information Retrieval. Addison-Wesley Pub Co., Reading, MA.

4. Guidelines for Intelink Metadata, Version 1.1: Intelink Conference, San Antonio TX, August 1998

5. Proceedings Intelink Conference, New Orleans LA , May 2002

KEYWORDS: metadata, indexing, text understanding, intelligent systems, document tags, XML, search engines

AF04-100 TITLE: Achieving Ubiquity: Technologies to Make Intelligence Available Everywhere on Demand

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Make warfighting data, information, and knowledge available on demand everywhere on earth.

WARFIGHTER IMPACT: Provide warfighters with the information they need, in a format that they can use, no matter where they are, or what communication equipment they possess.

DESCRIPTION: Develop an adaptable capability for the automated tailoring of intelligence for dissemination to a wide variety of warfighting users anywhere on the planet. Current intelligence communication protocols are network and host dependent and extremely constrained by a combination of bulk and internal encryption based on the specifics of the transmission path. Subscribers to intelligence product lines, or warfighters desiring point-to-point transfer of specific data, should be able to send queries with identifying features that will allow the providing systems to adapt both the data stream characteristics and content according to the requester's host and communication constraints. Required is not a new hardware communication infrastructure, but a set of applications and protocol modifiers capable of adapting to the universe of protocols that might be required in the battle space for dynamic routing management. The focus will be on the methods to expedite the sensor-to-shooter linkage in a future IP-centric architecture. This will entail not only protocol management, but achieving dynamic routing within tactical environments. One example is the need to pass formatted threat data (via Link 16) to an imperiled F-15 aircraft that has requested threat status.

PHASE I: Produce a feasibility study of a specific subset of intelligence information management as it pertains to our current view of sensor-to-shooter network-centric warfare. Focus on the process of how intelligence information flows from the integrated sensor platforms and ground stations to the warfighter in the field. Identify what application and communication protocol (including encryption and multi-level security) bottlenecks exist that prevent the orderly flow of intelligence information from the collection point to the end-user. Identify what protocols and data identification tools exist (XML Metatags, JAVA APIs, etc.) that will contribute to data interoperability. Identify current protocol and format management and data compression techniques that enable ubiquitous information transmission.

PHASE II: Develop and demonstrate (in a Government-designated laboratory) a prototype of a software capability for the automated tailoring of Intelligence for Ubiquity (IU). Sample data sets, communication path specifications and client configurations will be provided by the Government for acceptance testing.

PHASE III: Continue system development, develop an IU CONOPS and demonstrate an IU prototype in the Air Force Transformation Center (alternatively CAOC-X and/or AF DCGS's DGS-X).

DUAL USE COMMERCIALIZATION: Technology developed under this program will be directly applicable to delivering advanced sensor capabilities to a wide variety of ground ISR users and providers (through AF DCGS) and to operational end-users of ISR products in the AOC and Theaters. I&W and S&W are the most heavily impacted missions. There are no standardized data transport and point-to-point protocol management applications strong enough to operate at the enterprise level. Additionally, an adaptive capability to take into account changing network structures (as in coalition warfare) is absent. Creating an adaptive capability has great promise for commercialization. The underlying technology that enables the screening and interpretation of different types of intelligence information can be used to enable the receipt and interpretation of different types of industrial information without building a new tool for each situation.

KEYWORDS: C4ISR, DCGS, Network-Centric, Collection Management, Dynamic Routing, Data Transport, Dynamic Protocol Management, Tactical Communications Networks

AF04-101 TITLE: Data Compression

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop image and video compression techniques that will significantly increase the transmission capability of current data links by providing greater compression ratios without additional degradation relative to current techniques for targeting and tracking.

DESCRIPTION: The timely collection and / or distribution of digital information is critical to modern warfighters operating in a system of systems environment. The capability and speed of collection, storage, and distribution mechanisms continues to increase, but it still lags the demand for data. The advent of higher resolution collection systems and the tying together of multiple aircraft and aircraft sensors is further widening the gap. Conventional compression techniques, including those based on JPEG, wavelet,and fractal algorithms, cannot meet the current data transmission requirements and offer little potential for meeting future requirements. The intent of this solicitation is to develop new techniques that exceed the performance of existing bandwidth compression techniques should not degrade data to be compressed and analyzed further than current techniques. Likewise, the computational complexity of new Techniques should not significantly exceed that of current techniques in areas of data security, image tracking and video streaming.

PHASE I: Define details of the new compression technique at a level sufficient to permit implementation in software during Phase II. Provide evidence for the technique's potential by estimating performance in terms of compression ratios relative to losses, along with computational complexity. Develop a plan to integrate the technique into the F/A-22 integrated avionics system including multi-level data security (watermarking) during Phase II.

PHASE II: Develop prototype software to implement the Phase I approach. Demonstrate the technique's performance using real data pertinent to the F/A-22 weapons system. Use these results to develop a preliminary design for a deployable Phase III implementation, consisting of hardware and software as appropriate.

DUAL USE COMMERCIALIZATION: The technology developed would significantly improve the performance of all military and commercial systems that rely on the collection and distribution of digital data. The biggest commercial application is in Video Streaming via the Internet, itself, which is currently choked with digital image and video data. In the medical arena, x-ray compression and remote analysis of patient information and monitoring equipment, will see strong benefits.

REFERENCES: 1) R. Gopinath and C. Burrus, Introduction to Wavelets Transform, A Primer. Englewood cliffs, NJ: Prentice-Hall 1998.

KEYWORDS: Bandwidth compression, watermarks, wavelets, networks, data links, hardware implementation

AF04-102 TITLE: Sensor Resource Management for Improved Situational Assessment

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop approaches and techniques for performing sensor resource management based upon the information requirements needed to detect and identify tactically significant activities.

WARFIGHTER IMPACT: Improved Situational Awareness enabling the identification of militarily significant units and tactically significant activities within the battlespace.

DESCRIPTION: Sensor Resource Management (SRM) is the process by which strategies are determined for scheduling the allocation of sensor activities. Effective sensor management is an essential problem encountered in several areas such as aerospace, automation, defense, environmental, geographical, meteorological, and medical, to name a few. Today, the management of distributed sensor systems is mainly focused on reducing uncertainty in the detection, tracking and identification of objects of interest. In essence, current technology developments are concentrated on improving the performance of object assessment fusion engines (algorithms). Object assessment (level 1 fusion) is defined as the estimation and prediction of entity states based on observation-to-track association, continuous state estimation (e.g. kinematics) and discrete state estimation (e.g. object type and identification). However, over the last several years, a number of technologies have been introduced which attempt to perform situation assessment fusion. Situational assessment (level 2 fusion) is defined as the estimation and prediction of relations among entities, to include force structure and cross force relations, communications, and perceptual influences, and physical context, etc. Situational assessment is the process of providing understanding to a decision-maker about a situation, including people, objects, and events. In order for sensor resource management to be truly successful, it must be able to allocate sensors and sensor platforms to detect tactically significant activities, i.e. situation awareness. Examples of tactically significant activities for the environmental area could be possible events and sources for nuclear, biological, or chemical incidents, locations of high occurrences for earthquakes, floods, natural disasters for the geographical area, potential terrorist targets for the homeland defense area, and typical locations and types of viral disease outbreaks for the medical arena. Detection of tactically significant activities for the war fighter could be bridge crossings, engineering battalion activities, traffic flow analysis, lines of communications, and identification of military units like theater ballistic missile battalions, etc. This effort shall seek to advance the state-of-the-art by extending the sensor resource management paradigm by creating sensor control policies optimized for meeting the information requirements of a situational assessment module. Sensor types that need to be included are Radar (Ground moving target indicator, synthetic aperture radar (SAR), inverse SAR, Environmental Situation Assessment Radar (ESAR)), Signal Intelligence and Imagery Intelligence platforms.

PHASE I: Develop and demonstrate a prototypical system for using the information requirements of a Situational Assessment fusion engine as the means for computing optimal sensor policies. The Situational Assessment module can be developed or integrated under this SBIR with the sensor management module.

PHASE II: Continue system development. Demonstrate system against an extended set of situations. Characterize system performance. Extend the systems to support multiple domains (areas) and other sensor types.

DUAL USE COMMERCIALIZATION: The technology that will be developed under this program will be directly applicable to advanced sensor systems such as those being developed for environmental, geographical, meteorological and medical applications as well as for the warfighter in providing an improve picture of the battlespace.

REFERENCES: 1. C.S. Agarwal and P.K. Garg, " Textbook on Remote Sensing: In Natural Monitoring and Management", Wheeler Publishing

2. Paul Gibson and Clare Power, "Introductory Remote Sensing: Principles and Concepts", Taylor and Francis

3. Floyd M. Henderson and Anthony J. Lewis, "Manual of Remote Sensing, Volume 2: Principles and Applications of Imaging Radar, 3rd Edition", John Wiley and Sons

4. R.L. King, " A challenge for high spatial, spectral, and temporal resolution data fusion", IEEE 2000 International Geoscience and Remote Sensing Symposium

5. E. Shahbazian, J.R. Duquet, M. Macieszczek, P. Valin, "A generic expert system infrastructure for fusion and imaging decision aids", Proceeding of EuroFusion 98, International Data Fusion

KEYWORDS: Multi-sensor resource management; Intelligence, Surveillance, and Reconnaissance (ISR); ISR sensor management; distributed sensing; situational assessment; object assessment

AF04-103 TITLE: Enabling Technologies for Free Space Quantum Cryptography

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Provide enabling components for secure key distribution channel for ground-space or space-space quantum communication link.

DESCRIPTION: A continuing DoD/commercial need exists to develop secure communication systems for free-space links, including space-ground and space-space links. Secure communication on encrypted channels requires some means of establishing and sharing cryptographic "keys" (e.g., for "one time pads.") Quantum cryptography (QC) provides a secure solution to the key-distribution problem, not based on the (presumed) intractability of computations or on physical security of the channel, but on fundamental laws of quantum physics. Practical implementation of this key distribution protocol for ground-space links will require advances in both transmitter and receiver technologies. The space-ground link (as well as long-range ground-ground free space links) will not be limited to fiber telecom wavelengths, but must contend with atmospheric transmission, as well as significant diffraction losses for reasonable receiver sizes. Required components must meet the wavelength requirements of atmospheric propagation, while shorter wavelengths are favored to reduce diffraction losses. Furthermore, since losses will inevitably be high (>30 dB), efficient single-photon detection and high transmission bit-rate will be at a premium. High bit rate single photon transmitters improve both the security and efficiency of the system by avoiding problems associated with using weak laser pulses.

PHASE I: The contractor shall be free to make design choices in protocol, physical basis of QC method (polarization coding, phase coding, continuous variables, single photon vs. weak pulses, …) wavelength trades, transmitter repetition rate etc., but must demonstrate that (i) the chosen embodiment is scaleable to a space system, (ii) the system can achieve a net raw key-generation rate of at least 500 bit/s, (iii) the system and protocol are conditionally secure at least under the relaxed eavesdropping threat assumptions: an eavesdropper cannot (a) store photons longer than 1 ms, (b) measure the number of photons in a pulse without destroying them, or (c) replace a lossy channel by a lossless channel. (Designs that promise higher key generation rates and unconditional security without assumptions will be favored.) Activity shall include (but not be limited to) 1) identification of key distribution protocol and optical implementation for the free-space link including basic system architecture, and link budget establishing implementation viability; 2) design of optical and electronic elements of transmitter and receiver; 3) comprehensive system level design of complete link; 5) breadboard demonstration of all components individually and as a complete free space QC system executing the chosen protocol.

PHASE II: Activity shall include (but not be limited to) 1) construction of transmitter, receiver and synchronization system; 2) demonstration of quantum key distribution over significant free-space distance (5 km in atmospheric conditions), achieving key generation rate and security scaleable to a space system meeting full system requirements.

DUAL USE COMMERCIALIZATION: Secure communications are important in many private sector applications, including commercial telecom and financial transactions. Conventional free-space optical communications systems and fiber-optic quantum cryptographic systems are currently on the market (also quantum random number generators for key generation). Successful development of a practical quantum key distribution system for free-space secure communication will have broad application to both commercial and DoD users.

REFERENCES: 1. C. H. Bennett, F. Bessette, G. Brassard, L. Salvail and J. Smolin, "Experimental Quantum Cryptography," J. Cryptol., 5, 3-28 (1992).

2. T. P. Spiller, "Quantum Information Processing: Cryptography, Computation and Teleportation," Proc. IEEE, 84, 1719-1746 (December, 1996).

3. W. Buttler, et al., "Free-space quantum-key distribution," Phys. Rev. A, 57, 2379-2382 (April, 1998).

4. J. G. Rarity, P. R. Tapster and P. M. Gorman, "Secure free-space key exchange to 1.9 km and beyond," J. Mod. Opt., [48] 13, 1887-1901 (2001).

KEYWORDS: Quantum Cryptography, Key Distribution, Satellite Communication, Optical Communication, High bit rate, Single photon transmitters.

AF04-104 TITLE: High Data Rate Error Correction

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop high data rate burst error correction unit.

DESCRIPTION: With the advent of laser communications, data rates associated with military satellite communications are expected to grow dramatically for the foreseeable future and on-satellite error correction will likely be required in order to keep the bit error rate acceptably low. Errors result when the signal strength falls below the sensitivity of the photodetectors as a result of atmospheric attenuation. Sources of atmospheric attenuation include absorption due to particulates and aerosols interacting with the optical beam over the link span and atmospheric scintillation as a result of either natural or man made effects. The purpose of this topic is to develop a high speed, space qualifiable error correction unit able to withstand error bursts while minimizing the signal delay.

PHASE I: Starting from state or the art error correction technology, design a new innovative error correction coder optimally suited to burst errors associated with high data rate (> 40 Gbps) laser communications. Design a error correction test module using FPGA logic modules for implementation and testing, and determine improved performance of this new code using simulations over a the expected range of probable error bursts. Figures of merit include BER, latency, implementation complexity as a function of computational area (elements) required and power. Goal will be to eventually obtain a radiation hardened ASIC.

PHASE II: Using the results of phase I, implement the correcting modules in FPGA. Develop a final ASIC design which would be implemented in Phase III. Using the FPGA implementation, characterize the operation over a wide range of error bursts. Write a final report that fully describes its operation, including the maximum length or error burst that can be fully corrected, timing latency and the maximum data rate for reliable operation.

DUAL USE COMMERCIALIZATION: Commercial telecommunications has a broad range of applications for low bit error rates requiring error correction for such things as banking transactions.

REFERENCES: 1. Chuen, Kyungwoon and Stark, Wayne, "Optimal Selection of Reed Solomon Code Rate and Number of Frequency Slots in Asynchronous FHSS-Ma Networks", IEEE Transactions on Communications, Vol 41 No. 2, February 1993. 2. Morelos-Zaragaza, Robert H. "The Art of Error Correcting Coding", John Wiley & Sons, 2002 ISBN 0471 49581 6

KEYWORDS: Bit error rate, laser, error detection and correction, attenuation, Reed Solomon code, Cyclic Redundancy Check Code, Turbo Codes, Low Density Parity Check Codes

AF04-105 TITLE: Dynamically Sensing and Adapting Wireless Network

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop security protocols and custom hardware for non-interfering wireless local area telecommunications network.

DESCRIPTION: In wartime situations, military wireless communications traffic can grow dramatically and, in cases in which insufficient spectrum has been allocated, mutually destructive interference can occur between terminals in proximity of each other. A similar situation may occur in the case of commercial overload. The DARPA sponsored Next Generation (XG) communications study, recently found that at any given time, the vast majority of spectrum is under utilized and could become available for emergency use if the terminals were designed with the necessary protocols and hardware flexibility to autonomously adapt to changing traffic conditions. In order to access the under utilized spectrum, terminals would need the capability to determine if destructive interference were occurring, locate available spectrum lying within the terminal's operating bands, and autonomously plan and implement communications network on an alternate channel. The purpose of this topic is to develop the algorithms, hardware, and protocols required to implement a dynamically sensing and adapting wireless network.

PHASE I: Investigate algorithm(s) and protocols to direct and control resource allocation for wideband sensing of low-power transmissions. Algorithm(s) capabilities shall include (among others) identification of mutually destructive interference, location of open bands within assigned operating spectrum, and the implementation of a new communications channel in and open band. Develop the protocols to implement algorithm(s) and develop computer simulation. Develop preliminary hardware/software designs. Provide sub-scale demonstration.

PHASE II: Design/fabricate the hardware components and software algorithms necessary to implement an adaptive communications link, including resource reallocation under an end-to-end networking scenario. Demonstration should include automated allocation/reallocation of resources consistent with time varying network activity. Once key peformance parameters have been characterized, write final report detailing operational performance.

DUAL USE COMMERCIALIZATION: This topic applies to both commercial and military wireless networks, since both are subject to destructive interference.

REFERENCES: 1. Clar, Pamela et. al., QoS-based Provisioning of ATM Services of DAMA-Controlled SATCOM Networks, MILCOM 99 Vol II, pp1358-1362, October 1999.

KEYWORDS: Next Generation Communications, Destructive interference, Autonomous adaptation, Communications protocols, Networking, Communications traffic.

AF04-106 TITLE: Q/V/W-band High Powered Amplifiers

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop low cost/power MMIC chips for phased array 49-51 and 71-78 GHz transmit applications.

DESCRIPTION: As users require higher data rates the SATCOM community must be able to utilize the higher frequency satellite communications bands to achieve these data rates. A key to the user community being able to afford these higher frequency communications systems is the cost of the airborne transmitter. This effort will propose a HPA (High Powered Amplifier) design to operate in the 49 – 51 GHz and the 71 to 78 GHz bands. A baseline design will be developed and performance defined. The cost to implement the design will be quantified.

PHASE I: Develop designs for power amplifier MMICs (Monolithic Microwave Integrated Circuit) at the above mentioned frequencies. Power levels will be in the 100 mW to 1-Watt range. Begin device design fabrication as benchmark.

PHASE II: Fabricate a minimum of four prototype MMIC devices. Characterize for output power, linearity and gain.

DUAL USE COMMERCIALIZATION: These chips will be required for future commercial design requirements for millimeter-wave applications including automotive radar. The design tools and skills from previous phases of this SBIR will be used to show synergistic military and commercial applications of these MMIC chips in high volume production

REFERENCES:
1. Hong-Yeh Chang; Huei Wang; Yu, M.; Yonghui Shu; "A 77-GHz MMIC power amplifier for automotive radar applications", Microwave and Wireless Components Letters, IEEE [see also IEEE Microwave and Guided Wave Letters] , Volume: 13 Issue: 4 , April 2003, Page(s): 143 -145
2. Huei Wang; Samoska, L.; Gaier, T.; Peralta, A.; Hsin-Hsing Liao; Leong, Y.C.; Weinreb, S.; Chen, Y.C.; Nishimoto, M.; Lai, R.; "Power-amplifier modules covering 70-113 GHz using MMICs", Microwave Theory and Techniques, IEEE Transactions on , Volume: 49 Issue: 1 , Jan 2001, Page(s): 9 -16
3. Hong-Yeh Chang; Huei Wang; Yu, M.; Yonghui Shu; "A 77-GHz MMIC power amplifier for automotive radar applications", Microwave and Wireless Components Letters, IEEE [see also IEEE Microwave and Guided Wave Letters] , Volume: 13 Issue: 4 , April 2003 Page(s): 143 -145

KEYWORDS: MMIC, Q-band, V-band, W-band, Power Amplifier, Solid State

AF04-107 TITLE: A Family of Decision-Centric Software Applications for the Future ISR Network

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Provide a core-set of decision making applications, with a user interface, that assists the decision maker in aggregating relevant data, information and knowledge and guides the decision maker through the various options and potential outcomes.

WARFIGHTER IMPACT: Supports quality decision making for the warfighter throughout the Kill Chain PF2T2EA.

DESCRIPTION: Develop an operational software capability which aids the decision maker to make the “best” decision given the information available, possible alternatives, and uncertain outcomes. Military decision makers are often in the unenviable position of having to make critical decisions with little time, incomplete information and uncertain outcomes. The set of software tools to be developed will assist the decision maker in understanding his alternatives, filter, explore, and aggregate information that will aid him in the decision making process, and help him align outcomes with the goals of the campaign. Often in decision theory, the alternative space explodes exponentially. The software developed must contain tools that quickly reduce the size of the alternative space so that timely decisions can be achieved. .Evolution of a very powerful ISR network is envisioned for delivery in the period 2003-2012. New sensor data streams to be introduced in the same period will enrich the memory of the ISR community far beyond humans’ ability to process even a small fraction of the data in the networked data stores. The software tools developed must contain methods that search the input data streams and filter the non relevant information. And finally the software tools must refine and fuse the data, focusing on an end-product that provides options for action with probabilities of outcomes. .The core tool mix must support a wide range of application types, including data mining, data filtering, Artificial Intelligence, Evidence-Based Decision Making and Expert Systems. Ideas inherent in the Associate Pilot program and commercial mentoring software should be accommodated easily in the operational prototype. Innovative display, fusion, storage and user interface (UI) ideas will naturally complement the core-and-applications environment.

PHASE I: Design a prototype set of decision-centric software tools, validate its capabilities against government-provided criteria.

PHASE II: Develop a set of decision-centric tools, test and validate the tools against a government provided scenario and data set

DUAL USE COMMERCIALIZATION: Decision makers are required to decide among alternatives in every endeavor attempted by man. Often these decisions have to be made in the face of incomplete information, and uncertain outcomes. Data and rule management is a key ingredient of any complex system. The merging, fusing, and use of many different types of information simultaneously requires specialized processing that must be able to evolve over time as new information is received and new lessons are learned. This decision centric software application will provide the hub to update the rules for handling information as new information is received, new data sources are added and new lessons are learned. Commercial systems that require the receipt and processing of different types of information within a central system will benefit by an engine that is able to adapt to changes in the commercial needs (e.g. shipping, production, and information dissemination systems).

REFERENCES:

KEYWORDS: decision support, information management

AF04-109 TITLE: Disseminating ISR Products, Including Real-Time Moving Imagery, as a Multi-Service Enterprise

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a capability that automatically disseminates the latest information products across the DOD enterprise community based on user-defined information needs.

WARFIGHTER IMPACT: Satisfies the warfighter's need to access, search and receive intelligently packaged data products, including data streams, to support mission planning and execution operations.

DESCRIPTION: Warfighters have an insatiable need for the latest information, irrespective of where that information resides, for improved decision-making and to respond to a dynamic battlespace. The user needs a coherent way to access and disseminate required information in an effective and efficient manner. The information dissemination capability must be intuitive with minimal user training. The design should be flexible and extensible to accommodate delivery of information products to the requestor with different formats and media. The capability should provide a mechanism that matches published information user needs against available, on-line information products. The matching process would search globally for relevant information sources and document contents. This would be based on pedigree to select the appropriate information source and metadata tags to select the appropriate information product. It is envisioned that a user would pre-define the information products he needs to create. This information definition process could include a template or outline of what the finished user product should look like (e.g. target folder), the type of source data needed to be accessed to populate the template, defined area of interest (e.g. geographic location), timeframe for providing the finished product and the currency of the source data (e.g. <12 hours old). The dissemination capability would provide an alert to the user when new information is automatically received that may impact the information product being created. This would allow the user to rapidly respond to changing conditions. Although most information products would be pre-defined, a data discovery feature is needed to create ad-hoc information products.

PHASE I: Develop an overall system design for automated dissemination based on information content and provide a proof-of-feasibility demonstration within the developer’s facility.

PHASE II: Develop and demonstrate a prototype system using a realistic information flow and operational scenario. Conduct testing to prove feasibility in a realistic user environment.

PHASE III DUAL USE COMMERCIALIZATION: This system could be used in a variety of military and civilian applications where rapid information dissemination is needed to support dynamic decision-making. Air Force application would include support to mission planning and execution within the Deployable Common Ground System (DCGS). Automated delivery of information products within the public sector would improve just-in-time inventory control and rapid product introduction to the marketplace.

REFERENCES:

1. Liu, Bing, Mining Topic-Specific Concepts and Definitions on the Web, Proceedings of the twelfth international conference on World Wide Web, May 2003

2. Marshal, Catherine C., Making Metadata: A Study of Metadata Creation for a Mixed Physical-Digital Collection, Proceedings of the third ACM conference on Digital Libraries, 1998

3. Cahlin, Michael, Web searching--faster, faster! Pushing information, PC World v. 16, Mar. 1998

KEYWORDS: Automatic web content generation, metadata, multi-sensor data integration, web portal

AF04-110 TITLE: Campaign Level Adversarial Modeling System

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Development of Adversary models for Command and Control Intelligence Surveillance Reconnaissance (C2ISR) Course of Action predictive assessment.

DESCRIPTION: In the current world environment, the rapidly changing dynamics of organizational adversaries are increasing the difficulty for Military analysts and planners to accurately predict potential actions. As an integral part of the planning process we need to assess our planning strategies against the range of potential adversarial actions. This dynamic world environment has established a necessity to develop tools to assist in establishing hypotheses for future adversary actions. Our research investigated the feasibility to utilize an adversarial tool as a core element within a predictive simulation to establish emergent adversarial behavior. Emergent behavior refers to dynamic adversarial actions generated at the operational level in response to the execution of the primary force within the simulation. Multiple adversarial models with varying belief systems would be capable of automatically posing different actions and counter actions. It is our desire to use this intelligent adversary models to generate alternative futures in performing Course of Action (COA) analysis. Such a system will allow planners to gauge and evaluate the effectiveness of alternative plans under varying actions and reactions. Planners need to understand and predict how upstream decisions impact operations and assess their evolution during execution. Models can be used to predict the consequences of various decisions made at each step of the command processes associated with disaster relief, homeland defense, military operations, etc. The sequence of these decisions constitutes a course-of-action (COA). When the first decision in a given COA is implemented, subsequent decisions must be evaluated based on the new state of the world. This sequential analysis concept requires predictive adversary models incorporating the variants introduced by all entities. These adversary models are vital in performing predictive assessment of planned decisions and the conflicting goals of adversarial forces.

PHASE I: Identify an existing C2ISR model that can be utilized in the context of a predictive simulation (e.g. course-of-action, adversary behavior, force structure simulation, etc) of sufficient complexity to demonstrate the concept. The model choice should be compatible with the types of decisions that might be made in a military operation. Given that model, determine the modeling requirement for adaptation and incorporation of an adversarial model that would allow the system to be dynamic based on the planned COA. Identify opportunities for adversary model formation and reconfiguration. Develop an initial adversary model and demonstrating feasibility of the approach.

PHASE II: Design, develop, and demonstrate an adversarial modeling system in the context of a complete military operation. Demonstrate how high performance computing could be utilized to perform concurrent assessments.

DUAL USE COMMERCIALIZATION: Predictive simulations are exploited by the commercial Industry as decision support tools for assessing and evaluating strategies related to marketing assessments, business process management, enterprise management and network control. Adversary modeling technology will result in higher quality decision improving the predictive analysis relative to competitors and at the same time reducing a user's input investment.

REFERENCES: 1. "Modeling for Campaign Analysis: Lessons for the Next Generation of Models", Richard Hillestad, Louis Moore, and Bart Bennett, MR-710-AF, 1996, ISBN 0-8330-2438-8.

2. "Commander Behavior and Course of Action in JWARS", Vakas, Price, Blacksten, and Burdick, Proceedings of the Tenth Conference on Computer Generated Forces, 2001

KEYWORDS: predictive Course-of-Action, adversary modeling, model prediction, predictive simulation, adversary behavior, decision theory

AF04-111 TITLE: An Integrated COA versus eCOA Tool

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop tools and techniques for assessing friendly Courses of Action (COA) versus enemy Courses of Action (eCOA), as an integrated process.

DESCRIPTION: Predictive Battlespace Awareness (PBA) is predicated on the ability to generate accurate and timely Courses of Action for both the friendly and enemy combatants. COA development today is predominantly an ad hoc manual process with one side trying to counter his opponent's (anticipated) overall course of action. As such, it fails to address the fact that each side's COA is inexorably linked to what the other is doing, one move at a time. What is needed is a way to assess multiple friendly COAs against multiple enemy COAs, and more to the point, to "dovetail" each individual COA vs eCOA assessment into one chain of events that constitutes the interplay between the two combatants. Ideally, one would like to optimize his/her status at multiple steps (if not at each step) along the way; and of course, an optimization function here would be a duple whereby we aspire to maximize our progress towards achieving our overall offensive goal, while minimizing the enemy's progress in achieving his.

PHASE I: Define the/a process for Friendly and Enemy COA interaction, and the algorithms for an integrated COA versus eCOA assessment tool.

PHASE II: Prototype the integrated COA versus eCOA assessment tool and demonstrate it within an Effects Based Operations context.

DUAL USE COMMERCIALIZATION: The burgeoning concept of Predictive Battlespace Awareness and its dual, Intelligence Preparation of the Battlespace, make this a fertile area in all of the military services for many years to come. At the same time, applications of this approach and envisioned system are rife. Potential commercial applications are Economic Forecasting, Actuarial Computation/Prediction, Gaming/Entertainment.

REFERENCES: 1. "Predictive Battlespace Awareness to Improve Military Effectiveness," Vol. 1, United States Air Force Scientific Advisory Board; SAB-TR-02-02, July 2002.

2. A. Sisti, "Dynamic Situation Assessment and Prediction," Fall 2002Simulation Interoperability Workshop (SIW) Predictive Battlespace Awareness Forum; Sep 02.

KEYWORDS: Course of Action, Predictive Battlespace Awareness, Intelligence Preparation of the Battlespace, Game Theory, Optimization

AF04-112 TITLE: New Information Technologies for Crisis Operations

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop information technologies to improve distributed operations and planning for crisis actions.

DESCRIPTION: The 21st century has brought an age of widespread uncertainty and anxiety with frequent crises and emergencies in the commercial and government sectors. There is increased need for crisis management, emergency planning, distributed crisis operations for both industry and government. For the Year 2000 (Y2K) problem, 85% of the America's biggest firms built Year 2000 crisis management and command centers in anticipation of Y2K snafus. Within the commercial and government sectors, multiple organizations or divisions of global companies must jointly collaborate, assess dynamic situations, execute complex plans, and interpret terabytes of information that often is incomplete or conflicting. The national defense leadership and military commanders must handle similar crises and emergencies. As part of this research and development effort, the researcher shall develop and demonstrate innovative information and simulation technologies to improve the assessment, integration, and presentation of decision quality information for improved decision support for crisis operations, crisis planning, and contingency and emergency management. Special emphasis is placed on innovative utilization of intelligent agents, data mining, simulation for predictive analysis, and collaborative technologies. Human-computer interface and advance information infrastructure technologies could include innovative approaches such as multi-user information/knowledge walls, wireless handheld or tablet input devices, and virtual local area networks. Since key stakeholders may be geographically dispersed, a distributed collaborative environment may be necessary to integrate and disseminate the relevant information to the right people in a timely manner. Typical crisis action functions could include: incident management; field command post organization and management; emergency operations center operations; development of response strategy, tactics, and plans; emergency communications; information display; and incident documentation. Proposed methodologies must be capable of executing on commercial-off-the-shelf desktops or workstations and be platform independent. Any graphical depiction and output should comply with industry or international standards, such as HTML, VRML, and graphics metafile images. Methodologies implementing a distributed collaborative environment should be open and standards based to support interfaces to various domain analysis, and simulation and modeling tools.

PHASE I: Specification of information technologies, methodologies, or environment for crisis operations; development of a design concept to assess, integrate and present decision support information for crisis operations, and a proof-of-feasibility demonstration of key enabling concepts.

PHASE II: Design, develop, and demonstrate the information technologies, methodologies, or environment for distributed crisis operations, and detail the plan for Phase III effort.

DUAL USE COMMERCIALIZATION: A robust, off-the-shelf distributed crisis action planning/crisis operation environment for use in defense and emergency preparedness.

REFERENCES: 1. Joint Chiefs of Staff, J-7, "Planning For Joint Operations" http://www.dtic.mil/doctrine/jrm/plans.pdf

2. McQuay, William, "Distributed Collaborative Environments for the 21st Century Laboratory", 2001 Aerospace Conference, March 2001. http://www.collaborationforum.org/collaboration/publications/F45_1.pdf

KEYWORDS: collaborative environment, decision support, crisis action planning

AF04-113 TITLE: Information Management Staff Toolkit

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Investigate and develop a suite of tools for a staff to administer a Net Centric Infosphere.

DESCRIPTION: In an attempt to integrate the capabilities of multiple weapon and information systems, Network Centric Warfare has become a predominant theme in DoD. Part of the network centric warfare approach is the management of the information required by different systems. Information Management is defined as adding structure to semi-structured and unstructured information within an information space as well as the ability to filter, aggregate and disseminate upon this information to allowed and interested parties.

While an information management infrastructure is necessary for Network Centric Warfare, what is lacking are the tools for the administration and operation of the overall information space. It is envisioned that an information/data management staff will be required to rapidly apply and execute policy in the information space. This policy would set the priority of information flow throughout the space and set access to pieces of information within the space. With potentially such a large number of information objects available in the space, and more objects appearing constantly, some innovative means of assessing the state of the information space is critical. This assessment would be influenced by the number of users within the space as well as physical network infrastructure, number of different info object types and available bandwidth.

Innovative and practical approaches would be needed for, but not limited to:

- Dynamic object access policy representation

- Visualization of the information space exclusive of the communication infrastructure for determining quality of service

- Simulation of the introduction of new object types and object traffic to predict the impact of introducing new client applications into the space.

The tools making up the toolkit should access the infosphere and its internals via an Information Management Staff Application Programmer Interface (API).

Throughout this topic it must be clear that the topic is addressing the assessment, administration, and operations of the information space and not the network or bandwidth management. Though each of these have direct influence upon, and are effected by, proper administration of the infosphere.

PHASE I: Define and design a small integrated set of tools and utilities for administering a Network Centric Infosphere. Minimum required capabilities include simulation of the information objects and object flows in the infosphere and its interaction with dynamic policy management.

PHASE II: Develop and demonstrate a prototype set of tools for overall management of an information space.

DUAL USE COMMERCIALIZATION: Military applications include incorporation into the Joint Battlespace Infosphere (JBI) to permit rapid assimilation of military units and systems into a deployed JBI [1]. Commercial application of force templates includes management of trading partner agreements (TPAs) in business-to-business (B2B) commerce [2].

REFERENCES: 1. Building the Joint Battlespace Infosphere, Air Force Scientific Advisory Board Technical Report SAB-TR-99-02, http://www.sab.hq.af.mil/Archives/index.htm

2. The Business Integrator Journal, Summer 2001

3. A Jini-Based Publish and Subscribe Capability http://www.rl.af.mil/programs/jbi/docs.cfm

4. Mercury Class JBI capability Guidelines http://www.rl.af.mil/programs/jbi/mercury.cfm

KEYWORDS: Information Management, Information Management Staff, Joint Battlespace Infosphere (JBI), B2B, Information objects, Infosphere, Application Programmer Interface (API)

AF04-114 TITLE: <u>Physical Layer Information Assurance for Wireless Networks</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop innovative physical layer technologies to provide increased information assurance for commercial wireless local area networks.

DESCRIPTION: Wireless networks are becoming an important, and permanent, part of the Global Information Grid. In many cases, free space networking is replacing traditional wired networks because of lower costs, increased flexibility, smaller logistics tail and the advantages of mobility. However, unlike wired networks, limiting the physical access to a wireless network is an extremely challenging problem.
The objective of this effort is to improve overall information assurance by conceiving, developing and demonstrating innovative physical layer enhancements to current and near-term planned commercial wireless networking technologies, topologies, devices, and systems. Current commercial networking technologies within the scope of this effort include those described by the family of IEEE 802.11 standards and Bluetooth. Near-term planned technologies within the scope of this effort include the anticipated follow-ons to the current technologies above. Areas that may be addressed include but are not limited to antennas, modulation, coding, RF watermarking, frequency control, and adaptive techniques. Simple "add-ons" to commercial devices are not as desirable as modifications that are highly integrated or can be done largely through additional/modified software/firmware.

Benefits to be derived include increased data and network security, jam resistance, higher availability, increased integrity, stronger authentication, and non-repudiation while keeping cost low due to an efficient leverage of commercial technology.

PHASE I: Feasibility study. Define physical layer techniques to be developed and demonstrated in Phase II.

PHASE II: Prototype demonstration. Develop and demonstrate a prototype network that incorporates the techniques and enhancements defined in Phase I.

DUAL USE COMMERCIALIZATION: Military use of commercial wireless local area network devices will become more feasible with the success of this topic. Examples include critical tactical applications. Future commercial standards and implementations of the same will benefit from having this technology defined and available as an option for high assurance applications.

REFERENCES: 1. Arbaugh, W. A., N. Shankar, Y.C. J. Wan, "Your 802.11 Wireless Network Has No Clothes," http://www.cs.umd.edu/~waa/wireless.pdf, March 30, 2001.

2. Walker, Richard W., "Air Force Lab Struggles to Get a Handle on Wireless Security," Government Computer News, Vol. 20 No. 27, September 10, 2001 (http://www.gcn.com/20_27/news/17036-1.html).
3. Ståhlberg, Mika, "Radio Jamming Attacks Against Two Popular Mobile Networks," Seminar on Network Security, Helsinki University of Technology Telecommunications Software and Multimedia Laboratory, Fall 2000 (http://www.tcm.hut.fi/Opinnot/Tik-110.501/2000/papers/stahlberg.pdf).

KEYWORDS: Network, security, wireless, physical layer, radio frequency, antennas, modulation.

AF04-115 TITLE: <u>Innovative Approaches to Fusion 2+</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Development of innovative approaches to support Information Fusion for improved Situational Awareness

DESCRIPTION: The Joint Directors of Laboratories (JDL) Subpanel on Data Fusion has defined Data Fusion as "a process dealing with the association, correlation, and combination of data and information from single and multiple sources to achieve refined position and identity estimates, and complete and timely assessments of situations and threats, and their significance. The process is characterized by continuous refinements of its estimates and assessments, and the evaluation of the need for additional sources, or modification of the process itself, to achieve improved results".

To date the majority of data fusion research, development, and applications focus primarily on the lowest levels of data fusion (e.g., Level 1 - Object Refinement). The higher levels of information fusion, referred here as Fusion 2+, are inadequately being addressed. This SBIR effort will therefore address the Fusion 2+ domain.

Specific areas of research within Information Fusion for improved Situational Awareness are:

1. Research, development and application of novel methods in knowledge representation and information fusion is desired;

2. Techniques that are able to combine data-driven inputs with learned knowledge structures, to establish multiple hypotheses of interpretation are strongly desired;

3. Inputs are to be obtained from multiple modalities of sensing (e.g., imagery, signals, MTI) as well as text-based data;

4. The derived knowledge structure must be able to support learning of new relationships and higher-level concepts, and support human-guided learning.

PHASE I: Develop an innovative approach to a subset of the Fusion 2+ area that directly supports for improved Situational Awareness.

PHASE II: Develop a prototype Fusion 2+ system based on the Phase I design. Demonstrate the developed Fusion 2+ prototype to prove feasibility for a Situational Awareness capability.

DUAL USE COMMERCIALIZATION: There are many dual use applications of Fusion 2+ techniques. For example in the law enforcement community, this research could be applied to counter narcotics arena. On the commercial side, this research is applicable to business intelligence, where companies attempt to determine what their competitors are doing by collecting and analyzing data available over the web.

REFERENCES: 1. A. Steinberg, C. Bowman, F. White, "Revisions to the JDL Data Fusion Model", Proc. Of the SPIE Sensor Fusion: Architectures, Algorithms, and Applications III, pp 430-441, 1999.
2. E. Waltz and J. Llinas, "Multisensor Data Fusion", Artech House, 1990.

3. R. Antony, "Principles of Data Fusion Automation", Artech House, 1995.

4. M. R. Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems", Human Factors Journal, 37(1), pages 32-64, March 1995.

KEYWORDS: Information Fusion, Fusion 2+, Data Fusion, Knowledge Discovery, Situation Assessment, Threat Assessment, Impact Assessment

AF04-117 TITLE: Coalition Shared Database Implementation

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Investigate methods of storage, dissemination, and retrieval of Ground Moving Target Indicator (GMTI), Synthetic Aperture Radar (SAR) and other various types of data, in an synchronized and registered manner, that will support a commander's battlefield awareness.

DESCRIPTION: This is to stimulate the effort of enabling the exchange of Ground Moving Target Indicator (GMTI), Synthetic Aperture Radar (SAR) imagery, and associated products in a multi-system environment by developing capabilities that exploit evolving joint and coalition interface standards from the Coalition Aerial Surveillance Reconnaissance (CAEASR) ACTD or the Shared Tactical Ground Picture (STGP) initiative. This will allow any workstation that implements Application Program Interfaces (APIs) that adheres to specified standards, or implements a web-based XML interface, to access stored GMTI, SAR data types from various US and coalition sensors. Additionally, the capability to store exploited GMTI and SAR products, or derived products such as nominated tracks and collection plans.

PHASE I: Conduct research on GMTI and SAR storage, dissemination, and retrieval methodologies. This is to include optimization techniques in maximizing data transmission across a wide area network with limited bandwidth. PHASE II: Construct a prototype system based on the design plans from Phase I and demonstrate the capabilities of the system.

DUAL USE COMMERCIALIZATION: Commercial applications include traffic flow analysis based on GMTI history and synchronized SAR imagery. Database could also store track information for athletes on sports teams for analysis on player movement and location tendencies.

REFERENCES:
Overview on GMTI (or MTI) and SAR: See web-page on E8-C Joint STARS - http://www.fas.org/irp/program/collect/jstars.htm

Web-page/paper on Global Hawk radar:
http://www.raytheon.com/products/globalhawk_iss/ref_docs/globalhawk.pdf

For overview on web-based XML data dissemination:
http://www.mitre.org/news/events/tech02/briefings/info_management/kane_presentation/kane.pdf

Overview on CAESAR ACTD: http://disam.osd.mil/pubs/INDEXES/journals/Journal_Index/v.23_4/long.pdf

Overview on STGP Initiative:
http://www.ndia.org/committees/slaad/pdf/SIPFinalReport/APPENDIX%2028%20NATO%20Ground%20Picture%20Paper%205-Power%20Strawman.pdf

KEYWORDS: Ground Moving Target Indicator, GMTI, Synthetic Aperture Radar, SAR, coalition interoperability, coalition GMTI data storage and dissemination, coalition SAR imagery storage and dissemination

AF04-119 TITLE: Mentoring Software for the Warfighter

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace, Human Systems

OBJECTIVE: Examine the technologies required to create a mentoring system to support the JFACC in understanding the actions required to direct air operations in support of Joint operations, including needed information, decisions, and timelines, and create an interactive system that advises the JFACC on those elements of the C2 process.

WARFIGHTER IMPACT: Provide the warfighter with an intelligent software advisor to insure that an inexperienced JFACC can clearly articulate the directions of air operations and an experienced JFACC can enhance his C2 situation awareness.

DESCRIPTION: Although the Joint Senior Staff Course provides an overview of the JFACC structure and responsibilities, it does not provide the hands-on experience that enables a flag offier assigned those duties to efficiently and effectively carry out his or her responsibilities. At present, a JFACC must rely on his or her exposure to the short familiarization course and on personal understanding of the job, leading to wide variations in command environments and less than efficient peformance by the JFACC and his or her staff. An intelligent software advisor can provide the JFACC with the knowledge and methods he or she requires to manage air operations, including workflow, staff requirements and responses expected, information sources and access methods. The advisor is not a planner, scheduler, or battlespace information source itself, but rather a place where the JFACC can ask about them in the context of tasks that must be accomplished, and which can be tailored to match the JFACC's own style of command, much in the way that computer "desktops" become a reflection of the user. It will capture the essentials of the JFACC's command process and provide the tools needed to reflect individual preferences.

PHASE I: Develop the conceptual basis for an intelligent advisor, to include specifics of a knowledge base and business rules, and develop a corresponding architecture specifications that could be used to build a prototype.

PHASE II: Using the results of Phase I, build the prototpye advisor, populate the knowledge and rule base, and demonstrate a tailorable user interface in a realistic environment.

PHASE III: Develop an accreditable operational core and application environment for installation, demonstration and test in the Air Force Transformation Center and eventually for fielding throughout AF DCGS (Block 20).

DUAL USE COMMERCIALIZATION: The primary functions will be to provide on-line advice to high-level, e.g. JFACC, commanders who may have only limited experience in the command position. It will incorporate experience from multiple experts and work in an interactive manner. This type of on-line training can be used in the commercial sector for the training and operation of systems in the field (whether they are operational systems or service oriented tasks) so that the user is provided pertinent guidance based on their specific performance. This type of software could provide industry with the ability conduct highly effective on-the-job training by tailoring the advisor as the operator learns the functions required.

REFERENCES: There were no current activities in military on-line advisory capabilities.

KEYWORDS: Command and Control, JFACC, advisor, planning.

AF04-120 TITLE: Technologies for Injecting Targeting and Re-targeting Data in Precision-Guided Weapons in Flight

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop automated means of delivering results of precision mensuration derived from the intelligence analyst's workstation as a string of targeting data directly to a precision guided weapon on a platform or in flight, with or without a decision maker "in the loop."

WARFIGHTER IMPACT: Provides the warfighter with an automated sensor-to-shooter capability.

DESCRIPTION: Automated Weaponeering is the major focus of this topic. Open unclassified information on the success of recent US Navy experiments with EPPIC-derived precision mensuration data indicates the viability of passing the refined targeting data, reformatted as necessary, directly to selected precision guided weapons (PGWs) while in flight. Initiatives have included the discovery of solutions for a wide variety of PGWs, and Joint planning envisions standards and protocols for a range of battle space activities, including targeting and retargeting, for virtually all PGWs in the nation's arsenal. For now the decision maker is clearly still "in the loop," serving as the human interface between ISR and operations. Envisioned is a capability whereby targeting data is associated with a wide range of icons in a battlespace, and decision makers can interact with those icons and other icons representing weapons available for solution to effect automated engagement of user-matched weapons and targets. Required is an automated end-to-end environment within which default and user-specified gaming as well as operational ROE can be followed while utilizing this evolving, powerful capability. Lessons learned in US Navy experiments and JEFXs will be germane.

The philosophy is to start out with an "Air Operations Decision Aid" (AODA) like capability and improved on it to better pair up the weapon with the target and then added a "Super JMEM " capability that could rapidly weaponeer the target for the available weapons (as determined by AODA) and could then pass the required data to the weapon or weapon carrying aircraft, then the overall targeting chain for real-time/near real-time targets/missions. A software correlation tool and process is needed to take available data input from various sources to accomplish this philosophy.

PHASE I: Investigate the feasibility of enabling automated end-to-end environment for targeting and retargeting and demonstrate the ability of the capability to extract mensuration data from, at minimum, EPPIC, Raindrop and PGL precision mensuration tools, convert that data to targeting data and transmit that data reformatted as appropriate to a government-provided list of PGWs. Phase I will design a software process will take input from several sources and fuses the data where the output would be targeting quality data acceptable to PGM's. The software process will need to be able to rapidly determine where the aircraft is, where the target is, and then compute steering cues to send to the aircraft to re-vector the aircraft to get to the LAR. Other info might be needed such as expected time of arrival, fuel consumption, etc. Sources of this data for the software process are not centrally available and this topic will investigate how to obtain the data from individual processes. Phase I will examine systems such as the AODA and the Joint Continuous Strike Environment (JCSE) tools to determine if data from these systems is useable for the software process and if the software process can reside within these systems. The intent is to reduce work load via automation for the targeting operator (automated weaponeering) and reside within existing Battle Management processes and aids. Phase 1 will also examine Airborne Mensuration which has not been considered in existing systems and concepts. Existing programmable impact parameters (impact angle, impact azimuth) for weapon fuses as well as programmable fuse parameters will be considered in the software process. "Final mile" communication links to weapons will be taken into consideration.

PHASE II: Develop the software process as defined in Phase I. The software process will be hosted on laboratory computer systems for test and demonstration. This phase will also define the interfaces required to transition the software process to operational tools for installation and refinement at existing Air Operation Centers (AOC). If feasible, existing AOC tools will be used as the test and demonstration system.

DUAL USE COMMERCIALIZATION: The evolved capability can be tailored for use within the entire Joint targeting community, cutting across the intelligence and operations boundary (e.g., ISR and AOC) as well as traditional service boundaries (e.g., USAF and USN). The key objective of this development effort is to enable the delivery of updated targeting information in real-time to the delivery platforms (e.g. guided missiles) for military applications. In the commercial sector, the delivery of real-time information can be essential for monitoring the performance of delivery systems and for providing new information (e.g. maintenance instructions) to systems that are in the field or on the production line.

REFERENCES: 1. FY 04, Defense Planning Guidance, Long Range Global Engagement Study, Final Report, Apr 2003,
JDAM ORD (CAF 401-91-III-A), JASSM: ORD (CAF 303-95-II), Miniature Munitions: Draft ORD (CAF 304-97-B-A), Small Diameter Bomb (Phase I and II).

KEYWORDS: Re-Targeting, Time Critical Targeting, Moving Targets, Precision-Guided Weapons, Precision-Guided Munitions, Weapon Data Links

AF04-121 TITLE: RA-2 Over the Horizon (OTH) Communications for Small UAV's

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop the architecture, the enabling technologies, and demonstrate OTH communications for command and control, secure and reliable transfer of mission data, and the integral design of an architecture that can be readily included in a data link communications network to allow the exchange and timely relay of communications information. The effort should include the identification and evaluation of the various enabling technologies, an architecture that considers the constraints of operating on small UAVs, simulations models to provide evaluations of the various system tradeoffs, a notional terminal and system design, and a spiral schedule describing the development and insertion of the enabling technologies.

DESCRIPTION: Small UAVs require a reliable communications system to provide a real time control and the transfer of mission critical data. The data link to provide this remote control should be reliable, have sufficient range to allow their information to be entered into the overall theater communications architecture either as a point to point communications link or a part of a communications network, incorporate good anti-jam techniques that allow for operation in a noisy RF environment, compatible with constraints of a small UAV (size, weight, and prime power), and include the necessary enabling technologies to provide secure encrypted data transfer, and use modulation/ demodulation, encoding/decoding schemes to maximize reliable data throughput, extend the communications range, and minimize the latency. RF, laser, and integrated RF/laser communications, including shared apertures should be considered. The life cycle cost of any potential architecture and the insertion of new technologies should be considered in the system design.

PHASE I: The enabling technologies to accomplish a small UAV communications systems architecture shall be identified and evaluated. Integrated RF and laser communications should be considered including the use of shared apertures to allow stand alone RF or laser communications operation, or combined RF/laser communications. These include modulation/demodulations, encoding/decoding schemes compatible with either RF or laser communications systems, minimize data processing and latency, extend the range, and minimize the required transmit power; techniques to minimize acquisition time and provide reliable RF/laser tracking and minimize system complexity; and packaging to allow the shared use of the antennas and the integration of the RF LNA and the optical receiver. The evaluation of notional designs of tactical UAV communications architectures, including the use of shared apertures and the combined RF and laser communications operation shall include the tradeoffs to maximize the communications range, minimize system complexity and data latency, state of the art modulation/demodulation schemes such as Turbo Codes compatible with either RF or laser communications, encoding/decoding schemes should minimize system complexity and latency and maximize data throughput, and integration, including monolithic fabrication opportunities should be identified and evaluated. Technologies. The design shall include risk identification, alternative designs, and schedule of technology insertion. The Phase I deliverables shall include a notional system and terminal architecture, a detailed work plan for the Phase II including a planned demonstration of the various enabling technologies. During Phase I the emphasis should be placed on technology expected to be available in 2010.

PHASE II: Develop a system level design for selected architectures and include alternatives to reduce the development risk. The deliverables for Phase II include comprehensive communications system architecture for small UAVs, a demonstration of the various identified enabling technologies, a forecast of technology availability, risk assessment of the overall system architecture, and a schedule for technology insertion.

DUAL USE COMMERCIALIZATION: Although tactical UAVs are considered military systems today, they have numerous dual civil/military applications (crowd monitoring, traffic monitoring, etc). Therefore, any tactical UAV communications system implemented must be very reliable as safety-of-flight/life situations may be dependent on the communications system. Commercial applications also desire a relatively inexpensive system with low maintenance.

PHASE III: Concentrate on maturing a system architecture via identification/demonstration of high-risk technologies identified on the architecture technology path. The objective is a highly reliable tactical UAV communications system. This would include designs for integration and monolithic fabrication to reduce size, weight, and power consumption, and improve speed. System performance parameters would be refined to create this tactical UAV communications, and a technology pathway that Aeronautical Systems Center can follow to achieve this goal.

REFERENCES: 1. Skylar. Digital Communications, Fundamentals and Applications, Prentice Hall publishers, Englewood Cliffs, NJ. 1988.

KEYWORDS: Jam resistant, Coding algorithms, RF technology, Satellite networks, Frequency hopping, Spread spectrum, Laser technology

AF04-122 TITLE: <u>Mixed Excitation Linear Prediction (MELP) algorithm development</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Initiate the development of new voice processing algorithms that may be used as an "application" which can be transported to fielded or future software programmable radios.

DESCRIPTION: Link 16 today uses 2.4 Kbps LPC-10e and 16 Kbps CVSD voice. New enabling technologies such as COTS processors and modern voice processing algorithms, such as the Mixed Excitation Linear Prediction (MELP) algorithm, now allow for significant improvements in voice quality with minimal sacrifice in network capacity. MELP has been chosen by the Department of Defense Digital Voice Processor Consortium (DDVPC) to replace LPC-10 as the 2.4 Kbps federal voice-coding standard. MELP is the best technique currently available for real-time, high quality, low data rate tactical communication. The JTRS Cluster 1 Link-16 Waveform developer plans to implement 2.4 Kbps EV within its software communications architecture code. However it is not clear that this code will be portable to other communication systems. (The existing LPC-10e and CVSD algorithms will be maintained for interoperability). The critical factor is the interaction of the Link-16 network design based on the required Quality of Service needed for the MELP to be of high quality without a significant voice delay. This effort must define and verify the network and voice coding limits for future Link-16 network designers and MIDS/JTIDS voice implementers.

PHASE I: Develop coding that allows for functional code transfer to other software programmable radios.

PHASE II: Continue algorithm development and characterize system performance with MIDS and JTIDS L-16 terminal hardware architectures and determine the boundaries on the network designers to guarantee MELP Voice Quality of Service. Upon completion of the detailed simulations performed in phase 1, The proposed vendor will implement and evaluate the MELP algorithm in MIDS LVT(1) terminals and/or a JTRS architecture that supports the Link 16 waveform. A future goal entails localizing the terminal modifications to the maximum extent so that retrofit of this capability in the future can be done at minimal cost and lowest complexity. Ideally, future upgrades will be limited to one MIDS SRU or one JTIDS module for legacy architectures with no changes to MIDS or JTIDS software. For JTR systems, the implementation of this MELP capability will be simply a software update.

DUAL USE COMMERCIALIZATION: Implementation in MIDS and JTIDS terminals will require the forward fit and retrofit designs to guarantee interoperability and ease of retrofit. Thus the design issues of intercom interfaces and terminal interfaces must be solved and designs generated for each of the retrofit and forward fit platforms. This research could be useful in the commercial cellular phone area.

REFERENCES: 1. "Channel-encoded transmission of MELP-compressed speech," T. Fazel and T. Fuja, 1998 IEEE International Symposium on Information Theory.

2. "Enhanced Error Correction of the US Federal Standard MELP Vocoder Employing Residual Redundancy for Harsh Tactical Environments," D. Rahikka et al., NATO Tactical Mobile Communications Symposium TMC-99, June 1999.

KEYWORDS: MELP, enhanced MELP, JTRS, Software Defined Radios (SDRs), application layer, JTIDS, Link-16

AF04-123 TITLE: Improved Liveness Testing Techniques for Biometrics Applications

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Investigate improved liveness testing techniques for biometric authentication systems.

