

ARMY SBIR 11.1 PROPOSAL SUBMISSION INSTRUCTIONS

The US Army Research, Development, and Engineering Command (RDECOM) is responsible for execution of the Army SBIR Program. Information on the Army SBIR Program can be found at the following Web site: <https://www.armysbir.army.mil>.

Solicitation, topic, and general questions regarding the SBIR Program should be addressed according to the DoD portion of this solicitation. For technical questions about the topic during the pre-Solicitation period, contact the Topic Authors listed for each topic in the Solicitation. To obtain answers to technical questions during the formal Solicitation period, visit <http://www.dodsbir.net/sitis>. For general inquiries or problems with the electronic submission, contact the DoD Help Desk at 1-866-724-7457 (8:00 am to 5:00 pm ET). Specific questions pertaining to the Army SBIR Program should be submitted to:

John Smith
Program Manager, Army SBIR
army.sbir@us.army.mil

US Army Research, Development, and Engineering Command (RDECOM)
ATTN: AMSRD-PPB
6000 - 6th Street, Suite 100
Fort Belvoir, VA 22060-5608
(703) 806-2085
FAX: (703) 806-0675

The Army participates in three DoD SBIR Solicitations each year. Proposals not conforming to the terms of this Solicitation will not be considered. The Army reserves the right to limit awards under any topic, and only those proposals of superior scientific and technical quality will be funded. Only Government personnel will evaluate proposals.

Please note that the Army SBIR maximum award amount beginning with the 11.1 Solicitation has been increased to \$100,000 for a Phase I, \$50,000 for a Phase I Option and \$1,000,000 for a Phase II efforts that directly result from Phase I efforts awarded under this solicitation.

SUBMISSION OF ARMY SBIR PROPOSALS

Army Phase I Proposals have a 20-page limit including the Proposal Cover Sheets (pages 1 and 2, added electronically by the DoD submission site and not requiring you to leave blank pages or duplicate the electronically generated cover pages), as well as the Technical Proposal (beginning on page 3, and including, but not limited to: table of contents, pages left blank intentionally by you, references, letters of support, appendices, and all attachments). Therefore, a Technical Proposal of up to 18 pages in length counts towards the overall 20-page limit. ONLY the Cost Proposal and the Company Commercialization Report (CCR) are excluded from the 20-pages. As instructed in Section 3.5d of the DoD 11.1 Phase I Proposal Format instructions, the CCR is generated by the submission website, based on information provided by you through the “Company Commercialization Report” tool. Army Phase I proposals submitted over 20-pages will be deemed NON-COMPLIANT and will not be evaluated. This statement takes precedence over section 3.4 of the general DoD 11.1 SBIR Solicitation instructions. Since proposals are required to be submitted in Portable Document Format (PDF), it is the responsibility of those submitting the proposal to ensure any PDF conversion is accurate and does not cause the proposal to exceed the 20-page limit.

The entire proposal (which includes Cover Sheets, Technical Proposal, Cost Proposal, and Company Commercialization Report) must be submitted electronically via the DoD SBIR/STTR Proposal Submission Site (<http://www.dodsbir.net/submission>). When submitting the mandatory Cost Proposal, the Army prefers that small businesses complete the Cost Proposal form on the DoD Submission site, versus submitting within the body of the uploaded proposal. The Army WILL NOT accept any proposals which are not submitted via this site. Do not send a hardcopy of the proposal. Hand or electronic signature on the proposal is also NOT required. If the proposal is selected for award, the DoD Component program will contact you for signatures. If you experience problems uploading a proposal, call the DoD Help Desk 1-866-724-7457 (8:00 am to 5:00 pm ET). Selection and non-selection letters will be sent electronically via e-mail.

Any proposal involving the use of Bio Hazard Materials must identify in the Technical Proposal whether the contractor has been certified by the Government to perform Bio Level - I, II or III work.

Companies should plan carefully for research involving animal or human subjects, or requiring access to government resources of any kind. Animal or human research must be based on formal protocols that are reviewed and approved both locally and through the Army's committee process. Resources such as equipment, reagents, samples, data, facilities, troops or recruits, and so forth, must all be arranged carefully. The few months available for a Phase I effort may preclude plans including these elements, unless coordinated before a contract is awarded.

If the offeror proposes to use a foreign national(s) [any person who is NOT a citizen or national of the United States, a lawful permanent resident, or a protected individual as defined by 8 U.S.C. 1324b (a) (3) – refer to Section 2.15 at the front of this solicitation for definitions of “lawful permanent resident” and “protected individual”] as key personnel, they must be clearly identified. **For foreign nationals, you must provide technical resumes, country of origin and an explanation of the individual's involvement. Please ensure no Privacy Act information is included in this submittal.**

No Class 1 Ozone Depleting Chemicals/Ozone Depleting Substances will be allowed for use in this procurement without prior Government approval.

Phase I proposals must describe the "vision" or "end-state" of the research and the most likely strategy or path for transition of the SBIR project from research to an operational capability that satisfies one or more Army operational or technical requirements in a new or existing system, larger research program, or as a stand-alone product or service.

Every Phase I proposal will be reviewed for overall merit based upon the criteria in section 4.2 of the DoD 11.1 SBIR Solicitation.

PHASE I OPTION MUST BE INCLUDED AS PART OF PHASE I PROPOSAL

The Army implemented the use of a Phase I Option that may be exercised to fund interim Phase I activities while a Phase II contract is being negotiated. Only Phase I efforts selected for Phase II awards through the Army's competitive process will be eligible to exercise the Phase I Option. The Phase I Option, which **must** be included as part of the Phase I proposal, covers activities over a period of up to four months and should describe appropriate initial Phase II activities that may lead to the successful demonstration of a product or technology. The Phase I Option must be included within the 20-page limit for the Phase I proposal.

A firm-fixed-price or cost-plus-fixed-fee Phase I Cost Proposal (\$150,000 maximum) must be submitted in detail online. Proposers that participate in this solicitation must complete the Phase I Cost Proposal not to exceed the maximum dollar amount of \$100,000 and a Phase I Option Cost Proposal (if applicable) not to exceed the maximum dollar amount of \$50,000. Phase I and Phase I Option costs must be shown

separately but may be presented side-by-side in a single Cost Proposal. The Cost Proposal DOES NOT count toward the 20-page Phase I proposal limitation.

Phase I Key Dates

11.1 Solicitation Pre-release	November 10 – December 12, 2010
11.1 Solicitation Opens	December 13, 2010 – January 12, 2011
11.1 Solicitation Closes	January 12, 2011; 6:00 a.m. ET
Phase I Evaluations	January - March 2011
Phase I Selections	March 2011
Phase I Awards	May 2011*

**Subject to the Congressional Budget process*

PHASE II PROPOSAL SUBMISSION

Army Phase II Proposals have a 40-page limit including the Proposal Cover Sheets (pages 1 and 2, added electronically by the DoD submission site and not requiring you to leave blank pages or duplicate the electronically generated cover pages), as well as the Technical Proposal (beginning on page 3, and including, but not limited to: table of contents, pages left blank intentionally by you, references, letters of support, appendices, and all attachments). Therefore, a Technical Proposal of up to 38 pages in length counts towards the overall 40-page limit. ONLY the Cost Proposal and the Company Commercialization Report (CCR) are excluded from the 40-pages. As instructed in Section 3.5d of the DoD 11.1 SBIR Phase I Proposal Format instructions, the CCR is generated by the submission website based on information provided by you through the “Company Commercialization Report” tool. Army Phase II proposals submitted over 40-pages will be deemed NON-COMPLIANT and will not be evaluated. Since proposals are required to be submitted in Portable Document Format (PDF), it is the responsibility of those submitting the proposal to ensure any PDF conversion is accurate and does not cause the proposal to exceed the 40-page limit.

Note! Phase II proposal submission is by Army invitation only.

For Phase II, no separate solicitation will be issued and no unsolicited proposals will be accepted. Only those firms that were awarded Phase I contracts, and are successfully executing their Phase I efforts, will be invited to submit a Phase II proposal. Generally, invitations to submit Phase II proposals will not be earlier than the 5th month of the Phase I effort. The decision to invite a Phase II proposal will be made based upon the success of the Phase I contract to meet the technical goals of the topic, as well as the overall merit based upon the criteria in section 4.3. DoD is not obligated to make any awards under Phase I, II, or III. DoD is not responsible for any money expended by the proposer before award of any contract. For specifics regarding the evaluation and award of Phase I or II contracts, please read the front section of this solicitation very carefully. Every Phase II proposal will be reviewed for overall merit based upon the criteria in section 4.3 of this solicitation.

Invited small businesses are required to develop and submit a technology transition and commercialization plan describing feasible approaches for transitioning and/or commercializing the developed technology in their Phase II proposal. Army Phase II cost proposals must contain a budget for the entire 24 month Phase II period not to exceed the maximum dollar amount of \$1,000,000. During contract negotiation, the contracting officer may require a cost proposal for a base year and an option year. These costs must be submitted using the Cost Proposal format (accessible electronically on the DoD submission site), and may be presented side-by-side on a single Cost Proposal Sheet. The total proposed amount should be indicated on the Proposal Cover Sheet as the Proposed Cost. Phase II projects will be evaluated after the base year prior to extending funding for the option year.

Fast Track (see section 4.5 in the DoD 11.1 SBIR Solicitation). Small businesses participating in the Fast Track program do not require an invitation. Small businesses must submit (1) the Fast Track application within 150 days after the effective date of the SBIR Phase I contract and (2) the Phase II proposal within 180 days after the effective date of its Phase I contract.

CONTRACTOR MANPOWER REPORTING APPLICATION (CMRA)

Accounting for Contract Services, otherwise known as Contractor Manpower Reporting Application (CMRA), is a Department of Defense Business Initiative Council (BIC) sponsored program to obtain better visibility of the contractor service workforce. This reporting requirement applies to all Army SBIR contracts.

Beginning in the DoD 2006.2 SBIR solicitation, offerors are instructed to include an estimate for the cost of complying with CMRA as part of the cost proposal for Phase I (\$100,000 maximum), Phase I Option (\$50,000 max), and Phase II (\$1,000,000 max), under “CMRA Compliance” in Other Direct Costs. This is an estimated total cost (if any) that would be incurred to comply with the CMRA requirement. Only proposals that receive an award will be required to deliver CMRA reporting, i.e. if the proposal is selected and an award is made, the contract will include a deliverable for CMRA.

To date, there has been a wide range of estimated costs for CMRA. While most final negotiated costs have been minimal, there appears to be some higher cost estimates that can often be attributed to misunderstanding the requirement. The SBIR Program desires for the Government to pay a fair and reasonable price. This technical analysis is intended to help determine this fair and reasonable price for CMRA as it applies to SBIR contracts.

- The Office of the Assistant Secretary of the Army (Manpower & Reserve Affairs) operates and maintains the secure CMRA System. The CMRA Web site is located here: <https://cmra.army.mil/>.
- The CMRA requirement consists of the following items, which are located within the contract document, the contractor's existing cost accounting system (i.e. estimated direct labor hours, estimated direct labor dollars), or obtained from the contracting officer representative:
 - (1) Contract number, including task and delivery order number;
 - (2) Contractor name, address, phone number, e-mail address, identity of contractor employee entering data;
 - (3) Estimated direct labor hours (including sub-contractors);
 - (4) Estimated direct labor dollars paid this reporting period (including sub-contractors);
 - (5) Predominant Federal Service Code (FSC) reflecting services provided by contractor (and separate predominant FSC for each sub-contractor if different);
 - (6) Organizational title associated with the Unit Identification Code (UIC) for the Army Requiring Activity (The Army Requiring Activity is responsible for providing the contractor with its UIC for the purposes of reporting this information);
 - (7) Locations where contractor and sub-contractors perform the work (specified by zip code in the United States and nearest city, country, when in an overseas location, using standardized nomenclature provided on Web site);
- The reporting period will be the period of performance not to exceed 12 months ending September 30 of each government fiscal year and must be reported by 31 October of each calendar year.
- According to the required CMRA contract language, the contractor may use a direct XML data transfer to the Contractor Manpower Reporting System database server or fill in the fields on the Government Web site. The CMRA Web site also has a no-cost CMRA XML Converter Tool.

Given the small size of our SBIR contracts and companies, it is our opinion that the modification of contractor payroll systems for automatic XML data transfer is not in the best interest of the Government. CMRA is an annual reporting requirement that can be achieved through multiple means to include manual entry, MS Excel spreadsheet development, or use of the free Government XML converter tool. The annual reporting should take less than a few hours annually by an administrative level employee. Depending on labor rates, we would expect the total annual cost for SBIR companies to not exceed \$500.00 annually, or to be included in overhead rates.

DISCRETIONARY TECHNICAL ASSISTANCE

In accordance with section 9(q) of the Small Business Act (15 U.S.C. 638(q)), the Army will provide technical assistance services to small businesses engaged in SBIR projects through a network of scientists and engineers engaged in a wide range of technologies. The objective of this effort is to increase Army SBIR technology transition and commercialization success thereby accelerating the fielding of capabilities to Soldiers and to benefit the nation through stimulated technological innovation, improved manufacturing capability, and increased competition, productivity, and economic growth.

The Army has stationed six Technical Assistance Advocates (TAAs) across the Army to provide technical assistance to small businesses that have Phase I and Phase II projects with the participating organizations within their regions.

For more information go to: <https://www.armysbir.army.mil/sbir/TechnicalAssistance.aspx>.

COMMERCIALIZATION PILOT PROGRAM (CPP)

The objective of the CPP effort is to increase Army SBIR technology transition and commercialization success and accelerate the fielding of capabilities to Soldiers. The ultimate measure of success for the CPP is the Return on Investment (ROI), i.e. the further investment and sales of SBIR Technology as compared to the Army investment in the SBIR Technology. The CPP: 1) assesses and identifies SBIR projects and companies with high transition potential that meet high priority requirements; 2) provides market research and business plan development; 3) matches SBIR companies to customers and facilitates collaboration; 4) prepares detailed technology transition plans and agreements; 5) makes recommendations and facilitates additional funding for select SBIR projects that meet the criteria identified above; and 6) tracks metrics and measures results for the SBIR projects within the CPP.

Based on its assessment of the SBIR project's potential for transition as described above, the Army utilizes a CPP investment fund of SBIR dollars targeted to enhance ongoing Phase II activities with expanded research, development, test and evaluation to accelerate transition and commercialization. The CPP investment fund must be expended according to all applicable SBIR policy on existing Phase II contracts. The size and timing of these enhancements is dictated by the specific research requirements, availability of matching funds, proposed transition strategies, and individual contracting arrangements.

NON-PROPRIETARY SUMMARY REPORTS

All award winners must submit a non-proprietary summary report at the end of their Phase I project and any subsequent Phase II project. The summary report is unclassified, non-sensitive and non-proprietary and should include:

- A summation of Phase I results
- A description of the technology being developed
- The anticipated DoD and/or non-DoD customer
- The plan to transition the SBIR developed technology to the customer

- The anticipated applications/benefits for government and/or private sector use
- An image depicting the developed technology

The non-proprietary summary report should not exceed 700 words, and is intended for public viewing on the Army SBIR/STTR Small Business area. This summary report is in addition to the required final technical report and should require minimal work because most of this information is required in the final technical report. The summary report shall be submitted in accordance with the format and instructions posted within the Army SBIR Small Business Portal at <https://portal.armysbir.army.mil/SmallBusinessPortal/Default.aspx> and is due within 30 days of the contract end date.

ARMY SUBMISSION OF FINAL TECHNICAL REPORTS

A final technical report is required for each project. Per DFARS clause 252.235-7011 (<http://www.acq.osd.mil/dpap/dars/dfars/html/current/252235.htm#252.235-7011>), each contractor shall (a) submit two copies of the approved scientific or technical report delivered under the contract to the Defense Technical Information Center, Attn: DTIC-O, 8725 John J. Kingman Road, Fort Belvoir, VA 22060-6218; (b) Include a completed Standard Form 298, Report Documentation Page, with each copy of the report; and (c) For submission of reports in other than paper copy, contact the Defense Technical Information Center or follow the instructions at <http://www.dtic.mil>.

ARMY SBIR PROGRAM COORDINATORS (PC) and Army SBIR 11.1 Topic Index

Participating Organizations	PC	Phone
<u>Armaments RD&E Center</u>	Carol L'Hommedieu	(973) 724-4029
A11-007	Wireless Power Transfer	
<u>Army Research Laboratory</u>	Mary Cantrill	(301) 394-3492
A11-008	CT-Based System for Quantitative Internal Deformation Measurements and Failure Analysis in Targets during Impact	
A11-009	Broadband long wavelength large format focal plane array sensors	
A11-010	Inexpensive Scalable Manufacturing Process for Degassing of High-Strength, Nanostructured, Lightweight Composite Powders	
A11-011	Instrumented Projectiles for Measuring Impact Forces to Characterize Ballistic Behavior of Fabrics and Composites	
A11-012	Coilable crystalline fiber (CCF) Er-doped eye-safe laser gain medium	
A11-013	Carbon nanotube (CNT)/graphene based supercapacitors	
A11-014	Negative Electron Affinity Thermoelectric Devices	
A11-015	Direct Sensing of Micro Unmanned Aerial Vehicle Lift	
A11-016	Modular Model Interface for Network Discrete Event Simulation Engines	
A11-017	Integrated Graphical User Interface (GUI) Assessment Suite	
A11-018	Long Lasting Wide Temperature Range Power Source for Unattended Ground Sensors	
<u>Army Research Office</u>	Nicole Fox	(919) 549-4395
A11-019	Plasmonic Nanosensors for Chemical Warfare Agents	
A11-020	Ultrasound for neuromodulation and control of post-trauma pain	
A11-021	UV-enhanced Raman sensors with high SNR and spectral selectivity	
A11-022	Direct Ethanol Fuel Cell	
<u>Aviation and Missile RD&E Center (Aviation)</u>	PJ Jackson	(757) 878-5400
A11-001	Desktop CFD Analysis for Rotorcraft and Wake Aerodynamics	
A11-002	Unsteady Airfoil Design Optimization with Application to Dynamic Stall	
A11-003	Development of an Improved Unsteady Low Mach Number Navier-Stokes Simulation Module for Rotorcraft Aerodynamics	
A11-004	An External Pressure Data System for Rotors and Wings	
<u>Aviation and Missile RD&E Center (Missile)</u>	Buddy Thomas Dawn Gratz	(256) 842-9227 (256) 842-8769
A11-005	Multiple Reaction Control Jet Modeling	
A11-006	Phased array three-dimensional beam steering system for millimeter wave sources emitting in the 100-300 GHz region	
<u>Communications Electronics Command</u>	Suzanne Weeks	(732) 427-3275
A11-023	Advanced Multi-Fueled 300 W 28VDC Thermoelectric Power System	
A11-024	Safe High Rate and Ultra High Capacity with Minimum 4.0 Amp. hour 18650 lithium ion rechargeable cell	
A11-025	Laser Beam Delivery Sub-System for Multi-Band Mid-Infrared Laser	
A11-026	Toolset for Maintaining Data Integrity in Vast Amounts of Data	
A11-027	Behavioral Discrimination of Moving Targets in Ground Moving Target Indicator (GMTI) Radar	
A11-028	Asynchronous Network Signal Sensing and Classification Techniques	
A11-029	Mid-Infrared Laser Beam Combining Module for Infrared Countermeasure Application	
A11-030	Defect Reduction in (112) Si Substrates, Used for HgCdTe Heteroepitaxy	
A11-031	Optically Fused Thermal Imaging Module	
A11-032	Optimization of Active Polarimeters for Real-Time Imaging	
A11-033	High Quantum Efficiency Ultraviolet Silicon Avalanche Photodiode	
A11-034	Long Range, Non-cooperative, Biometric Tagging, Tracking and Location	
A11-035	Behavior Recognition in Urban Terrain Using Multi-INT Fusion	
A11-036	Detection, Tracking, and Classification of Dismounts	

A11-037 Real Time Adaptable ROIC for improved Power and Performance Optimization in Imager Systems
 A11-038 Optimized Demodulation Techniques
 A11-039 Compression Relevant Notification
 A11-040 Improved Forward Looking Ground Penetrating Radar Array
 A11-041 Information and Decision Dynamics in Network Centric Environments
 A11-042 Feature Detection Architecture for Low Processing Capable Radios
 A11-043 High Performance/Throughput, Low Latency and Low Power Field Programmable Gate Array (FPGA) for Software Defined Radio (SDR) and Cognitive Radio (CR)

Edgewood Chemical and Biological Center **Martha Weeks** **(410) 436-5391**

A11-044 Passive Infrared Detection of Liquids on Surfaces
 A11-045 Continuous Dissemination Techniques for Particulate Obscurants

Natick Soldier RD&E Center **Arnie Boucher** **(508) 233-5431**
Cathy Polito **(508) 233-5372**

A11-046 Volume and Weight Reduction Method for Intermediate Moisture Ration Components and Snacks
 A11-047 Individual Soldier, Active Flame Suppression/Avoidance/Barrier System for Head/Face Protection

PEO Ammunition **Vince Matrisciano** **(973) 724-2765**

A11-048 Intelligent Vehicle Behaviors for Explosive Hazard Detection & Neutralization on Narrow Unimproved Routes

PEO Aviation **Dave Weller** **(256)-313-4975**

A11-049 Refurbishment/Repair of High Value Aerospace Spiral Bevel Gears

PEO Combat Support & Combat Service Support **Robert LaPolice** **(586) 909-9945**

A11-050 Water Generation from Atmospheric Humidity Technologies
 A11-051 Expeditionary Wastewater Treatment Technologies

PEO Ground Combat Systems **Peter Haniak** **(586) 574-8671**
Jose Mabesa **(586) 574-6751**
Jim Muldoon **(586) 770-3513**

A11-052 Development of High Power Density Final Drive for the Bradley Infantry Fighting Vehicle
 A11-053 High Efficiency Fans for Underhood Cooling of Military Vehicles

PEO Missiles and Space **George Buruss** **(256) 313-3523**

A11-054 Advanced High Voltage Optical Switches for Launchable Compact RF Warheads

PEO Simulation, Training and Instrumentation **Rob Forbis** **(407) 384-3884**

A11-055 Weapon Orientation Sensor for Simulated Tactical Engagement Training

Space and Missile Defense Command **Denise Jones** **(256) 955-0580**

A11-056 Poled Films for Compact Single Shot Power Supplies
 A11-057 Lightweight Nanosatellite Constellation Communications System
 A11-058 Vertical Cavity Surface-Emitting Laser (VCSEL) pumps for High Energy Erbium or Thulium Fiber Lasers
 A11-059 Hybrid Variable Velocity Electric Gun
 A11-060 All-Digital Radar

Tank Automotive RD&E Center

Jim Mainero

(586) 282-8646

Martin Novak

(586) 282-8730

A11-061 Innovative Appliqué Attachment Methods for Army Vehicles
A11-062 Increased Autonomous Vehicle Mission Performance Using Advanced Electrical Architectures
A11-063 High-Strength, Lightweight Material for a Bridge Applications
A11-064 Advanced Rotary Diesel Engine Fuel Injection System for Unmanned and Manned Ground Vehicles
A11-065 Lithium ion battery separator development
A11-066 Low Cost Embedded Dust Detector (EDD) for M1 Abrams/Ground Combat Vehicle (GCV)
A11-067 Measuring Fuel Quantity in Collapsible Fabric Storage Tanks
A11-068 Small Diesel Engine for Modular Power

DEPARTMENT OF THE ARMY PROPOSAL CHECKLIST

This is a Checklist of Army Requirements for your proposal. Please review the checklist carefully to ensure that your proposal meets the Army SBIR requirements. You must also meet the general DoD requirements specified in the solicitation. **Failure to meet these requirements will result in your proposal not being evaluated or considered for award.** Do not include this checklist with your proposal.

____ 1. The proposal addresses a Phase I effort (up to **\$100,000** with up to a six-month duration) AND (if applicable) an optional effort (up to **\$50,000** for an up to four-month period to provide interim Phase II funding).

____ 2. The proposal is limited to only **ONE** Army Solicitation topic.

____ 3. The technical content of the proposal, including the Option, includes the items identified in Section **3.5** of the Solicitation.

____ 4. **Army Phase I Proposals have a 20-page limit including the Proposal Cover Sheets (pages 1 and 2, added electronically by the DoD submission site and not requiring you to leave blank pages or duplicate the electronically generated cover pages), as well as the Technical Proposal (beginning on page 3 and including, but not limited to: table of contents, pages left blank intentionally by you, references, letters of support, appendices, and all attachments). Therefore, the Technical Proposal up to 18 pages in length counts towards the overall 20-page limit. ONLY the Cost Proposal and the Company Commercialization Report (CCR) are excluded from the 20-pages. As instructed in Section 3.5d of the DoD 11.1 Phase I Proposal Format instructions , the CCR is generated by the submission website based on information provided by you through the "Company Commercialization Report" tool. Army Phase I Proposals submitted over 20-pages will be deemed NON-COMPLIANT and will not be evaluated. This statement takes precedence over section 3.4 of the general DoD solicitation instructions. Since proposals are required to be submitted in Portable Document Format (PDF), it is the responsibility of those submitting the proposal to ensure any PDF conversion is accurate and does not cause the proposal to exceed the 20-page limit.**

____ 5. The Cost Proposal has been completed and submitted for both **the Phase I and Phase I Option** (if applicable) and the costs are shown separately. The Army prefers that small businesses complete the Cost Proposal form on the DoD Submission site, versus submitting within the body of the uploaded proposal. The total cost should match the amount on the cover pages.

____ 6. Requirement for Army Accounting for Contract Services, otherwise known as CMRA reporting is included in the Cost Proposal (offerors are instructed to include an estimate for the cost of complying with CMRA).

____ 7. If applicable, the Bio Hazard Material level has been identified in the technical proposal.

____ 8. If applicable, plan for research involving animal or human subjects, or requiring access to government resources of any kind.

____ 9. The Phase I Proposal describes the "vision" or "end-state" of the research and the most likely strategy or path for transition of the SBIR project from research to an operational capability that satisfies one or more Army operational or technical requirements in a new or existing system, larger research program, or as a stand-alone product or service.

____ 10. If applicable, Foreign Nationals are identified in the proposal. An employee must have an H-1B Visa to work on a DoD contract.

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A11-047	Individual Soldier, Active Flame Suppression/Avoidance/Barrier System for Head/Face Protection

A11-048 Intelligent Vehicle Behaviors for Explosive Hazard Detection & Neutralization on Narrow Unimproved Routes

A11-049 Refurbishment/Repair of High Value Aerospace Spiral Bevel Gears

A11-050 Water Generation from Atmospheric Humidity Technologies

A11-051 Expeditionary Wastewater Treatment Technologies

A11-052 Development of High Power Density Final Drive for the Bradley Infantry Fighting Vehicle

A11-053 High Efficiency Fans for Underhood Cooling of Military Vehicles

A11-054 Advanced High Voltage Optical Switches for Launchable Compact RF Warheads

A11-055 Weapon Orientation Sensor for Simulated Tactical Engagement Training

A11-056 Poled Films for Compact Single Shot Power Supplies

A11-057 Lightweight Nanosatellite Constellation Communications System

A11-058 Vertical Cavity Surface-Emitting Laser (VCSEL) pumps for High Energy Erbium or Thulium Fiber Lasers

A11-059 Hybrid Variable Velocity Electric Gun

A11-060 All-Digital Radar

A11-061 Innovative Appliqué Attachment Methods for Army Vehicles

A11-062 Increased Autonomous Vehicle Mission Performance Using Advanced Electrical Architectures

A11-063 High-Strength, Lightweight Material for a Bridge Applications

A11-064 Advanced Rotary Diesel Engine Fuel Injection System for Unmanned and Manned Ground Vehicles

A11-065 Lithium ion battery separator development

A11-066 Low Cost Embedded Dust Detector (EDD) for M1 Abrams/Ground Combat Vehicle (GCV)

A11-067 Measuring Fuel Quantity in Collapsible Fabric Storage Tanks

A11-068 Small Diesel Engine for Modular Power

Army SBIR 11.1 Topic Descriptions

A11-001 TITLE: Desktop CFD Analysis for Rotorcraft and Wake Aerodynamics

TECHNOLOGY AREAS: Air Platform

ACQUISITION PROGRAM: PEO Aviation

OBJECTIVE: It is required to develop a wake CFD (Computational Fluid Dynamics) tool that facilitates the efficient and effective use of the latest generations of multiprocessor workstations for the solution of common, but notably-difficult, rotorcraft engineering problems. Such development must be based on those particular types of Eulerian method marked by an intrinsic grid compactness that is necessary for the use of small, easily accessible computers.

DESCRIPTION: The state of the art flow computation methods employ Eulerian CFD with viscous turbulent approximation. For wake convection problems, these methods often have a grid density requirement that is far greater than physical resolution or accuracy requirements. With the advances in high performance parallel computing, these methods are being applied to a wide variety of rotorcraft problems. However, these are often inefficient. Rotorcraft flowfields are dominated by vortical wake structures and their convection accuracy places extreme demands on the grid density requirements for CFD. As a result, even the largest of the grids being used today are not sufficient to accurately predict some key rotorcraft phenomena like rotor hover performance, downwash and brownout. Several alternate methods for efficient wake convection have been developed based on elliptic solvers applied to either compressible potential or incompressible NS equations. These methods also enforce explicit or implicit models for high-gradient regions, enabling grid sizes as small as 1% of the grids used in traditional CFD computations. In the past these methods have been effective in solving the rotor wake flowfield problems. However these legacy methods/tools have not employed the latest parallel, high performance computing technology as they typically run only on a single processor. As a result their efficiency and ease of use is less apparent to today's engineers with ready access to powerful multi-processor desktop computers. The motivation for this solicitation is to provide a practical conversion path to upgrade such legacy sparse-grid methods.

A feature that such methods have in common is the use of an elliptical solver. These include the approximate factorization methods originally developed for compressible potential methods or the myriad methods used for projection-type Euler/NS solvers (conjugate-gradient, multigrid, FFT, etc.). In order to accomplish the envisioned modernization it is required that a general parallel solver package be developed that is readily usable (by engineers rather than computer scientists) and that encompasses general grids, boundary conditions and non-constant coefficient systems. Another solution feature found in sparse-grid methods is the need to search solutions (for example to locate vortical regions/structures or flow markers within a grid), and to conditionally apply equation terms (as in confinement methods) or build local solution models (as in embedding methods). The ability, in some general form, to facilitate such conditional solution features is typical of sparse-grid methods. However, these tend to be somewhat unique to the code. A development of a general parallel elliptical solver will greatly enhance the application of a wide range of these legacy methods. Success in this endeavor should enable the subsequent consideration of less common solution aspects.

PHASE I: The solution element most common to Eulerian wake analyses is the elliptic solver. The feasibility of the desired parallelization of elliptical solver(s) must be demonstrated by applying it to a desktop parallelization of a known sparse-grid analysis. Examples of such sparse grid solvers include the Army's HELIX-IA potential flow code (Ref. 1, 2), an incompressible NS solver (Ref. 3) and an Euler solver with vorticity confinement (Ref. 4). Initial parallelization capabilities may be demonstrated using one of these legacy solvers, but it should also be demonstrated that the elliptic solver conversion is suitable to a reasonably wide range of analyses. The remainder of such analyses is typically some type of explicit or implicit wake model, which may involve conditional logic. This latter part of the wake solver tends to be unique to the method. However, the matrix inversion is typical of many Eulerian codes and is a suitable model for a phase I parallelization demonstration. A minimum criterion for success would be the incorporation of an elliptic solver (with variable coefficient capability) suitable to all probable grid types and boundary conditions, with a low operations count and the ability to effectively employ all available processors with close to linear speedup without any impact on the accuracy. In addition, it should be shown that the mode of inclusion of these solvers can be generalized to future code improvements or to other types of solvers, the point being to evolve a system for the conversion of such legacy codes to everyday parallel workstation operation.

PHASE II: The ability to treat a full code (that is, including all conditional elements unique to the specific code) will be demonstrated by performing a full workstation parallelization of the chosen code. In addition, this code should include the necessary hybridizations to compute not only the wake, but the viscous blade surface flow as well. This latter solution element is almost certainly a typical RANS codes, but it must be parallelized with the same ease as is sought for the wake analysis. These developments will culminate in a full comparison of results from the original analysis. A valuable element of this process is that it should not be purely defined by the structure of a particular wake code, but rather that it should reflect features that all such codes have or can be easily reformulated to have. It should thereby constitute a process that can, in some definable way, be generalized to the treatment of other such codes (including future upgrades of any such code). A suitable demonstration of this capability should be proposed and executed.

PHASE III: The proposed wake CFD capabilities would constitute a unique engineering tool that can easily constitute a commercial product. Elliptical flow solvers are widely used in applications ranging from aircraft analysis to gaming animations, thus providing a broad area for civilian application and commercialization. Even more unique would be the ability to develop a formalized software environment for the conversion of codes to modern-day parallel workstations. This would be especially valuable because of the large number of legacy codes that are in use in the engineering community, and can be readily commercialized. Such commercialization would require the development of an intuitive user interface that can be tailored to suit the needs of different legacy codes.

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KEYWORDS: rotorcraft, aerodynamics, wake flows, vortex embedding method, elliptic solvers, scalability

A11-002 TITLE: Unsteady Airfoil Design Optimization with Application to Dynamic Stall

TECHNOLOGY AREAS: Air Platform

ACQUISITION PROGRAM: PEO Aviation

OBJECTIVE: Develop and use state-of-the-art engineering computational fluid dynamics (CFD) and optimization tools and methodologies to design and optimize fixed geometry two-dimensional airfoils for improved characteristics in unsteady dynamic stall.

DESCRIPTION: Dynamic stall is an unsteady aerodynamic phenomenon on airfoils, wings, and rotor blades, which results in adverse lift, drag, and pitching moment characteristics, compared with static stall [1,2]. Fundamental research into dynamic stall on pitching airfoils has been ongoing for decades. Recent advances have experimentally investigated passive and active dynamic stall alleviation techniques with generally good success [e.g. 3,4, and many others], but often using trial and error or low-order, steady aerodynamic design methods, with limited understanding of the underlying physical mechanisms. Thus, our overall understanding is still lacking as to the effects that airfoil shape modification have on dynamic stall characteristics and the resultant detailed changes to the flow field.

Computational fluid dynamics (CFD) analyses can obtain some success in predicting dynamic stall [e.g. 4,5, and many others], but some deficiencies are expected due to engineering turbulence and transition modeling. It is expected that the proposers will use efficient state-of-the-art engineering models that should be able to model some of the physics of dynamic stall and predict trends. CFD tools, therefore, should solve unsteady, viscous, and turbulent flow equations. Creative temporal approximations, such as time spectral or harmonic balance [9], are possible if proven to be suitably efficient and accurate for the frequencies of dynamic stall. The development of advanced turbulence models (DES, LES) is not the intent of this topic.

Aerodynamic shape optimization can be used to achieve specific performance objectives through the application of suitable geometric shape modifications. The development of a wide range of optimization techniques and processes, such as adjoint formulations, genetic algorithms, multipoint design, and inverse methods, has proven to be an enabling technology for fixed wing optimization. However, because of the flow field complexity and computational cost, optimization of unsteady problems has received much less attention [6,7,8,9,10], and is at the forefront of current research. Suitable objective functions and constraints must be developed for unsteady flows.

OBJECTIVES: The objectives of this topic are to 1) implement an unsteady optimization technique employing unsteady, viscous, turbulent CFD, 2) apply the CFD-based optimization technology to alleviating dynamic stall, 3) investigate and understand the influence of geometry modification on flow physics. The end result of the current effort will be the development and application of a design methodology for devising passive airfoil profiles with improved dynamic stall characteristics and minimal performance impact in the attached flow regime. Increased understanding of CFD dynamic stall prediction capability and the trade-offs necessary to tailor airfoil design for dynamic stall will be obtained.

In the long term, this capability could significantly improve the airfoils used in Army helicopter rotor blade design. Eventual extension of the methodology to three dimensions would further expand the design envelope without limiting 2D assumptions. Designing for dynamic stall reduction thus has the potential for improving rotorcraft performance and capabilities (speed, payload) while reducing structural loads and vibration and resulting maintenance costs, which are all affected by aircraft stall characteristics.

PHASE I: In Phase I, The unsteady optimization strategy and tools must be developed, applied, and verified, possibly on a model problem simpler than the intended dynamic stall airfoil application. The project may demonstrate general competence of the current engineering-quality CFD capability for simulating two-dimensional (2D) dynamic stall using unstructured or structured mesh technology.

PHASE II: In Phase II, an unsteady, turbulent CFD-based optimization methodology will be further developed, validated, and tested. The feasibility of alleviating 2D dynamic stall, including developing suitable and obtainable objective functions, constraints, and optimization strategies, will be investigated. Being able to then exercise the software and understand the final design results from a flow physics viewpoint is equally important. The end goal will be the development and application of a design methodology for devising passive airfoil profiles with improved dynamic stall characteristics and minimal performance impact.

