AIR FORCE
STTR PROPOSAL PREPARATION INSTRUCTIONS

The responsibility for the implementation and management of the Air Force STTR Program is with the Air Force Research Lab, Wright-Patterson Air Force Base, Ohio. The Air Force STTR Program Manager is Mr. Steve Guilfoos, (800) 222-0336. The Air Force Office of Scientific Research (AFOSR) is responsible for scientific oversight and program execution of Air Force STTRs.

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For general inquires or problems with the electronic submission, contact the DoD Help Desk at 1-866-724-7457 (8am to 5pm EST). For technical questions about the topic during the pre-solicitation period (22 Jan through 19 Feb 07), contact the Topic Authors listed for each topic on the website. For information on obtaining answers to your technical questions during the formal solicitation period (20 Feb – 21 Mar 07), go to http://www.dodsbir.net/sitis.

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

Unless otherwise stated in the topic, Phase I will show the concept feasibility and Phase II will produce a prototype or at least show a proof-of-principle.

Phase I period of performance is typically 9 months, not to exceed $100,000.

Phase II period of performance is typically 2 years, not to exceed $750,000.

The solicitation closing dates and times are firm.

FAST TRACK

Detailed instructions on the Air Force Phase II program and notification of the opportunity to submit a FAST TRACK application will be forwarded with all AF Phase I selection E-Mail notifications. The Air Force encourages businesses to consider a FAST TRACK application when they can attract outside funding and the technology is mature enough to be ready for application following successful completion of the Phase II contract.

NOTE:

1)Fast Track applications must be submitted not later Than 150 days after the start of the Phase I contract.
2) Fast Track phase II proposals must be submitted not later than 180 days after the start of the Phase I contract.
3) The Air Force does not provide interim funding for Fast Track applications.
4) For those Fast Track proposals selected for award, the Air Force will only provide funding of an amount equal to the outside funding provided.

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

PROPOSAL SUBMISSION INSTRUCTIONS

PHASE I PROPOSAL SUBMISSION

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

The Phase I award winners must accomplish the majority of their primary research during the first six months of the contract. Each Air Force organization may request Phase II proposals prior to the completion of the first six months of the contract based upon an evaluation of the contractor's technical progress and review by the Air Force Technical point of contact utilizing the criteria in section 4.3 of the DoD solicitation The last three months of the nine-month Phase I contract will provide project continuity for all Phase II award winners so no modification to the Phase I contract should be necessary. **Phase I proposals have a 20 page-limit (excluding the cost proposal and Company Commercialization Report).** The Air Force will evaluate and select Phase I proposals using review criteria based upon technical merit, principal investigator qualifications, and commercialization potential as discussed in this solicitation document.

ALL PROPOSAL SUBMISSIONS TO THE AIR FORCE MUST BE SUBMITTED ELECTRONICALLY.

It is mandatory that the complete proposal submission -- DoD Proposal Cover Sheet, **ENTIRE** Technical Proposal with any appendices, Cost Proposal, and the Company Commercialization Report -- be submitted electronically through the DoD SBIR/STTR website at http://www.dodsbir.net/submission. Each of these documents is to be submitted separately through the website. Your complete proposal **must** be submitted via the submissions site on or before the **6:00am EST 21 March 2007** deadline. A hardcopy **will not** be accepted. Signatures are not required at proposal submission when submitting electronically. If you have any questions or problems with electronic submission, contact the DoD SBIR/STTR Help Desk at 1-866-724-7457 (8am to 5pm EST).

Acceptable Format for On-Line Submission: The technical proposal should include all graphics and attachments but should not include the Cover Sheet or Company Commercialization Report (as these items are completed separately). Cost Proposal information should be provided by completing the on-line Cost Proposal form..

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

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

COMMERCIAL POTENTIAL EVIDENCE

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

ELECTRONIC SUBMISSION OF PROPOSAL

If you have never visited the site before, you must first register your firm and create a password for access (Have your Tax ID handy). Once registered, from the Main Menu:

Select "Prepare/Edit Phase I Cover Sheets" –

1. **Prepare a Cover Sheet.** Add a cover sheet for each proposal you plan to submit. Once you have entered all the necessary cover sheet data and clicked the Save button, the proposal grid will show the cover sheet you have just created. You may edit the cover sheet at any time prior to the close of the solicitation.
2. **Prepare a Cost Proposal.** Use the on-line proposal form by clicking on the dollar sign icon.
3. **Prepare and Upload a Technical Proposal.** Using a word processor, prepare a technical proposal following the instructions and requirements outlined in the solicitation. When you are ready to submit your proposal, click the on-line icon to begin the upload process. You are responsible for virus checking your technical proposal file prior to upload. Any files received with viruses will be deleted immediately.

Select "Prepare/Edit a Company Commercialization Report" –

4. **Prepare a Company Commercialization Report.** Add and/or update sales and investment information on all prior Phase II awards won by your firm.

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

Once steps 1 through 4 are done, the electronic submission process is complete.