WARFIGHTER IMPACT: As the DoD increases its reliance on biometric authentication systems to grant access to both physical and logical assets, it becomes increasingly important to ensure that these systems minimize the risks associated with biometric spoofing. Improved liveness testing will reduce this risk by strengthening the assurance that a biometric property is indeed authentic, thus preserving logical, as well as physical, warfighter assets.

DESCRIPTION: As it pertains to biometrics, the term "liveness" describes qualities of a given biometric sample, which provide assurance that the sample is indeed coming from a living subject. Some biometric systems have already been shown to be susceptible to capture and replay attacks. For example, some biometric implementations employing fingerprint scans can be fooled into believing that a gelatin mold of a valid user's fingerprint is in fact, that user's finger, e.g., the "Gummy Bear" attack.

PHASE I: Conduct feasibility study of attacks and required solutions to improve upon existing Commercial Off The Shelf (COTS) biometrics testing techniques. Determine how to improve "liveness" testing accuracy based on innovative combinations of existing technologies, or propose new approaches. The focus of this effort will be fingerprint and iris scan technologies.

PHASE II: Perform prototype demonstration of proposed approach that shows improved resistance to spoofing by other than live, valid user. Transfer improved liveness testing techniques to the biometrics industry.

DUAL USE COMMERCIALIZATION: The commercial world including the airline industry and other industries that require strong authentication and plan to use biometrics in the future will have substantial interest in taking this effort to a Phase III.

REFERENCES:

1. T. Matsumoto, H. Matsumoto, K. Yamada, S. Hoshino, "Impact of Artificial Gummy Fingers on Fingerprint Systems," Proceedings of SPIE Vol. #4677, Optical Security and Counterfeit Deterrence Techniques IV, 2002.
2. J. Ernst, "Iris Recognition: Counterfeit and Countermeasures," http://www.iris-recognition.com/counterfeit.htm
3. B. Schneier, "Biometrics: Truths and Fictions," http://www.counterpane.com/crypto-gram-9808.html#biometrics

KEYWORDS: Biometric, Information Assurance, Information Security

AF04-124 TITLE: High Performance Biomolecular Computing Architectures for Information Technology

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Design and build new architectural components for hybrid information systems performing computation utilizing Biomolecular materials.

DESCRIPTION: Several trends are converging to generate a need for development of hybrid computation systems containing subsystems utilizing biomolecular devices along with conventional CMOS components. The current CMOS computing paradigm is approaching fundamental limits to further improvements in performance. New materials are needed to overcome limits in device size, the rising cost of the fabrication facility, limits to fault tolerance and rising energy/heat densities. To increase cognizance, future computing systems are expected to have integrated environmental awareness and contextual addressing schemes. Changes are expected in the human-computer interface, which will require new interfaces between silicon and biological materials. With this convergence, new computation paradigms and the increase in nontraditional capabilities will come a blurring of the traditional divisions in computational systems. Concepts such as hardware/software, devices/data, sensor/computer, and architecture will need to change. Some component areas are approaching the level of maturity in which bridge technologies can be developed for near term commercialization. These include simple, specialized information components, design tools that address hybrid systems and interfaces between bio-operations and electronic operations, and algorithms for transduction at the interfaces and higher-level compute operations of biomaterials. Areas of interest with near term potential include, but are not limited to application of DNA as a taggant or authentication/watermark material where information is stored in the DNA and retrieved as a function of detecting the tag. Another area includes the use of Biomaterial for high performance memory. Development is sought in the performance of the biomaterial and the I/O and addressing techniques. Scalable parallel generic algorithm development is of interest where it pertains to computation operations performed by biomolecular materials for information processing. The approach would entail a clear and rapid transition path from emulation by silicon computers to operation by biomolecular hybrid computers. This approach may benefit from embedding equation solvers in hardware in the cluster nodes. This SBIR topic is not a solicitation for sensor development or medical oriented computationally inspired biology. Projects should address components of a hybrid computing system designed for use in information processing. Integration and interfaces for a hybrid system will be prominent features in successful proposals.

PHASE I: Develop system design and plan for interface integration.

PHASE II: Demonstrate a prototype system in a realistic working environment. Show plan to transition technology to a commercially viable market.

PHASE III DUAL USE APPLICATIONS: Each of the above areas of interest holds the potential for extensive Dual Use application, which are generally apparent. All have far greater potential in commercial market application than the military use envisioned.

REFERENCES:
Seeman, N. C., (2003), Nature, 421, pp. 427-431
Reif, J. H., (2002), Comput. Sci. Eng. Mag.: Special Issue on Biocomputation, 4, pp. 32-41
Deaton, R., Kim, J. W., Chen, J., Appl. Phys. Lett., 82, pp. 1305-1307

DARPA Biospice program. An open source tool for modeling biological systems. wwww.biospice.com
Lee, J., Kim, C.J., Journal of MEMS, 9, pp. 171-180

KEYWORDS: Biomolecular Computing, DNA Computing, Hybrid Computers, And High Performance Architectures

AF04-126 TITLE: Development of On-line Fuel Tank Oxygen Sensor for Aircraft

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop an on-line oxygen sensor to determine the oxygen content of the air above the fuel in aircraft fuel tanks.

DESCRIPTION: The oxygen content of the air above the fuel level in aircraft fuel tanks must be controlled to levels of 9 to 12 percent by volume. Procedures currently exist to control the oxygen levels to that range, both on the ground as well as in-flight. It is accomplished through the use of nitrogen generators. It is more efficient to use the existing Onboard Inert Gas Generation System (OBIGGS) in flight because it can be done in significantly less time than is required using the ground-based support equipment. To accomplish this effectively and efficiently, however, an on-line sensor is required to be able to determine the oxygen content of the air space above the fuel in the fuel tanks and provide that information to the flight crew. The sensor must be lightweight, reliable and low cost. It also must be compatible with the fuel vapors that will be present in the air above the fuel in the fuel tanks. It also must be compatible with the aircraft electrical system and not require special electrical power. The sensor must be capable of accurate and reliable operation over the pressure and temperature ranges experienced in the aircraft fuel tanks during operation.

PHASE I: Demonstrate the feasibility of the proposed technology to meet the requirements stated in the description section of this topic. A suggested method to demonstrate feasibility would be to develop a working prototype that demonstrates the contractor's sensor device capable of determing the oxygen content of the air above the fuel level in a simulated fuel tank.

PHASE II: The anticipated results of the Phase II effort are the complete development of the sensor in its final form and demonstration that it is capable of all of the requirements stated in the objective. The probable long-term compatibility of the sensor with the fuel vapors will be demonstrated by the accelerated materials compatibility testing of the sensor materials of construction with JP8+100. A full-scale, simple-to-operate working unit will be delivered to the Air Force for testing at the completion of the contract.

DUAL USE COMMERCIALIZATION: This technology is directly applicable to the commercial aircraft community where determining the oxygen content of the air above the fuel is also very critical. An on-board on-line capability will have great applicability.

REFERENCES: 1. Ritter, K.J.. and T.T. Wilerson, "High Resolution Spectroscopy of the Oxygen A Band," Journal of Molecular Spectroscopy, 121: 1-19, 1987.

2. Smith, R.J. and William L. Casey, "Dart: a Novel Sensor for Helicopter Flight Safety," Photonics Spectra, 110-116, July 1992.

3. Silver, Joel A., "Frequency-modulation Spectroscopy for Trace Series Detection: Theory and Comparison Among Experimental Methods," Applied Optics 31 (6), 707-717, 1992.

KEYWORDS: oxygen sensor, fuel tank oxygen level

AF04-127 TITLE: Development of High-Temperature Aircraft Camouflage Coatings

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop high temperature camouflage coatings for aircraft outer mold-line applications to temperatures up to 1200 °F (650 °C).

DESCRIPTION: Current military aircraft require a low gloss (low visible reflectance) coating for survivability. These coatings are polymeric based and long-term exposure above 250 °F (120 °C) will seriously degrade the coatings. A variety of current aircraft have serious coating deterioration issues near engine and power generation unit areas where the elevated temperatures degrade current coatings (MIL-C-85285). These high-temperature areas are typically titanium or superalloy structure; metal surfaces not extremely compatible with conventional coatings.

Future high-mach (M > 3) aircraft and weapons will require a high-temperature exterior coating with similar requirements. High-temperature stability, adhesion to titanium, superalloy, and advanced metallic (intermetallics, metal matrix composites), and survivability features will be required from high temperature camouflage coatings.

A variety of high-temperature polymers have been developed for advanced composite applications and adhesive bonding applications. These polymeric materials may serve as useful binders for coatings with applications up to 700 °F (370 °C). Preceramic polymers and sol-gels have been developed for ceramic matrix composite construction. These materials may serve similarly as coating binders with increased temperature performance to 1200 °F (650 °C). Pigments used for optical properties (gloss, reflectance) are generally stable to high temperature but some development may be necessary to impart thermal stability and compatibility with higher temperature binders.

This SBIR program would identify candidate polymeric and preceramic binders as well as thermally stable pigment for incorporation into coatings. Further development would optimize coating formulations for processing and performance. A demonstration of thermal stability, compatibility with high-temperature structure, and coating properties would finish the Phase II program.

PHASE I: Identify candidate binder and pigment materials to develop a high-temperature coating that meets the general specification requirements of the current camouflage coating (MIL-C-85285). Key coating performance parameters are thermal stability, color, gloss and compatibility with high-temperature structure substrates. The contractor shall identify candidate polymeric (nominal use temperature up to 700 °F) and preceramic (nominal use temperature up to 1200 °F) materials as candidate high-temperature binders. The contractor shall identify candidate pigments that will impart the proper optical performance. Trial coating shall be formulated, coated onto high-temperature structure substrates, and evaluated against the key performance parameters. Succession into Phase II will be based upon the results of this evaluation.

PHASE II: Further development of binder and pigment materials for improved thermal stability and coating performance. Processing techniques shall be developed with the assumption that individual parts will be coated, leading the way to innovative curing/heat-treatment techniques. Large-scale coating processes for entire aircraft are not to be pursued. A demonstration component of sufficient size (approximately 100 sq ft) will be coated at the end of this program, with limited thermal and coating performance testing on subelements.

DUAL USE COMMERCIALIZATION: Similar high-temperature components on commercial aircraft. Industrial and automotive components may also benefit from these high-temperature coatings.

REFERENCES: 1. Organic Coatings: Science and Technology, 2nd Ed., Eds. Wicks, Zeno, et al., ISBN 0-471-24507-0.

KEYWORDS: high-temperature coating camouflage aircraft

AF04-128 TITLE: Pilot Extraction Tool

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop universally applicable system that provides improved firefighter and rescue personnel access to cockpits and speeds pilot extraction under ground emergency conditions.

DESCRIPTION: Advanced fighter/bomber aircraft require improved access for firefighting and rescue personnel to reach the cockpit. Emergency personnel must be able to open the canopy, accomplish engine shutdown, make the ejection system safe, and extract the pilot during ground emergencies. The proximity of engine inlets to the cockpit and the toughness of modern canopies prevents successful application of traditional approaches to pilot extraction. There is a significant risk of damage to high value-aircraft components and low-observable surface finishes during recurring live aircraft training involving simulated pilot extraction. The required system must be easily carried by one person, fire resistant, and compatible with aircraft and high-value aircraft parts. The system must also be safe for fire or rescue personnel to use for emergency situations (Note: Pilot extraction training and actual ground emergencies requires access to both sides of the cockpit.)

PHASE I: Demonstrate the feasibility of the proposed tool via a prototype demonstration or subscale model demonstration and provide system concept for a potential Phase II effort.

PHASE II: Build a full-scale system, delivered at the end of the Phase II effort to demonstrate its utility in tests with trained aircraft crash/rescue personnel on actual or closely simulated aircraft conducted by Air Force or contractor personnel.

DUAL USE COMMERCIALIZATION: This tool would likely have commercial applications for emergency rescue personnel as well as DoD firefighting/rescue personnel.

REFERENCES: 1. Air Force Document: Aerospace Emergency Rescue and Mishap Response Information (Emergency Services)TO 00-105E-9. Available at:
http://www.robins.af.mil/ti/tilta/documents/to00-105E-9.htm

KEYWORDS: fire, rescue, crash, open canopy, engine shutdown, safe ejection system, pilot extraction, ground emergency

AF04-129 TITLE: Direct Manufacturing of Advanced Gas Turbine Engine Diffuser Cases

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Demonstrate a direct manufacturing technique for fabricating diffuser cases that significantly reduces the time and cost of development and production.

DESCRIPTION: Nickel based alloys like INCO 718 and IMI 939 are widely used in the investment casting of diffuser cases for gas turbine engines. Modern engine designs have made these castings very complex and difficult to develop and produce at affordable costs with the first-time quality desired by OEM engine companies. Component manufacturing involves extensive, iterative development cycles resulting in undesirable levels of cost and time-to-first-article. The eventual product design is usually compromised to accommodate process difficulties and shortcomings such as shrinkage and inclusions associated with areas of abrupt section thickness changes and geometrical complexity. Therefore, an alternative method for fabricating diffuser cases is sought to reduce development cycle time and preclude these cost and quality issues. Several emerging direct manufacturing processes have the potential to greatly reduce first-article development cost and time and offer significant cost reductions in production. They also offer engineers the flexibility, during engine development, to easily and quickly modify designs to minimize weight while improving overall utility. However, these emerging direct manufacturing processes must be further developed for the manufacture of gas turbine components and rigorous economic analysis conducted to address both the technical and business questions associated with implementation and qualification to warrant industry support and investment.

PHASE I: Demonstrate the engineering and economic feasibility of emerging direct manufacturing processes to fabricate diffuser cases from nickel based superalloys of interest to the gas turbine engine industry. The ultimate goal is to reduce first article development time and cost by over 50 percent, and to reduce final part production costs by 35 percent and product delivery cycle times by 50 percent. This phase will investigate the feasibility to directly manufacture sub-elements of typical diffuser case designs that represent anticipated areas of concern during fabrication. Subelement fabrications should include areas containing abrupt changes in cross-sectional thickness, sections containing hollow cavities, and elements containing bosses, flanges, or other types of attachments. Each element will be sectioned and characterized to evaluate dimensional and microstructural characteristics and for the presence of any metallurgical anomalies. Specific data will be gathered during the sub-element fabrication study to enable construction of an economic model of the process to project the savings offered and to provide clear understanding of the cost drivers and their respective magnitude of influence on overall process economics. An initial business case will be developed to understand the investment in equipment changeover and qualification expenses to warrant industry support and adoption. Additionally, a production capable supply chain scenario (from material suppliers to the delivery of a complete, machined component) will be proposed for further evaluation during the commercialization planning task in Phase II of the program.

PHASE II: During Phase II of the program the process will be further developed to demonstrate full-scale fabrications of nickel based superalloy diffuser cases using production-capable direct manufacturing processes. Several first article cases will be fabricated to demonstrate process reproducibility under realistic production conditions. Cases will be heat treated, inspected using typical nondestructive evaluation and dimensional inspection techniques, and sectioned to document process capabilities and to establish an initial design data base. Portions of the fabricated cases will be further evaluated microstructurally to demonstrate acceptable material quality and metallurgical characteristics. General material property testing to obtain preliminary data per standardized testing techniques will be conducted to show the material acceptability for industrial use. Commercialization plans will be developed based on the supply chain scenario developed in Phase I. Qualification requirements will be established to introduce this new direct manufacturing process for fabrication of diffuser cases to the aerospace industry for production transition and qualification in Phase III. Deliverables shall include a detailed description of the processing path or paths used to create the prototypes plus one complete prototype component.

DUAL USE COMMERCIALIZATION: Commercial applications shall include the manufacture of diffuser cases and other components for advanced gas turbine engines used for commercial aircraft and, potentially, for land-based turbines used in the power generation industry.

REFERENCES: 1.D.L. Bourell and J.J. Beaman, Jr.,; "Freeform Fabrication - History and Current Processes," in Proceedings of Symposium on Rapid Prototyping of Materials, TMS Fall Meeting 2002, Columbus, OH, pp. 3 - 17, 2002.

S.C. Danforth, D. Dimos, and F.B. Prinz (eds.), "Solid Freeform and Additive Fabrication - 2000," Proceedings of Materials Research Society Symposium, Vol. 625, 2000.

J.W. Sears, "Solid Freeform Fabrication Technologies: Rapid Prototyping - Rapid Manufacturing," in International Journal of Powder Metallurgy, Vol. 37, No. 2, pp. 29 - 30, 2001.

KEYWORDS: direct manufacturing, rapid manufacturing, solid freeform fabrication, diffuser cases, nickel-based superalloys

AF04-130 TITLE: <u>Ceramic Matrix Composites (CMCs) for Aircraft Brake Friction Materials</u>

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Demonstrate and optimize CMCs as high-performance aircraft brake friction materials.

DESCRIPTION: Carbon-carbon (C-C) composites are the state-of-the-art friction material for aircraft brakes. C-C composites suffer from a relatively low friction coefficient, a high variability in friction coefficient as a function of temperature, moisture content, pressure, susceptibility to oxidation at the use temperature, generation of a nuisance dust (through brake wear), and degradation from fluids commonly used on and around the aircraft. CMCs offer an alternative to C-C composites which may ameliorate many of these deficiencies, as well as provide for reduced wear rate and improved volumetric heat capacity. Silicon carbide (SiC)-based CMCs have been the primary focus of attention to date, and preliminary results have been promising [1-2], but other compositions may also be candidates.

PHASE I: Optimize the CMC composition and brake configuration for maximum performance based on analysis and laboratory testing, and demonstrate the feasibility of the proposed brake material system through subscale testing. Assess the results, identify material and process refinements, and consider brake design modifications.

PHASE II: Fabricate and dynamometer test at least two full scale military aircraft brake stacks over the course of the Phase II effort. The focus of the effort should be on 1) demonstrating desirable brake performance characteristics, 2) analytically evaluating brake design modifications to optimize brake performance with the CMC friction material, 3) improving/scaling up key fabrication steps, with an eye toward cost reduction and commercialization, and 4) Providing comparison of CMC versus C-C brake material characteristics (e.g. improvement in volumetric heat capacity of CMC versus C-C).

DUAL USE COMMERCIALIZATION: The resulting advanced friction materials will be directly applicable to the large commercial aircraft brake market, where improved performance will result in reduced cost per landing.

REFERENCES: 1. Vaidyaraman, Purdy, Walker, and Horst, "C/SiC Material Evaluation for Aircraft Brake Applications," in High Temperature Ceramic Matrix Composites, Eds. Krenkel, Naslain, and Schneider, pp. 802-808, Wiley-VCH, Weinheim, Germany (2001).

2. Heidenreich, Renz, and Krenkel, "Short Fibre Reinforced CMC Materials in High Performance Brakes," in High Temperature Ceramic Matrix Composites, Eds. Krenkel, Naslain, and Schneider, pp. 809-815, Wiley-VCH, Weinheim, Germany (2001).

KEYWORDS: aircraft Brakes, ceramic matrix composites (CMCs), friction materials, C/SiC (carbon fiber reinforced silicon carbide), process development

AF04-131 TITLE: Erosion Protection Materials for High-Temperature Composites

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: The objective of this research effort is to develop and demonstrate new erosion protection material systems for use on high-temperature polymer matrix composite (HTPMC) materials in aircraft turbine engines.

DESCRIPTION: HTPMCs have tremendous potential to reduce the weight and cost of military aircraft turbine engines if producibility and durability in service environments can be demonstrated. An important factor for engine durability is resistance to ingested particle erosion. This requires that viable erosion protection materials can be developed. Erosion protection coating materials have not been demonstrated that are suitable for use in hot engine components with service temperatures of up 650 °F for the life of the engine. This research effort is to develop affordable coating systems (materials and processes) that are compatible with candidate HTPMCs such as Avimid N, PMR-II-50, AFR-700, and AFRPE.

PHASE I: Candidate materials and processes will need to be screened for: 1) erosion protection at engine service temperatures, and 2) compatibility with HTPMC materials and processes used for turbine engine components. For the Phase I effort coupon-level evaluation is appropriate. Erosion protection requirements should be coordinated with engine manufacturers for specific evaluation methods and pass/fail criteria. Selection of specific HTPMC substrate materials should be coordinated with engine manufacturers to ensure the relevance and suitability of erosion protection materials developed under this proposed research effort. This Phase I screening should result in down-selection of best performing erosion protection concepts that will be further developed under a Phase II effort. A feasibility study shall be performed as part of Phase I evaluating implementation issues including manufacturing and material development costs.

PHASE II: The selected materials and processes will be fully optimized and scaled up to demonstrate engine service environments. These environments include durability, affordability and erosion resistance. All critical engine environmental durability factors should be addressed and demonstrated. These requirements must be determined through coordination with engine manufacturers.

DUAL USE COMMERCIALIZATION: Commercial aircraft, rotorcraft, and power generation turbines have similar durability and temperature performance requirements to military turbine engines. These commercial applications will benefit from coating technology that will enhance erosion protection of composite components.

REFERENCES: 1. "Mechanical Testing of PMCs Under Simulated Rapid Heat-Up Propulsion Environments (1. Temperature Measurement)", SAMPE Proceedings, May 12-16, 2002, Long Beach, CA

KEYWORDS: erosion protection, polymer matrix composites, turbine engines, coatings

AF04-132 TITLE: Encapsulated Resin for Non-Autoclave Resin Film Infusion Composites Repair

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Develop processing techniques for on-aircraft repair of composite components using encapsulated resins that can be stored at room temperature.

DESCRIPTION: Repair of composite aircraft structure in the field generally requires an adhesive bonding 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, nonporous adhesive layer. Resin film infusion (RFI) is a process in which calendared film or plaques of resin are placed on top of or below fiber preforms and then consolidated and cured together under vacuum-only conditions. Achieving the high performance characteristics has not been realized as yet by RFI due, in large part, to difficulty in achieving void-free parts. Air entrapped in the resin films cannot be removed from the resin film when in its solid form, and once the resin melts, poor flow characteristics lead to an inability to evolve the air from the consolidating laminate. Encapsulating a predetermined amount of resin and applying vacuum prior to flow offers a solution to the limitations of the RFI process.

Innovative approaches will improve the RFI process and reduce costs for aircraft repair. The program goal is to develop a method to use materials that can be stored at room temperature and which bond with existing adhesive materials (for a 250 to 275°F bond temperature), although other materials and processes may be considered. 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 nor requiring environmentally controlled storage conditions.

PHASE I: Identify candidate materials and processes and demonstrate resin film infusion processing procedures to achieve mechanical and physical properties with a decrease in repair cure time. The contractor shall demonstrate, at a laboratory scale, properties that are comparable to existing autoclave cured (350F) epoxy materials and withstand a minimum service temperature of 180F.

PHASE II: 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., heating equipment, vacuum bagging materials, etc.), and the environmental considerations they entail.

DUAL USE COMMERCIALIZATION: The Air Force has a variety of aircraft applications that a successfully developed material would find use in. Commercial applications include recreational sporting industry.

REFERENCES: 1. MIL-HDBK-337, 1982-12-01, Adhesive Bonded Aerospace Structure Repair

2. MIL-HDBK-17/1F, Composite Materials Handbook Volume 1, Polymer Matrix Composites Guidelines for Characterization of Structural Materials

3. MIL-HDBK-17B(1), Polymer Matrix Composites, Volume 1. Guidelines (S/S by MIL-HDBK 17/1)

4. MIL-HDBK-17/2F, Composite Materials Handbook, Volume 2, Polymer Matrix Composites Materials Properties

KEYWORDS: composites, repair, processing, nonautoclave

AF04-133 TITLE: Damage Detection in Composites via Passive Monitoring Techniques

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a graphite fiber composite damage detection method which improves rapidity, cost, and/or certainty of post-damage inspections at different levels of depth.

DESCRIPTION: Damage in graphite fiber composites can be detected in numerous ways. The objective of this program is to detect damage easily. The techniques proposed may be for field and/or depot maintenance. They should not involve real-time acquisition schemes, but rather, schemes that embrace either presently unused detection techniques, or schemes that make present methods faster and/or more efficient. Examples that will be strongly considered include, but are not limited to:

1) Pressure-sensitive paint. Paint responds to impact by changing color due to microencapsulants; possibly different impact levels might trigger different colors. Color change readily indicates impact events to field and/or Air Logistic Center personnel, who can then focus attention on detailed inspection of affected areas. Paint must be compatible with the usual requirements on competing aircraft paint systems, as well as permit maintenance crews to work on the aircraft without triggering the paint impact detection properties.

2) Rapid application of ultrasound coupling medium. Most of the time involved in ultrasonic inspection is associated with assuring the presence of water (usual coupling medium) between the body to be inspected and the ultrasonic transducer. Methods exist, and/or can be improved, which dramatically reduce the time associated with insuring proper application of couplant (normally water).

3) Proposed methods involving electrical changes [5] due to graphite fiber or matrix strains, or eddy current phenomena, will be considered only if accompanied by very convincing evidence of suitability to full-scale aircraft application by the end of Phase II. Such evidence will necessarily be based on the maturity of such technology at the time of the Phase I proposal submission.

4) Radio-opaque embedded fiber strategies are not encouraged due to concerns about potential needs to re-qualify materials systems, which in general would be cost prohibitive.

PHASE I: Demonstrate damage sensing (and possibly strain sensing) capabilities at lab environment level, for systems of interest to the Air Force such as IM7/5250-4 and IM7/977-3 in laminated tape and woven forms. Deliverables include all data generated, and reports regarding progress on the concept and feasibility of meeting the Phase II objectives. Early and continuing interactions with sponsors are recommended.

PHASE II: Develop and deliver a technology approach which can produce a product that can be inserted in an Air Force system program with a minimum of additional effort, preferably within 2 years following Phase II completion. A production-capable system for application to aircraft is thus desired. A prototype will be a required deliverable, in addition to the usual data and reports. Collaboration in this phase with aircraft manufactureres and/or Air Force personnel with systems access is highly encouraged.

DUAL USE COMMERCIALIZATION: This technology can be applied to damage sensing in graphite fiber-reinforced structures, e.g., in civil aircraft, armor, advanced vehicle powertrains, off-shore drilling platforms, Naval or civilian marinecraft, etc. Collaboration in this phase with aircraft manufacturers and/or Air Force personnel with systems access is highly encouraged.

REFERENCES: 1. Light, G.M., 1986, Development of Encapsulated Dye for Surface Impact Damage Indicator System, Phase II: Southwest Research Insititute SwRI Project No. 17-1056. More info at http://www.swri.edu/4org/d14/ndedept/home.htm

H. W. Schlameus, G. L. Light, and C. H. Parr, Impact Indicator Coatings, Second DOD/NASA Composites Repair Technology Workshop, San Diego, CA, November, 1986. More info at http://www.swri.edu/4org/d01/appchem/encap/home.htm and
http://www.swri.edu/3pubs/papers/d01/01pres.htm

Crane, R., 1981, Composite Structures and Method of Detecting of Mechanical Damage Thereto: Assigned to USAF, USA, Patent No. 4,255,478.

Buynak, C.F. and Crane, R.L., 1987, A Novel Acoustic Coupling Device using Permeable Membrane: Materials Evaluation, Vol. 45, No. 6, pp. 743-746.

KEYWORDS: damage, composite, graphite, paint, ultrasound

AF04-134 TITLE: Nondestructive Inspection (NDI) of Fastener Holes in Thick Multi-Layer Structure

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop NDI to detect cracking within Taper Lok fastener holes of thick multilayered structures without the removal of fasteners.

DESCRIPTION: A requirement exists to conduct NDIs on a thick multilayer wing structure. Unfortunately, due to the thickness and complexity of the structure, there is currently no means of inspecting this hardware without removing the Taper Lok fasteners and conducting bolthole 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 structural configuration of greatest 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-Lok 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 the wing lower external surface to the top layer 0.38 inch of titanium, 2.0 inches of aluminum and 0.38 inche of titanium and 0.64 inches of aluminum. The extreme case outboard consists of 0.9-inch of titanium, 0.9 inch of aluminum, 0.9 inch of titanium and 0.5 inch of aluminum. Access is open to the lower wing surface. Access is very restricted at the upper side of the structure. Polysulfide sealant may not be present between each layer of the splice joint sandwich. For the wing carry-through, the flaws of most concern are corner cracks initiating at the fastener bore within the tapered aluminum tang of the wing plank. The current goa is 0.050-inch corner flaw detection sensitivity.

PHASE I: Demonstrate concept feasibility. Demonstrate the ability to detect fatigue damage within the borehole of an aluminum structure with steel fasteners installed. The inspection must be conducted through a total of 0.4 inch of titanium and 2 inches of aluminum. The fatigue flaws shall be place within the fastener bore at the back surface of the 2-inch aluminum plank. The Government can provide these specimens. Design the prototype system to be built in Phase II.

PHASE II: Develop and demonstrate the system prototype on a demonstration article representative of the actual B-1B structure containing known fatigue damage. Review prototype design with AF personnel for robustness, comformance 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. It is desired to have an integrated team approach to the development of the prototype that will incorporate user feedback.

DUAL USE COMMERCIALIZATION: 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.

REFERENCES: 1. ASM Handbook, Nondestructive Evaluation and Quality Control, vol. 17, J.R. Davis, S.R. Lampman, ASM International, 1994

2. Ultrasonic Testing of Materials, Krautkramer, Krautkramer, Springer Verlag, 1990.

KEYWORDS: nondestructive inspection, crack detection,

AF04-135 TITLE: Lean Techniques for Project Management in the Acquisition Environment

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Establish a teaching module using simulation to demonstrate how lean concepts can provide benefits to project management in the acquisition environment.

DESCRIPTION: Project managers involved in acquisition processes are routinely estimating project task completion dates. In large projects, the uncertainty of these approximations and an extensive set of milestone dates, precedence constraints and resource limitations can combine and lead to unrealistic predictions and the development of very complex analytical program management tools. Lean concepts (i.e., more specifically Critical Chain Project Management (CCPM) from the Theory of Constraints) are simple concepts that are typically applied to work content. However, when these concepts are applied to the way work is scheduled rather than performed, significant reductions in cycle times may also be achieved, independent of the work content. Applying lean techniques such as CCPM may be the most simple and promising approach available today to reduce development cycle time and cost. It could take advantage of hidden capacity in program execution to reduce acquisition development cycle time/costs.

PHASE I: Demonstrate the concept that the application of lean techniques (CCPM) to project management, either independent or in conjunction with lean tools applied to work content, can reduce cycle time and costs. It could be applicable to any project and provide similar benefits that lean techniques have done for manufacturing. A focus on a literature search for applicable project management studies could facilitate the concept demonstration.

PHASE II: Implement the concept demonstrated in Phase I by developing an education module that uses/expands simulations completed to date that explains the dynamics of project management and how lean concepts (i.e., such as CCPM) can improve schedule performance and reduces negative individual behaviors which are barriers to accomplishing program schedule objectives. Additionally, obtain expert review to verify completeness of simulation.

DUAL USE COMMERCIALIZATION: The developed product would have potential applications in commercial acquisition environments as well as in DoD applications. Follow-on activities are expected to be aggressively pursued by the offeror, namely documenting the results in commonly available media and potentially selling of the product as a program management training tool.

REFERENCES: 1. "Critical Chain Project Management;" Lawrence P. Leach; Artech House; February, 2000.
2. "The Measurement Nightmare;" Debra A. Smith; Saint Louise Press; December, 1999.
3. "Program Management in the Fast Lane;" Robert C. Newbold; CRC Press; February, 2000.
4. "Critical Chain;" Eliyahu Goldratt; North River Press Publishing Corp; April, 1997.5. "Theory of Constraints;" Eliyahu Goldratt; North River Press Publishing Corp; June, 1990.

KEYWORDS: risk management, program management, theory of constraints, lean production, critical chain program management, risk analysis tools, project management tools, Parkinson's Law, multi-tasking

AF04-136 TITLE: Waste Disposal/Waste Management System for Low Observable (LO) Composite Materials

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a waste disposal system that is capable of destroying LO waste materials generated by the maintenance operations of fighter aircraft.

DESCRIPTION: Fighter aircraft use composite materials that are very high strength and have low reflection to radar. These materials may be of value to enemy intelligence organizations. Construction, maintenance, and repair of these aircraft will result in scraps and residues that should not enter the normal waste stream, and should be completely destroyed. Consequently, a waste disposal system is needed to convert these materials into a condition that is of no intelligence value (i.e grind, chop, etc). The purpose of this topic is to develop and deliver a waste disposal system capable of destroying generated composite waste in an environmentally acceptable manner. The system shall be easy to operate, requiring only one person for startup. Once started, it shall process wastes without operator participation.

PHASE I: Evaluate potential destruction methods. Down select to a particular technology that is most effective. Design, build, and demonstrate a bench scale system to demonstrate the technical feasibility. Conduct a series of experiments to evaluate the system's performance.

PHASE II: Design, build, and test a prototype waste disposal system that can handle composite wastes generated by AF maintenance operations. Verify operation on actual waste materials. Determine composition of processed residues, including solid, liquid (if any), and gaseous effluents. Evaluate solids to determine if these materials can be disposed in a landfill. Determine if liquids can be discharged into a sanitary sewer. The protoype unit will be a deliverable of the Phase II program.

DUAL USE COMMERCIALIZATION: A successful development of a waste disposal/waste management system will have a multitude of commercial applications in addition to AF operations. Similar composites, although without the radar absorbing qualities, are used in commercial aircraft construction, sporting goods including golf clubs, surf boards, bicycle frames, and pressure vessels. Destruction of wastes from the manufacture of these items, as well as disposing of these products at the end of their useful life could be accomplished using this disposal system. Depending on the characteristics of the waste disposal system developed, a broad range of solid wastes could be destroyed, including the entire organic fraction (over 80 percent of the waste stream) of municipal solid waste.

REFERENCES: 1. Solid waste, US EPA Website, http://www.epa.gov/municipal/facts.htm

2. MAS 603 Military Aircraft Development, http://faculty.erau.edu/ericksol/courses/ms603/military

3. Land Disposal restrictions: summary of requirements, http://www.epa.gov/epaoswer/hazwastes.sum.pdf

KEYWORDS: waste disposal, waste management, composites

AF04-137 TITLE: Reusable Internal Mandrels For Composites Repair or Fabrication

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a reusable compound-curved/complex-shape internal mandrel with the ability to rapidly create a precisely dimensioned component.

DESCRIPTION: Internal mandrels for compound-curved repair or fabrication can be very expensive to develop, produce, and remove from a cured component such as ducting. Removal of the mandrel is often a tedious or slow process and exposes the cured part to handling damage, especially with lightweight, thin-walled sections. The mandrel fabrication is time consuming, and every new part requires its own mandrel. In addition, the materials used for melt-out or breakout mandrels are often employed once and then thrown away, requiring disposal as hazardous or noxious waste materials.

Innovative internal mandrel production and removal technologies are needed that will significantly speed up and reduce the costs of developing, producing and removing internal mandrels from cured composite components. Preferred tooling technologies would incorporate, in a single system, a rapid, low cost method for producing hard mandrels from existing parts or patterns, and an equally rapid method for extracting the mandrel from the finished composite part, which removes the need for dedicated molds to produce the mandrels. A preferred mandrel material would not only be rapidly shaped and hardened but would also be reusable without requiring extensive reprocessing.

Requirements for a mandrel forming and removal system include the following: 1) imprint an existing component or master, 2) rapidly create a precisely dimensioned, compound-curved/complex-shape internal mandrel, 3) compatible with autoclave cure cycles of up to 100 PSI and 375 °F, 4) be easily extracted from the cured part, and 5) rapidly reconstitute the mandrel material for the next production or repair cycle.

PHASE I: Identify candidate materials and demonstrate the feasibility of the selected concept for reusable tooling. The contractor demonstration may be at a laboratory scale but should demonstrate properties that are comparable to existing mandrel concepts.

PHASE II: Develop, demonstrate and deliver a prototype tooling system which creates a dimensionally accurate, autoclave-tolerant, rapidly removable, reusable or reusable-material mandrel with minimum dimensions of 48 inches in length, 12 inch minimum diameter, and incorporating at least two out-of-plane bends of 45 degrees or more.

DUAL USE COMMERCIALIZATION: The Air Force has a variety of aircraft applications where a successfully developed mandrel concept could be used, including ducting, stiffeners and wings. The Navy and Army have similar applications and also have applications in shipbuilding and rotorcraft. Commercial applications include recreational sporting industry, commercial aircraft and ship building.

REFERENCES: 1. Lombardi, J.L. et al., "A Water Soluble Mandrel Material for Fabricating Complex Polymer Composite Components," Proceedings of the 46th International SAMPE Symposium/Exhibition, The Society for the Advancement of Material and Process Engineering, Covine, CA, May 2001.

2. Crowley, T.J., "Innovative, Water Wash-Out, Trapped Mandrel System for Composites," Proceedings of the 32nd International SAMPE Technical Conference, The Society for the Advancement of Material and Process Engineering, Covine, CA, November 2000.

3. Jacobson, T., Crowley, J., Stratton, R, and Clements, L., "Characterization of Low-Cost Reformable Multiuse Tooling System for Composite Repair Applications," Proceedings of the 47th International SAMPE Symposium/Exhibition, The Society for the Advancement of Material and Process Engineering, Covine, CA, May 2002.

KEYWORDS: composites, processing, mandrel, fabrication

AF04-138 TITLE: Improved Processes for Joining of Polyetheretherketone (PEEK) Thermoplastic Components

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop environmentally friendly concepts and processing procedures for structural joining of PEEK components.

DESCRIPTION: While advanced thermoplastic materials have been placed on advanced fighter aircraft from the F-117 to the F/A-22, methods for performing bonded repairs fabricated with these materials have been limited. The problem is especially acute for parts fabricated from PEEK, which does not lend itself to a bonded-patch repair. Currently approved adhesives and surface preparation methods have provided inadequate adhesive strengths and have driven the repair procedure to bolted patches. Bolted repairs are not feasible for repairing some damaged areas of these panels, and could result in having to replace an entire component.

Innovative approaches that will significantly improve the bonding process to PEEK, and reduce program costs for aircraft repair and existing aircraft part fabrication, are sought. Ideally this process improvement will consider environmentally friendly surface treatments, selection of repair materials (adhesive and patch) and on-aircraft curing on curved surfaces. The program goal is a method to prepare these surfaces and bond with existing adhesive materials, or development of an alternate adhesive material (for a 250 - 275 °F bond temperature), although other materials and processes may be considered. The process improvement must be cost effective and not require excessive capital equipment or labor. Any materials must be compatible with the military aircraft environment.

The preferred method of repair will be one that not only returns adequate strength and durability, but also maintains the aircraft's outer mold line characteristics. Unfortunately, PEEK (a thermoplastic) does not lend itself to traditional surface preparation concepts employed for bonding of thermosets (e.g. surface abrading). It requires techniques (e.g. corona discharge, plasma treatments, acid etches, oxidizing flame treatments) that either rely upon the use of hazardous chemicals, are not readily adaptable to on-aircraft repair, are limited to relatively small areas, or require a significant investment in capital equipment.

Processing procedures for structural joining is not limited though to only the consideration of surface preparation techniques, but could include the evaluation of concepts such as welding, resistance heating, or fusion bonding of thermoplastics for example. The processing procedures should be able to be performed, without removing the part from the aircraft (i.e. on-aircraft repair), at the depot-level but ideally at the field-level as well.

PHASE I: Identify candidate processes and demonstrate procedures to achieve mechanical and physical properties. The contractor shall demonstrate, at a laboratory scale, properties that are comparable to existing materials and adhesives. Issues to consider include cure time, service temperature, repair environment, and power requirements.

PHASE II: 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.

DUAL USE COMMERCIALIZATION: The Air Force has a variety of aircraft applications that a successfully developed material would find use in. Commercial applications include recreational sporting industry.

REFERENCES:

1. Wu, Szu-I Y.; Schuler, A.M.; and Keane, D.V.; "Adhesive Bonding of Thermoplastic Composites, 1. The Effect of Surface Treatment on Adhesive Bonding", 19th International SAMPE Technical Conference, pg. 277-290, October 13-15, 1987.

2. Silverman, E.M. and Griese, R.A., "Joining Methods for Graphite/PEEK Thermoplastic Composites", SAMPE Journal, Vol. 25, No. 5, pg 34-38, September/October 1989.

3. Kodokian, G.K.A. and Kinloch, A.J., "Surface Pretreatment and Adhesion of Thermoplastic Fibre-Composites", Journal of Materials Science Letters 7, pg. 625-627, 1988.

4. Holmes, S.T.; McKnight, S.H.; and Gillespie Jr., J.W.; "Scaling Issues in Resistance Welded Thermoplastic Composite Joints, CCM 93-39, Center for Composite Materials, University of Delaware, 1993.

5. Don, R.C.; Gillespie Jr., J.W.; and McKnight, S.H.; "Bonding Techniques for High-Performance Thermoplastic Compositions", U.S. Patent No. 5643390, issued July 1, 1997.

KEYWORDS: composites, thermoplastics, surface preparation

AF04-139 TITLE: Fatigue Life Enhancement of Fastener Holes Manufactured from High-Strength Aluminum Alloys

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop an understanding and demonstrate fatigue life enhancement techniques (for example, cold working holes) that will eliminate fastener hole cracking and improve fatigue life of high-strength aluminum alloys.

DESCRIPTION: Current high strength aluminum alloys (7050, 2297 Al-Li) have a tendency to crack when traditional life enhancement techniques (split sleeve cold working) are performed. Sensitivity to fastener hole life extension techniques (cold hole expansion) has been shown to cause cracking in the short transverse grain orientation. A program to evaluate new and existing techniques, limits and the practical use for fatigue enhancement of mechanically fastened joints is required.

PHASE I: Select and demonstrate the feasibility of new and existing fastener hole technologies specifically in the area of cold working holes. These technologies shall be aimed at eliminating the cracking of holes in the short transverse grain orientation and to improve the fatigue life of mechanically fastened joints involving advance high-strength aluminum alloys. Data generated in Phase I shall provide sufficient information to support a viable Phase II effort.

PHASE II: Fully develop and test the most viable fastener hole technique demonstrated in Phase I. Phase II testing shall consist of mechanically fastened joints or elements that are representative of actual AF aircraft components and shall document the improvements of the most promising technique. Testing shall be conducted to evaluate the practicality, joint effectiveness, and degree of fatigue life enhancement. In addition, the viable technique must also be rated for cost effectiveness.

DUAL USE COMMERCIALIZATION: After a viable technique has been identified, the technology would have broad impacts. The aerospace industry relies heavily on high-strength aluminum alloys, especially ones that are lighter than traditional alloys. This would not only give aircraft manufacturers a new design alternative but could also impact materials insertion for DoD's aging fleet.

REFERENCES: 1. R.J. Burt and S.E. Minarecioglu, Finite Element Analysis of Stresses Surrounding Cold Expanded Holes in Aluminum-Lithium Plate, presented at the 2002 USAF Aircraft Structural Integrity Program Conference, December 2002.

KEYWORDS: fastener hole techniques, cold-worked holes, fatigue life enhancement, high-strength aluminum alloys

AF04-140 TITLE: Enabling Materials Processing Technology for Low-Cost Fabrication of Integral Bladed Rotors (IBR)

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Explore and demonstrate innovative materials and manufacturing technologies that enable affordable fabrication of IBRs for advanced gas turbine engines.

DESCRIPTION: Alloys of titanium and nickel base superalloys have long been used as compressor disk and blade materials for both small and large gas turbine engines. The more advanced engines use IBRs throughout the compression section to reduce weight and improve performance. However, integral blade-to-disk designs inherently limit the ability of conventional manufacturing processes to affordably produce IBRs: thus the costs for this type of components have remained high. Therefore more cost-effective innovative manufacturing methods must be developed to significantly reduce the cost of this type of component. This dual use technology project should demonstrate the capability to produce fine-grained materials to enable manufacturing of IBRs at 35-50 percent below current production costs. This project should address the metallurgical challenges associated with affordably producing fine grained materials and their application to minimize the largest drivers of IBR manufacturing costs - raw material consumption, rough machining and final machining. Emerging materials and manufacturing processes have shown the capability to produce fine-grained superalloys that enable IBRs to be produced well below current cost levels while gaining improvements in inspectability. However, to warrant industry support and investment, these processes and their application to IBRs must be further developed. In addition, rigorous economic analysis must be conducted to address both the technical and business issues associated with implementation and qualification. Proposals for laser additive manufacturing processes are not sought at this time.

PHASE I: Demonstrate the engineering, manufacturing, and economic feasibility of emerging processes to fabricate fine-grained IBRs from titanium or nickel based superalloys by specifically targeting the high-cost elements of current manufacturing methods. The feasibility to economically produce materials conditioned for subsequent near net shape forging is to be demonstrated. Upon successful conditioning, material samples shall be processed at representative deformation parameters for forging IBRs, heat treated, and microstructurally characterized. Temperature and flow stress improvements shall be quantified to assess the capability to forge full-scale, very near-net shape geometries. Additionally, a detailed process assessment shall be made to document the potential of fine-grained, near-net shape forgings to minimize the cost of rough and final IBR machining operations. An economic model of the process shall be constructed to quantify the potential savings and the cost drivers and their respective influence on overall process economics. An initial commercialization plan shall be developed and a business case established to quantify future investments, including equipment changeover and qualification expenses.

PHASE II: Demonstrate full scale manufacturing processes to produce low cost IBRs with net or near net shape blades using innovative metalworking and machining methods. Tooling and processes to produce full-scale prototype preforms and final forgings will be fabricated to demonstrate process reproducibility under relevant production conditions. Techniques eliminating or minimizing rough and final machining requirements shall be demonstrated and cost reductions validated. Methods for cost-effectively generating finished airfoils shall be assessed for compatibility with near-net forged IBRs. Full-scale forgings shall be produced, heat treated using low distortion techniques, and evaluated using conventional nondestructive inspection, dimensional inspection, and microstructural analysis methods to demonstrate acceptable material quality and metallurgical characteristics. Material property testing shall be conducted to obtain engineering data per standardized testing techniques to document material acceptability for future industrial use. The cost savings potential of the demonstrated processes shall be validated. Finalized commercialization plans and qualification requirements shall be established to offer low-cost IBR manufacturing processes to the aerospace industry for production transition and qualification in Phase III.

DUAL USE COMMERCIALIZATION: The developed technology will have applications for both military and commercial gas turbine engines.

REFERENCES: 1. Younossi, O. et al., "Military Jet Engine Acquisition," p. 29-30, ISBN 0-8330-3282-8.

KEYWORDS: intregrally bladed rotors, blisks, materials processing, fabrication

AF04-141 TITLE: Damage Identification Algorithms for Composite Structures

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop an innovative damage identification algorithm and verify through a low-cost, reliable actuating/sensing structural health monitoring (SHM) system with interpretation algorithms for composite structures.

DESCRIPTION: The integrity of in-service composite structures needs to be inspected to determine their physical condition throughout their lifetime. Such inspection will be crucial for the future aircrafts due to the increased use of composites which will be expected to perform near their limit conditions. To respond to any structural anomaly as a result of impact loads and environmental stresses, associated damages should be detected, identified, quantified, and, if possible, continuously monitored. The damage, such as delamination and matrix cracks, can be extensive, yet hidden. Consequently, accurate detection, identification, quantification, and monitoring of internal damage are of major concern in the operational environment. Therefore, acquiring knowledge into the nature, extent, and distribution of damage and degradation in a structure while in service using SHM systems is critical to develop subsequent timely strategies to retard deterioration and enhance the air safety.

Innovative and commercially viable concepts are being solicited for the development of structural health monitoring for signal processing and data interpretation to establish quantitative characterization of damages occurred in composite structures. The proposed damage identification algorithms should have capability to identify, quantify, and monitor damage of various forms. The proposed approach should go beyond a simple monitoring system that merely detects the presence of damage without identifying its importance of the safety of the airframe structure.

PHASE I: Develop an accurate and efficient damage identification methodology for detecting, locating, and quantifying the damages in fiber-reinforced composite laminates. The methodology is expected to recognize the size, forms of the failure modes such as matrix cracks, delamination, etc. The methodology also would have the capability of identifying the multiple damages.

PHASE II: Validate the methodology by integrating composite structural systems with sensors and actuators through experiments. The sensors and actuators may include piezoelectrics, fiber optics, acoustic emission sensors, etc. The enhancement of damage image resolution through different excitation signals and filtering techniques should be addressed in the simulation and experimental results. Optimal placement of sensors and actuators by using techniques such as optimization techniques or genetic algorithms should be developed and verified. A beta version of the damage identification software with user-friendly interfaces should be delivered to the Air Force. The product must be insertable into an Air Force system program with a minimum of effort, preferably within 2 years following the completion of the Phase II program.

DUAL USE COMMERCIALIZATION: Use of composite materials in civil and spacecraft will require an accurate and fast assessment of damages under the conditions to be experienced during service. The system developed could be used in any DoD platform, since they all have critical structural components that require health monitoring. Significant cost savings could be achieved by using a wide-area inspection system of this nature since real-time health monitoring would decrease inspection costs by reducing unnecessary inspections and tear-downs for inspection.

REFERENCES: 1. The First and Second International Workshop on Structural Health Monitoring, Stanford University, 1997 and 1999.

KEYWORDS: composite structures, structural health monitoring, matrix cracks and delamination, multiple damages, damage identification algorithms.

AF04-142 TITLE: Robust Bearings and Gears

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Develop and produce surface treatments and materials for bearings and/or gears capable of exceeding the current physical limitations of material systems and design architectures of jet engines.

DESCRIPTION: Anticipated bearing and gear materials for use in complex jet engine nozzle and lift/vectoring components are not expected to meet desired service life and strength requirements. The application requires stable material performance at high contact loads, temperatures as high as 350 °C, and in the presence of corrosive environments. Typical ball bearing materials (e.g., M50) provide the required strength but will suffer from corrosive degradation and fatigue, while high performance stainless steel alloys (e.g. Pyrowear 675) provide corrosion resistance and fracture toughness but suffer from low yield strength. Anticipated gear materials need surface corrosion protection (e.g. Pyrowear 53 and AMS 6265) or surface strengthening (e.g. Pyrowear 675). All will benefit from surface modifications to reduce high temperature wear and friction. Technologies are sought to provide bearing/gear performance that has the corrosion resistance and can withstand the high temperature environments.

These technologies may include, but are not limited to, enhanced mechanical performance of corrosion-resistant steels through alternative material selection, surface strengthening, and application of high-temperature solid lubricants with lifetime endurance. The program should address both cost and weight considerations of the material system. Project coordination with jet engine manufacturer is recommended.

PHASE I: Demonstrate the feasibility of developing more robust materials, surface strengthening techniques, wear and friction reducing treatments for bearings and/or gears for use in mechanical systems of jet engines such as the three bearing swivel duct and the lift fan. Develop prototype bearings and/or gears with the use of advanced materials and treatments and demonstrate the performance improvements.

PHASE II: Develop a technological process for new gear/bearing material or surface modification and a procedure for testing the prototype bearings and/or gears for predetermined endurance limits. Assess the benefits of using these bearings and/or gears and cost savings associated with the improvements.

PHASE III Dual Use Applications: These robust bearing and/or gears could have numerous mechanical applications for both military and commercial applications. These developments could be employed in almost any mechanical system where fatigue results from wear.

REFERENCES:
M. Johnson, J. Laritz, and M. Rhoads, "Thin Dense Chrome Bearing Insertion Program; Pyrowear 675 and Cronidur Wear Testing," Report No. R98AEB240; AFRL-PR-WP-TR-1998- 2110 (ADA361451).

M. G. H. Wells, J. C. Beck, R. M. Middleton 4, P. J. Huang, and D. E. Wert, "Rolling contact fatigue behaviour of Pyrowear 675," Surface Engineering 15 (1999) pp. 321-323.

C. E. Campbell and G. B. Olson, "Systems design of high performance stainless steels I. Conceptual and computational design," Journal of Computer-Aided Materials Design, 7 (2001) pp. 145-170.

KEYWORDS: bearing, gears, jet engines, high temperature wear, fatigue failure, surface strengthening, high-temperature solid lubricants.

AF04-143 TITLE: Shape Recovery Polymer Nanocomposites (PNCs)

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop polymer nanocomposites (PNCs) that exhibit enhanced shape recovery performance as well as enabling actuation by triggers other than external heating.

DESCRIPTION: Shape memory (recovery) refers to the ability of a material to reversibly recover inelastic strain [1]. Metallic shape-memory alloys are the classic archetype. They undergo a phase transformation (in this instance martensitic) upon deformation below a critical temperature that locks-in the deformation. Raising the temperature alters the morphology, allowing the material to recover its original shape. Shape memory polymers (SMP) exhibit the same physical phenomenon, however are lighter weight, exhibit larger recovery strains, are lower cost, and are easily processed into complex shapes by injection molding. Potential applications not only exploit the magnitude of force exerted by the SMP upon recovery but also the ability to reversibly access the dissimilar properties above and below the transition temperature, such as moisture permeability, thermal expansivity, damping ratio and index of refraction. PNCs are typified by the addition of low volume fractions (1 to 5 percent) of highly anisotropic nanoparticles, such as layered silicates or carbon nanotubes, which provide property enhancements with respect to the neat resin that are comparable to that achieved by conventional loadings (15 to 40 percent) of traditional fillers [2]. The lower loadings facilitate processing and reduce component weight. In addition, unique value-added properties not normally possible with traditional fillers are also observed, such as reduced permeability, tailored biodegradability, optical clarity, self-passivation, and flammability, oxidation and ablation resistance. The combination of these two concepts (shape recovery polymers and nanocomposites) is anticipated to enhance shape recovery performance as well as provide unique mechanisms to trigger actuation beyond direct external thermal heating [3].

PHASE I: Evaluate current shape recovery polymers to identify base-line capabilities. Fabricate promising polymer nanocomposites and evaluate shape recovery performance, including efficiency of energy recovery, extent of strain recovery, energy budget (power) necessary for actuation, temperature range of operation, and reproducibility upon deformation cycling. In addition, demonstrate novel mechanisms to trigger actuation, such as electrical or optical stimuli.

PHASE II: Further develop the proposed material system, focusing on the optimization with regard to necessary energy budget of the novel trigger mechanisms. Develop the manufacturing processes/methods to produce the material in various forms (foam, monolith, film, fiber). Demonstrate the capability of the selected material to deploy a structural unit. A small quantity of the material will be produced and tested at the end of the Phase II effort.

DUAL USE COMMERCIALIZATION: Shape recovery polymers are utilized broadly. Current commercial concepts include such diverse applications as dolls hair that can be styled and reset, intravenous needles that soften in the body, temperature dependent moisture-permeable fabrics, rewritable digital storage media, and self-deployable structures.

REFERENCES: 1. Monkman, G.J., "Advances in Shape Memory Polymer Actuation," Mechatronics, 10 (2000) 489-498.

2. Pinnavaia, T.J. and Beall G.W., eds. Polymer-Clay Nanocomposites, Wiley, New York (2001).

3. Koerner, H.; Wang, C-S; Vaia, R.A.; Alexander, M.D.; Pearce, N.; and Bentley, H., "Stimuli-Responsive Nanocomposites: New Opportunities For Aerospace," in Proceedings of Additives '03, San Francisco, CA, April 7-9, 2003.

KEYWORDS: nanocomposite, shape recovery, shape memory, smart material, remote actuation

AF04-145 TITLE: Biologically Inspired Luminescent Technology

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop luminescent materials technology for lightweight, low-cost, environmentally friendly military and commercial applications.