PHASE III: The long term objective of this research is that it can shed light on the complex flow physics of dynamic stall and enable us to better understand the possibilities for dynamic stall alleviation or modification. The long term vision is the development of a validated design tool which is useful for airfoil shape design taking into consideration unsteady dynamic stall characteristics in an aerospace industrial setting. Techniques for including multi-objective optimizations could be pursued, and strategies for simultaneously computing the various design points on parallel computers implemented. For example, unsteady dynamic stall optimization may be combined with high speed advancing blade transonic capability and optimum hover performance in a three-dimensional flowfield on a DoD rotorcraft configuration. A potential commercial application would be to modularly couple the unsteady optimization strategy to the broad range of available CFD solvers in use in government, industry, and academia.

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KEYWORDS: dynamic stall, optimization, CFD, rotorcraft, adjoint, unsteady, airfoil

A11-003 TITLE: Development of an Improved Unsteady Low Mach Number Navier-Stokes Simulation Module for Rotorcraft Aerodynamics

TECHNOLOGY AREAS: Air Platform

ACQUISITION PROGRAM: PEO Aviation

OBJECTIVE: Development of a Navier-Stokes solver module with innovative unsteady low Mach preconditioning methodology that demonstrates accuracy levels and convergence rates independent of the Mach number and physical time-step size. Evaluation of the module should be focused on application to rotorcraft aerodynamics simulations. The module should interface with the Helios computational platform in order to benefit rotorcraft acquisitions users within the Department of Defense and industry contractors.

DESCRIPTION: Low Mach number flowfields are computationally inefficient and prone to numerical inaccuracies [1-3]. Preconditioning methods are a well-established approach to ameliorate these issues for steady fixed-wing aerodynamics [4], but the application of these methods for unsteady rotorcraft flowfields remains a challenge [3]. Recent research developments indicate that low Mach number issues in an unsteady context can be successfully treated with a redesign of the flux discretization scheme as well as appropriate scaling of the preconditioning matrix [5-7]. This topic is concerned with the implementation of such improved flux schemes and solution algorithms within a Navier-Stokes code module, and the evaluation of the module for rotorcraft flight regimes ranging from hover to representative forward flight Mach numbers. It is also envisaged that the new module would interface with the US Army's Helios rotorcraft computational platform, which is a modular framework for integrating single-discipline codes for computational fluid dynamics, domain connectivity, structural dynamics and flight dynamics [8]. Helios provides documented Application Programming Interfaces (API) to facilitate such integration. Both

structured and unstructured solvers are supported in the framework, but preference will be given to unstructured solvers because of grid generation flexibility. Successful development and integration of the new module would have a profound impact in facilitating high-fidelity rotorcraft analysis and design for the DoD acquisitions workforce and industry contractors.

PHASE I: Initial demonstration of enhanced flux formulations for unsteady low Mach number flows using preconditioning approaches such as those outlined in Refs. 5-7 or alternate approaches yielding similar potential performance benefits. The improved Navier-Stokes module must demonstrate that the solution error and convergence rates are independent of Mach number and unsteady time scale (i.e., Strouhal number) using exact solutions for vortex propagation and acoustic wave propagation.

PHASE II: The Phase II portion of the study involves the extensions of the best schemes identified in Phase I to accommodate complex unsteady flow situations typical of rotorcraft flight: (1) moving bodies and meshes to capture relative motion between rotor and fuselage, (2) rotational and inertial coordinate frame calculations applied to hover simulations, and (3) multiple time scales and flow speeds occurring within the same flowfield, eg., transonic rotor tip speeds and low-Mach forward flight speeds. The Phase II study will also involve application of the methods to practical rotorcraft simulations, including conditions representative of hover and forward flight. Finally, it is anticipated that appropriate API's will be developed to enable modular plugging into the existing Helios computational platform used by government engineers and industry contractors [8]. Performance metrics of the proposed solver module should involve detailed verification and validation tests of local accuracy, convergence characteristics and robustness for such complex flowfields. In addition, it is expected that the module development will include appropriate regression test suites for continuous quality assurance of the software product as well as detailed developer and user documentation.

PHASE III: Upon successful completion of the Phase II portion, the newly developed Navier-Stokes module should be fully tested and validated within the Helios multi-disciplinary rotorcraft computational environment [8]. This will facilitate commercial acceptance of the module and help transition its use to the government and industry rotorcraft analysis and design communities. We anticipate that the technology can potentially impact the redesign of existing rotorcraft as well as facilitate the design of next-generation rotary wing vehicles. In addition, development of the general unsteady low-Mach technology would have applicability to turbomachinery and wind turbine flowfields as well as to fixed-wing aircraft during take-off and landing.

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KEYWORDS: Low Mach number, unsteady flows, local preconditioning, accuracy improvement, convergence enhancement, rotorcraft simulations

A11-004 TITLE: An External Pressure Data System for Rotors and Wings

TECHNOLOGY AREAS: Air Platform

ACQUISITION PROGRAM: PEO Aviation

OBJECTIVE: It is required to develop and demonstrate an easily-appliable and easily-useable transducer array system for the acquisition of pressure time-histories and chordwise spatial distributions, for use on air-vehicle surfaces, especially rotors and wings.

DESCRIPTION: Rotorcraft fly under a huge variety of conditions, a number of which entail unpredictable airloads. As a result, the development or modification of rotorcraft is often delayed by the occurrence of unforeseen and sometimes dangerous flight anomalies, of unclear cause. Understanding these conditions is difficult without the ability to easily acquire diagnostic data that identifies aerodynamic loading sources (mainly surface pressures) – especially on wings and rotors. Similar needs also exist with wind-tunnel testing, where a major (and often prohibitive) source of cost is in the pressure instrumentation of models. The point of this solicitation is to eliminate the cost and difficulty of such measurements by developing an externally applicable pressure measurement strip with the ability to acquire and store large data quantities and to receive, respond-to and record wireless command and time-synchronization signals, thus eliminating the need for costly slipring and cabling assemblies.

Typical pressure instrumentation (along with its wiring) is embedded into the interior of a model, which greatly magnifies its complexity and cost. Typically a wing or rotor chordwise section should contain about 30 or more piezoresistive pressure transducers. This number (as well as the chordwise placement) is determined by the ability to integrate the pressures to obtain accurate lift and pressure-drag. Transducers for such applications are designed to have maximum pressure sensitivity with negligible temperature sensitivity. These interior installations must tolerate high centrifugal and vibratory loads. In addition, the process of powering, acquiring, digitizing and storing the resulting data is typically contained in a remote data system that must be connected via long, loss-and-noise-prone cabling. Present levels of data quality are always required, but the goal here is to determine and demonstrate the ability to obtain these from a system entirely contained within the rotating system (and close to the measurement point), using an exterior “pressure strip”. The following is an example of a conceptual system having these qualities.

The pressure strip should conform closely to the surface of a straight rotor or wing and be minimally intrusive, and easily attached via non-permanent adhesive. Transducer data must be digitized and stored at a site (also easily attachable and removable) located as close as possible to the strip (within the rotating system) and be connected to it either by a thin wire ribbon or wireless connection. Likewise the transducer power must be self contained or supplied via a thin wire. Command information (start, stop, case identification, etc.) to this system must be given via a remote wireless system. The strip should also receive real-time synchronization signals for use with unsteady data. The system should contain adequate memory to permit considerable test or flight time before needing to stop (or land) to download the data. Necessary considerations for this system are ease of application and removal, lightness and safety, ease and reliability of use and the ability to tolerate high centrifugal and flight loads. To the maximum extent, components should be commercial off-the-shelf, thus permitting wide cost reduction latitude.

PHASE I: A pilot feasibility system will be designed, fabricated and tested on a simple model, preferably a fixed-wing model, for which pressure data is available, in a readily available wind tunnel. (The Moffett Field 7X10 tunnel and existing wing models are possibilities that cannot be presently assured – the proposer should be prepared to offer a suitable alternative.) Such testing will acquire pressure data and compare it to known pressures. The data will be evaluated for accuracy (including the effect of strip thickness on pressures) and ease of use. In addition it must be shown through simple analysis and laboratory loads-testing that the basic scheme is compatible with later rotor testing to be performed in Phase II - that is, that it can meet reasonable requirements of safety, accuracy and frequency response entailed by anticipated Army testing (TBD).

PHASE II: Assuming that the fixed model testing is successful and deemed suitable for rotary wing use, a version will then be built and evaluated on a rotor. There are several possibilities for such testing. Again it may be possible

to perform such tests on existing or planned Army rotor models, which would have a chord of about 6", a diameter of about 7' and an approximate tip speed of 600fps. However, such availability cannot be assured due to schedule uncertainties. The proposer should be prepared to offer a suitable alternative, which may include actual rotorcraft flight testing.

PHASE III: The proposed pressure system will constitute a unique diagnostic capability that can be used in a wide range of fixed-wing and rotorcraft model and flight tests. Such a capability will constitute a unique capability that will be an invaluable aid in aeronautical research as well as in many types of flight development programs. Given its uniqueness and envisaged ease-of-use, this capability has great potential as a commercial aeronautics support technology.

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KEYWORDS: rotor pressure instrumentation, piezoresistive pressure instrumentation, rotorcraft airloads measurement

A11-005 TITLE: Multiple Reaction Control Jet Modeling

TECHNOLOGY AREAS: Air Platform, Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To develop an advanced physics based model capable of capturing the flowfield physics for a missile in supersonic flight during a guidance event in which multiple lateral jet-iteration thrusters are fired.

DESCRIPTION: There is an increasing interest in developing missiles for area protection systems. Such systems are tending to require very precise control in a time-critical mission role. Reaction control jets offer a very attractive system because of their size, simplicity, and extremely fast response time. However, the precision achievable with these systems are a direct function of the understanding of the interaction with the aero-propulsion flow field. A great deal of progress has been made in this area for the case of a single jet or a jet that does not interact with any other jet. For the time critical missions posed by area protection, multiple precision jets are required to achieve the control required. This introduces the added complication of one jet interacting with another jet both in proximity and time. This interaction has a first order effect on the precision and control effectiveness of the system. Therefore, a very precise control system is critically dependent on the interaction forces between the jets that will be governed by the geometric placement of the jets and the timing sequence for their initiation. Recent advances in aero-propulsion CFD offer the framework for the addition of the capability to accurately design and analyze multiple jet control systems used in missiles for area protection systems.

PHASE I: Innovative solutions techniques are sought that can advance the state-of-the-art for the prediction of the flowfield of a missile during a guidance event in which multiple lateral jet-interaction thruster flowfields interact with the missile flowfield while accounting for the effects of incoming boundary layer, asymmetric body flows, arbitrary particle size/number densities at combustor exits, chemistry, three-dimensional arbitrary geometry, and temporal effects. The model shall be able to predict the flow separation environment, particle distribution fields, chemical reactions, and the resultant body forces/moments for flight Mach numbers from 1 to 12 and altitudes from

0 to 30 km. One meaningful demonstration will then be executed and a flow field solution produced with this advanced computational model during Phase-I. This demonstration shall model the case of separated flow over a missile interceptor configuration with two jet-interaction thrusters as follows: Axisymmetric cylindrical body (no external fins or control surfaces) Conical (30 degree half-angle) nose Blunt base (no propulsive exhaust) Missile length = 1.50 m Missile diameter = 150 mm Flight Mach number = 8 Flight altitude = 45 km Flight angle-of-attack = 0 degrees with jet-interaction thruster properties as follows: Gaseous H₂/O₂ fuel Equivalence ratio = 1.0 Combustor pressure = 13.8 MPa Exit radius = 25.2349 mm Throat radius = 7.9629 mm Conical nozzle with a 15 degree half-angle The jet-interaction thrusters will be located with: One jet centered at 685 mm from the aft end and clocked at 0 degrees One jet centered at 700 mm from the aft end and clocked at 11.31 degrees where 0 degrees is directly overhead. The outcome of this test case will serve as a gauge to assess the potential for Phase-II success.

PHASE II: The physical model formulated in Phase I will be developed and refined using computational fluid dynamics to evaluate jet-interaction control over a broad range of missile and thruster parameters of interest wherein multiple reaction jets interact in space and/or time. Additionally, this advanced computational fluid dynamics model will be run blind for a supersonic jet-interaction test case for which detailed flowfield data will be available to demonstrate the advanced capabilities for analyzing and modeling complex jet-interaction control schemes.

PHASE III: If successful, the end result of this Phase-I/Phase-II research effort will be a validated predictive model for the analysis of missile designs which employ jet-interaction control thrusters for pitch and roll control. The transition of this product, a validated research tool, to an operational capability will require additional upgrades of the software tool set for a user-friendly environment along with the concurrent development of application specific data bases to include the required input parameters such as missile geometries, solid rocket motor properties, jet-interaction thruster properties, and performance parameters. For military applications, this technology is directly applicable to all missile systems and gun launched projectiles using multiple jet-interaction control thrusters. For commercial applications, this technology is directly applicable to all commercial launch systems such as the NASA Aries, and the Delta and Atlas families. The most likely customer and source of Government funding for Phase-III will be those service project offices responsible for the development of advanced missile concepts such as the KEAPS, KEI, and PAC-3 programs.

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KEYWORDS: jet-interaction, computational fluid dynamics, two phase, gas particle flow, chemistry, combustion, propulsion, aerodynamics, missile.

A11-006 TITLE: Phased array three-dimensional beam steering system for millimeter wave sources emitting in the 100-300 GHz region

TECHNOLOGY AREAS: Sensors, Electronics, Weapons

ACQUISITION PROGRAM: PEO Missiles and Space

OBJECTIVE: Develop a phased array three-dimensional beam steering system for millimeter wave sources emitting in the 100-300 GHz region.

DESCRIPTION: Millimeter wave (mmw) imaging and sensing has become increasingly important for both military and commercial applications, providing capabilities for RADAR-type precision targeting, terminal guidance, height-of-burst fuzing, navigation assistance RADAR, imaging through obscurants, non-destructive testing, detection of chemical toxins, and extremely high bandwidth communication. [1-2] One major drawback of present single detector mmw imaging systems is the need to steer the mmw beam mechanically by moving the entire antenna system. [1] Phased array antennas utilize the coherence of a beam to perform three-dimensional (3D) beam steering with a stationary antenna. An essential part of such an antenna is the phase shifter, which controls the phase angle of the transmitted signal. The phase shifters are preceded by a fan-out beam routing architecture and are followed by output horns for impedance matching into free space. While phase shifters have been developed in the mmw region up to 100 GHz using ferrite, semiconductor, and mechanical (trombone) technologies, generally their performance decreases quickly above 100 GHz. [3-5] Liquid crystal phase shifters are used in some infrared applications but have shown limited phase shifting performance below 1 THz. [6] Metamaterials have shown some promise as potential phase shifters. [7]

This solicitation requests the design, construction, and delivery of a scalable, N-element beam splitter/ phase shifter/ output horn combination capable of independently shifting the phase of each element on demand by 2π at frequencies between 100-300 GHz. Solutions that meet the minimum requirement will develop at least $N = 3$ non-colinear, balanced elements to demonstrate 3D beam steering with a maximum angle switching time of 1 msec and a maximum 3D beam steering angle of ± 60 degrees. Strong preference will be given to cost-effective, fast switching solutions that can deliver, or may be scaled to, large N, balanced high gain arrays. There is also some interest in solutions that can operate at frequencies above 300 GHz. Compact, highly coherent mmw sources using standard 120 V power supplies have been developed in the 100-300 GHz region with output powers from 0.1 – 100 mW.[8-9] The lack of appropriate mmw power amplifiers requires the phase shifting system to have minimal insertion loss ($< -3\text{dB}$) over a full 2π phase shift. Input power to the mmw phase shifters is assumed to be a frequency-dependent 0.1 – 10 mW before splitting into multiple beams occurs. If a digital phase shifter is proposed, it should have at least six-bit phase shifting capability. The physical size of the phase shifters should fit within a single mode waveguide unless some fan-out feed is proposed to avoid grating lobes.

Furthermore, the multi-element phase shifting system should be designed so it can be attached to the output waveguide of a mmw source operating in the 100-300 GHz region. The beam must be reproducibly steered in 3D space with continuous or discrete angular steps controlled by a computer-based graphical user interface (GUI). The GUI must allow the user to choose between a variety of common beam steering patterns such as raster scan, conical scan, spiral scan, single and multiple scan steps which may be non-uniformly spaced. The GUI must also provide real time information on the location and shape of the steered beam in commonly used coordinate systems and take into account compensation algorithms to optimize performance.

PHASE I: Design a multi-element phased array beam steering system according to stated requirements and quantify its expected performance. Specifically, the design must: a) Expand a physics-based description of the proposed phase shifting technology into a realistic model that predicts the performance of the far field antenna beam patterns as a function of frequency and angle. b) Provide a trade-off analysis among critical performance characteristics (mmw power, insertion loss, frequency-dependent output balance among elements, switching rate, maximum achievable phase shift, beam shape, maximum steering angle, operational frequency, polarimetric effects, etc.). The Phase I deliverable will be the completed design of the multi-element phased array beam steering system. The design must outline plans to construct, test, and deliver a working prototype during Phase II, including a risk and cost assessment for hardware and software on a component and system level.

PHASE II: Construct, demonstrate, test, and deliver to AMRDEC a multi-emitter phased array for 3D beam steering based on the design proposed in Phase I. The prototype must include at least three non-colinear emitter elements and demonstrate rapid, low insertion loss, balanced 3D beam steering on demand as specified above. Assume the prototype will be flange-attached to an existing mmw source emitting up to 10 mW at 100 GHz and 0.1 mW at 300 GHz. The prototype's salient performance parameters (e.g. beamwidth/ beam pattern vs. beam angle, angular beam steering speed, frequency dependence, balance) must be measured, compared with model predictions, and reported.

PHASE III: Develop a phased array mmw RADAR operating in the 100-300 GHz region. The system must include mmw source and detector transceivers in conjunction with a phased array capable of rapid beam steering in 3D. The

system must be able to search for, acquire, and track suitable moving targets at a standoff distance and provide real time range detection of tracked targets. The system must be capable of continuously and rapidly acquiring mmw RADAR images over its angular field of view and present them in commonly used coordinate systems.

DUAL USE APPLICATIONS. A phased array mmw beam steering device will find wide use for military and commercial RADAR applications such as precision targeting, terminal guidance, height-of-burst fuzing, navigation assistance RADAR, imaging through obscurants, non-destructive testing, detection of chemical toxins, and extremely high bandwidth communication. Furthermore, a fast scanning beam integrated into a compact terahertz (THz) transceiver is a necessary step for the cost-effective, reliable deployment of portable imaging systems.

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KEYWORDS: millimeter wave, phased array, RADAR, beam steering, terahertz, sub-millimeter

A11-007 TITLE: Wireless Power Transfer

TECHNOLOGY AREAS: Information Systems, Ground/Sea Vehicles, Electronics

ACQUISITION PROGRAM: PEO Missiles and Space

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Design, develop and demonstrate a wireless power transfer device capable of charging battery operated systems at moderate distances.

DESCRIPTION: Today's warfighter is reliant on small battery operated devices for communication, enemy detection, and battlefield management. As such, these devices must be recharged on a regular basis to ensure sustained operation. Current charging technologies require the device to be plugged into a charging station via a wired connection. This wired power connection requirement decreases the battlefield flexibility due to limited number of units that can be charged at one time. Additionally, the wired power connectivity increases the logistical footprint and operation complexity.

Recently, advances in power transfer technology have been demonstrated that may allow batteries and other electrical systems to be charged and powered wirelessly. Researchers at Massachusetts Institute of Technology describe a method of transmitting power wirelessly through the use of resonant coils coupled magnetically. These

researchers were able to power a 60W light bulb wirelessly from over 2 meters away. However, efficiency of this method was only 40%.

It is envisioned that this wireless technology could have a dramatic impact on the portable electronic devices being used on the modern battlefield. This wireless technology could be harnessed in several applications to ease the logistical footprint and increase the flexibility of the devices. First, rechargeable battery operated devices could be recharged from a short to moderate distance from the charging source without the tether of wires. By not having a wired connection limitation, a greater number of systems could be charged at one time at these stations. A range of five meters is specified to address space and efficiency considerations for battery recharging situations. A charging station should be effective at this short to moderate distance and not occupy a large footprint within the facility. A more important possibility that could be leveraged in the future from this effort would be longer range power transmission that would allow these devices to be constantly powered in the active battlefield, thus eliminating the use of batteries altogether. With the constant power source available, soldiers could rely on their electronic devices to function for extended periods of time without shutdown or recharge.

PHASE I: Identify method of wireless power transfer that will function at/or above 50% efficiency at a distance of at least 5 meters. Conduct trade-off study to determine best components for laboratory scale apparatus. Perform modeling to predict potential capabilities of designed system.

PHASE II: Develop and prototype a proof-of-concept device that is able to recharge battery operated devices wirelessly at a distance of at least 5 meters. Device must be able recharge non-line-of-sight systems (i.e. recharge through barriers and other obstacles). Environmental conditioning tests (humidity, high temperature and low temperature) shall be conducted per MIL-STD-810G to ensure that environmental conditions do not adversely affect transmission properties. Additionally, EMI testing shall be conducted to ensure power transmission does not affect essential electronic equipment. Prototype shall show path that leads to the manufacturing of a mobile transmitter unit that can be mobilized via standard Army vehicles.

PHASE III: Finalize system technology and develop manufacturing capabilities for large scale production. Dual use applications include use for all portable electronic devices, both in defense applications and commercial applications. Development may lead to a wire-free electronic lifestyle.

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KEYWORDS: Keywords: Wireless Power Transfer, Portability, Electronic Devices, metamaterials

A11-008 TITLE: CT-Based System for Quantitative Internal Deformation Measurements and Failure Analysis in Targets during Impact

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Design and develop a CT-based (computed tomography) volumetric measurement system that acquires, analyzes and converts internal-volumetric images of deformed and undeformed test samples from different materials (polymer matrix composites, biological/biomimetic materials, metals, ceramics) into internal deformation and motion measurements with optimal accuracy at quasi-static and high rate loading conditions.

DESCRIPTION: Surface digital image correlation (SDIC) methods are being used regularly in academic and government laboratories to measure full field 2D and 3D surface displacements during deformation of objects [1]. In recent years, advances in affordable laboratory scale internal imaging methods of objects have opened up opportunities for quantitative measurement of the 3D-displacements/motion of internal positions of an entire object. Computed Tomography (CT) scanners, Confocal Imaging Microscopes (CIM), and Magnetic Resonance Imaging (MRI) systems are examples of some of these hardware that are able to obtain and store massive amount of digital

volumetric images showing the inside details of an object, oftentimes exceeding the ability of the computer hardware and software to process and analyze the data. In the past decade, the SDIC methods/algorithms are being extended to the quantitative analysis of the movement of the internal locations from the volumetric images [2-10], but only at academic institutes. An “in-situ” CT-based volumetric measurement system, incorporating these advances in hardware and software algorithms to study the motion of internal material points while undergoing deformation will enable researchers at the Weapons and Materials Research Directorate (WMRD) of the Army Research Laboratory (ARL) to use these systems on various ongoing investigation that are relevant to the Army systems. One such application is for the investigation in the effect of “z-direction fibers” reinforcement in woven composites for the mitigation of delamination in support of efforts to develop and design lighter weight armor systems for both personnel and vehicles. However, such a system is not limited to textile-based composites, but can also be used to measure internal displacements in biological and biomimetic tissues when subjected to an external mechanical loading. Volumetric measurement system will allow researchers to study the failure behavior in biological systems, which are naturally anisotropic due to the tissue/cell structures. Such internal quantitative measurements can validate material models that are used in computer codes to enhance understanding of blunt trauma and tearing in tissues, and allow Army researchers to develop effective protection for soldiers. In addition, the proposed system will not only have quasi-static measurement capability but also the ability to extend its versatility to high rate loading experiments. These are significant benefits to study deformation and failure of the composite armor systems during ballistic impacts as well as in the urban materials study of concrete for deformation and fracture at the interfaces between the aggregates and cement. This SBIR topic addresses the development of a hardware/software based portable and robust volumetric measurement system to provide quantitative internal deformation data of a deforming object.

PHASE I: Define the issues associated with hardware and software methods for the accurate internal volumetric measurements for quasi-static as well as high rate deformation and failure events. Evaluate and propose methods/devices to obtain volumetric images and develop algorithms and initial beta VDIC software for image analysis of internal images obtained from such devices. An ideal system shall be capable of resolving voxel (volumetric pixel) displacements in the order of 0.01% and the ability to encompass a volumetric field ranging from 0.5 cm³ to 30 cm³. Evaluate the feasibility of implementing the proposed integrated hardware/software technology. At the end of Phase I, provide a final report showing the concept of an integrated hardware/software system. Report also should contain the process of selection of the proposed hardware including the efforts of a market research to determine a suitable compact CT imaging system and the concepts associated with the proposed VDIC software.

PHASE II: During Phase II, the Contractor shall design and integrate the components of the CT imaging hardware with the software for a volumetric digital image correlation (VDIC) system based on the feasibility concepts from Phase I. The Contractor shall establish the performance parameters of the system through experiments at laboratory facilities of the Material and protection Divisions (MD and PD) of the WMRD/ARL at the Aberdeen Proving Ground (APG) to demonstrate the viability of the prototype to measure deformation and failure behavior in composites as well as biological tissues while under loading in a slow and high loading rate test machines. At the end of Phase II, the Contractor shall deliver a final prototype with the documentation of the design and user manual to the TPOC (Technical Point of Contact) at the Army Research Laboratory for further evaluation of the system with other ongoing investigations in WMRD.

PHASE III: The transition of this VDIC technology into a robust, turnkey "commercially-available" system will provide significant data in greater detail and more importantly to understand the internal failure behavior of materials and structures while under high rate or quasi-static deformation. Below is a list of potential applications:

- This will enable Army reserachers to investigate the delamination between tiles and composite laminates during impact or quasi-static loading. There probably would not be a need to conduct post mortem analysis of composite armor panels since this information will be acquired directly during the test.
- Medical researchers will have the ability to directly acquire the deformation behavior between tissues and medical devices such as a stent expanding within a coronary artery.
- Automotive tire industry can use this technology to study the internal steel reinforcements of radial tires while spinning at high RPMs.
- Concrete industry can investigate the interface between the cement and aggregates or the concrete and the steel rebar reinforcement while going through the cure process and also under high static loading
- The aerospace industry can measure the deformation of key internal structures of an aircraft wing during design load qualification testing

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KEYWORDS: digital image correlation, volumetric measurements, computer vision

A11-009 TITLE: Broadband long wavelength large format focal plane array sensors

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: PEO Intelligence, Electronic Warfare and Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Proposals are sought to develop an advanced readout electronic readout circuit (ROIC) to enable fast operation of large format corrugated quantum well infrared photodetector (C-QWIP) focal plane array (FPAs) for long wavelength detection.

DESCRIPTION: At present, C-QWIP FPAs use off-the-shelf ROICs, which have limited resolution less than 1 mega-pixels and bias range less than 1V. These deficiencies limit the sensor surveillance radius to less than 1.5 km (e. g. a local neighborhood) and require an exposure time longer than 4 msec. In order to perform wider area

surveillance (e. g. a city downtown) and to operate the FPAs at higher speed on fast moving platforms, ROICs need to be 4 mega-pixels in resolution and to be able to provide higher than 3V bias to shorten the exposure time to less than 2 msec. This SBIR project seeks innovative circuit designs to demonstrate large format (2K x 2K) and high speed (2 msec) long wavelength infrared (LWIR) C-QWIP FPAs.

This topic seeks to improve the current technology of C-QWIP detector long wave infrared imaging by developing integrated circuit design concepts optimized specifically for C-QWIP detectors. Recent development in C-QWIP technology has shown improvements in detector sensitivity compared to the current QWIP technology. Due to the mature detector material system, C-QWIP has shown to be a viable cost-effective candidate to meet US Army's needs for large format, high performance LWIR imaging in the areas such as persistent surveillance and helicopter pilotage. The broadband nature of the C-QWIP also makes it capable of hyperspectral imaging for chem/bio detection. To date, most of the C-QWIP infrared imaging demonstrations consist of mating C-QWIP detector arrays to existing ROIC designs or off-the-shelf ROIC designs. To realize the full potentials of the technology, a dedicated readout is needed. This ROIC development will allow the realization of fast FPAs with enhanced spatial resolution and increased field of view.

Successful development of advanced ROICs for C-QWIPs will improve the Army's infrared capability across many platforms. Applications include manned and unmanned aerial reconnaissance under obscuration and poor weather conditions, identifying targets at maximum range of future weapons, discriminating between military and civilians, between live and decoy systems, between operational and non-operational systems or provide objective resolution performance. Because of the cost-effectiveness of the technology, several C-QWIP FPAs can be deployed at the same time to provide a 360 degree hemispheric observation capability regardless of orientation of sensors or aircraft. Lack of this capability reduces ability to detect all threats or hazards and limits situation awareness. The broadband C-QWIP FPAs will also be able to perform hyperspectral imaging for chem/bio detection, which improves the Chemical, Biological, Radiological, Nuclear (CBRN) capability of the Army helicopters in general. Present unmanned aerial systems lack the range necessary to effectively conduct aerial reconnaissance and surveillance across the company/platoon area of operations. They also have limitations in range finding and designation that reduce the ability to perform cooperative engagements. The improved C-QWIP technology will allow rapid detection, location, assessment, and identification of enemy dismounted soldiers to provide early warning to impacted soldiers and to support effective and efficient command and control (C2).

PHASE I: Investigate, research, and design a readout architecture optimized specifically for high performance C-QWIP technology through the use of modeling, analysis, empirical testing or construction. Readout designs with innovative approaches to cancel dark current, support large detector biases, N/P and P/N polarities, and have short circuit protection, with low read noise, in support of large format (2K x 2K), small pixel pitch C-QWIP detector arrays are desired. Additionally, it is preferred that the ROIC can support a wide dynamic range through the use of novel circuit concepts that enable high dynamic range. Establish working relationship with the SBIR technical point of contact to acquire C-QWIP detector models for the ROIC design effort, and detector arrays for possible phase II effort.

PHASE II: Using results of Phase I, design, develop and fabricate 2K x 2K ROICs. To demonstrate performance of ROICs, the offeror will hybridize ROICs to C-QWIP detector arrays provided by the SBIR technical point of contact at no cost to the contract and evaluate performance of FPAs through lab characterization. Develop and fabricate camera electronics for imaging demonstration. Deliver selected C-QWIP imaging system(s) or camera(s) to the government for independent performance evaluation.

PHASE III: Transition this sensor prototype to mass manufacturable technology. There are several US companies which are producing QWIP FPA cameras. Making the developed ROICs available to these companies will improve their products. Dr. K. K. Choi, an ARL scientist, will be involved at the conclusion of Phase II. He will seek funding from several government sources, such as Night Vision and Electro-optics Directorate (NVESD) and NASA, for further research, development and acquisition. This sensor will be useful in a broad range of military and civilian applications, among other areas, where stand-off remote sensing of toxic chemicals and contaminated environments and substances is required.

KEYWORDS: sensors, readout integrated circuit, electronics, long wave infrared, focal plane array, detector array, imaging

A11-010

TITLE: Inexpensive Scalable Manufacturing Process for Degassing of High-Strength, Nanostructured, Lightweight Composite Powders

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop and demonstrate an inexpensive, high throughput manufacturing process for degassing lightweight, nanostructured composite powders. The manufacturing process must be fast and robust to be integrated into the existing conventional manufacturing processes for aluminum (Al) based composites for structural and survivability applications.

DESCRIPTION: Fabrication of bulk nanostructured materials begins with the production of nanostructured composite powders followed by consolidation into a bulk form. Cryomilling has been extensively used to produce nanostructured powders including Al based high strength lightweight nanostructured composite powders with B4C reinforcement [1,2]. In cryomilling of powders, a process control agent (PCA), e.g. Stearic Acid, is very often used to prevent extensive cold welding between the powder particles and also between the powder particles and milling media. A typical Al-based nanocomposite is produced by cryomilling powders of Al 5083 and boron carbide (6:1 or 5:1 mass ratio) along with 0.2 wt. % stearic acid in a liquid nitrogen slurry in an attritor with a stainless steel vessel and balls with ~0.25" diameter (balls to powder mass ratio is 32:1). Details of the synthesis procedures are given in Reference [3,4] and references herein. Once milling is completed, the PCA has to be removed before consolidation to allow for a clean and strong interfacial bonding between the powder particles during the consolidation into a bulk form [3,4]. The removal process, known as degassing, is done by heating the powders at high temperature under vacuum for 14 hours [3,4] and the whole process starting from loading powders in a degassing can, achieving the desired vacuum level, ramping up the temperature, etc., to the end of the process may take more than 24 hours to degas a couple of pounds of powders in lab scale. For tens of pounds of powders, it may take even longer time to degas. Such long degassing process adds cost to the manufacturing process and is considered a bottleneck for bulk production of lightweight Al based composites.

The focus of the current SBIR is to design, develop, and demonstrate an inexpensive and highly scalable manufacturing system suitable for degassing bulk quantities of Al based nanostructured powders without exposing the powder to very high temperatures and long times so as to retain the original microstructure to the extent possible. The manufacturing system must be scalable to be directly integrated into existing manufacturing processes for bulk nanostructured composites.

PHASE I: Design, build and demonstrate a degassing system and its capability for degassing Al based nanostructured composite powders with no adverse effects on the microstructure of the powder after degassing. Powders obtained by cryomilling Al 5083 and boron carbide (6:1 mass ratio) for 24 hours in liquid nitrogen typically consist of agglomerates approximately 10 vol.% of which have average agglomerate size of less than 10 micron, approximately 38 vol.% have less than 20 micron and approximately 80 vol.% have less than 44 micron. Average grain size of similar cryomilled powders reduces to approximately 35 nm and 25 nm after 4 hours and 8 hours of cryomilling respectively and decreases very little, if at all, upon further cryomilling beyond 8 hours. Longer milling time, 16-24 hours, is required for stabilization of the nanostructure of powders. Demonstrate that the system can be used to degas a minimum 20 lbs of powders in one batch for period of time not exceeding 8 hours. Powders which will be degassed in the Phase I effort should have been cryomilled for 16-24 hours and should have an average grain size of 35 nm or less and after degassing the average grain size of the powders should not exceed 60 nm. After degassing, the hydrogen content in the powders should not be more than 10 ppm by weight. Care should be taken to choose proper PCA for cryomilling such that it does not create any hindrances in consolidation of the degassed powders and no oxidation of powders should take place during the degassing process. Demonstrate that the design is scalable, and the degassing manufacturing system can be integrated into existing conventional manufacturing processes for bulk nanostructured composites.

PHASE II: Scale up the degassing system design, build one prototype system and demonstrate that the system can handle degassing of 200 lbs of powders in one batch for a period of time not exceeding 8 hours. The requirements

regarding the average grain size of the powders before and after degassing, hydrogen content of powders after degassing, proper choice of PCA and avoiding oxidation during degassing are the same as those mentioned in Phase I. Integrate the degassing manufacturing system into existing manufacturing processes for bulk nanostructured composites. Explore the potential for a continuous degassing system.

PHASE III: It is well established that entrapped gas in powder metallurgy alloys in general can lead to formation of blisters which severely affects ductility. Additionally entrapped gases may result in cracking of the compact during thermomechanical processing of powders. Therefore Inexpensive scalable manufacturing process for degassing of powders will be widely applied in powders metallurgy industry in addition to its use in degassing of high-strength, nanostructured, lightweight composite powders for military applications.

Transition the manufacturing technology to civil and military sector applications. The manufacturing technology transition to military applications includes partnerships with major MMC armor plate manufacturers, and/or DoD prime vehicle integrators. Deliverables and technical data packages resulting from this SBIR will support a variety of ATOs, MTOs, and Army PMs and Army PEOs for Army warfighters and vehicle survivability.

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KEYWORDS: Degassing Manufacturing Process, Degassing Manufacturing System, Aluminum based Nanostructured Composites, Process Control Agent, Stearic Acid, Hydrogen Content, Ductility, and Damage Tolerance

A11-011 TITLE: Instrumented Projectiles for Measuring Impact Forces to Characterize Ballistic Behavior of Fabrics and Composites

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The objective is to design, fabricate, experimentally validate and deliver instrumented projectiles to report the dynamic forces imparted to textiles and composite materials subjected to intermediate-speed ballistic impacts.