DESCRIPTION: The Air Force is constantly looking for ways to reduce the power requirements and reduce the cost for its systems and subsystems and, at the same time, reduce their environmental impact. This applies to systems across the board, from stealth aircraft to electronics rework facilities, from maintenance on the flight line to search and rescue (SAR). Chemical glowsticks and battery-powered infrared strobes are used to mark landing zones. Glowsticks leave behind plastic evidence. IR strobes leave behind the evidence of the strobe, the battery, and add to the weight carried by Air Force personnel. Inspiration for an environmentally friendly, novel approach to tagging and marking used in SAR that doesn't require a power supply or batteries can be found in biology. A firefly, or lightning bug, is a self-powered luminescent system that is inherently lightweight and environmentally friendly. The lightning bug's bioluminescence comes from a chemical reaction. Bioluminescent reactions require a minimum of three components: 1) the enzyme, luciferase, 2) the bioluminescent substrate, luciferin, and 3) oxygen. The energy required for light production comes from the oxidation of the luciferin usually through a cyclic oxygen dioxetan or dioxetanone intermediate. Luciferin and luciferase are generic terms and refer to a number of distinctly different enzymes and five different families of substrates, respectively, found in, for example, marine organisms, beetles and earthworms. The wavelength of the emitted light is different for the different natural luciferase/luciferin combinations and can be shifted by either preparing luciferase mutants or by synthetically modifying the luciferin.

PHASE I: Design and demonstrate the feasibility of a luciferin/luciferase bioluminescent materials system for use in marking, tagging, and anti-tamper applications. The proposed materials system must be able to be incorporated into biodegradable landing zone markers, anti-tamper systems, perimeter security systems, friend versus foe marking systems, etc. The bioluminescent materials system shall only emit after proper activation and not spontaneously. Phase I shall include or incorporate by reference data showing the biodegradation qualities of the materials system.

PHASE II: Incorporate the bioluminescent materials system into at least two marking, tagging, or anti-tamper systems. The offeror shall demonstrate variations of these systems with bioluminescent materials systems designed to emit at least two significantly different wavelengths. The offeror shall demonstrate and test the performance and utility of the materials systems to include, but not limited to, factors to quantify the luminescent and biodegradable qualities of the systems. The deliverables from Phase II should include demonstration quantities of each materials system, the performance and test data, and the final report.

DUAL USE COMMERCIALIZATION: Successful development of the biodegradable bioluminescence technology has many applications in the commercial world. Bioluminescent markers can be used in applications as diverse as emergency lighting and party favors. Bioluminescent coatings can also be used in anti-tamper and other security-related applications.

REFERENCES: 1. DeLuca, M., "Firefly luciferase," Adv. Enzymol. 44 (1976) pp. 37-68.

2. Wood, K. V., "The chemical mechanism and evolutionary development of beetle bioluminescence," Photochem. Photobiol. 62 (1995) pp. 662-673.

3. Hastings, J. W., "Bioluminescence," Cell Physiology Source Book, Sperelakis, N., Ed., Academic Press, New York (1995) pp. 665-681.

4. B. Branchini, "Chemical Synthesis of Firefly Luciferin Analogs and Inhibitors," Methods Enzymol., Vol. 305, Part C, M. M. Ziegler and T. O. Baldwin, Academic Press, San Diego, CA, (2000) pp. 188-195.

5. B. R. Branchini, M. H. Murtiashaw, R. A. Magyar, N. C. Portier, M. C. Ruggiero, and J. G. Stroh, "Yellow-Green and Red Firefly Bioluminescence from 5,5-Dimethyloxyluciferin," Journal of the American Chemical Society, Vol. 125 (10), (2002) pp. 2112-2113.

KEYWORDS: luciferin, luciferase, biological, tagging, marking, luminescence, bioluminescence

AF04-146 TITLE: <u>Biologically Inspired Thermal Detector Technology</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop biologically derived or biologically inspired thermal detection technology for lightweight, low-cost, environmentally friendly military and commercial applications.

DESCRIPTION: Current uncooled thermal/infrared (IR) detectors and imaging systems are extremely expensive, rigid, hard to produce at high yield, and require exotic materials and processes for fabrication. The Air Force is interested in looking to nature for materials and/or designs that can be incorporated into existing thermal detection/imaging systems to enhance performance or that can enable new tactics and platform concepts. Nature has many examples of how biological organisms such as snakes (pythons and pit vipers), beetles (Melanophila), and bacteria, can sense IR and/or thermal radiation. This sensing process is of interest to the Air Force because of the high sensitivity these systems possess and the fact they do this without the need for cryogenics. From a materials perspective, we are interested in how organic materials are accomplishing the same task sensor designers accomplish with inorganic composites. Biological systems use either functional material systems of different mechanical architectures or molecular structures to facilitate the thermal sensing. The biological systems then use chemical signals to perform cellular functions or trigger nervous systems responses. Using techniques including biochemical, microscopy, and molecular biology, one can characterize the unique biological material systems that allow infrared sensing to occur. The Air Force is interested in characterizing, synthesizing, and fabricating these material systems using various techniques to duplicate biological thermal sensing in a synthetic system producing a signal for processing in detection and imaging devices.

There are a number of potential users and benefactors of this technology. Thermal detection and imaging has many applications in the military as well as commercial world. Civilian applications include thermal imagers for fire, police, and rescue. Other military applications include affordable thermal detection and imaging for individual soldiers, UAVs, and unmanned ground vehicles (UGVs).

Potential operational concepts include the following:
o Integrated with gear for thermal detection/warning
o Integrated with high bandwidth imaging to focus high bandwidth using thermal cues and low bandwidth for the rest of the scene
o Integrated into conformal sensor to aid IV insertion
o Thermal imaging to aid interrogation of people of interest
o Low cost, uncooled sensor for unmanned combat aerial vehicles (UCAVs) and UGVs
o Distributed network around the periphery of the airframe to provide global thermal threat awareness
o Low cost, disposable thermal sensors for distributed network

PHASE I: Design and demonstrate the feasibility of a biologically inspired or biologically derived thermally sensitive material system for use in low-cost detection or imaging applications. The proposed materials system must be able to be incorporated into lightweight, room temperature sensors. Phase I shall include or incorporate by reference data showing the environmental robustness qualities of the materials system.

PHASE II: Incorporate the thermally sensitive materials system into at least two thermal detection or imaging systems. The offeror shall demonstrate and test the performance and utility of the materials systems to include, but not limited to, factors to quantify the thermal sensitivity, stability, and processing repeatability qualities of the materials system. The deliverables from Phase II should include demonstration quantities of the materials system, the performance and test data, and the final report.

DUAL USE COMMERCIALIZATION: Successful development of a bio-inspired thermal detection technology has virtually limitless applications in the military and commercial marketplace. Law enforcement, medical imaging, security, recreational, and automotive applications are too numerous to mention.

REFERENCES: 1. Rajesh R. Naik, Sean M. Kirkpatrick, and Morley O. Stone, "The thermostability of an alpha-helical coiled coil protein and its potential use in sensor application," Biosensors & Bioelectronics 16 (2001) 1051-1057.

2. Ugo Mayor, Nicholas R. Guydosh, Christopher M. Johnson, J. Gunter Grossmann, Satoshi Sato, Gouri S. Jas, Stefan M. V. Freund, Darwin O. V. Alonso, Valerie Daggett, and Alan R. Fersht, "The complete folding pathway of a protein from nanoseconds to microseconds," Nature Vol. 421, 20 February 2003, 863-867.

3. Brandon R. Brown, "Sensing temperature without ion channels," Nature Vol. 421, 30 January 2003 495.

KEYWORDS: thermal detection, thermal imaging, biological, bio-inspired, bio-derived

AF04-147 TITLE: Active Calorimetry Development for Testing of Active Thermal Control Coatings and Devices

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop the necessary calorimetry hardware and devices necessary for testing of active spacecraft thermal control materials and systems in the space environment.

DESCRIPTION: Active thermal control materials and coatings (both variable emittance and absorptance devices) are advantageous as they allow for real-time thermal management of spacecraft/satellites while in space. In-service lifetimes can be improved by 3 to 5 times those of current state-of-the-art passive thermal control coatings. In addition, active materials will allow for the use lighter weight and higher power vehicles to be implemented.

Currently there are several developmental programs for active thermal control materials both within the Air Force and in industry. However, prior to Air Force and aerospace industrial acceptance and usage on space hardware, these material systems will need to be verified actively in the space environment. This includes both on the ground (simulated) and on actual space flight experimental testing. Explicitly, the most successful coatings/devices proven in ground/simulated testing will not be allowed to be put onto military space hardware until it is also demonstrated that they survive in the actual space environment.

Presently, there are no calorimeters available that are capable of testing the various thermal control materials currently under development or used in space now. While there have been calorimeters developed previously for space applications, those calormeters have been very heavy, have high power consumption requirements, and are extremely complex with multiple layers of electronics and tens of thousands of readout channels that make them inappropriate for testing of active thermal control materials.

This effort consists of designing and building the electronic calorimeter hardware needed to conduct the qualification tests in space of the newly developed thermal control material systems. The new calorimeter to be delivered at the end of the Phase II effort must be simple to use, lightweight, and able to perform in both the low earth and geosynchronous orbits. It must send real-time data back to earth on the performance of the materials being tested. It must be responsive and immediately adjustable to the dynamic changes in the space environment. This entails accurately testing the voltage pulse required to accomplish active thermal control, as well as surface temperatures, etc., and accurately recording this data.

PHASE I: Demonstrate the proof of concept and feasibility of a new active calorimeter for use in space. The new calorimeter design will be simple to use, lightweight, and be able to perform in both the low earth orbit and geosynchronous orbits. It will provide real-time data back to earth on the performance of the active thermal control materials being tested.

PHASE II: The calorimeter proposed in the Phase I will be built, tested with active thermal control systems in a simulated space environment, and a prototype delivered. The end product of the Phase II will consist of the actual hardware of the calorimeter that is ready for testing active thermal control devices on an actual space flight experiment/mission. It must be responsive, and immediately adjustable to the dynamic changes that occur in the space environment. This entails accurately testing the voltage pulse required to accomplish active thermal control, as well as surface temperatures, etc., and accurately recording this data.

DUAL USE COMMERCIALIZATION: The fully developed active calorimeter will be actively testing thermal control coating materials and devices on an actual space flight experiment, and will be providing actual, real-time data on the performance of these materials back to earth. This system will be applicable for testing materials that will be used both by military, as well as commercial space satellite, vehicles, and platforms ranging from the low earth to the geosynchronous orbits.

REFERENCES: 1. Karem, Robert D., "Satellite Thermal Control for Systems Engineers," Progress in Astronautics and Aeronautics, Vol. 181, published by the American Institute of Aeronautics and Astronautics, Inc. 1998.

2. Brunetti, M.T., Codino, A., Federico, C., Giacomucci A., Grimani, C., Menichelli, M., Minelli, G., Miozza, M., Salvatori, I., and De Bortoli, L., "Readout Architecture of a Highly Segmented Silicon Calorimeter Operating in Space," IEEE Transactions on Nuclear Science, Vol. 41, No. 4, August 1994, pp. 1714-20.

KEYWORDS: active calorimeters, calorimeters in space environment, calorimetric measurement, active thermal control, thermal control coatings

AF04-149 TITLE: Microelectromechanical Systems (MEMS) for Vehicle Health Monitoring

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Development of a wireless vehicle health monitoring system, using presently available MEMS or related technology to enable minimization of system size.

DESCRIPTION: Wireless sensors/MEMS technology presents a new opportunity for vehicle health monitoring without need for wire or optical interconnects. Such systems would not be vulnerable to some of the major traditional concerns of vehicle health monitoring, for example, how the degradation of one unit or one wire or interconnect, or battle-damaged or environmentally degraded regions thereof, may affect the entire health monitoring system. The concerns regarding repair of embedded wiring or optical interconnects are also eliminated. Wireless sensors/MEMS have been successfully applied to measure the response characteristics of composites under environmental and mechanical loading conditions. Although the technology exists in different forms, there is a need of concerted effort to bring it into routine use. Further, the inherent characteristics of composites lend themselves to the use of MEMS and present an opportunity for attractive dividends on further work in this field, thereby enhancing the utility and applicability of composites.

PHASE I: Develop and demonstrate a wireless system using MEMS or miniature sensors for measuring response, failure initiation, and crack propagation in composites, coupled with miniaturized transmission and remote recording capability. The phase I program should develop a circuit technology that can be produced as an integrated circuit chip in phase II. The system should permit interrogation of the damage sensors once an equipped aircraft has completed its mission, via inductive coupling. No on-board power source should be required. The interrogating, or "read," coil should be capable of reading signals from the transmitting antenna of the damage sensor at a minimum distance of 6 inches; the 6 inches must include a 1 inch thick composite plate covered with an Air Force compatible paint system. The crack location(s) can be detected using crack propagation strain gage technology for sensing potential multiple circuit breaks on a single strip. (See e.g. reference 4.) The signal transmission/reception characteristics of the phase I system should be demonstrated on an F-22 aircraft or a substitute aircraft acceptable to the F-22 System Program Office. The demonstration should simulate the inductively-coupled remote detection of a crack. An example potential detection system candidate could be based on existing RFID tag (RFID chip, antenna and connector) technology for multiple open/closed circuit remote inductively-coupled detection (see e.g. reference 3).

PHASE II: A working prototype system will be developed and demonstrated in simulated service environments during the Phase II effort. In-service vibrational, temperature and humidity environments will be simulated during testing. The product or products will be applicable for retrofits of existing aircraft systems, as well as for incorporation into new systems. The ideal product would limit processing circuitry to approximately 1 square inch (excluding antenna and potential external capacitors), with the processing circuitry mounted directly to a 12-18 inch crack detection strip capable of sensing multiple open (strain/crack) circuits per inch. The Phase II program is expected to produce a product or products which can be transitioned to an Air Force system development program within 2 years following Phase II completion. Composite material systems are the primary target for the technology, but additional applicability to non-composite systems is encouraged. If further work is supported by system program offices, a Phase II Enhancement Program may be considered.

DUAL USE COMMERCIALIZATION: A further application for this technology is the remote sensing of strains and/or damage in test articles, which can then be transmitted to a remote data acquisition system. This strategy eliminates many complicated and cumbersome wire connects, which are prone to failures and require substantial effort to strand effectively so as to permit viewing of the test article and avoid fixture and part obstacles.

REFERENCES: 1. Krantz, Donald G., Belk, John H., Biermann, Paul J., Troyk, Philip R., "Project summary: applied research on remotely queried embedded microsensors." Smart Structures and Materials 2000: Smart Electronics and MEMS, Proc. SPIE Vol. 3990, Vijay K. Varadan, Ed. June 2000, pp. 110-121.

2. Walsh, Shawn M., Butler, John C., Belk, John H., Lawler, Robert A., "Development of a structurally compatible sensor element." Advanced Nondestructive Evaluation for Structural and Biological Health Monitoring, Proc. SPIE Vol. 4335, Tribikram Kundu; Ed., July 2001, pp. 63-73.

3. Remotely Interrogatable Apparatus and Method for Detecting Defects in Structural Members, U.S. Patent 5,969,260.

4.http://www.vishay.com/company/brands/measurements-group/guide/500/lists/cpg_list.htm

KEYWORDS: MEMs, miniature, sensor, transmit, receive, damage, composite

AF04-151 TITLE: In-Flight Protective Transparency, and Personnel Armor

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Enhance personnel/aircraft survivability in hostile environments through advanced ballistic protection, aircraft windscreen transparencies, and advanced personnel armor protection materials.

DESCRIPTION: Improved protection of aircraft windscreens from hostile environments and ballistic threats offers operational forces the potential for enhanced survivability in low flying environments. Advanced materials, such as aluminum oxynitride transparencies, provide significantly reduced weight; greater resistance to birdstrikes, runway debris, crazing, hard particle scratching, rain erosion (no damage at 650 mph), and ballistic penetration; and lower cost, higher durability alternatives for the protection of sensors for navigation and targeting equipment. Coatings for this transparent material will also improve anti-reflection performance. With special treatments, the resistance to ballistic penetration by .30 and .50 caliber projectiles, as well as armor-penetrating rounds, for aluminum oxynitride transparencies can be improved significantly over its current capability. This provides the potential not only to reduce windscreen weight, but also offers the opportunity to increase personnel armor protection without weight increase as an insert to standard Kevlar personnel jackets and armor appliqués for in-flight protection. Additional improvements to mission readiness result from an increase in windscreen service life and the reduction in windscreen weight. Low/slow flying aircraft and numerous special-purpose ground combat vehicles that are routinely exposed to a variety of lethal/hostile threats will be better protected through the use of this tremendously improved ballistic transparency.

PHASE I: Develop and optimize improvements to ballistic performance of aluminum oxynitride transparency material and develop other protective surface treatments. Conduct ballistic testing on up to 10 panels to quantify improvements. The major aim of this development is to enable reduction of aereal density by 70 percent over current state-of-the-art transparent armor and by 30 percent over personnel body-armor inserts.

PHASE II: Scale optimized designs to full size windscreen transparencies through process improvements and reduce cost per aereal unit by 20 percent over Phase I costs. Conduct ballistic testing on one full size, or its equivalent, aluminum oxynitride windscreen and ballistically test the standard windscreen material for quantitative comparison. Deliver one full size aluminum oxynitride windscreen for disposition at the convenience of the program manager.

DUAL USE COMMERCIALIZATION: Commercial applications include barcode scanner windows, commercial transparent armor, semiconductor chip processing carriers, and high-intensity lighting envelopes.

REFERENCES: 1. Goldman, L.M., Hartnett, T.M., Wahl, J.M., Ondercin, R.J. and Olson, K.R., "Recent Advances in Aluminum Oxynitride (ALONTM) Optical Ceramic," SPIE Proceedings, Vol. 4375, pp. 71-78 (2001).

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KEYWORDS: ALON, aluminum oxynitride, transparent armor, ceramic powder processing, aircraft windscreens, personnel protection, laser protection

AF04-153 TITLE: Wiring System In-Situ Health Monitoring Diagnostics

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop in situ sensors and associated controlsystems to monitor the health of aircraft wires and wiring systems.

DESCRIPTION: A study on Air Force aircraft mishaps/accidents revealed 5 percent were related to electrical system failures, of which 43 percent were related to the wiring interconnection system, which includes numerous types of connector failures, wiring faults, and circuit breaker failures. The Navy currently expends approximately 1.8 million staff-hours annually troubleshooting and repairing aircraft wiring systems. The objective of this activity is to develop a wiring and wiring connector diagnostics capability suitable for near-real-time on-board sensing of system health to capture system failures as they occur to reduce can not duplicate (CND) or re-test OK" (RTOK) that occur during post-flight or on ground diagnostics. The ability to capture trends in the wiring system such as degradation, increased impedance, data bus anomalies, corrosion in metallic wiring elements, misfit connectors, degraded connector conductivity, wire insulation degradation, and moisture intrusion will enable the growth of a prognostic capability that will give the ability to plan detailed maintenance actions as required as opposed to as scheduled. This wiring health monitoring capability will be designed to retrofit into aging aircraft as well as new system designs.

PHASE I: Review the current wiring systems designs and investigate access to wires, wire harnesses and wiring connectors to optimize placement of diagnostic sensors, sensor control logic and data management networks. Investigate the integration of wiring prognostics and diagnostic sensor systems that can be placed within the present wiring architecture to provide system coverage. Investigate existing and planned system level architectural capabilities/systems with which a wiring health monitoring capability can be integrated. Fabricate hardware and develop software to demonstrate a proof-of-principal prototype incorporating sensors integrated into the wiring for fault detection and fault isolation. Implement a wiring fault reporting system compatible with the chosen aircraft system. The initial demonstration can be a ground-based demonstration.

PHASE II: Demonstrate a wiring health management system integrated with the aircraft diagnostic system on an operational or operational evaluation aircraft. This system shall detect, isolate, and provide distance to fault type data in the wiring harness for a variety of conductor-based faults/anomalies as well as insulation degradation. The system should report the wiring system failure to the upper level diagnostic manager and provide the technician with enough knowledge necessary to make repairs. After the repair, the system should verify and validate that the repair action has restored the performance of the wiring harness.

DUAL USE COMMERCIALIZATION: Transition the system into the fleet of aircraft as an enhancement to present health management systems. The system will also have the ability to be transitioned to the commercial aircraft fleet. Aircraft certification, vehicle safety, and manufacturer liability concerns are major reasons for utilization of this technology. With the continued aging of both commercial and military fleets, wiring problems will continue to grow. The diagnostic tools developed under this SBIR will have widespread use.

REFERENCES: 1. C. Furse and R. Haupt, "Down to the Wire: The Hidden Hazard of Aging Aircraft Wiring," IEEE Spectrum, Feb. 2001, pp. 35-39.

2. G. Smith, J.B. Schroeder, K. Blemel, and R. McMahon, "Prognostics for Wiring: Managing the Health of Aging Wiring Systems," Proc. of the Aging Aircraft Conference, September 1999.

3. G. Smith, J.B. Schroeder, R. McMahon, and R. Beach, "Organized Wiring: 21st Century Aircraft Infrastructure Backbone (in 20th Century Aircraft)" Proc. Of the Aging Aircraft Conference, May 2000.

KEYWORDS: wiring, diagnostics, health management, sensors, nondestructive evaluation

AF04-155 TITLE: Modeling and Simulation for the Accelerated Development of Materials

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop and commercialize simulation and experimental techniques for reducing the time to develop new materials.

DESCRIPTION: The Air Force depends upon the timely development of materials to deliver technically advanced systems. However, materials development is time consuming and evolutionary. Modification and insertion of known materials into systems often spans 7 to 15 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. A challenge for the 21st century is to shorten the materials maturation time and to insert materials earlier into systems. Proposed efforts should focus on one or more of the following needs:

1) The prediction of key parameters that determine the nonlinear optical behavior of optical limiting materials for agile laser eye protection applications. In the condensed phase, first principles calculations of ground and excited states properties, such as reverse saturable (RSA) and two-photon (TPA) absorbing molecules are required. Furthermore, these methods have to be combined with hierarchical simplified models in multiscale simulations, to study the effects of the environment, for example, on the excited state properties of the green fluorescent protein biological chromophore, using mixed classical/quantum mechanical techniques, and large-scale molecular dynamics simulations, while in modeling periodic 1-D nanostructures such as nanotubes, computationally intensive first principle methods have to be applied. Available commercial codes do not address these state-of-the art requirements, for example, for carrying out time-dependent density functional theory calculations for TPA cross-sections predictions, in order to gain a fundamental understanding of structure-to-property relationships, being assessed as potential materials in devices that protect from optical threats. Such simulation tools could significantly accelerate the development of materials for laser protection, to be integrated with a comprehensive experimental program in laser protection, to assist in tackling the very difficult task of developing materials for laser protection that meet specific requirements.

2) Multi-scale integration and visualization of materials modeling and experiments. With many different material systems and at many size scales, our ability to develop models of material behavior has advanced well beyond our ability to efficiently evaluate and calibrate these models. Evaluation and calibration of sophisticated, physics-based models are hampered by the relative paucity of data that is available through traditional test techniques. One approach for efficiently acquiring large amounts of good-quality data is through full-field, two- or three-dimensional (2-D or 3-D) deformation or strain mapping accomplished with machine vision. With these techniques, it is possible to study material behavior under a wide variety of conditions and at a wide variety of spatial scales. It is also possible to efficiently calibrate and evaluate probabilistic models through automated and extensive sampling. Study of both the experimental data acquired through these techniques and modeling results and the successful integration of the two would benefit greatly from advanced visualization techniques.

Phase I of the proposed SBIR should concentrate on developing a system for acquiring full-field, 2-D data for regions of interest (ROI) of 200 mm or greater at room temperature. The physical translation, including focusing, of the acquisition system may be manual in Phase I. Also, correlation with model results and visualization of both experimental data and modeling results may be accomplished post-test in Phase I. Phase II should extend the accomplishments of Phase I to smaller size scales and to higher temperatures. Phase II should also incorporate automated machine-vision techniques for physical translation, including auto-focusing, and enable full communication between the experimental operations and the modeling, including feedback. Further, the modeling, correlation between the model and experiment, and visualization should be in real- or near-real time. The resulting system should be modular in design, enabling easy insertion of a wide variety of material models, including analytical and numerical models, and microstructural characterization of the experimental specimen through image-analysis techniques that would, in turn, be reflected in the material-behavior model.

3) Tools for simulation of unplanned thermal and chemical effects on component parts during heat treatment and, particularly in service, non-ideal conditions can occur in which parts can be exposed to atmospheres containing out-of-specification amounts of impurities or thermal spikes can occur during heating in which the temperature is out-of-specification. This could happen, for example, when an engine fire occurs or an unusual substance is ingested. To assess the air worthiness of parts subjected to these out-of-specification conditions, their effects must be estimated. Insofar as the microstructure is concerned in component parts, structures can be altered either through the appearance of an additional phase or the growth of existing phases within the microstructure. Ideally, a tool that would be able to simulate the effects of both of these conditions would be extremely helpful in assessing the effects of these out-of-specification conditions. This would involve both thermodynamic as well as kinetic modeling. That is, thermodynamics can predict evolutions that can happen and rule out those that cannot. Kinetics can predict the extent to which a phase would evolve and the extent to which it would compete with other relaxation mechanisms.

A Phase I project should implement the thermodynamic modeling aspects of a simulation tool for predicting the effects of unplanned events on microstructure. In particular, this tool would predict, given an approximate environmental and thermal history, the set of phases that could have formed during these excursions from the ideal. A user interface would consist of methods of inputting (1) alloy composition, (2) gas composition, and (3) approximate time-temperature profiles. It would provide, in graphical form, a display of the phases that could have formed under these conditions. In addition to constructing the interface described above and integrating the technology for making thermodynamic computations in commercial alloy systems, this work would involve constructing a database of impurity elements expected to be present as environmental contaminants. Phase II efforts should extend the work to include kinetic modeling of microstructural effects to allow assessment of the likelihood of undesirable formation and growth of phases.

PHASE I: 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. The 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: 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.

DUAL USE COMMERCIALIZATION: 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.

REFERENCES: 1. Defense Advanced Research Projects Agency (DARPA), Proposer Information Pamphlet,BAA 98-03, Accelerated Insertion of Materials (AIM), Defense Sciences Office, January 2000, www.arpa.mil/ito/Solicitations/PIP_9803.html.

KEYWORDS: materials simulation, materials representation, materials insertion, development time, computational materials science, materials performance prediction, materials affordability

AF04-156 TITLE: Vertical Cavity Surface Emitting Lasers (VCSEL)

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Exploit advances in the fiber optic communications to develop higher power and more reliable devices for replacing edge-emitter diode technology.

DESCRIPTION: There are basically two concepts which have been developed for semiconductor lasers operating at wavelengths in the 0.8-1.0 micron region: edge emitters and surface emitters. Edge emitters were developed first and have been used since the 70`s for both pulsed and continuous-wave operation in single and multiple emitter and array (bar) configurations. The single emitter devices suffer from inherent optical damage, divergence and wavelength stability due to temperature dependence which limit the utility for many pulsed laser radar type applications. The optical damage is a rapid heating problem at the output facet (where the fluence is highest) and is exacerbated by residual absorption in the coating materials. When the pulse durations are short (less than 20 nanoseconds) there is no effective heat sinking to the bulk material and the coatings undergo large temperature excursions. The divergence problem is coupled to the damage problem. To compensate, the width of the diode must be increased to provide the sufficient energy, the increased width leads to multi-transverse modes and associated poor beam quality. The wavelength shift with temperature (approx. 0.3 nm per oC) is material dependent and has significant performance implications when transceivers must work over the temperature (-54 to 160) ranges required for military systems.

Vertical cavity surface emitting lasers (VCSEL) have undergone rapid development in the US and Europe during the 1990's and may be able to overcome the limitations of edge emitting diodes. Commercial devices provide diffraction limited circular beams with good wavelength stability. This feature is derived from selective wavelength feedback designs which compensate for temperature shifts and effectively reduce the wavelength shift by a factor of 4 to 5. The relatively large active area of the surface emitters as compared with edge emitters makes these devices particularly attractive for pulsed applications and would be immune to optical damage at pulse energies that are substantially higher than those achievable with single and even multiple edge emitters. VCSELS for mid and long wave infrared operation have been demonstrated with near room temperature and quasi CW operation.

PHASE I: Investigate and determine the feasibility of high powered VCSEL and VCSEL array technology in military applications. The program will initially focus on baselining the performance of existing commercially available VCSEL lasers under short-pulse excitation conditions. Measurements should include an assessment of beam quality and wavelength stability as a function of energy and repetition rate to assess performance. Develop a model to appropriately model or project performance. Investigate operation and maturity of current developments in infrared (1.5 to 11 um) laser diode sources.

PHASE II: Construct and demonstrate operational prototype(s) that includes test samples to validate performance. Packaging issues will also be addressed to arrive at an appropriate rugged low-inductance configuration suitable for military applications. Appropriately packaged VCSEL diodes will be tested for evaluation and comparison with our existing edge emitting diodes to project performance improvements.

DUAL USE COMMERCIALIZATION: High-speed fiber optic communications connections, collision avoidance systems, variety of ranging applications. Recent developments of mid and long wave infrared laser diode sources have shown the promise of uses in law enforcement, military, and communications applications.

REFERENCES: 1. Sandia Technology, Volume 3, No. 4: VCSEL Technology Leads to Successful Spin-off Company, Author: Kevin McMahon, Report Date: Winter 2001, http://www.sandia.gov

2. Applied Physics Letters, Volume 80, Number 2: Microlensed vertical-cavity surface-emitting laser for stable single fundamental mode operation, Authors: Si-Hyun Park, Yeonsang Park, Hyejin Kim and Heonsu Jeon, Report Date January 14, 2002, DOI: 10.1063/1.1432744

3. VSCEL White Paper, Textron Systems, Author: Victor Hasson, PhD., Report Date: November 08, 2001

4. Applications of Lead-Salt Microcavities for Mid-Infrared Devices, W. Heiss, T. Schwarzl, M. Böberl, and G. Springholz, Institut für Halbleiter und Festkörperphysik, Universität Linz, AUSTRIA, and J. Fürst, M. Aigle, and H. Pascher, Experimentalphysik I, Universität Bayreuth, GERMANY http://www.avs.org/conferences/miomd2001/presentations/Heiss-W215_files/frame.htm

5. 2.5-µm InGaAsSb/AlGaAsSb Diode Lasers Emitting 1 W Continuous-Wave, J.G. Kim, R.U. Martinelli, , W. K. Chan, L. Di Marco, S.J. Hudak, and D.B. Gilbert, Sarnoff Corporation, USA, and L. Shterengas and G.L. Belenky, State University of New York at Stony Brook, USA http://www.avs.org/conferences/miomd2001/presentations/KimW500_files/frame.htm

KEYWORDS: Vertical cavity surface emitting lasers (VCSEL), Edge emitting diodes, Lasers, Smart Pixel Array, Midwave IR laser diode, Longwave IR laser diode

AF04-157 TITLE: Innovative Technologies for Reducing Unexploded Ordnance (UXO)

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Eliminate armed submunition unexploded ordnance (UXO).

DESCRIPTION: Explosive devices (ordnance) can be extremely hazardous when they are made ready for firing (armed) but do not function as intended. Because a large number (hundreds) of submunitions are delivered with each weapon deployed and 100% functioning reliability cannot be achieved, many hazardous UXO result. For example, submunition weapons employment in Southwest Asia, Kosovo, and Afghanistan have revealed a significant unexploded ordnance (UXO) concern (DOD Policy Memorandum on Submunition Reliability dated January 10, 2001) (Ref 1). UXO rates ranging between 2% - 30% (average 7%) have been reported by Non-Governmental Organizations (NGOs) (i.e., International Committee of the Red Cross) during these regional operations (Ref 2). Some submunitions, such as the BLU-97 for example, once they are armed and if they fail to function when deployed, remain armed indefinitely thereby creating an immediate UXO hazard for friendly forces and NGO battlefield cleanup operations. Since improved submunition reliability will not in itself solve the UXO concern due to weapon system reliability problems such as those caused by weapon delivery conditions or the dispense mechanism itself, and since approaches to improve submunition reliability most often run counter to fuze design safety requirements imposed by MIL-STD 1316E, the objective of UXO reduction can be most readily achieved through incorporation of self-destruct, neutralization, or sterilization mechanisms in the submunition design. Definitions: Self-Destruct – rendering the submunition safe through destruction of the explosive by a secondary firing system upon failure of the primary system to perform the intended function. Neutralization – rendering the submunition inoperable through removal of the stimulus required to function the explosive. Sterilization – rendering the submunition inoperable through a process, which modifies the explosive and renders it incapable of function.

PHASE I: Select and investigate an innovative approach(s) for reduction of armed submunition UXO by self-destruction, neutralization, or sterilization. Develop a plan to implement the proposed design in a new or existing submunition.

PHASE II: Develop a breadboard design of the approach investigated in Phase I. Demonstrate through analysis and test the capability of the design to meet the requirements for a successful solution. Conduct limited laboratory and/or field tests of the breadboard design. Investigate and report on the producibility of the design.

PHASE III DUAL USE APPLICATIONS: Technology/techniques developed under this effort may have applicability beyond submunition fuzing. For example, the probability of a hazardous dud in a 2000 lb warhead is much less than that of submunitions, however, the individual level of hazard is much greater. This is especially true in many commercial applications (i.e., mining, building destruction, etc.). The necessity of friendly personnel involvement with any commercial misfire application is automatic due to the hand-emplaced nature of commercial applications. Benefits include techniques for miniaturization of fuze and fuze components and techniques for rendering non-functioning explosives safe to handle and dispose of. The multiple paths available for this development precludes defining the specific nature that the commercial application may take. For example, an increasing percentage of commercial blasters are switching to EBW (Exploding Bridgewire Detonator) or EFIs (Exploding Foil Initiator) due to their inherent safety. If EFIs are chosen for this SBIR application, the miniaturizing and cost reduction necessary for EFI and its associated CDU (Capacitor Discharge Unit) will feed directly into these applications. This is especially true when applied to the new technology of blasting caps employing electronic delays.

REFERENCES:
1. DoD Policy on Submunition Reliability, Secretary of Defense Memorandum, 10 Jan 2001; (Requests for this document may be made by contacting the sponsor).
2. CLUSTER BOMBS IN AFGHANISTAN, A Human Rights Watch Backgrounder, October 2001; http://www.humanrightswatch.org/backgrounder/arms/cluster-bck1031.pdf

KEYWORDS: Unexploded Ordnance, UXO, submunition, Exploding Bridge Wires, Exploding Foil Initiators, self-destruct

AF04-158 TITLE: Minimum RF Bandwidth Approaches to Human Interaction with Weapon Terminal Attack

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Determine the minimum RF bandwidth (Kbits/s) required to data link imagery from a weapon seeker which will be used for Bomb Impact Assessment, target ID, Go/No go human decision making, and man-in-the-loop (MITL) control of the weapon.

DESCRIPTION: Smart weapons are likely to be the next systems that will be integrated into a warfighting C4I network. This means RF data linked weapons. Unfortunately, RF bandwidth is costly. Minimimizing it is the key to low cost network centric operations with weapons.

Contingent on proper implementation, imagery from weapons with terminal seekers can be data linked back to the warfighter during the terminal phase of flight. This imagery can be used for target ID, Go/no go decision making, and MITL control of the weapon. It is best to achieve these capabilities using a data link that allocates the least amount of RF bandwidth possible to imagery functions. The required bandwidth is a function of many variables. These include focal plane array size, gray scale, seeker FOV magnification (which could be changed during terminal flight), focal plane array scanning patterns, data compression algorithm's, focal plane array update rate.

Given the variables listed above, it is first important to understand the minimum RF bandwidth required for receiving a single still frame image for use in Bomb impact assessment.

Next, it is important to understand the proper implementation of the variables listed above that will result in the ability for a warfighter to identify the target and make a go/no go decision based on still frame imagery from the weapon during the terminal phase of flight. This still frame methodology is assumed to require the least amount of RF bandwidth for a warfighter to ID a target, and make a go/no decision.

Finally, methods of MITL control that minimize RF bandwidth should be investigated. An example is aim point selection and refinement on still frame images during terminal flight.

PHASE I: Perform an analysis which shows digital RF bandwidth required for still frame images from a weapon terminal seekers of varying characteristcs (focal plane array size, gray scale)and data compression methods. Next, determine if a weapon in terminal flight should continue or terminate attack based on the ability of a human to ID a target during terminal flight from single or multiple still frame images of varying quality, characteristics, and time before impact.

PHASE II: Determine the best techniques to achieve repeatable man-in-the-Loop (MTIL) control of a weapon during terminal flight while using the least amount of RF bandwidth possible. It is postulated that weapon control can be achieved by identifying exact target impact points on still frame images (one or more) during terminal. These new impact points would then be communicated to the weapon in order for the weapon to correct its course. Next, determine the minimum RF bandwidth required to direct a weapon to the the target aimpoint using full motion video.

DUAL USE COMMERCIALIZATION: Modify and perform full-scale ground/flight testing of missiles. The further refinement of the amount of autonomous control versus man-in-the-loop control will improve ability to track and target over limited bandwidths. The potential for commercial applications is tremendous. This firm-ware will help scale the level of autonomy in a system. The ability to selectively chose the objects of interest in a frame of video and transmit that at high resolution while transmitting clutter information at low band width could significantly reduce other military and commercial bandwidths.

REFERENCES: 1. Presently researching SLAM and SLAM-ER program for related information.

KEYWORDS: Missile, seeker, Man-in-the-loop, MITL, terminal, RF bandwidth, data link, data rate, still frame, imagery

AF04-159 TITLE: Shock Hardened High Bandwidth Through Media Transmission Technology

TECHNOLOGY AREAS: Weapons

OBJECTIVE: This topic will investigate various technologies suitable for the transmission and reception of data in excess of 250,000 bits per second through earth, soil and concrete media. The technology proposed should address the following system requirements: shock hardened (>20KG's), small, affordable, and practical to implement including power source and antenna. The critical parameters to be determined include: operating frequency, frequency stability, modulation scheme and rate, and the transmitter power output. Where ever possible off-the-shelf technologies should be considered.
DESCRIPTION: The ability to transmit data from an underground location to the surface without a physical hookup is desired. For Air Force penetrating weapons utilizing a hard target smart fuze, information is available from the fuze to aid in determining target damage. Future weapons may incorporate additional sensors increasing the size of the data to be transmitted. This information must be transmitted from the buried weapon through layers of soil, concrete and other media such that it arrives at a receiver location at ground level or on an aircraft in the area. The weapon will also contain a system to accept interrogation and commands signal. This program will examine methods for relaying this information between the buried weapon and the receiver location on or above ground. Systems to transmit/ receive the data should be investigated and proposed by the respondent. As an option, the respondent may propose new systems for collecting and relaying the data required to assess battle damage to the target. It is highly desirable that no warhead case modification be required.

PHASE I: Phase I of this effort will include analysis of the proposed transmission concept(s). This analysis must include system performance under the loads anticipated during hard target impact. Static laboratory tests and demonstrations of critical components of the system are anticipated. The system will be contained or attached to an air delivered penetrating weapon. This project will develop a system concept and analytically determine the feasibility of data transmission through dense target media. The feasibility of packaging the concept in a penetrating weapon will be determined. Methods of verifying feasibility in Phase II shall be proposed and documented in a Phase II test plan.

PHASE II: Fabricate and demonstrate the Shock Hardened High Bandwidth data transmission system for a penetrating munition. A shock hardened transmitter/ receiver system will be built and tested on shock machines and in gun launches against hard targets. Demonstrations will be conducted to insure that data can be transmitted through various media and depth.

DUAL USE COMMERCIALIZATION: The developed communication link may have industrial application in transmitting data in harsh environments including directly through stationary or moving bulk media. Underground communications for shallow mining, urban below street access tunnels and emergency transmission for subways. Other commercial applications may apply to vehicles for the transmission of auto or aircraft crash information.

REFERENCES: 1. E. Nyfors and P. Vainikainen, Industrial Microwave Sensors, Artech House, 1989.

2. R. W. P. King and G. S. Smith, Antennas in Matter Fundamentals, Theory, and Applications, The MIT Press, 1981.

3. C. A. Balanis, Antenna Theory, John Wiley and Sons, 1997.

4. The ARRL Handbook for Radio Amateurs, The American Radio Relay League, 1997.

5. Heys, "Digital Communications - Encoding" ,3rd edition (1994)

KEYWORDS: G- Hardened Digital Transmitter, G-Hardened High Power Transmitter, Penetrators, explosives, signal transmission, warhead, fuzes, AF04-160 TITLE: Penetrator Trajectory Path Control

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Investigate methods for providing real-time trajectory control of a penetrator path in a soil target.

DESCRIPTION: Recent improvements in penetrator case materials technology have provided significant improvements in depth of penetration performance of steel high strength-low alloy (HSLA) penetrators into hardened targets. To achieve a high level of precision in defeating critical assets housed in buried hard targets, though, the ability to tailor a penetrator's trajectory through soil in a predictable manner must be achieved. New and innovative concepts, processes and materials are required for penetrator trajectory path control for air delivered non-nuclear munitions. The necessity for trajectory control is apparent as targets are further hardened and additional counter-measures are added.

The goal of this SBIR effort would be to devise methods for achieving predictable/desired trajectory path control; approaches to the problem could include, but are not limited to, an investigation of: (a) gradient microstructure development via differential heat treatment, (b) composition gradient of nose materials, and (c) bonding of dissimilar metals at critical locations on the penetrator nose. One should keep in mind that the penetrator must survive a highly abusive penetration (impact) event prior to initiating its trajectory in the soil medium; this operating environment will play a role in the development of the various path control mechanisms. Materials parameters that must be considered in this development process include ultimate tensile strength (UTS), yield strength (YS), percent elongation, abrasion resistance, and fracture toughness. These parameters will prove critical in the performance/effectiveness of the weapon. It is recommended that the base steel penetrator have the following minimum mechanical properties because of the high stresses that will be placed on it by the trajectory “control” process: a) 285ksi Ultimate Tensile Strength, (b) 240ksi Yield Strength, (c) 14% elongation and d) 24 ft-lbs Charpy Impact Strength at –40F.

Once developed, these wear control materials and processes will have a dual use and high commercialization potential. Military applications include bombs, penetrators, sub-munitions, warheads, projectiles, etc. Commercialization uses include metallic wear surfaces and frictional behavior of other high performance materials.

PHASE I: Investigate new and innovative concepts, processes, and materials for trajectory control of high-velocity penetrator warheads (i.e., methods for ensuring that a penetrator impacting a soil target at 4000 ft/sec will steer itself in a desired, predefined trajectory through the target material). Develop proposed concepts, processes and materials, demonstrate (through appropriate modeling and/or testing that can be accomplished within the limited Phase I budget) that they are technically feasible and valid for proven high-velocity penetrator materials such as Aermet-100 and AF-1410, and evaluate technical risk associated with each proposed concept. Develop methodology of the proposed materials/processes, establish control parameters, and provide a hierarchy of recommendations.

PHASE II: Apply trajectory control processes developed in Phase I to materials (selected by the contractor) that have lower cost than Aermet-100 and AF1410, but that demonstrate equal high-velocity penetration performance through geologic target materials. Develop mechanical properties database for the selected material to support hydro-code development (for insertion into penetration hydrocode material property libraries) and produce one-quarter-scale prototype trajectory-control penetrators (nominal outer dimensions to be supplied by the Air Force). These prototypes will be used to verify (by field testing) the mechanical properties developed for the trajectory control materials and processes. Demonstrate that the new trajectory control compositions and processes developed are robust enough to justify further developmental testing. For information on penetration testing and performance, please see the Related References section below. (Although these references, which describe low-velocity penetration phenomena, provide very useful information, one should keep in mind that the penetration of metallic projectiles through soil targets in the high-velocity regime (i.e., 4000 ft/sec) is very different from that in the low-velocity region, and that very little high-velocity data exists.)

DUAL USE COMMERCIALIZATION: This exploratory development program has extremely high utility for both the military as well as the commercial sectors. Military tactical program objectives of increased penetration, terra-dynamic steering, and reduced costs will benefit from the improved trajectory control mechanical wear processes. Military aircraft developers will have greater latitude in design of weapon bays and deployment options by utilizing smaller, more efficient weapons. Commercial steel users will have new materials and processes for application to abrasion problem areas. The new materials and processes will provide greater abrasion control measures for extended life for their respective applications.

REFERENCES: 1. Forrestal, M. J., and Luk, V. K., "Penetration into Soil Targets," International Journal of Impact Engineering, 1992, Vol. 12, pp. 427-444.

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4. Garrison, Jr., W. M., "An Investigation of the Role of Second Phase Particles in the Design of Ultra High Strength Steels of Improved Toughness," DTIC Reference AD Number ADA226056, Report Number CMU-1-50129, 1990.

5. Aerospace Structural Metals Handbook, 1985, Metals and Ceramics Information Center, Batelle Columbus Laboratories.

KEYWORDS: High Strength Low Alloy (HSLA) steel, gradient wear materials, abrasion resistance, wear control, ultimate strength, fracture toughness, trajectory control, soil penetration

AF04-161 TITLE: Ultra-High Speed Analog Lightwave Components For Ladar Scene Projection

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Research and Develop High Dynamic Range, Ultra-High-Speed Lightwave components in high-density packaging to demonstrate a 256 by 256 channel Ladar simulator.

DESCRIPTION: Imaging laser radar sensors are being developed that require not a 2D but 3D image (data cube) to be projected for each frame; these ladars measure time-of-flight and therefore range for each pixel, using a direct detection ladar (i.e., not a coherent laser system). Configurations are expected for up to 512 by 512 channels at 30 to 100Hz frame rate. Ladar sensors measure the spatially distributed time delay and intensity associated with a laser pulse reflecting off of background and target objects. An inexpensive approach to representing the dynamically changing return distribution is required to test ladar sensors in hardware-in-the-loop facilities. The "scene" content is calculated offline to drive the ladar scene projector based on the relative geometry between the sensor and the background/target objects. Optical sources are required with programmable delayed response. Large pixel formats are desired to allow the sensor to move within the projected scene while maintaining adequate spatial resolution. In a typical scenario the ladar sensor transmitting the laser pulse will trigger the projector. Based on current scene content (ranges and intensities) calculated by the external scene generation computer, the ladar scene projector would emit a sequence of return pulses from each projector pixel at the appropriate times, corresponding to returns from objects at different ranges in the pixel. Innovative and low cost approaches are required for the optical sources and for the arbitrary waveform generator chips and control electronics that drive the sources. Concepts for investigation may include either high-speed laser diode arrays or electro-optic modulator arrays (Semiconductor Optical Amplifier, polymer Mach-Zehnder, electro-absorption modulator, VCSEL, edge emitter or similar devices). The system will be triggered by the prototype ladar sensor transmitter under test and project laser signals into the optics of the sensor receiver simulating a real world return including fog, clouds, trees, wires, ground, and targets. The eventual goal is a 512 by 512 element array (up 262K channels in a minimal size footprint) to simulate return from ladar sensors. The approach should be expandable to from 64 by 64 pixel to multiple-hundred pixel squared array formats. Return pulse timing accuracy on the order of 500 picoseconds is desired. Uniformity corrected intensity resolution of at least 12-bits is desired.

PHASE I: Investigate and demonstrate different approaches to fabricate and demonstrate a minimum 8 optical channel per chip planar light source and or modulator system with drive electronics. Objectives are to demonstrate performance, scalability, and integration potential for at least 128 channels per "card".

PHASE II: Address integration with different Photonic components and investigate large-scale integration and use of 3D packaging technologies. The ultimate goal is a very high-density cross-connected system with 128 to 256 channels per "card". The "cards" would be packaged using multilayer packaging to form a cube integrated with arbitrary waveform generator chips and memory. Demonstration will include sources, modulators, driver integrated with power, control, cooling and individual channel non-uniformity adjustment. The phase II effort should also address interfaces for timing and real-time drive interface electronics using standard PC interfaces.

DUAL USE COMMERCIALIZATION: Develop a 3D packaged system with up to 10 kilometers of waveform memory of memory per channel (133K cells at 250 picosecond per cell for a total of 33 microseconds). Commercial/military applications include threat system simulators for test/training ranges, phased array radar control, 2D digitizing systems, collision avoidance, high-density communications cross-connect switching buffers. Other commercial applications include digital cinema, phased array radar control for air traffic control, and medical imaging.

REFERENCES: 1. AD Number: ADA355943, Recent Technology Developments for the Kinetic Kill Vehicle Hardware-In- The-Loop Simulator (KHILS), Murrer, Robert L., Jr.; Thompson, Rhoe A.; Coker, Charles F.,Report Date: 1998.

2. AD Number: ADA381265, Semiconductor In-line Fiber Devices for Optical Communication Systems, Harris, J. S, Final technical rept. 1 Apr 1998-31 Mar 2000.

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KEYWORDS: HWIL, Ladar Projector, Radar Simulator, arbitrary waveform generation, VCSEL driver, semiconductor optical amplifier, polymer fiber modulator, phased array, analog photonics, RF photonics.

AF04-162 TITLE: Innovative Material Processing for Warhead Applications

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Exploitation of novel properties of candidate materials for chemical energy warhead applications

DESCRIPTION: Material processing technologies are sought that enhance the ballistic performance and lethality of conventional warheads. Property enhancements are sought in liner material flow strength, strain to failure ductility, material density, texture, and lethal energy release. The Air Force utilizes wrought oxygen-free electronic copper (99.99% Cu) and has development work underway with pure tantalum and tantalum-tungsten alloys. Improvements are sought to the properties of these and other candidate materials by innovative processing techniques such as severe plastic deformation (SPD), equal channel angular pressing (ECAP), chemical vapor deposition (CVD), plasma arc deposited and nano-structured materials, etc. Nano-technologies might include top down approaches, i.e., processing large grain wrought material to achieve extremely fine grain structure or bottom up approaches, where ultra-fine particles are consolidated to produce a continuous medium. All technology developments must be suitable to size and fabrication constraints of chemical energy warheads.

PHASE I: Demonstrate the viability of a selected material(s) and processing technique that produces desirable characteristics for enhanced warhead performance. Limited sub-scale property testing and characterization is expected.

PHASE II: Process scale up to size sufficient for prototype warhead testing and full characterization of material properties. The Air Force will conduct prototype warhead experiments without cost to the contractor. Data generated by the Air Force on material properties will be shared with the contractor; warhead performance data will be provided in accordance with security classification guidelines. Deliverables would include processed liner blanks of generic sizes and thickness for proof of principle testing.

DUAL USE COMMERCIALIZATION: Enhanced properties can be exploited across a suite of commercial applications where strength and ductility play a role in service conditions or limit the use of fabrications techniques, i.e., deep drawing, etc. Direct application of enhanced warhead performance, outside the DoD, is limited to the oil well servicing industry.

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2. Chen, S. R. and Gray, G. T, "Constitutive Behavior of Tantalum and Tantalum-Tungsten Alloys," Met. Trans. A, vol 27a, pp. 2994-3006, October 1996.

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4. Langdon, Terence G. "A Critical Evaluation of the Factors Influencing High Strain Rate Superplasticy," Final Report Aug 1996-2000, University of Southern California, Los Angeles, ADA378955, Contract Number DAAH04-96-1-0332

KEYWORDS: Warhead, Plasticity; Flow Strength; Density; SPD; CVD; Nanotechnology

AF04-163 TITLE: Software Architecture for Universal Plug and Play of Weapons

TECHNOLOGY AREAS: Air Platform, Weapons

OBJECTIVE: Define and Develop innovative architectures for real-time and safety critical processes to enable universal plug and play of weapons.

DESCRIPTION: The level of interoperability achieved by the adoption of Mil-Std-1760 interfaces is based on the provision of a standard electrical interface and a catalog of standard data entities. Although Mil-Std-1760 mandates certain standard data messages, it also permits weapon systems integrators the freedom to use non-standard entities. This situation enables weapon integrators to effectively ignore any synergies with other compatible smart weapons in the existing inventory. The proliferation of smart weapons and aircraft platforms, i.e. jets, bombers, and UAVs within the DoD arena is causing integration costs to spiral out of control. The fielding of new weapon system capabilities is being delayed as a result of high integration costs and long integrations cycles. Technical advances have been made that are specific and or proprietary to a particular platform. Universal plug and play self-configuring platform/weapon systems require the adoption of a single interoperability technology that is pervasive throughout the weapons community. New innovative architectures that will allow universal plug and play of smart weapons on aircraft platforms are required. Plug and play technologies like the ones used in personal computers don't address the real-time and safety critical requirements of weapons. In Phase I universal plug and play architectures should define the foundational interfaces that enable platform and weapon contractors to develop and deploy platforms and weapons that interoperate with platforms and weapons from other contractors. Since the architectures define the fundamental interoperability mechanisms, once in place, contractors are then free to focus their effort on developing and deploying high performance weapon systems. A universal plug and play architecture is independent of any particular operating system, programming language, or physical medium and leverages existing standard protocols. Using standardized protocols aids in ensuring interoperability between contractor implementations. Defined architectures will simplify the development and integration process and allow contractors to provide self-configuring, interoperable weapons to the war fighter at lower development and integration costs. The combination of lower development and integration costs enables new capabilities to be brought to the war fighter faster at affordable levels. Consequently, a universal plug and play architecture makes it possible for the war fighter to finally realize the compelling benefits of being able to load and launch weapons anytime and anywhere.

PHASE I: Define innovative architectures for universal plug and play of weapons that meet real-time and safety critical requirements.

PHASE II: Produce prototype and demonstrate the most promising architecture defined in Phase I.

PHASE III DUAL USE APPLICATIONS: This technology will simplify the development process and allow DoD contractors to provide self-configuring, interoperable products, i.e., sensors and robots to be fielded faster with lower development costs. On the commercial side, universal plug and play enables wireless products such as cell phones, personal data assistant (PDAs), and personal computers (PCs) to connect to each other seamlessly.

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5. Universal Plug-n-Play (UPnP™) Forum Home Page: http://www.upnp.org

KEYWORDS: Weapon Platform Integration, operational flight program (OFP), Universal Plug-n-Play, Embedded System, Mil-Std 1760, Miniature Munition Store Interface, Open architecture

AF04-164 TITLE: Unitary Warhead Airburst Fuzing Capability

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Investigate unique concepts for determining weapon safe separation, free flight, and altitude above a pre-surveyed area.

DESCRIPTION: Air Bursting munitions that separate from an air vehicle have three flight regimes that must be sensed for successful operation: Safe Separation, Free Flight, and Terminal Altitude. Traditionally safe separation and free flight have been sensed using various inertial, gravity, and barometric pressure sensors while the terminal altitude relied on an active (radiating) sensor. Unfortunately, existing conventional weapons used for impact and penetration missions have no airburst capability because they were not designed with any sensor for active ranging. The Air Force is looking for opportunities to expand the operational capability of these weapons by adding a height-of-burst capability, but no active sensors or modifications to the exterior skin of the weapon are allowed. Weapon sensor information that is available includes airspeed (total and static), barometric pressure (static and dynamic), vertical velocity, INS information, GPS information, and passive infrared imagery. Additional sensors may be added to the interior of the weapon, but no active sensors or modifications to the weapon skin are allowed. Weapon velocities from 50-500 meters per second are possible.

PHASE I: Develop initial conceptual designs and model key elements (including error budgets) needed to determine weapon safe separation, free flight, and altitude above a pre-surveyed impact using available sensor data. Analysis should be performed to define acceptable uncertainties of sensor data.

PHASE II: Develop a brassboard sensor suite and software algorithm that can be used to demonstrate the concept when mounted on an inert INS/GPS guided weapon airframe.

DUAL USE COMMERCIALIZATION: This concept could be used in a broad range of military and civilian cargo airdrop/parachute applications where safe separation before chute opening, and altitude above the ground for airfoilstalling to land, are critical.