DESCRIPTION: Modern soft body and military vehicle armor systems consist of various fabrics, composite materials and sandwich structures to achieve high ballistic impact resistance at minimum weights. Understanding the details of dynamic failure processes of these and other material systems and of the penetration mechanics involved in the ballistic impact events would significantly benefit the development of new fabric and composite armor solutions for ballistic protection. An effective real-time measuring technique, such as an instrumented projectile capable of reporting the load-time history encountered during impact, would provide essential information for evaluation and design of fabric and composite configurations common to these armor systems.

Currently, experimental evaluations of textile armor fabric performance for ballistic impact applications lack time dependent load information. Proper characterization of the dynamic response and failure of individual fabric yarns requires the knowledge of the associated dynamic load spectrum imparted by the projectile to the fabric. Therefore, a dynamic load recording projectile detailing the time dependence of interactive impact forces would significantly enhance the understanding of fabric response, which in effect, constitutes the fundamentals of optimization in efficient armor designs.

Measurements of dynamic force [1] during ballistic impact [2] pose great challenges to sensor design, data acquisition and signal processing. Both efficiency and accuracy are of primary concern in the design of instruments for ballistic impact measurements. During these events, forces are very high and impact durations are very short. Large deformation and severe damage can take place not only in the target materials and structures but also in the impacting projectile.

Although the impacting projectile may not be sufficiently rigid, the sensing, acquisition and processing components must have extremely high bandwidth. Since a wide range of ballistic projectiles exists in military applications, the proposed instrumented projectiles should be able to accommodate this variation. A projectile designed with the flexibility to adopt a multitude of various impact tips is desired.

The instrumented projectile should survive at least until the data is properly measured, recorded and transferred. Resolution of the time scale should be sufficient enough to fully capture and record the load profile for experimentally specified impact velocities. Refinement of the proposed device could result in smaller and higher resolution data sets for expanding applicability to various impact scenarios (i.e., hard targets, increased velocities, various gun bore launching, etc.).

PHASE I: Proof of Concept - Develop a design concept to demonstrate the ability to measure the impact load imparted by a projectile, at loads ranging from those of a drop-weight test to an upper load measurement approximating that of a Kolsky Bar test. The maximum diameter of the instrumented projectile should not exceed 1.25 inch. Various impacting nose cones may be employed to provide some degree of flexibility in controlling impact area, cross-sections and conditions. The instrumented projectile shall survive a minimum of 40,000G loading.

Initial designs for the instrumented projectile should be able to capture impact load spectrums in single layer textile target applications. The design should have the potential capability to fulfill the required efficiency and accuracy for measuring and reporting dynamic forces in projectile impacts as a function of time.

PHASE II: Development of Prototype – In the second phase, the objective is to finalize the designs and build prototype instrumented projectiles. Validate the designs by testing the force sensor, data acquisition and signal processing components to assess the performance and applicability of the individual components to multiple layer textile and composite targets. Instrumented components shall then be assembled for final validation against fabric and composite targets. A demonstration of the flexibility in the design of the projectile to simulate impacts approaching the velocities and cross-sectional impact areas of common military small arms projectiles shall be required. A minimum of three projectiles shall be fabricated to demonstrate the capability of measuring the dynamic force for ballistic impacts on targets of thin fabrics (≤ 5 layers), thick fabrics (> 5 layers), thin composites (≤ 0.5 inch) and thick composites (> 0.5 inch).

PHASE III: In addition to military applications, the developed sensors and instrumented devices can be applied to many other civilian applications involving high rate impacts. Some examples are severe weather damage, puncture resistance, police protection, crashworthiness in vehicle designs and characterization of impact properties for applications ranging from composite structures such as lightweight shelters to sporting goods such as helmets.

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KEYWORDS: Instrumented projectile, ballistic impact, dynamic loading, textiles, composites

A11-012 TITLE: Coilable crystalline fiber (CCF) Er-doped eye-safe laser gain medium

TECHNOLOGY AREAS: Sensors, Weapons

OBJECTIVE: High energy lasers with improved eye safety are important for the development of directed energy weapons (DEW) and related applications. One promising class of lasers to achieve this is fiber lasers. The purpose of this program is to develop Coilable Crystalline Fiber (CCF) Er-doped laser gain medium [as opposed to conventional glass-based fibers] for highly power-scalable eye-safe room-temperature or cryogenic laser operation. Technology must be developed with the potential for manufacturability, low operating cost, efficiency, ease of use and with thermal management potential adequate for Directed Energy Weapons.

DESCRIPTION: High power diode-pumped lasers that are capable of multi-kW power operation are of great interest to the Army as an engine for potential weapon against artillery and rockets of all types (C-RAM application). Eye-safer wavelengths are highly desirable for reducing eye damage hazards in urban battlefield environment. As of late, fiber lasers have significant potential for this application, and have much better ruggedness and compactness than the bulk ones - though existing fiber lasers need to be further developed to exhibit much greater optical-to-optical efficiency as well as greater wall-plug efficiency while maintaining close to diffraction limited beam quality. Eye-safe lasers are one of the key elements in current DEW development, and eye-safe fiber lasers are getting more and more attention lately. There has been substantial speculation that fibers, unlike bulk solid-state lasers, are nearly immune to effects associated with heat deposition in the gain medium and that power scaling in fibers is therefore limited only by nonlinear effects. However, realistic analysis of fiber laser power scaling based on previously reported data [1, 2] indicates that heat generation associated with pumping is still sufficiently detrimental that fibers may reach fracture limits before nonlinear scaling limits. Thermal distortions in glass fiber are capable of spoiling beam quality well before that. Recent successes with resonantly pumped Er:YAG bulk solid-state lasers [3, 4] as well as Yb-free, Er-doped fiber lasers [5, 6] point to significant advantages of direct resonant pumping in minimizing detrimental heat deposition. Nevertheless, fiber laser materials with much higher thermal conductivity than that of glass and better spectroscopy than that of rare-earth in glass (e.g. an order of magnitude higher absorption and emission cross-sections), are required for ultimate power scaling to application-sufficient power levels, so that logistically burdensome fiber laser power combining could be avoided. Therefore, thinking toward real (i.e., coilable to a diameter of ~12-13 inches or less, not just "stiff thin rod" type) rare-earth (RE)-doped double-clad fibers made of crystalline laser materials (single-crystalline or low-loss polycrystalline, e.g., ceramic) starts to prevail lately. A few scientific groups (in Taiwan, Japan and USA [7]) are trying to produce RE doped crystalline fibers, but no tangible success has been reported so far. The purpose of this topic is to boost development of cladded poly- or single-crystalline coilable to a diameter of ~12-13 inches or less and polarization-maintaining waveguiding gain medium designs with low scattering and absorption loss, consisting of a single-core or multiple-core large mode area, which will enable the next generation of compact and robust directed energy weapons. Fiber designs sought in this solicitation are not limited to "conventional" circular geometry.

PHASE I: The focus at this technical feasibility stage is expected to be the design and demonstration of proof-of-concept flexible (coilable!) low-loss ceramic- or single-crystalline fiber or fiber-like (waveguiding) CCF configurations fabricated by a process that is scalable for producing laser components for directed energy weapon-class laser during a follow-on Phase II project. Concepts for pumping the laser medium with diode bar arrays should be explored. Phase I deliverables are to include single-mode (SM) flexible/coilable Er-doped (0.25-0.5%) structures, with the length not less than ~200 mm, suitable for demonstrating CCF laser performance advantages for high efficiency resonant pumping and allow for baseline thermal management capability estimates. Typical lateral core dimension of 5-6 μm and numerical aperture (NA) not to exceed 0.12 is expected in Phase-I. A best-effort device with performance goals listed above and demonstrated bendability corresponding to a diameter of ~12-13 inches or less shall be provided to the Army Research Laboratory for comprehensive testing and scalability evaluation.

PHASE II: Building on manufacturing and design developments of Phase I, advanced crystalline flexible/coilable structures useful for initial high-power (at least 1 kW) lasing demonstrations, with the length not less than ~1.5 m, shall be produced by a process that is scalable to designs for multi-kilowatt operation. A full characterization of optical and mechanical properties of developed CCFs should include scattering and absorption losses and refractive index evaluations critical for the fiber core/cladding design. Design, fabrication and testing of special pump couplers intended for acceptance of high power from diode bar stacks and/or other large pump module formats have to be a mandatory part of Phase-II development. Close cooperation with the Army Research Laboratory's laser testing facility for establishing critical manufacturing, design and lasing parameters is essential for a successful transition to rugged crystalline flexible/coilable lasing media resonantly pumped with 1530 nm diode bar arrays. The scaled-up single or multiple core lasing media (LMA-sized core with NA not to exceed 0.1 is expected in Phase-II) will be further characterized for optical, mechanical and thermal properties to provide a data base for eye-

safer laser weapons development. The deliverables, no less than three devices coilable onto a spool diameter of ~12-13 inches or less, with specifications listed above are to be delivered for testing at the Army Research Laboratory.

PHASE III: Coilable crystalline fiber (CCF) Er-doped eye-safe laser gain media resonantly pumped with stacked laser diode arrays and/or other large pump module formats at 1530-1535 nm will result in higher eye-safe overall efficiency, reduction in weight/size, will provide much higher DEW design flexibility and improved ruggedness. Both military and commercial applications are in equal need of efficient high power lasers that demand an intrinsically much reduced concern about harmful stray radiation. The military has a strong interest in incorporating advanced eye-safe HEL's based on the resonant, low-photon-defect, diode-pumped operation of crystalline Er³⁺-doped gain media into directed energy weapon systems. Department of Defense organizations with interest in such lasers include the Army Space and Missile Defense Command, Missile Defense Agency and the High Energy Lasers Joint Technology Office. Current specific tasks would include laser-based remote mine clearing and counter-RAM (rockets, artillery, mortars) applications. Another important area of application is the use of the developed laser technology for pumping tunable mid-IR OPOs for infrared countermeasures and atmosphere pollutant monitoring. Further commercial applications that would benefit from this technology's high beam quality and power include longer-working-distance laser welding and cutting, such as in the automotive industry, and higher power densities for endoscopic surgery.

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KEYWORDS: fiber laser, eye-safe, rare-earth doped, single-crystalline, laser ceramics, laser diode pumping.

A11-013 TITLE: Carbon nanotube (CNT)/graphene based supercapacitors

TECHNOLOGY AREAS: Ground/Sea Vehicles, Materials/Processes, Electronics

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: Proposals are sought to develop carbon nanotubes (CNT)/graphene supercapacitors that exceed the specific energy and power of state-of-the-art activated carbon (AC) supercapacitors. The SBIR will focus on developing capacitors based on CNTs or graphene that enable new applications based on their superior electrical performance or novel form factors. A cost effective manufacturing approach compatible with standard coating processes is desired but other novel techniques/approaches will also be considered. The manufacturing approach should be compatible with a wide range of substrates/current collectors to enable the fabrication of flexible or conformal supercapacitors that could be integrated into micro- or man-portable systems. It is expected that these requirements will result in a solution based process, although other approaches will be considered, so that developments in CNT/graphene solutions and their processing to form supercapacitors are encouraged.

DESCRIPTION: The Army has wide ranging needs for portable power. Currently, each soldier carries a significant weight of batteries to power their equipment. In addition, demanding new mobile/portable power/energy storage and handling requirements are emerging as new technology is developed including micro-autonomous robots, distributed sensors, and other devices that have extended mission times or other constraints. It appears that CNT/Graphene based supercapacitors have valuable contributions to make in these areas.

Supercapacitors have stable performance: ~ 10 x higher specific powers than batteries, millions of charge/discharge cycles, rapid charge and discharge times, high efficiencies (98%), and they perform well at extreme temperatures. Such properties mean they will be useful by themselves or as part of a hybrid system where the supercapacitor is coupled with a battery/fuel cell/or power harvester to use their superior energy capacity while having the benefit of the supercapacitor for burst power.

Supercapacitors owe their high capacitance to high electrode surface areas. AC consists of porous particles of carbon having high surface areas as measured by nitrogen adsorption. However, not all of the surface area inside of the pores is in fact accessible to the electrolyte and therefore it does not contribute to capacitance. Single wall carbon nanotubes (SWCNTs) and graphene, which is a monolayer of graphite, potentially have extremely high surface areas since all of their atoms are surface atoms. If one can generate this surface area by debundling the tubes or deaggregating the sheets in solution and then preserve the accessibility of this surface area to the electrolyte in the fabricated electrode, then supercapacitors with significantly improved capacitance and therefore energy density should be realizable. CNTs/graphene have good carrier mobilities so that electrodes with good conductivity and therefore good power capabilities should result, as well. In addition, CNTs/graphene have large aspect ratios and mechanical properties that lend themselves to the fabrication of flexible/conformal electrodes which will foster their integration into systems which have unique volume or weight requirements.

While the technology is expected to be scalable to different power regimes, it is expected that initial demonstrations will focus on soldier power (<50W) applications where aspects such as flexibility, printability, etc. will provide additional impact. Approaches significantly reducing the cost of CNT/graphene supercapacitors and which enable larger scale devices will be given extra consideration.

PHASE I: During Phase I, the program shall develop processes and process flows and demonstrate initial unpackaged prototype CNT/graphene based electrodes with superior electrical and/or mechanical (e.g. flexible/conformal) performance as compared to AC supercapacitors. Target metrics for the electrical performance of the electrodes in a three electrode measurement are to match or exceed current AC supercapacitor performance (e.g. >120 F/g weight of CNTs/graphene only). The measured capacitances shall exclude contributions from any pseudocapacitances present. Phase I deliverable shall be a final report to include; the individual electrode performance data, a description of the solution/electrode preparation process, and analysis of the scalability of the process(es), and a mutually agreed upon volume(s) of CNT/graphene solution(s) developed.

PHASE II: During Phase II, the program shall complete the final development of the CNT/graphene supercapacitor fabrication process. The Phase II program shall demonstrate packaged supercapacitors and evaluate their energy and power densities (per total packaged mass and volume), equivalent series resistance/time constant and self discharge rates. Packaged supercapacitor metrics include: > 10 F/g, > 15 F/cc, and a time constant of < 5 s. The performance metrics exclude pseudocapacitance although pseudocapacitance contributions may be desirable in the final capacitors. The Phase II deliverables shall include a final report detailing the overall fabrication process, scalability and cost analysis, an analysis of the potential form factors, and a comparison of cost and performance to available commercial AC supercapacitors. In addition, the performer shall deliver twenty (20) supercapacitors or mutually agreeable quantities for evaluation.

PHASE III: Phase III will focus on the manufacturability and reliability of the CNT/graphene supercapacitors. The program shall demonstrate the scalability of the manufacturing and packaging processes developed in phase II. Significant numbers of supercapacitors will be produced and subjected to reliability studies to characterize the electrical and mechanical performance (power density, energy density, life time, self discharge, shelf life, mechanical reliability, etc.). In addition, the performer shall deliver supercapacitors in mutually agreeable quantities for evaluation in Army systems such as power harvesting, sensor power, microrobot power, and hybrid power systems. As electronic technology is ubiquitous, it is expected that supercapacitors meeting Army needs will also have numerous commercial applications such as quick charge portable electronics, and power leveling and lifetime extension for rechargeable battery systems.

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KEYWORDS: Electrochemical double layer capacitor, supercapacitor, graphene, carbon nanotube, CNT, manufacturing process, manufacturing productivity, manufacturing materials, manufacturing equipment, manufacturing systems, manufacturing technology

A11-014 TITLE: Negative Electron Affinity Thermoelectric Devices

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics

ACQUISITION PROGRAM: PEO Intelligence, Electronic Warfare and Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Design and build a thermoelectric cooling device that can be integrated with an infrared imaging sensor, or threat-warning sensor that will outperform commercial COTS thermoelectric (Peltier) cooling modules, and extend that work to demonstrate that mobile electric power can be generated from the thermoelectric device by operating the component in reverse, and to promote dual-use of such device technologies.

DESCRIPTION: Thermoelectric (TE) devices form the heart of Peltier coolers, which have widespread application for Army needs in IR imaging/reconnaissance, driver's vision enhancement, and IR seekers. The operation of TE devices for cooling requires close control of three major heat flows: Joule heat (from electrical resistance), thermally conducted heat, and Peltier cooling (negative heat). The requirement for this SBIR work is derived from the fact that Joule heat and thermally conducted heat counteract the Peltier heat and set fundamental limits on the maximum cooling possible. The goal of this project is to apply negative electron affinity (NEA) technology to TE devices such that the operational device physics is fundamentally changed and thermally conducted heat (penalty) can be eliminated. NEA has much greater promise compared with other known technologies for achieving such high performance gains for TE devices. NEA has been implemented in night-vision goggle technology to successfully extract IR photoelectrons from an IR absorber material across a vacuum gap into a high-gain photoelectron-multiplier to produce a visible image via electron impact phosphor excitation. By integrating NEA technologies within a TE device, a vacuum gap can be integrated within the TE device such that the thermally conducted heat flow can be entirely eliminated. If this approach is successful, the cooling performance of TE coolers can be improved more than 200% because thermally conducted heat is a major parasitic performance penalty to Peltier coolers. Further, performance metrics in comparison to COTS Stirling coolers should be analyzed and spelled out:

1. The NEA cooler can be packaged in a volume of roughly one cubic centimeter versus a Stirling cooler which has a volume of nearly 1000 cubic centimeters,
2. the cost is anticipated to be less than \$1000/unit versus \$10,000/unit cost for a Stirling cooler.
3. Because this innovation is new, a predictive analysis of the maximum cooling performance metric will be a critical part of this work so that the cost/performance trade-off space is determined, and feedback to Army/Government subject-matter experts is available.
4. the service lifetime for the NEA devices should significantly extend beyond that for a Stirling (~10,000 hours MTTF).

PHASE I: Design, analyze and optimize notional device design for proof-of-concept testing. This will involve analyzing heat flows and electrical current flows through the thermoelectric device materials on substrates that can

be activated for negative electron affinity (NEA). Produce a simple predictive analysis of the maximum cooling performance metric to provide perspective on size, cost and cooling performance.

PHASE II: Fabricate a working NEA prototype using state of the art thermoelectric materials and conventional NEA technology and analytically determine the critical function of the NEA device and/or characteristic of operation by showing proof of concept. It is anticipated that TE materials deposited onto GaAs substrates will provide the most straightforward approach. Measure ultimate temperature difference as a function of applied current as the metric for cooling performance and determine optimum characteristics. Integrate working TE cooling devices with simple infrared detectors and show active cooling of the composite structure. Deliver two breadboard lab-demonstration integrated TE cooler/IR detector components to Army for measurements of infrared detector response. Initiate lifetime testing measurements of fabricated TE coolers.

PHASE III: Develop simple tools for manufacturing base for high-volume production. Conduct extended lifetime testing, and perform analysis and testing for ruggedizing requirements for Army service. Develop dual use applications for electrical power generation: by operating the device in reverse, electrical power can be generated from such devices. In Phase III, the dual-use power generating capability will be analyzed and alternative structures to optimize electrical power generation will be developed. Civilian applications for this technology include medical applications in DNA sequencing and spot-cooling for surgery, as well as automotive applications for all-electric temperature control, and all-electric refrigeration such as that for wine cabinets/freezers and portable food and beverage coolers. For civilian power generation, there is application for electrical power generation from waste-heat from automobiles such as the "Efficient Dynamics" technology that will be integrated into select BMW cars over the upcoming next years.

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KEYWORDS: Alternatives to Stirling cryocoolers, Thermoelectric cooler, low-cost, Peltier cooler, Thermoelectric power generation, mobile electrical power, power, energy, recharge batteries

A11-015 TITLE: Direct Sensing of Micro Unmanned Aerial Vehicle Lift

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Better dynamic measurements of lift are needed for small and micro Unmanned Aerial Systems (UAS) that maneuver in a highly cluttered near surface environment.

DESCRIPTION: Insects and quite likely birds are elaborately instrumented for flight. The sensors they use seem to more directly measure lift than conventional airspeed indicators. Lift depends on circulation about the wing, or more directly, upon the integrated Lamb vector over the whole surface (the Lamb vector is the vector cross product of the vorticity and the velocity). The tiny hairs or setae with which insects fliers are equipped may well measure something very similar to the above. In concert with simple neural based closed-loop systems these provide the very precise control over lift that is required for precise maneuver in gusty winds in cluttered environments.

The very small and micro Unmanned Aerial Systems that aim to operate in similar environments will require control with equivalent precision. Biologically inspired measurement of wing circulation or the Lamb vector could potentially provide the sensing and control paradigms needed for more effective implementation of their flight control.

PHASE I: Identify and define the potential of such biologically inspired sensors to more directly sense the critical parameters controlling lift, including total circulation or the integrated Lamb vector.

Design a concept for equipping small and micro Unmanned Aerial Systems with equivalent capability to sense and respond to small scale turbulent motions in the atmosphere.

PHASE II: Develop, test and demonstrate the concept developed in phase I. Such demonstration should include at least wind tunnel testing, but ideally demonstration on an actual small or micro Unmanned Aerial Vehicle.

Phase II deliverables should include a prototype of the conceptual system and a comprehensive report detailing theory, design, and test results for the prototype system.

PHASE III: If successful, the technology developed would be a major step toward construction of small and micro unmanned aerial systems which could penetrate all sorts of environments which are now hidden from conventional sensors. Inconspicuous operation in buildings, dense foliage, caves, air vents and air conditioning systems would provide intelligence at an level of detail, permitting far greater operational precision and major improvements in soldier safety.

The technology is equally applicable to a wide range of civilian operations where inspection or surveillance of restricted spaces is needed in timely fashion. Such operations could include search and rescue in crumpled structures or underground, inspection of equipment on towers or near the tops of tall building, and similar operation.

If the more direct sensing of lift proves possible, it might also prove to be valuable to other aircraft. Stall remains a major cause of air crashes, apparently even for large jet aircraft. Better instrumentation to sense the stall threat or provide closed loop response to a threatened stall might be a valuable safety improvement.

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KEYWORDS: micro, unmanned, aircraft, lift, stall, sensor, biomimetic

A11-016 TITLE: Modular Model Interface for Network Discrete Event Simulation Engines

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: The objective is to develop a modular model interface architecture that enables use of radio models developed for a specific network modeling Discrete Event Simulator (DES) to run on a different DES without modification. Some examples of network modeling Discrete Event Simulators are OPNET, QualNet, and ns-3. Currently, radio models are developed for a specific simulator and are not compatible with other simulators. Running a model on a different simulator requires extensive effort in porting to the new target simulator.

DESCRIPTION: The battlefield environment is a complex mix of radio types. Informed purchasing decisions regarding types and quantities of radios require an understanding of radio performance and interoperability with systems already deployed in these hybrid networks. Battlefield simulations, including high fidelity radio models, can provide sufficient scale to perform the necessary analysis in a more cost-effective approach to field testing.

Radio models are developed for a specific simulator. Significant effort is put into developing and validating the code for these high fidelity models with timeframes often spanning years resulting in a valuable analysis tool. This process works well in an environment where only one radio type needs to be analyzed; however, when a simulation hybrid network is desired, it is common for radio model developers to use incompatible network simulation tools.

A more desirable approach is to have an adapter between the DES and the radio model. The adapter layer would support a plug-in architecture that allows a model developed for one DES to be used by a different DES. The architecture needs to account for existing simulators and also provide a path for developers to write adapters for future simulators.

The desired solution involves the description of a programming model and demonstration of the programming model implementation. Network modeling simulators generally run on Linux and Windows platforms, so the approach should be applicable to either platform.

The potential for commercialization of this technology is substantial. DoD and industry spend significant resources porting radio models, not only for research, but also for analysis and tuning of existing network infrastructures.

PHASE I: Design a programming model to enable use of radio models developed for one Discrete Event Simulator (DES) to be used on another without modification of the radio model code. Develop and demonstrate an approach that will allow an existing 802.11b model to be used on ns-3 plus one of the following network simulation tools: OPNET or QualNet.

Documentation for Phase I shall include a detailed description of the programming model design.

PHASE II: Develop and demonstrate an approach to enable two surrogate radio models of interest to the Army to be shared between ns-3 plus one of the following network simulation tools: OPNET or QualNet. The Army will supply suitable surrogate radio models for this phase.

PHASE III: Develop a complete solution to include three or more surrogate radio models working on the following network modeling simulators: OPNET, QualNet, and ns-3. Continue to improve performance.

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3. The ns-3 Network Simulator; <http://www.nsnam.org/>
4. OPNET Modeler; http://www.opnet.com/solutions/network_rd/
5. Scalable Network Technologies – Qualnet; <http://www.scalable-networks.com/products/qualnet/>

KEYWORDS: Discrete Event Simulation, Radio Models, High Fidelity, Network Modeling

A11-017 TITLE: Integrated Graphical User Interface (GUI) Assessment Suite

TECHNOLOGY AREAS: Information Systems, Human Systems

ACQUISITION PROGRAM: PEO Missiles and Space

OBJECTIVE: Develop an integrated set of tools to assess quantitatively the usability of graphical user interfaces (GUIs) with the goal of improving their design while reducing assessment resource requirements. The tool suite may incorporate non computer-based components but components should be synergistic; reduce time, labor and cost to perform assessments; and improve identification of usability issues and remediation guidance. Benefits of well designed user interfaces include reduced training and manpower resource requirements, greater user acceptance, reduced mental workload, increased processing speed, and reduced risk of error and fratricide.

DESCRIPTION: Many Army and Department of Defense systems incorporate highly interactive, visual computer-based interfaces i.e. graphical user interfaces (GUIs). Application of GUIs includes weapon platform crew station displays, hand held electronic devices, operator control units for semi-autonomous systems, medical device screens, and web-based business enterprise systems. The GUIs are often designed to optimize system functionality, efficiency of software code and information assurance but their usability in terms of intuitiveness, speed of use, clarity, and imposed workload is overlooked until too late in acquisition to make design changes necessary to address deficiencies. Training is then proposed as remediation for usability problems. The lack of timely assessment and evaluation of usability is exacerbated by the increase in rapidly developed systems some of which are fielded with limited human systems integration, qualitative rather than quantitative evaluation, and insufficient user training. Constraints imposed by rapid acquisition are not insurmountable and usability methods can be developed to work within them(1). When limited to assessment of the GUI rather than all of the other user interface aspects of the system (of which the GUI is a part), the usability issues are general enough from which to develop an assessment suite that covers a wide range of GUI types and applications. This has already been demonstrated in the applicability of models of human interaction with GUIs(2).

Current GUI assessment tools and methods require advanced expertise to employ and are for the most part not automated. No single method or technique provides both the qualitative information (e.g., user preferences and misconceptions) and quantitative data (e.g., task performance time and errors) to identify potential problems and perform tradeoff analyses to predict the best redesign solution efficiently. Design standards and guidelines provide a useful first screening technique and are relatively easy to automate but may miss qualitative information and be too inflexible to anticipate new technologies or features. Models and simulations of human performance (e.g., task network models and cognitive models) provide traceable quantitative predictions but are often resource intensive to use even though progress has been made in reducing resource requirements(3). Other usability evaluation techniques such as cognitive walkthroughs and heuristic evaluation produce qualitative information but lack repeatability(4). An integrated suite of tools and methods will capitalize on the strength of each as well as synergy among them. For example, an analyst conducting a heuristic evaluation could observe automatically generated usage traces executing within a GUI. Adding automation to usability evaluation has many potential benefits, including reducing the costs of unautomated methods, aiding in comparisons between alternative designs, and improving consistency in usability evaluation(5). The quantitative aspects of the various methods may lend themselves to integration in analytical predictive models. Advances in predictive modeling of novice GUI users(6,7) may result in synergies with methods that excel at producing qualitative information. Automating more of the methods, standardizing them into a suite and integrating them to leverage data will improve the consistency and efficiency of GUI evaluation leading to a greater number of evaluations including those for rapid development programs.

PHASE I: Develop a framework for integrating GUI evaluation methods, techniques and tools. The framework should address synergy among components of the GUI suite and produce both quantitative and qualitative usability information. Design and develop an initial prototype of a GUI assessment tools suite to assess quantitatively the usability of GUIs while reducing assessment resource requirements. The resource requirements to be reduced include time to evaluate as well as the knowledge, skills and abilities of personnel evaluating a GUI. Improvements in quality of GUI evaluation should be demonstrated E.g. number and type of usability problems identified, capability to address novice and expert users, and specificity of redesign guidance produced. For those components of the GUI evaluation suite that are computer-based, refine concepts for the tools suite by applying the prototype suite to these components.

PHASE II: Develop and demonstrate a functional prototype of the GUI assessment tool suite designed in Phase I. Conduct validation studies of the tool suite showing its ability to aid GUI developers and human systems integrators in identifying GUI usability design issues and lead them to better design alternatives supported by quantitative data. Validation metrics will include time, labor, expertise, and cost to perform assessments as well as the number and quality (e.g. improves usability, implementable in design, clarity of recommended design change) of usability issues and guidance produced. For software based components of the suite, demonstrate capability to run executable code

or access through a web-based application on a personal computer. Demonstrate flexibility in the format in which the concept for the GUI to be evaluated is represented I.e. electronic file formats.

PHASE III: Because graphical user interfaces pervade military and commercial systems, the assessment tool set could be applied to a broad range of government and private sector domains. The GUI tool suite will be of immediate benefit to designers in any industry in which humans interact with computer-based visual interfaces. This includes the automotive, aerospace, maritime, financial and telecommunications industries and is not limited to office automation settings. The touch screens used in Service industry kiosks, airline check in counters, automated teller machines, and call centers are common examples of GUI centered systems. Websites designed to improve the efficiency of business processes would benefit from this technology. Military application includes Government and defense contractors responsible for development of weapon platform crew station displays, hand held electronic devices, operator control units for semi-autonomous systems, medical device screens, and web-based business enterprise systems.

The tools suite would be especially useful for systems developed by programs under the program executive office for enterprise information systems (PEO EIS). The resource efficiency of the integrated tools should interest the test and evaluation community (e.g., the Army Evaluation Center), organizations that perform human systems integrations assessments, and their supporting contractors especially when addressing rapid acquisitions.

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KEYWORDS: graphical user interface, design, enterprise systems, human engineering, workload, usability

A11-018 TITLE: Long Lasting Wide Temperature Range Power Source for Unattended Ground Sensors

TECHNOLOGY AREAS: Ground/Sea Vehicles, Materials/Processes

ACQUISITION PROGRAM: PEO Intelligence, Electronic Warfare and Sensors

OBJECTIVE: Develop a direct liquid fuel based fuel cell system with no precious platinum catalyst. The system should be able to function at the temperature range of -25 to 80 °C, with electricity output at 14 to 18 V and 10 to 500 mA. The system should be designed and constructed to work in either the mode of operation or hibernation as power demand changes and be well adapted to hidden and concealed locations while in operation.

DESCRIPTION: Energy storage and conversion technology is increasingly more important to Army's operations as power need grows. High energy carriers such as liquid fuel, together with efficient fuel reformation processing and fuel cells, may offer a unique possibility to meet this growing power need. However, for applications in the power range of 10 to 20 watts, where JP-8 fuel may not be suitable for direct electricity generation, an alternative energy source such as simple liquid hydrocarbon fuel is needed to fill the gap with a low cost electrochemical device. Direct conversion of chemical energy in the liquid hydrocarbon fuel to electrical energy will be realized if this low cost electrochemical device becomes available. It is well documented that some non-precious metal catalysts perform satisfactorily, to a certain degree, in either H₂-O₂ fuel cells [1], or in direct methanol fuel cells [2], or in alkaline fuel cells [3-4]. The goal of this topic is to develop an alkaline fuel cell system that uses no precious metal such as platinum as the catalyst, and uses ethylene glycol (rather than JP-8 and other liquid fuels) as an alternative fuel for power generation in battlefield situations. In certain applications, the system to be developed should be able to function in hidden and concealed locations.

PHASE I: Demonstrate that suitable catalyst, electrolyte, and other component materials can be used for electrochemical reaction of liquid fuel with laboratory experimental investigation and verification. Document the results and progress in technical reports.

PHASE II: Design, construct, and evaluate a prototype of the complete liquid fuel base alkaline fuel cell system that meets all the technical requirements outlined in this solicitation. Deliver one complete system to the Army.

PHASE III: Successful development of this low cost liquid fuel based fuel cell system will enable flexible power generation at low material cost with high fuel efficiency. This will have impact on some military power applications and will enhance the Army's operational capability and survivability in the battlefield with reduced logistic burdens. The technology is also applicable to commercial power and energy applications with developed renewable energy sources.

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KEYWORDS: alkaline fuel cells, liquid fuel, non-precious metal, catalyst

A11-019 TITLE: Plasmonic Nanosensors for Chemical Warfare Agents

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To develop the fundamental knowledge which is required to build a prototype sensor based on the phenomenon of localized surface plasmon resonance (LSPR) for real-time detection of chemical warfare agents (CWA) at ultralow concentrations.

DESCRIPTION: The U.S. Army has a need for small, portable sensors for the real-time detection of ultralow concentrations of chemical warfare agents. These sensors may be used to support chemical demilitarization efforts and provide for force protection in battlefield environments. Recent developments in the study of LSPR in metallic nanodots have shown a possible path toward greatly improved sensitivity of putative optical sensors based on metal nanoparticle arrays. LSPR, a phenomenon which occurs when light incident on metal nanoparticles induces the conduction electrons to oscillate collectively with a resonant frequency, causes nanoparticles to absorb and scatter

light with an extremely high intensity. Research has shown that when molecules adsorb onto a plasmonic nanoparticle, the local electromagnetic fields around the particle can enhance the Raman scattering by as much as 10¹⁵ for a single molecule. This phenomenon, known as surface-enhanced Raman scattering (SERS), results in a highly specific and sensitive method for molecular identification. The electromagnetic enhancement in SERS results from Raman excitation and emission coupling with the nanoparticle LSPR modes. Because LSPR is tunable by changing the size and shape of the nanoparticle, sensors based on LSPR phenomenon would be ideal candidates for a complementary molecular identification platform with SERS.

The objective of this SBIR effort is to develop fundamental knowledge which is required to allow for the construction of highly sensitive and selective sensors which would be able to detect a specific chemical warfare agent simulant at a vapor-phase concentration equal to or less than 0.0001 mg/m³ in a response time of less than one minute.

PHASE I: Investigate the SERS effect for one CW agent simulant (such as dimethyl methylphosphonate or other commonly accepted simulant) with various sizes and types of metallic quantum dots. This phase of the work should determine the feasibility of the research and should specifically identify the optimum size and type of metal nanodot which will yield maximum SERS signal upon binding of the target analyte. It is expected that an outcome of Phase I will be a quantitative estimate of the detection sensitivity and signal to noise ratio achievable in the laboratory of the SERS signal upon binding of the target analyte to the optimized nanodot.

PHASE II: Develop, test, and demonstrate a prototype sensor under laboratory conditions for a selected chemical agent simulant that can detect the target analyte at a concentration equal to or less than 0.0001 mg/m³ in a response time of less than one minute. Optimize the prototype sensor for selectivity and sensitivity. At the end of Phase II, a technical report detailing the results of all work must be submitted to the SBIR program. The report must highlight successes and failures of the research project and present a plan for transitioning the results to a fieldable CWA sensor.

PHASE III: The results of the laboratory work should be transitioned to allow for the construction of a prototype sensor which can detect a target CWA at a concentration equal to or less than 0.0001 mg/m³ in a response time of less than one minute. Bare nanoparticle surfaces offer limited possibilities for isolating the target analyte from complex matrices. Methods should be developed to prevent non-specific binding of potential interferences while allowing selective binding of the target CWA.

It is anticipated that SERS sensors based on quantum dots will be useful for chemical demilitarization activities and real-time battlefield detection of agent threats. Potential military customers of this technology may include units within the Army (e.g., ECBC, Special Forces, etc.) and DTRA. Outside of the military, the technology could be used by state and local HAZMAT response teams, by the Department of Homeland Security, and by the chemical industry for monitoring of industrial areas for worker protection.

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KEYWORDS: sensor, nanosensor, chemical warfare agent, biological warfare agent, quantum dots, nanoparticle, Raman spectroscopy

A11-020

TITLE: Ultrasound for neuromodulation and control of post-trauma pain

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: To demonstrate the feasibility of safely reducing or eliminating the perception of pain through the use of peripheral nervous system ultrasonic modulation of neurons. The effort should result in development of a prototype system that could be easily used by a medic or other healthcare provider with limited training.

DESCRIPTION: Pain management has been a significant challenge for military healthcare providers throughout the history of human conflict. Recently, innovative approaches for battlefield anesthesia and analgesia, such as regional anesthesia and total intravenous anesthesia (TIVA) and novel drugs or drug mixtures (e.g. Ketamine/propofol) have been welcome additions to the existing armamentarium of opioids and general anesthetics. Ideally, pain control would be complete yet the patient's cognitive and perceptive abilities should be maintained. Additionally, analgesics would exhibit a low abuse potential and not require close monitoring that in turn requires committed personnel to be near the bedside/stretchers. We have been modestly successful in achieving these goals with existing technologies (e.g. regional anesthesia of extremity trauma) but there remain many injuries that may not be amenable to these methods.