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KEYWORDS: GPS, Barometric Pressure, Altimeter, INS, fuzing, Sensor Fusion

AF04-165 TITLE: Visible/UV Image Projector for Sensor Testing

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop an optical image projection technology to provide complex, dynamic stimuli for ultra-violet and visible/near-IR sensors in a hardware-in-the-loop environment.

DESCRIPTION: Guidance, tracking, and navigation systems are under development that take advantage of signature characteristics of objects in ultra-violet, visible, and near-IR wavebands. Image projection systems are required for laboratory closed-loop testing of the sensors and their associated control and image processing systems. In hardware-in-the-loop tests a scene generation computer produces an image based on the relative position and orientation of the sensor and the objects/background being observed. This digital scene data is then transmitted to a calibrated projection system for presentation to the sensor. Past scene projection research has been predominantly focused on the use of infrared Resistor Arrays to realistically simulate dynamic infrared objects and background at temperatures up to roughly 700 Kelvin. This SBIR topic is focused on the development of technologies that can project images between 200 and 1000 nanometers at apparent temperatures up to 6000K. Challenges include non-modulated addressing methods to minimize test article interface issues, simultaneous "Snapshot" pixel update, scene dynamic range of 14 bits, a rise (0-90%) or fall time (100-10%) of less than 1 millisecond, pixel non-uniformity of less than 1%, and scene formats of 1024x1024 or greater. Approaches involving, but not limited to, conventional and organic light emitting diodes, liquid crystals, phosphors, field emission devices, and MEMs technologies are of interest.

PHASE I: Focus on defining a visible projection concept that meets the above defined objectives over some or all of the waveband of interest. An initial concept demonstration is highly desired that will show the subject component technologies can provide the desired performance.

PHASE II: develop a prototype projection system based on the Phase I concept definition. The goal is to demonstrate full functionality of the system including up to 400Hz frame rate, with an image format of 1024x1024 or greater.

DUAL USE COMMERCIALIZATION: High brightness tactical and commercial displays, spectroscopy sources, photo-therapy sources. The visible projector has the potential to enhance the state-of-the-art of Digital Cinema movie projection systems for the entertainment industry by increasing dynamic range, intensity resolution, and frame rate.

REFERENCES: 1. AD Number: ADA355943, Recent Technology Developments for the Kinetic Kill Vehicle Hardware-In- The-Loop Simulator (KHILS), Murrer, Robert L., Jr.; Thompson, Rhoe A.; Coker, Charles F.,Report Date: 1998.

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KEYWORDS: Hardware-in-the-loop, scene generation, scene projection, MEMs, Organic LEDs, LCD, flicker-less, field emission, Phosphors.

AF04-166 TITLE: Plasma Aerodynamics for Munition Control

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Development of solid-state actuators using plasma aerodynamics for flight control of a small munition.

DESCRIPTION: Solid-state actuators for aerodynamic control are desirable for a number of reasons, including absence of mechanical failures, reduced protrusions, reduced aerodynamic drag, and increased control flexibility. Low power plasma has been demonstrated in the laboratory to generate sufficient air movement to provide some level of control authority. Currently, the level of authority is low, limiting the application to small, subsonic munitions. However, this class of munition is of great worth and is currently receiving much attention. We seek novel actuator designs with improved application flexibility, small physical presence (lightweight with little or no protrusion from the surface), improved control authority, and an associated control system that optimizes the device effectiveness. Robustness is also important: the actuator must tolerate some exposure to the weather, physical impacts, scratches, etc.

PHASE I: Develop and design the proposed solid-state plasma actuator. An outline of the basic concept, a technical evaluation of the design, and an approach to assess and analyze the performance should be produced. A mathematical model of the system is also appropriate in order to predict and optimize the design. A prototype of the device shall be implemented on a bench-level, and validation experiments conducted.

PHASE II: Test the design using a hardware-in-the-loop apparatus to determine the effective control forces. Test and demonstrate the device in a wind tunnel. Test flight on a small munition-type airframe is also highly desirable.

DUAL USE COMMERCIALIZATION: Plasma actuators have potential application throughout the aerospace industry. Rocket control for space launch, control for high efficiency commercial aircraft, control for unmanned air vehicles (UAVs), and improved turbine performance are specific examples.

REFERENCES: 1. Enloe, C., McLaughlin, T., VanDyken, R., Kachner, K., “Mechanisms and Responses of a Single Dielectric Barrier Plasma,” AIAA Paper 2003-1021, 2003.

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4. Roth, J. and Sherman, D., “Electrohydrodynamic Flow Control with a Glow-Discharge Surface Plasma,” AIAA Journal, 38, 1166-1172, 2000.

KEYWORDS: plasmas, aerodynamic control surfaces, flow control, aerothermodynamics, configuration integration

AF04-168 TITLE: Global Positioning System (GPS) Jammer Threat Homing Munition Guidance System

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Research and development of passive sensor capable of guiding small powered munition to GPS jamming threat

DESCRIPTION: Currently, delivery platforms and munitions employ integrated GPS/INS guidance systems to provide accurate position, velocity and time (PVT) information. If GPS is denied, the platform/munition uses a degraded INS only guidance mode. This will directly impact future munitions that are planned to loiter in high threat areas. Because the trend is to develop munitions that are smaller, lighter, have longer flight times, improved accuracy, and a reliance on GPS, GPS denial will not be acceptable. Our adversaries are actively pursuing technologies to defeat/degrade our most effective weapon systems through exploitation of vulnerabilities inherit to GPS systems. The relative simplicity of such threats and our increasing reliance on GPS will encourage their widespread development and use on the battlefield in the future. The problem area addressed in this topic is GPS threat elimination. Small munitions, result in small antenna apertures for the seeker, limiting performance overcoming this physical limitation will require significant innovation.

The innovator will be required to show a feasible design capable of homing to a 10 watt GPS threat from an initial distance of 50 miles or less, in the presence of multiple L-Band threat emitters. The design must consider size, weight, power consumption, and operational complexity. The innovator may assume that the threats location is provided with an accuracy of at least 5 kilometers. The innovator may assume the munition is a sub-munition, with low operating speed and will have a maximum flight time of 20 minutes. Because the design of such a system is likely dependent on the munition size, shape and placement of the antenna(s), the innovator may develop the design on a custom munition platform. Successful integration of sensor performance with munition platform size, cost and suitability requirements is the significant challenge of this topic

PHASE I: The product of phase one should be a detailed design(s) meeting the following performance and suitability criteria, proven through modeling and simulation or other similar analytical approach, and provide a sound means and approach for prototype development:

-capable of homing to a 10 watt GPS threat from an initial distance of 50 miles or less, in the presence of multiple L-Band threat emitters
-design must consider size, weight, power consumption, and operational complexity
-may assume that the threats location is provided with an accuracy of at least 5 kilometers
-may assume the munition is a sub-munition, with low operating speed and will have a maximum flight time of 20 minutes
-innovator may develop the design on a custom munition platform
-Successful integration of sensor performance with munition platform of an acceptable size at a low per unit cost

PHASE II: Development the prototype system designed in Phase I. The prototype is not required to perform full munition functionality (flight, threat elimination, etc…), but must be designed to accomplish full functionality in the future. The system should provide sufficient data to allow man-in-the-loop testing of the homing capability on ground mobile or airborne test platforms.

DUAL USE COMMERCIALIZATION: This application has several dual uses. The most direct duality is the adaptation of the technology for use in Homeland Security. With the simplicity of GPS threat designs, the current threat environment and our commercial dependence on GPS, locating GPS jammers in an urban environment will be an issue easily handled by this technology. The requirement for a miniature design, will lead to smaller systems capable of being man-portable again supporting Homeland Defense initiatives. The technology developed for this program could be adapted to provide a jammer locator capability to the military and Federal Aviation Administration (FAA), both of which have growing concerns and frustrations with locating GPS jammers.

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KEYWORDS: Home-On Jam, Sensor, Guidance, GPS, Jammer, Seeker, Munition

AF04-169 TITLE: Efficient High Power Amplification Technology for Munitions

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop efficient, flexible, high power radio frequency power amplification technology to enable munitions to communicate with other platforms and users.

DESCRIPTION: Future loitering, search weapons with Automatic Target Recognition (ATR) capability will not only have information on their own status, but will also be able to provide Situational Awareness, similar to Intelligence, Surveillance, and Reconnaissance (ISR) assets. Loitering weapons may very well require a communication link in order to provide an operator the ability to make a go/no-go decision prior to target attack or provide the ability to coordinate munitions against high priority fleeting targets. Also, future military radio systems will have to comply with the Joint Tactical Radio System (JTRS) to be interoperable. JTRS radios for weapons will have to operate over multiple frequency ranges (400MHz – 4GHz), different modulation schemes, varying power output from 1W to 50W, and have a high degree of efficiency to reduce power consumption and heat dissipation. Various transistor materials and structures have properties with potential to benefit theses radio parameters. Recently, Indium Phosphide (InP) has shown promise compared to Gallium Arsenide (GaAs) considering the maximum operating frequency. Heterojunction Bipolar Transistor (HBT) structures have higher power densities than Field Effect Transistors (FET) leading to greater power output and small chip sizes. Additionally, the power amplifier design will have to operate AM, FM, PSK, and OFDM modulation schemes, which place restrictions on linearity requirements. The short expendable nature of munitions (minutes to hours) dictates both a lower mean time before failure (MTBF) and lower cost compared to long term systems. Technology meeting these objectives must be produced at costs ranging from one-half to one-fifth that which can be achieved using present design approaches and manufacturing capabilities. The ability to incorporate munition communication characteristics such as extreme range, limited power budgets, and small volume is necessary for a comprehensive approach. Enabling information flow between weapons and users in disadvantaged RF environments is a challenging aspect, which requires development of innovative, flexible power amplification technologies to meet strict cost, size, weight, and power requirements for weapons.

PHASE I: Define the proposed concept, incorporate requirements, and perform comparison analysis, though modeling and simulation or other methodology of the proposed RF hardware, to predict the performance of the proposed design. Identification of critical parameters and utility of technology with existing communication standards are key requirements.

PHASE II: Using results from Phase I, fabricate and validate a prototype that successfully demonstrates the intended concept for various communication standards.

PHASE III DUAL USE APPLICATIONS: Technology developed on this program will have application for both commercial and military systems requiring efficient robust communication for disadvantaged users. Mobile telephones or wireless internet users will benefit greatly from pursuit of this technology. This technology will increase performance of many commercial wireless information technologies. This technology could also be inserted into dismounted radio or communication equipment to enhance range or reduce power requirements.

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KEYWORDS: Radio frequency, power amplifier, miniaturization, efficiency, data link, weapon data link, military communication, Joint Tactical Radio System (JTRS), miniature munitions, loitering munitions, unmanned air vehicles.

AF04-170 TITLE: Structure from Motion

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a real-time structure from motion capability to calculate and render 3 dimensional scenes using video from an aerial sensor.

DESCRIPTION: Current passive imaging systems typically rely on stereo vision when 3D capability is required. The use of paired cameras on munitions is difficult due to the need for spatial separation of the cameras for depth resolution and the general desire to minimize the weight and cost of seeker payloads. Structure from motion (SFM) techniques offer 3D imaging capability through the use of a single sensor. The "stereo baseline" can be created in time with vehicle motion between video frames establishing the required spatial separation to resolve 3D structure. Structure from motion also allows the use of an arbitrary number of frames in the 3D reconstruction rather than a single stereo pair. This should improve the quality of the scene reconstruction by reducing occlusions and reducing image noise. Various SFM techniques have been proposed in the literature. The resolution of the 3D SFM reconstruction normally drives the computational requirements. Most SFM algorithms are formulated for batch processing on uncalibrated imagery with unknown camera motion. In the munitions context, a high-resolution, real-time SFM is required resulting in stiff computing requirements for uncalibrated imagery. Fortunately, the availability of attitude and position estimates from munitions guidance systems should simplify much of the SFM processing and provide a path for real-time capability.

For the purposes of this SBIR, it will be assumed that sequences of registered video frames are available as a system input. In this context, "registered" means that the camera calibration, location, and pointing angles are known for each frame in a video sequence. The prototype system should use an arbitrary number of frames to construct 3D scene geometry in real-time. The output format should be a 3D surface representation that can be rendered with off-the-shelf PC graphics processors and tools. The 3D representation should also be low-bandwidth to enable transmission over bandwidth-constrained networks. Potential applications include passive autonomous target acquisition (ATA)/recognition (ATR), model extraction for LADAR ATR handoff, and detailed 3D remote sensing over low bandwidth networks.

PHASE I: Focus on algorithm development for the structure from motion 3D scene generation. Trade studies should be conducted to determine 3D reconstruction performance and computational complexity vs. frame-to-frame overlap and number of frames used. Ground-truthed synthetic imagery will be the primary data source. Phase I should also result in hardware requirements for a real-time system demonstration in Phase II.

PHASE II: Develop a real-time demonstration of 3D scene reconstruction from registered passive EO video. This will likely require optimization of the Phase I code to achieve high throughput – especially in the 3D geometry construction. It is anticipated that the reconstruction output will be rendered using established 3D applications (openGL, D3D, etc…) and leverage commercial GPU technology. Real-time scene generation should be demonstrating using synthetic and AFRL provided real imagery at NTSC video rates (30 Hz) or better.

DUAL USE COMMERCIALIZATION: Successful completion of phase II will enable important technology transitions to the military and civilian sectors. For military use, the phase II system could be incorporated into networked munitions to enable real-time, man-in-the-loop control or BDA. It should also be expanded to include an autonomous target acquisition capability for wide area search on loitering munitions or ISR platforms and can serve as a cue for active sensors. Civilian uses include aerial surveying, rapid and inexpensive 3D model prototyping, and 3D remote sensing from unmanned vehicles.

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KEYWORDS: Structure from Motion, Passive Ranging, Stereo Vision, 3D Scene Generation

AF04-171 TITLE: Reaction Kinetics for Shock Driven Droplet Interactions

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop numerical simulation techniques for particulates and droplets in multi-species chemical reacting fluid flows.

DESCRIPTION: In order to neutralize certain chemical agents, it may be necessary to introduce a neutralizing reactant directly into a volume of aerosolized chemical agent. While equally true for vaporized agents, this topic concentrates on droplet dynamics. It is desirable to maximize both mechanical interactions and the chemical reaction rate between the agent and the neutralizer. In the best case scenario, the neutralizing reaction will propagate throughout the affected volume in a stable manner consuming the agent. In combat situations, it is likely that the reacting volume will be subjected to one or more shock waves. A study of the effects of shock waves on droplet interactions and chemical reaction rates is the focus of this effort. This effort is intended to provide new numerical simulation techniques for inclusion in computational fluid dynamics codes involving particulates, droplets and multi-species chemical reactions. The scope of the work required to achieve this capability could be very broad as droplet interaction dynamics must be simulated in the presence of air with chemical reaction Kinetics (for agent combining with neutralizer). The new simulation techniques and algorithms must also possess logic designed to model the initiation of the reaction. The effects on the agent/neutralizer droplet interfaces are of particular interest. It is evident that a stable set of droplet interfaces (and vapor phase reaction zones) is essential for effective agent neutralization. Prompt interface consumption could result in sporadic neutralization leaving large volumes of agent viable whereas sluggish interface consumption may result in a stalled reaction. Either case produces poor results. As droplets collide and separate, it is desirable to have a stable reacting interface considering all droplets. The reacting interface may be defined by the total reacting area for all colliding droplets. A stable reacting interface should be characterized by steadily increasing area that approaches a maximum and then drops to zero as the reactants are consumed. The effects of a series of shock waves occurring in the fluid volume is of great interest. It is possible that, on the average, a shock wave may effectively reduce the droplet interface area and instantaneously drive the reaction to stall. The trailing "release" section of the shock could then return the area to an increased value intermediate to the original and shocked states. An important scenario exists when containers of a given agent are opened via ballistic impact. In this case, agent is likely to be aerosolized creating collateral effects. This research provides the means by which we may study just how effective proposed neutralization schemes may be at destroying the agent released. By performing these studies in a shock environment, we increase the realism of the simulation, and we are better able to assess proposed weapons systems.

PHASE I: Conceptualize and design an innovative numerical scheme and interface methodology for the interaction and collision of droplets in chemically reacting flows.

PHASE II: Modify the algorithm to account for chemical reaction kinetics, initiation (or non-initiation) of the reaction, and shock-droplet interactions. Perform studies varying the agent dispersal patterns, droplet size distributions, agent/neutralizer chemistry, shock wave strengths, and droplet velocity distributions.

DUAL USE COMMERCIALIZATION: The industrial processes for the commercial biotechnology industry and a biological warfare facility are nearly the same. The results of this SBIR would be very valuable in the commercial biotechnology industry.

REFERENCES: 1. Alibek, Ken, "Biohazard : The Chilling True Story of the Largest Covert Biological Weapons Program in the World-Told from the Inside by the Man Who Ran It Towards a Coherent Strategy for Combating Biological Weapons of Mass Destruction," Random House, 1999.

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KEYWORDS: Biological Agent; Droplets, Particulates, Chemically Reacting, Fluid Dynamics, Computational, Numerical

AF04-172 TITLE: <u>Processing Methodology for Reactives Enhanced Munitions</u>

TECHNOLOGY AREAS: Materials/Processes, Weapons

OBJECTIVE: Demonstrate manufacturing technology for high-strength materials capable of releasing energy upon demand for the enhancement of Air Force munitions.

DESCRIPTION: It is well established that intermetallic and thermite reactions liberate substantial thermal energy. On a thermodynamic basis, these materials are capable of outperforming even military explosives. In order to achieve miniaturization of weapon systems, the replacement of inert structural components with high-strength materials capable of undergoing shock-initiated intermetallic or thermite reactions is sought. Controlled initiation sensitivity, high rates of reaction, and good total energy content are desired in a material with a greater strength-to-weight ratio than steel. Many concepts have been developed, however most fail to achieve economic feasibility or are otherwise not conducive to large scale production. Methods such as powder consolidation and fiber composites have thus far proven to be the most promising candidates for creating metastable microstructures with the requisite strength and reactive properties in a cost effective manner. Potentially successful concepts need not be limited to these two areas. The goal of this SBIR Topic is the demonstration and characterization of manufacturing processes for achieving reactive structural compositions or composites. The process must be suitable for use with a variety of materials combinations within either the intermetallic or thermite categories. In a Phase II effort, scale up the Phase I manufacturing technique to a commercially viable level would be accomplished. As a minimum, the developed process must be capable of producing simple geometries such as cylinders. Performance testing will not be conducted as part of SBIR efforts.

PHASE I: Demonstrate proposed fabrication methodology and characterize the resulting microstructure. Analyze economic feasibility of scaled-up production process.

PHASE II: Scale-up fabrication technique and confirm material characteristics. Develop a database of processing conditions and the corresponding pertinent properties including strength and initiation sensitivity. Produce full-scale munition structure.

DUAL USE COMMERCIALIZATION: Reactive material structures for use in military munitions to enhance effectiveness.

High-strength composites for aerospace and sporting applications (inert materials).

Intentional reaction of near-net shape parts to produce intermetallic alloys or metal/ceramic composites (depending on proposed fabrication methods) for low-cost production of advanced materials used in aerospace, microelectronics, and industrial applications.

Precision cutting-torch or welding applications including complex geometries or in confined locations.

REFERENCES: 1. AFRL/MN Home Page: http://www.mn.afrl.af.mil

2. SH Fisher and MC Grubelich; "A Survey of Combustible Metals, Thermites, and Intermetallics for Pyrotechnic Applications" Sandia Report SAND95-2448C

KEYWORDS: composite materials, structural components, chemical reactions, incendiary mixtures, thermite, intermetallic compounds

AF04-173 TITLE: Digital Signal Processing in Radar Altimeters

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Explore the use of digital signal processors (DSP) for cost reduction of radar altimeters used in aircraft launched cluster munitions.

DESCRIPTION: The current method used to design radar altimeters of the "trip wire" type is to use a transmitter that sends a Frequency Modulated Continuous Wave (FMCW) signal in the S-band frequency range. The term "trip wire" means that the altimeter issues signals at specific altitudes instead of continuously returning altitude values. The frequency modulator is a 50% up and 50% down saw-tooth waveform. Waveforms that vary from the 50/50 method (e.g., 70/30) produce troublesome side lobes that occur inside the desired spectrum, making the analysis to determine altitude more difficult and more prone to false alarms. The transmitter issues single FM deviations that correspond to an altitude, which can be determined by recognition of relationships between harmonics in the received spectrum.
The antenna is a miniature strip-line annulus type that relies on the use of passive hybrids to allow both transmission and reception from the same structure. The hybrid design keeps transmission and reception signals separated in phase by 90 degrees preventing self-jamming and cancellation. The small size requirements necessitate the use of metal materials plated on dielectric PC boards that constitute tuning for the antenna. This type of antenna is a high expense item. It is possible that the use of DSP techniques might reflect back into the type of antenna, offering possibilities for cost reduction.

The software algorithm relies on the received FMCW signal to be mixed with a portion of the transmitted signal (the homodyne method) to produce a sinx/x (sinc) spectrum that is processed by analog methods (e.g., filtering). Due to requirements on size and power drain, most of the analog circuitry is implemented in multi chip module (MCM) packages that are relatively expensive. The operating temperature range of the product (-55C to +125C) and low power drain add performance requirements to the processor.
In addition to determining altitude, the processor must also function as a standard microcontroller unit(MCU). The MCU must run a program from an internal Read Only Memory (ROM) that controls other activities that are being done as the weapon falls to the ground.

PHASE I: Investigate the current altimeter system algorithm and the use of FMCW for the transmission/reception process and the implications that the modulation process has on the use of digital signal processing. If other modulation techniques are possible and more amenable to use of DSP in the receiver section, they should be introduced and compared to the present technique (FMCW). The result of the investigation is to be a system algorithm.

Develop a block diagram model for the altimeter system that illustrates the use of less expensive DSP techniques. It is expected that the use of DSP will largely be in the receiver- detection parts of the system, regardless of the selected type of modulation and the transmitter implementation. The block diagram is to be modeled in a computer language (e.g., visual basic) suitable for simulation so that performance and false alarm rates may be analyzed.

PHASE II: Construct and demonstrate the system of Phase I into a working breadboard that establishes the performance of the system. Recommendations on electronic components are to be made for each of the system blocks in the breadboard. A cost analysis is to be made and compared to estimates of the cost of the present system.

DUAL USE COMMERCIALIZATION: This type of device can be used for many other applications in the field of distance measuring and altitude measurement. A reference search for radar altimeters using the www.google.com search engine on the web will produce hundreds of references. This indicates that the topic is currently very active and of interest in a wide variety of applications.

REFERENCES: 1. Eaves, Jerry L. and Edward K. Reedy, ed. Principles of Modern Radar. Van Nostrand Reinhold. 1987.

2..J.R.Jensen “Radar Altimeter Gate Tracking: Theory and Extension”, IEEE Trans. Geosci. And Remote Sensing, Vol. 37, pp. 651-658, 1999.

KEYWORDS: Radar Altimeter, Digital Signal Processing, Altimeter Algorithms, Frequency Modulated Continuous Wave, Micro-controller, Homodyne Mixing

AF04-174 TITLE: Munition Sensor Electronics/Processor Integration

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop an integrated electronic architecture that performs both sensor control and system processing.

DESCRIPTION: The sensor suite for next generation Air Force munitions may include passive imaging infrared (IIR), laser radar (LADAR)—(active infrared), and passive/active millimeterwave (MMW). The sensing element for each includes PiN, Avalanche or P/N Photodiodes, microantenna arrays, bolometer arrays, and hybrid complementary metal oxide semiconductor/charge coupled device (CMOS/CCD) image sensors. Each sensor type typically has a separate drive/control electronics module. A particular sensor when coupled with an embedded image/signal processor module forms a seeker. Seeker processors traditionally tend to be separate from guidance/navigation/control (GN&C) processors. Air Force Research Laboratory, Advanced Guidance Division (AFRL/MNG) is interested in the research and development of integrated electronic architectures, which perform both the sensor control and system processing functions. The hybrid architecture must be modular to handle a disparity of sensor types. The architecture should consist of reconfigurable/programmable processing elements that can perform sensor control, sensor information processing, and system level GN&C functions. The data throughput capability must be sufficient to handle all on-board high-rate, high-resolution sensors. The computation throughput capability must be sufficient to implement complex autonomous target acquisition, GN&C, and fuzing algorithms. A combination of electronic and optical components is of interest. A combination of conventional and biologically inspired information processing architectures is also of interest. Image flow and synthetic resolution enhancement for sparse arrays is of similar interest. Such a system must have at a minimum the following capabilities: 1) provide the chosen sensor with its required control signals (i.e., for an IRFPA, generation of appropriate digital clocks and analog bias voltages and currents); 2) provide for the operation of one or more sensors at both ambient and cryogenic temperatures; 3) incorporate a convenient data and control interface to the host controller; 4) provide for "seamless" integration of a variety of digital data streams from a variety of system sensors into a common sensor fusing processing platform; 5) provide the capability for systems designers to apply a variety of programmable algorithms to the real-time multi-sensor data; and 6) allow for the results of such algorithm applications to be used for a variety of system control functions.

PHASE I: Perform a systems analysis task to explore and define the concepts of an integrated sensor control and processing architecture. The design and development of such "next generation" seeker head assemblies that exhibit highly modular, programmable and highly capable sensing and processing operations shall be investigated. Novel design, fabrication and integration approaches shall be defined that will result in an affordable system. Real-time image-based and GN&C processing algorithms must be applicable to the AFRL mission. A feasibility study of the various design concepts will be produced. A preliminary design concept for a proposed system to be developed as a prototype in Phase II will be identified.

PHASE II: The concept identified in phase I will be designed and developed into a prototype modular sensor electronics system that has the capability to fuse sensor inputs from a variety of sensor types. A demonstration of the system operation will be performed. A commercialization plan, including descriptions of specific tests, evaluations, and implementations to be performed will be developed.

PHASE III DUAL USE APPLICATIONS: Micro/miniature disparate sensors are being used in everything from automobiles to household appliances and consumer electronics. Being able to easily control the wealth of information in a cost effective manner is essential, and will be an important application of this topic. Phase III efforts would include integration of the prototype demonstrated in Phase II into the Kinetic kill vehicle Hardware In the Loop Simulator (KHILS) facility at AFRL/MNG for characterization and evaluation.

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KEYWORDS: Electro-magnetic Sensors, Integrated Sensors and Electronics, Integrated Sensor and Image/Signal Processing, Sensor Fusion, Conventional Weapon Guidance & Control, Conventional Weapon Guidance Integrated Fuzing, Conventional Weapons Integrated Electronics Suite, Biologically Inspired Sensor and Control Processing

AF04-175 TITLE: A Hydrodynamic-Stochastic Neutralization Model for Biological Agent Defeat

TECHNOLOGY AREAS: Chemical/Bio Defense, Weapons

OBJECTIVE: Develop a hydrodynamic-stochastic neutralization model and couple it with an incompressible, turbulent computational fluid dynamics code.

DESCRIPTION: Many biological agents may be stored in liquid solution, e.g., a saline based solution such as blood plasma. It is desirable to defeat this stored agent by mechanically damaging the associated containers and by then preventing a dangerous release of agent. The release of agent may be mitigated by injecting a neutralizer at the time of impact. In theory, the neutralizer will diffuse convectively (as forced by projectile motion) and will neutralize agent on a particle-by-particle basis. Given the nature of microscopic particles, uncertainly casts some doubt on the likelihood of success for this defeat mechanism. For instance, the initial quantity and viability of the agent are unknowns. The dispersal of agent particles within the container is also unknown. These uncertainties make it difficult to compute time accurate predictions of agent viability in space. Given that the agent and neutralizer consist of microscopic bodies it is desirable to address them via probability density functions defined over the container's interior. In turn, these functions may be used to build probability representations of agent propagation and viability. The fluid dynamics of this problem are solved through deterministic CFD methods. The agent and neutralizer growth and death equations should be cast in a stochastic CFD framework. The transport of these species across fluid cell boundaries is very important, and the method should be consistent for stochastic methods. Properties directly associated with the agent are represented by random variables defined in time and space. An example output of this research is a three-space map of biological agent viability in time. A similar map set can be developed for neutralizer potency. These maps are characterized by probability contours. A probability of zero constitutes the absence of viability whereas a probability of one constitutes live, infectious agent. The strength of this approach is that probability modeling allows the use of a larger state space. That is to say, a particle of agent may have varying degrees of viability. A stochastic model should be selected for the chosen biological agent and neutralizer and then be integrated into a three-dimensional unsteady, incompressible CFD code with moving boundary capability. Problems of interest entail the passage of a solid body through a fluid mass. The neutralizer may enter the agent fluid through the wake of the solid body. Cavity formation and collapse may be important aspects of the problem. The resulting fluid flow will transport the neutralizer throughout the container. Complex neutralization schemes for biological agents pose serious questions concerning efficacy. It is incorrect to assume that the agent may be neutralized by the simple act of injecting neutralizer into the fluid volume. This effort is designed to produce a high fidelity computational tool that may be used to study the evolution of agent in the presence of a neutralizer. The end product of this research allows certain neutralization schemes to be studied. Currently, there are no effective tools for simulating the time-dependent performance of these neutralization methods.

PHASE I: Conceptualize and design an innovative approach for integrating a stochastic model for a biological agent and neutralizer in to a three dimensional incompressible turbulent CFD framework with moving boundaries.

PHASE II: develop the stochastic model(s) to cover a wide range of biological agent and neutralizer combinations. Integrate the models into an incompressible turbulent CFD framework. Then perform studies to demonstrate the performance of various neutralization approaches.

DUAL USE COMMERCIALIZATION: The results of this SBIR would be useful for modeling industrial processes involving liquids, and liquid transport systems. Military uses involve novel agent defeat warhead designs.

REFERENCES: 1. Alibek, Ken, "Biohazard : The Chilling True Story of the Largest Covert Biological Weapons Program in the World-Told from the Inside by the Man Who Ran It Towards a Coherent Strategy for Combating Biological Weapons of Mass Destruction," Random House, 1999.

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KEYWORDS: Hydrodynamic, reaction kinetics, neutralization, stochastic models, agent, biological

AF04-177 TITLE: Multi-Mode Mobility

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop and advance enabling technologies to allow a small device to transition between air and land mobility.

DESCRIPTION: In the ever changing battlespace environment, the ability to have a Micro Air Vehicle (MAV) change its physical shape by collapsing its wings on to its airframe could enable its new geometry to take advantage of an alternate mode of mobility and thus enhance its operational utility. This technology would allow a single vehicle the ability to perform multiple missions. An example would be to have a MAV fly to the top of a building, land, and then change geometry, and then move to the edge of the roof (rolling, crawling, hopping, etc.) and collect video imagery. Following mission completion, the device would reconfigure its geometric shape, fly off the building, and then return to its home base or continue its mission. This ability to change physical shape or "morph" will require innovative technologies such as miniature smart structures, power miniaturization and management, micro conformal sensors, and MEMS technologies. The major technical risks will be in the development of a small power system, and in the miniaturization of required components. It is envisioned that this technology will be applied to an MAV with a maximum wingspan of 12 in and weighing less than 1.0 lb, and will have the ability to maximize mission effectiveness to support the warfighter.

PHASE I: Define the proposed concept, identify key technologies, and predict the performance of the proposed design of a multi-mode mobility device using simulation techniques. Identification of critical parameters and application to Concept of Operations (CONOPS) are key.

PHASE II: Finalize the design of the multi-mode mobility device. Develop an operable prototype or suitable device that demonstrates the intended technological concept. Final report should include how CONOPS are supported, and how multi-mode mobility transformation affects overall robot device architecture.

PHASE III DUAL USE APPLICATIONS: Technology developed on this program will have military application to future urban environments. The morphing technology to be demonstrated under this topic will provide the enabling technology for weapons to fly, perch, crawl and then fly again; necessary capabilities of a urban weapon system. The morphing technologies can be applied to commercial robotic markets, i.e. wheelchairs that can climb stairs, automobiles that can morph into trucks or amphibious vehicles.

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KEYWORDS: Multi-Mode Mobility, Micro-robots, miniature robots, flying robots, crawling robots, robotic system integration

AF04-181 TITLE: Development of Phenomenological Liquid Spray Design Tool for Augmentor Operability and Performance

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop and validate an advanced numerical model to predict the liquid fuel breakup in gas turbine augmentor flows.

DESCRIPTION: In gas turbine augmentor systems, fuel is injected into a high-speed vitiated air stream produced by the engine. The light off, blowout, efficiency, and screech characteristics are directly related to the behavior of the fuel/air mixture resulting from the injection process. To provide a robust, low-cost system, a typical approach for injecting fuel involves the injection of a small-diameter stream of liquid into the vitiated air stream. The injection process, while simple in concept, results in complex, rapid behavior associated with liquid column breakup, stripping, secondary atomization, transport, evaporation, and mixing prior to combustion. As a result of these complex phenomena, detailed design strategies that relate the fuel injection process to the subsequent augmentor performance are not available. As a result, optimization of augmentor performance must be done through a cut-and-try methodology, which adds to the production cost of augmented gas turbines.

Injection of a liquid stream into a high-speed crossflow is applicable to many combustion applications, including augmentors. Liquid stream injection has been studied extensively in recent years. The studies have resulted in some design tools directed at jet breakup length, jet penetration, and spray features. Despite these studies, however, wide variation in expressions describing even basic features, such as jet penetration, are apparent, reaffirming the lack of sufficient design tools. Currently, a comprehensive physics-based design code (i.e., computational fluid dynamics (CFD)) cannot deal with breakup, secondary atomization, and strong phase coupling. The most advanced codes with quick turnaround typically require an average droplet size of spherical particles (e.g., Sauter Mean Diameter), gas phase velocity, population density, and size distribution information as a function of position in space. These general spray features are present in augmentor systems, but well downstream of the key phenomena that ultimately describe the spray presentation. Hence, to provide an accurate description of the augmentor efficiency, light off, and stability, improvements in design tools, either empirical or CFD based, are required. In particular, tools that provide spatial and temporal characteristics associated with the dispersion of the fuel, evaporation, and mixing are key.

PHASE I: Develop an advanced numerical model for predicting liquid fuel jet breakup in a cross-flow. Validate the feasibility of the numerical model using existing data. Analysis of the numerical model shall include identifying deficiencies and the necessary requirements to alleviate the analytical deficiencies.

PHASE II: Identify and obtain the experimental data required to perform a prototype demonstration of the advanced numerical model to diminish the analytical deficiencies of predicting liquid fuel jet breakup in a cross-flow. This could be accomplished by identifying an experiment to be controlled exclusively by the small business or partnering with a major engine manufacturer utilizing an augmentor test with additional instrumentation, or other methods as required. Results of the numerical simulation of the experiment shall be analyzed and the advanced numerical model shall be improved and demonstrated.

DUAL USE COMMERCIALIZATION: This program will produce a numerical simulation tool that can be used to study and improve the operability of military gas turbine augmentors. This could be used in civilian aerospace applications requiring high speed flight or temporary high performance. Also, the numerical simulation software may find application in power generation duct burners for environmental pollution control. Commercial applications include the use of improved liquid jet models in CFD codes and in the design of combustors with reduced pollutant emissions and increased performance.

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KEYWORDS: augmentor, combustor, screech, efficiency, blow out, light off, liquid jet, liquid fuel jet breakup

AF04-182 TITLE: Control of Fuel Atomization and Mixing for Emission Reduction in High Performance Gas Turbines

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Demonstrate novel fuel atomization methods for reduced emission, improved stable gas turbine combustion with high combustion efficiency, low pattern factor, and tailored thermal profiles for military applications.

DESCRIPTION: The performance of gas turbine combustors depends directly on effectively mixing fuel spray and air/gas streams. Current combustors are inherently limited by the fundamental spray quality and jet penetration limits associated with fuel spray jets. Given recent successes in control of ultra-fine sprays mixing and development of advanced numerical tools, control of atomization and mixing in realistic gas turbine combustors is now an achievable goal. The use of intelligent fuel injectors capable of producing ultra-fine spray may be the key to enabling effective interaction between spray and gas streams with improved mixing. Recent experiments have demonstrated that controlled atomization can yield reduced emissions and control of unsteadiness. These effects could result in reduced fuel consumption, augmented specific thrust, and increased control authority for future gas turbine engine combustion systems. The purpose of this program is to reduce emission and improve performance of gas turbine engines by developing new fuel atomization and mixing techniques. A related goal is to integrate development of novel fuel injection methods with advanced numerical simulation tools, which will be required to fully understand spray behavior and realize the full benefits of improved fuel atomization and mixing.

PHASE I: Provide novel fuel injectors capable of controlling variations of extremely small spray droplets and investigate spray droplet size, spray penetration, and trajectory. Integrate candidate fuel injectors into combustion systems to study atomization of hydrocarbon fuel and mixing as a function of flow rates and air-to-fuel ratios.

PHASE II: Integrate prospective fuel injectors and perform physical demonstration of the complete fuel injection system on a representative military turbine engine platform for a range of operating conditions. Demonstrate combustion performance enhancements and reduced emissions in a simulated combustion environment.

DUAL USE COMMERCIALIZATION: Commercial applications include land-based gas turbines for power generation and improved fuel mixing technologies for the automobile industry. Military applications include high-performance military engines for global power and unmanned aerial systems.

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KEYWORDS: fuel injection, increased mixing, NOx reduction, advanced numerical simulation, fuel spray droplet size distribution, dense spray, two-phase model

AF04-183 TITLE: Thermal Barrier Coating (TBC) Durability

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop the capability to assess the structural integrity and life expectancy of thermal protective coating systems for turbine engine components.

DESCRIPTION: Low-cost nondestructive inspection (NDI) methods are needed to obtain quantitative measures for TBC structural integrity and life expectancy for both as-fabricated and fielded turbine airfoils. There are three areas in which such methods are applicable: (1) maintenance inspection, (2) screening method for new coating systems, and (3) quality assurance. Premature failure of thermal protective coatings is a significant contributor to the high cost of maintaining turbine engines, and the ability to detect and predict such failures should enable the maintainer to remove components for cause rather than as a precaution. In recent years, efforts to improve coating durability has been hampered by the inability to objectively compare the relative merits of competing coating systems. Developing more reliable materials screening methods should enable the developer to rank order potential coating systems more systematically. Lastly, ensuring the quality of the applied TBC is critical to the durability and life of the coated turbine engine part. Applying the thermal protective coatings uniformly over the entire complex turbine airfoil shapes can be quite a challenging task, and any variations in the thickness, tightness of the bonding to the substrate, etc., can have a major impact on coating durability. Quantitative durability measurements of as-fabricated coatings could form a basis for an objective acceptance test. These methods could also be used to provide a baseline for future parts inspection in the field. In summary, the inspection methods to be considered in this effort must be compatible with the inspection capabilities of the shop floor of the typical manufacturing plant or the maintenance depot. For both as-fabricated and fielded parts inspection, the emphasis must be on accuracy, speed, and cost. For fielded parts inspection, the developer must remember that engine disassembly will significantly increase the cost of performing the inspection. Therefore, a reasonable effort should be made to develop methods that can be used on fully assembled engines.

PHASE I: Determine technical feasibility of incorporating existing NDI methods into an inspection protocol and breadboard device for coated components.

PHASE II: Produce a refined inspection protocol and device and apply the method to a fully assembled turbine section.

DUAL USE COMMERCIALIZATION: The potential military applications for this technology include the depot maintenance for existing fighter, bomber, and helicopter advanced engines. The potential commercial applications include manufacturing quality assurance inspections and end-user maintenance inspections of commercial aircraft and ground-based power generators.

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KEYWORDS: thermal protective coatings, TBC, thermal barrier coatings, coated turbine airfoils, inspection, nondestructive inspection, TBC durability, TBC life determination

AF04-184 TITLE: Genetic Algorithm Optimized Probabilistic Maintenance Scheduling

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Development of a Genetic Algorithm (GA) based probabilistic reliability-centered maintenance scheduling tool.

DESCRIPTION: Component maintenance and replacement for a large fleet spread over many operational bases and logistic centers with differing maintenance capabilities is a difficult scheduling problem. That schedule must also be combined with an operations tempo that requires the maximum fleet readiness possible to support field operations. Genetic algorithms present an innovative approach to address the complex scheduling issue. As component life prediction methods transition from a deterministic value to a retirement for cause or probabilistic life requirement, the current scheduling and replacement part fabrication becomes a cloudy issue. The maintenance actions would no longer be planned and foreseeable years in advance. However, the distribution of the aircraft in the fleet that requires action is still predictable. Genetic algorithms offer the ability to determine if this new maintenance schedule is possible while maintaining a high level of operational readiness. The scheduling software must be able to use as input the expected life, fleet unscheduled maintenance rates (component failure rates), operational readiness, technical order required scheduled maintenance, maintenance action costs, and replacement manufacturing lead time to determine a maintenance schedule and replacement ordering schedule. The payoff is a reduced maintenance cost since more of the usable component life is used as the retirement is transitioned from deterministic to probabilistic or retirement for cause. Novel algorithms and operations must be incorporated into the algorithm to ensure convergence and to reach an optimum with such a complex problem.

PHASE I: Demonstrate an algorithm that uses multiple time, cost, and readiness constraints to produce a maintenance schedule as well as gather the constraints, costs, and other input for a fully developed code.

PHASE II: Produce a code to assess cost per engine flight hour where there is limited cost data. The code will demonstrate robustness and convergence to an optimum.

DUAL USE COMMERCIALIZATION: Military uses include satellite launch scheduling, test facility scheduling, ground transportation maintenance scheduling, etc.

Civil applications are similar such as airline or freight maintenance scheduling.

REFERENCES: 1. T. Back,D. B. Fogel, and Z. Michalwicz, Evolutionary Computation 1: Basic Algorithms and Operations, Vol. 1, Lop Pub, Bristol, United Kingdom, 1999

2. T. Back, D. B. Fogel, and Z. Michalwicz, Evolutionary Computation 2: Basic Algorithms and Operations, Vol. 2, Lop Pub, Bristol, United Kingdom, 1999

KEYWORDS: Genetic Algorithms, Scheduling, Maintenance, Probabilistic, Optimization, Cost

AF04-185 TITLE: Nanomaterial-Based Lithium Ion Batteries

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

OBJECTIVE: Develop a prototype nanolithium battery utilizing high-capacity, high-rate nanomaterials as the electrodes.

DESCRIPTION: Conventional NiH (nickel hydride) and silver zinc batteries used on satellites and launch vehicles have limited capacity and charge/discharge rates. Additionally, silver zinc batteries suffer from limited activated lifetime prior to launch and low reliability. Lithium ion batteries offer an excellent alternative to the current NiH and silver zinc technology. By using nanomaterials, advanced lithium ion batteries can deliver very high capacities with charge/discharge rates of more than 100 times the conventional batteries. This is possible through the optimization of particle size and nanostructure of the electrode materials. Nanomaterials such as nanocarbon tubes and nanolithium metal oxides can be utilized as the electrode materials for lithium ion batteries to obtain superior electrical performance with very little capacity fade for thousands of cycles. Some of these nanoparticles exhibit capacities that are close to theoretical values, and are suitable for the development of high-power, rechargeable lithium ion batteries. One technical challenge is to find the proper technique to pack these nanoparticles in the form of an electrode without altering the nanostructure and electrical performance. The other challenge would be to identify an electrolyte that can support such high rates.

PHASE I: Characterize the electrical properties of nanoparticles and demonstrate performance at various environmental conditions. Identify optimal battery components, including the binder, current collector and electrolyte that are capable of supporting high charge/discharge rates.

PHASE II: Build prototype batteries and demonstrate operation by testing. Characterize the battery for capacity, rate of charge and discharge, and operating lifetime.

DUAL USE COMMERCIALIZATION: Commercial applications include hybrid electric vehicles and all types of portable power devices, such as notebook computers and mobile phones. Military applications include onboard power for strategic missiles and satellites.

REFERENCES: 1. N. Li, C. R. Martin, and B. Scrosati, J. Power Sources, 97-98 240 (2001).

2. A. S. Claye, J. E. Fischer, C. B. Huffman, A. G. Rinzler, and R. E. Smalley, J. Electrochem. Soc., 147 (8) 2845 (2000).

KEYWORDS: batteries, lithium battery, nanostructure materials, nanoparticles, nanomaterials, energy storage

AF04-186 TITLE: Thermal Battery with Low Internal Operating Temperatures for Missile Applications

TECHNOLOGY AREAS:

OBJECTIVE: Advance the state of the art of thermal batteries for tactical and strategic weapons applications that require dependable onboard power.

DESCRIPTION: Recent new thermal battery electrochemistries have demonstrated improved high-temperature stability and lower internal operating temperatures. This topic seeks proposals with innovative concepts related to thermal batteries for power generation and energy storage for weapons. Thermal batteries with mission lives measured in hours rather than minutes are possible with the new emerging technologies. Thermal batteries with hangfire and wetstand capabilities are also possible. New, higher voltage cathodes are also needed as well as thermal batteries with cooler skin temperatures. Alternative pyro heat sources are also required for these new technologies. Rechargeable molten salt batteries would be desirable for long missions.

PHASE I: Demonstrate that the proposed design can meet the desired energy and power requirements in a package compatible for thermal battery or molten salt batteries.

PHASE II: Deliverables will include hardware that clearly demonstrates a manufacturable device, component, or system that results in improved existing technology either through exceptionally high performance, significantly reduced cost, or improved robustness.

DUAL USE COMMERCIALIZATION: Commercial applications include providing emergency power for intensive care units, operating rooms, and commercial aircraft. Military applications include onboard power for guided munitions and replacement of environmentally unfriendly hydrazine emergency power units for military aircraft.

REFERENCES: 1. Visvaldis Klasons, “Thermal Batteries,” Handbook of Batteries, 2nd Edition, edited by David Linden, Mc Graw-Hill, (1994), pp. 22.1-22.22.

2. Ron Guidotti, et al., "Screening Study of Lithiated Catholyte Mix for a Long-Life Li(Si)/FeS2 Thermal Battery," SAND85-1737, 1988.

KEYWORDS: thermal batteries, molten salts, missiles, weapons, pyros, electrolytes

AF04-187 TITLE: Hypersonic Sensor Architecture Evaluation, Sensor Testing and Communication Needs

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Development of sensor system architecture needed for hypersonic in-flight testing to characterize flight vehicle and engine performance.

DESCRIPTION: There exists a void in sensor system architecture for hypersonic in-flight testing. In the next few years, the Propulsion Directorate of the Air Force Research Laboratory (AFRL) anticipates performing flight tests of hypersonic engines currently under research and development. In order to acquire in-flight instantaneous data from the vehicle, and more specifically, the engine, a robust sensor system architecture is needed that would be able to withstand the high temperature and high-g encountered in hypersonic flight. The majority of these sensors are off the shelf (OTS). The difficulty lies in the packaging (architecture) of these sensors, given the volume or shape constraints imposed by a vehicle’s configuration. These physical determining factors may force preferential use of one sensor over another, resulting in trade-off(s) between sensing capabilities, communication capabilities, and in extreme cases, small changes in vehicle performance capabilities. The AF project manager will work with the contractor in identifying a potential shape and configuration for the hypersonic vehicle after the award. However, as a starting point, contractors should consider sensing packages for insertion into a vehicle similar in size to the advanced medium-range air-to-air missile.

PHASE I: Many sensor suites are available to the user. Critical engine and flight data can be obtained from an air-vehicle and communicated in-flight to the user; and if necessary from the user back to the air-vehicle. Packaging feasibility of sensor suites for high mach flight will need to be explored for Phase 1: layout carrier frequency(ies) and bandwidth(s) required, define the needed accuracy of the sensors and their dynamic ranges. Sensors and communication suites will have to be robust to withstand high g maneuvers, small volume, lightweight, and possibly multifunctional in their capabilities. For example, operating temperatures will range from 400 degrees R (vehicle exterior) up to or exceeding 2000 degrees R for the engine. Pressures will vary from a few psi (atmosphere) to several hundred psi (working liquids). The Propulsion D irectorate is interested in measuring and acquiring the following data streams: pressure, heat flux, temperature and others that may be offered; however, the initial emphasis will be on innovation in the design architecture and packaging for the severe conditions of a vehicle in hypersonic flight.

PHASE II: One or more prototype sensing system architectures will be designed, fabricated, packaged and tested (objective is to show flight worthiness). AFRL ground-based facilities will be available on a non-interfering basis, to demonstrate and evaluate the improved rugged sensor capabilities, if desired.

DUAL USE COMMERCIALIZATION: A sensor system architecture for hypersonic flights will allow the Air Force to maximize acquisition of in-flight data that is most important for the characterization of vehicle and engine performance. These sensor suites would have the potential to become pervasive throughout DOD/NASA aero-space vehicles. Also, the potential would exist to identify probable system failures before they become catastrophic. These packaged system suites, capable of withstanding the extreme operating regimes experienced by hypersonic vehicles, would easily provide the type of data required by automobile manufacturers (internal combustion and/or future hybrid vehicles) and should ease the costs associated with automobile engine testing and development.

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1. Castracane, J.; Glow, L.P.; Wegener, S.; Seider, G., "64 channel fiber optic spectrometer for a dual wavelength interferometric pressure sensor array," Review of Scientific Instruments, Vol. 66,No. 6; pp.3668-71; June 1995.
2. Kidd, C.T.; Adams, J.C., Jr., "Fast-response heat-flux sensor for measurement commonality in hypersonic wind tunnels," Journal of Spacecraft and Rockets, Vol. 38, No. 5; pp.719-729; September/October 2001.
3. Acton, F., Best, D., Happe, R., Garner, E., "Flight Instrumentation and Sensors," Final Report Date: 01 July 1991; Media Count: 456 Page(s); Contract Number: F33657-86-C-2126; Report Number(s): ASC*-TR-94-9525; XC-NASP (ADB193452).
4. Heiser, W.H.; Pratt, D.T., "Hypersonic Airbreathing Propulsion", AIAA Education Series, 1994.

KEYWORDS: sensors, hypersonic testing, in-flight data acquisition, dynamic pressure, sensor architecture

AF04-188 TITLE: Aero Propulsion and Power Technology

TECHNOLOGY AREAS: Air Platform

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 that offer 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 (nonpropulsive) are focused on advanced techniques for power generation, energy storage, and power management 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 systems (MEMS), and engine related materials technologies. The intention is to enable Mach 8-10 strike/reconnaissance aircraft and provide affordable, on-demand access to space with aircraft like operations. Our current baseline is 6.4 Thrust to Weight, .860 SFC (SLS, Mil Power), $230/pound Fn, and $1300/EFH. Our goals are 12 Thrust to Weight, .74 SFC (SLS, Mil Power), $152/pound Fn, and $845/EFH maintenance (includes depot cost but not fuel costs) by 2010.

Offerors are strongly encouraged to establish relationships with suppliers of the aerospace systems relevant to their research in order to facilitate technology transitions. 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.

PHASE I: Develop the concept and perform analyses and subscale testing to demonstrate the feasibility of the proposed technology. Modeling and simulation are encouraged to guide the research.

PHASE II: Provide detailed analytical derivations and prototypical device or hardware demonstrations.

DUAL USE COMMERCIALIZATION: Military applications include satellite, spacecraft, aircraft, air-launch-missile, legacy fighter and bomber propulsion, and power technology for the military warfighter. Commercial applications include satellite propulsion, space propulsion, and air propulsion for commercial aircraft.

REFERENCES:
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2. Air Force programs to reduce particulate matter emissions from aircraft, Corporan, Edwin; Roquemore, Mel; Harrison, William; Jacobson, Andy; Phelps, Donald, USAF, Research Lab., Wright-Patterson AFB, OH [Corporan], 38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Indianapolis, IN, July 7-10, 2002, AIAA Paper 2002-3722, Reston, VA: American Institute of Aeronautics and Astronautics, Inc.
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4. Propellant requirements for futureNBaerospace propulsion systems AU: Author, Edwards, Tim; Meyer, Michael L, USAF, Research Lab., Wright-Patterson AFB, OH [Edwards], 38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit,
Indianapolis, IN, July 7-10, 2002, AIAA Paper 2002-3870, Reston, VA: American Institute of Aeronautics and Astronautics, Inc.
5. Optical diagnostics for characterizing advanced combustors and pulsed-detonation engines, Gord, J R; Brown, M S ; Meyer, T R, USAF, Research Lab., Wright-Patterson AFB, OH [Gord], 22nd AIAA Aerodynamic Measurement Technology and Ground Testing Conference, Saint Louis, MO, June 24-26, 2002, AIAA Paper 2002-3039, Reston, VA: American Institute of Aeronautics and Astronautics, Inc.

KEYWORDS: turbine engines, high speed propulsion, scramjets, fuels, lubrication, electrical power systems

AF04-189 TITLE: <u>Propulsion Health Management – Future, Legacy, and Integrated Power System Technology</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop integrated propulsion health management (PHM) technology for future and integrated power systems.

DESCRIPTION: Engine health monitoring (EHM) is the basic monitoring of sensed parameters, like pressure, temperature, and speed, and the provision of this data for further analysis. During flight, engine performance data, which may include instrumented readings, are recorded and stored, either as streamed data or data snapshots that relate to specific flight events. After flight, and usually before the next sortie, the data is downloaded and processed. Typically, individual parameters are then plotted against time or speed and presented on two-dimensional graphs for human analysis. Personnel who carry out this work have to assimilate performance and cross-reference charts to provide an assessment of health and usage. These assessments are largely founded on individual experience, awareness of limits to identify threshold exceedances, and historical trending and projection. Timely advice is then provided to maintainers to preserve safety, plan scheduled maintenance, and assist in the selection of the most suitable aircraft for operations. This is a conservative approach that can be improved by direct monitoring and management of propulsion system modules and data generated to improve performance, provide accurate assessments of engine health, and increase the life of the propulsion system. To evolve condition-based maintenance, it is desirable to develop model based systems for diagnostics, information fusion, active component control, virtual sensing capability and calculation of useful remaining service life. There is also a need to provide accurate scheduling of maintenance events based on the calculation of the useful remaining service life. Aerospace power system health monitoring is the basic monitoring of voltage, frequency, and event timing, to evaluate out-of-tolerance limits. Fault logic sets conditions to protect critical components and wiring. Independent monitoring of generator, bus, and load conditions, communication, and storage of fault conditions is also accomplished. Diagnostics and fault protection on state-of-the-art systems can be extensive; however, modern systems do not assess system health. This is especially important in proposed more-electric systems with advanced generator designs. In these systems, failure modes and safety-related issues have not been completely addressed in current research activities. Advanced nnmanned air ehicles for example, will require higher levels of integration between full authority digital engine controls (FADECs) and the electrical power system as well as management of electrical component health and life. Development of PHM technology encompassing the engine control and electrical power system is desired for applications on all future advanced aircraft engines. Further development of integrated engine/power system technology will require modeling of interaction between the power system, engine, and vehicle. Development of novel, efficient architectures may be required in incorporating PHM into these new systems. The approach should consider integration of the PHM system to the engine FADEC. EHM systems must be applicable to upgrading current and future turbine engine diagnostic systems, including analysis, remaining useful service life, and offboard data logging and storage in a data warehouse. It is desired to demonstrate through simulation, the potential capabilities and benefits of employing life and performance models of the electrical system integrated with the turbine engine. Development of methodologies to predict wiring, generator, and control degradation is appropriate.

PHASE I: The objective of the Phase I effort is to evaluate the feasibility of advanced health management technologies for EHM and Integrated Power System Applications. Novel sensors, mathematical algorithms, and architectures, including modeling and simulation at the system level are appropriate. The approach developed should address the suitability of employing an integrated FADEC (Full Authority Digital Engine Control) and EHM system in managing critical propulsion system requirements such as electric power and thermal management.

PHASE II: The goal of the Phase II effort is to develop a prototype design (hardware and/or software) based on the Phase I EHM concepts evaluated. Demonstration of the integrated EHM system should be accomplished using both simulation and test hardware. Applicability of the system hardware and software for a real turbine engine application should be considered.

DUAL USE COMMERCIALIZATION: The commercial applications for this technology are commercial aircraft engine controls, monitoring systems, auxiliary power systems (APUs), and aircraft main electrical power generation. The military applications include ground-based turbine controls, monitoring systems, and electrical power generation.

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1. Hardman, W., Hess, A., and Sheaffer, J., “SH-60 Helicopter Integrated Diagnostic System (HIDS) Program – Diagnostic and Prognostic Development Experience,” 1999 IEEE Aerospace Conference.
2. Bursch Paul, John Meisner, and Mark Jeppson, “Flight Control Maintenance Diagnostic System,” final report March 1993, WL-TR-93-3022.

KEYWORDS: controls, power generation, prognostics, integrated flight propulsion control, turbine engines, life models, engine controls

AF04-190 TITLE: MEMS Based Sulfur Detection for Logistic Fuel-Based Fuel Cell Power Generators

TECHNOLOGY AREAS: Air Platform, Sensors, Electronics, Battlespace

OBJECTIVE: Develop a low-cost method for determining sulfur content in logistic fuel refor-mate effluent.

DESCRIPTION: Currently, fuel cell-based, ground power generators are being developed by the USAF to replace aging diesel systems because the fuel cell replacements are generally more effi-cient, modular, and significantly quieter. Through a series of chemical and electrochemical proc-esses, these units convert military logistic fuel into premium power (Ref 1). The fuel cell cannot tolerate direct injection of JP-8 fuel. Instead, a fuel processor is incorporated upstream which catalytically oxidizes the fuel to hydrogen and carbon monoxide synthesis gas which is the prin-cipal fuel for the fuel cell module. The synthesis gas then continues downstream to the solid ox-ide fuel cell where it is converted to DC current through a high temperature electrochemical mechanism (800°C). Military logistic fuel (JP-8), however, nominally contains 300-400 ppm (max 3000 ppm) sulfur which consists primarily as dibenzothiophenes and related components (Ref 2, 3). If these sulfur containing compounds are not removed, they will permanently adsorb on the process units and cause considerable performance degradation to both the fuel processor and fuel cell elements. As a result, the logistic fuel is initially fed into a sulfur scrubber process unit which preferentially adsorbs sulfur containing compounds thus removing them from the process stream. In order to continuously remove these deleterious species, it is necessary to in-corporate multiple, parallel, regenerable sulfur scrubbing units which are upstream from the fuel processors. These systems operate by selectively adsorbing and removing the sulfur containing fuel constituents, thereby significantly decreasing fuel sulfur content. Once the sulfur scrubber reaches capacity, the feed is directed to a second bed and the saturated bed is regenerated in air. Currently, a timing algorithm, based upon fuel sulfur content, is used to predict when the bed will likely reach saturation. However, if the algorithm is incorrect and sulfur breaks through unpre-dictably, then significant damage will occur to the fuel processor and fuel cell. The USAF is seeking innovative strategies for detecting gas phase sulfur content for various constituents to a level of 10 to 150 ppmv at a resolution of ~1s. The sulfur detection technology must be able to operate at 300-400° and be able to resolve bulk sulfur in a background of aromatic and aliphatic hydrocarbons (Ref 4).

PHASE I: Develop an innovative solution for detecting 10-150 ppmv of sulfur in a gas stream at a resolution of approximately 1 second. The result of this phase will be a bread-board prototype which demonstrates the proposed concept with corresponding data to substantiate that the pro-gram objectives have been met. Submitting an estimate of the performance capability and the an-ticipated size and cost of the finalized device shall be required.

PHASE II: Produce prototypical sulfur detection units which can be readily integrated into the Government's fuel cell-based power generators. Downselected parameters generated under the Phase I effort will be used as the design benchmark for this phase. At the conclusion of this phase, show the device is readily manufacturable. Significant evidence of the contractor's ability to commercialize the proposed device will be required at the conclusion of this phase.

PHASE III DUAL USE APPLICATION: Demonstrate large scale manufacturability of the sen-sor device. Anticipated dual use applications include sulfur detection for commercial fuel cell auxiliary power generators and automobile power plants. Military applications include use as a sulfur sensor for diesel, turbine engine, and fuel cell auxiliary power generators.

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2. Hu, J., et. al., Chemical Engineering Journal, 93, 1, May 15, 2003, pp. 55-60.
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4. Maurice, L.Q.; Lander, H.; Edwards, T.; Harrison III, W.E., Fuel Volume: 80, Issue: 5 April, 2001, pp. 747-756.

KEYWORDS: JP-8, sulfur, fuel cell power generators, fuel processing

AF04-191 TITLE: Analytical Diagnostic Tools for Heat Utilization Effects on High-Speed Aircraft

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Design and demonstrate predictive tools, sensors, and control logic that make it possible to optimally meter hydrocarbon fuel as it undergoes changes in thermodynamic state and chemical composition in a heat exchanger/cracker.

DESCRIPTION: As the flight envelope of high-speed aircraft continues to expand, the demand on aircraft fuel as the primary airframe/engine heat sink increases dramatically. Existing high-performance aircraft use fuel to cool engine oil, structural components, and aircraft electronics. After performing these functions, the fuel, heated hundreds of degrees, is then injected into the engine combustor. This amount of heat load does not substantially affect the fuel composition or physical properties. Therefore, conventional metering devices and techniques are adequate. In contrast, next-generation long range strike aircraft and hypersonic vehicles will subject the fuel to enormous heat loads (a factor of ten increase from current heat loads), resulting in significant changes in chemical composition and physical properties. Proper fuel metering will be a tremendous challenge as the fuel undergoes these changes throughout the flight profile. New analytical tools (sensors and control logic) must be developed in order to achieve optimal fuel metering to the combustor despite the thermal decomposition of the fuel. Metering instrumentation must be developed to route fuel to heat exchangers or the engine based on the fuel's remaining available heat sink capacity and its gravimetric energy content. Potential coking of fuel injectors and over/under fueling during transients must also be controlled.

PHASE I: Design analytical tools (predictive methods and sensors) for evaluating the energy content of the fuel – remaining thermal capacity and/or gravimetric heat content. Identification of its major constituents may be sufficient to determine the extent to which it has been cracked and provide a reasonable estimate of its molecular weight for proper metering. In any case the measurement must be rapid, robust, and of size and weight consistent with in-flight application.

PHASE II: Experimentally demonstrate control of a fuel heat exchanger/cracker and optimal metering of hydrocarbon fuel to a combustor as the heat load is varied. Control should be sufficient to set total fuel flow to the heat exchanger based on the fuel's remaining heat sink capacity. It should also be able to set an engine bypass flow rate if the total fuel energy exiting the heat exchanger exceeds the demand of the combustor. This level of control should be demonstrated for a range of heat flux from several hundred to 2000 BTU/pound fuel. AF facilities will be made available to the contractor in order to complete Phase II testing.

DUAL USE COMMERCIALIZATION: This technology is relevant to any hydrocarbon fuelled engine in which thermal demands of the engine/airframe structure exceed the ability to cool with ingested air. Generally, this cooling problem occurs above Mach 2.5. Military aircraft clearly want to operate above the 2.5 limit. Space access vehicles will also operate well above that limit. The most immediate commercial use of this technology will be to lower the cost of access to space. This technology will be relevant to NASA's future flight vehicles. Beyond that, in lower speed applications and ground power generation, the ability to track the chemical state of a fuel will be valuable as a system diagnostic tool. Realistically, one could look for contaminants within the fuel in place of the low molecular weight products of the cracking processes.

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2. "Measurements of Scramjet Engine Performance by Gas Sampling," AIAA-98-1590.
3. Developments in High-Speed-Vehicle Propulsion Systems, Progress in Aeronautics and Astronautics, Vol. 165, AIAA Publications.
4. High-Speed Flight Propulsion Systems, Progress in Aeronautics and Astronautics, Vol. 137, AIAA Publications.

KEYWORDS: fighter aircraft, turbine blades, film cooling, endothermic fuels, heat exchangers, high temperature fuel metering, precombustion shock

AF04-192 TITLE: Self-Powered Wireless Micro Electro Mechanical Systems (MEMS) for Vibration Monitoring

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Development of an integrated MEMS device that will have power, sensing, and data transmission while maintaining affordability.

DESCRIPTION: The ability to instrument a component relatively nonintrusively, quickly, and affordably is becoming possible by using MEMS technology. Using mass fabrication techniques, the cost of sensors will decrease at the same time the instrumentation costs also decrease. Lower cost enables more instrumentation during flight evaluation or can be included in a distributed network health management system. The vision is to create a postage stamp sensor that can be applied and acquire data, yet be affordable enough to be disposable as sensors fail. MEMS sensors, power storage, and telemetry already exist, but reducing the size and price to fit the goals of the effort is currently unavailable. The package will use a MEMS accelerometer representative of the current state of the art commercial sensors (±5g with 1% error and at least 10kHz bandwidth, 2mA at 3-5V power usage). The battery will power the device for at least 2 months with 3 hours sensing and transmitting a day. The telemetry unit will wirelessly transmit the real-time accelerometer data using Bluetooth or similar technology.

PHASE I: Design a breadboard-level system consisting of current technologies that would demonstrate the ability to connect the separate systems into a functional wireless powered sensor.

PHASE II: Develop prototype sensor that will optimize the Phase I system into an integrated system.

DUAL USE COMMERCIALIZATION: Military uses include sensing for health management, test sensing, or remote detection in military vehicles or space applications.

Commercial uses are for automotive engine performance sensing, power plant health management, and commercial aviation.

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March 2, 1998 San Diego, CA.

KEYWORDS: MEMS, distributed networks, sensors, wireless telemetry, size minimization.

AF04-193 TITLE: Solid-State Electrolyte for High Pulse-Power Energy Sources

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a single ionic conducting polymer electrolyte specifically for lithium ions where ion transport depends primarily on an electric field gradient instead of polymer segmental motion.

DESCRIPTION: Proposals are sought with advanced and innovative concepts related to developing a single ionic conducting polymer electrolyte specifically for lithium ions where ion transport depends primarily on an electric field gradient as would be encountered in a 3- to -5 volt lithium battery. Polymer electrolytes to date have been based primarily on alkyl-ethers such as polyethylene oxide (PEO). Lithium salts are added to the alkyl-ethers to form the polymer electrolyte. This being the case, these electrolytes are dual ion conductors where the contribution of the lithium ion to ionic conduction is estimated to be on the order of 30 to 50 percent. In this type of electrolyte, ion transport depends primarily on polymer segmental motion. The room temperature ionic conductivity for a PEO-based electrolyte is on the order of 10–8 S/cm. Attempts at preparing a single lithium ion conducting polymer electrolyte where the anion of the lithium salt is attached to the polymer backbone has also resulted in very low ionic conductivities at room temperature. Nonaqueous liquids can be added to these electrolyte compositions to improve ionic conductivity; however, under these conditions, dimensional stability of the electrolyte as well as increased electrode/electrolyte interfacial resistance can strongly affect electrochemical cell performance. To minimize or eliminate these problems, the emphasis of this investigation is to develop a low dimensional fast ion conductor specifically designed for lithium ions that does not depend on polymer segmental motion for ion transport. This can be accomplished if ion transport is dependent upon the electric field gradient established between the anode and the cathode. This being the case, one could anticipate very good low temperature ionic conductivity that cannot be attained in present polymer electrolytes without resorting to the use of nonaqueous liquid additives. This is important because one of the primary applications for this electrolyte in a rechargeable lithium battery is for space-based radar where the battery would have to function at temperature extremes, such as –40 °C or +90 °C. In addition, the battery must have a high cycle life that is consistent with mission parameters.

With this development, the solid-state electrolyte can function over a broad temperature range, thereby enabling rechargeable lithium batteries to meet a broad spectrum of mission requirements. The technology developed under this topic will be useful for computer equipment, communications equipment, land, sea and air vehicles (manned and unmanned), and for advanced weapons power.

PHASE I: Describe a technical approach in order to develop this type of electrolyte and provide experimental data that validates the approach.

PHASE II: Fabricate rechargeable lithium cells with this electrolyte and evaluate electrochemical performance characteristics as a function of cycle life at 100 percent depth of discharge.

DUAL USE COMMERCIALIZATION: The technologies developed for high-energy-density batteries are for space applications. Commercial applications can be used for cellular phones and lap top computers.

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KEYWORDS: energy storage, batteries, electrochemical energy storage, solid-state electrolyte, lithium, lithium ion

AF04-194 TITLE: <u>Fuel Cell Power System with Parallel-Connected Bi-directional DC-DC</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a space power system employing fuel cells and fast-responding control electronics.

DESCRIPTION: Fuel cells have shown promising potential for several areas of applications such as remote communication facilities or remote-ground support stations. Coexistence of solar array source and fuel cell technologies makes the fuel cell source renewable and environmentally safe by using the electrical energy from the solar array source to convert the consumed fuel (such as water) back to the usable fuel (such as hydrogen gas). However, fuel cell energy sources require a much more complex controlling scheme that must ensure efficient and robust power transfer from the sources without risks of their rapidly degraded reliability due to prolonged over-current and/or under-voltage conditions. The power architecture and control scheme dedicated for fuel cell sources must provide a smooth power flow to the load. This requires a bi-directional dc-dc converter that interfaces between a standby battery and the system output bus connected to the fuel cell source. Bi-directional power flow through the fuel cell source must be prevented by a protection diode. Otherwise, the reverse power flow into the fuel cell source can cause damage or dramatically shorten its operating life. During light or typical load conditions, the fuel cell source can supply most or all of its power to the load, and at the same time some or none of its power to charge the standby battery through the bi-directional dc-dc converter. During peak heavy load conditions, the system controller enables the discharge mode of operation in which additional power is transferred from the standby battery through the bi-directional converter to support the load demand, thereby, preventing the operation of the fuel cell outside its undesirable operating regions. During any blackout or brownout state within the fuel cell source, the controlled bi-directional converter must react quickly to fulfill the load demand and to sustain the system bus voltage, thereby, sufficiently preventing a subsequent over-current which can occur immediately after disappearance of the blackout or brownout state. Under a fast over-current or a short-circuit condition across the system output bus, the system controller must immediately disconnect the fuel cell source from the bus and at the same time enable a current-limiting operation through the bi-directional converter to prevent an excessive current drawn from the battery. The system bus voltage should be properly regulated at a slowly adjustable voltage that is compatible with an optimum output voltage of the fuel cell source such that the system achieves a maximal energy conversion efficiency of fuel supplied to the fuel cell source without degrading its reliability. During repetitive pulsating or turbulent load conditions, the controlled bi-directional converter should quickly absorb most of the load ripple current and allow for very smoothed current drawn from the fuel cell. For future expansion, the bi-directional dc-dc converter should be constructed from parallel-connected converter modules that can have their inputs and outputs, respectively, parallel-connected or only parallel-connected outputs with their distributed inputs dedicated to the respective distributed standby battery banks.

PHASE I: Determine technical feasibility of various power architecture approaches that yield high efficiency of at least 95 percent. Identify the best system control approach for a medium and high power fuel cell, determine the power system design blocks to achieve the robust system performance, stability and reliability, and validate the concept of the proposed fuel cell power system.

PHASE II: Design all the power system components, build a prototype, and validate by testing.

DUAL USE COMMERCIALIZATION: Anticipated military applications include use in remote telecommunication stations or space-and-ground support facilities. Commercial applications include utility, commercial launch facilities, and onsite power.

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KEYWORDS: Fuel cells, dc-dc converter, bidirectional converter, energy conversion, power source, standby battery

AF04-197 TITLE: Improved Jet Canopy Properties Through Hybrid Polymers

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Synthesis and processing of POSS-polycarbonates to improve physical and mechanical properties of polycarbonates [also enhance compatibility with methacrylates and POSS-methacrylates].

DESCRIPTION: Over the last nine years the Air Force Research Laboratory (AFRL) has invested in an innovative new polymer technology (POSS = Polyhedral Oligomeric Silsesquioxane) that results in dramatic property enhancements when blended, grafted or copolymerized into almost any polymer system. One area of focus involves studying how the incorporation of POSS improves the use temperature of methacrylate polymers, and how such technology could increase the capabilities of plastic jet canopies. Polycarbonates also play a key role for plastic canopies, and have the similar upper use temperature lim-its. It is the goal of this program to develop the POSS monomers and POSS-polycarbonates, followed by extensive testing to show the improvement in critical properties (e.g., stiffness, fracture toughness, and abrasion resistance) of the polymer system as applied to a jet canopy. In addition, demonstrated com-patibility with methacrylates and POSS-methacrylates is recommend since mixed polycarbon-ate/methacrylate systems have tremendous commercial applications. Demonstration that the copolymeri-zation/condensation to form a POSS-polycarbonate on a significant scale (>100g) along with written plans detailing scale-up and subsequent cost reduction is required. Current physical and mechanical properties of the POSS-polymers will be provided to the interested parties.

PHASE I: A successful Phase I would demonstrate the synthesis of POSS-polycarbonate copolymer and provide full physical/mechanical characterization of the material. In addition, the program would also demonstrate processability of the material and provide compatibility testing data with methacrylates and POSS-methacrylates. Finally, a successful program would scale up the synthesis to >100g/batch, demonstrate small-scale processability to form a part by heating & bending, demonstrate small-scale cost reduction, and provide list of required properties for canopy implementation.

PHASE II: A successful Phase II would fully optimize the material properties of targeted POSS-polycarbonate and demonstrate optimization by providing data of full physical/mechanical characterization of POSS-polycarbonate. In addition, the materials production should be scaled-up to a larger-scale with delivery of no less than a 1 Kg batch. Large-scale processability by heating& bending (4'x8' sheet), 10 time price decrease in POSS-polymer should also be demonstrated.

DUAL USE COMMERCIALIZATION: Military applications of POSS-polycarbonates include superior high-temperature jet canopies, bulletproof glass, and military face-shields. Commercial examples include bulletproof glass, lenses, signs furniture, illuminated consoles, windshields and appliance parts.

REFERENCES: 1. Haddad, T.S.; Mather, P.T.; Jeon H.G.; Phillips, S.H. "Hybrid Inorganic/Organic Diblock Copolymers. Nanostructure in Polyhedral Oligomeric Silsesquioxane Polynorbornenes," Organic/Inorganic Hybrid Materials III, Edited by: R. Laine, C. Sanchez, E. Giannelis and C. Brinker, Materials Research Society Symposia Proceedings, 2000, 628.

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5. General information on the Propulsion Directorate can be found at: http://www.pr.afrl.af.mil

KEYWORDS: polymers, Polyhedral Oligomeric Silsesquioxane (POSS), silsesquioxanes, jets, plastics, canopy, methacrylate, polycarbonate

AF04-198 TITLE: High Power Hall Thruster Technology Development

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop "high power" Hall thruster technologies that improve thruster operating characteristics and 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. 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 missions, multiple Hall systems operating at powers exceeding 20 kW are envisioned. These high power levels are especially applicable for communications satellites, where high on-board power availability enhances the primary mission. 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: Identify and evaluate candidate technology improvements applicable to 10 kW and greater thruster power. Perform initial validation of high payoff concepts through analysis and/or test. Develop preliminary designs implementing the selected technologies.

PHASE II: Deliver a full scale prototype Hall thruster at a power greater than 10 kW.

DUAL USE COMMERCIALIZATION: High power Hall thrusters will find military applications by providing propulsion for orbit transfer vehicles and for repositioning large DoD space assets. The primary commercial application will be in performing orbit raising for final insertion of large geosynchronous communications satellites.

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.

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KEYWORDS: Electric Propulsion, Hall Effect Thruster, Anode Layer Thruster, Stationary Plasma Thruster, Orbit Transfer, Total Impulse, High Power

AF04-199 TITLE: Advanced Rocket Propulsion Technologies

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Establish progressing concepts, operating systems, and combine technical methods that will significantly enhance rocket propulsion for the next ten years.

DESCRIPTION: Present bold concepts to modify current abilities that will dualize current rocket propulsion opportunities in the next ten years. These fresh concepts will be the foundation for research in the future. Base thoughts on legitimate mathematical, aeronautical, astronautical, and chemical principles. Use indicators of excellence to raise the outcome of laboratory achievements and diminish the costs of operations. The new approaches are beneficial to all areas of the military community. If the new approaches incorporate existing technologies from the civilian community – this is considered to be ‘a plus.’ The program's main aspiration is to raise the specific impulse and mass fraction for propulsion while reducing the stage failure rate. Reduce program costs through significant halving in the area of production and hardware manufacture is encouraging. Scale up thrust-to-weight ratio for liquid rocket engines whenever possible. Increase the total impulse to wet mass ratio for electrostatic and electromagnetic satellite propulsion systems for all systems. Double the effectiveness of density impulse of monopropellants for satellite propulsion systems. In the current stage of worldly concerns, an advance in technical contribution that is environmentally friendly is most advantageous to the military community. Advancements in the daily maintenance of rocket systems lower hours for preparation and diminish expenses for preparation. Enhance the delivered energy of tactical missile propulsion systems. Limit additional environmental hazards or constraints caused by new propellant materials or manufacture of rocket motors while exceeding the existing propulsion efficiency for all systems. Enhance daily tasking and sustainability of cost-effective space launch applications. An example of such a concept may include establishment of a beamed energy vehicle concept. This new development should withstand the thermal and aerodynamic stresses encountered during flight into space. The fabrication of the design can encompass lightweight ceramic and composite materials. These materials are incorporated into the conception and establishment of advanced air inlet designs. This system is dependable and maintained at a high level of operation. Many applications of technical processes increase the operability of sensors, displays of exhaust plume radiation, combustion identification, propellant, and service life indicators. Use state of the art concepts that embody topics of advanced fuels and oxidizers, nuclear isomers, nanotechnology innovations, and applications for beamed energy propulsion. Opportunities for research in highly developed propulsion topics is included and framed 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 FY03 Small Business Innovation Research (SBIR) topic shall not be considered for this topic.

PHASE I: Continue research and form the thought process demanded to conduct measurements for certain hypothesized methods. Modeling and simulation are needed to monitor the measurements of equivalents.

PHASE II: Finalize the design from Phase I and generate technologies for a demonstrator or prototype that will give indicators and demonstrate that the measurements are valid. Garner a technology improvement method for operations in the future that may also be applicable to commercial interests.

DUAL USE COMMERCIALIZATION: Advanced rocket propulsion technologies will move toward ultimate achievement. Transition to prominent performance and diminish the expenses to the U.S. military and U.S. aerospace industry.

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KEYWORDS: Rocket Plume, Rocket Engine, Rocket Propellants, Satellite Propulsion, Beamed Energy Propulsion, Boost Transfer, Orbit Transfer

AF04-200 TITLE: Nanomaterial Reinforcement for High Strength Solid Rocket Motor (SRM) Case Materials

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a new high strength case resin and demonstrated compatibility and good translational strength with a sustainable fiber for SRM Boost and Orbit Transfer casing.

DESCRIPTION: In order to succeed systematic improvements of every component area are required including a significant increase in the strength of current composite cases, which also means high strength resins and good resin/fiber interaction. The resin/fiber system is only limited to demonstrated sustainability (e.g., various uses in industrial marketplace) and must have delivered strength and compressive stress significantly greater than 800 Ksi and 20Ksi, respectively. Complete resin characterization of the polymer system (thermal, mechanical, electrical, physical properties) should be followed by resin/fiber compatibility studies and small pressure bottle fabrication and testing. Demonstration of reinforcement from the nanomaterial incorporation is required along with analysis of processing and dispersion. Preliminary cost and weight reduction analysis, commercialization efforts, and tie-in to rocket component leads are critical. Innovative programs will look at ways exceeding the temperature and stress requirements.

PHASE I: Develop a high performance resin, demonstrating high delivered strength/compressive stress, and small pressure bottle testing at use temperature.

PHASE II: Integrate the use of the new high-strength resin for a SRM demonstrator and show transition pathways.

DUAL USE COMMERCIALIZATION: The Military Application is for Solid Rocket Motor Casing for Minuteman III and Minuteman IV. The primary civilian commercialization application is for replacement of heavy metal liquid propane/natural gas tanks with lightweight, high strength composites.

REFERENCES: 1. Thermoplastic Composite Materials. L. A. Carlsson, ed., Elsevier, NY, 1991.

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KEYWORDS: Materials, Resins, Rockets, Casing, Composites, Pressure Vessel

AF04-203 TITLE: Real Time Cueing and Identification – Coherent Combining

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop and evaluate advanced software algorithms for identifying non-cooperative airborne targets by integrating Coherent Combining techniques.

DESCRIPTION: Radar signal processing ID techniques, unlike ID systems that only provide identification of cooperative targets, enable identification of non-emitting, non-cooperative aircraft. Techniques developed on the Real Time Cueing and Identification (RTCID) program were shown to provide long range ID capability for S-Band surveillance radar. However there were limitations to the capability for several target types due to the short dwell time of the radar. To correct this shortfall, a technique known as Coherent Combining was conceived. The development of Coherent Combining would enhance non-cooperative ID capability to provide effective long-range non-cooperative identification for all known target types.

PHASE I: Develop the Coherent Combining software, and will define the necessary data evaluation and data collection required to effectively evaluate the new ID software/algorithm.

PHASE II: Integrate Coherent Combining with existing ID software, then evaluate the combined ID software/algorithm using recorded radar data.

DUAL USE COMMERCIALIZATION: User interface and systems integration into an operational weapons system will be completed. Real-time performance of the new ID software/algorithm will be verified. Operational measures of effectiveness will be evaluated. It may also be possible to implement this Target Identification technique in FAA Air Traffic Control radars to identify the target type for incoming aircraft not responding to IFF.

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KEYWORDS: Combat Identification, non-cooperative target identification, signal processing

AF04-204 TITLE: Innovative Filtering Techniques for Ground Target Tracking

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop practical single and multiple ground target tracking algorithms that account for real world non-linearity to improve ground target tracking performance.

DESCRIPTION: Intelligence, Surveillance and Reconnaissance sensors are key contributors to forming a Common Operational Picture of the battlefield. The Kalman filter and extended Kalman filter (EKF) are widely used to track targets observed by these sensors. These filters depend on assumptions about linearity and Gaussian nature of the dynamic and measurement models and probability distributions. In many real world tracking problems these assumptions do not hold. A number of factors contribute to this including; low signal to noise, clutter, target obscurations, low update rates, closely spaced groups of targets and vehicles moving on roads and in less trafficable regions. Ad hoc measures have been introduced to attempt to ameliorate these problems, with varying degrees of success. Recently, various approaches to non-linear filtering have become, or are becoming, computationally tractable. This effort is for development novel tracking algorithms for multiple ground moving targets. These algorithms should properly take into account non-linearity introduced by target motion on road networks and less trafficable regions. They should also show improvement in tracking performance for low update rates, low signal to noise, clutter and target obscurations.

PHASE I: Develop innovative, efficient and practical single target and multiple target tracking algorithms for ground moving targets accounting for non-linearity introduced by real world effects. Address motion on road networks and less trafficable regions. Demonstrate the filtering and multi-target tracking algorithms using simulated data and realistic scenarios for a small number of targets. Compare the performance and computational complexity of these algorithms with extended Kalman filters (EKF). Demonstrate the advantage of these algorithms over the EKF.

PHASE II: Demonstrate the multi-target multi-sensor tracking algorithms for realistic ground target tracking scenarios involving GMTI data. A detailed comparative evaluation of these algorithms with a conventional tracker using an EKF and an interacting multiple model (IMM) should be performed for determining the transition of this technology to operational systems.

DUAL USE COMMERCIALIZATION: Military applications are surveillance of ground moving targets and precision target tracking. Commercial applications include tracking coronary vessel centerlines in angiograms.

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KEYWORDS: ground target tracking, nonlinear filter, particle filter, track before detect, clutter, group tracking

AF04-205 TITLE: Environmentally Driven Signal Processing Technology for Overland Height Finding

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop algorithms to provide critical overland, low target height-finding capability to airborne ISR radar sensors which presently have either minimal or no target height finding capability.

WARFIGHTER IMPACT: Accurately detecting and tracking low, slow flying airborne vehicles is a key operational requirement in the Multi-Sensor Command and Control Constellation (MC2C) arena that must be, but currently is not, met by conventional ISR radar sensors due in part to lack of available vertical antenna aperture. The warfighter effectiveness can be improved by significantly greater detection sensitivity against small RCS targets and substantially improve elevation angle measurements, applicable to hand-over to fire control systems, without requiring a corresponding increase in power/aperture product.

DESCRIPTION: Airborne surveillance platforms often lack vertical antenna aperture precluding any meaningful direct angle measurement. For example, the E-3C (AWACS) employs direct elevation beam steering, but at best provides only a crude estimate of target height. For low altitude targets, the signal is corrupted from multipath reflections off the earth's surface. Many multipath reduction techniques have been proposed in the area of array signal processing, including digital beamforming techniques such as Minimum Variance and Maximum Entropy methods and related procedures for estimating positions of both the target and its image. These procedures show promise in cases where the target signal-to-noise is high, reflections are purely specular, and the target and its image are uncorrelated in range. These methods fail when the diffuse reflections are significant and the target and/or its image are highly correlated as in the very low-elevation case, and don't take into account environmental effects such as ducting. More importantly, the multipath signal contains useful information and thus measurements can improve if this information can be used rather than suppressed.

High fidelity modeling has progressed to the point where predictive knowledge of the environment can be used to substantially improve the performance of radar sensors, and further extract critical position data that ordinarily would not be available using conventional processing methods. This topic focuses on the application of advanced signal processing techniques that use a computation tropospheric propagation model to enhance detectability of low flying targets and provide precise estimates of target altitude by virtue of the external interactions of the target with the earth's surface and propagation channel. These techniques should be compatible with augmented AMTI signal processing such as Space-Time Adaptive Processing (STAP) and be applicable to both monostatic and bistatic radar applications.

PHASE I: Investigate advanced signal processing algorithms for altitude estimation of low flying targets using existing airborne surveillance radar assets based upon predictive knowledge of the environment.

PHASE II: Evaluate and refine algorithms and perform sensitivity analysis quantifying dependence of errors on the accuracy of environmental knowledge for a significant number of geo-specific environments. Provide hardware and software specification to incorporate into an operational system.

DUAL USE COMMERCIALIZATION: The innovative technology developed will have direct benefit to significant sensor problem areas, including height finding, ESM tracking, sensor evaluation, hot clutter mitigation and ATR/Foliage Penetration systems. This will enable future tactical implementations involving precision hand-over from surveillance systems in the MC2C to fire control assets, such as forward pass, OTH targeting and defensive ESM.

It is anticipated that cartographic data derived directly from geo-specific remotely sensed imagery will be used to drive the advanced signal processing algorithms. With continued advances in computing hardware and software, remote sensing and its kindred information technologies, such as Geographic Information Systems (GIS), could be directly inserted into tactical systems as a result of this applied research.

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KEYWORDS: Signal Processing Techniques and Algorithms, Multipath Reduction Techniques, High Fidelity Modeling, Height Estimation.

AF04-207 TITLE: Adaptive Hyperspectral Sensor Designs

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop designs for the next generation of hyperspectral systems that are capable of fast response measurement of the temporal evolution of the spectra of rocket plumes, aircraft plumes, and other energetic point target events.

WARFIGHTER IMPACT: Full spectrum coverage, broad area coverage, real time ISR, and more effective Battle Damage Assessment have been long standing Air Force ISR needs which this MASINT/HSI system/technology will address.

DESCRIPTION: Hyperspectral imagers sense intensity of radiation both spatially and spectrally; and are an emerging sensor technology that has shown significant promise for a broad range of military reconnaissance, surveillance, and targeting missions. Research and development in the hyperspectral area has primarily focused on air-to-ground and space-to-ground reconnaissance of stationary military targets and terrestrial backgrounds. Military scenarios often evolve rapidly, and there is significant untapped potential in the application of this technology towards surveillance missions of transient signals and rapidly occurring events such as explosions, rocket launches, low contrast aircraft, cruise missiles, and artillery fire. The primary reason this application has not received significant attention is that it demands a wide field of view large format array imager with near continuous area coverage capability. The sensor also needs a rapid spectral sample rate. These requirements cannot be met with the current state of the art conventional hyperspectral sensors.

PHASE I: Develop system or component design for a hyperspectral system that combines advances in mathematical algorithms with adaptive sensing capabilities.

PHASE II: Develop a proof of concept hyperspectral sensor based on the phase one design.

DUAL USE COMMERCIALIZATION: Transition proof of concept system to commercialization for military and civilian applications.

Dual Use: Military reconnaissance, surveillance, and targeting missions. Medical imaging/diagnosis, geological/environmental survey applications

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KEYWORDS: Hyperspectral, Temporal Evolution, Chromotomographic,Spectra

AF04-208 TITLE: Improved Missile Launch Detection Techniques (IMLD)

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop a passive technique to improve missile launch detection performance by enhancing the discrimination between missile launches and bachground clutter.

DESCRIPTION: The Missile Launch Detection (MLD) system must detect both surface-to-air missile launches and air-to-air missile launches in heavy clutter bachgrounds. Achieving high probabilities of detection and declaration of ground launched and air launched missiles with low probabilities of false alarm is a challenging task for the MLD. The amount of data being processed is very large and the ability to discriminate between real missile launches and false alarms is extremely difficult. Operating in many different locations with different types of background and mant types of potential false alarm sources adds to the challenge for the MLD. The key to achieving high probability of detection and declaration is the abvility to reject clutter and false alarm sources. One method to do this is to use the motion of the targets in relationship to the background. A passive, optical detection mechanism based on the motion of objects within the field-of-view is unique and does not have the pitfalls of traditional detection techniques. Regardless of their spectral, thermal, or spatial characteristics, stationary background objects are rejected while moving objects can be automatically detected. This detection enhancement / algorithm would be added on to the existing MLD system.

PHASE I: Determine the technical parameters of the MLD system and perform analysis to determine the viability of an improved missile launch detection technique for the MLD while considering the performance characteristics of the aircraft i.e. speed, operational altitude, roll rates etc. Perform a limited demonstration of the ability of the improved MLD technique by processing representative MLD flight test data with the IMLD algorithm operating standalone. Define a preliminary design for the improved MLD technique.

PHASE II: Develop a prototype suite of software to implement the Phase I approach. Demonstrate the technique's performance while incorporated into a complete detection, tracking and declaration algorithm suite using real flight test data from the MLD system. Using these results, develop a preliminary design for a Phase III system implementation.

DUAL USE COMMERCIALIZATION: The technology developed would significantly improve the performance of any optical detection system that is trying to detect moving objects. Intrusion detection / border protection and commercial IR search and Track (IRST) systems are potential applications.

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KEYWORDS: Missile Launch, Detection Techniques, Target Discrimination, Optical Detection

AF04-209 TITLE: Combat Identification for Difficult Targets

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop information fusion methodologies to support identification and recognition of difficult targets (e.g., camouflage, concealment, and deception) by combat air platforms in realistic scenarios.

DESCRIPTION: The Air Force Research Laboratory (AFRL) is investigating technologies that would provide reliable combat identification for engagement of ground targets by combat air platforms. These platforms are often ingressing toward the target area at high velocities and low altitudes; This limits their ability to employ sensors and identify a target. Further, it is often desirable to limit communication just before a strike so that the platform may stay covert. Ideally, one would like to get reliable identification of target type despite these relatively difficult conditions. To address this reliable identification problem, the Air Force Research Laboratory and the Joint Strike Fighter System Program Office have begun to develop a Reliable Combat Identification for Surface Targeting (RCIST) program concept. However, the RCIST effort does not address difficult targets when camouflage, concealment, or deception (CC&D) techniques are employed to protect the target.

New innovations are required in order to accurately identify difficult targets for strike operations. Clearly, one key to success may be to increase sensor dimension not just sensor resolution by combining information from multiple sensors. If possible, association of difficult targets with past information (possibly when the same target was in the open) may provide some assistance. Issues to be examined include how to cue the strike platform from offboard information (More complex missions/scenarios will likely require passing data from offboard intelligence and surveillance assets to strike platforms) and handling communication limitations for the particular scenario at hand. Technical considerations such as how to combine diverse sensor information from multiple sensor types (this may include Synthetic Aperture Radar, High Range Resolution Radar, Forward-Looking Infrared, Laser Radar) and how to manage sensors to effectively obtain identification should also be considered

PHASE I: Develop, test, and document a feasibility concept for an example problem. Establish current baseline capabilities for detection, identification, and engagement of concealed targets in realistic battlefield conditions. The Government will help to identify and provide scenarios, descriptions, analytical models, and software tools that can be used to conduct the research.

PHASE II: Develop a prototype system and demonstrate its utility for recognition of hidden targets and an appropriate commercial use (to be determined in consultation with the government). Refine integrated fusion/resource management methods based on findings in Phase I. Characterize system performance via simulation for an assortment of mission scenarios involving multiple platforms, numerous sensors of disparate type, and realistic operational concepts. Identify limitations of the designed system and cite avenues for future research.

DUAL USE COMMERCIALIZATION: The development of robust fusion and resource management methods for detection, identification, and engagement of hidden targets has application to many commercial fusion domains. Detection and identification of faulty machines/processes in manufacturing operations may require fusion processing and intelligent re-routing of process resources (e.g., resource management). Intelligent vehicle control systems can also benefit from sound fusion/resource management methodologies.

REFERENCES: 1. E. Waltz and J. Llinas, "Multisensor Data Fusion", Artech House, 1990

2. J. Manyika and H. Durrant-Whyte, "Data Fusion and Sensor management: An Information Theoretic Approach", Prentice Hall, 1994.

3. S. Blackman and R. Poploi, "Design and Analysis of Modern Tracking Systems", Artech House, 1999.

KEYWORDS: Multi-sensor Fusion, Automatic Target Recognition, Concealed Targets, Concealed camouflaged Decoy (CCD), Strike Aircraft, Intelligence, Surveillance, and Reconnaissance (ISR)

AF04-210 TITLE: NCID

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Laser-based identification derived from designator laser or designator-class laser

DESCRIPTION: Detection and identification of similar class military targets can be extremely difficult, especially at extended ranges. The wide variety of deployment scenarios further complicate this effort. Existing DoD investments in inventory aircraft also limit possible solutions. This effort would investigate innovative ladar techniques or exploitation methods for target detection and identification. Solutions should focus on either of the following approaches with consideration given to future cost of modifying existing aircraft. First, Develp novel techniques to exploit as many target identification discriminants as possible without significant modification to the existing designator laser. Discrimimants to be considered include but are not limited to 1D, 2D, 3D, vibration, polarization. Highest prioty will be given to novel techniques capable of exploiting multiple phenomenologies. Second, if there is a compelling need to replace the designator laser because of either significant improvement in detection capability, develop multifunction ladar transceiver which represent nearly form fit replacements of the laser. Designation functions must be maintained. Engineering a laser to fit in the space allowed for the designator laser is not required as part of the Phase I effort; however, a design which shows a path to miniaturization should be presented. Exploitation techniques may include automatic target recognition, signature enhancement and extraction, multi-signature fusion, or target reconstruction techniques.

PHASE I: Candidate concepts will be developed and evaluated for feasibility and efficacy. Design, implement and assess critical component technologies or algorithms to provide proof of concept for the approach. Determine approach utility and feasibility and perform tradeoff analysis for airborne applications. Phase I will culminate with generation of performance specifications and a preliminary design for the Phase II effort.

PHASE II: Design, implement and demonstrate the advanced ladar technique and supporting hardware including transceiver and processing platform. The transceiver need not conform to JSF form-fit requirements, but traceable pathway to JSF implementation must be demonstrated. Demonstrate the technique/transceiver through field trials and perform utility analysis and develop operational sensor/algorithm specifications.
Although the system may not be fully flight qualified, the device should be adaptable so that it could be flown in an airborne demonstration. Therefore, consideration should be taken of size and shape as well as prime power and cooling requirements.

DUAL USE COMMERCIALIZATION: Potential Phase III applications for this technology could be the Air Force "Targets Under Trees" program and Reconnaissance/surveillance missions aboard UAV's and other, smaller vehicles. Additionally, many airborne applications for laser radar have counterparts within industry (e.g. terrain following/ obstacle avoidance could be applied to autonomous vehicles, mapping and natural resources management efforts). The systems demonstrated in this program could be readily adapted to these commercial markets.

REFERENCES: 1. "1 Dimensional Direct Detection LADAR Signatures and Automatic Target Recognition for ERASER (Enhanced Recognition and Sensing LADAR) Utility Analysis," Lawrence J. Barnes, Matthew P. Dierking, Fredrick Heitkamp, Clare Mikula (IRIS, March 1998)

2. L.B. Wolff, "Applications of Polarization Camera Technology," IEEE Expert, 10:5, p. 30.

3. Steinvall, O., H. Olsson, G. Bolander, C. Carlsson, D. Letalick, "Gated viewing for target detection and target recognition." Proceeding of the SPIE, Conference on Laser Radar Technology, Apr 1999, v3707 pp. 432-448.

4. Hutchinson, J.A., C.W. Trussell, T.H Allik, S.J. Hamlin, J.C. McCarthy, M.S. Bowers, M. Jack, "Multifunction laser radar." Proceeding of the SPIE, Conference on Laser Radar Technology, Apr 1999, v3707 pp. 222-233.

5. Ayer, L., W. Martin, J. Jacobs, R. Fetner, "Laser Imaging and Ranging System (LIMARS)," WL-TR-92-1053 (14 Apr 1992)

KEYWORDS: Laser Radar; Polarmetric; Active Imaging; Polarization; Multi-Discriminent; Shape Echo

AF04-211 TITLE: Polarization Compensation for Phased Array

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Assess dual polarization interference effects on phased arrays and determine methods to minimize potential interference.

DESCRIPTION: Proposals to increase the overall bandwidth capacity from satellites, includes the use of dual polarization, within the coverage beam of a single satellite. For this to provide the capacity improvements desired, the polarization isolation between the dual polarized signals must be at a sufficiently low level to avoid excessive cross polarization noise being introduced into the channel. The cross-polarized component is a combined result of de-polarization through the atmosphere, radome effects, and the transmitting and receiving antenna axial ratio. Aircraft, as well as other mobile platforms, have considered using phased arrays for reception of satellite signals. However, phased arrays experience high axial ratios at the higher scan angles. The high axial ratio makes it difficult to isolate the desired channel from the satellite. Prior to integration of the cross polarization concept, it is necessary to determine the level of polarization isolation that is required along with identifying methods for minimizing this interference and quantifying the cost impact.

PHASE I: The contractor will, as a goal, quantify the de-polarization effects through the atmosphere under various weather conditions from 20 to 45 GHz. The effects of de-polarization on induced channel noise will be determined. The communication channel will be defined assuming the ground terminal utilizes a phased array. A bound on antenna axial ratio will be assigned. Methods for adjusting the ground terminal phased array axial ratio as a function of scan angle will be proposed. Implementation losses will be computed. The results will be documented in a report.

PHASE II: The proposed polarization compensation technique identified in Phase I will be prototyped. The prototype performance will be measured and compared against the theoretical predictions.

DUAL USE COMMERCIALIZATION: Both commercial and military satellite communication systems would like to increase the satellite capacity. One method of doing this is to utilize two channels within a frequency band in opposite polarizations. Information gained from this initiative will be applicable to Advanced Extremely High Frequency (AEHF) and Advanced Wideband System (AWS) satellite designs as well as commercial systems.

REFERENCES: 1. Olsen, R.L., “Cross polarization during Clear-Air conditions on Terrestrial Links: A Review,” Radio Science. 16, 631-647, 1981.

2. J.J. A. Lempianen, J. K. Laiho-Steffens, A.RF. Wacker: “Experimental Results of Cross Polarization Discrimination and Signal Correlation Values for a Polarization Diversity Scheme” IEEE 47th Vehic. Technol, Conf, VOL 3, PP 1498-1502, May 1997.

KEYWORDS: Phased Array, Polarization compensation, Axial Ratio, Frequency Re-Use, Polarization Isolation, De-polarization.

AF04-212 TITLE: <u>Advanced Waveform Processing</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Design, fabricate and demonstrate a receiver capable of demodulating spectrum efficient waveforms.

DESCRIPTION: While the available usable frequency spectrum is fixed, the demand for military communications satellite capacity is expected to rise exponentially over the next 20 years, and, despite the potential for laser communications to augment existing capacity, radio frequency (RF) bandwidth will still be required for "last mile" connectivity. The goal of this topic is to develop and demonstrate a bandwidth efficient receiver that is robust enough to withstand jamming and other types of interference while minimizing the modulator/demodulator design complexity. Goals include spectrum efficiency of at least five bits per Hz [TBR], power consumption of less than 10 watts [TBR].

PHASE I: Survey bandwidth efficient modulations modes. Goals include low BT product (bandwidth multiplied by time), low power consumption, and low design complexity. Utilizing the spectral/capacity goals shown above, develop specific receiver design approaches for evaluation. Develop and validate computer simulation models of selected receiver designs. Based on the simulation results, and with government concurrence, select a final candidate approach and develop a preliminary specification/design. Demonstrate key elements of the selected design.

PHASE II: Finalize selected receiver design. Build an operational sub-scale prototype of the chosen receiver design and demonstrate (to mutual Government/contractor agreed) functionality.

DUAL USE COMMERCIALIZATION: Due to the limited availability of spectrum commercial telecommunications are continuously seeking bandwidth efficient and power efficiency waveforms to enhance profit margins..

REFERENCES: 1. J. B. Anderson, et al, "Digital Phase Modulation", Plenum Press, 1986.

2. K. Murota and K. Hirade, "GMSK Modulation for Digital Mobile Radio Telephony", IEEE Tran. Comm., vol. COM-29, pp. 1044-1050, July 1981.

3. G. K. Kaleh, "Simple Coherent Receivers for Partial Response Continuous Phase Modulation," IEEE J. Selected Areas Commun., vol. 7, pp. 1427-1436, Sept. 1989.

4. J. R. Fonseka, "Noncoherent Detection with Viterbi Decoding for GMSK Signals", IEE Proc.- Commun., vol. 143, pp. 373-379, Dec. 1996.
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5. A. Svensson, et al, "A Class of Reduced-Complexity Viterbi Detectors for Partial Response Continuous Phase Modulation", IEEE Tran. Comm., vol. COM-32, pp. 1079-1087, Oct. 1984

KEYWORDS: GMSK, Modulation, Receiver, Spectral Masking, Waveform, Communications, Useable Frequency Spectrum.

AF04-213 TITLE: Global Position System (GPS) Control Segment Precision Estimation Techniques

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: develop algorithms to improve GPS Control Segment estimation and short-term prediction.

DESCRIPTION: The GPS Control Segment estimator for satellite and monitor station states has been improved by better tuning. Recent and planned events offer the opportunity for additional improvement. In particular, the Block IIR clocks are more stable than their IIA predecessors and the number of monitor stations will more than double. Estimation accuracy will also be more important in the future because, with the increased ground contact of Navigation Message Update and better clocks, there will be less degradation due to clock prediction. Military benefits of greater accuracy include improved precision munitions delivery. Civilian user performance will also be meaningfully improved because their signals are no longer deliberately degraded and they will be able to form measurements on multiple frequencies to remove ionospheric delays. Proposals should describe approaches to developing and testing navigation algorithms, rather than hardware, to improve GPS navigation. Reasonable performance goals are root mean square signal in space contributions to User Range Error of less than ¼ meter for estimation (all satellites) and ½ meter during an three hour prediction interval for the IIR satellites.

PHASE I: Design and document navigation algorithms with special attention to motivation for its innovative aspects. A test plan will be developed that involves evaluation against an established precise ephemeris. The test plan should include means of assessing the value of new techniques.

PHASE II: The necessary code will be developed and exercised against a minimum of two weeks of real data. Performance will be documented.

DUAL USE COMMERCIALIZATION: Conceivably, technique/code developed could have a use in super-precise surveying work; however, more research needs to be done.

REFERENCES: 1. Parkinson, B.W., Spilker, J.J. “Global Positioning System: Theory and Applications” (1996) Vols 1 and 2, American Institute of Aeronautics and Astrodynamics, Washington D.C.

2. Bierman, G.J., “Factorization Methods for Discrete Sequential Estimation” (1977) Academic Press, Orlando, FL.

KEYWORDS: Satellite navigation, Estimation theory, Orbital dynamics, Kalman filters, Global Positioning System, GPS signal-in-space

AF04-214 TITLE: Revolutionary Photoreceivers Based on Combining Si-MOS Process with SiGe Nanotechnology

TECHNOLOGY AREAS: Electronics, Space Platforms

OBJECTIVE: Develop and manufacture revolutionary photoreceiver modules based on combining of conventional Si-MOS process with SiGe nanotechnology.

DESCRIPTION: Certain type of three-dimensional SiGe (Silicon Germanium) nanostructures is known to have a modified energy band structure such that it can detect IR (InfraRed) radiation with high efficiency in the range of interest for optical communication. This technology is compatible and integrable with the conventional C-MOS (Complimentary Metal-Oxide Semiconductor) process making it possible to develop high performance photodetectors at low cost. The goal of this effort is to integrate SiGe photodetectors on silicon chips to provide design flexibility and performance for spacecraft communication applications.

PHASE I: Design and develop prototype SiGe/CMOS photoreceivers for 10 Gbps operation. The prototype may use discrete components but shall show a path to integration. The design should take advantage of co-locating the photodetection and signal amplifying circuits in close proximity on the same chip to demonstrate merits in increase signal to noise ratio and decrease in production cost. The operation of the photoreceivers shall be in the 1300 or 1550 nm optical bands

PHASE II: Based upon Phase I results develop and demonstrate integrated SiGe/CMOS photoreceivers prototype units for testing. Use actual measurements on prototype to design and fabricate engineering test devices for end-use applications. Refine design to increase operation speed to 40 Gbps. Demonstrate 40 Gbps chips.

DUAL USE COMMERCIALIZATION: The main effort is focused on production and bringing to market the SiGe/CMOS photoreceivers. These high-performance low-cost photoreceiver chips and modules will find numerous military and commercial applications where wide bandwidth communication is a requirement.

REFERENCES:
1. S.J. Jeng et.al. IEEE-Electron-Device-Letters. 22, 542 (2001)

2. O.G. Schmidt, Materials-Science-&-Engineering-B 89, 101 (2002)

KEYWORDS: Photoreceivers, Optoreceivers, SiGe, SiGeNanostructure, SiGe Receiver, Quantum Structure.

AF04-215 TITLE: Monolithic Microwave Integrated Circuit (MMIC) Beamforming Weights

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop a lightweight MMIC beamformer

DESCRIPTION: Advanced spacecraft antenna technologies form an integral element of an overall MILSATCOM communications system. For EHF (44 GHz band) uplink signals, the ability to provide adaptive, nulling beam patterns via the receiving antenna system can enable a significant measure of protection from uplink jamming. Based on initial architectural design trades, the development of high performance adaptive nulling antennas will be a key leveraging element of the planned Transformational Communications(TC)Program. These future systems will also feature enhanced bandwidth channels, and the capability to provide nulling across frequency bands up to 100?s of MHz is also needed. A critical component of such nulling antennas, is the beamformer weighting elements capable of applying the adaptive weight information to multiple elements of a nulling antenna. The replacement of currently used ferrite technology with MMIC components would dramatically reduce weight and power while reducing settling times. The purpose of this topic is to develop a MMIC based beamformer weighting element with at least eight bits of amplitude and nine bits of phase information. The beamformer must also be capable of operating in the EHF band (43.5-45.5 GHz), maintain Root Mean Squared (RMS)element-to-element phase tracking of three degrees over the entire 43.5-45.5 GHz band, RMS element-to-element amplitude tracking of 0.3 dB over the entire 43.5-45.5 GHz band and minimize weight settling times.

PHASE I: Survey current MMIC foundries and capabilities. Select a promising approach and design a MMIC beamformer consistent with foundry requirements and performance requirements identified above for phase tracking, amplitude tracking and weight settling times. Simulate beamformer design and optimize for gate complexity, power consumption, settling time and phase and amplitude accuracy. Evaluate system integration into a nulling antenna, and estimate cost, weight and power benefits over conventional technology.

PHASE II: Fabricate design providing a minimum of ten operating sample for government evaluation. Characterize for phase and amplitude accuracy, power consumption, and settling times.

DUAL USE COMMERCIALIZATION: Nulling antennas have potential benefits for a wide range of commercial applications like cellular telephony.

REFERENCES:

KEYWORDS: Beamformer, MMIC, Settling Time, Nuller, Antijam, EHF.

AF04-216 TITLE: Multi-Band/Beam Module

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop a low cost multi-band/beam module for future Military Satellite Communication (SATCOM) phased arrays.

DESCRIPTION: Multi-band/beam phased arrays provide an airborne platform with a single installation capable of supporting multiple connections simultaneously. For platforms with highly populated antenna farms and limited real estate, this is an attractive concept. The objective of this SBIR is to develop a phased array antenna module for a multi-band/beam, dual polarized receive array operating at 15 GHz(RIGHT HAND CIRCULARLY POLARIZED) and 20 GHz (LHCP (Left Hand Circular Polarization and RHCP (Right Hand Circular Polarization)supporting three simultaneous beam formations. Various module architectures will be examined and the impact to the Gain over Temperature (G/T)will be quantified. Module packaging size and thermal dissipation are critical and will be defined.

PHASE I: Develop a multi-band/beam module design for receiving a single RHCP signal at 15 GHz and 2 20GHz satellite signals (RHCP and LHCP). Determine the isolation required within the module components to prevent interference between the three channels. Derive the necessary requirements to avoid cross-polarization interference between beams. The module connections are to be compatible with low cost beamforming techniques for antennas at these frequencies. Provide breadboard demonstration of basic module operational characteristics.

PHASE II: Develop/fabricate multi-band/beam receive modules. Demonstrate module operation including the required RF (Radio Frequency) and cross polarization isolation between channels.

DUAL USE COMMERCIALIZATION: Commercial interest in multi-band/beam communications is presently evolving from handheld cellular systems to higher frequency commercial markets. High isolation packaging techniques are also expanding in the commercial market. In this phase, the low cost, high isolation packaging techniques derived in prior phases will be leveraged into commercial applications and lower production cost multi-band/beam military modules.

REFERENCES:

KEYWORDS: Millimeter Wave Modules, EHF, Phased Array, Isolation, Multi-Beam,
Multi-Band

AF04-217 TITLE: Synchronized Space Object Tracking

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop better search, track and identification system performance characteristics especially for items with small cross sections or hard to see designs, such as wind patterns or stealthing objects, or to track larger objects with less transmit power, such as automobiles in a collision avoidance system. Do it without having to resort to a costly monolithic radar system. Using this next generation of a low cost, synchronized radar constellation, increase detection and tracking capabilities to accurately find and monitor objects of interest with half of the cross section and half the Signal to Noise Ratio (SNR) currently required or better, or use less than half the current power to detect current targets.

DESCRIPTION: Develop a suite of signal processing algorithms, and software to coordinate multiple receive, and possibly multiple transmit stations to inter-operate synchronously. Develop a tool that translates needed performance into number of synchronized units, dis-location distances, angular placement and power levels required to achieve the performance gains. The goal for the new hardware is to only use currently available commercial-off-the-shelf components when fabricating the new transmit and receive stations. Two immediate products are envisioned, one is a transportable receive only unit that can be quickly connected to one of many existing civilian or military radar systems to provide enhanced coverage from that system. Only systems that can record beam return data and subsequently transfer that data to our system are candidates for this product. The target results will be provided in near-real time. The second is a new set of transmit and receive stations which can interconnect with each other and will provide results in real time.

PHASE I: Identify the most promising equations for target detection using more than one radar site's received beam data. Determine the best method for beam data analysis to maximize target detection with minimum SNRs. Develop the requirements necessary to allow effective synchronization between multiple receivers/transmitters. Engineer a computer nomogram which translates the required power levels and return characteristics into placement and configuration parameters for multiple receive units.