Recently, the use of ultrasound as an analgesic tool and neuromodulator has come to our attention as a possible modality for ideal analgesia. It has been known for several decades that tissues and now neurons could be activated or inhibited by sound waves. Recent ultrasound technology has been developed that allows precise delivery of ultrasonic energy through the spine or skull in a manner that could potentially safely be used to modulate neurons. Ultrasound systems are also now sufficiently small to allow use at home or in a field environment by people with minimal medical training. Ultrasound can be utilized for pain management via direct application to injured tissues- this alone is promising-yet it also appears feasible to control pain via direct neural modulation at least in the peripheral nervous system, following the example of regional pharmacological pain blockage. Ultrasound energy is capable of being highly focused on parts of the spinal cord or nerves responsible for perception of pain without necessarily affecting the patient's ability to control the injured part of the body or affect consciousness. Given the emergence of these ultrasound technologies, we wish to challenge industry to develop a safe, easy to use ultrasound based pain management system that can be used with minimal requirement for patient monitoring. Ideally, such a system would be small and simple enough for a medic or a patient to use. Short of a novel, small form-factor independent device, any proposed system should at least be able to be used with existing portable ultrasound systems, requiring only the addition of specialized probes and software.

PHASE I: In phase I the performer should demonstrate the feasibility of safe use of ultrasound technology for the control of pain via US stimulation of peripheral pain generators, their associated nerves, or via the dorsal root ganglia and/or spinal cord (lateral spinothalamic tracts and dorsal root entry zones). Limited in vitro, animal and cadaver or phantom testing shall demonstrate the ability to control pain without damage to neurons, glia or the blood brain barrier. Phantom and/or cadaver testing shall demonstrate that appropriate US energy levels can be delivered through the average human soft tissues and/or spine to the appropriate anatomic targets. The successful proposal will demonstrate that for a pain indication, there is or will be developed evidence supporting 1) the identification of a suitable anatomical target that is involved in the perception or transmission of pain, 2) that ultrasound stimulation parameters required to modulate the target are known (and deliverable), and 3) that stimulation of the target (by whatever means) modulates pain. The performer should evolve through an initial design concept for the hardware and software required for a fieldable system to an alpha prototype system by the end of phase I. The performer will provide a device development and testing plan for phase II, to include drafts of research protocols required for animal and possible human testing. The performer will also provide a regulatory compliance plan and commercialization plan for this addressing both the military and civilian markets.

PHASE II: In phase II the performer will test and characterize the prototype system based upon plans from and lessons learned in phase I. The prototype system will be characterized for its ability to safely control pain for extended periods (hours to days) and will be further characterized to determine whether after a given amount of treatment time/intensity the subject/patient can be removed from active therapy and have residual benefit. Phase II shall conclude with the presentation of a refined Beta-prototype system and system characterization data to military subject matter experts. The performer will also have begun to address regulatory requirements such as Good Laboratory and Good Manufacturing Practices based upon successful progress in Phase II. The performer will present plans for meeting FDA requirements that would allow for transfer of this technology to clinical use.

PHASE III: The prototype developed in Phase II will be further evaluated and enhanced in Phase III for transition into a viable product for sale to the military and private sector markets. A plan including how FDA approval will be achieved, utilizing current Good Manufacturing Practices (cGMP), Quality Management and device applications will be completed and executed. A successful system will be one that can be safely utilized by at least a minimally trained healthcare provider at the level of medic and above and at least at echelon II (Forward Surgical Team) or above. A successful system will be moved into the advanced development pathway through the Combat Casualty Care Research Program and/or the Clinical and Rehabilitative Medicine Research Program of the U.S. Army Medical Research and Materiel Command (USAMRMC). Appropriate acquisition authorities within USAMRMC will be engaged should a successful solution result.

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KEYWORDS: Pain, peripheral analgesia, neuromodulation, ultrasound, pain control

A11-021 TITLE: UV-enhanced Raman sensors with high SNR and spectral selectivity

TECHNOLOGY AREAS: Sensors, Electronics

OBJECTIVE: Utilize advancements in UV LEDs, spectrometers, and photonic integration to miniaturize advanced Raman spectroscopy techniques for handheld sensors.

DESCRIPTION: Raman spectroscopy is an important tool for a vast array of chemical and biomolecule detection and identification. Current systems generally utilize red laser diodes to produce Raman spectra that are enhanced via surface effects known as SERS (Surface Enhanced Raman Scattering) spectroscopy. Background emission,

particularly through luminescence of the desired moiety or other particles, as well as Raman signals from non-desired moieties, degrade signal-to-noise (SNR) ratios and make it difficult to discern the desired Raman peaks. Adding a secondary light source in the UV-C range (240-285nm) and tuning the wavelength across a certain range can enhance detectivity of a given species [1,2]. Spectral resolution and SNR can be improved through additional resonances affected from UV excitation. Advancements in UV LED technology in the past 12 months make the development of reliable handheld systems possible which can compete with much larger and expensive systems based on UV lasers (<250 nm). Water and air monitoring for bacteria, bio-warfare agents, and chemical species can be enhanced through means such as these. Nanophotonics and silicon photonics can also be used for microfluidic channel integration with electronic circuitry, photodetectors, and spectrometers to make handheld, low-power sensors. Detection and identification of biomolecules and chemical can be made possible with incorporation of SERS nanoparticles in the sensor region [5,6] in addition to the aforesaid method.

PHASE I: Develop a UV-enhanced Raman spectroscopy system which demonstrates improved SNR and spectral resolution. Demonstrate signal-to-noise (SNR) enhancements of $1e5$ and spectral resolution of $1e2$, from standard Raman spectroscopy (enabling $1e5$ factor decrease in sample concentration and $1e2$ times improvement in distinguishability from adjacent Raman peaks). Analysis of compact system performance and design for phase II implementation including cost, performance, and compatibility with existing miniature systems. UV LEDs are particularly desired for use in the design in conjunction with miniature spectrometers. Such integration and packaging designs should be laid out and specified. Portable, rugged and flexible designs are sought.

PHASE II: Develop a miniaturized system based on the results of phase I. Use of state-of-the-art UV LEDs and other miniature photonics should be considered (without sacrificing sensor performance for a given application). Particularly, AlGaIn LEDs incorporated with tunable cavities and miniature or integrated spectrometers with microfluidic or other gas-flow channels. Laser diodes should also be used for excitation of the emission as opposed to larger HeNe or other lasers.

PHASE III: To move the laboratory breadboard design into relevant environment testing and prototype development. Manufacturable systems design should be considered as well as optimization of LED wavelengths and photonic cavities for water monitoring or biothreat detectors.

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KEYWORDS: UV-enhanced Raman spectroscopy, surface enhanced Raman scattering, microfluidics, miniature spectrometers, biomolecule sensors, chemical sensors

A11-022 TITLE: Direct Ethanol Fuel Cell

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: Develop a direct ethanol fuel cell system that is capable of converting ethanol fuel into electricity in an efficient, small, lightweight, portable power system.

DESCRIPTION: Ethanol has a 33% higher energy density than methanol, the current fuel being evaluated for small soldier power systems (8000 vs. 6000 Wh/kg). Direct ethanol fuel cells have recently been receiving increased attention in the literature however, previous studies in acidic media have demonstrated only 2 or 4 electrons generated per ethanol molecule rather than the 12 that are possible when ethanol is fully oxidized resulting in poor system efficiencies. The recent development alkaline membranes that conduct hydroxyl ions (OH⁻) makes alkaline membrane fuel cells very attractive largely due to more facile kinetics for both the fuel oxidation and oxygen reduction reactions. The rapid kinetics makes the use of catalysts with lower noble metal contents feasible and potentially enable the cleavage of carbon carbon bonds at low temperatures. Use of ethanol as a fuel in alkaline membrane fuel cells has the potential to significantly increase the fuel utilization and fuel cell performance, lower the cost and improve safety.

PHASE I: In phase I preliminary results from a stack showing complete oxidation of ethanol to produce electrical energy at low temperature will be demonstrated. These results should support the potential to develop a 40W system which can operate at a power density over 150 mW/cm², and system energy density over 1000 Wh/kg.

PHASE II: In phase II, based on the results from the successful phase I program, two 40W direct ethanol fuel cell systems with power densities over 150 mW/cm², and system energy densities over 1000 Wh/kg will be developed and delivered to the US Army for testing and evaluation.

PHASE III: Advanced alkaline direct ethanol fuel cell technology will significantly impact both military and commercial applications, accelerating product development, particularly for lightweight low power devices. Because the market and the number of devices in the commercial sector is much larger than the military market, widespread usage of this technology will drive down the cost of devices for the military and ensure a reliable manufacturing base. The alkaline membrane technology and optimized catalysts will transition into fuel cell system technology for dismounted soldiers. Likely sources of funding if the phase III program is successful include PEO Soldier and CERDEC.

Applications for the advanced direct ethanol fuel cell system include soldier power to complement batteries and to charge lithium-ion rechargeable batteries, significantly reducing the logistical burden (weight and volume) for the soldier by reducing the number of batteries required for extended mission time as well as a myriad of civilian electronics applications.

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KEYWORDS: fuel cell, alkaline membrane, alcohol, ethanol

A11-023 **TITLE:** Advanced Multi-Fueled 300 W 28VDC Thermoelectric Power System

TECHNOLOGY AREAS: Ground/Sea Vehicles, Materials/Processes

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: To design, develop, and demonstrate an advanced multi-fueled, 300 Watt, 28 VDC continuous output Thermoelectric power system which takes advantage of recent advances in band gap engineered nanostructured thermoelectric materials and multi fuel (liquid and gaseous) burner designs. The goal is to realize a logistically compatible, alternative power technology solution for silent direct power and battery charging applications in the forward area of the tactical battlefield.

DESCRIPTION: Silent, man portable, logistic fuel compatible power sources that can fill the power gap in the less than 500 Watt range are needed to support key capabilities within the C4ISR requirements such as communication, computers, surveillance, and reconnaissance and to enable quiet battery recharge stations. Recent breakthroughs in nano-enhanced thermoelectric materials with a thermoelectric figure-of-merit, ZT, of > 2; multi-fuel burners capable of burning both gaseous (propane) and liquid (JP-8/DF-2) fuels; advanced power electronic designs; and advanced materials for thermal management have the potential to form the basis for a highly power dense, fuel flexible, quiet alternative power system that is man portable and compatible for operation in extreme tactical environments. New nano-enhanced materials, advanced burners, and control techniques are regarded as critical building blocks for future tactical power systems and are poised to radically transform and enable numerous current and future tactical battlefield applications.

The Army seeks to design, develop and demonstrate a lightweight, quiet, multi-fueled, thermoelectric power system capable of providing 300 Watt, 28 VDC continuous output. This design shall consider the use of emerging nano-enhanced technologies that have potential to augment system performance and the use of new manufacturing techniques with potential to reduce O&S costs. Technological advances to be considered shall include high performing thermoelectric materials and nano-enhanced thin-film/bulk materials, advanced control techniques, thermal management techniques (micro-channel heat sinks), and multi-fuel burner techniques (i.e. atomization combustion, evaporative combustion or other fuel combustion technique) that improve component conversion efficiencies, system efficiency (fuel energy to power out) and power density. Technology selected shall enable full system operation in extreme tactical environments.

The operational and performance goals for a 300 W, 28 VDC thermoelectric power source shall include:

- Weight - (< 22 lbs or 10 kg (dry)
- System should be capable of being stored in a rucksack
- Noise - (less than 50 dBA at 7 m)
- Multi-fuel - Propane, JP-8, DF-2
- Fuel Consumption - 24 kg of JP-8 for 72 hour, 300 Watt Mission or better
- Voltage - 28 VDC connection using 13 pin NATO connector (acceptable voltage range from 21 to 30 VDC)
- TEG conversion Efficiency (thermal to electrical) - 15 - 18 %
- System Efficiency (Fuel to Electric) - 10 - 12%

PHASE I: The contract shall explore/identify/specify existing and future thermoelectric generator power system technologies which include but not limited to thermoelectric materials (converter modules), multi-fuel burner designs, thermal management approaches and power electronics, that can be applied to improve the efficiency, power density and environmental performance of the power system. The contractor shall develop a conceptual system design per the above. The design should include the following elements:

- a. Narrative and graphical depiction of the design
- b. Projected physical attributes (size, weight)
- c. Projected performance metrics (fuel consumption, power output, etc.)

A decision model of selected components and subsystem designs shall be constructed with weighted values for performance & operational/logistics parameters. Weighting factors shall be assigned to each parameter by the contractor and justification for these weights shall be provided. It shall also be possible to easily change weighting factors to study the effects on the overall utility of the design.

Using a decision model, or another suitable approach, the contractor shall propose an optimal combination of critical power components for development in Phase II and integration into an operational thermoelectric power system capable of providing continuous output power and operating on multi- fuels. Component / Subsystem designs shall consider integration issues. The integration of components into a system shall result in a system that is electrically and environmentally compatible with tactical applications

PHASE II: Using the Phase I design, the contractor shall develop and fabricate a proof of concept 300 Watt 28 VDC Thermoelectric Power System. The contractor shall validate electrical performance prior to delivery. The proof of concept system must be demonstrated to have the ability to start and operate on multiple fuels and provide full continuous output of 300 Watt at 28 VDC.

PHASE III: Commercial migration of the Phase II Design: the contractor shall finalize the development of the 300 Watt thermoelectric power system. Identify target markets for applications and industry partners for production to minimize cost.

Develop partnerships with Army Project/Program Offices to enable opportunities for fielding to support future forward area soldier and tactical platforms. The results from the Phase II effort will afford the contractor the capability to provide US Army and the DoD a new advanced state-of-the-art 300 W thermoelectric power system. The resulting system can be transitioned to Increment 2 of the Ground Soldier System (GSS) acquisition program, executed by the Project Manager Soldier Warrior (PM SWAR) and various military platforms.

REFERENCES:

1. Pamphlet 525-66, Military Operations - Force Operating Capabilities
2. Army Regulation 70-38, Research, Development, Test And Evaluation Of Material For Extreme Climatic Conditions

KEYWORDS: Thermoelectric Generator (TEG), Power Electronics Multi-Fuel, Thermoelectric Generator Converter Module

A11-024 TITLE: Safe High Rate and Ultra High Capacity with Minimum 4.0 Amp. hour 18650 lithium ion rechargeable cell

TECHNOLOGY AREAS: Ground/Sea Vehicles, Materials/Processes

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: To develop an ultra high capacity and safe 18650 lithium ion cell with 4 Ah minimum capacities that in turn will increase the BB-2590 battery to 12 Ah capacity. It will by far exceed the performance of the current primary lithium battery BA-5590 at 7 Ah and current rechargeable lithium ion battery BB-2590/U at 6.8Ah.

DESCRIPTION: Today the Land Warrior uses the commercial lithium ion cell with specific density of 170 Wh/Kg. With this program, Army is now looking for much higher energy density than the rechargeable lithium ion cell can provide greater than 300WH/Kg. Achieving this goal will provide for a much lighter package for the battery. This technology will provide a base technology for the next ATO in FY 2011 for hybrid primary battery and rechargeable battery system. The proposed battery will provide 66% improvement of energy density over the current commercial lithium cell. This proposed battery will allow a Soldier to have a much longer mission run time and reduce the frequency of changing the batteries.

Using the 300WH/kg cell as a power source, will require fewer batteries to be carried to the field and therefore reduce the overall weight. Since the battery can be recharged quickly, it can be reduced to a smaller size battery and thereby reduce the weight and volume of the battery. This will allow less primary battery to be used and reduce overall weight for the Soldier as well. This battery can help to meet the 400WH/Kg for 72 hours.

PHASE I: Research, identify, and build the high energy material for 4 Ah 18650 lithium ion rechargeable cell for Land Warrior/Ground Soldier System battery application (which consisted of at least 16 each 18650 cells connected 4 in series and 4 in parallel or BB-2590 battery with 8 series and 3 in parallel). The cell shall be able to recharge at least 100 cycles at rate of C/3 charge and discharge at rate of C/2 to 2.5 volts cutoff. It should demonstrate at least 300 Wh/kg at 18650 cell level. It shall deliver at least 3 each cells for evaluation.

PHASE II: Fabricate at least 50 or more each 18650 cell using the high energy electrodes for demonstration of the energy density, safety aspects and cycle life capability. Develop the battery pack either in Land Warrior battery Li-145 or BB-2590 Army standard battery configuration for delivering at least 10 batteries to CERDEC for evaluation.

PHASE III: There are many applications that will be able to use these high energy density batteries. This technology has potential of being quickly adapted to army standard batteries as such BB-2590/U, BB-2557 etc. and commercial

cell phone and laptop batteries, military robot, or the NLOS application for high rate as well as at low temperature environment on the military side.

REFERENCES:

1. J. Fan et al 11th Electrochemical Symposium." Superior High Energy Density and High Rate Rechargeable Lithium ion Battery for Army Applications", 14 July 2009
2. F.B. Tudron, U. et al 2004 Proceedings of the 41st Power Sources Conference on Secondary Lithium Batteries/ Lithium-ion Batteries Session 20.4, pg 337, title: Development of a 300WH/Kg solid-state rechargeable lithium battery.

KEYWORDS: lithium ion, 18650, rechargeable battery

A11-025 TITLE: Laser Beam Delivery Sub-System for Multi-Band Mid-Infrared Laser

TECHNOLOGY AREAS: Sensors, Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To develop an efficient midwave infrared laser beam delivery sub-system for infrared countermeasure systems.

DESCRIPTION: Midwave infrared lasers are of high importance to the U. S. military for multiple applications including infrared countermeasures, free space optical communications, and imaging laser radar. To provide increased capability in these areas, the Department of Defense has made significant investment in high power midwave infrared laser sources. The objective of this SBIR is to leverage the advancing laser technology for infrared countermeasure systems (IRCM) by developing a corresponding high efficiency beam delivery system. The development of a more efficient beam delivery system will allow higher intensity jam signals from current and future high power midwave infrared lasers to be delivered onto target IR threats. This will lead to improved performance of future IRCM systems including higher probability of defeating IR threat missiles. The focus of the proposed work will be to develop beam delivery techniques that can increase system efficiency without sacrificing reliability. Technical challenges will include developing a beam delivery system that is light weight (= 5 lbs), low power, and high efficiency in order to maximize IRCM effectiveness while minimizing the footprint of the equipment on the aircraft.

PHASE I: Design a new beam delivery system for mid-infrared laser with potential improvements in output power and efficiency. The system should be able to withstand high laser peak power in the pulsed mode or high overall energy in the continuous wave mode. It should have minimal loss, which means it should be capable of transmitting as much of the energy launched into it as possible. The transmitted beam shape should be as close as possible to a smooth Gaussian beam which would typically be launched into it. Since there is more than one wavelength to be covered, it should be able to transmit a broad range of wavelengths. The fabrication cost of the system should be low. Develop an initial system design and provide a performance assessment of the design against the above stated requirements. The phase I deliverable will be a final report including the initial system design and performance assessment.

PHASE II: Develop a laser beam delivery system that can transmit high beam quality characterized by a beam propagation factor of less than 1 in multi-kilowatt power from 2 to 5 micron and with an efficiency greater than 95%. The key factors for this system are reliability, reproducibility, cost, and transmission characteristics. Build and test the beam delivery system with an existing laser system in a laboratory. Evaluate key elements of the system in a laboratory environment. Required Phase II deliverables will include a prototype, test in a laboratory environment, and a final report.

PHASE III: Commercialize mid-infrared beam delivery system and develop full manufacturing process working with system integrators for various wavelengths and packages to meet military needs. The technology developed under this effort will be transitioned for military application. Production should allow a repeatable and reliable performance under various conditions. Civilian use applications include free-space optical communications and biohazard monitoring.

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1. Jennifer Gibson, Bradley Duncan, Philip Bosb, Vassa sergan, Proc. SPIE, 4723, 100 (2002).
2. Vansuch G., "IRCM Requirements for Mid-Infrared Semiconductor Lasers", AFRL/DELS, Workshop on 6.1Å III-V Semiconductors, Naval Research Lab, 24-26 August 1998.
3. Woods, R.M., The Power-and Energy-Handling Capabilities of Optical Materials, Components and Systems, SPIE Press, 1 (2003).

KEYWORDS: mid-infrared lasers, beam delivery, diffraction-limited, mode shape, single mode, infrared countermeasures, chemical sensing, free-space communications

A11-026 TITLE: Toolset for Maintaining Data Integrity in Vast Amounts of Data

TECHNOLOGY AREAS: Information Systems, Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop techniques and tools based on formal logic to detect, manage, and correct data integrity within vast amounts of data.

DESCRIPTION: Develop a practical and robust set of software tools operating within very large data sources for the effective removal of strictly logical inconsistencies including duplications, false implications, and other logical information relations. If information is removed from the data sources as a result of a detected inconsistency, the toolset will additionally provide for any adjustment or recovery of the data sources to a consistent state, if necessary.

The proposed toolset seeks to minimize strictly logical data integrity issues within very large data bases, derived from various sensor and INTEL sources. Growing digitization of modern military systems including the Cloud & Distributed Common Ground System - Army (DCGS-A) utilizes these huge military databases containing uncertain, inconsistent, incomplete, deceptive and/or missing information (sometimes called the "digital fog of war"). There are currently few reliable consistency and other logical checks on non-imagery information in existing Army tactical databases. The potential inconsistencies and deception in databases complicate military analyst's Situation Assessment (SA) tasks & functions (Level 2+ fusion), and trustworthy processing results for INTEL analysts and other intelligence system users may be difficult to obtain in realistic situations. This effort will focus only on the inconsistency issue with military databases.

Furthermore, when large amounts of additional data is continuously being ingested, analyzed, refined, and enriched, this results in data stores that grow larger and larger, and the data integrity problem will only compound. Problems caused by this "bad" information in the huge data bases in the operational use phases may make reliable analysis of these systems difficult at best. Ensuring data integrity at the start of any intelligence cycle is thus critical to current and future military intelligence operations. The goal of this SBIR will be to develop simple techniques and tools based on formal logic to detect, manage, and correct data integrity within these vast amounts of data.

PHASE I: Phase I is a feasibility study of a toolset which removes several logical inconsistencies by simple and reliable formal methods. The toolset will be conceived to operate on a reasonably large contractor-provided data set, with justification for successful operation on much larger and more realistic data sets anticipated in Phases II & III. The software design plan will leverage COTS products to the maximum extent possible. During phase I, an

implementation plan of the inconsistency removal toolset will be completed, with details for data recovery. A final report detailing implementation plan of the toolset, logical inconsistency removal techniques, and data recovery methodology with justifications will be delivered to the government. The final report will also define a set of metrics for the effectiveness of the inconsistency removal and data recovery, for use in Phase II.

PHASE II: In Phase II, a prototype of the inconsistency removal and recovery toolset will be developed. Emphasis will be placed on the practical implementation and testing of both the inconsistency removal and the data recovery portion of the toolset. The prototypes should be demonstrated and tested with an existing, contractor-provided large data store. The contractor shall provide a report of the results of the demonstration.

PHASE III: In Phase III we will further mature the inconsistency removal and recovery toolset and demonstrate them within a government based cloud based system, using realistic government provided large data sources. This functionality would enhance the fielded DCGS-A system's knowledge enrichment and management capabilities and thus have direct impact on providing the warfighter with actionable information. This capability could be integrated into the DCGS-A System potentially through the ongoing DCGS-A ACAT 1 Program. This type of functionality could also be applied in commercial markets to help identify anomalies (e.g. outliers) in data and to help manage large data sets. Potential commercial applications include fraud detection, intrusion detection, identity theft, data management, and data protection. Other government agencies and law enforcement could also use these applications in their efforts to investigate and fight criminal activity.

REFERENCES:

1. J. de Kleer, An Assumption-based TMS, Artificial Intelligence, Vol. 28, pp. 127-162, 1986.
2. J. Doyle, Truth Maintenance Systems, Artificial Intelligence, Vol. 12, No. 3, pp. 231-272, 1979.
3. K. D. Forbus, and J. de Kleer, Building Problem Solvers, MIT Press, 1993.

KEYWORDS: Data integrity, Large distributed databases, Data Management, Analytic activity

A11-027 TITLE: Behavioral Discrimination of Moving Targets in Ground Moving Target Indicator (GMTI) Radar

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

ACQUISITION PROGRAM: PEO Intelligence, Electronic Warfare and Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop behavioral discrimination techniques for Ground Moving Target Indicator (GMTI) radar to aid with the identification of patterns hidden within large volumes of GMTI data.

DESCRIPTION: The discrimination of dismounts from fauna and other targets has been a rich area of investigation over the past several years. Almost all of these efforts have directly involved the exploitation of range-doppler signatures as the sole means for classifying moving targets. Some of these techniques rely on high sensitivity, several seconds of persistent stare, and/or little to no relative movement from the air platform. Furthermore, light weight aircraft and unmanned aerial vehicle (UAV) applications are pushing the development of smaller, less power intensive GMTI systems with the performance of their larger counterparts. In order to achieve solid performance at greater ranges, new innovative processing techniques are a must. The goal of this program will be to focus on developing techniques that discriminate moving targets based on the behavior of subsequent observations collected over longer observation intervals and shorter dwell durations.

PHASE I: Feasibility study into the development and performance of behavioral discrimination techniques using only historical and currently unclassified collected GMTI data that the government will supply. The data inputs shall

be in the STANAG 4607 format. The study should include discussions on necessary accuracies of the sensor, required fields/segments from the STANAG 4607 format, as well as effects of length and continuity of available historical data. The final report will address the viability of implementing the behavioral discrimination techniques. All models and results derived from the study will be delivered to the government for testing and evaluation.

PHASE II: Develop the behavioral discrimination techniques algorithm(s) into code. Test and demonstrate using simulated and/or real data that the government will supply. Investigate the performance and potential enhancements.

PHASE III: The completion of this phase would result in a mature technology which would undergo an appropriate operational demonstration, such as surveillance and reconnaissance. The system should prove the ability to discriminate between classes of moving target (i.e. dismounts, fauna, vehicle) over long periods of surveillance. The system would then be applied to commercial security applications in law enforcement, homeland defense, etc.

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(1) Ruan, Y.; Hong, L.; "Feature Aided tracking with GMTI and HRR measurement via mixture density estimation," Control Theory and applications, IEE Proceedings, 9 May 2006 Pages(s): 342-356

(2) Huimin Chen; Yanhua Ruan; "Joint target recognition and tracking using class specific features," Signals, Systems and Computers, 2004. Conference Record the the Thirty-Eighth Asilomar Conference, 7-10 Nov. 2004 Vol. 2 Page(s). 2101-2105

KEYWORDS: GMTI, Sensor, Radar, Discrimination, Target, Dismount

A11-028 TITLE: Asynchronous Network Signal Sensing and Classification Techniques

TECHNOLOGY AREAS: Information Systems, Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop a low-cost sensor network that can perform signal sensing and automatic modulation classification (AMC) of weak signals that normally cannot be detected with traditional single sensor methods.

DESCRIPTION: With the emergence of software-defined radios (SDR) and cognitive radios (CR), hostile communication devices have the capability to transmit in low power, change the transmitting frequency, as well as modify the modulation format on-the-fly. To face this new challenge in a non-cooperative transmission environment (i.e., no handshake between the transmitter and receiver), an RF interceptor must sense and extract weak signals then blindly classify them. The objective of this research is to leverage the new or existing wireless sensor networks to achieve a technological breakthrough in signal sensing and automatic modulation classification (AMC) of weak signals that cannot be detected using traditional single sensor methods. Multiple, low-cost sensors are linked to a master sensor, where data fusion is implemented to artificially boost the signal-to-noise ratio (SNR) of weak signals, as well as eliminate channel distortion.

PHASE I: Algorithm development and proof of concept for both synchronous and asynchronous signal sensing and classification methods will be completed in this phase. The success of the implementation will be demonstrated through theoretical analysis, detailed algorithm descriptions, and software simulation. Technical reports, with relevant equations, software source code with corresponding flowcharts, along with initial test reports and technical analysis will be delivered to the government in a phase I report discussing the viability of implementing the system.

PHASE II: In this phase, improvements will be made to the algorithm, along with trials for distributed signal sensing. Additionally, classification hardware prototypes will be built and a robustness test of the new methods will be presented. The development of real-time software implementing this system will be produced and demonstrated. Relevant technical and test reports will be furnished to the government in a phase II report.

PHASE III: Fine tuning the algorithm and software for reliability and robustness would be completed in this phase. The completion of this phase would result in a mature technology, which would undergo operational tests with real world signal transmission and reception with a fully functional, distributed sensor network. The system would perform automatic modulation classification (AMC) on various weak signals that a traditional single sensor would not be able to classify. A final technical report as well as detailed test results and manuals would be provided for transition to customers.

Potential DoD programs/military applications that could benefit from a completed Phase III implementation of this project include:

- Army: PM Prophet, PM Signals Warfare
- Air Force: KESTREL system from the Air force Research Laboratory's PROFORMA SIGDEV program.

Commercially, this research could be used for analysis of 3G/4G wireless communications (WiMAX, LTE, etc). Cognitive radio (CR) and software defined radio (SDR) applications for commercial settings could benefit as well.

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- (1) W. Su and J. Kosinski, "Framework of Network Centric Signal Sensing for Automatic Modulation Classification," in IEEE ICNSC10, Apr. 2010.
- (2) J. Xu, W. Su, and Zhou, Likelihood function-based modulation classification in bandwidth-constrained sensor networks," in IEEE ICNSC10, Apr. 2010.
- (3) P. Forero, et al., "Distributed Feature-based Modulation Classification Using Wireless Sensor Networks," in MILCOM'08, San Diego, CA, Nov. 2008.

KEYWORDS: automatic modulation classification (AMC), software defined radio (SDR), signal sensing, sensor networks, data fusion, cognitive radio

A11-029 TITLE: Mid-Infrared Laser Beam Combining Module for Infrared Countermeasure Application

TECHNOLOGY AREAS: Sensors, Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To develop highly reliable, low cost and compact mid-infrared diode laser beam combining module for integration into infrared countermeasure systems.

DESCRIPTION: Recent advancements in mid-infrared diode laser technology offer highly efficient room temperature continuous wave operating laser sources. Current mid-infrared single emitters have low output power. Coherent beam combining of several single emitter into a single beam will improve the power. The purpose of this SBIR work will be to develop a highly reliable, lightweight and compact module that combines a large number of mid-infrared diode lasers into a high power output beam. Such high power beams could be used in multiple military applications which include infrared countermeasure systems, free-space optical communications, tracking and surveillance including imaging laser radar, and laser based chemical sensing. The module should be designed to allow a timely manufacturing process that will produce the module in a cost-effective manner and in volume.

PHASE I: Demonstrate a design of beam combining techniques to combine the power from multiple laser elements into a single beam for mid-infrared quantum cascade or another semiconductor laser. Design should show potential improvements in state-of-the-art output power, wall-plug efficiency and wavelength span from around 3 to 5 microns. Designs should be made at one wavelength with potential application to other wavelengths. Establish feasibility of the proposed concept by modeling and bench-top demonstration of key components. The phase I deliverable will be a final report including the initial system design and performance assessment.

PHASE II: Develop room temperature beam combining module for the mid-infrared quantum cascade laser or semiconductor laser with wall-plug efficiency = 20% and with continuous wave power = 20 W with beam divergence of = 4 mrad and beam collinearity of = 250 μ radian for numerous military applications. The size of the beam combining module should be = 18"x12"x4". Required Phase II deliverables will include a prototype, test in a laboratory environment, and a final report.

PHASE III: Commercialize beam combined module of mid infrared laser and develop full manufacturing process working with system integrators for various wavelengths and packages to meet military needs. The technology developed under this effort will be transitioned for military application. The availability of high-power, high efficiency mid-wave infrared diode laser will have potential applications in chemical sensing, LADAR, noninvasive medical diagnostics and free space optical communications.

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(1) R. K. Huang, B. Chann, L. J. Missaggia, J. P. Donnelly, C. H. Harris, G. W. Turner, A. K. Goyal, T. Y. Fan, and A. Sanchez-Rubio. High-brightness wavelength beam combined semiconductor laser diode arrays. IEEE Photonics Technology Letter. 19, 209, 2007.

(2) S. Slivken, Y. Bai, B. Gokden, S. R. Darvish, M. Razeghi. Current Status and Potential of High Power Mid-Infrared Intersubband Lasers. SPIE Proceeding, 7608, 76080B, 2010.

KEYWORDS: mid-infrared lasers, laser arrays, coherent beam combining, mode shape, single mode, infrared countermeasures, chemical sensing, and free-space communications

A11-030 TITLE: Defect Reduction in (112) Si Substrates, Used for HgCdTe Heteroepitaxy

TECHNOLOGY AREAS: Materials/Processes, Electronics

ACQUISITION PROGRAM: PEO Intelligence, Electronic Warfare and Sensors

OBJECTIVE: To improve the crystallinity and lower the defect density and impurity content of (112) Si wafers.

DESCRIPTION: The Army and DoD relies heavily upon HgCdTe-based photovoltaic technology for high-performance, thermal imaging systems. Next-generation systems are envisioned to entail large-format (>1M pixels), infrared focal plane arrays (IRFPA). Large-area growth of HgCdTe for thermal imaging is primarily performed using (112) Si substrates. The lattice mismatch between HgCdTe and Si is ~ 19%, resulting in high dislocation density. (112) Si substrates are a critical component for the heteroepitaxy of CdTe/ZnTe as a buffer layer for the subsequent deposition of HgCdTe. Si substrates have been previously presumed by the infrared community to be nearly defect-free as they are the micro-electronics industry's 'gold standard' semiconductor wafers. The standard crystallographic orientation for the Si microelectronics industry is, however, (100) or (111). Because molecular beam epitaxy (MBE) requires that the HgCdTe epitaxial film have a (112) B orientation to reduce twins and hillock formation, (112) Si wafers are standard for heteroepitaxial II-VI/Si deposition [1]. Commercially available (112) Si wafers have far worse crystallinity and a much higher defect density than the industry standard (100) or (111) oriented Si wafers. X-ray diffraction full width at half maximum (XRD FWHM) values for (112) Si wafers are ~ 20 arc-sec while (100) Si wafers are ~ 9 arc-sec. The defect densities, as revealed by etch pit density (EPD) [2], for (112) Si wafers have been found up to ~ $2 \times 10^3 \text{ cm}^{-2}$. These defects are attributed to Crystal Originated Particles (COPs) due to chemical mechanical polishing (CMP). In CMP the mechanical action of the slurry particles and the polishing pad can combine with the chemical etching process to reveal (or form) defects in the wafer surface [3]. Residual polishing patterns and polishing induced defects have been observed in (112) Si wafers. This indicates that the polishing techniques employed for the (112) orientation are not as successful as current standard (100) and (111) Si wafer polishing. This research effort seeks to improve the polishing techniques for (112) Si wafers to meet or exceed the quality of current (001) and (111) Si surfaces.

PHASE I: Demonstrate improved crystallinity for 3 inch float zone (FZ) grown (112) Si wafers. The (112) Si wafers must be $380 \pm 20 \mu\text{m}$ thick, double side polished, undoped or Phosphorous doped (n-type), and beveled per SEMI standards. This demonstration must also include at least a reduction in XRD FWHM values below 20 arc-sec and defect density (determined by the Yang EPD etch) below $1 \times 10^3 \text{ cm}^{-2}$. The contractor shall deliver at least 20

such improved wafers to the Government, such that the Government can determine probability for Phase II success. An impurity analysis for the delivered (112) Si wafers is also required. In addition a final Phase I report should address, in detail, the following critical aspects: 1. Plans for expanding to 4, 6, and 10 inch improved crystallinity FZ (112) Si wafers. 2. Mitigation of contamination of (112) Si wafers by unwanted impurities.

PHASE II: Demonstrate improved crystallinity for 3, 4, and 6 inch float zone (FZ) grown (112) Si wafers. The (112) Si wafers must be $380 \pm 20 \mu\text{m}$ thick, double side polished, undoped or Phosphorous doped (n-type), and beveled per SEMI standards. This demonstration must also include at least a reduction in XRD FWHM values below 20 arc-sec and defect density (determined by the Yang EPD etch) below $1 \times 10^3 \text{ cm}^{-2}$. The contractor shall deliver at least 100 such improved wafers of each diameter to the Government, such that the Government can determine batch uniformity. In addition a fully documented analysis of impurities from a representative sampling of these Si wafers must be provided.

PHASE III: Successful completion of Phase II, followed by validation of improved crystallinity and reduced impurity content by Government experts, will likely, immediately lead to commercialization of the product. It is conservatively anticipated that up to 100 (112) Si wafers per month would be purchased by domestic IRFPA foundries, university and government laboratories upon completion of Phase II and validation by Government experts. Revenue from wafer sales would maintain the small business. Additionally, the technology developed under Phases I and II, could potentially be applied to other, non-semiconductor standard Si wafer orientations.