PHASE II: Implement a transportable receiver and find a cooperative existing radar system that can supply us with beam data in near-real time. Develop the interface components necessary to acquire synchronization and beam data. Using several positions validate the nomogram software. Summarize the results and lessons learned from this stage. Postulate whether multiple transmitters in conjunction with multiple receivers will increase performance characteristics. Using this information engineer the common components necessary to synchronize and coordinate any radar system and to provide for the integrated transmit and receive real-time products.

PHASE III: With the integrated transmit and receive real-time product designs, enter into agreement(s) with major radar developer(s) to produce a line of low-cost, low-power, mobile and mostly remote-controlled radar components which can be ganged together as necessary. These systems will be used in air traffic control, various academic studies such as asteroid locating/cataloging, weather pattern identification and automated transportation systems.

REFERENCES:
1. Kevin M. Cuomo, Jean E. Piou, Joseph T. Mayhan, "Ultra-Wideband Sensor Fusion For BMD Discrimination", 2000 IEEE International Radar Conference (0-7803-5776-0/00)
US Army Space and Missile Defense Command, Sensor Analysis Division, results under Air Force contract F19628-95-C-0002.

2. De Elia, R. and I Zawadzki, "Sidelobe contamination in bistatic radars", J. Atmos. Oceanic Tech 2000.

3. Protat, A. and I Zawadzki, "A semi-adjoint method for real time retrieval of three dimensional wind field from multiple-Doppler bistatic radar network data", J. Atmos. Oceanic Tech 1999, 16, 432-449.

4. S. Sivananthan, T. Kirubarajan and Yaakov Bar-Shalom, "Radar Power Multiplier For Acquisition of Low Observables Using an ESA Radar", IEEE Transactions on Aerospace and Electronic Systems, VOL 37, No. 2, April 2001.

KEYWORDS: Radar Sensors, Electro-Optical Sensors, Space/Upper Atmosphere Environment, Space Object Tracking, Space Situational Awareness, Space Object Catalog, Electronic Counter Counter Measures

AF04-218 TITLE: Efficient High Frequency Electromagnetic Source for Communication Devices

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Manufacture high power/high frequency EM (electromagnetic) source generation that will enhance or replace TWT technology

DESCRIPTION: The availability of a new technology that utilizes lighter weight, smaller, compact techniques such as focused local plasma generation and much more efficient electron sources will have numerous applications in military and commercial systems. Present structures have design and construction principles developed over 50 years ago. They are large and energy inefficient. New materials and nano-fabrication principles have been identified that have the potential to significantly impact the development of future space communication components and systems. This SBIR topic seeks to develop the technology for the manufacture of EM sources that accomplish present requirements of frequency and power-out with volume and power-in parameters significantly less. The goals are to develop the technology and scientific underpinning that is required to fabricate such TWT (Traveling Wave Tube) equivalents and to provide the infrastructure for their manufacture and insertion into military and commercial applications.

PHASE I: Design/fabricate prototype to demonstrate the concept of the conventional TWT replacement. Power-in requirements should be improved by at least 5-10% and size and weight reductions > 50% over present state of art. Design and develop approach to replace magnetic focusing with alternative such as electron beam focusing via plasma manipulation, reducing weight and improving efficiency. Gather and analyze performance data on prototype cold cathodes. Develop a theoretical model to improve the efficiency of the device.

PHASE II: Refine the design and materials system to enhance the efficiency, reliability and output of the new EM source device. Use model predictions and actual measurements on prototype to design/fabricate an engineering model device. Prepare a manufacturing and commercialization roadmap to market the technology.

DUAL USE COMMERCIALIZATION: A superior transmitter source offers numerous opportunities for enhancement in both military and commercial applications. It would impact display efficiency and compactness and medical imaging for example.

REFERENCES: 1. E. G. Wintucky, et al, Proceedings of the Second International Vacuum Electron Sources Conference, Tskuba, Japan, Tskuba Information Laboratory, Inc., 1998

2. C.Ribbing, et al, “Miniature X-ray Sources with Diamond Electrodes”, 8th International Conference New Diamond Science and Technology, July 2002, The University of Melbourne, Australia

KEYWORDS: electron sources, cold cathode, traveling wave tubes, plasma focusing, field emission, field emitters.

AF04-219 TITLE: <u>Signal Processing and Amplifier Design for Non-Constant-Envelope Modulation</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Minimize effective losses in power and spectral efficiency of Milsatcom systems due to nonlinear power amplifiers.

DESCRIPTION: The ever-increasing demand for higher data rates coupled with fixed allocations of bandwidth requires the use of higher order (non-binary) modulation techniques in Milsatcom systems. Unfortunately, many high order modulation techniques do not result in constant envelope waveforms and consequently result in undesirable signal properties at the output of nonlinear power amplifiers. The undesirable properties include both distortion of the amplified signal and emissions outside the desired frequency band. Amplifiers of interest operate in the frequency range from 7 to 45 GHz, with between 4 and 7 percent bandwidth, and at power levels from 1 to over 100 W. A conventional solution is to operate the amplifier in a range over which the characteristics are linear at the cost of decreased amplifier efficiency. Two possible approaches (among others) to this problem are: (1) signal processing techniques such as predistortion and equalization; or (2) development of a power amplifier with a greater degree of linearity. Some of the undesirable characteristics can be prevented or mitigated with the use of signal processing algorithms prior to amplifying the signal. Techniques such as predistortion have been developed to linearize the output of amplifiers, but further work is needed to create techniques that work well with higher order modulations such as 64-ary quadrature amplitude modulation (QAM) and pulse-shaped phase-shift keying (PSK). Equalization at the receiver may also provide benefits to performance. The algorithm development should not be limited to a single amplifier model. Furthermore, performance needs to be demonstrated using real components, not only simulations. In conjunction with signal processing algorithms, it is also desirable to investigate the construction of amplifiers that are more linear than current models. The end result of this study should include a number of techniques to reduce the effects of non-linear amplifiers. The criteria used to evaluate the proposed solutions shall include the performance of the desired signal as well as interference caused to signals in adjacent frequency bands.

PHASE I: In depth analysis of current high-power amplifier technology, including traveling wave tube amplifiers (TWTA) and solid state power amplifiers (SSPA). Analytical models, from literature searches and as a result of experimental measurements, shall be compared. Signal processing solutions and new linear amplifier designs shall be conceived and evaluated through analysis and simulation. The Phase I goal will be to select/present a short list of potential solutions for Phase II evaluation and demonstration.

PHASE II: Consist of evaluating/demonstrating the techniques proposed in Phase I using actual hardware. The effectiveness of each proposed solution must be evaluated and documented. Basic hardware shall be designed/fabricated and advanced demonstrations conducted for one or two selected solutions.

DUAL USE COMMERCIALIZATION: Technology developed under this program is appropriate for all forms of satellite communications, both military and commercial, and a wide variety of other commercial applications, such as terrestrial wireless communications, including cellular and personal communications systems.

REFERENCES:

KEYWORDS: Communications, SATCOM, Amplifier, Signal Processing, Predistortion, Quadrature Amplitude Modulation.

AF04-220 TITLE: Manufacturing Technology for Conformal Arrays

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop novel manufacturing techniques for producing multi-layer microstrip antennas and arrays conformal to the body of a high performance aircraft.

DESCRIPTION: One technique for meeting the future satellite communications needs of high performance military aircraft is to create antenna arrays conformal to the aircraft surface. Antenna arrays that are low profile and flush-mounted to the aircraft surface can provide significant advantages in terms of size and weight reduction without affecting the aerodynamic performance of the vehicle. Unfortunately, current techniques for making conformal antennas are difficult to apply to high performance aircraft. While conformal substrates can be directly molded onto small, regularly shaped objects such as cylinders and cones, large, irregular and doubly-curved surfaces such as those found on the wings and tail of an aircraft are more difficult to populate with antenna substrates and radiating elements. Experimental models of conformal aircraft antennas are typically made by etching the antenna onto very thin, flat, pc-board type substrates, bending the substrate around a stiff frame, and then bolting or gluing it in place. While this technique may be acceptable for antennas on singly-curved surfaces with large radii of curvature, it presents severe problems when applied to surfaces with small radii of curvature, doubly-curved objects, or multi-layer configurations. To be bent around tight curves, the antenna substrates must be soft and very thin. This limits the choice of substrates and also results in very narrow antenna bandwidths. In addition, bending of the substrate can produce tiny micro-cracks in the dielectric or the copper, which can affect the radiation pattern. The bolts and adhesives used to mount the antenna can also affect the radiation pattern, and present serious problems with the structural integrity of the aircraft. To overcome these difficulties, new technologies and processes need to be developed to produce thick, low loss, dielectric substrates and broadband, multi-layer microstrip antennas on large, doubly-curved surfaces. These technologies must produce conformal arrays that satisfy both the electrical and aerodynamic requirements of future airborne satellite communications systems.

PHASE I: Include the following tasks: 1) Select a candidate substrate and manufacturing process for building a single layer conformal microstrip patch array on a curved surface. The selected substrate should have the appropriate electrical and mechanical properties to provide acceptable antenna performance at microwave frequencies (low loss, low dielectric constant, uniform and isotropic), while maintaining the structural integrity of the aircraft. The process should be applicable to a C-band antenna conformal to a five-foot scale model of an aircraft wing, with exact dimensions to be provided by the Air Force.

2) Describe in detail the manufacturing process. The process may consist of any combination of techniques including extrusion, molding, machining, melt processing, spraying, painting, or other methods of the offeror's choosing. Discussion of the process shall include such factors as ease of fabrication, cost, controllability of the material properties (dielectric constant, loss, thickness, uniformity, etc.), manufacturing tolerances, health and environmental factors, and any other details which are critical to the process and the performance of the resulting antenna.

3) Perform detailed analyses of the mechanical and electrical properties of the conformal array, including effects on both aircraft and antenna performance. Factors to be evaluated include dimensional, mechanical, and thermal stability, layer-to-layer adhesion, substrate thickness, material losses, isotropy and uniformity, antenna bandwidth, radar cross section, and aerodynamic effects.

4) Demonstrate the feasibility of the process by fabricating and testing a small scale (single antenna element) prototype in a single layer configuration(ground plane, dielectric, radiator).

5) Describe methods for extending this process to produce multi-layer antennas with at least two dielectric substrate layers and two patterned metal layers, as well as a protective cover layer. Examples to consider include a two-layer stacked microstrip patch configuration or a slot-coupled patch with a microstrip feed network. Provide a detailed description of the process and its affect on antenna performance.

PHASE II: Demonstrate the process selected in Phase I by designing, fabricating and testing a small C-band, multi-layer, conformal array on a scale model of the leading edge of an aircraft wing. Model dimensions and antenna design parameters will be provided by the Air Force. Testing will include verification of the electrical and mechanical properties analyzed in Phase I, as well as complete testing of the antenna. If necessary, far field testing of the antenna can be completed using Air Force facilities.

DUAL USE COMMERCIALIZATION: Conformal array antennas have widespread potential for commercial application in mobile communications and information systems. Conformal array technology can easily be transferred to uses in commercial aircraft and automobiles, and to other DoD platforms such as tanks, ships, and armored personnel carriers.

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KEYWORDS: microstrip antennas, conformal arrays, phased arrays, microwave substrates, airborne antennas, satellite communications

AF04-221 TITLE: Advanced High Frequency Tunable Filters for Wide-Band Arrays

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop filters capable of operating between 37 and 52 GHz, and tunable over 1 GHz bandwidth.

DESCRIPTION: As radar and communications continue to develop higher frequency applications, there is a clear need for having many channels operating in relatively narrow frequency bands. While large filter banks can accomplish this, such banks are difficult to deploy in space and are not ideal for air or ground based operation. What would help advance high frequency applications are affordable, tunable filters that allow for operation over a wide bandwidth. Filters based on thin film technology look most promising. A number of techniques have been tried to make thin film tunable filters including 1) changing the dielectric constant of the substrate material by using a ferroelectric, 2) making MEM?s switches to switch between filters, 3) altering the effective permittivity by physically moving tuning material with a piezoelectric, 4) making high temperature superconducting filters with selection switches, as well as combinations of these methods. Once developed, high frequency tunable filters will be a significant help in both phased array antennas, allowing them to be wide band, and digital beam forming, allowing control of both frequency and beam shape. Communication systems employing such frequency agile (tunable) antennas would become superior for use in a global satellite network, as they would be capable of covering many channels and rapidly switching channels thereby making for secure space-based communications. Tunable filters should also result in a lower noise level which would result in sensors and communication systems with greater dynamic ranges.

PHASE I: Include the following tasks:
1. Propose the design of at least two independent tunable filter designs. These must be electronically tunable and have a center frequency in the 37 to 52 GHz range.
2. Propose how the entire 37 to 52 GHz range can be covered with various designs of tunable filters.
3. Perform detailed modeling of the filter designs and calculate the loss at the center frequency and within the tunable range. Determine the bandwidth, or channels per GHz, that can operate within the tunable range.
4. Propose how in Phase II the losses can be reduced, the tunable range increased, and how the number of channels per GHz can be increased.

PHASE II: Demonstrate the ability of tunable filters and will include the following tasks:
1. Design filters which cover the frequency range of 37 to 52 GHz.
2. Design both the packaging and controls for the filters.
3. Build the filters, including their packaging and controls.
4. Test the filters. This will include measuring the actual bandwidth, the loss within the bandwidth, and channel width.
5. Deliver filters to AFRL/SNHA for testing and evaluation for Air Force and DoD applications.

DUAL USE COMMERCIALIZATION: While the main thrust of this work is high frequency and space-based communications, it should be easy to adapt high frequency tunable filter designs to lower frequencies. Such tunable filters would be competitive with existing filter banks that are used for commercial communications, such as cellular communications, where many channels must exist close to each other and channel cross talk must be minimize.

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KEYWORDS: RF Filter, Tunable filter, Wide band, High frequency, W-band, Phased array antennas

AF04-222 TITLE: <u>High Speed Optical Limiter for Laser Communications Systems</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Design/develop a high-speed optical limiter for protecting laser transmitters and receivers against laser attack.

DESCRIPTION: Optical limiters are nonlinear optical devices that limit the amount of power or energy transmitted. They function through either optically-induced nonlinear absorption or refraction or a combination of the two. At low incident optical power or pulse energy, the transmission of the system is high enough to allow nominal operation of the system. At high incident optical power or pulse energy, the transmission drops to protect sensitive components such as optical receivers or transmitters. Optical limiters have achieved fast turn-on, but high speed turn-off is limited by the recovery time of the medium which is often slow. The goal of this project is to develop a high speed optical limiter to protect optical receivers or transmitters on a laser-based space satellite communications system. Development of high power laser systems has reached the maturity that such systems are economically and technically feasible even for third world nations. Even scattered light from a nearby strike from such pulses may be energetic enough to damage highly sensitive optical transmitters and receivers. The optical limiter must protect against high energy laser pulses (nanosecond to femtosecond) and must support optical communication rates of > 100 Gbps with no more than one lost bit per pulse for laser threats from sources with pulses of < 5 psec duration. For threats from longer laser pulses, the response of the optical limiter system must follow the attacking laser pulse. The materials and systems used must be suitable for the space environment.

PHASE I: Activities in this phase include: designing an optical limiter with low insertion loss, capable of supporting telecom rates of > 40 Gbps for near infrared (800-1600 nm) laser communications systems and capable of protecting the system from laser attack by nanosecond to femtosecond laser pulses; determining requirements for operate-through and operate after modes; and determining the effects of the natural space radiation environment on optical limiter performance.

PHASE II: Activities in this phase would include: development of a high speed optical limiter system for protection of > 40 Gbps laser communications systems; demonstration of the performance of the optical limiter for a digital optical communications system at data rates > 40 Gbps under irradiation with ultrashort laser pulses at repetition rates of up to 100 Hz; demonstration of the effects of the space radiation environment on optical limiter performance using gamma ray irradiation to 10, 50, 100, and 200 krads as well as proton irradiation (> 50 MeV protons) to the equivalent gamma ray doses.

DUAL USE COMMERCIALIZATION: Optical limiters with these characteristics will be useful for military, civil, and commercial communications satellite systems. They may also be useful for terrestrial free-space optical communications systems.

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KEYWORDS: Optical limiter, laser threat, Optical bandwidth, laser communications, optical communication, laser pulse

AF04-223 TITLE: Optical Communication Turrets

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop systems architecture designs for building optical communications turrets system/subsystems. Design/demonstrate a chosen system/subsystem

DESCRIPTION: As users requirements for satellite communications capacity continues to grow, development of innovative technologies that support optical communications for satellites, UAVs (Unmanned Aerial Vehicles) and airframes is highly desirable. In order to exploit higher optical communications capacity the terminal interface must be made reliable, power efficient, light, portable and affordable. In particular, integration onto the platform must avoid costly modifications to the airframe. UAV mounted systems present the most arduous requirements. These requirements (among others) include packaging, weight and power requirements compatible with UAV system capabilities, Basic gimbal requirements include pointing accuracy of at least one arc second, absolute smooth (non-cogging) rotation over the pointing range of 0 to 100 degree elevation, ±200 degree azimuth, signal tracking rate (closed loop) of 30 degrees per second, open loop slewing rate of 100 degrees per second, operational vibration isolation of 3-4g for frequencies between 70 and 140 Hz, fault tolerance capable of continuous operational performance without field maintenance. Specification details including optical system specifications and gimbal requirements such as size, weight, power consumption, and impact on UAV performance must be compatible with UAV capabilities, to be supplied by the Air Force contract representative.

PHASE I: Utilizing Air Force contract monitor input, study component/subsystem technology, including amplifiers, splitters, discriminators, pointing/tracking assemblies, etc, to determine current capabilities. From this effort develop a systems architecture and assess the required physical characteristics and functional performance of components to optimize communication link capacity. Identify components/subsystems requiring development beyond current technology. Select one or more of the identified components/subsystems for Phase II development. Design/construct laboratory sub-scale assembly(s) capable of demonstrating basic UAV application requirements. Perform demonstrations, document results, define areas requiring improvement and describe corrective solutions.

PHASE II: Design/develop/fabricate/demonstrate Phase I selected component(s)/subsystem(s) to UAV required physical and performance parameters, utilizing (to the extent possible) commercially available components. Measure performance, correlate to predictions, and identify areas for improvement. Identify airborne platform integration methodology.

DUAL USE COMMERCIALIZATION: Optical communication links are available commercially for ground stationary systems. Component advancements can be applied to both the commercial market as well as the DoD.

REFERENCES:

KEYWORDS: Laser turret, Optical frequency discriminator, Semiconductor laser amplifier, Wave division multiplex, Gigabit link, Beamsteering

AF04-225 TITLE: RA-1 Multi-mode Collision Avoidance Technology for UAVs

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a multi-mode collision avoidance technology to facilitate improvements in air safety and integration of Unmanned Air Vehicles into civil airspace globally.

DESCRIPTION: Unmanned Air Vehicles (UAVs) are an increasingly important part of US military force projection and are receiving ever-increasing attention for commercial aviation applications. However, for UAVs to flourish in either application, they must obtain unfettered access to civil airspace (as defined by the Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO)). To achieve this, developers must deliver collision avoidance equipage sufficient to assure air safety. Current procedures for UAV operation within the U.S. National Airspace System (NAS) are effective, but cumbersome and unsustainable for the long term. They serve to segregate UAVs from manned aircraft, often requiring separate attention from air traffic control authorities, limiting user flexibility and responsiveness, and hindering effective operations - military or commercial. At the same time, they limit UAV flexibility by forbidding UAV deviations from previously agreed-upon routes. Telegraphing of UAV position as a result of restricted routes through civil airspace was an important contributing factor in the loss of many UAVs in Bosnia and Kosovo. One technology key to realizing integrated UAV operations is the ability to detect and avoid both cooperative (transponding) and non-cooperative aircraft. Various means of detecting and deconflicting cooperative aircraft are currently employed on civil and military aircraft. They enhance pilot awareness and warning of encroaching traffic through continuous transmission and receipt of respective aircraft positions and intentions. Likewise, various means of detecting non-cooperative aircraft (via radar, passive or other sensors) are in development. Separately, these approaches cannot cover the spectrum of traffic that UAVs and manned aircraft face. The intent of this solicitation is to develop a small low cost solution, combining cooperative (such as TCAS II or Skywatch HP Traffic Avoidance System) and non-cooperative sensor detection concepts. This will produce an integrated detection and deconfliction capability sufficient to support UAV operations seamless to human pilots and air traffic control authorities – integrated display, cues and warnings. This would promote steps toward a standard data format, pilot interface/data feed, and algorithm/processing scheme. Such capability is crucial to providing military services and industry with sustainable, flexible UAV operations, sufficiently robust to safely deploy whenever and wherever needed. Additionally, these technologies will increase safety in the civil sector through integration on manned aircraft.

With applicability across UAV platforms, this topic is supported by ASC/RA, ASC/FB, and AFRL/SN.

PHASE I: Define concept to include cooperative and non-cooperative detection sensors and processors. Design interface between the two major components and UAV operators. Model scenarios to predict detection/deconfliction performance for the combined system.

PHASE II: Develop prototype hardware and software to implement the Phase I approach. Integrate into brassboard system and fly on a surrogate UAV to provide test data to verify scenario performance model developed in Phase I. Use these results to develop a preliminary design for a Phase III implementation that can be deployed on Global Hawk or similar UAV.

DUAL USE COMMERCIALIZATION: The technology developed under this solicitation will significantly improve the utility of UAVs across all three services and should have application to the commercial UAV sector and general aviation aircraft as well. Procedural methods, such as those currently being used for Global Hawk, cost the government significantly in time and funds while limiting operational flexibility. Technology developed under this solicitation would eliminate that recurring expense while moving the UAVs significantly closer to meeting User requirements for “file (a flight plan) and fly” operations. It will also be key to commercial industry as Global Hawk and other UAVs proliferate into the civil sector. It is also expected this application will be of interest to the FAA in supporting increased safety for general/commercial aviation aircraft; it may have prevented the recent mid-air collision over Switzerland which resulted in many lost lives.

REFERENCES:

KEYWORDS: collision avoidance; UAV; detect and avoid

AF04-226 TITLE: Multisource Data Registration Tools

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Data registration from multiple sources must take place in real time to support required capabilities ranging from rapid detection and engagement of mobile targets to “first look, first shot, first kill” against airborne threats.

DESCRIPTION: The objective of this effort is to develop autonomous registration technology in the form of a software toolkit for the spatial alignment of image, signals intelligence (SIGINT), and ground moving target indicator (GMTI) data collected from the battlespace. The focus of this research is to develop the novel approaches to georegistration by first, developing geo-reference invariant features that can be extracted from each data source and second, developing algorithms for correlating/integrating these features across the multiple data sources and a fiducial database for relative and absolute registration. Examples of features that cross multiple source data domains could be radio/TV transmission towers, command and control centers, road intersections, fixed search radar towers, and cellular phone towers. Correlation/integration algorithms will tie disparate types of sensor data together with the fiducial database while exploiting the knowledge of physics and phenomenological models (exact or approximate) of sensors and source types that might be available. The research will exploit innovative approaches including multi-agent knowledge-based systems, neural networks, modeling field theory, multiresolutional architectures, evolutionary computation. Most appropriate approaches will be identified for each sensor, source type, and for integrating/correlating all the data and available knowledge. The result will be a reliable, flexible system that can coregister multiple sensor data, estimate and account for errors and uncertainties, and identify measures of effectiveness for automatic convergence to minimize human intervention. The algorithms will be implemented as a software toolkit to enable the flexible system integration. The effort should take advantage of innovative approaches to integrated intelligent computational systems exploiting the current knowledge about the integrative abilities of human mind.

PHASE I: Investigate innovative approaches to the development of geo-reference invariant features and correlation/integration algorithms. Develop and demonstrate a proof of concept for multisource data registration using salient features on a limited multisource data set that would be provided by the Government. Develop a software design that can be extended to integrate different algorithmic approaches based on a generic concept of a feature.

PHASE II: Further diversify and enhance the prototype developed in Phase I effort to support additional functionality, knowledge, information, sensors, and sources. Develop and integrate a complete suite of data registration algorithms in the form of a software toolkit. Characterize performance over a wide range of data including multisource imagery, GMTI, and SIGINT. Identify transition pathways to the warfighter.

DUAL USE COMMERCIALIZATION: This technology is directly applicable to a broad range of military applications. Potential commercial application areas include remote sensing, oil exploration, security systems, and extensions of this technology to integrating data beyond geo-registration domain to medical diagnostics, biophysical and drug-discovery applications, financial industry, internet search engines, application-specific information search engines, and other commercial applications.

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KEYWORDS: georegistration, correlation, integration, multiple sensors, intelligent systems, image registration,

AF04-227 TITLE: Small Aircraft Self Protection

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Design a system, using a small expendable device, that can be used for the self protection of a small aircraft such as an unmanned aerial vehicle (UAV).

DESCRIPTION: As the United States military force establishes its global reach, global power capability, UAVs of all sizes and capabilities become more and more important for reaching this goal. In response to this UAV capability, the enemy will develop methods of defeating them. To preserve the capabilities of these UAVs and to conserve this resource, the UAVs will need a capability to protect itself from modified or new antiaircraft missiles that have the capability of seeking and destroying them. One such approach to self protection is the concept of a destructive expendable (DEX). The Sensors and Air Vehicle Directorates of the Air Force Research Laboratory have been extensively involved in modeling and simulation of the flight of the DEX for approximately two years. The detailed results of that modeling and simulation indicate that a DEX has the potential to be an effective countermeasure against various anti-aircraft missiles.

In the basic DEX concept, a small, rocket powered projectile is dispensed from an existing or modified flare dispenser after threat missile detection by the aircraft's warning system. An onboard, aircraft computer predicts the flight path of the threat missile and calculates the flight path and launch time of the DEX that will intercept the missile at a safe distance. The DEX is dispensed at the appropriate time, intercepts the target missile and destroys it. A multitude of questions, involving trade-offs between a multitude of technologies, need to be favorably answered to validate the DEX concept. It is possible that the DEX can be designed to destroy the attacking missile with a hit-to-kill approach. The DEX sensors, guidance system, aerodynamic control surfaces and propulsion approaches must be compatible with the small size of the device that will be needed to provide the UAV with self protection. This will require sensing the attacking missile and determining the optimum intercept point. Allocation of the required functional capability, as well as the physical allocation of the sensors, to the UAV or to the DEX will directly affect the throw away cost of the expendable component. Propulsion system requirements will need to address propellant types and propellant performance. Control power requirements and associated actuation schemes will need to look at accomplishing performance objectives through aerodynamic control only, thrust vectoring only or a hybrid aerodynamic/thrust vectoring control.

PHASE I: Investigate the DEX concept, clearly identify all assumptions, the implications of those assumptions and identify the major trade spaces. It is also expected that at least one major trade will be accomplished during this phase. For example, the contractor could address the need for the DEX to have a thrust vectoring capability to assure intercept; examine if hit-to-kill accuracy is feasible or if a warhead would be required; study sensor availability and requirements. A preliminary DEX concept should result from this phase.

PHASE II: During this phase the contractor will discuss all major issues, trades and assumptions as it relates to the DEX concept developed during Phase I in sufficient detail to validate the concept. The contractor could also demonstrate the performance of key technologies, such as the DEX itself, that will be needed for the DEX concept to succeed and develop a plan for the advanced development of the entire DEX system.

DUAL USE COMMERCIALIZATION: This concept has direct application to providing self protection to our commercial aircraft which are now in need of a capability to protect them from a missile threat.

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Missile Countermeasures Using a Destructive Expendable" for the 46th Annual Joint
Electronic Warfare Conference", Monterey , CA , May 2001.

3. P. McKeehen, M. Pershing, D. Warner, W. Blake, "Dynamic Modeling and Simulation of a Small Destructive Projectile" at the 2001 AIAA Modeling and
Simulation Technologies Conference , Montreal , Canada, Aug 2001.

KEYWORDS: Expendable;Maneuverable;small;self guided; thrust vectoring;self protection; hit-to-kill

AF04-228 TITLE: Compact, Lightweight, Low-Power Hyperspectral Sensor

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop miniature infrared hyperspectral imaging sensor technology for the longwave and/or shortwave spectral range(s) capable of meeting performance requirements for remote material detection.

DESCRIPTION: Current remote sensing using infrared hyperspectral imaging systems requires large, complex optical systems, highly sensitive focal planes, and elaborate mechanical/electrical systems to perform long-range material detection. The advent of small, low-cost uninhabited aerial vehicle (UAV) platforms has resulted in the need to assess sensor concepts capable of meeting the size, weight, and power constraints for these platforms. The design trade space for UAV platforms is significantly different than for other more conventional airborne platforms and a number of tradeoffs are possible for infrared hyperspectral imaging sensors, including relaxed resolution requirements for reduced range that translate into reduced optical aperture size. It is desired that the miniature infrared hyperspectral imaging sensor concept maintain the spatial/spectral fidelity of current hyperspectral sensors.

PHASE I: Focus on assessing concept feasibility, sensor performance trades, investigating innovative enabling technologies, and developing possible design concepts for further development in Phase II.

PHASE II: Design and fabricate a prototype breadboard miniature infrared hyperspectral imaging sensor. Demonstrate data quality and sensor fidelity.

DUAL USE COMMERCIALIZATION: This technology has the potential for use in a wide range of military and civilian remote sensing applications, including geology, agriculture, surveillance, drug enforcement, etc.

REFERENCES:
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KEYWORDS: Passive Hyperspectral Imaging, Hyperspectral Imaging Sensor, Imaging Spectrometer, Remote Sensing, Uninhabited Aerial Vehicle, UAV, Micro UAV, Material Detection, Infrared.

AF04-229 TITLE: Low Cost Electro-Optic Sensors for Mini/Micro UAV's

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Investigate innovative approaches to develop low cost active/passive EO sensors suitable for use on small UAV platforms that still retain high performance target sensing capabilities

DESCRIPTION: Current programs are developing a wide range of sensor technology applicable to many Air Force platforms. However, the increasing presence and utility of smaller, uninhabited air vehicles (UAV's) places additional requirements on the technology development. The purpose of this effort is to develop lower cost, size, weight, and range technologies to accomplish sensing functions from smaller airborne platforms (Mini/Micro UAV's). Conventional sensor technology and techniques usually require unacceptably high powers and volumes or else performance has to be degraded to reduce the size. The thrust of this effort will be to investigate hardware and signal processing concepts that would lead to the development of inexpensive, reduced range sensor packages for active/passive multidiscriminant sensing. Novel concepts suitable for Predator or Mini/Micro class platforms can have shorter range requirements but can still accurately and persistently queue / sense multi-mode signatures. Modes to consider include but are not limited to passive & active 2-D sensing, 3-D imaging, and polarization and vibration sensing.

PHASE I: During this initial phase, the feasibility of various candidate concepts will be evaluated. Sensor technology and signal processing techniques needed to support the concepts will also be defined. A concept(s) will be chosen and a preliminary design(s) for that concept(s) will be developed. Sensor technology and processing techniques needed to implement the concept(s) that would require additional development during Phase II will also be identified.

PHASE II: During this phase, final design for candidate sensor system will be completed. Critical hardware and processing techniques identified during Phase I will be developed or improved. A prototype system will be built and demonstrated.

DUAL USE COMMERCIALIZATION: Potential Phase III applications for this technology could be the Air Force "Targets Under Trees" program and Reconnaissance/surveillance missions aboard UAV's and other, smaller vehicles. Additionally, many airborne applications for laser radar have counterparts within industry (e.g. terrain following/ obstacle avoidance could be applied to autonomous vehicles, mapping and natural resources management efforts). The systems demonstrated in this program could be readily adapted to these commercial markets.

REFERENCES:
1. Compact 1.55-micron fiber-optic coherent Doppler lidar for low-airspeed measurements, P. Mamidipudi, P. Gatchell, R. Changkakoti, P. Rogers, Optical Air Data Systems [5086-22], Laser Radar Technology and Applications VIII, 21–25 April 2003, Orlando, Florida, USA

2. Identifying targets under trees: Jigsaw 3D ladar CFT results, H. T. Albrecht, Litton Laser Systems; D. E. Ludwig, Irvine Sensors Corp.; A. W. Kongable, B. Rouman, Northrop Grumman Laser Systems; D. Brown, Pixel; G. J. Fetzer, Arete Associates; K. Hanna, Sarnoff Corp. [5086-02], Laser Radar Technology and Applications VIII, 21–25 April 2003, Orlando, Florida, USA

3. Equipping small robotic platforms with highly sensitive more accurate biological and chemical detection systems, A. J. Scott, J. R. Mabesa, Jr., U.S. Army Tank-Automotive Research, Development, and Engineering Ctr. [5083-65], Unmanned Ground Vehicle Technology V, 21–25 April 2003, Orlando, Florida, USA
KEYWORDS: Target Detection, Multi-Discriminate Sensing, Low-Cost Active/Passive EO Technology, Hardware and Signal Processing.

AF04-230 TITLE: <u>Machine Learning for Robust Automatic Target Recognition</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: The objective of this effort is to develop approaches to improve Automatic Target Recognition (ATR) system performance in operating conditions different than for which the system was trained. The resulting improved ATR system performance will improve time critical targeting and surveillance operations.

BACKGROUND: Simply stated, the purpose of an ATR system is to make correct decisions concerning target identification. The desired attributes of a good ATR are discrimination and robustness. That is, it should correctly classify a target of a particular type regardless of variations in the targets appearance or extended operating conditions (EOCs). EOCs might include: clutter and noise variations, minor design differences, pose, revetment, partial obscurations, and articulation of movable parts. At the same time, the ATR should reject out-of-class targets despite their similarities to in-class targets. Machine learning techniques could greatly improve performance in EOCs. For instance, perhaps an algorithm could be developed to automatically adapt thresholds based on learning of samples from several known operating conditions to scenarios with new operating conditions i.e. interpolate/extrapolate ATR parameters or select/adjust features based on estimates of current conditions. AFRL/SNA has been leading the research in model based ATR systems because the approach offers greater robustness to hard EOCs such as partial obscurations and part articulation. Model based ATR uses detailed phenomenon models of targets which can be articulated and varied as needed to predict measured data. One significant problem has been the mismatch between synthetic and measured data. Machine learning techniques might be able to develop mappings between synthetic and measure data so that synthetic driven model based ATRs could improve performance. Another issue is known as the feature aided tracking problem where the system seeks to assure that different looks at a target actually come from the same target. While identification may be impossible from single looks at a target, the system could still learn the target on the fly so that future looks are predictable and therefore can support tracker report association functions.

DESCRIPTION: The overall goal of this effort is to develop innovative machine learning algorithms and techniques that lead to improved ATR robustness. AFRL/SNA is especially looking for improvements to Model-Based ATR and feature aided tracking. Suggested problems to consider include but are not limited to:
1) Learning mapping between synthetic and measured radar data
2) Automated ATR parameter selection
3) Learning targets on the fly
A variety of sensor data may be considered; these include radar, video, IR, SAR, and laser. Preferably, initial efforts should focus on radar data such as 1D profiles, SAR, range-Doppler, and 3D imaging. Ideally, the techniques developed might expand to other sensors.

PHASE I: Develop an approach and prototype algorithms to improve ATR robustness. Develop arguments for feasibility of approach. This likely includes combinations of small demonstrations and theoretical arguments. Phase I proposals should identify data to be used and how progress will be measured.

PHASE II: Further develop the approach and algorithms identified in Phase I. Develop and demonstrate attributes not specifically demonstrated in Phase I. Conduct performance analysis and demonstrate utility to improve ATR robustness. Phase II proposals should identify data to be used and how progress will be measured.

DUAL USE APPLICATION: A wide of potential applications exist for automated target recognition including medical diagnosis, forensic analysis, and automated facial recognition applied to anti-terrorism screening.

RELATED REFERENCES;

1. http://www.mbvlab.wpafb.af.mil/paper.html has several dozen papers in the area. The first three references given below are available there and are specified here because they are most relevant.

2. J. C. Mossing, T. D. Ross, "An Evaluation of SAR ATR Algorithm Performance Sensitivity to MSTAR Extended Operating Conditions", pp.554-565, Proc. SPIE, vol 3370, Algorithms for Synthetic Aperture Radar Imagery V, April 1998

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KEYWORDS: Automatic Target Recognition, Model Based ATR, Machine Learning, High Range Resolution Radar, EO/IR, laser

AF04-231 TITLE: Modeling and Simulation Technologies for Multi-Sensor Dynamic Targeting

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop physics based modeling and simulation technologies for dynamic targeting applications.

DESCRIPTION: The Air Force Research Laboratory (AFRL) is investigating modeling and simulation technologies that could provide the Air Force with an improved capability to find, identify, and engage mobile targets. Modeling and simulation of widely varied scenarios and highly dynamic environments that accurately reflect what the sensor observes including any all derived target/object features is required to address this requirement. Dynamic scenario simulation and analysis techniques should support trade studies and analysis for Automatic Target Recognition (ATR) and sensor fusion algorithms and dynamic multi-sensor planning and exploitation.

The goal of this research is to develop simulations of dynamic target and background behavior and phenomenology to aid in the development of ATR and sensor fusion algorithms and the characterization of their performance, including the modeling of the ATR and sensor fusion algorithms/components/systems themselves. This topic solicits innovative solutions in the following areas: (1) Large scale scene modeling and simulation techniques. (2) Phenomenology prediction methods for dynamic targets in backgrounds (3) Modeling and simulation of algorithm performance characteristics (4) Methods for simulating ATR and sensor fusion performance in systems and family of systems context. Proposals that address one or a combination of these technology areas will be considered.

PHASE I: Address at least one of the following: (1) Develop a proof of concept for large scale dynamic scenario simulation that models platform/sensor interacting with the environment (2) Prototype physics-based modeling tool for a simple object or an object in terrain setting. (3) Develop a proof-of-concept software design document for ATR and sensor fusion performance estimation tools. (4) Develop a design for a simulation environment that enables interactive platform/sensor feedback and control analysis.

PHASE II: Develop and demonstrate at least one of the following: (1) Large Scale dynamic scene simulation that models platform/sensor interacting with the environment (2) Physics-based modeling tools for a complex moving object in a terrain setting (3) Software tools for efficient ATR and sensor fusion performance estimation. (4) Simulation environment that enables interactive platform/sensor feedback and control analysis.

DUAL USE COMMERCIALIZATION: A wide range of potential applications exist for large scene modeling such as oil and other natural resource exploitation, optimum use of agricultural assets, management of forestry resources, and demographic environmental impacts being prime examples.

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KEYWORDS: Modeling and Simulation Techniques, Dynamic Targeting Applications, Detect and ID Mobile Targets, Sensor Fusion Algorithms.

AF04-232 TITLE: Dual-Use Simulation Technologies for Advanced Technology Demonstrations in Synthetic Battlespace

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop dual-use simulation technologies that enable advanced technology demonstrations to be conducted in synthetic battlespace.

DESCRIPTION: Current application research demonstration methodologies utilize open-air range testing to conduct advanced technology demonstrations. This approach is time-consuming and requires extensive/costly flight testing. Open-air ranges cannot generate the dense threat 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. This research topic will focus on reducing the heavy reliance on open-air range testing for advanced technology demonstrations. Current simulation technologies do not provide the required fidelity and real-time simulation support environment required for synthetic battlespace advanced technology demonstrations. The goal of this research is to develop/evolve high fidelity, dual-use, real-time simulation technologies that leverage DoD High Level Architecture (HLA) concepts to enable advanced technology demonstrations to be conducted in a laboratory generated synthetic battlespace. This research should address utilizing constructive (digital models), virtual (man-in-the-loop) and hardware-in-the-loop simulation for synthetic battlespace advanced technology demonstrations. This research should also provide for the capability to trace the military worth of research contributions due to insertion of advanced technologies within constructive or virtual simulations. The dual-use "tool" technology base established by this research will enable significant reductions in the time/cost for both commercial and military aircraft technology research. This SBIR research addresses simulation technology needs for the DoD High Level Architecture (HLA) concepts/requirements being sponsored by the Defense Modeling and Simulation Office under the DMSO M&S Master Plan.

PHASE I: Define affordable dual-use, real-time simulation technologies for conducting advanced technology demonstrations in synthetic battlespace. The Phase I research will identify the critical technology challenges and define the Phase II approach for developing/demonstrating the required simulation technologies for synthetic battlespace advanced technology demonstrations. Phase I risk reduction experiments will be conducted to demonstrate the feasibility of the proposed Phase II approach.

PHASE II: Implement and demonstrate the critical simulation technologies required to conduct advanced technology demonstrations in synthetic battlespace.

DUAL USE COMMERCIALIZATION: Real-time simulation technologies that enable advanced technology demonstrations in laboratory generated synthetic battlespace are dual-use technologies that have extensive commercial applications for market such as commercial aircraft, automobile and video game entertainment industries. These technologies enable the aircraft/automotive/video game system design engineer/analyst to rapidly conduct advanced technology demonstrations to establish concept feasibility and benefits. These same technologies can be implemented in government laboratories for rapid assessment of military benefits.

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KEYWORDS: Simulation, Synthetic Battlespace, Military Worth, HLA, Systems Engineering

AF04-233 TITLE: Multisensor Time Synchronization

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop technology (algorithm, commutation modes, and hardware) to allow multiple airborne sensor packages (either on a single platform or across multiple platforms) to distribute and synchronize system time so that the maximum offset is 1 nanosecond.

DESCRIPTION: With the recent developments in time transfer algorithms, such as two way satellite time transfer, GPS, Link-16, etc., many new capabilities that take advantage of precise time synchronization are being explored. These capabilities span both single platforms and also across multiple platforms.

Currently the sensors on a single platform are loosely steered to an on board time reference. This synchronization is routinely accurate only to the microsecond or even millisecond level. While this is sufficient for most current applications, this time offset between the different onboard sensors can limit the performance of future communications, navigation, identification and mission sensor capabilities. The objective of this program are is to develop an algorithm and supporting hardware to perform accurate time synchronization of all on board time references.

Presently, the military community utilizes GPS for multiplatform time synchronization. In the future, it is likely that the military will have to conduct operations in electronically challenged environments where GPS may be unavailable. Therefore, a means to perform time synchronization using existing communication channels is desirable. The time synchronization method must be able to function on platforms containing only LPI/LPD data links. The objective of this program area is to develop an algorithm and supporting hardware to perform accurate time synchronization to a platform in flight using existing data links.

PHASE I: dDevelop the necessary algorithms, and notional architecture to distribute time to multiple sensor packages. The results will be evaluated both on performance and on the amount of additional hardware required (less is better).

PHASE II: Modify the phase I results to accommodate real world limitations on bandwidth and available communication systems. The contractor will identify any changes to the local reference system necessary to interface over existing communication systems to various sensor packages. The contractor's system will then be demonstrated and its performance will be measured using laboratory grade atomic standards for reference.

DUAL USE COMMERCIALIZATION: Advanced navigation and communication equipment for air transports and earth sensing platforms.

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KEYWORDS: Time Synchronization, Advanced Sensing, Network Centric Engagement, GPS

AF04-234 TITLE: <u>Algorithms for Real Time Corrections of Multi-Path Errors using Modernized GPS Signals</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop algorithms for Global Positioning System (GPS) receivers to make real time corrections and minimize navigation and timing errors due to signal multi-path phenomenon using the modernized GPS signals (M-Code on L1 & L2, C/A on L2, and the new civil safety-of-life signal on L5 (L1=1575 MHz, L2=1227 MHz, and L5=1176 MHz)).

DESCRIPTION: GPS receivers may suffer accuracy degradation by processing a reflected signal with the direct one. After the correlation process in the GPS receiver, the error in the resulting pseudorange and carrier phase measurement that results from multipath can be amplified such that the total tracking error exceeds the multipath delay. It is desired to have hardware and/or software to detect and, if possible, mitigate the multipath signal to restore the full accuracy of the direct signal. The introduction of new codes and frequencies into the modernized signals may enable multipath mitigation techniques that have not been feasible with the current GPS signals. Of particular importance is the mitigation of multipath in situations where the multipath has many sources and may last for substantial amounts of time due to the slow geometry change of the satellites, such as a stationary antenna for a monitor station.

PHASE I: Explore various techniques using analysis and simulation tools to determine the best approach.

PHASE II: Implement the most promising techniques from Phase I and perform testing of the techniques under controlled conditions for the evaluation of their effectiveness.

DUAL USE COMMERCIALIZATION: The techniques that prove to be most promising may be useful in all GPS user equipment and monitor stations. The techniques may also have applicability to other systems that are subject to multipath as well. Handheld GPS users and monitor stations will be the biggest benefactors of this technology due to the more severe multipath environment and the long duration of the multipath due to the slow geometry change of the satellites.

REFERENCES: The following references are from ION GPS, 14-17 September 1999 at Nashville, TN:
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2. Multipath Considerations for Ground Based Ranging Sources, C.G. Bartone, Ohio University
3. The Benefits of the GPS Three Frequencies on the Ambiguity Resolution Techniques, C. Bonillo-Martinez, M. Toledo-Lopez, M. Romay-Merino, GMV S.A.
4. Performance of GPS Receivers with More Than One Multipath, C. Macabiau, B. Roturier, A. Benhallam, CNS Research Laboratory of the ENAC, France; E. Chatre, STNA
5. GPS Carrier Phase Multipath Reduction Using SNR Measurements to Characterize an Effective Reflector, Reichert, P. Axelrad, University of Colorado

KEYWORDS: Multipath, GPS, Error Compensation, Range Error, Multi-frequency, Navigation Accuracy

AF04-236 TITLE: <u>Digital Array Analog to Digital Converter</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop an analog-to-digital converter (ADC) to operate at the Extremely High Frequency (EHF) range. The ADC will be able to be used in a phased array system to mitigate signal interference and provide rapid links to satellites for communication applications.

DESCRIPTION: Multi-beam phased arrays can provide an airborne platform with a single installation capability of supporting multiple connections simultaneously. This can lead to reducing the amount of apertures on the platform. The design can lead to a modular sub-array architecture, which can be combined digitally to support the high data rates. The ADCs will enable the use signal processing to adapt the beam to suppress interference and form beams to link with orbiting communication satellites.

PHASE I: The goal of the Phase I will be to determine the state-of-the-art of ADCs at the EHF range. Based on this information a study will be done to determine the signal-to-noise ratio, sampling rate, and the dynamic range necessary for the ADC to adequate handle the link requirements at the EHF frequency range. Using the results of the study a candidate array architecture design will be provided detailing how the ADC will be implemented. The effort will take into consideration how the signals will be down-converted to a usable Intermediate Frequency (IF) if the design requires to use ADC that are not achievable at EHF.

PHASE II: Based on the candidate architecture developed in Phase I, the effort will build and test a small operational prototype demonstrating the capability of the candidate ADC.

DUAL USE COMMERCIALIZATION: Commercial interest in digital arrays for communications is evolving, with a high degree of interest in the cellular systems.

REFERENCES:
1. R.H. Walden, "Analog-to-digital converter survey and analysis," IEEE Journal on Selected Areasin Communications, vol. 17, no. 4, pp. 539-550, April 1999.

2. R.H. Walden, "Performance trends for analog-to-digital converters," IEEE CommunicationsMagazine, vol. 37, no. 2, pp. 96-101, February 1999.
KEYWORDS: Multiple Beams, Phased Arrays, Analog to Digital (A/D) Converters, EHF, Sub-Arrays, Digital Signal Processing.

AF04-241 TITLE: Verification of Coldworking and Interference Levels at Fastener Holes

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a technique for determining the residual stresses at coldworked fastener holes and at interference fit fasteners.

DESCRIPTION: The residual stresses that result from coldworking a hole, or using an interference-fit fastener, can significantly increase the life of a structure subjected to fatigue loading. Manufacturing tolerances cause variability in the effectiveness of coldworking holes and interference fit fasteners. Furthermore, there are no inspection techniques to ensure that every fastener hole has been properly worked. Hence, the beneficial effects of coldworking holes and interference fit fasteners are not accounted for in the structural integrity analyses used to determine when to inspect aircraft structure for cracks. A technique for measuring the residual stress around a coldworked hole or interference fit fastener, and ensuring that the beneficial stresses are there, would allow the benefits of coldworking to be accounted for when establishing inspection intervals for critical locations. These time between inspections could be increased resulting in less aircraft downtime. Accurate measurement of residual stresses is difficult in a textured materials such as wrought aluminum with current methods such as x-ray diffraction. Current techniques are not readily deployed to the field. And the time required to make a measurement is not compatible with a maintenance operation.

PHASE I: Demonstrate that the proposed technique can differentiate between holes in aluminum and titanium plate that have been cold expanded different amounts. Establish the accuracy and resolution of the technique. Show that the proposed technique is suitable for use on and around aircraft in a maintenance environment in terms of safety, measurement time and system portability.

PHASE II: Develop prototype system for use on and around aircraft. Establish the accuracy and resolution of the prototype system in the relevant environment. Explore the capability of the prototype system to measure residual stresses from other sources such as fit-up or shot peening.

DUAL USE COMMERCIALIZATION: Residual stresses are found in many different types of structures. Residual stresses can be beneficial or deleterious. A field deployable method for determining the magnitude of residual stresses would be useful for chemical plants and pipelines, ship building, ground vehicles, as well as aviation.

REFERENCES: 1. Split Sleeve Cold Expansion, Fatigue Technology Inc., http://www.fatiguetech.com.

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KEYWORDS: Residual Stresses, Coldworked Holes, Interference Fit Fasteners, Welding, Structural Integrity, Fatigue, Fracture

AF04-242 TITLE: Comprehensive Structural Health Monitoring (SHM) System

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop data-adaptive signal analysis techniques for SHM of air vehicles without stationary and Gaussian assumptions.

DESCRIPTION: The Air Force needs to localize structural damage in an automated manner, thereby enabling the use of integrated SHM systems in future generations of air and space vehicles. There are several Air Vehicles Directorate efforts to reduce development time for new air and space vehicle design through increased use of modeling and simulation technologies. Achieving these needs results in innovative designs in extreme environments. Consequently, the Air Force needs to perform additional health monitoring and management to detect structural and thermal protection system damage in extreme environments. In particular, structural health management of aerospace vehicles would benefit greatly from new data analysis techniques to identify incipient damage while the vehicle is prepared for its next flight. Current maintenance strategies and analysis techniques detect and compensate for damage hot spots as they are observed in practice, but they are too expensive, time-consuming, and insensitive to detect damage in an automated manner. These difficulties motivate the use of distributed sensor arrays to detect local damage. However, the leading-edge algorithms currently used to process structural health data are not designed to handle efficiently the large quantity of data obtained from large array of sensors. The problems are compounded by the continued use of aging aircraft in new or expanded operational envelopes, which has proven to be a constant source of new fatigue and failure modes. Current fatigue prediction and damage detection methods have not kept pace with these increasing performance requirements and the use of new materials, nor with the need to use aircraft beyond their designed service lives. These considerations highlight the pressing need for innovative analysis techniques to facilitate the intelligent use of health monitoring data. This data typically will be sampled non-stationary and non-Gaussian time histories-from sensors obtained from limited experiments, flight tests and operational use. Traditional Fourier analysis models are inappropriate, since they require stationary data.

Recent wavelet signal processing developments may overcome these problems. The power of wavelets is that they capture local scale activity in data. Donoho, Mallat, and von Sachs offer a method for finding a locally stationary wavelet transform model. Attention is focused on local features in the data while simultaneously retaining a spectral description that is not predicated on the stationary assumption. Suter's work presents a framework for studying non-stationary issues. Transient-detection algorithms based on these adaptive signal processing concepts could be used to detect automatically any large transient loads so as to provide an accurate statistical characterization of the extreme load history experienced by a structure. Furthermore, recent developments in SHM technologies and data analysis based on adaptive signal processing techniques demonstrate that an array of embedded sensors could facilitate the localization of cracks, delaminations, and impact events without expensive and potentially damaging disassembly of the structure for traditional inspections. Signal processing techniques in addition to wavelets can be considered.

PHASE I: Demonstrate the feasibility for applying distributed health-monitoring systems to future Air Force vehicles. New techniques to evaluate include (1)developing wavelet-based adaptive signal processing techniques for processing and extracting information from non-stationary and non-Gaussian sensor time histories,(2)improving understanding of wavelet signal processing using realistic models and improved wavelet-based adaptive signal processing algorithms,(3)developing a quantitative measure of local stationarity,(4)understanding data compression techniques that enable the use of distributed health-monitoring systems,(5)formulating adaptive signal processing techniques for detecting and localizing multiple flaws in simple structural components, and (6)developing a computer-based testbed for examining various sensor layouts and damage detection methods.

PHASE II: Perform experiments to demonstrate the feasible techniques identified in Phase I. Prepare and test a prototype system for detecting and localizing multiple flaws in simple structural components in the laboratory or on a flight vehicle.

DUAL USE COMMERCIALIZATION: The aviation industry, gas pipeline industry, materials industry, automotive industry and any commercial application where acoustic or vibration fatigue impact a product's lifetime all require the analysis of non-stationary, non-Gaussian data. The new techniques enhance use of structural health data to predict and design future military spacecraft, aircraft, naval vessels, wind tunnels and ground vehicles.

REFERENCES: 1. Pettit, C.L., Jones, N.P., and Ghanem, R., "Detection, Analysis, and Simulation of Roof-Corner Pressure Transients," 10th International Conference on Wind Engineering, Copenhagen, 1999.

2. Donoho, D.L., Mallat, S., and von Sachs, R., "Estimating Covariances of Locally Stationary Processes: Rates of Convergence of Best Basis Methods," Technical Report No. 517, Department of Statistics, Stanford University, 1998.

3. Suter, B. W., Multirate and Wavelet Signal Processing, Academic Press, San Diego, CA, 1998.

4. Ikegami,R., Haugse, E., Trego, A., Rogers, L., and Maly, J., Structural Technology and Analysis Program (STAP) Delivery Order 004: Durability Patch, AFRL-VA-WP-TR-2001-3037, 2001. ADA408003(Available full text at: http://handle.dtic.mil/100.2/ADA408003)

KEYWORDS: Localize Structural Damage, Integrated Structural Health Monitoring, Distributed Sensors, Wavelets, Non-Stationary, Non-Guassian, Time History

AF04-243 TITLE: System Engineering -- Thermal/Power- Efficiency Assessments of Air Vehicles

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop system engineering relationships and models for performing thermal/power-efficiency assessment of emerging advanced air vehicle designs.

DESCRIPTION: Effective and timely assessments of total thermal and power energy management is critical to the design and eventual cost-effective deployment of emerging air vehicles. Vehicles designed without appropriately taking these issues into account results in vehicles with sub-optimal performance, cost and weight. Existing analytical tools do not incorporate the capability to complete system-level analysis and vehicle level impacts. They cannot support timely system level optimization requisite for roll up from the subsystem to the vehicle level. Expanding current theories, integration framework, modeling techniques and possibly fundamental methodologies including energy-based integration, thermo-economics or exergy analysis may be required for realization of these goals for advanced air vehicle trends. Some of these emerging trends are on-vehicle directed-energy weapons, extremely slow long-loiter-time vehicles that burn fuel at extremely low rates, onboard energy storage systems that transform energy into different forms for temporary storage, extremely small vehicles, and vehicles with no onboard liquids other than fuel. The technique and models should be such that they can be used to model normal behavior of these subsystems and also failed conditions or other abnormalities in which nonlinear and/or second-order effects come into play. Additionally, the subsystem-to-vehicle relationship models must be easily changed as the need arises by personnel who are not experts in computer codes.

PHASE I: The R&D effort in this phase is to identify and evaluate the required expansion of current theories, integration framework, modeling techniques and fundamental methodologies for identify and evaluate emerging air vehicle trends and to develop a limited set of parametric or other relationships that relate subsystem characteristics to vehicle level metrics. Secondly, identify and provide rationale for the most appropriate modeling techniques that can handle both nominal and failure-induced degraded performance for timely trade studies and assessments. The feasibility of these techniques will be demonstrated by the integration of these techniques into existing analysis programs.