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KEYWORDS: (112) silicon, float zone, substrate, HgCdTe, semiconductor, infrared detectors, infrared focal plane arrays, IRFPA, manufacturing process, epitaxy

A11-031 TITLE: Optically Fused Thermal Imaging Module

TECHNOLOGY AREAS: Sensors, Electronics

OBJECTIVE: Identify the most cost effective method of optically performing sensor fusion of thermal long wave infrared and low-light visible-near infrared sensor imagery for the dismounted soldier. The emphasis is a system which makes use of the existing inventory of Night Vision Goggles (NVG) already in the US inventory with a system which matches the current resolution ($>38^\circ$ FOV) and reduces size, weight, and power (SWAP). Presently there is no good way to achieve the field of view required without causing SWAP to increase and performance to decrease. The objective is to solve this optical fusion problem while maintaining system performance.

DESCRIPTION: For the dismounted soldier, the sensor technology gap between US forces and their adversaries has narrowed. In order to regain an overmatch capability, the soldier on the ground must be able to quickly detect potential targets and threats at ranges that exceed the typical image intensifier vision system while still maintaining a high degree of mobility in very low light conditions. The user also needs to maintain situational awareness (SA) in conditions of zero light, smoke, and obscurants which significantly reduce or eliminate the effectiveness of current NVG systems. This new capability can be achieved through the fusion of thermal sensor imagery and passive low-light sensor imagery. The most cost effective approach to increase the SA of the user is the addition of a thermal capability, while at the same time retaining the advantages of the current low light level (LLL) technology. Optical fusion approaches include using a beam splitter or front end optical injection, both of which has drawbacks. The beam splitter causes a loss in range performance and the injection technique causes too much obscuration of the scene. Therefore, the army is seeking an innovative approach to the study and implementation of functional optical fusion techniques for head borne thermal and visible-near infrared sensors which utilizes the current NVG's. A low-cost, low power, and comparable resolution approach to optical overlay compatible with legacy imaging intensifier

hardware would open the door for large scale fielding of multi-spectral vision systems within the US arsenal and in turn could produce better performing components at lower cost.

PHASE I: Identify, evaluate and compare innovative concepts for an optically fused thermal imaging module. The key system parameters to be investigated shall include cost, weight, power consumption, resolution, predicted thermal or combined imager range performance, and imager field(s) of view. Current NVG systems have a Field of View (FOV) of at least 38°, while existing Clip On Thermal Imagers (COTI) have a FOV of less than 22°. The newly solicited ENVG requirement will only increase the FOV of the thermal capability to 28°. The goal of this research is to find innovative new techniques to completely match the current 38° FOV of existing NVG without a major increase in SWAP from existing low cost COTI units. Current existing technologies can increase the required FOV only at a high cost in terms of additional size, weight, power, and cost. Additionally, the engineering research shall address the level of compatibility of the optical overlay concepts with legacy hardware. The impact of the optical overlay concept on the legacy hardware inherent performance shall minimize the loss of contrast, resolution, sensitivity and field of view. It is assumed that the candidate systems will have a resolution of at least 640 x 480 pixels, and a field of view (>38°) that closely matches the current NVG systems, in order to match the optical properties of the current LLL systems.

PHASE II: Fabricate, and deliver at least 5 optical overlay imaging demonstration prototypes based on the results of the Phase I research.

PHASE III DUAL USE APPLICATIONS: Support Government conducted field tests of the optical overlay imaging demonstration prototype. These field tests will be conducted to assess thermal and image intensifier performance parameters at the component and system level. Provide design and engineering analysis of laboratory and field test data in a final report. This technology is applicable to both military and law enforcement organizations. Commercialization of the low cost thermal imaging system will be directly applicable to local police, search and rescue, firefighting and border patrol operations. All of these non-military applications are extremely cost sensitive and will benefit dramatically from a low cost thermal imaging module.

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- 3) Brown, J., and S. Horn, "Microsensor technology: the Army's future force multiplier," Proceedings of SPIE, Infrared Technology and Applications, XXV, Orlando, FL 1999.
- 4) Bigwood, C., L. Eccles, A. Jones, B. Jones, D. Meakein, S. Rickard, and R. Robinson, "Thermal Imager for dismounted infantry", Proceedings of SPIE, Electro-Optical and Infrared Systems: Technology and Applications, Orlando, FL 2004.

KEYWORDS: thermal, sensor, fusion, image intensifier, infra-red, imaging, optical fusion, optical overlay, Clip-On

A11-032 TITLE: Optimization of Active Polarimeters for Real-Time Imaging

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To develop algorithm and SWIR sensor hardware augmentations for active polarimetric imaging for use in real-time, ground-based, detection of roadway threats. Algorithms must provide optimal discrimination of targets via active polarization signatures.

DESCRIPTION: The problem of detecting roadway and roadside targets in cluttered scenes at sufficient distance to give military advantage remains unsolved. This problem is even more pronounced when situated at ground level while on-the-move. Improvised Explosive Devices (IEDs) and hostile vehicles are the more dangerous the closer they are when finally detected. In order to maintain full spectrum dominance, the Army must take advantage of all sensing modalities. Lately, active polarization signatures (which have been useful in aerial reconnaissance) have been suggested as a feature for discriminating roadway and roadside targets on the ground. These signatures can be determined at a distance via a laser polarimeter, which directs multiple polarized beams at the remote object and analyzes its reflective polarization via construction of its Mueller matrix. There are several unsolved problems associated with this approach. First, the target's polarization signature, determined by its 16-element Mueller matrix, requires a large number of measurements. The time required for multiple measurements could be fatal in a hostile environment while on-the-move—thus requiring that detection be possible after minimal measurements utilizing partial Mueller matrices. Second, the signature itself is subject to distortion by noise. Finally, there remains the signature classification problem. Even if the signature is accurately determined, how effectively can it be grouped with signatures of related targets or with signatures of itself under varying conditions (atmosphere, range, pose, time of day, etc.), and how effectively can it be distinguished from background signatures and the signatures of random roadside debris? There is also the complication that targets are not uniform—they could present multiple signatures in various spatial orientations. The variance of target signatures is far more pronounced in ground over aerial sensing. Use of an active polarimeter gives more information than a passive polarimeter in terms of target signature due to control of the light source and analyzer. This makes an active polarimeter system more robust with much better SNR. Thus to be effective in using laser polarimetry in ground surveillance, the Army must develop both algorithms to rapidly and accurately collect active polarization signatures and algorithms to conduct very sophisticated signature clustering and classification. An innovative solution would, in an integrated fashion, reduce the number of initial measurements and the computational complexity of the final classification. In addition, a high level of accuracy must be achieved and maintained. Finally, the algorithms and active polarimeter system approach must be implementable for demonstration and testing purposes.

PHASE I: Develop proof of concept for prototype algorithm to reduce computational complexity of signature classification and greatly increase classification effectiveness (high probability of detection with minimal false alarms) of active polarimeters. Prototype algorithm will optimize Mueller Matrix construction for polarization signature classification through possible elimination of matrix elements. Success at milestone at end of Phase 1 will be to show proof of concept of algorithmic achievement.

PHASE II: Design a device to augment existing laser active sensors and implement detection algorithm. Integrate algorithm into comprehensive algorithm suite. The Government will GFE documentation, including design details, of an existing stabilized gimbal system called Multi-Sensor System (MSS), having a Short-Wave Infrared, Mid-Wave Infrared, color visible sensors and a laser illuminator that may form the basis of the active polarimeter. The MSS will be made available for all phases based on testing results. Based on successful feasibility study, MSS can be used for development. Otherwise system must be based on other commercial SWIR sensor. Success at milestone at end of Phase 2 will be to show algorithmic achievement such that potential Phase 3 algorithmic development demands no major breakthroughs but would be a natural continuation and development of Phase 2 activity.

PHASE III: Complete algorithmic development. Build the active polarimeter. Produce test data set. Complete optimization of algorithms and system using data set. Test completed system on data set. System must achieve 90% detection rate with less than 5% false alarms. Algorithms (along with system software and hardware) will be further tested and demonstrated by the Government on roadway and roadside targets. System will be utilizable in roadside IED detection by Army. Specifically, system will be capable of insertion into EOIR Command Route Wire and IED Detection Program at NVESD. System will also be utilizable in border protection by Department of Homeland Security. In private industry, real-time polarization signature classification will be utilizable for medical diagnosis (especially in optometry) and all forms of substance analysis. System will be of use in mining for the detection of specific mineral deposits.

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KEYWORDS: Polarimetry, Mueller Matrix, Target Detection, Impromptu Explosive Device

A11-033 TITLE: High Quantum Efficiency Ultraviolet Silicon Avalanche Photodiode

TECHNOLOGY AREAS: Sensors, Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: A large area (2-5mm diameter), high multiplication gain ($M=100$), low noise ($k < 0.03$ at 20C) silicon Avalanche Photodiode (APD) with 80% QE in the 350-380nm range is required. The APD's 3dB bandwidth should be >100 MHz at $M=100$ and the reverse bias voltage at $M=100$ should be $<90V$ from -40C to 70C.

DESCRIPTION: Recent advances in diode lasers and LEDs in the 350-380nm range have made possible free-space, medium-range optical communications links in this eye-safe wavelength range in which there is low solar loading. In order to take full advantage of these transmitters, large area, high bandwidth avalanche photodiode (APD) receivers need to be developed with high quantum efficiency in this wavelength range. To the best of our knowledge, the highest quantum efficiency APDs achieved to-date in commercially available devices in the 350-380nm range is 55%. Ideally the APD would have reduced responsivity in the visible and near-infrared regions and a reverse bias voltage of $<90V$ would be required to facilitate the use of extremely compact IC-based APD bias supplies in the APD receiver module.

PHASE I: Fully design and simulate the characteristics of a UV-optimized APD structure with an AR coating at $M=100$ and temperatures from -40C to 70C. In addition to quantum efficiency curves from 350-380nm, the simulations should include predictions of the noise performance, dark current, small- and large-signal transient responses and bandwidth performance for 2mm and 5mm diameter APDs. The company is expected to deliver monthly reports along with simulation code and calculations.

PHASE II: Develop, build and deliver 20 optimized, uncooled large-area APDs in a hermetic transistor-outline package (TO-can) receiver capable of operating between -40C and 70C.

PHASE III: The APD modules should be ruggedized to be compliant with MIL-STD-883H Mechanical Shock, (Method 2002.5, Test Condition D) and MIL-STD-883H Vibration Fatigue (Method 2007.3, Test Condition A). The APD receiver modules should also include an integrated high speed, low-noise transimpedance amplifier in the package. With this on-board transimpedance amplifier, the detector's suitability for UV optical communications systems would be further increased and this APD may also find use in scientific applications, such as laser-induced UV fluorescence, in which an on-board transimpedance amplifier would reduce the total system noise. In such scientific systems, it would also be highly advantageous to insert a thermoelectric cooler (TEC) into the receiver to reduce the dark current to a minimum.

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KEYWORDS: Keywords: UV, ultraviolet, silicon, optical communication, detector, APD, avalanche photodiode

A11-034 TITLE: Long Range, Non-cooperative, Biometric Tagging, Tracking and Location

TECHNOLOGY AREAS: Information Systems, Electronics

ACQUISITION PROGRAM: PEO Intelligence, Electronic Warfare and Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Provide Long Range, non-cooperative, biometric detection, in all weather, on an existing UAV payload. Deliver the ability to tag, track, and locate high value targets in environments from urban to rural where user constant tracking is unlikely.

DESCRIPTION: Enabling technologies include Predictive methods to enhance TTL even when only sporadic data is received and enhanced facial recognition algorithms are required. The enhanced TTL algorithms build off basic research work that is now ready to transition into an SBIR program. That includes work based on Yu and Zhou for UAV tracking video applications. This is valuable to the warfighter since it will enable correct UAV position determination given a lack of highly accurate POS/NAV systems. This work will be supplemented with basic research work in sparse data prediction of tracking object locations, which in turn enables all weather, urban and cave operation for TTL missions. This overcomes a basic limitation in current TTL operations where inclement weather and objects of interest only appearing periodically from sheltered positions or crowds. The long range portion of the biometrics piece will enable stand-off, non-cooperative identification of high value targets. These three enabling technologies will give the warfighter a new, robust capability in the TTL area.

PHASE I: Feasibility study and extension of research area in 1) long range biometrics- the long range biometric capability will be based upon facial recognition techniques utilizing enhanced algorithms that will be able to make high percentage facial identifications with only sparse return information from a long range imaging sensor. 2) Sporadic data array algorithms - the sporadic data array algorithms will be able to fill in data, not received from the imaging sensor, by extending the data received and extrapolating that real data to fill in simulated data as if it was received, and 3) Predictive Location algorithms- this is again an algorithmic technique that will take 'last known location', behavioral methods and/or location tracks, and predict location at a time after the target of interest was not acquired so that a prediction can be made where the target would most likely be so that it can be re-acquired after the interrupted loss of tracking due to weather, target obstruction (i.e. entering a building or cave), or being temporarily out of range of the imaging sensor. The study phase in Phase I will determine the extent of effort, approach, and metrics for Phase II.

PHASE II: Develop the algorithms mentioned above, that utilize sparse or interrupted data and can 1) fill in data by simulation and 2) make a prediction as to the most likely location of the target of interest so that it can be re-acquired. These algorithms will enable the long range, non-cooperative application of biometric (facial recognition) and sporadic position and prediction algorithms into a single operational capability for incorporation onto an Airborne UAV platform.

PHASE III: The completion of this phase would result in a mature technology which would undergo an appropriate demonstration, such as Tagging, Tracking and Locating. The system should prove the ability to track object of high value in any weather and when only appearing momentarily throughout the area of interest. This technology is applicable to the BCT Modernization effort. The transition point is into the Bio-NODE ATO-R that I2WD has for an FY 11 Start and into Homeland Defense operations as well as general high value site protection.

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KEYWORDS: Biometrics, Algorithms, Standoff, Non-Cooperative

A11-035 TITLE: Behavior Recognition in Urban Terrain Using Multi-INT Fusion

TECHNOLOGY AREAS: Information Systems, Electronics

ACQUISITION PROGRAM: PEO Intelligence, Electronic Warfare and Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: The objective of this SBIR is to provide for specific recognition and summarization of human covert adversarial activities, through an analysis of the people of interest that are characterized by multi-source sensor data. Data sources will be limited in this effort to a maximum of HUMINT, COMINT, BIOINT and Social/Cultural.

DESCRIPTION: The ability to identify intent of individuals who may be hostile would significantly improve asymmetric counter-insurgency and peace-keeping operations. Such individuals are generally embedded in extensive "clutter" of neutral and friendly human beings and various physical objects. At present, covert adversarial intention is identified through judgment of soldiers and close-range sensing and searching, which often entail significant danger and possibly high false-positive and false-negative rates. Determining covert adversarial intent will help shift the balance in operations, mission planning, training, and simulation from more costly and dangerous sweeping operations toward much safer pinpoint operations based on refined estimates of people from which danger may come. Currently, there are many collected data sources from sensors (urban terrain, and captured entities), network (raw data), wide-area surveillance imagery, HUMINT reports, COMMS, BIOINT, and MASINT. It is very difficult for any INTEL analyst to infer the whole picture of an event by going through individual information collected from a large number of data sources. In order to have a better picture of the situation, we propose to create a tool with the capability to satisfy this shortcoming, while restricting the data sources to make this effort realizable and lower risk [from REF #1]

Based on the results of the Adversarial Intent Panel study of reference[1], a tool and methodology will be defined and developed which leverages existing fusion technology and capabilities, for example[4], and limited data sources for input. It will provide analysts information about behavior of adversarial activities and aggregated summaries of the individuals of interest.

PHASE I: Establish a plan, investigate and analyze tasks, and conduct a feasibility study that provides a proof of concept for identifying the intent of humans from the fusion of specific data sources, and provide one or more approaches for government evaluation. Predict improved recognition of human covert adversarial activities and provide analysis of an aggregated adversarial intent summary of the individuals from the named data sources. Identify the critical technology issues and risks that must be overcome to achieve a reasonable human adversarial intent tool operation using the existing sources. Develop a modeling & simulation plan, data requirements and recommended approach as part of the final Phase I report.

PHASE II: Develop, prototype, test and demonstrate an implementation of an approach based on Phase I recommendations for human covert adversarial intent detection and summarization. The development approach shall make full use of modeling and simulation, and contractor-provided data based on the data source requirements from phase I. Demonstration of the approach(s) for government evaluation. A report shall document and explain the approach(s), implementation, risks, and results of the overall effort.

PHASE III: The Government will provide realistic data from the specific sources utilized in Phase II. A single recognition approach developed in Phase II shall be upgraded in an incremental fashion, if necessary, with multiple insertions into the Governments systems integration laboratory (SIL) for testing using realistic data for evaluation. The technologies developed under this effort will be transitioned for the US Army under the DCGS-A program. Other military services and the Department of Homeland Security (DHS) shall be considered for transition. Many acquisition programs would benefit immediately from this technology, including Distributed Common Ground System - Army (DCGS-A), CI/HUMINT and many other Intel-analysis tools/programs across the services.

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KEYWORDS: Keywords: sensor, fusion, processing, exploitation, algorithms, natural language processing, Extraction, smart filter, optimization, knowledge extraction, knowledge acquisition, knowledge representation

A11-036 TITLE: Detection, Tracking, and Classification of Dismounts

TECHNOLOGY AREAS: Information Systems, Sensors, Electronics

ACQUISITION PROGRAM: PEO Intelligence, Electronic Warfare and Sensors

OBJECTIVE: To develop algorithms and implement algorithms in software for detection, tracking, and classification of dismounted targets in infrared imagery. Algorithms must be applicable to video sequences.

DESCRIPTION: The problem of detecting dismounts in cluttered scenes is of critical interest to the Army. Urban pedestrians in an occupied city or a group of people walking across a deserted landscape are typically not a military threat, but their threat level cannot be ascertained if they are not noticed. Usually human observers conduct this threat-determining surveillance, but humans are subject to fatigue and manpower is limited. To maintain necessary situational awareness, it is vital to automate the detection process as much as possible. Also, when video imagery is available, it is important to determine the subsequent movements of detections through tracking. And there remains the issue of dismount classification. Even if the detection and track are accurately determined, how effectively can they be grouped with tracked detections of related targets in order to effectively cluster these targets according to threat level? In others words, how can one categorize the almost infinitely variable motions and poses of humans to separate hostile from friendly or indifferent behavior? The problem presents immense computational complexity and is unsolved. All difficulties are additionally compounded when using infrared imagery, as color cues do not exist. An innovative solution would in an integrated fashion first detect targets in multiple-frame infrared imagery, then reliably track targets and efficiently and accurate utilize tracked sequences to classify target threat level. Solutions may involve varying levels of human-in-the-loop involvement in the detection and classification problems (or in any decision area of the proposal), but this level of involvement should be as minimal as viable, and needs to be explicitly and quantifiably defined by the system. Meta-data and contextual inputs to the algorithms are also permitted—with the same restrictions as for human-in-the-loop involvement. The tracking, detection, and classification literature is vast—although true success has been elusive. An innovative solution would avail itself of any combination of techniques while adding to these its own improvements—and also attempt (and justify) new

methodologies. Due to the complexity of the problem, an effective solution may not cover all areas with equal thoroughness.

PHASE I: Show proof of concept for algorithms for detection of dismounted targets in multiple-frame infrared imagery. Show proof of concept for algorithms for accurate long-term tracking of detected targets. Show proof of concept for algorithms to reduce computational complexity of dismount classification and greatly increase classification effectiveness (high probability of detection with minimal false alarms). Integrate algorithms into comprehensive algorithm suite. Test algorithms on existing data.

PHASE II: Complete primary algorithmic development. Complete primary software system implementation of algorithms. Test completed algorithms on government controlled data. System must achieve 95% detection and tracking rate and 90% classification rate with less than 5% false alarms. Software implementation is required for testing and demonstration. However, principle deliverables are the algorithms. Documented algorithms (along with system software) will be fully deliverable to government in order to demonstrate and further test system capability. Successful testing at end of Phase 2 must show level of algorithmic achievement such that potential Phase 3 algorithmic development demands no major breakthroughs but would be a natural continuation and development of Phase 2 activity.

PHASE III: Complete final algorithmic development. Complete final software system implementation of algorithms. Test completed algorithms on government controlled data. System must achieve 95% detection and tracking rate and 90% classification rate with less than 5% false alarms. Software implementation is required for testing and demonstration. However, principle deliverables are the algorithms. Documented algorithms (along with system software) will be fully deliverable to government in order to demonstrate and further test system capability. System will be utilizable in urban scene analysis and population surveillance by Army. System will also facilitate detection and threat awareness of individuals and small groups in rugged, isolated terrain. Specifically, system will be capable of insertion into Cerberus Towers Ground Sensors for Persistent Surveillance Program at NVESD. System will also be utilizable in border protection by Department of Homeland Security. In private industry, system will be utilizable for all aspects of urban and property surveillance and crowd control.

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KEYWORDS: Aided Target Detection, Dismount Target Tracking, Human Activity Classification, Threat Determination

A11-037 TITLE: Real Time Adaptable ROIC for improved Power and Performance Optimization in Imager Systems

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: PEO Intelligence, Electronic Warfare and Sensors

OBJECTIVE: Develop a focal plane array (FPA) read out integrated circuit (ROIC) with real time adaptability to enable visible, near IR, and short wave IR imaging systems to operate in the most power efficient mode dependent upon the application and/or current scene content by focusing on the analog and mixed signal processing chain within the ROIC.

DESCRIPTION: The fielding of digital low light and N/SW-IR focal plane arrays for dismounted, UAV and unattended sensors is critically dependent upon the sensor systems' ability to operate at the lowest possible power so that mission duration can be maximized. In an imaging system, the largest contribution to power consumption is in the analog and mixed signal domain. Traditional component development efforts which address the power consumption issue for imaging systems achieve low power through performance tradeoffs based on narrowly defined performance requirements. Thus image systems designed for low power operation in one application often cannot meet the performance requirements for low power sensors in a different application. In addition, image sensors optimized for specific applications are also limited to specific operational scenarios. Some of the key tradeoffs to reduce power are array size, frame rate, dynamic range and sensitivity. Since these are application and scenario driven parameters, it would be desirable to have a dynamically adjustable ROIC design that adapts performance parameters to meet the needs of the situation in the lowest possible power configuration. The ideal system would sense the scene content and dynamically adjust resolution, frame rate, dynamic range and/or sensitivity as needed to that power requirement, and would fluctuate to meet the current operational needs. The ROIC will also allow for reduced power consumption for applications that require reduced noise immunity, frame rate (sample rate), bit depth and dynamic range.

The Army seeks a real time adaptable ROIC designed to dynamically adjust resolution, frame rate, dynamic range and low signal sensitivity. The ROIC design should be scalable for array sizes from 640X480 to 2048X2048 with pixel pitches ranging from 5 microns to 25 microns and should accommodate different front end amplifier designs to support both charge and voltage domain signal inputs (depending on the focal plane array type). The dynamic parameters desired are: 1) frame rates: 15-120Hz at all resolutions, 2) dynamic range: 40 to 100 dB, 3) support windowing and binning and 4) bit depth: 8-14 bits.

PHASE I: Design, modeling and analysis will be conducted during phase I resulting in a preliminary ROIC design including the theory of operation, different types of modes of operation, a block diagram and/or schematic of ROIC (from input to output) and a detailed description of the functions in each block/schematic. Develop a simulation model of the proposed adaptable ROIC to optimize design parameters for and analyze ROIC performance in all modes and the impact of those modes on system power. The design should also address system level control issues for modes of operation which include but not limited to system level timing and basic FPA operation. Measured and/or simulated ROIC performance parameters to be reported for different operating modes shall include but not necessarily be limited to noise and noise sources (including spatial and temporal), SNR, linearity, bit depth range, sample rate range, total dynamic range and estimated power consumption. The phase I final report will also contain an investigation of the CMOS process required for fabrication, types and number of physical I/O, system level real time ROIC control architecture, implications to ROIC design parameters with respect to type of focal plane array (Vis-NIR, SWIR), estimated ASIC layout block size and estimated production cost. Analyze requirements for interface of system level controls (i.e. communication speed, when settings are applied, etc).

PHASE II: Design feasibility will be demonstrated in this phase. Demonstration hardware will be provided to the Government which will include a functional packaged dynamically adaptable ROIC with supporting hardware and software capable of demonstrating different operating modes as well as providing power monitoring capability. The final report for this phase will include a characterization report and supporting data on the dynamically adaptable ROIC.

PHASE III: Military applications include man portable, UAV or unmanned surveillance systems using solid state low light image sensors.

Commercial applications include any portable solid state imaging system ranging from still to video photographic equipment.

Transition from research to operational capability may include partnership with a DoD or commercial solid state manufacturer for implementing the real time adaptable ROIC to an existing solid state focal plane array.

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KEYWORDS: Read Out Integrated Circuit, Focal Plane Array, Visible-Near InfraRed, Short Wave InfraRed, Image Sensors, dynamic range

A11-038 **TITLE:** Optimized Demodulation Techniques

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: To develop angle modulation receiver techniques which are able to process multiple overlapping signals simultaneously and maintain the information content of each signal. As a parallel but complementary task, determine the minimal structure of a modulated signal necessary to communicate the intent of the message.

DESCRIPTION: Current demodulation techniques are focused on the practice which has proven to be the most economically practical, and technically conventional. As a result of this standardization, unique techniques which may be more applicable to certain received signal conditions have been ignored. In some cases these novel techniques may have initially been excluded due to their complexity but have now become practical due to the current processing power of today's circuits.

By developing more sophisticated techniques of presenting signals for demodulation, similarly but to a lesser extent for modulation, improved performance in signal separation, and simultaneous reception can result. For example, OFDM (Orthogonal Frequency Division Modulation) selects the appropriate characteristics of the modulatable tones to minimize their interference. Using this technique, and capitalizing on a subset of operating channels results in improved data throughput.

Tailored demodulation techniques can capitalize on existing untapped processing capability in existing platforms to improve information extraction from transmitted signals. This is a two step process, first the multiple signals which coexist in space when transmitted must coexist at the receiver and be made available to the demodulator, and secondly the (each) demodulator action must attach itself to only a selected signal.

Modulation of the message may be crafted to be coincidentally transparent to other than a matched receiver. Using this technique will minimize the ability of detection/interference of transmissions by generic receivers. For example, instead of continuous variations in frequency deviation, discrete changes in frequency may show improved performance and be transparent to other receivers which do not use these same discrete deviation values.

PHASE I: Multiple signals are to be processed at the receiver concurrently, different techniques to perform the demodulation/modulation will be investigated, and strengths of each of these techniques will be evaluated by their ability to maintain the aggregate information. The type conditions where these techniques excel will be described and demonstrated. The demonstration will show the improvement of one demodulation technique over the other in contrived scenarios to emphasize the possibility for improvement.

Implementation in hardware, based upon that commonly available is encouraged but a simulation is acceptable. If a simulation is the only technique presumed possible then additional effort is necessary to identify the potential

availability of the technique in hardware, or in the processing capability of existing computing platforms, and uncertainty in the granularity of the simulation.

PHASE II: Demodulation and modulation techniques determined in Phase I to be most effective at preserving the aggregate received signal will be further developed to capitalize on their strengths. If phase I was a software only simulation then the technique will be shown in hardware. If a hardware solution was initially conducted then optimization of the technique will be provided here.

Decisions as to the overall effectiveness of hardware implementation as opposed to software validation/implementation of the effort is to be performed. This portion of the program is to identify that there is a technical feasibility for improvement, but that the cost in general purpose software or dedicated hardware may be excessive. There may be two possible outcomes at this juncture: (1) implementation in dedicated special purpose hardware would be practical after the identified non reoccurring costs have been met. (2) The special purpose software running on general purpose machines would require a level of complexity which may limit the applications to special purpose scenarios. The result of phase II would then be an implementation design that is either available as IP (intellectual property) as software for inclusion on general purpose processors or as circuit design for hardware development.

PHASE III: At phase III there will be specific hardware which can optimize demodulation associated with specific channel conditions, or a new superior demodulation technique for overall use. IP (intellectual Property) which can be run on the core processor of the JTRS software programmable radio module which will scan through the various newly developed techniques and select the method with best performance.

While maintaining the proper modulation characteristics, improve the modulator to convey higher information content, which is still compatible with existing techniques but can show enhanced performance when coupled with the proper demodulator. For example, on an FM (frequency modulated) signal a dynamic modulation index/deviation pair can be better decoded by a matched demodulator than by any fixed demodulation technique although both would recognize the signal. A product with this capability will have application commercially for improved audio quality, such as in FM commercial broadcast and in two way radio communication receivers to improve quality of the communications.

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KEYWORDS: Demodulation, Modulation, Optimized demodulation techniques, Capture effect, simultaneous signal reception

TECHNOLOGY AREAS: Information Systems, Electronics

OBJECTIVE: Compression algorithms such as MPEG, JPEG are essential to communicate information over bandwidth restricted resources. Due to the compression technique employed however the granularity of the resulting file is unknown. The objective is to automatically identify that the granularity requested is not consistent with the information communicated due to the compression algorithm utilized.

DESCRIPTION: Compression algorithms make decisions regarding how the entire file will be interpreted. For example, it may be in the design to remove any information from an audio file 20ms after a 80db drum event, even if the dynamic range of the raw data recording device were capable of the required granularity to capture the softer tones at 1-19ms after the drum event. By design however the compression algorithm would not contain any artifact of these soft tones due to the assumption that the human ear could not recover from the 80dB drum blast until 21ms later.

In some instances however the information at 1ms -19ms after the drum blast could be analyzed independently of the time when the drum blast occurred, and done so with meaningful results. Due to the compression algorithm however this information is lost, and even worse its possible omission is unknown to the person analyzing the MPEG file. This results in incorrect conclusions.

What is needed is a automated process where the process identifies that the detail of information being requested is not available due the compression algorithm and that the particular information requested is only available if the raw data file were requested.

PHASE I: During phase I, the details of the compression algorithms will be investigated to determine the type information which was omitted in each type. The information content under investigation will be analyzed to determine if there was the possibility of information being deleted due to the compression algorithm and the operator alerted that the raw data should be accessed.

Popular compression algorithms will be selected and omissions of data due to the compression will be shown in a demonstration. The information apparently lost, but available from the raw data file will be shown.

PHASE II: Once the relationship between the loss of information in the compressed data and the compression algorithm is revealed this phase will automate the process where requested resolutions greater than that conveyed accurately by the compression algorithm are automatically processed.

The compressed data file and information attempting to be extracted will be accurately determined to be omitted and the correlated information from the raw data file will be retrieved.

Also necessary for completeness during this phase is the need to analyze the content of the compressed file and determine what areas are suspect, and what groups are suspect. With this information it can be determined if there is any hidden/lost information in the compressed data file.

PHASE III: At phase III there will be an application which resides on the pair of information users. The source of the compressed image/file will contain a relationship between the compressed data and the raw data file. The user end of the pair will process the type of compression used and identify the type and area were the resolution is limited. When this limited portion of the data file is accessed there will be an automated request sent to the source to obtain the raw data which will make the compressed data valid. At this point, with the new information the error of the compressed data will again be analyzed and a new set of questionable data areas revealed.

Imagery files communicated by sensor systems can initially communicate the compressed files and if there is interest shown then the file will be tagged as "of interest" and no additional information requested. If however the compressed file has multiple areas where potential information is lost then the raw data can be requested of only that relevant portion and only the necessary bandwidth will be consumed.

As a commercial application, a very rough file with exaggerated compression can be communicated with an indication to the consumer of the type degradation and its extent. After initial review of this compressed information and its quality communicated the consumer can make a determination if the additional information is worth the communication request or the identified expense. For example, if a relatively small file is initially communicated, with associated expense and consumer cost, and an indication of improvement potential is determined through this algorithm the consumer is in a better position to determine if he wants the full raw file or portions of it.

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KEYWORDS: lossy compression, distortion, aliasing, lossless compression

A11-040 TITLE: Improved Forward Looking Ground Penetrating Radar Array

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: PEO Ground Combat Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Investigate ground-based forward looking radar antenna array designs for compact physical size, narrow beamwidth, and ultra-wideband operation applied to standoff explosive hazard detection.

DESCRIPTION: The Countermine Branch, of NVESD's Science and Technology Division, has previously investigated explosive hazard detection using forward looking ground penetrating radar. Previous efforts demonstrated a capability to detect explosive hazards at standoff distances. A key component to these systems is the GPR antenna array. However, current antenna arrays have limited performance due to their size and their capacity to introduce aliasing artifacts. For example, one current design was 1.5 m high and 3.4 m wide. It was single polarization and operated in the frequency band of 0.7 – 4.0 GHz. It had the spatial sampling that was sufficient to beam form up to 2.0 GHz without aliasing. Another current design was 1.3 m high and 3.5 m wide. It was dual polarization and operated in the frequency band of 0.44 – 3.0 GHz. It had a spatial sampling that was sufficient to beam form up to 1.0 GHz without aliasing. For this effort we are seeking novel antenna or antenna array designs that will be more compact and will operate over the entire frequency range without spatial-aliasing. Additional desired antenna or array characteristics include ultra-wideband (0.3 – 3.0 GHz or greater), and dual polarization. Singular antenna designs should be created to be used in an array with low coupling. Further, the antennas should have a good front-to-back ratio, high directivity, and low VSWR. The desired standoff range from the sensor to the target is 30 meters and antennas or arrays should be designed to operate at this range or further. An award will be made based on the novelty of the effort and tradeoffs with the above antenna and array characteristics. Ultimately, the objective is for the antenna or antenna array to be incorporated into a forward looking GPR system and generate high the probability of detection and low the false alarm rates against buried and obscured explosive hazards at standoff ranges.

PHASE I: In Phase I, a proof-of-concept shall be explored as well as a breadboard design. All relevant design variables should be defined and modeled as applicable. Laboratory testing will be required to obtain such data for analysis of design variables for hardware related efforts.

PHASE II: Construction of field technology demonstration apparatus shall be completed. Extensive laboratory testing shall be performed to confirm and/or adjust results of models completed in Phase I. Technology demonstrator will be used to perform field tests with representative targets.

PHASE III: Demonstrate prototype technology in warfighter surrogate environments against real target types. The use of this technology would be applicable to the DoD for standoff mine/IED detection. A potential commercial application would be UXO remediation.

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KEYWORDS: ground penetrating radar, antennas

A11-041 TITLE: Information and Decision Dynamics in Network Centric Environments

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Design, develop and demonstrate the algorithms and software components required to enable characterization and modeling of the complex human-machine dynamics of Network Centric Environments to improve very large scale distributed collaboration and decision making.

DESCRIPTION: Network centric military systems (NCW) are planned to involve hundreds to thousands of manned and autonomous entities cooperating to achieve complex joint objectives in uncertain and incomplete information environments. The introduction of pervasive networking and command architectures offers both exciting new opportunities and the possibility of unintended consequences or unanticipated changes to human roles. While in today's military tight automated coordination exists within isolated, stove-piped systems, most information and instruction still pass through a human chain of command. Benefits from pervasive networking are expected to result in enabling an increased pace of coordinated activity and reactivity among forward forces. By sensing, communicating, and acting locally in the context of a flattened command hierarchy and in the presence of large numbers of automated collection assets, forces are expected to be able to coordinate their actions laterally to take advantage of local and rapidly changing situations. The quantities of peer-to-peer information available at the edge of the network will be much greater than those currently handled by filtering and aggregating up the hierarchy and likely beyond cognitive human capabilities. Conversely, with decision making and cooperation occurring in the NCW environment, new mechanisms may be needed for conveying the commander's intent, assessing influence of trust in belief propagation and convergence and assessing progress on the battlefield. There is the need for techniques to model and identify potentially beneficial or damaging emergent effects that occur in these large networked human-machine systems.

This SBIR aims at developing (a) agent-based technology to characterize the dynamics of such large scale human-machine systems and (b) techniques and software components to guide systems towards beneficial global results (e.g. decision optimality, reliability and robustness) and mitigating potential harmful effects. By identifying potential bottlenecks, challenges to stability, and obstacles to human control the results of the SBIR will identify potential solutions before problems are built into procured systems.

The development of this technology must overcome many challenges, such as large scale effects, uncertainty and incompleteness of information, differential degrees of trust among network entities, and limited cognitive information processing capabilities of networked humans.

PHASE I: Investigate methods for characterizing and predicting resulting effects and behavior of large scale belief propagation and cooperative problem solving systems; model the role of trust in information propagation and fusion; characterize the emergence of potential system vulnerabilities and investigate technology for mitigation of harmful effects; investigate situation assessment methods; agent technologies; adjustable autonomy schemes to determine best algorithms and architecture approach to meet the topic requirements. Develop and document the overall software component design and accompanying algorithms.

PHASE II: Develop and demonstrate a prototype capability for insertion into a realistic NCO Command and Control (C2) scenario. One of the key sub-goals of phase two will be to establish performance criteria and metrics for the large scale network-centric hybrid human automation system that allows automated vulnerability detection and mitigation, as well as techniques for system tuning to desirable performance outcomes. The prototype will implement best of breed algorithms in the architectural approach investigated in Phase I, using C2 scenario that should be suitable for Network Centric Operations. The Phase II deliverables will include a software prototype and documentation describing the potential performance criteria

PHASE III: Integrate the capability developed in Phase II into an appropriate Battle Command application. During this phase, the capability needs to clearly demonstrate an ability to meaningfully and quantitatively reduce the cognitive demands on a decision maker or a collaborative team of decision makers operating within the confines of the net-centric environment. The end-state of such a capability would be a Network Centric Warfare (NCW) software service or application that reduces a commander and/or his staff's cognitive burden during mission planning or execution. This could be used in a commercial environment for emergency response situations where decisions must be made quickly. The topic will be linked to ATO R.ARL.2009.05 THINK.

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Corporate Author: NAVAL WAR COLL NEWPORT RI, Page Count: 22 page(s), Report Date: 05 FEB 2001

KEYWORDS: Network, information, decision, dynamic, collaboration, decision making, distributed

A11-042 TITLE: Feature Detection Architecture for Low Processing Capable Radios

TECHNOLOGY AREAS: Information Systems, Electronics

OBJECTIVE: Develop and demonstrate a Feature Detection Sensor architecture for embedded military radio applications with significantly improved performance capabilities over existing architectures in terms of decreased power consumption, faster detection time, and reduced processing and memory requirements.

DESCRIPTION: The DoD and Joint Services have identified the need for more intelligent communication systems to meet current and future Warfighter requirements. This has resulted in initiatives to develop radios incorporating Dynamic Spectrum Access (DSA), such as the XG DSA2100, EPLRS XF and PRC153 Dynamic Spectrum Access(DSA) radios. These "smart" or cognitive radios will provide greatly improved communication capabilities and ease of use over their predecessors. These radios adapt to their environment based on spectrum needs and available resources to provide superior reliability, interference sensitivity, resource efficiency and data throughput. The effectiveness of a cognitive radio to provide these improved capabilities is directly dependent on its ability to accurately detect its environment. Spectrum sensing for cognitive radio is still in its early stages of development.

There are a number of sensor methods that have been suggested [1], but the energy detector based approach is the most common due to its low computational and implementation complexity. The main drawback of this method is that it is ineffective in low SNR conditions. Feature detection sensing algorithms such as cyclostationary or waveform-based sensing offer superior accuracy, but require greater computational and processing resources. The state of the art GMR Technologies Roadmap FY10-17 includes: Development of a DSA application on Legacy Radios and development of a DSA Enabled Networking Waveform for JTRS radios. Both of these initiatives are supported by this proposed effort, which involves research, design and development of a novel architecture to implement a feature detection sensing algorithm with improved performance over existing architectures, such that it can be implemented on radios with low processing capability. An HDL model of the new architecture must be developed to demonstrate and evaluate the performance of the new architecture. These models should be developed such that they can be deployed on a typical radio platform for lab evaluation, such as the Spectrum Signal SDR4000 or the Ettus Research USRP, with final deployment on an existing DSA enabled tactical radio.

PHASE I: It is desirable that this architecture function with signal waveforms from 3MHz to 3GHz, but must operate over a minimum range from HF to UHF. The architecture must demonstrate the ability to detect multiple waveforms based on modulation scheme or waveform pattern. The modulation schemes of interest include: M-FSK, M-PSK, QAM, CPM, OFDM, NTSC and DTV and all other major digital waveforms. The waveform patterns of interest include: 802.11 preambles, WiMAX preamble, TDMA pilot, direct sequence spread spectrum and frequency-hopping spread spectrum. It is of interest to build a simulation model of this improved architecture capable of detecting one of the waveforms features or waveform patterns of interest. The model should be built with a commercially available tool, such as MATLAB. In addition it should be shown and clearly documented in the final report that the proposed state of the art technology is by a magnitude superior than other spectrum sensing techniques currently available. In addition metrics and performance improvements of the new feature detection architecture should be summarized.

PHASE II: The research and investigation of feature detection architecture and enhancement of the architecture to include at least 1 more waveform feature of interest and 1 more feature pattern of interest should transition to the prototype demonstration. The improved state of the art technology should be modeled and implemented in software that can be deployed and tested on an SDR platform. That means from MATLAB model that was developed in PHASE I the improved feature detection model should be implemented in HDL that can be deployed and tested on an SDR development platform. The milestone for the PHASE II is to deliver software and HDL working models. Provide support to deploy the models on an SDR development platform. Prototype will be delivered on a breadboard or a component for the validation in laboratory environment, and will be delivered as a TRL-4.

PHASE III: Developed architecture would require for the integration and testing on a platform. This state of the art architecture will be integrated on the DSA radio systems. Hence it needs to be proposed DSA tactical radio most suitable to use the feature detection model. HDL and software models need to be modified to allow integration of the feature detection model on an existing DSA tactical radio. Support to the radio manufacturer to integrate and test the feature detection capability on the identified radio needs to be provided. This effort also has possible application for commercial cellular service providers. With the arrival of 4G services, there is an increase in subscriber usage. The ability to provide increased capacity by traditional methods of cell size manipulation may have reached their limit, so cellular providers may turn to new spectrum sharing techniques which require low cost, efficient feature detection architectures. Also, service providers who have invested heavily in as yet unused spectrum or those looking to take advantage of TV white space, may desire to introduce newer lower cost services that rely on spectrum sharing. Feature Detection will be the optimal way to benefit and enhance the performance of current radio systems. This type of technology will demonstrate an alternative way of signal detection in current DSA system like XG DSA2100, PRC 153, 148 and legacy systems like EPLRS. Cyclostationary detection allows for additional waveform detection in addition to feature detection. This detection scheme is ideal for use in a Cognitive Radio system. It is an efficient technique for signal classification in the low SNR region where energy detector fails.

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KEYWORDS: Spectrum Sensing, Dynamic Spectrum Access, Feature Detection

A11-043 TITLE: High Performance/Throughput, Low Latency and Low Power Field Programmable Gate Array (FPGA) for Software Defined Radio (SDR) and Cognitive Radio (CR)

TECHNOLOGY AREAS: Information Systems, Electronics

OBJECTIVE: Develop a high throughput, low latency and low power consumption, development portable Field Programmable Gate Array (FPGA) to enhance the capability of Software Defined Radio (SDR) and Cognitive Radio (CR).

DESCRIPTION: The SDR lab, Tactical Radio Branch S&TCD in CERDEC is currently exploring new and innovative technology in Cognitive Radio/SDR via research, development and testing Cognitive Radio on SDR platform. The goal is to improve and enhance tactical radio performance, connectivity and survivability and serve the best interest of warfighter. In order to support and enable sophisticated waveform software to accomplish the goal, a high throughput, low latency and low power processor plays a crucial role.

Currently popular FPGA used by tactical radios either in the field or lab mostly are Xilinx and Altera which have FPGA design and the capacity to deliver desired performance is limited, i.e. throughput, speed and power consumption for CR/SDR. It is desired to have a breakthrough circuit design to eliminate the constraints of global clock in FPGA fabric. The ideal architecture will not only boost the performance several times faster (i.e. 1.5 GHz vs. 300 MHz) and higher I/O throughput. For example, from 300-400 Mbps to 10.5 Gbps. The proposed product should also have capability of significant power reduction advantage as compared to the current market available products. Another requirement is the portability that FPGA must provide easy migration and development with computer aid development tool for existing VHDL or Verilog developed on other FPGA.

The technical risk is relatively low since the enhanced FPGA will undergo rigid tests and performance evaluation from prototype to real product before applied to the military/commercial radio or RF in the later phase.

PHASE I: A Specification of Design and Architecture of FPGA with high I/O throughput, low latency, low power, low cost and high portability for development. Develop a test and evaluation plan. A simulation model or initial prototype to demonstrate the feasibility of the system.

PHASE II: Develop and implement a complete prototype based on the architecture and design generated in PHASE I to address: 1) high I/O throughput, i.e. 10.5 Gps, 2) Speed/low latency, i.e. 1.5 GHz, 3) low power consumption compared to the other market available FPGA, 4) low cost by design and efficiency, and 5) easy to port other VHDL/Verilog from other FPGA. In PHASE II, a test and evaluation platform should be developed and used to provide the test and analysis result of prototype proven the FPGA, beyond state of the art.

PHASE III: Upon successful completion and test of PHASE II prototype, the FPGA prototype shall be fully developed. In this phase, the vendor shall provide support to the radio manufacturer to integrate and test the performance and required specification. In addition, a future application plan to private industry in wireless and communication areas shall be provided.

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KEYWORDS: technical riskprototype

A11-044 TITLE: Passive Infrared Detection of Liquids on Surfaces

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors

OBJECTIVE: To design and build a lightweight wide area passive standoff imaging detection system capable of rapidly detecting liquids on surfaces for the purpose of contamination avoidance and reconnaissance. To design, build, and test a passive infrared sensor for wide area detection of persistent chemical agents on the ground. To understand the physics of cold-sky reflectance from surfaces contaminated with liquid agents or simulants.

DESCRIPTION: There is a need to extend the advantages of wide area passive infrared sensing of chemical contaminants to the problem of detecting liquid contaminants on surfaces. A passive wide area monitoring system would allow rapid evaluation of large areas for CW contamination and provide detailed information as to position of ground contaminated with a persistent liquid. Surface contamination by CB agents presents a serious threat both to the civilian and military sectors and an adequate defense against these weapons will require rapid detection and identification of both known and unknown agents.

Recent measurements in the scientific literature suggest that passive long wave infrared sensors are capable of detecting liquids on the ground by utilizing cold sky reflectance. The physics of passive detection of liquids on surfaces is not well understood. However, the cold-sky reflection drives the physics of passive detection of liquids on surfaces. The sky is radiometrically very cold, emitting far fewer infrared photons than objects on the ground. Due to cold sky reflectance, there is an apparent enhanced emission of the resonance bands of the liquid on the ground, which is at ambient temperature. A better understanding of the physics of cold-sky reflectance is needed to understand and exploit this phenomenon. The reflectivity of liquid-contaminated natural surfaces is generally not well-described using simple reflectance models. Microscopic masking and shadowing effects are generally not accounted for in many models of surface reflectivity. Measurements have shown that the reflectance from the ground due to the cold sky tends to be polarized. The origin of the polarized component of this reflection is not well understood.

It has also recently been demonstrated that the sensitivity of passive standoff sensors can be enhanced utilizing hyperspectral imaging (HSI) sensor technology. HSI passive sensors utilize differential radiometry, comparing spectral radiance from pixels or groups of pixels to enhance sensing capabilities. In the past decade, long-wave infrared imaging spectroradiometers have become available for numerous commercial applications such as surveying for minerals, detection of natural gas leaks, and pollution monitoring. There is a critical need in the Chemical and Biological community for wide area monitoring of persistent chemical contamination on the ground. A better understanding of cold sky reflectance and thermal physics of the environment could provide enhanced detection capabilities.

PHASE I: Conduct a feasibility study of detecting liquid contaminants on the ground using a passive long wave infrared hyperspectral imaging spectroradiometer operating in the 8 to 12 μm region of the electromagnetic spectrum. Develop models for cold sky reflectance onto a contaminated surface and determine the expected differential radiance when a contaminant, such as a silicon-based oil, is placed on a variety of surfaces such as painted metal, concrete, grass, and dirt. Examine the use of polarization information to enhance the detection and identification of chemical contaminants on surfaces. Using models for a hyperspectral imaging sensor operating in the long wave infrared region, determine the expected sensitivity of a passive infrared sensor in terms of grams of contaminant per square meter of ground.

PHASE II: Develop and build a breadboard hyperspectral imaging spectroradiometer operating in the 8 to 12 μm region of the electromagnetic spectrum specifically designed for detecting liquid contaminants on surfaces. The system should have a focal-plane-array and be capable of true imaging. The system should have sufficient spectral capabilities to detect identify chemical agents and simulants based on infrared absorption bands. Acquire data of cold-sky reflectance from detailed measurements on a variety of surfaces (sand, grass, painted metal, concrete, etc.) contaminated with a small amount of a silicone oil based simulant using an imaging spectroradiometer operating in the 8 to 12 micron region of the electromagnetic spectrum. Determine the sensitivity of such measurements

PHASE III: Further research and development during Phase III efforts will be directed toward refining a final deployable design; incorporating design modifications based on results from tests conducted during Phase II; and improving engineering/form factors, equipment hardening, and manufacturability designs to meet U.S. Army CONOPS and end-user requirements. In the past decade, long-wave infrared imaging spectroradiometers have been demonstrated to be useful for numerous commercial applications such as surveying for minerals, detection of natural gas leaks, and pollution monitoring. It is expected that such commercialization will accelerate once the sensors become less expensive and easier to use. It is one of the goals of this effort to produce affordable passive sensors that can be mass produced for the battlefield.

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KEYWORDS: Chemical Detection, hyperspectral imaging, surface reflection, liquid contaminant.

A11-045 TITLE: Continuous Dissemination Techniques for Particulate Obscurants

TECHNOLOGY AREAS: Chemical/Bio Defense, Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To develop a non pyrotechnic or cold burning pyrotechnic mixture that will generate a continuous cloud of particulate obscurant. This would include proof of concept of hardware designs for applications in both a hand held devices for individual protection, as well has a larger vehicle launched devices for equipment protection. For non pyrotechnic systems, novel new approaches are needed to generate forces to expel obscurant fills in a

continuous, uniform fashion. For example, optimum visible obscurants employ spherical shaped particles generally packed in a dry form. Typical examples of reduced-toxicity materials would be TiO₂ and carbon black powders. Optimized packing of these materials will be directly related to the expulsion design techniques (mechanical or gaseous). For cold burning pyrotechnic concepts, smoke production without any flame source is desired. Current grenade devices generate extreme heat which can burn personnel or cause fires.

DESCRIPTION: Currently infrared and visible obscurant grenades employ high explosives configured as a center burster to disseminate metal flakes and non-metallic spherical powders. These devices offer very short dissemination periods, making it difficult to maintain protection for the soldier and equipment. Pyrotechnic smokes are composed of fillers that typically consist of HC smoke mixtures (hexachloroethane/zinc) or TA smoke mixtures (terephthalic acid). In addition, Red Phosphorus is widely used to generate long duration visible obscuration. For all pyrotechnic or burning devices, there are many flame hazards associated that them that restrict their use. From past research, it has been determined that conductive high aspect ratio metallic flakes are ideal for infrared obscuration and spherical particles with high refractive index in the visible region are ideal for visible obscurants.^{1,2} The metallic flakes of interest have typical major dimensions between 5 and 10 μm and minor dimensions between 50 and 100 nm. The visible obscurants are typically spherical in shape, and depending upon the refractive index, the optimum diameters range anywhere from 0.2 to 1.0 μm . Although the primary goal of this effort is for visual obscuration, these techniques could be applied to other areas of interest in the electromagnetic spectrum, specifically infrared and microwave regions.

PHASE I: Demonstrate a concept that will continuously and uniformly disseminate a powdered material from a Coke-can sized device for 30 seconds. Concept must aerosolized at least 50% of the material in its original sized (the particle size that was initially packed into the device). Tests can be performed at ECBC obscurant chamber to determine dissemination efficiency and flow rate. For cold burning pyrotechnics, device should have similar size and duration times as above along with no visible flames being produced. Device should not generate enough heat on the outside of can to cause paper materials to ignite. By the end of Phase I, at least 5 devices should be available for testing at ECBC.

PHASE II: Refine the design into two fully-functioning grenades. The first must have the overall dimensions of the M106 handheld grenade. The second must have the overall dimensions of the M90 vehicle launched grenade. Details to be considered, among others, for this grenade include survival of the device subjected to launch and impact forces and whether orientation is an issue for dissemination. Improved packing strategies to optimize packing densities and device yield (a measure of much material actually gets out of the can and airborne). Consideration should also be given for the usual requirements of cost, storage and compatibility with existing launchers. By the end of Phase II, at least 20 devices of each style should be available for testing at ECBC.

PHASE III: Dual Use Applications: The grenades developed in this program can be integrated into current military obscurant applications. Improved visual devices are needed to reduce current logistics burden in needing to carry countermeasures to protect the soldier and his equipment. Improved dissemination techniques can be beneficial for all powdered materials in the metallurgy, ceramic, pharmaceutical and fuel industries. Industrial applications include electronics, fuel cells/batteries, and solar energy.

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KEYWORDS: Powders, Obscurant, Grenade, Continuous Dissemination

A11-046 TITLE: Volume and Weight Reduction Method for Intermediate Moisture Ration Components and Snacks

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Novel agglomeration or densification technologies will be explored to produce a variety of lightweight, low cube, highly nutritious, shelf stable and ready-to-eat foods for assault type military rations such as the First Strike Ration (FSR). Innovative research will be required to apply volume and weight reducing processing methods to nutritious ration components, while still maintaining acceptable sensory, functional and shelf life attributes.

DESCRIPTION: Current acceptable weight and cube reduction of ration components by means of standard compression is approximately 20-30% (e.g., 2.3 oz and 3.5 cubic inch for a First Strike Bar [FSB]). However, physically compressed products are often hard and brittle, can be easy to crumble, and can exhibit loss of component integrity and nutrients. Normal compression force will not produce a product with uniform texture unless excessive force is applied. This extra pressure will produce a product with exudates and a non-reversible, fiberboard-like texture. In addition, the heat generated by high pressure (Ref 1) will adversely affect some nutrients to be delivered. Innovative research will be required to apply volume and weight reducing processing methods to nutritious ration components, while still maintaining acceptable sensory, functional and shelf life attributes. A new method to reduce the volume and weight by 50-70% of complex ration components (e.g. 0.7-1.2 oz and 1.1-1.75 cubic inch for FSB), such as agglomeration technology, is needed to provide a radical departure from current and conventional compression methods. An agglomeration process, which to date has had limited application in the food industry (simple products), involves the dosing a predetermined quantity of a complex product mix in a forming chamber, compressing it and subsequently injecting a commensurate amount of energy to sustain the shape and structure of the agglomerate. Such energy, exerted by ultrasonic waves for example (Ref 2-6), would act upon sugar, proteins, starches and moisture within the mix and 'spot weld' the particulates together into any complex tridimensional shape of any desirable texture. A novel volume reduction or densification process would enable the use of natural ingredients, primarily from fruits, vegetable, and meat, with further addition of ingredients like nuts, seeds and beans. Unlike normal compression techniques, a new method of volume reduction could deliver a product in which each ingredient remains visible in its original particulate form and contributes to the product's fresh-like appearance; a true benefit for military rations. The technology shall not require the use of fat-based binding matrices, which, besides compromising the nutritional profile of the product, may also reduce the product stability and shelf life in high heat environments. The process shall be highly flexible with respect to the nutritional profiles achievable, to include tailoring a product to be high in protein and fiber, or have a customized calorie value.

The technology shall deliver a product in which temperature sensitive ingredients will not degrade through the process. This in turn will allow the addition of functional ingredients aimed at delivering performance benefits such as: alertness, mental acuity, muscle resistance to fatigue and/or rapid recovery from it, extended physical strength and endurance (though the incorporation of quercetin and curcumin, etc.). The specialized equipment developed in conjunction with the new method of volume reduction shall be commercially adaptable and shall eliminate the need for large assets such as ovens, cooker/extruders, cooling tunnels, etc, as well the need for peripheral systems. In addition, the processing method shall not entail any significant amount of scrap or rework. Overall, the technology shall provide a new food processing method that is cost effective, low-asset based, and of high-capacity which, if needed, can be made portable for potential relocation. The target goal of the novel technology is 50-70% weight and cube reduction with more than 80% retention of targeted nutrients.

PHASE I: Research, develop, and design an innovative concept to reduce volume and weight of food and snack products of a complex nature, using fruit, vegetable and meat ingredients. Verify that target weight and volume reduction, stated in the topic description, can be met with proposed densification process. Design the specialized prototype equipment and a process for using the equipment to create five prototype food and snack products. The Phase I tasks shall be completed in 6 months. The deliverable will be a final report outlining the details of the densification process, specialized equipment used, and how full-scale performance and control requirements will be met in Phase II. The report shall also detail the conceptual design, performance modeling, safety, risk mitigation measures, MANPRINT, and estimated production costs.

PHASE II: Produce five prototype products using a novel volume and weight reduction method developed in Phase I. NSRDEC will oversee progress and assist in selection of prototype products. Prototype products will be selected based on factors such as microbiological safety, weight/cube reduction, cost, shelf stability, complexity of ingredients, nutritional profile, sensory and functional attributes. Refine the concept and fabricate specialized prototype equipment and a process using the equipment to create five prototype food and snack products that meet all requirements specified in the description. The finished prototype equipment shall be sufficiently mature for a Warfighter technology demonstration. Produce a representative quantity of at least 3 selected ration components for limited field-testing, demonstration, and display. Define any anticipated manufacturability issues related to full scale production of the prototype system for military and commercial application. Identify any safety and human factor issues associated with the process or equipment. The TRL (Technology Readiness Level) goal at the completion of Phase II will be 5, component and/or breadboard validation in a relevant environment.

PHASE III: Reducing the footprint of soldier items in the field has been emphasized in DoD Food Program as well as other DoD organizations. There are projects working on reconfiguring the ration packages, and to apply nanotechnology in the development of lighter weight packages. This project addresses the reduction of cube and weight of military rations overall by focusing on the footprint of each ration component. If the SBIR effort is successful, the Combat Feeding Directorate of NSRDEC will recommend a Joint Service Requirement technical base non-SBIR funded program to further advance this technology, refine the products, test them in the field with soldiers, and obtain approval for their transition to the field as new ration items. The initial use for this technology will be to produce low cube, low weight, shelf stable and palatable ration components with designed nutrient content. Further application of the technology will provide lightweight, low-cube foods tailored to the commercial sector, to include low-calorie, low-fat foods.

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KEYWORDS: compression, agglomeration, low cube, low weight, nutritious rations, and snacks

A11-047 TITLE: Individual Soldier, Active Flame Suppression/Avoidance/Barrier System for Head/Face Protection

TECHNOLOGY AREAS: Human Systems

ACQUISITION PROGRAM: PEO Soldier

OBJECTIVE: To develop, demonstrate and produce a head/face protection, thermal/flame-activated system or technology capable of providing a protective envelope about the head/face for flame avoidance and/or providing an insulated flame barrier, or providing a combination thereof.

DESCRIPTION: Combat Soldiers encounter battlefield threats of fire from various sources such as pool fires and improvised explosive devices (IED)(Re: KPP 1 CSS Force Protection, Core Soldier CPD (1)). Fire, flame and thermal threats yield burn casualties of varying levels of severity and death. Passive systems of protective clothing systems are made with flame resistant finishes and inherently flame resistant fibers provide very good level of protection to covered areas, but not for exposed skin areas such as the face and neck. Current technology for face,

head and neck protection is limited to items such as flame resistant balaclavas, which may not be appropriate or convenient for all climates and missions.

The proposed SBIR concept of a thermal/flame-activated, Flame Suppression/Avoidance system(s) is envisioned to be used with passive protective clothing systems and would enhance a Soldier's survivability from a combat incident involving fire/flame/thermal threat (i.e., IED) through flame avoidance or barrier protection.

Flame avoidance is considered the primary goal of this effort. The system to be developed is intended to be a lightweight (< 1 pound [Objective], < 2 pounds [Threshold]), low bulk/profile (< 100 cu. inches [Objective], < 150 cu. inches [Threshold]) system worn by the individual Soldier and compatible, non-interfering or integrated with his fighting load. It is envisioned as a self-triggering device (<1 millisecond) that, when sensing (360 degrees [Objective], > 270 degrees [Threshold] about the vertical head/neck axis) a very high intensity (10 cal/sq.cm-sec)/low duration (milliseconds)[Objective] or high intensity (4 cal/sq.cm-sec)/long duration (>4 seconds)[Threshold] flame/thermal threat and blast overpressure acting on the Soldier wearing the system in an open environment, will instantaneously activate to provide a protective shield about the Soldier's head, face and neck (360 degrees [Objective], > 270 degrees (symmetric about the face) [Threshold] about the vertical head/neck axis and from shoulder level to top of head/helmet) (i.e., high velocity gas curtain to block/divert flame threat away from unprotected skin areas of head, face and neck) [Objective solution]. Alternatively, the system might involve a self-triggering device/materials capable [Threshold solution] of providing/generating a barrier capability or insulation capability (i.e., helmet or collar airbag barrier). One-time use systems will be considered, but recharge/refit capability is desired. Overall weight and cube must be addressed for the system proposed; the intent is low weight and bulk and little to no interference with other Soldier activities/functions (i.e., "transparent" to the Soldier). The system shall not itself in any way be a safety hazard to the wearer.

An example of current technology that might provide direction toward a materiel solution is motorcycle helmet airbag technology (2,3). Such a system concept, mounted as a lightweight and low bulk collar on the ballistic vest, could be designed with appropriate sensors to instantaneously deploy a conical airbag (made of lightweight, controlled air permeable, flame resistant fabric/film construction) around the head and neck, and automatically deflate, for example, after a preset time (2-4 seconds). An alternative might be a device that exhausts a high velocity, short duration, outwardly-directed burst of non-flammable gas to provide a curtain to flaming gas overpressure from a short duration blast (i.e., gas curtain) from a low bulk collar and/or helmet edging. Airbags for clothing have been invented to provide cushioning during impact situations(4), but not for the purpose of flame/thermal protection. Individual airbag technology with lightweight, low bulk, portable inflation technology, sensor technology, and garment/equipment design could provide a means of face, head and neck protection for Soldiers.

PHASE I: The initial Phase of the effort will determine the technical feasibility of man-portable, self-activated flame and thermal systems providing burn protection to individual Soldiers, to develop innovative technical approaches or combinations thereof with target performance capable of providing the thermal/flame protection required, to down select technical approaches for a Soldier-mounted system with greatest probability of success, and to develop an initial concept design and prototype for test and demonstration.

PHASE II: The Phase II effort will be directed to the fabrication of 50 prototypes for initial, technical testing and demonstration purposes. Based on test results, the contractor will finalize the system design by optimizing the system's form/fit/performance and manufacturability and reducing the individual system cost to an affordable level. 200 additional prototype systems will be fabricated for expanded Developmental (technical and safety) and Operational Testing purposes. Technical description, performance parameters/test methods and drawings necessary for development of product descriptions for acquisition purposes will be generated and delivered.

PHASE III: The Phase III effort will focus on the commercialization of the developed system. Expansion of manufacturing capabilities to satisfy military demand and development of other domestic markets (i.e., municipal fire departments, police and swat/Explosive Ordinance Disposal teams, other law enforcement, forestry service) will be emphasized. Although the envisioned military market is the dismounted Soldier, future military markets involving flame/thermal threats in confined areas (i.e., mounted Soldiers in ground and air combat vehicles, buildings) could involve further development opportunities.

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5. US Patent 7,017,195 (2006), R. Buckman, "Air Bag Inflation Device".
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KEYWORDS: Fire, Flame, Soldier, Flame Suppression, Flame Avoidance, Flame Barrier, Head Flame Protection, Face Flame Protection

A11-048 TITLE: Intelligent Vehicle Behaviors for Explosive Hazard Detection & Neutralization on Narrow Unimproved Routes

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: Develop an IED defeat Intelligent Behavior Engine (IBE) that can enable low-cost, mid-sized vehicles to protect dismounted troops on deep insertion missions, capable of significantly improved remote, standoff detection and neutralization of buried IEDs on narrow, unimproved routes.

DESCRIPTION: PM-IED Defeat is seeking concept and prototype development efforts that demonstrate remote, standoff detection and neutralization of buried improvised explosive devices on narrow, unimproved routes. A variety of component technologies have shown value for aspects of this mission including a variety of sensors, manipulators and neutralization tools. However, currently fielded technologies have limited utility for defeat of IEDs on narrow unimproved routes during deep insertions into rugged terrain. Existing small robots may not be able to go the necessary long distances (10 - 30 miles) and large vehicles such as the Husky cannot traverse the rugged terrain and narrow paths.

To address this need, an IED Defeat (IEDD) Intelligent Behavior Engine (IBE) is sought that can enable low-cost, mid-sized vehicles to protect dismounted troops on deep insertion missions. An IBE can be understood as a software tool that provides intelligent control for orchestrating vehicle hardware and software components towards mission goals. The IBE should be portable and reconfigurable so that it can interface seamlessly with multiple payloads, vehicles and sensors. While a highly skilled human operator may understand how to hold a sensor; where to position it; and what areas of the environment to investigate, successfully translating that skill into effective autonomous machine behavior is an open problem that requires innovation. A solution that merely integrates sensors with vehicles will not be sufficient. Rather, the IBE should focus on intelligent, adaptive software behaviors that provide standoff operation in terms of navigation, detection and neutralization. The IBE should allow the operator to initiate, monitor and sequence IEDD task elements such as scanning, digging and emplacing explosive charges. Specific areas for innovation include, but are not limited to the following:

Shared control driving: On long distance dismounted patrols, users require a standoff control scheme that offers off-board, "back-seat driving" capabilities. The IBE should permit operators to provide intermittent directional cues and to initiate various specific threat detection behaviors from a hand-held device that may include a visualization of nearby terrain and hazard data.

Characterization and Neutralization Behaviors: The variation in threats faced by warfighters must be met with versatility in terms of robotic capacity for using multiple hazard sensors effectively. These behaviors must effectively encapsulate the skill and techniques necessary to exploit hazard sensors, marking tools, and neutralization devices including how far from a surface to scan a particular sensor, how fast to scan it, and the advance rate of the vehicle while using a particular tool.

Intelligent Manipulation Control: The IBE should address general purpose manipulation skills that can be effectively used with hydraulic or electric arms to perform various reaching, scanning, sampling and digging tasks associated with the IEDD mission.

The mid-sized (500-3000lb) vehicle envisioned should be off-the-shelf and capable of traversing long distances on narrow, rugged paths and of supporting skid steer hydraulic arm attachments for various implements such as arms. Effective teams will provide a means to demonstrate at least one method for sensing buried hazards and one means for neutralizing them. Proposal teams may address key elements of the IEDD mission including pressure activated devices and command detonated explosive devices. The main focus of the work is not on the vehicle but rather the ability for intelligent software behaviors and human interfaces to support effective, semi-autonomous functionality that reduces workload and maximizes performance.

PHASE I: Conduct study/analysis of current IEDD tools and components that can be used from a mid-sized vehicle. By the end of Phase I, develop a plan includes a list and description of proposed IEDD tools (sensors) and the strategy for behaviors that maximize performance of each tool. The plan should include an interface control strategy to support tasking and situation awareness. The implementation plan should focus on the software and hardware strategy for plug and play of each tool.

PHASE II: Develop and refine the prototype toolkit in terms of hardware and software. Demonstration plug and play of subsystem components together with functionality of behaviors and operational tasking from the graphical interface. The Phase II hardware/software solution can be defined as follows: 1) Graphical user interface, Intelligent Behavior Engines, and other systems analysis toolkit functionality will reside on a rugged field ready laptop computer 2) from inside the vehicle the laptop computer will interface outside in front of the vehicle to a portable plug and play station suitable for mount on a medium sized vehicle. The plug and play station must be designed to be field rugged and not greater than 1 cubic foot. The plug and play station will be used as the interface from the control computer to various IED detect, locate, or defeat systems. The Phase II prototype and test system should be capable of supporting a warfighter assessment of system capability including vehicle mobility, navigation behavior subsystem, communication subsystem, and hand held operator control unit with visualization and tasking software. The system will also include at least one neutralization subsystem, one manipulator subsystem, one underground imaging systems (e.g. ground penetrating radar, electromagnetic induction sensor) and one chemical analysis sensor for sweeping and/or sampling. Component hardware/software interfaces will be fully documented and, where appropriate, conform to open architecture/messaging standards.

PHASE III: Transition to Military - The most likely path from SBIR to operational capability will be via Phase II enhancement and/or CPP which would allow final definition of the number and type of IED defeat systems necessary, and the efficient implementation of these systems on the vehicle. At this stage of the program close interaction with PM-IED Defeat and JIEDDO will facilitate development of a robust transition plan that identifies the IED Defeat subsystems necessary, overall system delivery schedule and cost per system.

A potential path to fielding will be to pursue a Rapid Equipment Fielding exercise, where the prototype Intelligent Behavior Engine will be used to define a suite of sensors and techniques for IED detect/defeat on medium sized vehicles for rough terrain operations. As part of this user evaluation phase there is also the potential to use the system to enhance or redefine the functionality of existing IED in-road defeat systems.

In parallel, Phase III transition may be facilitated via user-centric warfighter experiments to examine concepts of operation and to hone the system behavior and overall performance.

Military end applications for the IBE plug and play station and development environment may include 1) improved IED defeat systems for in-road or off-road, improved tunnel defeat systems which require a robust synergism of sensor types and 3) smart munitions systems which have complex functionality and would benefit from improved data fusion using a variety of sensor modalities.

Commercial Applications - A portable system laptop computer with interface station which allows a user to evaluate the synergy of subsystems in a plug and play environment while conforming to open architecture/messaging standards would have potential commercial market appeal. Such a system would reduce the development time normally associated with complex systems integration efforts. The system might find application in 1) sensor companies for evaluating new sensor products or the integration of several products together to meet special

customer requirements 2) surveillance systems companies to expand the functionality and performance of surveillance systems using different surveillance sensor systems.

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KEYWORDS: Intelligent Behavior Engine, standoff detection, neutralization, defeat, improvised explosive devices, deep insertion, unimproved routes, neutralization tools, behaviors

A11-049 TITLE: Refurbishment/Repair of High Value Aerospace Spiral Bevel Gears

TECHNOLOGY AREAS: Air Platform

ACQUISITION PROGRAM: PEO Aviation

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Summary: This topic seeks to develop affordable refinishing technique which can repair high value spiral bevel gears currently rejected at overhaul for damage to the gear teeth, splines and bearing surfaces.

DESCRIPTION: Description: The heavy usage of rotorcraft in the current conflicts in Iraq and Afghanistan are creating high demands for replacement parts. Helicopter drive trains are not immune to this operational tempo. Spiral bevel gears are a key component of the reduction gearboxes of all rotorcraft and are one of the highest cost precision components in the entire helicopter. Spiral bevel gears are unique in that they allow the an angular redirection of the power between two intersecting shafts. The gear teeth use a highly complicated 3-D geometry with a spiral tooth form that allows multiple teeth to be in contact at any one time. A significant cost savings could be realized with the development of a technique for repairing key precision features such as gear teeth, splines and bearing surfaces that have experienced light damage due to fretting, staining, debris damage and other types of light surface distress. The characteristics of this type of damage typically produce pits or roughening of the surfaces that extends 10-15 micro inches from the original surface. Potential repair processes can involve either adding new material or removing a small amount of the existing material. The proposed techniques should enable the refurbished gear to meet all of the geometry, surface finish, and metallurgical characteristics (hardness, grain size, residual stress) of the original new production gear. For processes that remove material, a very uniform material removal characteristic is critical. In addition, the ability to produce a very fine non-directional surface finish with Ra less than 0.5 micro inches is highly desirable as it is known to increase durability in marginal lubrication conditions. Innovative approaches that can also increase to surface residual compressive stress versus conventional shot peening as part of the refurbishment process are also sought as they will increase damage tolerance. The capability for uniform material removal is critical to maintaining the spiral bevel gear tooth geometry. Previous methods utilizing either light regrinding of the surface, or vibratory finishing processes with mixed ceramic media have resulted in excessive material removal at the gear tooth tips and low material removal down closer to the tooth root resulting in gears that no longer meet the tolerances of the original specification.

PHASE I: Effort in Phase I shall assess the potential application of the proposed process to spiral bevel helicopter gears rejected during overhaul at Corpus Christi Army Depot. A survey of the degree of damage and the potential number of parts that can be repaired shall be conducted. Army personnel will assist the successful offeror in this

process. Trials for the proposed process and its ability to repair damage shall be conducted. The characteristics of the proposed repair process and its effect upon the geometry and metallurgical characteristics of the repaired spiral bevel gear shall be evaluated. To facilitate process development and evaluation, the Army will provide the successful offeror with two spiral bevel gears previously rejected during the overhaul process at Corpus Christi Army Depot. These gears are from the tail rotor drive train of the UH-60 helicopter and are approximately 5 inches in outside diameter with a face width of 1.5 inches. The gears are fabricated from case carburized AMS 6265 steel. Effort in phase I should include the characterization of the initial surface topography and geometry of the provided gears followed by application of the refinishing process. Post treatment analysis should include documentation and analysis of the resulting surface topography and gear geometry.