PHASE II: In this phase, a prototype trade study and assessment capability for air vehicles will be developed and demonstrated.

PHASE III DUAL USE APPLICATIONS: This analysis and assessment capability will be useful for design of military and commercial air vehicle. The analysis capability developed in this topic would be applicable to all types of vehicles that employ engines that burn fuel vehicles such as aircraft, trucks, automobiles, and ships. The availability and application of the research results from this topics should enable the design of more efficient vehicles.

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3· Bejan, Adrian, "A Role for Exergy Analysis and optimization in Aircraft Energy-System Design," ASME International Mechanical Engineering Congress, Nashville, TN, 14-19 November 1999.

KEYWORDS: modeling and simulation, system engineering, thermal system analysis, advanced air vehicles, subsystems.

AF04-244 TITLE: Flow Control for Enhanced Sensor Beam/Directed-Energy (DE) Beam Quality

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a clear understanding of the mechanisms (and how to control those mechanisms) responsible for electromagnetic beam quality degradation as it passes through a turbulent shear layer.

DESCRIPTION: There exists a generic need for improvement of the range and clarity of electro-optic sensing/targeting systems. For the military, these sensors are used for strategic and tactical surveillance, identification and targeting of threats, and battle damage assessment. Next-generation active laser radar (LADAR) seekers are capable of producing high-resolution, three- dimensional imagery. New vibration spectrum laser sensors promise aspect invariant results, and represent the only target identification (ID) technique that is not tied to making a spatial measurement or comparison of features, which typically drives sensor resolution requirements. Both these new imaging/ID techniques (in fact, any technique which relies on the propagation of images or light) can benefit greatly from reduced aero-optical distortion as their laser beam passes through the aircraft near-field. The limiting performance factor for advanced vibration sensing is the energy received on target, not the target's size or geometry. This is, of course, the same figure of merit for new advanced DE weapons. Shear layers adjacent to aircraft bodies greatly degrade both image clarity (distorted wave front) and wave-front intensity. Early flight test data on KC-135 and Lear Jets demonstrated marked laser intensity decrease as a beam passed through the aircraft boundary layer, with losses ranging from 20 percent up to 60 percent (losses increased with decreasing altitude and increasing speed).

In aero-optical interactions between a propagating optical beam and a turbulent flow region, the resulting wave front degradation can be loosely described as having two causes. The first cause is small-amplitude, long-time-scale density variations accumulated over long propagation distances through the atmosphere. This cause of wave-front distortion can be dealt with using deformable-mirror adaptive optics techniques in a feedback control loop. The second cause of degradation, propagation through near-field boundary layers and shear layers, is characterized by very short time scales, which do not allow the use of adaptive optics. For DE systems, such as airborne laser (ABL), the second (boundary layer) problem was minimized by judicious placement of the beam director, and by flying at slower speeds and higher altitudes. Tactical vehicles, which fly at much lower altitudes and higher speeds, and which are volume constrained, do not have the same options as ABL for dealing with wave-front distortion.
Recent advances in the application of active flow control to shear layers offers hope that a solution to shear layer wave-front distortion can be found. It is expected that offerors will be familiar with both low frequency and high frequency types of flow control actuators, and will be prepared to investigate the effects of both types. Simulation

and modeling efforts are also encouraged (for questions of scaling), with the caveat being that high-frequency forcing is currently out of reach for most practical computational fluid dynamics (CFD) techniques. The technical areas to consider, but not limited to, shall include the following: principles of active flow control for management of beam degradation, development of improved methods of measuring and predicting beam degradation both in simulated wind tunnel tests as well as in flight, development of practical shear layer aero-optical degradation solutions, designs to improved tests for measuring beam degradation in optical turret/apertures integrated aboard modern aircraft, and development of simulation and modeling/CFD prediction tools for enhanced laser beam propagation.

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 demonstrate under simulated flight conditions.

DUAL USE COMMERCIALIZATION: High-payoff military applications include LADAR and vibration spectrum sensor range enhancement, with these technologies impacting most near term platforms. This technology could also be a crucial enabler for the tactical application of DE weapons. Examples of potential commercial applications include, law enforcement (suspect monitoring, tracking vehicles involved in crime, DE disabling of cars, boats, etc.), sensing for air and sea rescue, long distance monitoring of hostile political situations, etc.).

REFERENCES: 1. McMichael, J.M, "Progress and Prospects for Active Flow Control Using Microfabricated ElectroMechanical Systems (MEMS)," AIAA Paper 96-0306, January 1996.

2. Ho, C.H., and Tai, Y.C., “Review: MEMS and its Applications for Flow Control,” ASME Journal of Fluids Engineering, Vol. 118, September 1996.

3. Gad-el-Hak, M., “Modern Developments in Flow Control”, Applied Mechanics Reviews, Vol. 49, pp. 365-379, 1996.

4. Stanek, M. J., Raman, G., Kibens, V., Ross, J. A., Jessaji, O., and Peto, J. W., “Control of Cavity Resonance Through Very High Frequency Forcing,” AIAA Paper 2000-1905, 6th AIAA/CEAS Aeroacoustics Conference, June 2000.

5. Stanek, M. J., Sinha, N., Seiner, J.M., Pearce, B., and Jones, M. I., “High Frequency Flow Control – Suppression of Aero-Optics In Tactical Directed Energy Beam Propagation & The Birth of a New Model (Part I),” AIAA 2002-2272, 33rd AIAA Plasmadynamics & Lasers Conference, May 2002.

KEYWORDS: Flow Control, Active Flow Control, High Frequency Flow Control, Aero-optic Distortion, Boundary Layer Perturbation, Shear Layer Perturbation, Wave-front Distortion, Strehl Loss, MEMS – Microelectromechanical Systems, Coherent Structure, Sensor

AF04-245 TITLE: <u>Exergy–Based Design and Analysis for Optimization of Aerospace Components and Systems</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop the second–law of thermodynamics for system and sub–system–level integration and optimization, including the effects of turbulence.

DESCRIPTION: Deployment of future aerospace systems will require an intensive system–level integration of components to meet the urgent need at all system levels to minimize the risk and costs. The growing complexity of aerospace systems and the resulting increase in susceptibility to failure due to improperly design–integrated components, dictate a critical need for improved analysis and optimization methods for predicting, evaluating, and optimizing performance [1]. Traditionally, air vehicle analysis and design has relied almost exclusively on extensive trade studies and very costly prototype development of complete aircraft systems that provide only limited insight. The numerous combinations of test parameters required for an overall system–level analysis make complete testing of complex configurations prohibitively expensive if not impossible due to lack of ground–testing facilities capable of replicating critical trajectory regimes. A new approach based on extending the second–law of thermodynamics for complex systems–level analysis has emerged [2]. A computer–based system level simulation and analysis capability based on the concept of work–potential loss (exergy) could conceivably minimize ground–based testing and substantially reduce certification time and costs, as has been proposed for integrating turbine engine analysis and design [2]. While component level computational analysis techniques are well developed and understood, the same is not true for system level analysis where multiple physical phenomena are present and contribute to work–potential losses. Research is needed to bridge the gap between component level and system (e.g., aircraft) level aero–thermodynamic phenomena to more clearly ascertain the applicability and feasibility of an exergy–based approach. Knowledge gained from this research can then be applied toward the development of high–fidelity system-level analysis techniques that can be used to streamline the analysis, design, and optimization process.

PHASE I: To establish the applicability and feasibility of an advanced exergy–based design analysis capability for realistic thermal systems. The required analytical models should be derived at this stage, and the solution of the models should be demonstrated for selected aerospace components and/or systems. Since most thermodynamic systems of interest involve turbulent flows, the Phase I project must address the incorporation of turbulence. It is anticipated that high–fidelity computational design and analysis tools will incorporate the methodology developed.

PHASE II: Development, validation, and incorporation of the entropy–production model into a production–level software tool for aero–thermodynamic analyses of realistic aerospace systems and components.

DUAL USE COMMERCIALIZATION: Phase III military application is aimed at the full integration of aircraft system in the preliminary design, analysis, and optimization phase. This includes but not limited to engine–airframe integration, lifting surface–structure integration, etc. Commercial applications apply to any system or sub–system level analysis, design, and optimization where minimized work–potential losses and maximum performance effectiveness are desired. This includes heat exchangers, cooling sub–systems, etc.

REFERENCES: 1. A. Bejan, Entropy–Generation Minimization, CRC Press, 1999.

2. Roth, B. A., A Theoretical Treatment of Technical Risk in Modern Propulsion System Design, doctoral dissertation, Georgia Institute of Technology, Atlanta GA, May 2000. http://www.asdl.gatech.edu/staff/pdf/roth_thesis.pdf

3. Moorhouse, D. J., "A Proposed System–Level Multidisciplinary Analysis Technique Based on Exergy Methods," AIAA Paper No. 2000–4850.

KEYWORDS: Entropy, Exergy, Second–Law, Availability, Work–potential, Turbulence, Optimization.

AF04-246 TITLE: Technology for Affordable Validation and Verification (V&V) Software Design Processes and Safe Flight-Critical Software

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop and demonstrate innovative run-time and design-time software safety assurance techniques.

DESCRIPTION: The rigorous safety requirements inherent in flight-critical software make V&V generally the most costly and time-consuming step in the development of flight-critical software. It also holds much of the risk. Traditional V&V is a process that occurs throughout system design (design-time techniques). As such, V&V research and development efforts have focused on improvement within this paradigm of design-time V&V. Alternatively, some efforts have utilized limited run-time assurance methods such as built-in-test (BIT) and integrity management. Run-time assurance methods may enable elimination of some design-time V&V tasks. The flight research community has also successfully utilized run-time assurance methods to monitor high-risk systems having expanded functionality and provided reversion to low-risk systems with limited functionality. Further investigation into integrated design-time and run-time assurance techniques is needed to systematically reduce complexity and cost for development of future flight and safety-critical software. The goal is to reduce cost and risk of software development as well as maintain or increase safety margins. This may require a paradigm shift of fielded safety-critical systems from design-time V&V-centric solutions to run-time assurance-centric solutions, or an integrated concept of both. Requirements will be needed to define the continuum of V&V where at one end of the spectrum complete design-time V&V exists, and at the other end of the spectrum complete run-time assurance exists. This would allow designers to appropriately trade run-time assurance with design-time V&V. Areas of interest in this topic are as follows:

· Integrated hierarchical abstract design and formalized run-time assurance
· Fault tolerant software architecture/middleware
· Validation of static and dynamic requirements
· Runtime execution assurance and checking
· Mixed criticality partitioning
· Integrated software/hardware fault detection and recovery
· Critical data dependency and timing issues.

PHASE I: Investigate innovative ideas and designs for safety assurance techniques that can be incorporated into an integrated run-time and design-time software development environment. This phase requires appropriate research, and then design and analysis of a software assurance technique. Modeling and simulation to prove a feasibility analysis are desirable to demonstrate technique for further development in Phase II.

PHASE II: develop the technique into a software assurance tool and demonstrate its performance in a relevant software environment. Development and demonstration should address an identified critical issue and its application to associated topic goals and objective. A degree of commercial viability should also be demonstrated. This phase requires development of a software tool that is consistent in form, function, and protocol requirements for application to aerospace vehicle control system software.

DUAL USE COMMERCIALIZATION: During Phase III, the small business will pursue commercial application or transition of the assurance technique developed in Phase II as applied to space platforms, commercial aviation, and other applicable safety-critical control systems. Space platforms include the AFRL space operations vehicle, the NASA orbital space plane, and the NASA-AF space maneuver vehicle. Commercial aviation includes advanced fly-by-wire systems (i.e., 777). Military vehicles include F-22, JSF, Unmanned Combat Air Vehicles (UCAV), and future Unmanned Air Vehicles (UAV) systems.

REFERENCES: 1. Zelkowitz, Marvin V. and Rus, Ioana, “The role of independent verification and validation in
maintaining a safety-critical evolutionary software in a complex environment: The NASA space shuttle program,” Proceedings IEEE International Conference on Software Maintenance (ICSM 2001), Florence, Italy, Conference Date: 7 November – 9 November 2001 (http://www.cs.umd.edu/users/mvz/pub/icsm2001.pdf)

2. Hull, Jason; Ward, David; Zakrzewski, Radoslaw R., “Verification and Validation of Neural Networks for Safety - Critical Applications”, 2002 American Control Conference, Anchorage, AK, United States, Conference Date: 8 May 2002-10 May 2002.

KEYWORDS: Verification, Validation, V&V, Flight-Critical Software, Software Development, Safety-Critical Software, Adaptive Control, Assurance, Requirements Trace Ability, Intelligent Control, Flight Control, Non-deterministic Software, Reconfigurable Flight Control, Neural Networks, Artificial Intelligence, Fuzzy Logic, Expert Systems.

AF04-247 TITLE: Constraint Estimation for Aerospace Vehicle Trajectory Retargeting

TECHNOLOGY AREAS: Air Platform, Information Systems, Space Platforms, Weapons

OBJECTIVE: Develop creative methods and algorithms for the application of trajectory retargeting for air vehicles.

DESCRIPTION: Reconfiguration capabilities are essential to the success of autonomous aerospace reusable launch vehicles (RLVs). Vehicles equipped with such systems will be capable of recovering from control effector failures or vehicle damage when physically possible, thus increasing vehicle safety and reliability. A vehicle employing a reconfigurable control and guidance system will consist of three main components: control reconfiguration, guidance reconfiguration, and trajectory reshaping. The objective of control reconfiguration is to maintain inner-loop stability and recover as much maneuverability as possible when faced with modified vehicle dynamics. RLVs typically have a minimal control effector suite, and therefore recovering nominal inner-loop vehicle performance after a catastrophic event, such as a control surface failure, may not be possible. In this case, guidance reconfiguration can be utilized to maintain flight stability by modifying the commands to the degraded inner-loop attitude control system. Even with these capabilities, the desired end mission segments may be unachievable with the nominal trajectory commands. To circumvent this situation, the trajectories can be reshaped online so that the degraded vehicle can achieve the best possible end mission conditions. Therefore, it is pertinent to have either the ability to generate feasible reference trajectories or to be able to select feasible precomputed reference trajectories online in response to failures or damage. To do so requires the identification of critical parameters or constraints based on knowledge of the failure and prediction of the failure's future effects on vehicle performance.

PHASE I: Innovative ideas are sought for the design of an online trajectory retargeting algorithm that takes into account the effects of a failure or damage on future vehicle performance. Demonstrate a new and creative research and design approach for the application of online trajectory retargeting. This would be accomplished through appropriate research and then the design and analysis of a trajectory retargeting algorithm. A simplified simulation to demonstrate the capabilities is desirable.

PHASE II: Develop and expand the trajectory retargeting algorithm for an air vehicle and refine the analysis and synthesis tools. Demonstrate the concept on a detailed simulation.

DUAL USE COMMERCIALIZATION: The methods and tools developed under this effort will be applicable to a wide variety of air vehicles, including current and future RLVs, civilian space access vehicles, and other autonomous air and ground vehicles.

REFERENCES: 1. Eric N. Johnson, Anthony J. Calise, and J. Eric Corban, "Reusable Launch Vehicle Adaptive Guidance and Control Using Neural Networks," Proceedings of the 2001 AIAA Guidance, Navigation, and Control Conference, Montreal, Quebec, Canada, August 2001. (http://controls.ae.gatech.edu/papers/johnson_gnc_01.pdf)

2. J. Schierman, J. Hull, and D. Ward, "Adaptive Guidance with Trajectory Reshaping for Reusable Launch Vehicles," Proceedings of the 2002 AIAA Guidance, Navigation, and Control Conference, Monterey, California, August 2002. (www.barron-associates.com/media/pdf/AIAA_2002_4458.pdf)

KEYWORDS: Trajectory Generation, Adaptive Guidance, Adaptive Control, Variational Calculus, Two Point Boundary Value Problem, Aerodynamic Constraints

AF04-248 TITLE: Innovative Weight Efficient Combined Structural/Thermal Protection System (TPS) Concepts

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Explore the feasibility and establish the weight benefits of structural/TPS concepts that not only carry local thermal and aerodynamic loads, but also carry vehicle body loads.

DESCRIPTION: Traditional TPS approaches are largely parasitic in nature in that a separate TPS transmits the local aerodynamic loads to an underlying, highly efficient, primary structure. Hot structure requires no separate TPS in that the structure itself sustains the thermal loading. This approach, however, suffers from having to use generally less structurally efficient, high-temperature materials to sustain the thermal environment. The approach proposed by this topic is to investigate more unitized designs in which a highly efficient structure can be given an integral, load sharing, heat resistant, outer surface. Such structure is applicable to a future, all-rocket, two-stage-to-orbit (TSTO) Space Operations Vehicle that will provide reusable access to low Earth orbit (LEO). Other future vehicles that can also benefit from this structural approach include air-breathing hypersonic accelerators and cruisers that will operate in the range of Mach 6 to 8. An accelerator might be the first stage of a more advanced TSTO military space plane system that would deliver payloads to and return them from LEO. An air-breathing cruiser, unlike an accelerator, would operate hypersonically for extended periods of time within the atmosphere.

PHASE I: Develop analytical methodologies and concepts applicable to integrated TPS. A representative vehicle component should be selected upon which to base design development. Candidate approaches will be conceptualized and subjected to thermal structural analyses to assess weight and thermal compatibility. For those approaches deemed feasible, coupon and small panel specimens will be designed, fabricated and tested in to assess feasibility.

PHASE II: Methodologies and concepts developed in Phase I will be validated by experimentation. Phase II will involve the scale-up, design, fabrication, and testing of larger size components typical of the vehicle's outer moldline structure.

PHASE III DUAL USE APPLICATION: The development of structures using advanced materials can be transferred into the commercial market in both the aircraft and automotive industries. The development of these new structures will result in stronger, lighter more efficient commercial aircraft and automobiles.

REFERENCES:
1. The Composites Material Handbook—Mil-17, CRC Press, 1999.
2. Mackerle, Jaroslav, Ceramics and Ceramic Matrix Composites: Finite Element and Boundary Element Analyses, A Bibliography (1998-2000), Finite Elements in Analysis and Design, 38, pp. 567-577.
3. Holmquist, T.J. and Johnson, G.R. “Response of Silicon Carbide to High Velocity Impact,” J. Appl Phys. Vol. 91, No. 9, pp. 5858-5866, 2002.

KEYWORDS: hypervelocity vehicles, military space plane, space operations vehicle, integrated thermal protection systems, hot structures, cryogenic tanks, ceramic matrix composites

AF04-249 TITLE: Demonstration of Multiple Fiber Pre-forms for Local Property Tailoring

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Locally tailor and control engineering properties of interest in composite structures by precisely integrating local fibers and or resins different from “field” resins and fibers.

DESCRIPTION: Current composite structures rely on relatively continuous fibers and resins as constituent materials. A wing skin, for instance, is generally one resin system and one fiber type. In some instances, in order to achieve some particular performance objective, fibers may be mixed within a resin system. This is generally achieved through local inclusions of laminations from the desired fiber, or in some specific instances cloth is woven using two different fiber tows. Due to the orthogonality of the weave, benefits of such an approach are limited. And there are manufacturing problems involved in the location and placement of such specific separate laminations. To achieve performance that requires a resin variation, separate parts must be manufactured and then joined. Such joints have associated manufacturing costs, increases in structural weight, and may initiate structural failures. The Structures Division of the Air Vehicles Directorate is interested in developing concepts for more integrated composite structures that would rely on fabrication and manufacturing processes that would allow a gradual, local change in resin and fiber properties that does not require the inclusion of separate laminations.

PHASE I: Identify in current Air Force service, or envision a structural airframe application requiring multiple composite material forms for reasons generated from local requirements. Such an application may be, but is certainly not limited to, a local skin temperature markedly higher than found nearby, a local load increase commonly reacted through pad-ups or stiffeners, and a requirement for a window within a structure, or an area known to be locally subject to impact. Propose a local structural design that would meet requirements and result in a lower cost, lighter weight, or increased performance and is the result of a fabrication/manufacturing process that allows local insertion of fiber or resin forms different from the general structural composite. Demonstrate proof of concept sufficient to progress to Phase II through manufacture and test of characteristic structural test elements.

PHASE II: Develop the conceptual design for the component identified or envisioned in Phase I. Demonstrate features of the design concept and maturity of the manufacturing processes involved through the design, development, manufacture and eventual full-scale test of the component. (Final testing will be conducted by the Air Force – developmental will be conducted by the successful offeror.)

DUAL USE COMMERCIALIZATION: Demonstration of a successful process or technique that will allow manufacture of composite structure from locally varying materials, for local control of properties, structural response or function, and without the need for discrete mechanical joints, will enable a new generation of structure. Imagined uses include local heat shielding, fully integral antennas or windows, electrical or other energy transport, and selective control of mechanical response. Numerous commercial applications are expected to result from such generally enabling technology.

REFERENCES: 1. S.Suresh and A. Mortensen, Fundamentals of Functionally Graded Materials: Processing and Thermomechanical Behavior of Graded Metals and Metal-Ceramic Composites, London: IOM Communications Ltd, 1998.

2. Terry Richardson, Composites: A Design Guide, NY, NY Industrial Press, 1987.

3. J.E. Mark, C.Y, C. Lee, P.A. Bianconi, "Hybrid organic – inorganic composites," eds.
– Amer Chem Soc. Meeting (207th, 1994 San Diego), Washington D.C. ASC, 1995.

4. Jyongsik Jang; Cholho Lee, Dept. of Chemical. Technology., Seoul Nationak. University, South Korea, "Fabrication and Mechanical Properties of Glass Fibre-Carbon Fibre Polypropylene Functionally Gradient Materials," Journal of Materials Science , vol.33, no.22 , Page: 5445-5450, Publisher: Kluwer Academic Publishers , 15 November 1998.

KEYWORDS: Thermal Protection Systems (TPS), Weight Minimization, Integrated TPS, Extreme Environment, Thermal/Acoustic

AF04-255 TITLE: Next Generation, High Temperature Chip Based UV and IR Sensors

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Increase reliability and systems capability in monitoring Ultra Violet signature for detecting jet engine fire.

DESCRIPTION: The current system for detecting engine fire on fighter engines is a 1970s technology using a gas filled, glass tube to detect Ultra Violet signature for detecting engine fire. This system is expensive, rather bulky and heavy. Due to the high cost of this item (about $4,700.00 per unit), the U.S. Air Force is forced to purchase repair kits, and maintain repair procedures and trained personnel in order to support this system. This proposal will develop high temperature lightweight chip based sensing technology with additional secondary capabilities that will be significantly less expensive, with unmatched reliability. The reduction in unit cost will make this item an expendable part allowing the Air Force to perform needed maintenance at field level effectively eliminating the need to cycle engines in for this particular part replacement procedure. This will reduce the inherent expense of accompany repair procedures, freeing valuable maintenance personnel for other essential tasks. The material Indium Antimonide (InSb) is commonly used as a photo-voltaic detector with a peak response at 5.5 mm. Photo-conductors are slabs of semiconductor materials with a voltage applied to sense the change in resistance with flux. Perhaps the most common thermal infrared photoconductor material is HgCdTe (Mercury Cadmium Teluride, or MCT) with a response peak at about 11 mm. It turns out that a combination of InSb and HgCdTe detectors can be configured to cover the entire thermal infrared range.

PHASE I: Provide a proof of concept/design and technology capability for developing high temperature microcircuit system.

PHASE II: Build the prototype device for testing on a static engine test bed and proofing the reliability of the system.

DUAL USE COMMERCIALIZATION: With extreme temperature capabilities it would be easy to adapt this technology for applications in spacecraft, search and rescue operations, monitoring systems in harsh forbidding conditions and possible use of this technology in Home Land Defense. Application of this technology is viable across all weapons systems.

REFERENCES: 1. "Diamond Microcircuitry", Dr. Gisela A. Dreschhoff and Dr. Edward J. Zeller, Radiation Physics Laboratory of the Space Technology Center at the University of Kansas, in Lawrence.

KEYWORDS: High temperature, chip-based sensing, high reliability.

AF04-256 TITLE: Streamlined Site Investigation Procedures

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop new technologies for enabling efficient well locations.

DESCRIPTION: New technologies are needed for testing subsurface soils and groundwater, sampling, well completion techniques, sampling technologies enabling more efficient well location, minimizing the need for numerous wells.

A recommended phased approach would first develop a streamlined method for DNAPL contaminated site clean up. Typically, the path to site closure is a very long and indirect one. The accepted methodology of drilling and sampling monitor wells one year and, based on the sample results, going out again to drill infill monitor wells and take more samples is neither efficient nor cost effective. Site delineation can often take up to 3 years just to delineate the contaminant plume and often the appropriate data for a specific remedial technology will still not be obtained. By using the results of the technologies proposed for this project, along with additional new technologies, the result will be a streamlined site investigation flow-chart.

Next phase of this project is intended to test new field technologies that could be included as a part of this flow chart, but more importantly, be used for actual site investigation and remediation in a streamlined manner. There are many remediation technologies available for these types of contaminants, however, no remediation will be successful until the source of the contaminant plume is located. Also, more precise vertical and horizontal contaminant distribution is needed prior to remedial design. Due to the need to delineate the source area more completely, both horizontally and vertically, for effective remediation, more cost effective and technically efficient methods for site description and remediation are needed.

PHASE I: Perform a research that includes site data review, site investigation, source identification, field confirmation and recommendations. The research report should include a concept demonstration of the decision tree streamlined methodology.

PHASE II: The development of a complete Decision Tree Streamlined Methodology with validation on several sites that confirm the results of the source identification and site investigation technologies. This will consist of placing sample points in recommended locations to ensure that the results of the source identification can be reproduced.

DUAL USE COMMERCIALIZATION: This technology and developed product could be used by all of the AirForce centers as well as many industrial commercial centers. A commercial application could be developed in that the streamline methodology would serve as a sort of 'road map' for remediation of any site contaminated with any chemical. The user would determine basic site characteristics and, using the methodology, be able to take only the appropriate and necessary steps towards site remediation thus minimizing unnecessary site investigation and remediation costs.

REFERENCES: 1. Assessing Contractor Capabilities for Stream Site Investigation, EPA 542-R-00-0001.

KEYWORDS: Site investigation, well locations, subsurface soils

AF04-257 TITLE: Next Generation Confined Space Monitoring & Inspection System

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Reduce the requirement for physical inspection in hazardous confined spaces.

DESCRIPTION: Many aircraft inspections during depot overhaul are labor intensive and some are very dangerous and/or hazardous such as the Fuel Tank inspections. Improved inspections with the latest technology of remote cameras, new 3-D viewing technology, Fuel Tank bladder damage/leak detection, and Virtual Reality projector systems need to be researched and potential use analyzed. Monitoring systems need to be enhanced to track and monitor actual persons entering and inspecting these hazardous confines spaces. These same devices could potentially be used to monitor, track and locate remote sensors or cameras.

This research effort needs to investigate the latest Virtual Reality capabilities and projection systems for improving many of the labor intensive inspections and reducing the hazardous inspections such as the Fuel Tank areas as well as development of possible NonDestructive Inspection (NDI) for Fuel Tank damage detection in fuel vapor environment.

PHASE I: Provide a proof of concept demonstration of utilizing new confined space monitoring technology for protecting mechanic in hazardous spaces. Demonstrate total replacement of the need for mechanic to inter space with utilization of Virtual Reality remote system that can be used in hazardous environments.

PHASE II: Based on the success of the prototype concept demonstration, implement a production model for use aircraft line.

DUAL USE COMMERCIALIZATION: This technology can be applied to other DoD aircraft depot lines as well as commercial aircraft inspections.

REFERENCES: 1. NASA Example of 4-D Viewing Technology:
http://www.cnn.com/interactive/space/9905/atlantis.ipix/content.html

KEYWORDS: Detection technology, Inspection Technology, Virtual Reality

AF04-258 TITLE: Chemical/Biological Decontamination

TECHNOLOGY AREAS: Chemical/Bio Defense, Biomedical

OBJECTIVE: Develop and test a novel, spray-applied, water-based, two-part liquid formulation capable of decontaminating, through micro-encapsulation.

DESCRIPTION: U.S. Air Force Depot's may receive material/parts/components for repair/refurbishment returned from a forward operating location, which may have been exposed to Chemical/Biological agents. Although it is envisioned that decontamination will be accomplished at or near the threat location, the extent to which the items are decontaminated cannot be determined by the depot through current inspection techniques without the potential of exposure to personnel, facilities and equipment. Therefore a repair depot is at a heightened risk of contamination due to the processing of material/parts/components for repair from these forward locations. At this time, no decontamination system is currently in place to adequately protect the DoD employees, contract employees and facility integrity.

Presently, chemical/biological agent decontamination procedures involve spraying a liquid solution or foam on the exterior surface of the military asset, not the item or piece part level. The military's current decontaminating solutions (Decontaminating Solution 2 or DS2, and super tropical bleach) are corrosive and (in the case of DS2) contain aggressive organic solvents. These can damage critical component materials such as sensitive metals, high strength steel fasteners, o-rings, seals and sealant, as well as other components. This damage can even lead to catastrophic failure under conditions of high stress in the component's operating environment. Furthermore, standard decontaminating solutions such as DS2 are hazardous to Government and Contractor personnel. Large amounts of fluid must be applied in decontamination, and the fluids contain ingredients that are toxic, flammable, and corrosive. Additionally, the chemical and biological agents and decontamination fluids used may be trapped within items returned for repair. This poses an additional risk to the employee, the facility and the equipment that comes in contact with these items.

While several alternative products that have reduced toxicity and low risk of damage to materials have recently been developed, these products take longer than current decontaminating solutions to destroy chemical and biological agents. Even though field contamination will be performed, there is no guarantee that all components/materials and support equipment will be 100% decontaminated. A depot specific system insures the safety of depot employees and contractors and prevents cross contamination of other components/materials in the pipeline for repair.

A simple, facility-expedient or field-expedient method that does not damage parts or materials, is safe for personnel, and results in non-toxic waste products is needed for rapidly decontaminating military parts surfaces. This method must be effective against both biological and chemical agents. It must eliminate the threat from these agents within minutes. Finally, the product must possess long-term shelf stability allowing for support of sufficient quantities to be utilized in the day-to-day depot activities as required.

PHASE I: Develop an encapsulation system to test and verify its effectiveness against biological and chemical agent stimulants. This testing will further verify the "life" of the individual microencapsulate prior to desorbtion/leaching.

PHASE II: Incorporation of any potential modification to the encapsulation system indicated by Phase I testing. Testing and verification of the system demonstrated in Phase I with any subsequent modifications against actual chemical/biological agents.

DUAL USE COMMERCIALIZATION: This technology is needed for any biological or chemical agent that could be utilized by any party.

REFERENCES: 1) "Microencapsulation Renders Wastes Inert" Hydrocarbon Processing, August 2000.

2) "Encapsulation Transforms Hazardous Materials" Pollution Engineering, September 2000.

KEYWORDS: Chemical, Biological, Micro-encapsulation, Decontamination, Contamination

AF04-264 TITLE: Chemical, Biological, or Radiological (CBR) Agent-Resistant Composite Materials For Tactical Shelters

TECHNOLOGY AREAS: Chemical/Bio Defense, Materials/Processes

OBJECTIVE: Provide low-cost, effective composite material to withstand CBR exposure and decontamination without structural or functional degradation of tactical shelter.

DESCRIPTION: The operational requirements for tactical shelters require that they be capable of performing mission essential functions under normal battlefield environmental conditions and hazards. In today's battlefield that includes CBR agents. The Shelter Program Office has undertaken an initiative to design and produce a Composite Tactical Shelter, however the impact of CBR agents on the composite materials is not totally understood. This project seeks to develop a low cost process that will offer long-term protection and decontamination (Decon) capabilities against the known CBR agents (such as VX, Sarin, virus and radioactive materials like plutonium and

Cesium 137 etc). Some of the current Decon processes (which involve the use of solvent such as MEK and TCE etc) may be more toxic than the agents being protected against. Additional objectives are as follows: (i) The process shall be non-toxic & environmentally friendly, (ii) it shall be easily adaptable for incorporation into various composite manufacturing techniques, (iii) it shall be easy to repair at the field maintenance level, and (iv) it shall not shorten the composite material life span or degrade its performance.

PHASE I: Design or research existing materials, that will provide the following target capabilities: (i) Provide CBR protection and decontamination capability for composite shelter systems, (ii) shall be compatible with different types of composite manufacturing techniques.

PHASE II: Develop a commercially viable process for production of CBR-resistant composite materials for tactical shelters. Then incorporate this process into existing composite tactical shelter development and produce shelter components for testing.

DUAL USE COMMERCIALIZATION: The proposed material will have numerous applications for military and industrial communities including hazardous material storage containers, hazardous waste storage containers, and the development of CBR-resistant emergency response equipment for battlefield applications.

REFERENCES:
1. ASTM E1925, "Specification for Engineering and Design Criteria for Rigid Wall Relocatable Structures." Website http://www.astm.org

2. Natick Soldier Center, "DOD Standard Family of Tactical Shelters," January 2000. Web link: http://www.sbccom.army.mil/

3. CBR Incident Handbook, October 1998, website http://cia.gov/cia/reports/cbr_handbook/cbrbook.htm

4. FM 3-6, Field Behavior of NBC Agents, website http://155.217.58.58/cgi-bin/atdl.dll/fm/3-6/toc.htm

KEYWORDS: VX, Sarin, Virus, Plutonium, methyl ethyl keton (MEK), trichloroethylene (TCE), CBR, NBC, Handbook

AF04-265 TITLE: Low Cost, High Tensile Strength Composite Materials

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Provide a low-cost, high tensile strength composite cable wire.

DESCRIPTION: Composite materials have long been excellent materials for use in highly corrosive areas, such as salty/musty coastal air and chemical/acid environments, due to their corrosion resistance characteristics. However, composite materials' tensile strength is usually quite low (about 10% of their steel counterpart), thus making them undesirable for high tensile strength applications such as bridge cables, guy wires, nuts and bolts, and submerged under water fastening applications such as angle brackets, brace members, rivets etc. These applications require the need for expensive corrosion protection systems and significant maintenance costs. This project seeks a low cost composite material that will offer high tensile strength properties for applications mentioned above. Additional objectives are as follows: (i) the materials shall be non-toxic & environmentally friendly, (ii) it shall be ultraviolet (UV) resistant and (iii) it shall be easy to use and store.

PHASE I: Design a low cost, high tensile strength composite material with the following target capabilities: (i) applicable to major Department of Defense weapon system applications and (ii) able to resist against UV ray damage.

PHASE II: Develop a commercially viable high tensile strength composite product, which will meet or exceed all American Society for Testing and Materials (ASTM) guidelines. Proof of concept to be justified on a wide variety of tensile strength tests in accordance to ASTM standards.

DUAL USE COMMERCIALIZATION: The proposed high tensile strength composite will have numerous benefits to the military and commercial ships, service vessels, submerged flat forms, bridges, etc.

REFERENCES: 1. ASTM Standard D-3039/D-3039M-00, "Standard Test Method For Tensile Properties of Polymer Matrix Composite." Web link: http://www.astm.org

2. ASTM Standard A1023/A1023M, "Standard Specification for Stranded Carbon Steel Wire Ropes." Web link: http://www.astm.org

3. "The Right Stuff for Super Spaceship," Nanotube Composite, 16 Sep 02, NASA web link: http://science.nasa.gov/headlines/y2002/16sep_rightstuff.htm

4. Natick Soldier Center, "DOD Standard Family of Tactical Shelters," January 2000

KEYWORDS: Composite, Guy Wires, Cable, Corrosion, High Tensile Strength, Low Cost

AF04-266 TITLE: Self-Activate Corrosion Inhibitor

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a low cost, high performance corrosion inhibitor that will self-activate when moisture is present in sandwich/structural panels.

DESCRIPTION: The need to eliminate moisture-caused corrosion deterioration inside aircraft/shelter aluminum panels has been recognized for years. Corrosion caused by moisture inside these panels cannot be detected through the use of conventional Non-Destructive Inspections (NDI). Manual inspections and repairs are very costly and time-consuming. This project seeks a corrosion inhibitor that will activate when exposed to moisture in these panels. Additional objectives are as follows: (i) the inhibitor shall be non-toxic with a low impact on the environment and (ii) it shall be easy to apply and store.

PHASE I: Develop a corrosion-inhibiting compound with the following target capabilities: (i) provide corrosion protection for major Department of Defense weapon systems (aircraft wings & stabilizers, shelter wall panels, etc.); (ii) activate inside the panel in the presence of moisture.

PHASE II: Further develop a commercially viable corrosion inhibitor product, which will meet or exceed all Environmental Protection Agency safety guidelines. The product will be tested on a wide variety of test subjects and structural applications under severe service and environmental conditions.

DUAL USE COMMERCIALIZATION: This corrosion inhibitor project will have numerous benefits to the military and industrial communities. It will benefit both commercial & military aircraft, shelters, and commercial trailers, as well as offshore applications for ships, shipping containers, service vessels & platforms etc.

REFERENCES: 1. Merkle, D. H., "New Family of Portable Shelters," Vol.2, Air Force Research Laboratory Report No. WL-TR-97-3032, May, 1998.

2. ASTM E 1925, "Specification for Engineering and Design Criteria For Rigid Wall Relocatable Structures."

3. "Paint, Coatings, and Corrosion Control in Manufacturing," University of Wisconsin-Madison, March 1999.

4. "DOD Standard Family of Tactical Shelters," Natick Soldier Center, January 2000.

KEYWORDS: Corrosion, Inhibitor, Low Cost, Moisture, Self-Activate, Protective

AF04-267 TITLE: Advanced Composite Structural Members for Tall, Narrow Structures

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Provide a low cost, composite structural tubing product to replace the steel infrastructure in tall, narrow towers and platforms.

DESCRIPTION: The use of composite materials, which have been shown to be corrosion free in extremely harsh, high humidity environments, has been practically none-existence in tall, narrow civil infrastructure due to technical difficulties and high costs. A lower cost alternative consists of composite pultruded I-beams and tubes designed for use in a limited number of structural applications. These parts are made by pulling the material through a heated die. The process reduces the cost on a weight basis, however, the mechanical strength and stiffness are reduced when compared to fabric and filament wound composite parts. When using these parts in long length structures such as monopole or lattice self support, guyed, and truss type towers, an excess amount of material or cross bracing must be used to compensate for the property reductions. This excess material increases the cost many times beyond the cost of steel structures and reduces the value of the underlying corrosion free benefits. This project seeks a low cost composite solution achieved through an improvement in material properties. A primary objective will be an increase in stiffness to enable the use of efficient, long length members in axially loaded cross-braced platforms as well as guyed towers. A second objective will be to investigate a low cost manufacturing process. The final goal will be to validate the structural strength and economic viability with an economic cost equivalent to steel.

PHASE I: Design a low cost structural composite tubing product with the following target capabilities: (i) stiffness that is equal to or better than steel, (ii) develop a joining system to connect the tube segments together and (iii) determine the best resin/composite combination for the proposed environment.

PHASE II: Develop a commercially viable process for manufacturing the tubes. Based on Phase I design, build a wide variety of specimens as proposed for a tall tower or platform. Test the specimens for deflection, strength, and fatigue according to American Society for Testing and Materials (ASTM) standards. In addition, test specimens for degradation associated with moisture absorption and ultraviolet resistance.

DUAL USE COMMERCIALIZATION: The proposed product will have numerous benefits to military radar towers and civil infrastructure such as windmills, flag poles, and weather instrument poles.

REFERENCES: 1. ASTM Standard D2990-01, “Standard Test Method for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics.”

2. ASTM Standard D790, “Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics.”

3. “Composite Tower System Requirement Document,” AF Tactical Shelter & Radome Program Office, Dec 2002.

4. ASTM Standard A-871, “Standard Specification for High-Strength Low-Alloy Structural Steel Plate with Atmospheric Corrosion Resistance.”

KEYWORDS: Composite, Stiffness, Tall Structures, Tower, Flat Form, Low Cost

AF04-268 TITLE: Demonstrate Alternative Wear Coatings for Improvement of Landing Gear Performance

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Improve performance of aircraft landing gear (LG) components by development and application of alternative wear-resistant coatings.

DESCRIPTION: Current LG components have chrome as a wear-protective coating applied on their surfaces via aqueous electro-deposit. Chromic acid, used in the deposition process, is a hazardous substance as it is primarily hexavalent chromium, which is a known human carcinogen and is extremely expensive to dispose of. Executive Order EO13148 requires the reduction of this hazardous material usage by 50% by the end of 2006. Among many industrial coating techniques Physical Vapor Deposition (PVD) is known to produce the highest quality coatings. One of the PVD-type processes, Ion Vapor Deposition (IVD), has been successful in the application to LG components yet it is fundamentally limited to applying coatings of only one material - aluminum. Being a good corrosion resistant material, aluminum cannot provide protection of LG from wear. A novel prototype is required to develop a method of depositing wear resistant materials to LG components. The current effort will develop a novel technique to apply quality coatings of various wear resistant materials to external as well as internal surfaces of LG components. Specific efforts will be concentrated on methods of surface cleaning and preparation, as well as coating thickness control, and deposition rates comparable to electrolytic plating. The PVD process will demonstrate an ability to produce uniform, well-adhered hard coatings to comply with existing LG test protocol requirements.

PHASE I: Demonstrate the feasibility of applying a novel coating prototype device, materials and a process for wear protection of LG specimens under laboratory simulated exposure conditions. Common coating characteristics, such as uniformity, adhesion, and hardness, should be sufficient to maintain or exceed current system results.

PHASE II: Further develop and optimize the coating prototype device demonstrated in Phase I effort and exhibit the performance improvements using the developed technology on LG component. Emphasis should be given to quality control methods and non-destructive evaluation of coated LG components.

DUAL USE COMMERCIALIZATION: This coating technology will have multiple uses for both military and commercial aircraft applications. Any transportation or mechanical systems where steel is exposed to a corrosive environment will have applications for the developed coating system.

REFERENCES: 1. S.M. Rossnagel and J. Hopwood, “Metal Ion Deposition From Ionized Magnetron Sputtering Discharge”, J. Vac. Sci. Technol. B 12(1), 449 (1994).

2. U. Schulz, K. Fritscher, C. Leyens, M. Peters, and W.A. Kaysser, “The Thermocyclic Behavior of Differently Stabilized and Structured EB-PVD TBCs” Published by The Minerals, Metals & Materials Society (TMS) http://www.tms.org/pubs/journals/JOM/9710/Schulz/Schulz-9710.html

3. K. Tao, D. Mao, and J. Hopwood, “Ionized Physical Vapor Deposition of Titanium Nitride: A Global Plasma Model”, J. Appl. Phys., 91(7), 4040-4048 (2002).

4. Koval N.N., Goncharenko I.M., Grigoriev S.V., Schanin P.M., “Multiphase Wear-Resistive Coatings Produced on Steels By a Combined Vacuum Plasma-Ion Method” Proc. 1st Intern. Congress on Radiation Physics, High Current Electronics, and Modification of Materials. Tomsk, Russia, 2000. Vol. 3. P. 424-428.

5. S.L. Lee, M. Cipollo, D. Windover, C. Rickard, “Analysis of Magnetron-Sputtered Tantalum Coatings Versus Electrochemically Deposited Tantalum From Molten Salt”, US Army Research and Engineering Center, Benet Laboratories, NY; Published by Surface and Coatings Technology 120-121 (1999) 44-52.

KEYWORDS: Wear, Coatings, Chrome Replacement, Landing Gear, Quality Control, Adhesion

AF04-269 TITLE: <u>Thermo-Plastic Materials Replacement For Metal or Composite Shelters</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Identify and provide suitable Thermo-Plastic materials to replace 1) thermoset composite structures/shelters and/or 2) conventional metallic structures/shelters.

DESCRIPTION: The Department of Defense (DoD) spends millions of dollars every year to repair and refurbish numerous metal structures or shelters located all over the world. Thermo-Plastic materials have the potential to offer a lighter weight replacement for metal structures or shelters at a reduced cost. The proposed objectives for this Thermo-Plastic structure or shelter are as follows: (i) reduce manufacturing costs, (ii) reduce shelter foot-print to comply with the Air Force Expedition Force requirements, (iii) be environmentally safe for human occupation per American Society for Testing and Materials (ASTM) E1925, (iv) reduce the volatile organic compound (VOC) emissions in fabrication, (v) provide a shelter material that can be recycled to eliminate waste at end-of-life disposal.

PHASE I: Conduct research and determine feasibility of replacing current metal-based or composite-based materials with Thermo-Plastic materials with the following goals: (i) low cost and readily available, (ii) non-toxic and fire resistant/retardant, (iii) structure shall be made of 100% Thermo-Plastic materials with the same or greater strength as their metal or composite counterparts, (iv) meet requirements specified in ASTM E1925, (v) life cycle cost should be significantly less (50% or better) than comparable metal or composite counterpart.

PHASE II: Design and develop a cost effective manufacturing process to construct commercially viable Thermo-Plastic shelters. Structural analyses by computerized simulation shall be conducted to ensure the shelter will meet ASTM standard E1925. A prototype Thermo-plastic shelter must be constructed and subjected to formal testing to meet the ASTM E1925 requirements. Following successful testing of the prototype, the manufacturing process must be subjected to First Article testing to ensure the manufacturing process will produce compliant, cost effective shelters.

DUAL USE COMMERCIALIZATION: The proposed Thermo-Plastic shelter will have numerous applications to both the military and industrial communities including: commercial trailers for trucking and railway, offshore applications for ships, shipping containers, service vessels, platforms, and undersea facilities. Thermo-Plastic structures can be applied to residential dwellings as well as commercial service “bare base” hangers and storage containers. Thermo-Plastic shelters/structures offer the ability to replace numerous existing corrosion-prone and aging DOD metal shelters and containers.

REFERENCES: 1. ASTM E1925, “Specification for Engineering and Design Criteria For Rigid Wall Relocatable Structures.”

2. Natick Soldier Center, “DOD Standard Family of Tactical Shelters,” January 2000. Web link: http://www.sbccom.army.mil/

3. MIL-STD-1472D, Notice 3, “Human Engineering Design Criteria for Military Systems, Equipment and Facilities.”

4. ISO 668-1995 Series 1 Freight Containers-Classification, Dimensions and Ratings.

KEYWORDS: Thermo-Plastic, Structure or Shelter, Low Cost, ASTM E1925, ISO 668-1995, Reduce Foot-Print, Low VOC, Recyclable

AF04-270 TITLE: Advanced Sacrificial Dense Metallic Coatings for Aircraft Components

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Improve performance of aircraft components by development and implementation of dense corrosion resistant coatings.

DESCRIPTION: Physical Vapor Deposition (PVD) is known to produce good quality coatings. One of the PVD-type processes, Ion Vapor Deposition (IVD), applies aluminum and has been approved by aircraft maintenance facilities as a cadmium replacement alternative technique. Being a good corrosion resistant material, IVD-produced aluminum coatings have poor density and do not provide sufficient protection of aircraft high strength steel components from stringent corrosive environments without additional treatments and easily damageable sacrificial topcoats. The technique is also incapable of depositing any material or alloy other than essentially pure aluminum and is limited to coating application to external surfaces. As a result, many aircraft components still have cadmium as a corrosion resistant coating applied to their surfaces via aqueous electro-deposition. Cadmium is a hazardous substance, a known human carcinogen and is extremely expensive to dispose of. Executive Order EO13148 requires the reduction of this material usage by 50% by the end of 2006. A novel prototype is required to develop a method of depositing highly dense corrosion resistant coatings to aircraft components. The current effort will deploy a technique to apply quality dense coatings of aluminum, its alloys, and other various corrosion resistant materials to internal and external surfaces of aircraft components. Specific efforts will be concentrated on methods of coating quality control. A developed deposition process would demonstrate the ability to produce uniform, well-adhered dense coatings to comply with existing test protocol requirements. Improved protective coating systems that eliminate the need for sacrificial topcoats are of greatest interest.

PHASE I: Demonstrate the feasibility of novel coating system materials and/or processes for corrosion protection of steel substrates under simulated exposure conditions. Key test parameters include resistance to mechanical damage and corrosion protection of mechanically damaged/undamaged samples. Common coating performance tests, such as solvent resistance and flexibility, should be performed to maintain or exceed current system results.

PHASE II: Further develop and optimize the coating system developed in Phase I effort and demonstrate the performance improvements using the developed coating technology and materials on aircraft components.

DUAL USE COMMERCIALIZATION: These protective coatings will have multiple uses for both military and commercial aircraft applications. In addition, any transportation or mechanical systems where steel is exposed to a corrosive environment will have applications for this development.

REFERENCES: 1. S.M. Rossnagel and J. Hopwood, “Metal Ion Deposition From Ionized Magnetron Sputtering Discharge”, J. Vac. Sci. Technol. B 12(1), 449 (1994).

2. U. Schulz, K. Fritscher, C. Leyens, M. Peters, and W.A. Kaysser, “The Thermocyclic Behavior of Differently Stabilized and Structured EB-PVD TBCs” Published by The Minerals, Metals & Materials Society (TMS) http://www.tms.org/pubs/journals/JOM/9710/Schulz/Schulz-9710.html

3. K. Tao, D. Mao, and J. Hopwood, “Ionized Physical Vapor Deposition of Titanium Nitride: A Global Plasma Model”, J. Appl. Phys., 91(7), 4040-4048 (2002).

4. Koval N.N., Goncharenko I.M., Grigoriev S.V., Schanin P.M., “Multiphase Wear-Resistive Coatings Produced on Steels By a Combined Vacuum Plasma-Ion Method” Proc. 1st Intern. Congress on Radiation Physics, High Current Electronics, and Modification of Materials. Tomsk, Russia, 2000. Vol. 3. P. 424-428.

5. S.L. Lee, M. Cipollo, D. Windover, C. Rickard, “Analysis of Magnetron-Sputtered Tantalum Coatings Versus Electrochemically Deposited Tantalum From Molten Salt”, US Army Research and Engineering Center, Benet Laboratories, NY; Published by Surface and Coatings Technology 120-121 (1999) 44-52.

KEYWORDS: Corrosion, Coatings, Cadmium Replacement, Aluminum, Density, Aircraft Components

AF04-271 TITLE: Surface Protection of Aircraft Brake Pressure Plates

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Demonstrate improved performance of the Aircraft Brake Pressure Plate by development and application of novel surface protective concept.

DESCRIPTION: Pressure plates of the aircraft breaking system are carbon-carbon composite construction and subjected to very high heat, often above 1000° F. These components are exposed to many contaminants including aircraft and runway deicing chemicals. Upon landing, ground crews often apply a temperature-indicating crayon, or temp stick, to the pressure plate or adjacent rotor channel to determine the temperature of the brake to carry out refueling operations. Temp stick chemicals catalyze carbon oxidation, further accelerating the reaction and causing premature brake failures. Currently used oxidation inhibitors are ineffective in preventing these attacks. Surface protection of the pressure plate is required to lower the impact and, eventually, prevent the costly impact of this temp stick application. The current development effort will concentrate on producing a prototype device to generate an improved oxidation preventive system which, when applied, will protect carbon brake pressure plates and increase their performance characteristics and life span. A new surface protection system must be environmentally compliant and easily re-applicable in the event of damage or maintenance. The developed process would demonstrate an ability to produce uniform, well-adhered deposits to comply with existing Aircraft Brake System requirements.

PHASE I: Demonstrate the feasibility of producing the novel application and its suitability to extend the life of pressure plate specimens under laboratory simulated exposure conditions.

PHASE II: Further develop and implement the approach from Phase I and demonstrate the performance improvements utilizing the developed protection system and application techniques on Aircraft Brake Systems. Specific emphasis should be given to environmental compliance as well as improved maintainability.

DUAL USE COMMERCIALIZATION: The developed surface protective concept will have multiple uses for both military and commercial aircraft applications. Any transportation or mechanical system where carbon brakes are exposed to a highly oxidizing environment will have applications for this prototype device.

REFERENCES: 1. S.M. Rossnagel and J. Hopwood, “Metal Ion Deposition From Ionized Magnetron Sputtering Discharge”, J. Vac. Sci. Technol. B 12(1), 449 (1994).

2. U. Schulz, K. Fritscher, C. Leyens, M. Peters, and W.A. Kaysser, “The Thermocyclic Behavior of Differently Stabilized and Structured EB-PVD TBCs” Published by The Minerals, Metals & Materials Society (TMS) http://www.tms.org/pubs/journals/JOM/9710/Schulz/Schulz-9710.html

3. K. Tao, D. Mao, and J. Hopwood, “Ionized Physical Vapor Deposition of Titanium Nitride: A Global Plasma Model”, J. Appl. Phys., 91(7), 4040-4048 (2002).

4. Koval N.N., Goncharenko I.M., Grigoriev S.V., Schanin P.M., “Multiphase Wear-Resistive Coatings Produced on Steels By a Combined Vacuum Plasma-Ion Method” Proc. 1st Intern. Congress on Radiation Physics, High Current Electronics, and Modification of Materials. Tomsk, Russia, 2000. Vol. 3. P. 424-428.

5. S.L. Lee, M. Cipollo, D. Windover, C. Rickard, “Analysis of Magnetron-Sputtered Tantalum Coatings Versus Electrochemically Deposited Tantalum From Molten Salt”, US Army Research and Engineering Center, Benet Laboratories, NY; Published by Surface and Coatings Technology 120-121 (1999) 44-52.

KEYWORDS: Aircraft, Brake Pressure Plate, Carbon, Oxidation, Surface Protection, Uniform

AF04-273 TITLE: Aircraft Fatigue Damage Inspection

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop an inspection system/technique that can inspect for fatigue cracks in the secondary layer of multi layer metallic structures.

DESCRIPTION: There is a need to inspect for fatigue cracks, in multi-layer metallic structures. Presently the fatigue cracks cannot be found until the aircraft has been removed from service and some disassembly accomplished. These cracks are located under a thick layer of sealant, which makes it difficult to identify. A major drawback to utilizing current methods of inspection requires the aircraft to be removed from service and some disassembled required for inspection. This leads into a host of problems. The goal of this SBIR project is to research a method to inspect for the cracks without removing the skin of the aircraft.

PHASE I: Research and develop a method to detect the fatigue cracks in multi-layer metallic in aerospace vehicles. Demonstrate the ability to detect cracks within the different layers of metallic structure on an F-15 component.

PHASE II: Develop and demonstrate a portable, easy to use, and cost effective system to be used on the outside of the aircraft. This system should be able to detect the cracks on the aircraft. Apply the results of Phase I to the design, fabrication, and experimental validation of the prototype unit. Demonstrate the operability to Air Force personnel and provide a users/maintenance manual for expected operation.

PHASE III DUAL USE APPLICATIONS: Potential applications include inspection of composite structures including commercial aircraft. Potential customers include aerospace, Federal Aviation Administration, Department of Defense, and Department of Energy.

REFERENCES:
1. ASM Handbook, Nondestructive Evaluation and Quality Control, vol. 17, J.R. Davis, S.R. Lampman, ASM International, 1994, Ultrasonic Testing of Materials, Krautkramer, Krautkramer, Springer Verlag, 1990.

KEYWORDS: Aging aircraft, Non-Destructive Inspection, Non-Destructive Evaluation, Inspection

AF04-274 TITLE: Aircraft Corrosion Inspection

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop an inspection system/technique that can inspect for subsurface material loss (corrosion) in multi layer, dissimilar metallic structures and with the metallic structures being tapered in thickness.