PHASE II: The results of the Phase I effort shall be further developed to scale-up the proposed approach and optimize the refinishing technique and expand its application to spiral bevel gears of larger sizes (up to 20 inches in diameter). The specific approach to conducting this optimization and scale-up effort shall be conducted utilizing a rotorcraft airframe manufacturer or aerospace gear supplier as a consultant. Selected spiral bevel gears shall be repaired using the proposed process. Detailed inspection of the gear shall be conducted to assess its conformance to the original manufacturer's specifications. Testing of gears in rig type environment shall be conducted to assess any potential performance impacts from the repair process. Testing of repaired gears in a full scale helicopter transmission shall be conducted to assess the system level performance and durability. An economic analysis of the potential cost saving versus the cost of purchasing new gears shall be conducted.

PHASE III: Effort in this phase shall involve further collaboration with the helicopter manufacturers regarding design and manufacture of additional spiral bevel gears to which the process could be applied. Additional gears shall be processed incorporating any improvement resulting from the Phase II effort. Additional testing may be necessary to further prove the advantages of the process and potentially qualify it for service shall be performed.

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KEYWORDS: gears, refurbishment, pitting, surface finish, isotropic, manufacturing processes, residual stress

A11-050 TITLE: Water Generation from Atmospheric Humidity Technologies

TECHNOLOGY AREAS: Chemical/Bio Defense, Human Systems

ACQUISITION PROGRAM: PEO Combat Support & Combat Service Support

OBJECTIVE: The objective of this project is to develop a scalable energy-efficient technology to generate potable water from atmospheric humidity in hot arid environments. This technology must be adaptable to compact, rugged, mobile, water generation systems to support soldiers deployed in field environments.

DESCRIPTION: Water purification technology has undergone significant advances in the past few decades, however, water sustainment on the battlefield still follows the age old practice of locating a water source, treating the water to make it potable, and then transporting the water in bulky containers to the soldiers. For the current

forces over half of the sustainment requirement is the distribution of bulk liquids. As the Army evolves into a lighter and more deployable force focused on the concept of force projection water distribution becomes an even larger concern for military logistics. The ability to generate water at the point of use would reduce or even eliminate the transportation requirement and have a cascading effect on reducing the overall logistics requirement of the force.

The goal is to develop a system that has the capability to generate water on demand when no traditional source (i.e. river, lake, or ocean) is available using atmospheric humidity. The Army is not interested in simple refrigeration systems but rather novel technologies that reduce the energy requirements, size, and weight of the system. Current state of the art systems use mechanical vapor compression cooling systems with or without energy recovery and desiccant humidity concentration. These systems are energy intensive, requiring on the order of 570 watt-hour per liter of water produced for ambient conditions of 70 degrees F and 40 % relative humidity. Additionally these types of systems do not scale down well to mobile systems. The system must be able to generate potable water in sufficient quantities in all environments, including nuclear, chemical and biologically contaminated areas. The water generation units should be scalable to any size, sustainable, and generate enough water to be of use to the DoD in a timely fashion. As a baseline the system should have a production rate at least equal to the current military systems, for traditional sources, of the same size, weight, and power consumption.

PHASE I: Laboratory experiments and a proof of concept benchtop breadboard system should be completed. These experiments should demonstrate the capability to produce water from atmospheric humidity at 285 watt hour per liter or less at ambient conditions of 70 degrees F and 40% relative humidity. The system should also be able to produce water at conditions of 2 grams of water per kilogram of air at a maximum of 1140 watt hour per liter. The experiments should also demonstrate the feasibility of continuous operation. A conceptual design shall be provided demonstrating the feasibility of a 500 gallon per day system that would be transportable on a 5 ton trailer.

PHASE II: Based on best design parameters discovered in Phase I build and demonstrate a demonstrator which can be used by various military and other defense and support organizations for military, humanitarian assistance, and disaster relief operations. The demonstrator will be skid or pallet mounted, produce at least 2 gallons per hour, with an onboard storage capacity of 10 gallons and be able to operate for 24 hours without any required maintenance. The system will meet the phase I energy metrics and the product water will meet Technical Bulletin Medical 577 water quality standards.

PHASE III: Build scaled system to meet the needs for use at an expeditionary Army water treatment site and for humanitarian relief efforts. Create a manufacturing plan that will facilitate both product scaling and low rate initial production of both military and emergency response units.

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KEYWORDS: Water Generation, Water from Air, Atmospheric Humidity

A11-051 TITLE: Expeditionary Wastewater Treatment Technologies

TECHNOLOGY AREAS: Chemical/Bio Defense, Human Systems

ACQUISITION PROGRAM: PEO Combat Support & Combat Service Support

OBJECTIVE: Develop and demonstrate a high recovery, energy efficient gray and black wastewater treatment system that can be used to support a 150 person Army base camp during expeditionary operations.

DESCRIPTION: The current and future demands of a highly mobile, resource limited Army base camp call for new/advancements in technologies for wastewater treatment and reuse. The Army must continue to improve and optimize its water management to meet mission requirements. The need for reductions in the water supply burden

of base camp operations and the safe discharge of wastewater require innovative technologies with the capability to treat gray (i.e., shower, kitchen, laundry) and black water (i.e., toilet) so that it can be discharged into the environment, thus eliminating the need for waste hauling. Shower Water Re-use Systems (SWRS) are currently being employed in base camp operations to reduce water supply, however there is still a need for reducing the amount of wastewater that must be hauled from base camps.

The Army has identified the following areas as key technology challenges to developing and fielding a wastewater treatment system for base camp applications; rapid start up of biological systems, the ability to adapt to widely varying load conditions, and the reduction of the system energy demand [1-2]. Examples of technologies that have been identified with the potential to address the key technology challenges are: integration of biological processes with physical/chemical processes, microbial fuel cells, and hollow fiber membrane biofilm reactors [1-4]. These respectively provide potential approaches to reduce the impact of variable loading and reduce volume, reduce the energy and possible export energy by capturing energy available in the waste stream and addressing all of the areas above through the efficient delivery of gases to a fixed biofilm on a physical separation media. An acceptable technology solution should be energy efficient, low-maintenance, provide high recovery, and be operational over a wide range of temperatures (-25 F to 140 F). The system needs to meet the Army requirement to be deployable and mobile. This means the system must be set up and fully operational within 1 to 2 days. The system must also be adaptable to different and variable influent wastewater quality. Minimization of the production of any harmful discharge/by-products and any consumables needed is required; avoidance of these items is optimal. The system should be able to treat a capacity of 3,000-12,000 gallons/day. Power requirement should not exceed 29kW and the ability to use variable power sources including alternative energy sources is desirable.

PHASE I: A proof of concept laboratory-scale to breadboard unit that treats wastewater should be constructed and laboratory characterization experiments completed. Finalize a conceptual design for developing and prototyping a material system that is suitable for use by a small Army unit for expeditionary operations.

PHASE II: Based on best design parameters discovered in Phase I, build and demonstrate a quarter-scale pallet/skid-mounted prototype demonstrator that can be tested in a relevant environment. The system shall produce an effluent that meets or exceeds the EPA National Pollutant Discharge Elimination System limits for secondary treatment BOD 30 mg/L, TSS 30 mg/L, pH 6-9, and removal 85% for BOD and TSS [5]. A final prototype demonstration will be required 12 months from the initial demonstration that incorporates any updated user requirements and design changes. The final system should not exceed a pack out volume of 416 cubic feet and should weigh less than 7,110 pounds. The unit should be easy to operate with the ability to provide unattended automatic operation, provide real time system monitoring and be self-monitoring.

PHASE III: Build a commercialization scaled system to meet the wastewater treatment needs for a small unit (150 person) expeditionary base camp site and demonstrate the system in a relevant environment. Create a manufacturing plan that will facilitate both product scaling and low rate initial production of the system. Potential commercial applications of the system would include humanitarian assistance and disaster relief efforts.

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KEYWORDS: Wastewater treatment, Wastewater reuse.

A11-052 TITLE: Development of High Power Density Final Drive for the Bradley Infantry Fighting Vehicle

TECHNOLOGY AREAS: Ground/Sea Vehicles

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: To conduct basic research into the development of a high power density final drive for the Bradley Infantry Fighting Vehicle.

DESCRIPTION: Due to the installation of heavy survivability kits on today's fleet of combat tracked vehicles, the mobility performance of these vehicles have degraded from the increased vehicle weight and many platforms no longer meet mobility requirements. Efforts are underway to recapture the lost mobility performance through mobility upgrades of the engines, transmissions, final drives, and suspension systems. The practical approach is to recover lost mobility without requiring undesirable vehicle structural changes for integration. To achieve this, higher power density solutions are necessary so that more power can be generated and transmitted within the existing or smaller space claims. The Army has put significant effort in improving the power density of engines and transmissions; however, little effort has been placed on exploring opportunities to improve the power density of final drives. As vehicle horsepower increases to overcome vehicle weight growth, it is highly desirable to upgrade the final drive systems with new technologies so that they can transmit more power within their current packaging environment.

The Army is seeking innovative technology for cost effectively increasing the power density of final drive gearbox assemblies. Innovative solutions must allow for the provision of upgraded final drives for today's tracked vehicles that are identical in form and fit to today's final drive assemblies, but with the ability to transmit more power. Today's fleet of tracked vehicles would benefit by offering technology for increasing mobility performance without requiring significant changes to the surrounding final drive interfaces such as the vehicle structure, track system, or powerpack. Future Ground Combat Vehicle (GCV) design and development efforts would also benefit by offering improved final drive technology to maximize the mobility performance of this new tracked vehicle.

Proposed SBIR will be concentrated on power transmission for increased torque and horsepower capacity. Research will also investigate weight savings and efficiency gains. Expected gains are an increase in power transmission from 600hp to 800hp and a torque capacity of 62,000 ft-lbs for a finite duration while maintaining the same space claim. A weight savings of 20% and a 1-3% efficiency gain will be target objectives.

Innovative solutions that could improve power density of final drives include those for gear geometry, material selection and heat treating, coatings, lubrication, fabrication, and integration. Innovative concepts for reducing weight, improving efficiency, providing a quick driveline disconnect, reducing costs, and providing for condition based maintenance are desirable in addition to those that improve power density.

PHASE I: Evaluate feasibility of three concepts for improved final drive power density; including gear design and configuration, tribology studies, and application of existing light weight or composite materials (such as aluminum or magnesium alloy housings). Perform an analysis to select the best technical approach for a Phase 2 design, build, and demonstration phase. Demonstrate performance, weight, and efficiency improvements (see above metrics) through modeling and simulation with supporting engineering analyses.

PHASE II: Improve and refine, test, and apply concepts to current Bradley final drive. Analyze further, design, and produce one or more prototype final drive sets for dynamometer test and evaluation (demonstrate technology feasibility).

Commercial applications where high power density geared systems are sought would benefit from this technology. For example, wind turbine power generation, mining and heavy construction equipment manufacturers would significantly benefit from light weight, high power density gearbox solutions with increased efficiencies. Develop commercialization plans to identify target partners (both military and commercial) and facilitate the technology transition to manufacturing.

PHASE III: By partnering with a tracked vehicle platform integrator, develop, validate, and launch the higher power density final drive into Bradley combat vehicle. If successful, the technology will be adaptable to other platforms and transferable across the Army's existing fleet of tracked vehicles as well as new tracked vehicle development.

Commercial applications where high power density geared systems are sought would benefit from this technology. For example, wind turbine power generation, mining and heavy construction equipment manufacturers would significantly benefit from light weight, high power density gearbox solutions with increased efficiencies.

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KEYWORDS: final drive, power density, tracked vehicles, mobility performance, Bradley

A11-053 TITLE: High Efficiency Fans for Underhood Cooling of Military Vehicles

TECHNOLOGY AREAS: Ground/Sea Vehicles

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: Highly efficient cooling fans that can be integrated for underhood cooling of military combat, tactical and commercial vehicles which will improve vehicle operational capability in hot climates.

DESCRIPTION: Currently many vehicles in the Army fleet are using inexpensive, low technology, automotive axial flow fans which are in the neighborhood of 43% efficiency (static). More advanced technology fans have been implemented into a few vehicles which are in the neighborhood of 75% efficient. The static efficiency of a fan is a measure of how effectively a fan moves air against the system resistance. Static pressure times the airflow rate times a constant divided by static efficiency equals fan power. If static efficiency is increased, with the same airflow and pressure coming out of the fan, then the horsepower requirement for the fan is reduced, thereby providing more power for mobility. This additional power is significant, and can contribute to upwards of 8% more horsepower to be utilized for other vehicle requirements, or for operating in hot ambient environments. With improved fan efficiencies, more power can be dedicated to powering up hills, along with accelerating along level surfaces, or powering auxiliary equipment. Additionally, better vehicle fuel economy can also be achieved by operating with more efficient fans.

Building a compact fan that fits within the tight space-claim of military vehicles is paramount. Military vehicles generally require a cooling system capable of maintaining engine and transmission operating temperatures within specified limits while operating continuously under full load at 0.7 Tractive Effort to Gross Vehicle Weight ratio (TE/GVW) under the maximum conditions of +120 degrees F, and the cooling system must be capable of not exceeding temperature limits while operating at rated engine power (tractive effort is the force exerted at the running gear to propel the vehicle). At the end of Phase 3, meeting this full-load tractive effort at 120 degrees F is the goal of the program for the target vehicles utilizing the fan developed under this SBIR.

Two separate fans will be developed in order to target both combat and tactical vehicles. The combat vehicle planned for integration of the first fan will be the Paladin Integrated Management (PIM) vehicle, known as the PIM Paladin. The PIM Paladin is targeted for a cooling upgrade. The PIM has a Bradley powerpack with a different integrated cooling pack. Independent PIM TARDEC full-load cooling tests are upcoming within the next year. The tactical vehicle target for integration of the second fan will be Variant C of the Joint Light Tactical Vehicle (JLTV).

The JLTV vehicle most closely matches the requirements of a commercial truck and thus satisfies the commercialization requirement in the SBIR goals.

The SBIRs initial build will be for fans with a minimum static efficiency of 85%. This efficiency exceeds the efficiency of any vehicle fan known to be built. The innovative approach will attempt to meet the flowrate and pressure rise requirements while increasing the efficiency of the fan. A Research and Development approach will be needed in order to achieve the efficiencies required for the effort. Mixed-flow fan and accelerated vaneaxial flow fans are currently used in higher-efficiency applications (50-75% efficient range), however the offerer will have the freedom to explore the flow pattern that makes sense for the effort.

This effort will be completed within the minimal space-claim that will allow for retrofitting into existing military vehicles. The first phase will be a study to define the efficiency and component geometry of an underhood fan using technical engineering analysis which will include a Computational Fluid Dynamics (CFD) study. This CFD modeling will provide a defined envelope for the pressure and flow requirements of the PIM and JLTV vehicles. It will also provide details of the blade and housing design of the fan. In Phase 2, an initial prototype will be built and component tested. Additional CFD modeling will occur as the phase 1 modeling will be validated, and improvements and design improvements will be analyzed. Two fans will then be provided to the government for internal testing. In Phase 3, the contractor will be provided a vehicle from the Army for integrating the fan and conducting relevant testing. Testing will focus on maintaining engine and transmission operating temperatures within specified limits while operating continuously under full load at 0.7 Tractive Effort to Gross Vehicle Weight ratio (TE/GVW) under the maximum conditions of +120 degrees F.

PHASE I: Complete a feasibility study and preliminary design report for a high-efficiency fan build that fits the geometry space claim defined by the Government. This will include a Computation Fluid Dynamics study which will define and develop the fan requirements. Following this study, deliver sufficient initial fan design details to the Government to allow analysis within TARDEC's CASSI business group.

PHASE II: Build an initial prototype fan, and component test the fan. Use CFD to refine the fan design. With the lessons learned from this initial prototype, design and build a follow-on fan. Complete the component testing. Make fan available for government testing.

PHASE III: With the vehicles provided by the Army integrate the fan into the vehicles. Complete full-throttle, hot climate testing. If successful, complete engineering change proposal for the Army vehicle(s). Production fans can be then integrated into vehicles, as required. Commercial truck applications which more closely match with the JLTV vehicle will be explored in order to reduce the overall production costs to the government.

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KEYWORDS: Keywords: Fan, Propulsion, Engine Cooling, Airflow, Thermal Management

A11-054 TITLE: Advanced High Voltage Optical Switches for Launchable Compact RF Warheads

TECHNOLOGY AREAS: Weapons

ACQUISITION PROGRAM: PEO Missiles and Space

OBJECTIVE: The objective of this effort is to develop high voltage optical switch direct to RF conversion technology which integrates the switching light source and high voltage source within the supporting RF transmission line to form a self contained RF module that could be inserted into either the GMLRS or ATACMS missile platform.

DESCRIPTION: It has been shown that high voltage optical switches can be effectively integrated into a charged transmission line, at appropriate intervals, to create a direct DC to RF conversion of electrical energy in a frozen wave structure. These systems can be quite compact and effective against IED electronics and other electronic systems with the potential of long range interdiction, however they require an external high energy laser system to trigger the switching circuits, which limit the application and the size of the platform on which they could be mounted. They also require medium range high voltage sources mounted externally to the transmission lines for between pulse charging of the RF circuits, increasing the hazard and complexity of the system.

The focus of the SBIR topic to create a charged transmission line with integrated optical switches that also integrates the laser trigger source onto the transmission line as well as the high voltage power supply. The final embodiment of this effort will be an integrated module that can be stacked into arrays to form high power RF modules for a multitude of applications.

The modules should be of size and volume to fit within either the GMLRS or ATACMS payload bay and be totally self contained. The desired payload specifications are:

1. Total weight <200 lbs including power supply
2. A diameter less than 7.5"
3. A length less than 3'

The RF source developed under this research should operate at a frequency of either 915 MHz or 1.3 GHz and produce a minimum of 5 RF cycles. It should be able to operate for a minimum of 10 seconds with a pulse repetition rate of 1 kHz. The source should generate a nominal electric field of 50,000 V/m normalized to 1 meter. There is no preference as to the antenna pattern, gain, or beam width.

PHASE I: Investigate methods for incorporating the optical source technology and high voltage source within the supporting RF transmission line. This should include a trade study with predictions as to size and volume of the proposed RF modules and a basic demonstration of the optical switching technology. The source should be designed with shock hardening in mind with plans for the final embodiment to be hardened for missile launch.

PHASE II: Develop and demonstrate a standalone module and demonstrate free field RF transmission within a laboratory environment. The device should be capable of producing a frequency of 915 MHz or 1.3 GHz with a minimum of pulse length of 5 RF cycles. It should be able to operate for a minimum of 10 seconds with a pulse repetition rate of 1 kHz. The device should generate a nominal electric field of 50,000 V/m normalized to 1 meter.

PHASE III: The final embodiment of the module developed in phase II, would be a flight hardened, drop in device, which would be test launched on either a GMLRS or other in inventory GFE missile. At this phase of development, which would result in a TRL level 5 device, demonstrations of effectiveness would be sought and demonstrations of fly ability of the source would be performed.

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- 2) Photovoltaic-FET for optoelectronic RF/ μ wave switching, IEEE Transactions on Microwave Theory and Techniques, Vol 44, Issue 10

KEYWORDS: High Power Microwave, High Voltage Switching, Optical Switching

A11-055 TITLE: Weapon Orientation Sensor for Simulated Tactical Engagement Training

TECHNOLOGY AREAS: Sensors, Electronics, Human Systems

OBJECTIVE: Develop a novel approach to measure 6 Degree of Freedom (6 DOF) position orientation system which is ultra low power, can be used on a Soldier's weapon, is capable of determining absolute heading, and requires no calibration procedures.

DESCRIPTION: The Army is lacking a field proven way of training Non-Line-Of-Site weapon systems, such as M109A6 SP Paladin, M119A2 105mm Towed Howitzer, MK-19 Grenade Machine Guns, and Mortars in the Live Training environment. Laser based training systems, e.g. Multiple Integrated Laser Engagement System (MILES), have provided a method to simulate, only, Line-Of-Site weapon systems, e.g. M16 and M2 machine guns. Unfortunately, lasers cannot be used to train NLOS weapons.

Current Micro-Electro-Mechanical Systems (MEMS) technology has provided system on chip capabilities for measuring 6 DOF orientation, however, due to poor signal-to-noise ratios and their sensitivity to temperature changes, accuracy is sacrificed and has proven insufficient to meet the Army's technology gap. Current high-end, tactical grade Inertial Measurement Units (IMUs) provide the needed accuracy and environmental robustness, but remain unsuitable due to extraordinarily large size, power consumption and unit cost. We are seeking an innovative approach to precisely measure 6 DOF orientation, but in a low cost, small size, and low power form factor. It must be capable of measuring absolute heading (geodetic north) with an accuracy of 3 angular mils. The approach must be capable of measuring orientation in all environmental conditions where Soldiers can operate. The device must operate while undergoing a slew rate of 60° per second (threshold metric) / 300° per second (objective metric). Additionally, the sensor and its associated processing electronics shall be enclosed in a package no greater than 1 inch wide by 1 inch high by 4 inches long while assuming that minimal power will be provided from an external source to the sensor. Current sensor technologies require an extensive calibration procedure. This sensor should require no calibration procedure. We are also seeking a solution which is low cost, at a production cost of less than \$2,000 per unit.

PHASE I: Develop and provide a review of a detailed design which includes an Analysis of Alternatives (AoA) based upon cost and performance. The design review shall cover the hardware, software, sensor accuracy, power consumption, and weapon system applicability/viability.

PHASE II: Develop an Engineering Developmental Model (EDM) or prototype to be used in a laboratory demonstration of technology (TRL 4). Successful laboratory demonstration will be followed by further prototype refinement and a culminating in a relevant environment demonstration (TRL6).

PHASE III: Likely military applications are for simulated tactical engagement training, UAV (Unmanned Aerial Vehicle) flight control or ground based unmanned vehicle navigation and flight control, and for far target laser designators. Commercial application would be for light aircraft navigation and flight control. Likely transition opportunities in the test and training domains under PEO STRI are the One Tactical Engagement Simulation System (OneTESS) and the Operational Testing - Tactical Engagement Simulation System (OT-TES). In the operational domain, likely transition opportunity exists with PEO Soldier PM Soldier Systems & Lasers and their Laser Target Locator Modules (LTLM) that implement the use of a digital magnetic compass (DMC).

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- 1) "Optical Flow Estimation Using High Frame Rate Sequences", S. Lim and A. El Gamal, Stanford University, Department of Electrical Engineering, Information Systems Lab, Stanford, CA
- 2) "Real-time Accurate Optical Flow-based Motion Sensor", Z. Wei, D. Lee, B. Nelson, and J. Archibald, Dept. of Electrical and Computer Engineering, Brigham Young University
- 3) "Precise Image-Based Motion Estimation for Autonomous Small Body Exploration", Johnson, L. Matthies, 5th International Symposium on Artificial Intelligence, Robotics and Automation in Space
- 4) "State Estimation using Optical Flow from Parallax-Weighted Feature Tracking", J. Kehoe, A. Watkins, R. Causey, and R. Lind, Air Force Research Lab

KEYWORDS: Geometric pairing, image processing, optical flow, feature tracking, motion field analysis

A11-056

TITLE: Poled Films for Compact Single Shot Power Supplies

TECHNOLOGY AREAS: Weapons

ACQUISITION PROGRAM: PEO Missiles and Space

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: The objective of this effort is to develop energy storage films for very compact single shot power supplies to be used in missiles and munitions.

DESCRIPTION: Ferroelectric generators are compact single shot power supplies. This generator contains a ferroelectric material that stores energy when it is poled. When this material is shocked, the stored energy is released as electrical energy that can be used to drive various loads. In addition to the ferroelectric effect, the piezoelectric effect could also be exploited. In the case of piezoelectric materials, the electrical energy comes from the shock wave, when it stresses the material. Current generators use ferroelectric ceramics, which tend to crack under g-loading causing the generator to electrically breakdown under high voltage. Therefore, the objective of this effort is to investigate new types of ferroelectric and piezoelectric films with properties that are equal to or better than those of Lead Zirconate Titanate (PZT) 95/5, which is the current standard for ferroelectric materials. In addition, techniques for manufacturing, uniformly poling, and monitoring the polarity of the material while in the munitions are to be investigated. The ferroelectric generators in which these materials will be used will have a diameter less than 40 mm and be capable of delivering 100 kV to a load.

PHASE I: Investigate various ferroelectric and piezoelectric films to determine which films can maintain a surface charge density of at least 39 coulombs/square centimeter for long periods of time. Integrate these films into a Ferroelectric Generator with a diameter less than 40 mm and determine if the generator is capable of delivering 30 to 50 kV to a capacitive load. In order to perform the tasks identified above, the proposing firm will need to have access to explosive test facilities.

PHASE II: Design the generators so that they can deliver at least 100 kV to a variety of resistive and capacitive loads. Develop techniques for manufacturing and uniformly poling the energy storage films. Develop a technique for periodically monitoring these films while in the generator to determine if it is maintaining its polarization.

PHASE III: Ferroelectric materials are used in a variety of military and commercial devices. For example, PZT, which has been around for 50 years, is used in sonars, ultrasound imaging systems, sensors (vibration, pressure, acoustic, proximity, and flow), precision actuators, and power ultrasonic devices for therapy, machine tools, motors, and so on. The proposed new films could potentially be used in some of these applications. One application the Army and Navy are looking at is as a single shot high voltage power supply for use in munitions and warheads.

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- [1] E.F. Alberta, B. Michaud, W. Hackenberger, B. Freeman, D. Hemmert, and A. Stults, "Development of Ferroelectric Materials for Explosively Driven Pulsed Power Systems", IEEE Pulsed Power Conference, 28 June - 2 July, 2009, Washington DC.
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KEYWORDS: ferroelectric, pulsed power, explosives, warhead

A11-057 TITLE: Lightweight Nanosatellite Constellation Communications System

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

ACQUISITION PROGRAM: PEO Missiles and Space

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop a Lightweight Nanosatellite Communications subsystem based on LASER communications to enable high bandwidth spacecraft to spacecraft communications in a small size.

DESCRIPTION: The US ARMY Space & Missile Defense Responsive Space (SMDRS) program has been developed to meet the space-related urgent needs of the warfighter such as battlespace awareness and battle command in order to improve the observation and collection of information worldwide, the command and control of battlespace awareness assets, and communication in the combined/joint environment. The payloads that nanosatellites would carry to enable these capabilities would be Intelligence, Surveillance, and Reconnaissance (ISR) sensors and communications transceivers. These satellites would be launched into inclined low earth orbits (LEO) and operate for a period of six months to two years. The earliest classes of these satellites would be approximately 3 kg and conform to the "3U" cubesat form factor, with possible expansion to larger spacecraft later as new deployment concepts are developed.

A key area of need for these nanosatellites is a low-mass, low-volume solid state LASER Communications subsystem that would provide communications between nanosatellites and possibly to the ground. It is anticipated that a constellation of LEO nanosatellites would need to communicate large amounts of data from on-board sensors between each other and to the ground since only a few may be in view of ground stations at a time. In order to provide this capability to a nanosatellite, current LASER communications systems would have to be significantly reduced in size, weight and power utilization in order to accomplish these objectives.

It is also anticipated that the earliest classes of these nanosatellites would be launched as secondary payloads in the P-POD structure. These opportunities imply that reliability and the success of the primary payload is paramount, so nanosatellite communications systems based only on solid state LASER technologies shall be considered at this time.

The objective of this research is to create an experimental solid state nanosatellite LASER communications subsystem that has the following features:

Currently Nanosatellites can generate 10 to 20W of on orbit average power. Current pointing systems have a steady-state error of 0.15%. Current optical inter-satellite links achieve single-wavelength data transmission at 2.5 Gbps and high-precision tracking of 0.001 deg or less. There are no equivalent size laser communication packages with these parameters. Development of this system would advance the state of the art in size reduction, power consumption, and pointing accuracy of current laser communication systems.

- Has a total mass of less than 15% of the available mass, e.g., roughly 0.5kg of a 3U form factor, including reaction mass and control system;
- Fits within less than 15% of the available volume (assume an overall nanosatellite volume of 10cm X 10cm X 30cm);
- Have the pointing accuracy to communicate with fore and aft satellites based upon an SMDC-ONE nanosatellite in a simple 10-20 satellite ring constellation;
- Provide intersatellite communication data rates up to 2 Gbps per second;
- Power consumption should have a peak no greater than 10 Watts with a duty cycle of no more than 10 Watts for 10 minutes;
- Provides an in-orbit minimum design life of 1 year.

PHASE I: Conduct feasibility studies, technical analysis and simulation, and small scale proof of concept demonstrations of proposed lightweight nanosatellite LASER Communications innovations. Develop an initial conceptual approach to incorporating a LASER Communications system onto a nanosatellite and include system estimates for mass, volume, power requirements, and duty cycles. Deliverables should include monthly status reports, feasibility demonstration reports and any hardware produced.

PHASE II: Implement technology assessed in Phase I effort. The Phase II effort should include initial lightweight nanosatellite LASER communications designs, mock-ups, and, if possible, a launch-ready prototype ready to integrate into a nanosatellite bus. Initial technical feasibility shall be demonstrated, including a demonstration of key subsystem phenomena. Deliverables should include quarterly status reports, design documentation and any hardware produced.

PHASE III: The contractor shall finalize technology development of the proposed lightweight nanosatellite LASER Communications system and begin commercialization of the product. In addition to military communications or intelligence, surveillance and reconnaissance (ISR) missions, commercial civilian applications for a lightweight nanosatellite LASER communications subsystem could include space-based satellite communications. Phase III should solidly validate the notion of lightweight nanosatellite LASER Communications with a low level of technological risk. The goal for full commercialization should ideally be Technology Readiness Level 9, with the actual system proven through successful mission operations. Specifically, Phase III should ultimately produce lightweight nanosatellite LASER Communications suitable for nanosatellites applications, i.e., with a total satellite weight of less than ten kilograms, yet having capabilities comparable with larger satellites weighing hundreds or thousands of kilograms. The contractor must also consider manufacturing processes in accordance with the president's Executive Order on "Encouraging Innovation in Manufacturing" to insure that the lightweight systems developed under this SBIR can be readily manufactured and packaged for launch and on-orbit operability.

While initial (Phase I and II) sponsorship and funding may come from Army Space and Missile Defense Command, during Phase III that support could conceivably transition or expand to the appropriate division of the Army Program Executive Office for Missiles and Space (PEO M&S) upon full rate production and deployment. PEO M&S could maintain a stockpile of lightweight nanosatellite LASER Communications subsystems ready to mate to nanosatellite buses, which when launched responsively could meet urgent warfighter needs. Simultaneously, commercial versions of the Nanosat LASER Communications could be produced for civilian and scientific applications. Commercial satellite manufacturers could incorporate lightweight nanosatellite LASER Communications into a variety of commercial nanosatellites for sale of complete units to various interested customers. Commercial companies could also provide competitively priced nanosatellite-based communications or remote sensing services to paying customers, including the national security community.

PRIVATE SECTOR COMMERCIAL POTENTIAL: There is a perceived potential for commercialization of this technology. The primary customer for the proposed technology will initially be the Department of Defense, but there could also be other applications in the areas of commercial satellite communications.

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KEYWORDS: LASERcom, nanosatellite, nanosat, microsatellite, microsat, responsive space

A11-058 TITLE: Vertical Cavity Surface-Emitting Laser (VCSEL) pumps for High Energy Erbium or Thulium Fiber Lasers

TECHNOLOGY AREAS: Sensors, Weapons

ACQUISITION PROGRAM: PEO Missiles and Space

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To research and develop Vertical External Cavity Surface-Emitting Laser (VCSEL) array fiber coupled pumps or single emitters for Erbium or Thulium fiber lasers. The goal is to design, build and test a VCSEL array that surpass traditional edge emitting diode array performance for pumping fiber lasers in the areas of higher efficiency, lower production costs, higher brightness, and better thermal properties.

DESCRIPTION: While it has been determined that high energy lasers can provide a tremendous benefit to the Army for area protection against rockets, artillery, and mortars (RAM) and other potential threats, there is concern about current Nd:YAG based high energy laser systems potentially causing collateral eye damage due to scatter off of target surfaces. In addition, the efficiencies of slab based solid state lasers make it desirable to explore the possibilities of reduced eye hazard fiber based high power lasers. This SBIR topic focuses on development of the VCSEL pump array for pumping an Erbium or Thulium fiber laser. Early research investment in laser technology that supports higher efficiencies, more compact, reduced eye hazard wavelength, higher power, and lower cost is critical. The purpose of this SBIR is to investigate and demonstrate through laboratory experiments and demonstration, modeling and simulation, and building a breadboard VCSEL pump array in phase II, the potential of high brightness, and cost savings of using VCSEL technology for fiber laser pumping. The use of VCSEL technology for fiber laser pump source has many benefits. For field applications, it is important to note that VCSEL emitters have demonstrated high temperature operation and can be cooled at coolant flow rates that are much lower than traditional edge emitting diode arrays. It is anticipated that VCSEL pump arrays would tremendously reduce the size and weight for a fiber based laser system. The fabrication methods of the VCSEL arrays are appropriate for lowering the ultimate cost of the most expensive component for diode-pumped fiber lasers, the diode arrays, thus providing a long term cost advantage.

PHASE I: Conduct research, analysis, and studies on the selected VCSEL pump array architecture and develop measures of performance and document results in a final report. Provide analysis supporting the claimed VCSEL array performance. Identify requirements and performance metrics required for VCSEL fiber coupled pumping of a fiber laser. The phase I effort should include modeling and simulation results supporting performance claims. The effort should also produce a preliminary concept for VCSEL array proposed to be built during the phase II effort.

PHASE II: The Phase II effort should consist of, completing the breadboard VCSEL array fiber coupled pump design, building VCSEL base fiber coupled pump, and testing against the performance metrics identified in phase I. Added validation of the VCLES pump concept could be to actually perform an experiment demonstrating the performance by pumping an Erbium or Thulium fiber laser. The data, reports, and tested VCSEL array hardware will be delivered to the government upon the completion of the phase II effort.

PHASE III: If the phase II program is successful, the direct application to the developed VCSEL technology will be to insert it into the high power laser development program that is be managed by the US Army Space and Missile Defense Technical Center. In addition, the VCSEL technology can be used to replace many diode array pumped laser devices to reduce size, weight, and cost. There are many potential applications of a reduced eye hazard wavelength high energy laser. Commercial and Military applications include laser remote sensing, laser

communication, material processing, and remote target destruction. Industrial high-power applications of high-power solid-state lasers include welding, drilling, cutting, marking, and micro-processing. High energy DoD laser weapons offer benefits of graduated lethality, rapid deployment to counter time-sensitive targets, and the ability to deliver significant force either at great distance or to nearby threats with high accuracy for minimal collateral damage. Laser weapons for combat range from very high power devices for air defense to detect, track, and destroy incoming rockets, artillery, and mortars to modest power devices to reduce the usefulness of enemy electro-optic sensors. Building and testing a scalable reduce eye hazard wavelength high energy laser breadboard device using the demonstrated VCSEL technology would be a phase III effort.

REFERENCES:

1. W. Koechner, "Solid-State Laser Engineering," Springer-Verlag
2. D. Garbuzov and M. Dubinskii, "110 W Pulsed Power From Resonantly Diode-Pumped 1.6um Er:YAG Laser", Applied Physics Letters, 19 September 2005.
3. J. S. Sanghera, V. Q. Nguyen, P. C. Puresa, R. E. Miklos, F. H. Kung, and I. D. Aggarwal, "Fabrication of Long Lengths of Low-Loss IR Transmitting As₄₀S(60-X)SeX Glass Fibers," Journal of Lightwave Technology, Vol 14, No. 5, May 1996.
4. Annual Directed Energy Symposium Proceedings available at:
<http://www.deps.org/DEPSpages/forms/merchandise.html>
5. Electro-Optics Handbook, RCA Solid State Division, Lancaster PA, 1974

KEYWORDS: Fiber Laser Pumps, Vertical Cavity Surface-Emitting Laser (VCSEL), High Energy Fiber Laser, Thulium, Erbium

A11-059 **TITLE:** Hybrid Variable Velocity Electric Gun

TECHNOLOGY AREAS: Weapons

ACQUISITION PROGRAM: PEO Missiles and Space

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: The objective of this effort is to develop a hybrid electric gun that uses an environmentally friendly, non toxic liquid, in conjunction with electrical energy to propel small to medium caliber projectiles at velocities approaching 4,000 ft/sec, with variable launch velocity.

DESCRIPTION: Present day small caliber systems utilize propellants and other consumables that create a large logistics trail that includes energetic materials. This effort would provide the basis for the development of a small weapons platform that could be used for anti-personnel and counter rocket and mortar applications. What would be developed under this effort is a brass board gun which utilizes electrical energy in conjunction with a working fluid to provide the kinetic force to drive a projectile at velocities between 3,500 and 4,000 ft/sec, with the ability to vary the launch velocity based upon the electrical energy input. The working fluids for this prototype should be environmentally friendly and be readily available in either a urban or rural setting. Particular emphasis should be given to methodologies that would produce a prototype which could utilize conductive and non-conductive (ceramic) projectiles.

PHASE I: The initial research should focus on the breadboard design and development. The objective of this phase will be to design a prototype, and if possible demonstrate experimentally the feasibility to fire a projectile from the hybrid electric gun, at a velocity similar to that of a 22-caliber bullet.

PHASE II: The objective of this research phase will be to build a prototype gun based upon the prototype design developed in Phase I. This breadboard prototype should experimentally demonstrate measured projectile velocities of 3,500 to 4,000 ft/sec in projectiles greater than 45-caliber using standard rifle or pistol projectiles. In addition to the high velocity aspects, the proposer should be able to demonstrate the ability to modify the velocity on demand. Use of specialized reactive bullets or other projectiles is allowed for demonstration purposes.

PHASE III: A hybrid electric gun has many potential applications in the contexts of the US Army and US Navy. Included in these applications would be anti-personnel and counter rocket and mortar uses. To achieve this utility, the Phase II prototype must be extended to the level of a brass board prototype where some of the commercialization concerns for such a weapon must be addressed. The objective of this phase would be to extend the TRL level to 5, demonstration of the gun in a relevant environment against targets to be defined by the Phase III sponsor.

REFERENCES:

(1) MK 15 Phalanx Close-In Weapons System, <http://www.fas.org/man/dod-101/sys/ship/weaps/mk-15.htm>

(2) http://en.wikipedia.org/wiki/Electrothermal-chemical_technology

(3) <http://www.powerlabs.org/emguns.htm>

(4) http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?reload=true&arnumber=560066

KEYWORDS: Electro-Thermal, Gun, Variable Velocity, Liquid

A11-060 TITLE: All-Digital Radar

TECHNOLOGY AREAS: Sensors, Electronics

ACQUISITION PROGRAM: PEO Intelligence, Electronic Warfare and Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Significant advances have been made in the development of digital components and digital signal processing during the last few years. Improvements in analog-to-digital converters (ADC), direct digital synthesizers (DDS), and improved signal processing algorithms for tracking and discrimination, as well as other unique methods of converting analog received radar signals to digital format have provided the means for moving the ADC function closer to the radar antenna. The ultimate goal is to place this function directly at the output of the receiver low-noise amplifier (LNA), thus resulting in essentially an all-digital radar. Significant improvements in channel balance, phase stability, and implementation of beam forming would result from minimizing the analog components in radar systems. The objective of this topic is to develop methods of implementing radar subsystems that will perform as many radar functions as possible in the digital domain.

DESCRIPTION: Radar transmitters and receivers, which are analog components, have improved steadily over the last few years to the extent that operation of radars over bandwidths of several gigahertz (GHz) is possible. Improvements in antenna design have contributed to this wideband capability. Wide bandwidth leads to improved range resolution as well as to better radar performance in terms of imaging and signal processing, requiring precise range and Doppler information. Since virtually all radar signal processing is done in the digital domain, movement of the ADC function as close as possible to the antenna will result in better radar performance. The conventional radar receiver uses a low-noise amplifier (LNA) followed by a down-converter and intermediate frequency (IF) amplifier. At this point, the IF output may be detected and fed into an ADC to achieve a digital output for processing. Each of these functions is done in the analog domain, and further down conversion into sub-bands of limited bandwidth may be necessary if a single ADC cannot cover the wideband output. All of these functions lead to additional noise and errors due to amplitude drift, phase variations, and digitization which result in decreased tracking and discrimination accuracy. Clearly, the weak link in this functional chain is the ADC. Placement of the

ADC function closer to the antenna will minimize these errors. Such a move will require ADCs that have greatly improved sampling rates and dynamic range. The design of the ADC is based on the trade between dynamic range and sample rate. Dynamic range and bandwidth requirements are based on the radar mode (i.e., search requires high dynamic range and medium bandwidth and discrimination requires high bandwidth and medium dynamic range); therefore a tunable ADC is desired. Current commercial designs have fixed dynamic ranges and bandwidth. Performance at bandwidths of up to ten GHz with resolution of 8 bits is desired. This performance may be achieved by using multiple ADCs, improved ADCs, or by developing totally new approaches to implement the ADC function such as the use of electro-optical methods. One goal of the proposed effort is to improve the noise, linearity, and accuracy of the ADC function while providing increased bandwidth and resolution. Improved radar performance will benefit the warfighter by providing more accurate tracking of rockets, artillery, and mortar rounds, improved situational awareness, and better air defense. Commercial applications of this improved ADC are to weather and air traffic control radars. Although emphasis is placed on development of improved ADCs in this section, this topic is not necessarily an ADC development program. Rather, any reasonable approach to moving the digitization function closer to the antenna will be considered.

PHASE I: Identify and assess various methods of AD conversion. At this stage, innovative approaches to the implementation of this function, with a clear roadmap to the achievement of the stated objectives, are required. Development of new methods of achieving the ADC function is desired. Construction of a working model that demonstrates the proposed approach is highly desirable. In this phase it is recommended that the recipient of this contract work closely with one of the major manufacturers of radar systems to ensure that this work is compatible with existing or envisioned radar systems.

PHASE II: Use the approach(es) developed in Phase I to demonstrate the desired performance of 4 GHz bandwidth and 8-bit resolution by building a prototype. Characterize the performance of this prototype by measuring noise, resolution, linearity, and other errors. Show how the ADC or implemented ADC function would be used in a radar system and demonstrate the desired improved performance by experiment. Show a clear path to exploitation by interacting with radar manufacturers to ensure a commercially viable outcome.

PHASE III: Continue relationships with radar manufacturers with the objective of placing the improved ADC function in major defense and commercial radars, including those used for missile defense as well as tactical radars used for detecting and tracking rockets, artillery, and mortar rounds.

REFERENCES:

1. R. H. Walden, "Analog to Digital Converter Survey and Analysis", IEEE Journal on Selected Areas in Communications, Vol. 17, No. 4, pp. 539 – 550, April 1999
2. Calvin Plett, Foster Dai, John Rogers, Integrated Circuit Design for High-Speed Frequency Synthesis, Artech House, Norwood, MA, 2006

KEYWORDS: Digital Radar, Analog-to-Digital Converter, ADC

A11-061 TITLE: Innovative Appliqué Attachment Methods for Army Vehicles

TECHNOLOGY AREAS: Ground/Sea Vehicles

ACQUISITION PROGRAM: PEO Combat Support & Combat Service Support

OBJECTIVE: The integration of armor packages for Ground combat Systems. New Armor Packages will be mounted to vehicle Structures using successfully developed technology.

DESCRIPTION: The Army is in need of innovative methods of attaching Appliqué armor packages to Combat Vehicle Structures. Many of these armor packages use non traditional materials as a part of the package. These materials are very effective at increasing the protection level of the armor, and also reducing the weight burden on the vehicles. However, the methods of attaching these armor packages have not had a similar increase in effectiveness. The Army is looking to increase the capabilities of Appliqué attachments in several areas:

1. Current attachment methods that are effective are not quick to remove. In order to make needed combat vehicle repairs the attachment methods need to be quickly removed with either simple tools or no tools. This can be an issue as typically attachment methods that can be taken off easily do not hold under the large dynamic loading conditions seen by combat vehicles.
2. Current attachment methods need to improve isolation from vehicle automotive loading. The appliqué can be more optimally designed if they do not need to endure as much structural loading. Improved methods of isolation are required.
3. There is a potential that additional appliqués can be added on top of existing appliqués. These appliqués would be "daisy-chained" 2 (and potentially 3) deep. Attachment methods that can be robust enough to handle the additional weight (~100lbs.) and the resulting cantilever burden are desired. In addition, it would be desirable that a process to perform the "daisy chain" is highly desirable, as well.
4. The development of attachment concepts needs to be weight efficient. The Army has significant interest in increasing soldier protection while decreasing weight. The ability to meet our needs with reasonable weights is most essential to our continued success.

PHASE I: Phase I should be a concept development phase. The selected contractor will be able to finalize the design parameters with the Government and develop between 4 to 6 design concepts. As a part of the design downselect, a vehicle system for testing will be selected. These design concepts should be an entire panel system. The attachment method does not need to be just one type of attachment, but could be an attachment system. However, commonality is favored if and when possible. The concepts shall be developed and presented with supporting evidence for each concept, and a final evaluation. The details of the supporting evidence would be at the discretion of the contractor. However, such evidence may include (but is not limited too) engineering analysis. Material strength data, prototype (or similar design) demonstration, Finite Element Analysis (FEA). Up to two concepts could be downselected for Phase II.

PHASE II: Phase II of this program would involve the testing and further development of the two concepts developed during in Phase I. Prototypes of the downselected concept(s) shall be fabricated and tested under a battery of tests that should include structural, environmental, and ballistic testing. Additional tests may include testing the time it takes to install and remove. The parameters of the testing conditions will be based upon the vehicle system selected in Phase I.

PHASE III: This system does have vast defense vehicle capabilities depending on the degree of success and the adaptability of the final solution. Many current vehicles are employing a system of appliqué armors that could benefit from better attachment methods. In addition, the commercial application of an attachment method that is robust, lightweight, and easily detachable are probably fairly significant.

REFERENCES:

1. Improving Tactical Trucks for the Future, Major Richard L. Harris, Jr., Army Logistician (Sep.-Oct. 2005)
2. Composites on the front lines, Sara Black, High-Performance Composites January 2005

KEYWORDS: Attachments, Joining, Appliqué Armor, Integration, Vehicle Protection

A11-062 TITLE: Increased Autonomous Vehicle Mission Performance Using Advanced Electrical Architectures

TECHNOLOGY AREAS: Ground/Sea Vehicles, Electronics

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: By optimizing a small (100 lbs. or less such as a Talon/Packbot) Autonomous Unmanned Ground System's (AUGS) power storage, generation, and distribution as well as utilizing new power sources and energy

storage technology (batteries, ultra-capacitors, fuel cells, hybrid-electric), the goals of this effort are to improve the mission capability and ensure payload delivery of small unmanned ground robotic systems by:

- 1) Increasing AUGS power availability and mission length
- 2) Increasing AUGS energy storage capability
- 3) Increasing AUGS system efficiency

Promising solutions will improve mission capability by at least 25% with an objective target of 40%, will be compact, light weight, and will be easily configurable and transferable to multiple systems. A field upgradeable kit that includes hardware and software deliverables is envisioned.

DESCRIPTION: Small (100 lbs. or less) AUGS are increasingly important to the U.S. Army and its military and logistical operations. Each AUGS platform has a different main purpose and AUGS platforms can be physically configured for different mission priorities and payloads. The Department of the Army, TARDEC GVPM, TARDEC IGS, the RS JPO, and the NAC are collaborating to develop practical and cost effective ways of extending mission life without extensive re-design/modification. Early investigative studies predict that intelligent contribution from energy storage devices and improvements resulting from advanced system-level power management and control could increase the mission capability, having a positive impact across robotic system platforms.

PHASE I: Phase I will result in a design concept for a configurable and scalable intelligent power management system, which can be added to a variety of AUGS platforms. Technical feasibility and commercial viability will be essential considerations in the Phase I study.

PHASE II: Phase II will entail the design and development of the Phase I design concept. During the duration of Phase II, prototypes of the design concept will be built, configured, and implemented on several "generic" AUGS systems in bench-level technology demonstrators. Objective measurements will be made with a manual or semi-automated data acquisition system. Data will be analyzed and presented at design reviews and will be captured in a final technical report. All SBIR results (including, but not limited to, designs, drawings, electrical schematics, software source code) will be delivered at the conclusion of the program.

PHASE III: The results of the SBIR effort could be applied to military manned and unmanned ground vehicle systems to ensure mission payload and to extend silent watch missions. Commercial application could include autonomous robotic systems that operate in manufacturing environments and small electric vehicle systems that rely on battery operation.

REFERENCES:

1. "Power Management – An Integrated Approach", white paper, Global ET, 2009
2. "Exploring Cognitive Knowledge for Intelligent Vehicle Power Management in Military Mission Scenarios", white paper, 2009, U.S. Army RDECOM-TARDEC

KEYWORDS: electronics, control systems, robotics, power architecture, power management, intelligent power distribution

A11-063 TITLE: High-Strength, Lightweight Material for a Bridge Applications

TECHNOLOGY AREAS: Materials/Processes

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: This SBIR will be used to research an innovative material for use in bridge structures. This material needs to be lightweight, have high strength, high durability, good weather resistance, and high survivability. The material is desired to be used in the entire bridge structure as the main structural components. However, the material could also be used as an enhancement in conjunction with other materials, forming the main structural components. There is no restriction on whether the material is a fiber, ceramic, plastic, or other. A material solution that is only metal is not the desired result.

DESCRIPTION: The material has many desired properties. For ease, the material will be compared to common bridge materials such as steel and aluminum. Ideally, the material solution would allow for approximately a 50% (25%) weight reduction in comparison to a similar steel (aluminum) structure. Ideally, this material would possess similar qualities as steel and aluminum; however have a much greater strength-to-weight ratio. This material needs to withstand a large number of fatigue cycles, both for deck wear and structural fatigue. The desired fatigue limit would be 80% of the ultimate stress for the given material. Ideally, the material would not sustain a single, catastrophic, brittle failure like many fibrous materials; rather a slow, ductile failure is desired for safety. Fracture toughness 25% (50%) greater than steel (aluminum) would be desired. This material needs to withstand a wide variety of climates without any degradation in performance. Climates can be defined as temperature range (-25°F up to 125°F), extended UV exposure, precipitation, sandstorms, wildlife, etc. The material would be able to withstand all climates for 20 years without needing maintenance due to corrosion. It is desired that a single, concentrated, high impact would not compromise performance of the material.

In addition to the desired material properties, there are several desired attributes. If the material is used in conjunction with or attached to other materials, a solution for connecting the different materials is necessary. The desired deflection of the bridge under full load would be comparable to a similar structure made of steel or aluminum. It is desired to not increase the weight of the structure by more than 5% when using a deflection controlled design as compared to any other failure mode. If the material is used in conjunction with another material, it is desired that the materials have similar thermal expansion properties. Ideally, the method of producing the material and assembling the structure would be able to be done in a remote location with limited equipment.

PHASE I: Design and develop the concept material along with testing. During the Phase I effort, analysis of the technical approach proposed should be conducted in detail. This analysis should include discussions with TARDEC to identify the specific requirements for application of the process to a bridge. A preliminary analysis of the potential materials and projected cost of the proposed approach should be conducted. Small scale manufacturing trials and material characterization testing may be conducted to establish basic feasibility and guide the effort to be conducted in Phase II.

PHASE II: Develop, test and demonstrate concept material in a WADI bridge design. The results of the Phase I effort shall be further developed to scale-up the proposed approach and optimize the material methods. Coordination of the specific approach for optimization and scale-up effort with a WADI bridge. This development work shall be supported by necessary design and modeling effort. Manufacturing trials and material property development of increased complexity shall be conducted to evaluate the performance of the specific approach. Application of the material process to a full scale bridge shall be conducted. Fatigue testing to establish the potential benefits shall be conducted. Potential material applications shall be identified and plans for technology insertion and product development conducted.

PHASE III: Material concept would be used on and in the bridging structures to lessen the weight of the overall bridge but could be used to reduce the weight of armor protection. The commercial potential for this material could be lightweight bridging components. Effort in this phase would involve further collaboration with the bridging manufacturers regarding design and manufacture of a specific component to which the process could be applied. Additional testing to further prove the advantages of the material and potentially qualify it for service could be performed.

REFERENCES:

1. Trilateral Design and Test Code for Military Bridging and Gap-Crossing Equipment, Mr. Brian Hornbeck, U.S. Army Tank-Automotive & Armaments Command, 586-282-5608.
2. Strengths and Limitations of fiber reinforce polymer in the civil infrastructure, material advances and the influences on the present and the future developments, L.C. Hollaway & I. Hackman, School of Engineering, Civil Engineering, University of Surrey Guildford, Surrey, UK, 0871-432-6595.

KEYWORDS: Bridging, Weight, Material, Strength, Catastrophic.

A11-064 TITLE: Advanced Rotary Diesel Engine Fuel Injection System for Unmanned and Manned Ground Vehicles

TECHNOLOGY AREAS: Ground/Sea Vehicles

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: To examine, develop, and demonstrate the use of an advanced high pressure injection system in a heavy-fuel (DF-2 and JP-8 compatibility), rotary diesel engine for unmanned and manned ground vehicle applications.

DESCRIPTION: There currently is a shortcoming of heavy fuel engines that have a rated power between 10 and 80 BHP and are compatible with both JP-8 and DF-2, have high power to weight and power to volume density, provide good fuel consumption characteristics, and operate over extreme climatic ranges ranging from below -25 F to 125 F ambient. Today it is difficult to adapt light-duty, automotive diesel piston engines for such applications while meeting power density, packaging, and heavy fuel needs and thus other options are under exploration. One developing technology that could potentially fit this niche market are heavy fuel, rotary diesel engines that can provide from 10 BHP to 60 BHP per rotor, have peak brake fuel consumption less than 0.5 lbm/bhp-hr, and have an engine power density of 1 hp/lbm for ground vehicle applications. A major challenge with such engines revolves around the combustion system development of which the fuel injection system presents a significant challenge due to difficult spray targeting length and time scales associated with rotary diesel combustion systems. Such combustion chamber geometry have significant challenges in properly targeting injector nozzle geometry for JP-8 and DF-2 due the time varying impingement length of each injector spray and the limitation on rotor pocket geometry for enhancing spray mixing and combustion rates without excessive liquid fuel rotor impingement. This topic will focus on developing a flexible, high pressure fuel injection system that can be integrated onto a heavy-fuel, rotary diesel engine and meet the aforementioned power density, power to weight, power to volume, and climatic operating range conditions. Such a fuel system should be able to vary start of injection timing, deliver multiple injection events when necessary, and provide adequate spray formation to avoid excessive wall wetting while providing combustion characteristics amenable to both JP-8 and DF-2.

PHASE I: Identify and assess fuel injection technology that will meet the performance specifications described in the description section and also provide a relevant bench top demonstration. Assessment should include any necessary zero- or multi-dimensional analysis that will aid in selecting the proper fuel injector and nozzle geometry including hole size(s) and angle(s), and the bench top demonstration should provide evidence that the injector has single and multiple injection capability at various injection durations representative of light to high load engine operating conditions and qualitatively has a spray pattern that will minimize combustion chamber wall impingement. The fuel injector should have the capability for multiple injections within the operating speed envelope of a representative rotary diesel with engine shaft speeds up to 5500 RPM and peak injection pressures between 1000 and 2500 bar.

PHASE II: Demonstrate and validate the performance of the chosen phase I fuel injection system on a rotary diesel engine through computational analysis, bench top experimentation, and relevant engine hardware demonstration with the goal of meeting the aforementioned fuel consumption target, the rated power range per rotor, and the specific power characteristics described in the description section using both JP-8 and DF-2.

PHASE III: Develop a fuel injection system that can be readily integrated onto a heavy fuel rotary diesel engine for commercial vehicle or military ground vehicle use. The resulting fuel system should be available for rotary diesel engines used in future Army manned and unmanned ground vehicles or as a large vehicle auxiliary power unit ranging from 10 BHP to 80 BHP that delivers sufficient fuel consumption and specific power performance while operating on both DF-2 and JP-8. It is envisioned that this technology will be transitioned to a military rotary diesel engine manufacturer.

REFERENCES:

1. "Fundamental Spray and Combustion Measurements of JP-8 at Diesel Conditions", L. Pickett and L. Hoogterp, SAE Paper No. 2008-01-1083, 2008.
2. "On the Ignition and Combustion Variances of Jet Propellant-8 and Diesel Fuel in Military Diesel Engines", P. Schihl and L. Hoogterp, 26th Army Science Conference, Orlando, Florida, December 2008.

KEYWORDS: rotary diesel, combustion, JP-8, unmanned ground vehicles, wankel, UGV

A11-065 TITLE: Lithium ion battery separator development

TECHNOLOGY AREAS: Ground/Sea Vehicles

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: Develop an advanced lithium ion battery separator that has high temperature stability in order to increase battery safety.

DESCRIPTION: The electrification of tactical military vehicle technologies has been limited by the safety, performance, and excessive costs of power sources and storage devices. Lithium ion batteries have moderate energy density and power density. Lithium ion battery safety hazards, such as thermal runaway, limit their application in extreme military conditions. Residual stress and reduced mechanical properties of separators at high temperatures can lead to shrinkage, tearing, or pinhole formation, which contribute to battery failure. The Army is interested in identifying and developing innovative separator concepts for advanced lithium ion batteries which will improve safety, performance, extend the life, and reduce the cost of the separator. Grant applications must show how proposed innovations would result in significant advances in safety enhancement and cost reduction over state-of-the-art technologies. Therefore, grant applications are sought for new separator that offer high temperature stability (less than 5% shrinkage at 220°C or higher) and mechanical strength (tensile Strength: Less than 2% offset at 1000 psi) suitable for lithium ion battery applications. Proposed approaches could involve new polymer materials or composite materials; no limitation is placed on the alternatives that could be considered as long as the temperature stability and mechanical strength goals are met. Proposed materials must also meet all of the design requirements for a lithium-ion separator (performance, thickness, porosity, cost, etc.) at room temperature.

PHASE I: The contractor will develop and demonstrate the proposed concept through materials preparation, analysis and evaluation. A research study in the form of a report is expected from phase I deliverables.

PHASE II: The contractor shall refine and fully characterize the separator. 5 samples (50 cm² or larger) shall be delivered for verification and evaluation. The contractor will demonstrate proof of the concept with the fabrication and testing of 4 or more lithium-ion battery cells with produced separator material. The cells can be cylindrical or prismatic format with no less than 2Ah. The performance of the cylindrical and prismatic cells shall be tested and compared with those fabricated with commercial lithium ion battery separators.

PHASE III: Separator material developed in this topic could be scale up for the automated production process for mass-production for commercial and military lithium ion battery applications. The results of the development of the improved separator should enable the incorporation of advanced lithium ion battery configured in a 6T and/or Group 31 configuration into new type of military vehicle systems as well as commercial electric vehicle and hybrid electric vehicles. The goal in this phase will be to initiate the manufacturing processes to produce this separator material for lithium-ion batteries and to evaluate the products for military and commercial applications.

REFERENCES:

1. Richard S. Baldwin, NASA Technical Report, NASA/TM—2009-215590, March 2009.
2. P. Arora and Z. Zhang, Chem. Rev., 104, 4419 (2004).
3. P. Brant et al, Proceedings of the Fifth International Symposium on Large Lithium Ion Battery Technology and Application, June 9-10, 2009.
4. USABC Lithium Battery Separator Goals, http://www.uscar.org/guest/article_view.php?articles_id=85

KEYWORDS: lithium ion, battery, separator, temperature

A11-066 TITLE: Low Cost Embedded Dust Detector (EDD) for M1 Abrams/Ground Combat

Vehicle (GCV)

TECHNOLOGY AREAS: Ground/Sea Vehicles, Electronics

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: Develop a low cost embedded dust detector (EDD) for M1 Abrams/GCV and commercial vehicles. The EDD will be integrated into engine to warn an operator of high dust contamination for reducing engine damage and improve vehicle operational readiness.

DESCRIPTION: High power density military engine used in M1 Abrams and proposed for Ground Combat Vehicle (GCV) require huge volumes of intake air in order to meet mobility and power generation requirements. Operating these vehicles in desert environments exposes the engine to extended periods of dust contamination which drives up the frequency of air filter servicing, shortening intervals between major engine overhaul/replacement and ultimately increasing operating life cycle costs. The high air flow (up to 10,000 standard cubic feet per minute, SCFM) required for M1 Abrams gas turbine engine must utilize three air filters to trap the dust contaminants. M1 Abrams equipped with the self-cleaning Pulse Jet Air Cleaner (PJAC) provide reduced maintenance but still must be removed, cleaned and inspected on a semi-annual cycle. Non PJAC equipped M1 Abrams require more frequent servicing which can occur as often as every three months. Dust leaks into the engine can occur from the following sources, (1) low efficiency barrier filters, (2) dust falling in clean air plenum during barrier filter removal, (3) seal failures in plenum box and (4) improperly installed inlet plenum seal ring connecting air cleaner box to turbine bell mouth inlet. Thus, it is imperative that the EDD be placed down-stream of all leak sources. The turbine engine used in M1 Abrams is expensive and failures related to dust exposure are being experienced in desert theaters. An EDD will be explored and lab tested to demonstrate that it can measure dust penetration and withstand the shock/vibration and operating temperatures seen in military vehicle environments. Proper placement of an EDD in the turbine engine will be critical for assuring dust particles are sensed by the EDD which will require engine manufacturer participation and coordination. Such an effort was conducted in a dust detector SBIR program in the early 2000's. At that time design parameters included the following: (1) minimum concentration numbers going into the engine are .025 milligrams per cubic foot of AC Fine Dust, (2) target goal is to be able to detect 5 micron minimum dust particle size and 200 micron maximum dust particle size with an added goal to be able to measure dust particles between 1 to 5 microns, (3) it must produce a readout within 5 to 50 seconds and (4) it must operate at air flows from 500 to 10,000 SCFM for M1 Abrams. Other design parameters were established under the previous Phase II SBIR project and will be available under reference (3). The previous established design parameters will be reviewed to determine accuracy. The real time EDD in addition to specific design parameters cited above will establish the following design criteria which include, (1) maximum vacuum and pressure limits, (2) tolerance to shock, vibration and noise levels in the engine or vicinity in which it may be located which is downstream of plenum inlet seal, (3) minimum and maximum power consumption and (4) minimum intrusion of any EDD probe in clean air passage of engine inlet. Previous dust detector technology has been explored and installed in an older designed military tank but did not prove reliable and thus failed to achieve success however dust detectors are employed on foreign tanks. A new technology breakthrough that can be integrated into the engine and provide reliability will serve both military and commercial vehicles which must operate in high dust environments and regions of the world.

PHASE I: An EDD innovative concept will be designed including the development of a detailed analysis of predicted performance. The design parameters will be thoroughly investigated to determine if previously established design criteria is applicable in today's dust detector technology and development. The EDD innovative concept will detail computational fluid dynamic (CFD) and finite element analysis (FEA) with support from engine manufacturer, M1 Abrams and vehicle developer as needed. Location of the EDD in the turbine engine will be studied to determine to establish feasibility and practicability. A breadboard design concept will be proposed and demonstrated.

PHASE II: The EDD concept will undergo continued development and validation. A prototype breadboard will be constructed and the operation of the prototype will be demonstrated. The location of the EDD in the AGT 1500 turbine engine will be fully evaluated to determine a location which is acceptable and functional. The location of EDD must be approved and design integrity verified as to form fit and function. All design parameter previously established in Phase I will be verified and any changes made or additions will be concurred in by responsible organizations. The prototype EDD based on Phase I work effort will concentrate on lab tests to validate the design parameters. This may include lab testing of the engine and air cleaner system as a package to expose the EDD to a simulated real world condition to harden the EDD design package. Continued development and lab test with/without

engine components will be demonstrated. Necessary design changes will be incorporated to meet established EDD design criteria and environmental tests. The triggering mechanism of the EDD will be demonstrated requiring integration into the vehicle software network. This effort will require some support from responsible organizations.

PHASE III: The primary Phase III military application of the EDD is the M1 Abrams which uses the AGT 1500 turbine engine requiring up to 10,000 SCFM of air flow. Also, the GCV program which is targeting a diesel engine at around 3000 SCFM would benefit by developing an EDD. Potential commercial application includes mining machines and trucks with large engines which are exposed to dust environments.

REFERENCES:

(1) Analysis of particle Size Data, Final Report, SwRI Project No. 03-11566. Dated 07 Nov 2005, prepared for Physical Optics Corporation by Martin B. Treuhft, Southwest Research Institute.

(2) Web site for Dust Detectors (one of several) - [http://www.unitedconveyor.com/bulletins/Dust Detector.pdf](http://www.unitedconveyor.com/bulletins/Dust%20Detector.pdf)

(3) Contract DAAE07-03-L009, Section C, Statement of Work.

KEYWORDS: Dust Detector, dust concentration, micron size, zero dust visibility, turbine blade erosion, air filter efficiency, dust leaks

A11-067 TITLE: Measuring Fuel Quantity in Collapsible Fabric Storage Tanks

TECHNOLOGY AREAS: Ground/Sea Vehicles, Electronics

ACQUISITION PROGRAM: PEO Combat Support & Combat Service Support

OBJECTIVE: Develop a fuel measuring device that is capable of measuring fuel volume in collapsible fabric tanks with an accuracy of at least $\pm 1\%$.

DESCRIPTION: The Defense Energy Support Center (DESC) is responsible for fuel accountability on the battlefield. DESC is currently developing a system called Fuels Manager Defense (FMD) that will provide real time fuel tracking and inventory management of all fuel on the battlefield. DESC has a fuel accountability accuracy requirement of $\pm 1\%$. There are two methods that the army currently uses to measure fuel volume in collapsible fabric tanks used to store bulk fuel on the battlefield. Neither of these methods is capable of meeting DESC's $\pm 1\%$ accuracy requirement. The first method is to manually measure the height of the fabric tank with a tape measure and string and then look up the corresponding volume on a table called a strapping chart. This method is labor intensive and does not meet the $\pm 1\%$ accuracy requirement. The second method, found in the Fuel System Supply Point (FSSP), uses flow meters on the inlet and outlet of the tanks to determine tank volume by measuring the amount of fuel added to and removed from the tank. The short falls with this method are it can't account for fuel losses from a leaking tank and over time the cumulative error in the meters results volume measurement errors of $\pm 10\%$ or greater. In an effort to find a solution that meets the $\pm 1\%$ accuracy requirement from DESC, the Army has evaluated several alternate methods for measuring fuel volume in collapsible fabric tanks over the past two years. These methods have typically used the technical approach of calculating tank volume from measurements taken at single or sometimes multiple points on the tank. Although these methods are more accurate than measuring the height of the tank with a tape measure or flow meters, none of them have been capable of achieving an accuracy level of $\pm 1\%$. The best case accuracy was in the $\pm 4\%$ to $\pm 6\%$ range, and that was only achievable after the tank with filled to 10% of its total rated capacity. The shortfalls found in the alternative methods that Army is still working to overcome are: 1. In a 10,000 gallon fabric tank, the tank has to be filled with 1,000 gallons (10% of rated capacity) of water before tank volume measurements stabilize. 2. Volume levels of less than 1000 gallons in a 10,000 gallon tank were inaccurate by as much as $\pm 20\%$. 3. From the 1000 gallon to the 10,000 gallon volume level in a 10,000 gallon tank, accuracy in $\pm 4\%$ to $\pm 6\%$ range was typical. 4. None of the methods tested were capable of accounting high or low spots in the ground under the tank. 5. Accurate measurements of changes in tank geometry due to material relaxation over time are required.

PHASE I: During phase I, develop a technique to measure fuel volume in a collapsible fabric tank to within $\pm 1\%$ over the full volume range in the tank. Phase I will address how to overcome the following limitations experienced with previous tank volume measuring approaches and equipment:

1. The exact size, geometry, and construction material of a tank varies by manufacturer and tank.
2. The tank material relaxes over time changing the dimensions of the tank.
3. The ground under the tank is typically not completely level or uniform making it more difficult to accurately measure tank volume due to fuel "hiding" in low spots.
4. Temperature will cause the tank material to relax and change the tank geometry.
5. The tank height and geometry varies with the volume of fuel in the tank.
6. Consistently achieving a volume measurement accuracy of $\pm 1\%$ or better over the full tank volume range.
7. Small size and ease of set up and use are a priority.

PHASE II: Based on the results of phase I, construct and test a prototype device capable of measuring fuel in a collapsible fabric tank. All testing and demonstration for this phase will be done with water.

PHASE III: The technology developed in phase II will greatly enhance the Army's ability to account for fuel on the battlefield. This technology will be implemented into the Army's bulk fuel storage systems such as the Inland Petroleum System and FSSP that use bulk fabric storage tanks. The capability to measure volume levels in collapsible fabric tanks also has potential use in commercial and industry applications where collapsible fabric tanks are used.

REFERENCES:

1. MIL-DTL-83133, Turbine Fuels, Aviation, Kerosene Types; NATO F-34 (JP-8), NATO F-35, and JP-8+100, 1A 1000
2. MIL-PRF-370, Hose and Hose Assemblies, Nonmetallic: Elastomeric, Liquid Fuel.
3. Strapping chart for the 10K tank (uploaded in SITIS 11/19/10).

KEYWORDS: collapsible fabric tank, fuel storage, gauging, JP-8 fuel, volume, measurement

A11-068 TITLE: Small Diesel Engine for Modular Power

TECHNOLOGY AREAS: Ground/Sea Vehicles

ACQUISITION PROGRAM: PEO Ground Combat Systems

OBJECTIVE: To develop and demonstrate a 300-500W heavy fuel engine to provide modular power for an Unmanned Ground Vehicle (UGV), replacing a stock battery and extending UGV mission length.

DESCRIPTION: Heavy fuel engines are not available commercially off the shelf at extremely low power levels (less than 1 hp). Furthermore, there are presently limits preventing the scaling down of off the shelf diesel/JP-8 engines with respect to combustion: spray, injector size, bore size, etc. Past DoD programs on small modular power generation have provided engine-generator solutions, but focused more on the development of the generator and electrical system, rather than providing an engine with a modern fuel system. Small Unmanned Ground Vehicles (UGVs) such as the TALON and the Packbot are in need of additional power generation to extend their mission. Some of these missions include bomb diffusing and reconnaissance missions where it is too dangerous to involve soldiers. An operational needs statement for Autonomous Unmanned Ground Surveillance Systems was produced with the threshold of 24 hours runtime at payload and objective of 72 hours. Presently these UGVs have somewhere between 2-6 hours of battery life depending on the battery chemistry and mission profile. The Warfighter is in great need of UGV systems that can be operable for the entirety of the mission duration. This limited battery life restricts the missions of the UGVs and may potentially put soldiers in danger. Since the battery life varies greatly, the Army needs a small heavy fuel engine designed to be coupled with a generator that would maintain the state of charge on the batteries of the UGV; thus making the UGV a hybrid system. Maintaining the state of charge on the robots batteries would increase over all mission length significantly. However, there are system constraints because the UGVs are considered to be man portable and are used for many different missions. These UGV system restrictions

include weight, noise, and space limitations. These metrics are for the engine and any and all auxiliary systems required for the engine to operate (controls, electronics, cooling, gearboxes, etc), but does not include fuel. Therefore the assembled sum of all engine parts need to be able to meet the power output requirements while meeting the volume and weight requirements simultaneously. The weight of the engine shall not be more than 7.6 kg (T), 1.6kg (O), which is the weight of one lead acid and one Lithium Ion battery, respectively. The small engine must be able to run on DF-2 (T), both JP-8 and DF-2 (O). In addition, the system shall be considered audibly non-detectable, Level I, by MIL-STD 1474D at a distance of 800m(T), 400m(O) due to the nature of the UGVs' missions. This standard describes the frequency spectrum dB levels of the unit at 30m distance, then defines the non-detectability distance based on that data. The engine system shall have a volume no larger than 3.2L (T), 0.8L (O). This volume is crucial because the unit will replace a battery in the UGV system's battery bay. Specific dimensions will be provided to ensure the power system will replace the vehicle battery precisely.

PHASE I: Design a heavy fuel engine that meets the objectives of the above description. Use modeling and simulation to validate the design. Deliver a paper describing the accomplishments.

PHASE II: Develop the engine designed in Phase I. Build a prototype that meets the power level and space claim provided. Validate the design and the modeling and simulation through testing. Measure the power output of the system as well as operation length. Deliver the prototype with a paper describing the conditions the system subjected to.

PHASE III: The engine will be applied to an electric generator, providing power for small UGVs such as the TALON and the Packbot. Adding an engine generator would make the UGV a series hybrid. These small UGVs are used in bomb defusing activities and other reconnaissance missions too dangerous for soldiers. They have a restricted range due to their limited battery life and with an engine generator, the battery life will be extended, there by extending mission length.

REFERENCES:

1. <http://www.irobot.com/sp.cfm?pageid=325>
2. <http://www.foster-miller.com/lemming.htm>
3. MIL-STD 1474D - Noise Limits

KEYWORDS: engine, heavy fuels, power, diesel, JP-8, robot, unmanned ground vehicles, UGV, TALON, PackBot