DESCRIPTION: With the many aircraft within the Air Force becoming older, there is a need to inspect for corrosion, in the order a material loss of 0.030 inches in these multi-layer metallic structures. Presently the corrosion is not found until the aircraft has been removed from service and some disassembly accomplished. This corrosion causes troubleshooting and repair, which significantly add to Air Force sustainment costs. This leads into a host of problems. Methods and techniques must be developed to allow determination of the corrosion in the depth of the aircraft structure without removing the different layers of material to visual inspect each metallic surface.

PHASE I: Research and develop a method to detect the corrosion in multi-layer metallic in aerospace vehicles. Demonstrate the ability to detect corrosion within the material on a fighter aircraft component.

PHASE II: Develop and demonstrate a portable, easy to use, and cost effective system to be used on the outside of the aircraft. This system should be able to detect material loss on the different surfaces of metallic structures. Apply the results of Phase I to the design, fabrication, and experimental validation of the prototype unit. Demonstrate the operability to Air Force personnel and provide a users/maintenance manual for expected operation.

PHASE III DUAL USE APPLICATIONS: Potential applications include inspection of composite structures including commercial aircraft. Potential customers include aerospace, Federal Aviation Administration, Department of Defense, and Department of Energy.

REFERENCES:
1. ASM Handbook, Nondestructive Evaluation and Quality Control, vol. 17, J.R. Davis, S.R. Lampman, ASM International, 1994, Ultrasonic Testing of Materials, Krautkramer, Krautkramer, Springer Verlag, 1990.

KEYWORDS: Aging aircraft, Non-Destructive Inspection, Non-Destructive Evaluation, Inspection

AF04-275 TITLE: Advanced Battery Modules for Vehicle and Support Equipment

TECHNOLOGY AREAS: Ground/Sea Vehicles

OBJECTIVE: Research and develop an advanced modular battery system capable of providing power for electric vehicles, hybrid electric vehicles and equipment that incorporate the principals of common core power production (C2P2).

DESCRIPTION: Currently the Air Force has a growing need for clean, high quality DC ground power to operate electric vehicles and equipment. This project will conduct applied research into battery manufacturing technology that can meet the United States Advance Battery Consortium (USABC) and Department of Energy mid-term goals.

Batteries packs should be available in a single 12V, 24V and 42V module as well as configurable for a pack output of at least 312V nominal. Additionally, the manufacturing and design should allow for parallel and/or series configurations that increase capacity/power capability of the configuration. The battery or batteries must be able to communicate (SAE 1850) through a battery management system for common Level 3 charging (SAE 2293) systems. The batteries should also be designed with thermal and electrical management that optimizes operation through –40 to 120 degrees Fahrenheit. This technology should expand on the commercial leaders methods for Electrical Vehicle (EV) batteries and battery management that specifically meets the needs of the Air Force and Department of Defense yet is flexible enough for commercial use. The physical design must be modular and adaptable at the interfaces to meet a variety of applications without significant redesign of enclosures. Manufacturing by design would not require significant costs for manufacturing nor engineering for various applications whether for a single application or large-scale production.

PHASE I: Conduct applied research into various battery technologies that meet or exceed the current EV battery specifications while analyzing the best source considering battlefield availability. The research must consider mobility, safety, and environmental issues. Models, drawings and simulations shall indicate minimum risk for continuation to Phase II. Data should be available to prove concept and validate a commercial market.

PHASE II: Develop prototype systems to prove design performance, versatility, reliability, and improvements over the current system. Demonstrations should include, but is not limited to, integration in at least one United States Air Force electric vehicle, one hybrid electric van, one hybrid electric bus, and one hybrid electric tow tractor electric/hybrid electric bomb loader.

DUAL USE COMMERCIALIZATION: Civilian as well as military installation as well as other flightline applications where battery power is required.

REFERENCES: 1. http://www.mountainhome.af.mil/AEFB/default.htm

2. http://ev.inel.gov/fop/general_info/battery.html

3. http://www.ctts.nrel.gov/BTM/fctsht.html

KEYWORDS: Battery, Battery Management Systems, Thermal Management, High Voltage DC, Electric Vehicle

AF04-276 TITLE: Robotic Arm

TECHNOLOGY AREAS: Ground/Sea Vehicles

OBJECTIVE: Research and develop a robotic arm for multiple Air Force munitions loaders.

DESCRIPTION: Currently the Air Force has a growing need for a single device adaptable to different bomb lift trucks to load multiple munitions on multiple airframes. Development and design of new adapters are required with each new weapon and aircraft fielded. This project will conduct applied research into a robotic arm to be integrated initially into a nuclear-certified bomb lift truck (MHU-83) platform with the possibility of installing to the MJ-1 platforms. The current MHU-83 lift arm uses hydraulics to raise/lower/swing itself as well as the end-mounted table where a plethora of adapters are required to perform a variety of weapons loading tasks. Currently there are $71 million of authorized adapters in the United States Air Force (USAF) inventory, and the value grows with each new weapon and aircraft fielded.

The proposed arm shall fit inside the current truck physical constraints while exceeding current movement limitations. Current munitions range from 5”- 36” diameter; non-circular cross-sections shall be considered as well. This unit should lift 7000 pounds in normal use, have a safety factor of lifting 14000 pounds, and hold a static 21000 pounds (nuclear certification requirements). Movement shall be obtained in all six degrees of freedom and in any combination thereof. It must exceed any and all environmental, efficiency, maintenance and performance standards in effect or proposed through 2010. The arm must be ruggedized to the extent of operating in all present USAF theaters.

Market research has shown there is a gap in available equipment, which can do the required tasks and meet the specifications. No robotic arm can carry the capacity needed through the motions required while placing the load in a precise location for attachment under the aircraft's wing. Current precision robotics carry minimal loads indoor in fairly clean areas.

Due to the criticality of safely handling sensitive munitions, USAF has not visited robotics for lifting munitions, but the current state of the art shows promise to fulfill the entire USAF mission.

PHASE I: Conduct applied technology research to meet or exceed the current operational requirements while reducing manufacturing and maintenance costs. The research must consider mobility, safety, and environmental issues. Required concept drawings, simulations, and models shall indicate minimal risk to move to Phase II. Actual lab tests and demonstrations desired.

PHASE II: Develop prototype system to improve design performance, versatility, reliability, and improvements over the current system and manufacture two (2) of these prototype systems for testing.

PHASE III DUAL USE APPLICATIONS: Civilian applications of robotics are numerous. Current assembly, painting, and welding facilities use robotics to perform work. Potential uses for a robotic arm with the capacity the USAF needs are utility industries, hazardous material and waste handling, and heavy lift machinery where large capacity with precision movement is required. Reliability and maintainability will be accomplished via at least one USAF location.

REFERENCES:
1.http://www.kawasakirobot.com/robotscr2.gif
2.http://www.roboticsworld.com/archive/roboticsworld_200205/features.asp
3.Questions about bomb lift trucks or munitions can be directed to the Munition Material Handling Equipment Customer Service Representative SMSgt. Dale Stokes WR-ALC/LESVG (478) 926-7603 ext.114.

KEYWORDS: Munitions, Robotic Arm, End Effector, Bomb Lift Truck

AF04-277 TITLE: Automatic Test Markup Language

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop, implement, and define a set of industry standard definitions to represent test data and Test Program Set (TPS) using the Extensible Markup Language (XML).

DESCRIPTION: Information flow and content, through the course of Automated Test System (ATS) life cycles, offers many opportunities for improvement, modernization, and standardization. Data is produced and utilized from Automated Test System (ATS) inception to ATS retirement. Opportunities to provide cost savings, enhance capabilities, and to stream line work flows by utilizing modern and emerging text based information technologies and formats abound. These include test system requirements documentation, technical orders, internal communication formats, and many other specific application points. Schemata for using these evolving information formats are being developed and revised for use in the ATS domain. Insertion of these technologies can benefit numerous aspects related to Air Force Automated Test Systems. One particular technology that is clearly emerging as a present and future cornerstone is eXtensible Markup Language (XML). XML has been accepted by the computer industry and because of that acceptance there are various tools available for utilizing the data format. This solicitation is looking for innovative applications of the XML technology that can support and enhance ATS, development, usage, and logistical support.

PHASE I: 1) Define and baseline a collection of XML schemas that allows test data and TPS to be exchanged with other ATS in a common format adhering to the XML standard. 2) Identify all appropriate ATS architectural segments, elements, and critical interfaces for potential implementation of the emerging ATML specification/standard. 3) Select a subset of these ATS segments, elements, and critical interfaces for ATML implementation. 4) Design an ATS implementation of the emerging ATML specification/standard for a specific ATS. 5) Conduct a Preliminary Design Review and deliver a System/Software Requirements/Design Specification and Interface Requirements Specification.

PHASE II: 1) Implement the emerging ATML specification/standard in a specific ATS. 2) Develop a Test Plan and Acceptance Test Procedures. 3) Conduct a Test Readiness Review. 4) Perform acceptance testing. 5) Develop a Test Report. 6) Develop a prototype ATML standard.

DUAL USE APPLICATIONS: The ATML standard will provide a low cost solution for standard commercial off the shelf software tools to be incorporated in DoD and commercial ATS, replacing obsolete custom high maintenance software tools.

REFERENCES:

1. Web site for the ATML organization is http://www.atml.org
2. Email list server for the ATML is http://ecc05.eccnet.com/mailman/listinfo/atml
3. An alternative website for ATML is http://groups.yahoo.com/group/atml_org

KEYWORDS: XML, eXtensible Markup Language, ATML, Automatic Test Markup Language, ATS, Automatic Test System, TPS, Test Program Sets, Schema

AF04-278 TITLE: JP8 Solid Oxide Fuel Cell to Power Existing Hybrid 25K Loader

TECHNOLOGY AREAS: Ground/Sea Vehicles

OBJECTIVE: Research and integrate a JP8 Solid Oxide Fuel Cell (SOFC) with the capability of powering an existing hybrid electric 25K aircraft material loader.

DESCRIPTION: The Air Force is investing in many new advanced power technologies to enhance its mission effectiveness and reduce its environmental impact. In order to demonstrate the potential applications of these new technologies and to show how these developments can converge to provide the war fighter with a superior tool, the Air Force is interested in integrating a JP8 SOFC with an existing 25K Loader. Although previous JP8 Solid Oxide Fuel cells have been developed, these have been focused on proof of concept and in addition have not been integrated with other advanced power technologies. Innovation will be required to produce a system that meets real world requirements and that can be used to create a complete advanced power system. The JP8 SOFC system must produce minimum vibrations and possess controls matching the load profile for an efficient power process. As this system must demonstrate the application of JP8 SOFC, it is necessary that the system is dependable as well as maintainable.

PHASE I: Gain knowledge and determine the applicability of a JP8 SOFC capable of charging an existing 25K hybrid loader. The reformer must be able to provide adequate power such that loader effectiveness is not compromised. The research must consider mobility, safety, and environmental issues. Models, drawings and simulations shall indicate minimum risk for continuation to Phase II. Data should be available to prove concept and validate a commercial market. Specifications for this vehicle will be available by the technical point of contact and the loader itself will be made accessible for load profile data collection.

PHASE II: Develop prototype systems to prove design performance, versatility, reliability, and improvements over the current system. A prototype demonstration will conclude Phase II.

PHASE III Dual Use Applications: Phase III demonstrations should include but not be limited to integration in at least one USAF 25K loader and show that the resulting combination possesses equal or better characteristics than when the loader is powered by a control source. JP8 is one of the most difficult fuels to reform into hydrogen, yet is one of the military's most common and vital fuel. The military as well as the civilian market will be shifting to fuel cell technology in the future and this concept could help in developing more options for the fuel cell specifically in remote rural locations with barren landscapes.

REFERENCES:
1. http://www.calstart.org/about/pngv/pngv-0305.html
2. http://www.mountainhome.af.mil/AEFB/

KEYWORDS: Reformer, Solid Oxide Fuel Cell, JP8

AF04-279 TITLE: Completely Integrated Jamming Test System (CIJTS)

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop a universal open-air jamming and interference test capability, that does not require jamming clearance from the Federal Aviation Agency, but still provides a realistic system level test for Global Positioning System (J) receivers, antennas, and amplifiers.

DESCRIPTION: Chief of Staff of the Air Force is committed to ensuring that our weapons systems are jam resistant and the ability to test these systems is available. Loss of GPS jamming clearance capability could drastically reduce the ability to evaluate US weapon systems in a challenged environment. GPS receiver systems are subject to radio frequency interference. This interference can adversely impact the performance and reliability of GPS systems as defined in RTCA/DO-235. Current tests for GPS jamming and interference are conducted in the laboratory through simulation, in the field through injecting an interference signal into the live antenna feed to the system, and in the field through the use of live interference signals. All of these test methods have problems. Live field tests using actual interfering signals are the most realistic. However, with the expanding use of GPS by the civilian and military communities, live interference tests result in scheduling problems and safety of flight problems for the nations commercial air fleet. The CIJTS program seeks innovative methods and designs through which very low power (less than one watt) jamming and interference signals may be broadcast on the test vehicle itself into the receiving GPS antenna. The very lower radiated power levels near the test bed antenna will eliminate frequency clearance issues and provide the means to evaluate present and future GPS receiver systems in jamming and interference environments without impact to the safety of civil or military GPS users. CIJTS will provide a significant test capability for the war fighter and the Department of Transportation. A significant portion of the innovation will be dedicated to development of methods to adjust the jamming or interference signal to imitate approach to and departure away from the interference source by the test vehicle. The final CIJTS will be capable of generating the following jamming and interference signals. Any combination of these signals will be transmitted for from 1 to 20 jammer sources covering the GPS L1, L2, and L5 frequencies. The CIJTS will have adjustable power levels to emulate from 20 J/S up to 120 J/S of jamming interference at the test bed GPS antenna. The system will also be capable of testing multi-element antenna systems and producing correct multi-jammer wavefronts.

Non-coherent Continuous Wave (CW). A sinusoidal-like jammer signal at a single frequency with uniformly distributed random phase relation about the carrier frequency of the received GPS signal. The jammer center frequency can be anywhere in the 20.46 MHz bandwidth around L1, L2, or L5.

Swept CW. A non-coherent CW jammer whose center frequency is linearly swept across all or part of the 10.23 MHz bandwidth around L1, L2, or L5 center frequency. The maximum repetition rate for a frequency sweep across the entire 20.46 MHz bandwidth is 100 Hz.

Pulsed CW. A non-coherent CW jammer which is pulsed alternately on and off at a repetition rate up to 1 KHz and with a pulse duty cycle between 1% - 50%.

Narrowband Noise. Noise-like signal with a noise bandwidth greater than 1 KHz, but less than 100 KHz, centered within +/-10.23 MHz of the L1, L2, or L5 center frequency.

Broadband Noise. Noise-like jammer with a noise bandwidth greater than 100 KHz and less than or equal to 20.46 MHz located within a 20.46 MHz bandwidth around the L1, L2, or L5 center frequency.

Pulsed Noise. Narrowband noise or broadband noise jammer which is pulsed alternately on and off at a repetition rate up to 1 Khz and with a pulse duty cycle between 1% - 50%.

GPS representative waveforms. GPS like waveforms across the 20.46 MHz bandwidth around the L1, L2, or L5 center frequency.

PHASE I: Develop a feasibility concept for CIJTS radio frequency transmission system for all types of interference. Look at near-far issues, phase implementation, jammer power levels, and antenna spacing issues required for implementation. Determine optimum CIJTS hardware and configuration. Phase I deliverables will be CIJTS hardware and software design concept, along with implementation concept, along with implementation concept.

PHASE II: Develop a demonstration version of the Phase I hardware and software proposal to provide multiple jammer and interference types. Phase II deliverables will be CIJTS demonstration hardware and software and a comprehensive demonstration of the capabilities of this hardware and software to meet CIJTS requirements.

Phase III will further the dual use of CIJTS. Phase III will develop expanded capability for the Department of Transportation GPS Interference Location System, and similar systems required for anti-terrorist protection of GPS, Wide Area Augmentation System, and Local Area Augmentation System. Since the DoD must now self-certify its navigation systems for FAA and international require navigation performance, Phase III CIJTS will provide the DoD with the capability to assess the impacts of RFI on systems for the C-17, C-5, F/A-22, F-18, and F-15 in a realistic flight environment without effecting the safety of flight for civil and other military GPS users. It will also allow for the development and test of RFI location systems for the DoD and FAA in a realistic flight environment without effecting the safety of flight for civil and other military GPS users. This capability will be critical to the development of enhanced small diameter bomb(SDB) smart munitions coming at the end of the decade, and application of the SDB on the F/A-22 for its long-range interdiction role. Phase III deliverables will be CIJTS hardware and software required for extensive interference and jamming tests (with single and multiple jammer types), using a government test van and government C-12 test bed aircraft to be conducted at the completion of Phase III.

DUAL USE COMMERCIALIZATION: The Phase III CIJTS will be usable for both military and commercial test and evaluation of Radio Frequency Interference impacts on GPS receiver systems. Military applications include tests of high accuracy navigation systems (such as the Joint Strike Fighter navigation system) in a GPS jamming environment without interfering with the civil users of GPS. The Phase III CIJTS will allow the DoD to continue to conduct open-air jamming and interference tests, which otherwise may be discontinued due to the expanding civil reliance on GPS in the Global Air Navigation System. Civil GPS manufacturers must also demonstrate that their receivers have a limited immunity to RF interference as defined in RTCA/DO-235. The Phase III CIJTS will allow civil open-air tests, which are now beyond the capability of most manufactures.

REFERENCES: 1. Assessment of Radio Frequency Interference Relative to GNSS, RTCA/DO-235; July 1996.

2. NAVSTAR GPS Space Segment/Navigation User Interface, ICD-GPS-200B; 30 November 1987.

3. System Specification for the NAVSTAR Global Positioning System, SS-GPS-300E;?30 January 1995.

4. “NAVSTAR GPS User Equipment Introduction,” (FOUO), February 1991.

KEYWORDS: GPS, jamming, interference, radio frequency interference, interference location system, programmable electronics

AF04-280 TITLE: <u>Directed Energy Hardened Instrumentation (DEHI)</u>

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Investigate Directed Energy Hardened Instrumentation.

DESCRIPTION: Test and Evaluation (T&E) of modern weapon systems involves exercise of these systems in as realistic combat scenarios as possible and affordable. Components of a major weapon system are generally evaluated separately using all of the various test methods from Modeling and Simulation to open air. Instrumentation is required in all of these test environments to control the test; measure, process and transfer data; communicate; command control; satisfy security and safety functions; and many other support requirements. Directed Energy Weapons (DEW's) present some particularly difficult challenges because of the extreme high energy laser (HEL) and high power microwave (HPM) environments. Current instrumentation in most cases cannot function at all or long enough to provide the required support. A top level system of system technical evaluation is needed to identify and develop the instrumentation technology needed to support the DEW T&E mission requirements.

PHASE I: A multi-level scientific approach will be taken. Materials and external "shielding" technologies will be evaluated to assess level and duration of protection as the first level. The next level will address the external "connectivity" (antennas, fiber, and wire) to identify and evaluate viable technologies that can be used in the various methods of test applications. Advanced communications techniques involving multiple spread spectrum approaches will be assessed at the next level. The final level will identify and perform sub-system testing on transmitters, encryption, encoders, processors, and various recording techniques. Select promising hardening approaches and prepare demonstration plan.

PHASE II: Prototype and test the approach or approaches as described and approved in the demonstration plan.

DUAL USE COMMERCIALIZATION: 1) US commercial infrastructure may face a HPM threat to critical microelectronics (computer workstations, LANs(Local Area Networks), switches, robotic production controls, etc). Knowledge gained on methods to harden this equipment should be directly applicable to these commercial interests.

2) Companies who produce security systems based on electro-optical, radar, ladar, etc should find direct benefit from this work in assisting these companies to harden their sensors and integrated security networks to operate in these hostile environments.

3) Knowledge gained on hardening instrumentation should protect electronics from a HPM pulse could potentially reduce damage to electronics from lighting strikes.

REFERENCES: 1. High Power Microwave Hard Guide - Accession Number: DF981440
2. High Power Microwave Hardening Design Guidelines for Strategic Missiles in Flight - AD Number: ADB151843

KEYWORDS: High power radiofrequency, high energy laser , high power microwave, telemetry, data collection instrumentation, flight termination, microelectronics hardening.

AF04-287 TITLE: Arcjet Segment Development

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a water-cooled segments for arc-heated wind tunnels.

DESCRIPTION: A procedure is needed that will allow segments for constricted arc heaters to be produced. Segments are stacked together to make up the constrictor of a high pressure arc heater. These segments are subject to high heat loads, are typically made of copper, and contain intricate cooling passages. The technique should produce segments capable of operating at pressures approaching 200 atm, given an adequate segment design. The traditional fabrication technique for these segments involves a straightforward machining process followed by a furnace brazing process. The furnace brazing process involves a high degree of skill on the part of the operator. A new fabrication procedure should be developed which (once developed) can be routinely implemented with a minimum of operator skill, yet which will retain high reliability and acceptable cost. Furnace brazing might be replaced with an e-beam welding procedure. A typical segment for the arc heater has an approximate external diameter of 6 inches and an internal diameter of 2 inches. Segment thickness is 0.27 inches; segments are separated by an insulator 0.081 inches thick. When assembled, the arc heater constrictor must be able to withstand 200 atm as a pressure vessel. The insulator referred to above becomes an air gap near the internal surface and must withstand a potential drop of 150 volts between segments. The heat load on the internal constrictor surface can be as high as 5000 Btu/ft2 sec. Removing a heat load of this magnitude generally requires water velocities of at least 125 ft/sec. The prototype design provided under the SBIR contract will provide such information as fabrication technique, order of procedures, and other details related to the fabrication of the segments. It is anticipated that an electron beam welding of segment halves may be an appropriate choice, but other ideas will be entertained.

PHASE I: Provide a prototype process design and/or prototype segments to show that the approach is feasible to meet all technical objectives.

PHASE II: Provide a prototype process detailing the water-cooled segment production procedure for an arc-jet facility.

DUAL USE COMMERCIALIZATION: Arc segments are used in hypersonic testing facilities. Demand for segments are expected to be steady, given arc segments relatively short life (a few hours of operation). While segment designs vary from facility to facility, the same fabrication process can be shared by all.

REFERENCES: 1. Felderman, E.J., Chapman, R., Jacocks, J.L., Horn, D.D., Bruce, W.E.III, "High-Pressure Arc Heater Development and Modeling Status and Requirements", AIAA Journal of Propulsion and Power, Vol 12, no 6, pp 1044-1052, Nov-Dec 1996.

2. Felderman, E.J. and Bruce, W.E. III, "Application of Near-Electrode Model to Predict Inter-Segment Arcing", AIAA paper 96-2315, June 1996.

3. Felderman, E.J. and Mac Dermott, W.N., "Radiative Heating in High-Pressure Arc Heaters", AIAA Paper No. 92-2873, 1992.

KEYWORDS: Arcjet, Constricted Segment, Electron Beam Welding

AF04-288 TITLE: <u>Thermal Phosphor Based Heat Flux and Temperature Gauge</u>

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

OBJECTIVE: Develop and demonstrate a near real-time,high spatial resolution nonintrusive surface temperature and heat flux system for use in a turbine engine environment.

DESCRIPTION: The new optically based, non-contact method must be suitable for use in advanced developmental turbine engines. These base materials are generally titanium and nickel based alloys. These engines typically use ceramic Thermal-Barrier Coatings (TBC) on surfaces to achieve operating temperatures as high 2200°F in the first-stage turbine. Surface temperature measurements based on optical pyrometry suffers from the low emissivity of the TBC and the presence of reflected radiation. Viewing of these surfaces through high temperature, high-pressure, high-speed gas streams in the presence of direct and reflected combustion radiation is a requirement. Heat flux gauges have traditional relied on thermal electric junctions. Signal conditioning and, extensive bulky wiring schemes are currently required to transfer the signal off board from the test article, e.g., turbine engine. The requirement is to measure two-dimensional heat flux with spatial-resolution exceeding conventional (.125”) resolution in high-temperature environments.

PHASE I: Provide a proof-of-principal demonstration of a high-temperature (up to 2200°F), high-resolution heat-flux, surface temperature.

PHASE II: Demonstrate, a full-scale prototype measurement system(s) that meet the requirements and utilized existing optical pyrometry ports on turbine engines.

DUAL USE COMMERCIALIZATION: The proposed instrument systems will have commercial applications in the development of commercial engines or turbines used for power generation.

REFERENCES: 1. Allison, S. W., M. R. Cates, M. B. Scudiere and H. T. Bentley. III, "Remote Thermometry in Combustion Environment Using the Phosphor Technique," Proceedings of the 1987 Technical Symposium Southeast on Optics: Flow Visualization and Aero-optics In Simulated Environment, May 1987.

2. S. W. Allison, G. T. Gillies, “Remote Thermometry with Thermographic Phosphors: Instrumentation and Applications,” Review of Scientific Instruments, Vol. 68, No. 7, pp. 2615-2650, July 1997

3. B. W. Noel, et al "Evaluating and Testing Thermographic Phosphors for Turbine-Engine Temperature Measurements" AIAA-87-1761, AIAA/SAE/ASME/ASEE 23rd Joint Propulsion Conference June 29-July 2, 1987, San Diego CA

KEYWORDS: Surface Temperature, Heat Flux, NSMS, Advanced Turbine Diagnostics

AF04-289 TITLE: Dynamic Pressure Transducer Calibration Source

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a traceable dynamic pressure calibration source in a hand held package with associated computer-based controls weapons system ground testing.

DESCRIPTION: Dynamic pressure transducers installed in user test hardware and wind tunnel facilities cannot be independently calibrated with a dynamic pressure source because no hand-held dynamic pressure calibration systems are commercially obtainable. The primary hand-held calibrator uses a constant amplitude (134 dB) and constant frequency (250 Hz) to excite the dynamic pressure sensor. The development and demonstration of a source to verify the proper operation, configuration and data reduction of installed dynamic pressure transducers over their entire operating ranges during air-off periods is desired by both commercial and military customers. Currently, static pressure calibrations are available by pressurizing the test chamber at significant cost to the customer or by accepting data based on laboratory calibration constants that pose moderate risks to data fidelity. Typical systems used to dynamically calibrate sensors are very large and cannot be used for field/test cell calibrations. These items include shock tubes and hydraulic impulse calibrators. Some calibrators require the use of helium to provide fast response times. This prototype should be small and adaptable to a number of transducer installations as small a military aircraft models 1-2 feet in span. Advances in sound generation technology and component miniaturization may enable the development of this hand-held dynamic pressure calibration system. The system should include automatic closed-loop control and compensation in order to generate constant amplitude signals at most frequencies in the audio range, 20-20 KHz.

PHASE I: Demonstrate feasiblity of a basic system that can be utilized to supply a dynamic pressure calibration source.

PHASE II: Demonstrate a prototype system that is capable of supplying a calibrated acoustic source to pressure sensors distributed on a model in a transonic wind tunnel.

DUAL USE COMMERCIALIZATION: Acoustic calibration systems could provide customers accurate and traceable calibrations in support of weapons systems development, automobile noise testing, and audio system development.

REFERENCES:

1. Maly, Joseph R., Kienholz, David A. (CSA Engineering, Inc.) "Development of a Dynamic Pressure Response Calibrator." International Instrumentation Symposium, 39th, Albuquerque, NM, May 2-6, 1993, Proceedings (A93-54351 24-35) Page: p. 185-201.

2. McLean, Andrew Box, Phillip, "Calibrating Air Blast Transducers with the PCB Dynamic Pressure Pulse Calibrator." Defense Science and Technology Organization (Melbourne Australia, May 01, 2000.

3. Zuckerwar, Allan J., Cuomo, Frank W., Robbins, William E. "Fiber optic microphone having a pressure sensing reflective membrane and a voltage source for calibration purpose." NASA Langley Research Center (Hampton, VA, United States)

KEYWORDS: calibration, microphone, controls

AF04-291 TITLE: Measurement of Angular Valve Displacement in High Vibration Environments

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop a device that would be capable of measuring the angular displacement of shafts of quarter-turn valves that are subject to large vibrations.

DESCRIPTION: A device is needed to measure the angular displacement of the stem of various large air valves, and thereby determine valve percent open feedback. This device would be subject to significant vibrations due to the large flow rate of air controlled by these valves. A sensor is needed that could measure angular displacement with an accuracy of at least 0.10% of full range (0 to 100% open), provide digital output, and survive a shaker table test corresponding to the Power Spectral Density (PSD) plot shown in the references. The response time on the sensor must be at least 0.01 seconds, and the sensor must be able to resist the effects of the weather and operate accurately under ambient temperature extremes (-10 to 140 degrees F). Valves with more robust sensors would reduce failures and resulting downtime. It is acceptable to either design the sensor such that it can survive when mounted on the valve body or separate the sensitive components from the sensing element such that those components could be mounted on a structure not subject to the vibrations.

PHASE I: Demonstrate the basic sensing principle to show feasibility and accuracy within 0.50% of full scale (0 to 100% open).

PHASE II: Demonstrate a prototype of the position sensor that meets requirements in the topic description.

DUAL USE COMMERCIALIZATION: Sensor will have commercial applications in various areas, including mining, utilities, and the oil/natural gas industries where facility vibrations necessitate the use of a vibration-resistant angular position sensor.

REFERENCES: 1. Sevin, Eugene, 1928- Title: Optimum shock and vibration isolation [by] Eugene Sevin [and] Walter D. Pilkey. Publication info: [Washington] Shock and Vibration Information Center, U.S. Dept. of Defense, 1971. Physical description: vii, 162 p. illus. 24 cm.

2. Skousen, Philip L. Title: Valve handbook / Philip L. Skousen. Publication info: New York : McGraw-Hill, c1998. Physical description: xv, 726 p. : ill. ; 24 cm.

3. Coleman, P. Collins, J. Darejeh, H, NASA-CR-185210 Integrated Controls and Health Monitoring Fiberoptic Shaft Monitor. Task E.5 , Amendment 3.

KEYWORDS: valve position sensor, vibration isolation, vibration damping, quarter-turn valve, robust electronics

AF04-292 TITLE: Infrared Imaging Fiber Optic Bundles

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop rugged, flexible imaging fiber optic bundles with high transmission (low attenuation) in the infrared spectral region.

DESCRIPTION: Imaging (coherent) fiber optic bundles are in routine use in the visible and near infrared (0.4 - 0.9 microns.) However, the transmission of typical fiber materials drops rapidly at longer infrared wavelengths. Specialized infrared fibers (e.g. chalcogenide or ZBLAN (ZrF_4-BaF_2-LaF_3-AlF_3-NaF)) are under development, but these materials are typically very expensive and also relatively brittle and fragile. New technology is required to provide inexpensive, rugged, high fiber-count bundles for routine use in the infrared. Requirements: Length: 10-30 Ft Fiber Count: > 10,000 Max diameter of bundle: 10 mm Min bending radius: 3 inches Attenuation: <1 db/m Target cost: no more than 2X an equivalent visible bundle Spectral range: 1 - 12 microns, with possible divisions of 1 - 3 microns, 3 - 5 microns, and 5 - 12 microns. Coherent fiber bundles are used to couple imagers to visible cameras for viewing areas inaccessible to the camera for reasons of size and/or harsh environments. AEDC has requirements for infrared viewing of harsh environments - i.e. turbine engine augmentors.

PHASE I: Develop & demonstrate fibers with high transmission in the short, medium, and long wavelength infrared spectral regions.

PHASE II: Demonstrate imaging fiber optic bundles as listed in the topic description.

DUAL USE COMMERCIALIZATION: Visible imaging fiber optic bundles have found wide application in the commercial sector. It is anticipated that the availability of inexpensive, rugged infrared fibers and imaging bundles will generate many new commercial applications in the areas of sensors and communications.

REFERENCES: 1. Hiers, R. S. III, and Hiers, R. S. Jr. “Development of High Temperature Image Probes for Viewing Turbine Engine Augmentors,” AIAA-2002-2912, 22nd AIAA Aerodynamic Measurement Technology and Ground Testing Conference, St. Louis, Missouri, 24 - 27 June 2002.

2. Harrington, James A. and Katzir, Abraham, "Infrared fiber optics III; Proceedings of the Meeting, Boston, MA, Sept. 5, 6, 1991." Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Vol. 1591).

3. Melling, P. J., and Thomson, M., "Fiber-optic Probes for Mid-infrared Spectrometry.". In "Handbook of Vibrational Spectroscopy" John M. Chalmers and Peter R. Griffiths (Editors), John Wiley & Sons Ltd, Chichester, 2002

KEYWORDS: fiber optics, coherent bundles, image guides, infrared

AF04-293 TITLE: CFD Design Tool for Fuel Injectors in Turbine Engines

TECHNOLOGY AREAS: Air Platform, Ground/Sea Vehicles

OBJECTIVE: Develop and validated Computational Fluid Dynamics (CFD) tool for design of fuel injectors in gas turbine engine combustors.

DESCRIPTION: The quality of fuel delivery and injection characteristics is crucial to combustion system performance in modern gas turbine engines, particularly in the era of compact, high temperature rise combustors and stealth-oriented augmentation systems, and is expected to be an enabling technology for advanced combustion concepts such as inter-turbine burning. Mismatched fuel delivery or poor fuel injection characteristics lead to operational hazards as varied as main burner combustion instabilities (howl, growl modes), and augmentor combustion instabilities (rumble, screech modes), with resultant excessive vibrational stresses on the hardware. In order to avoid these operational and performance risks, the development and deployment of on-board, actively controlled fuel injectors is an attractive solution. While actively controlled fuel injection systems are common in automotive applications, the aerospace propulsion industry has not yet deployed such a system in any operational engine, and is only tentatively considering such systems for future planned aircraft. This program proposes to build on recent laboratory successes with different types of gas turbine fuel injectors, and to transition those design concepts into the gas turbine design and manufacturing processes, through a process of validation and standardization of the CFD processes for unsteady-state fuel injection and combustion modeling. The resulting tool, a robust, validated code capable of quantitatively predicting unsteady-state, liquid fuel injector performance, will be a key technological advance towards optimizing gas turbine combustion processes over the full flight envelope.

PHASE I: Develop a computer code for fuel injection in gas Turbine Engine combustion systems and demonstrate fundamental feasibility.

PHASE II: Demonstrate the critical components of the computational fuel Injection in Gas Turbine Engine using gas turbine combustor geometries.

DUAL USE COMMERCIALIZATION: The fuel Injector 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 a test bed for computing pollutant emission in local airport.

REFERENCES: 1.K.R. McManus, T. Poinsot, S.M. Candel, " A Review of Active Control of Combustion Instabilities", Combustion Science, 1993 Vol. 19, pp. 1-29

2.A. Brankovic, R. McKinney, H. Puyang, L. Porter, J. Kennedy, R. Madabhushi, "Comparison of Measurement and Prediction of Flow in a Gas Turbine Engine Fuel Nozzle", AIAA Paper 2000-0331, Reno, NV., January 2000.

3.A. Brankovic, R.C.Ryder, G.J. Sturgess, J. Lee, A. Kushari, E. Lubarsky, B.T. Zinn, "Computational and Experimental Study of Aerodynamics and Heat Release in a Liquid Fueled Combustor," AIAA Paper 2001-0976, Reno, NV., January 2001.

KEYWORDS: fuel injectors, active-control, Liquid Fueled Combustor, Combustion Instabilities, Gas Turbine Engine Fuel Nozzle

AF04-294 TITLE: <u>Temperature Sensitive Paint for Wind Tunnel Models</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a paint that can be used for the non-intrusive measurement of heat transfer rates on scaled vehicles/models in wind tunnel and ground test environments up to 1600 deg F.

DESCRIPTION: Global heat transfer rates could be derived from a time and temperature history of the vehicle if paints could be developed. Current temperature sensitive paints are not environmentally safe and require a specialized model substrate. This effort would focus on promising temperature paint coupled with a spray on substrate for use in mapping global heat transfer in a wind tunnel or ground test environment. Required temperature measurement accuracy is +/- 5 F over the range 200-1600 psf.

PHASE I: Proof of concept demonstration of a paint that meets the stated objective.

PHASE II: Demonstrate the paint meets all the objectives including procedures for it's application and removal, calibration for both static and dynamic testing.

DUAL USE COMMERCIALIZATION: There are a growing number of test centers in the aerospace, automotive, and electronics industries that require non-intrusive temperature measurements for quantitative and qualitative analysis, including health monitoring.

REFERENCES: 1. J. P. Hubner, B. F. Carroll, K. S. Schanze, H. F. Ji, and M. S. Holden, "Temperature- and pressure-sensitive paint measurements in short-duration hypersonic flow," AIAA Journal, v 39, n 4, April 2001, p 654-659.

2. T. Liu, B. T. Campbell, and J. P. Sullivan, "Fluorescent paint for measurement of heat transfer in shock-turbulent boundary layer interaction," Experimental Thermal and Fluid Science, v 10, n 1, Jan, 1995, p 101-112.

3. K. Asai, H. Kanda, T. Kunimasu, T. Liu, and J. P. Sullivan, "Boundary-layer transition detection in a cryogenic wind tunnel using luminescent paint," Journal of Aircraft, v 34, n 1, Jan-Feb, 1997, p 34-42.

KEYWORDS: Surface Temperature, Global Surface Measurement, Temperature Sensitive Paint

AF04-295 TITLE: Develop Plasma Radiation Source for >300 ns Simulators

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a flux compression approach to enhancing Plasma Radiation Source (PRS) load performance on radiation simulators.

DESCRIPTION: Electrically driven Flux Compression (FC) offers in principle the most efficient path to affordable Pulsed Power to drive high atomic number PRS loads for K-shell x ray production. In particular, on a machine like Decade Quad (DQ), and in the future Decade Half (DH), flux compression could, as a minimum, act as a very efficient pulse-sharpening device. This will allow the DQ and DH access to the K-shell of elements, otherwise unattainable at 300 ns implosions. Experiments have been conducted using wire arrays as the armature, and have not been yet geared to K-shell x-ray production. Systematic FC technology development has not yet been undertaken in the United States, and modeling simulation codes have not yet been validated. The ability to obtain measurable power amplification, to make critical measurements of the precursor plasmas characteristics, and current diffusion for driver times >300 ns when delivering current into the load on a 100 ns time scale.

PHASE I: Demonstrate feasibility using a novel flux compression design in a small-scale experiment.

PHASE II: Demonstrate increased PRS capability with the flux compression driver on the Decade Quad and optimize load design using validated computer model.

DUAL USE COMMERCIALIZATION: This technology could impact the present strategies using PRS sources for lithography applications where improved yield for a given load energy can significantly mitigate debris issues. Address scaling of the techniques developed in Phases I and II to lower power commercial lithographic sources.

REFERENCES: 1. Leon ,J.F.; Speilman R.B.; J.R. Asay; Hall, C.A.; and Stygar, W.A., "Flux Compression Experiments on the Z Accelerator," IEEE Conference on Plasma Science, 1999.

2. R.B. Speilman, et.al., Proc. of the 11th IEEE Pulsed Power Conference, 1997 Pulsed Power Conference

3. Goyer, John R.; The 3rd International Workshop on the Physics of Wire Array Z-pinches 23rd - 25th April 2001, Cosener's House, Abingdon, UK. http://www.pp.ph.ic.ac.uk/~magpie/workshop/agenda.htm, Wednesday's proceedings

KEYWORDS: Flux compression, plasma radiation source

AF04-296 TITLE: Global positioning system Software Radio (GSR)

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop algorithms required for an advanced global positioning system (GPS) software radio receiver suitable for use in the testing and evaluation of advanced GPS applications in the Air Force.

DESCRIPTION: Measurements of advanced GPS applications have been difficult in the past due to the lack of a high-accuracy truth reference receiver. Although traditional sequential-processing GPS receivers continue to advance in their capabilities, a software radio processes the signals in blocks following a digital down-conversion/sampling stage. Many non-causal as well as joint time-frequency domain processing methods are only possible through the use of block processing. For example, a block processor does not use tracking loops; instead, it estimates all parameters of interest using the entire block of data. The estimator will often process the block of data several times before arriving at the solution. Block processing provides for optimal observability of all GPS measurements making it a superior technique for use in the development of a truth or instrumentation receiver.
The intent of the research is to investigate processing algorithms and their real-time implementation in Field Programmable Gate Arrays (FPGA) hardware for advanced GPS applications. Specifically, existing block processing techniques of sampled GPS data need to be analyzed with respect to the estimation of all key GPS observables including pseudorange, carrier phase, Doppler, and carrier-to-noise ratio for both narrow-band (2-MHz C/A code) and wide-band (20-MHz P code) signals on the L1 and L2 frequencies. Because of the larger bandwidth of the wide-band signals, special consideration needs to be given to real-time implementation techniques. For example, C/A code signals can be readily processed using 1024-point Fast Fourier Transforms (FFT) in the frequency domain. P code signals would require much larger FFT sizes that would quickly become infeasible to implement in real-time FPGA hardware. New methods to enable the real-time implementation of the frequency domain processing of wide-band signals should be investigated. This part of the research will be kept generic in terms of the actual code to be used to ensure that the solutions will also apply to new signal structures resulting from the GPS modernization program. In addition, algorithms that assess the quality of the GPS signals will need to be developed. Because of the flexibility of software processing, quality indicators can be developed that characterize anomalies that may affect the quality of the GPS measurements. This information is of great importance in a test environment where it is desirable to identify anomalies in the equipment under test. All algorithms shall be prototyped and tested; important tools in the verification of the theoretical solutions. The results of these investigations should include all algorithms required for an instrumentation-quality GPS software radio that estimates precise pseudorange, carrier phase, Doppler, carrier-to-noise ratio, and quality indicators. Hardware requirements to implement these algorithms will be identified.

PHASE I: Investigate processing algorithms and their real-time implementation in FPGA hardware for advanced GPS applications.

PHASE II: Develop and demonstrate the code to be used for FPGA hardware for advanced GPS applications.

DUAL USE COMMERCIALIZATION: This research will ultimately find utilization within the general transportation segment of the economy. It will be suitable for land, sea, and air applications.

REFERENCES: 1. Elliot D. Kaplan (Editor)
Understanding Gps: Principles and Applications (Artech House Telecommunications Library)
Artech House; (February 1996)

2. Jeffrey H. Reed
Software Radio: A Modern Approach to Radio Engineering
Prentice Hall PTR; 1st edition (May 15, 2002)

KEYWORDS: processing algorithms, real-time implementation

AF04-298 TITLE: <u>Data Acquisition Error Budget Analysis Tools</u>

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

OBJECTIVE: Develop an abstract model for a reconfigurable airborne data acquisition system that includes the tools to analyze specific error budgets.

DESCRIPTION: The flow of data from a sensor through a data acquisition system and onto a final storage medium typically involves multiple devices with the raw data going through various transformations in format (both electrical and digital) during the process. For example, a sensor may make a measurement in analog form. The resulting signal may then go through several filters or other signal conditioners before passing through an analog to digital converter. The data may then be transmitted along several layers of networks using different digital encapsulation techniques before it is finally recorded for analysis. Each device, interconnect, transformation, and transmission introduces errors. These errors include inherent percent of error for a measurement, aliasing, hysteresis, bit error rates, etc. Further, new systems will be dynamically changing the data being acquired. For example, some sensors already do automatic gain switching when conditions change drastically. The dynamic nature of the data being collected will also increase as the ability for ground monitors to control data acquisition parameters in real-time increases. Although many of the individual steps along the way may have an established error margin, there are no tools currently available for analyzing the total error budget for an arbitrary data acquisition system. Additionally, devices capable of outputting raw or conditioned signals as well as any associated error contributions are not available. Current techniques for developing a total error budget utilize a pen and paper as the primary tools – costly, time consuming, and error prone.

Capturing total system error budget is critical to T&E. Without it the validity of raw and derived data cannot be established with confidence. Data systems are becoming more complex and dynamic. The already difficult and time-consuming process of determining total system error is only going to get worse without automated tools.

To develop a practical generic tool for analyzing specific system-error budgets, an abstract model of the data acquisition process that can be instantiated to describe a specific system must first be developed. Further, the error margin for each system component must be input into the tool. The ideal would be to obtain these errors directly from error measuring devices embedded in the instruments (A robust integration with error measurement devices is probably outside the scope of this project.). Given all of this, there is, perhaps, a final question to be asked regarding the definition of "error budget." How do you effectively combine the analog concept of "percent of error" with the digital concept of "bit error rate?" For example, how do you apply the bit error rate of a telemetry signal to an individual measurement being transmitted as one of many in the telemetered bit stream? A reliable automated-tool for error budget analysis would greatly enhance the ability of testers to state final results with confidence and accuracy.

PHASE I: Analyze and characterize existing advanced airborne data acquisition systems and sensors to establish the feasibility of developing new hardware capable of outputting raw or conditioned signals and the associated error margins or bit error rates. Both the hardware and the output of the hardware must be suitable for use in data acquisition systems used in flight test of current and future military air platforms and other aerospace test articles typically found in a Test and Evaluation environment. Propose a design for a reconfigurable airborne data acquisition system model for a military platform that will permit the combining of both analog and digital error measurements and provide an automated uncertainty analysis.

PHASE II: Develop the software for the model designed in Phase I and make enhancements as needed. Demonstrate the software's efficacy by modeling several specific data acquisition systems and verifying each of their error budgets.

DUAL USE COMMERCIALIZATION: This tool will provide direct support to Common Interoperable Tools for Modeling and Simulation Validation, a DoD standard. Model updating based upon test data throughout flight test programs is critical to successfully reducing test programs by as much as 50%. Data Acquisition Error Budget Analysis Tools will provide critical information regarding the accuracy of test data used to update the models thus increasing model accuracy and eliminating costly iterations and prolong flight-testing. These tools will make major contributions toward successfully reducing flight test requirements for JSF and future Air Force and Navy flight test programs. All ongoing DoD flight test programs will reap the benefits of this new capability. The need to replicate suspect data points during flight tests will be greatly diminished reducing time and conserving resources. Other applications involving extensive data collection from remote instrumentation devices, such as wind-tunnel testing, will also greatly benefit from these tools. Besides the testing of military hardware, hospital emergency room and long-term medical surveillance equipment, automobile testing (both commercial and racing), oil well monitoring, laboratory testing, etc will find extensive applications for these tools. The chemical/industrial processing industry, drug manufacturing, and the conventional fossil fueled and nuclear power plants rely heavily upon remote instrumentation; all with a critical need to ascertain the validity of the output of the myriad of sensors and process control instruments used. This software could also be used in an educational environment to provide critical hands on experience dealing with the complexity of error budget analysis.

REFERENCES: 1. Hugh W. Coleman and W. Glenn Steele, Jr., Experimentation and Uncertainty Analysis for Engineers, John Riley & Sons, 1989

2. Alan S. Morris,The Essence of Measurement,Prentice Hall, 1996

3. Ronald H. Dieck, Measurement Uncertainty Methods and Applications, second edition, Instrument Society of America, 1997

KEYWORDS: Error Budget Analysis, Data Acquisition, Modeling, Instrumentation, Test Equipment
AF04-299 TITLE: Multi-Object Radar Imaging Algorithms (MORIA)

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop and demonstrate algorithms for processing, analysis, and visualization from a high definition imaging radar.

DESCRIPTION: Precision tracking and imaging of events during a flight test mission enhance the Air Force's capability to support the customer needs. The AF is interested in determining alternative uses for imaging with X-band Continuous Wave Frequency Modulated (CWFM) radars. These types of radars have millimeter accuracy for imaging and the ability to track multiple objects.

Research in applying this technology to these areas will greatly enhance the Air Force's ability to support flight test missions such as bomb scoring and pattern determination, ground based imaging of weapons separation, and radar cross section in flight. Bomb drop and weapon separation tests are conducted to determine effect of aircraft modifications on weapons delivery performance. The AF currently uses ground-based optical sensor systems to conduct weapons separation testing. These systems, which use 35-mm film, require weeks of film processing and analysis to ascertain the final results. The turnaround time of these systems is very slow.

The current bomb-scoring systems use optical methods to determine dispersal patterns and flight patterns. When multiple bombs are dropped during a single pass, the dispersal patterns are estimated using the impact point of the first and last bombs. Research in this effort should determine the feasibility of identifying the individual flight patterns and impact patterns for bomb drops involving up to 60 bombs in a single pass, giving centimeter accuracy for each point of impact. The feasibility and measurement error associated with missions from 1 to 60 bombs should be determined. The research should describe the algorithms required and identify any limitations and expected results from using CWFM radar instrumentation in support of bomb drop test missions.

Research in this area should determine the feasibility and limitations of using CWFM radar to determine the relative positions during separation of the host vehicle and the objects being released (munitions, fuel tanks, cargo pallets, etc.). Research should address the accuracy and precision achievable, the required flight profiles for effective use of the radar, the expected turnaround time for real-time or post mission processing, and any other limitations or requirements on supporting these missions.

Direct measurement of radar cross section (RCS) has been restricted to special RCS ranges operating under strictly controlled static environments. Research should address using the CWFM radar to determine RCS of aircraft and weapons in-flight under high dynamic maneuvers. The submittals should address the algorithms required, the expected results, and limitations of using this instrumentation to perform dynamic RCS measurements.

PHASE I: Analyze the alternatives, select and justify an approach, and produce a work plan on how to proceed to develop and demonstrate a prototype solution. Quantify the CWFM radar radio-frequency beam width and loop gain required for various RCS in the range of +10 to -40 dBm2 to meet a 50-mile threshold and 200-mile objective. Investigate options for real-time range safety display algorithms for radar range and Doppler measurements to best describe target structure.

PHASE II: Develop and demonstrate a prototype solution. The demonstration must take place at an AF test facility.

DUAL USE COMMERCIALIZATION: The technology being developed here can be used in the arena of commercial space launch and recovery. This technology would develop algorithms that can provide invaluable data from a high resolution imaging radars. This data can be used to increase safety and analysis of departure and arrival events.

REFERENCES: 1. http://www.xontech.com/products/2000/Series_2000.pdf
Describes typical CWFM radar of the type considered for this endeavor.

2. http://www.fas.org/spp/military/program/track/260.pdf
Range Commanders Council, Radar Roadmap, Article 4.5, CW radars

KEYWORDS: radar imaging, multiple object imaging, impact scoring, weapon separation, and radar cross section.

AF04-302 TITLE: Real-Time Process Control Sensor for Measuring Arsenic Concentration in Water

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop an inexpensive, real-time sensor to measure the concentration of total arsenic in water.

DESCRIPTION: Many military activities in the western part of the United States have arsenic in their drinking water supply in excess of 10 mg/l. The 10 mg/l upper limit on arsenic concentration will become effective in July, 2006. As a consequence, many military activities, especially those located in desert areas, are planning to install secondary treatment systems to remove arsenic to below the forthcoming standard. At this time, there exists no low cost, on-line, real-time sensor for arsenic that can be used as part of a treatment plant process control system. Periodic checks of arsenic concentration can be made by plant operators using a number of colormetric methods, e.g., the Gutzeit spot test. Some reports suggest that this method can be in error by as much as ± 10 mg/l when performed by unskilled personnel. In addition, this method does not lend itself to automated control systems. At the other end of the spectrum of measurement systems, water samples can be collected and analyzed using inductively coupled plasma gas chromatography/mass spectroscopy. This analytical method is very precise (a detection limit of 0.03 mg/l) but is time consuming and expensive. What is needed is an inexpensive sensor that measure the concentration of total arsenic in water, that has a detection limit of ~ 1 mg/l, and has a continuous electrical output signal that can be used for plant process control. The preferred design would use no reagents and would require little or no maintenance.

PHASE I: Research methods of measuring arsenic concentration in water. Select a method (or methods) that can be adapted to real-time operation. Design conceptual system.

PHASE II: Using the research concepts developed in Phase I, prepare a detailed design of the instrument. Construct one or more prototype instruments. Prepare a test plan. Test prototype instruments and report findings.

DUAL USE COMMERCIALIZATION: Reduction of arsenic concentration in drinking water supplies will be an issue from many communities in the United States and other countries. The development of an inexpensive, real-time arsenic sensor would have a large market for treatment plant process control and well water testing.

REFERENCES: 1. Arsenic In Ground water, Kenneth G. Stollenwerk (Editor), Alan H. Welch (Editor), Kluwer Academic Publishers; (January 2003)

2. Arsenic in Drinking Water: 2001 Update, National Research Council Subcommittee on Arsenic in Drinking Water, et al, National Academy Press; 1st edition (December 15, 2001)

3. Chemistry & Treatment of Arsenic in Drinking Water, Ramesh Narasimhan, et al, American Water Works Association; (July 2003)

KEYWORDS: Environmental pollution and controls.

AF04-303 TITLE: Instrumentation Support Systems Smart Transducer Plugins

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop tools that can be integrated into instrumentation support systems to support smart sensors.

DESCRIPTION: When testing or performing activities requiring data acquisition, it is necessary to configure the transducers (sensors and actuators) and other associated devices; normally done by an Instrumentation Support System (ISS). As smart transducers become more common, the environment supported by ISSs will change. In the long run, smart transducers are expected to reduce configuration efforts. However, this is dependent upon successful integration of smart transducers technology into related ISSs. Current transducers have no ability to be queried. Newer, smart transducers can respond to queries with all the “vital statistics” regarding their functionality – e.g., whether they are working, what their calibration information is, what their serial number is, or simply what they measure. This would allow an ISS to know exactly what is available on a test vehicle, which, in turn, would allow the coordination of the instrumentation setup and the ground station setup for a test to be significantly simplified. Additional desired capabilities include the generation of simulated output and auto-calibration (changing the calibration coefficients in real-time). This would allow full pre-test checkout and dynamic error correction, which, in turn, would decrease maintenance and increase quality. The Institute of Electrical and Electronics Engineers (IEEE) P1451 committee is establishing a standard [1] for smart transducers although two critical portions, P1451.4 and P1451.5, have yet to go to ballot. Further, although, some companies are engaged in developing smart transducers, having smart transducers in hand is not a complete solution and tools to support such devices so that they are fully integrated into an operational environment are also required. The changes wrought by this emerging technology need to be researched in order to garner its full potential. First, the basic operational scenario for installing and maintaining instrumentation systems will change. Even at the simplest level, the mechanism for attaching a transducer to an instrumentation system will be different. Second, handheld devices to allow reading and writing information to smart transducers may be required. Third, software to do system wide queries of status and configuration information will be required. This software will have to interface with multiple vendors’ ISSs and may have to work within a multi-tiered network. Finally, in order to maximize the onboard processing, and thereby minimize network and telemetered bandwidth, new algorithms for low level interaction (e.g., transducer to transducer) may need to be developed.

PHASE I: Research and analyze changes in operational scenarios of ISSs as a consequence of transitioning to smart transducers. Evaluate smart transducer standards (most notably IEEE 1451) and ISSs (e.g., Iliad, VISTA, OMEGA, etc.). Design a set of tools (“plugins”) that can be easily integrated into these support systems and that will maximize the benefits of smart transducers. Provide a final report of analysis and recommendations.

PHASE II: Build prototype tools to support smart transducers. Test prototypes in ground based and airborne tests at an Air Force test facility.

DUAL USE COMMERCIALIZATION: Smart transducers are the “plug and play” devices in instrumentation systems. IEEE has a proven track record of establishing standards that are used industry wide. Approved versions of IEEE 1451.3 and IEEE 1451.4 standards are expected to be released soon and should instigate a wave of development of smart transducers. Thus, there is strong potential for such devices to be marketable to almost any user of data acquisition seems. Having a suite of support tools will fill a necessary niche in this growing market.

REFERENCES: 1. Robert Sinclair and Charles Jones, “Applying IEEE 1451 Standard to AATIS,” Proceedings of the International Telemetering Conference (ITC), Vol. XXXVII, 2001, paper number 01-07-5. (Unclassified, Uncopyrighted, Unlimited Distribution)

KEYWORDS: Test Equipment, Computer Sciences, Instrumentation, Data Acquisition, Smart Transducers, IEEE 1451