AIR FORCE PROPOSAL EVALUATIONS

Evaluation of the primary research effort and the proposal will be based on the scientific review criteria factors (i.e., technical merit, principal investigator (and team), and commercialization plan). Please note that where technical evaluations are essentially equal in merit, and as cost and/or price is a substantial factor, cost to the government will be considered in determining the successful offeror. The Air Force anticipates that pricing will be based on adequate price competition. The next tie-breaker on essentially equal proposals will be the inclusion of manufacturing technology considerations.

The Air Force will utilize the Phase I evaluation criteria in section 4.2 of the DoD solicitation in descending order of importance with technical merit being most important, followed by the qualifications of the principal investigator (and team), and followed by commercialization plan. The Air Force will use the phase II evaluation criteria in section 4.3 of the DoD solicitation with technical merit being most important, followed by the commercialization plan, and then qualifications of the principal investigator (and team).

PROPOSAL/AWARD INQUIRIES

We anticipate having all the proposals evaluated and our Phase I contract decisions by mid-Aug. All questions concerning the evaluation and selection process should be directed to the Air Force Office of Scientific Research (AFOSR). The Air Force will send out selection and non-selection notification e-mails by mid-Aug.

ON-LINE PROPOSAL STATUS AND DEBRIEFINGS

The Air Force has implemented on-line proposal status updates and debriefings (for proposals not selected for an Air Force award) for small businesses submitting proposals against Air Force topics. At the close of the Phase I Solicitation – and following the submission of a Phase II via the DoD SBIR / STTR Submission Site (https://www.dodsbir.net/submission) - small business can track the progress of their proposal submission by logging into the Small Business Area of the Air Force SBIR / STTR Virtual Shopping Mall (http://www.sbirsttrmall.com). The Small Business Area (http://www.sbirsttrmall.com/Firm/login.aspx) is password protected and uses the same login information as the DoD SBIR / STTR Submission Site. Small Businesses can view information for their company only.

To receive a status update of a proposal submission, click the "Proposal Status / Debriefings" link at the top of the page in the Small Business Area (after logging in). A listing of proposal submissions to the Air Force within the last 12 months is displayed. Status update intervals are: Proposal Received, Evaluation Started, Evaluation Completed, Selection Started, and Selection Completed. A date will be displayed in the appropriate column indicating when this stage has been completed. If no date is present, the proposal submission has not completed this stage. Small businesses are encouraged to check this site often as it is updated in real - time and provide the most up - to- date information available for all proposal submissions**. Once the "Selection Completed" date is visible, it could still be a few weeks (or more) before you are contacted by the Air Force with a notification of selection or non – selection.** The Air Force receives thousands of proposals during each solicitation and the notification process requires specific steps to be completed prior to a Contracting Officer distributing this information to small business.

The Principal Investigator (PI) and Corporate Official (CO) indicated on the Proposal Coversheet will be notified by Email regarding proposal selection or non-selection. The Email will include a link to a secure Internet page to be accessed which contains the appropriate information. If your proposal is tentatively selected to receive an Air Force award, the PI and CO will receive a single notification. If your proposal is not selected for an Air Force award, the PI and CO may receive up to two messages. The first message will notify the small business that the proposal has not been selected for an Air Force award and provide information regarding the availability of a proposal debriefing. The notification will either indicate that the debriefing is ready for review and include instructions to proceed to the " Proposal Status / Debriefings " area of the Air Force SBIR / STTR Virtual Shopping Mall or it may state that the debriefing is not currently available but generally will be within 90 days (due to unforeseen circumstances, some debriefings may be delayed beyond the nominal 90 days). If the initial notification indicates the debriefing will be available generally within 90 days, the PI and CO will receive a follow – up notification once the debriefing is available on - line. All proposals not selected for an Air Force award will have an on – line debriefing available for review. Available debriefings can be viewed by clicking on the " Debriefing " link, located on the right of the Proposal Title, in the " Proposal Status / Debriefings " section of the Small Business Area of the Air Force SBIR / STTR Virtual Shopping Mall**. Small Businesses will receive a notification for each proposal submitted. Please read each notification carefully and note the proposal number and topic number referenced. Also observe the status of the debriefing as availability may differ between submissions (e.g., one may state the debriefing is currently available while another may indicate the debriefing will be available within 90 days).**

PHASE II PROPOSAL SUBMISSIONS

Phase II is the demonstration of the technology that was found feasible in Phase I. Only those Phase I awardees that are **invited** to submit a Phase II proposal and all FAST TRACK applicants will be eligible to submit a Phase II proposal. The Phase I award winners must accomplish the majority of their primary research during the first six months of the contract. Each Air Force organization may request Phase II proposals prior to the completion of the first six months of the contract based upon an evaluation of the contractor's technical progress and reviewed by the Air Force Technical point of contact utilizing the criteria in section 4.3 of the DoD solicitation The awarding Air Force organization will send detailed Phase II proposal instructions to the appropriate small businesses. Phase II efforts are typically two (2) years in duration and do not exceed $750,000. (NOTE) All Phase II awardees must have a Defense Contract Audit Agency (DCAA) approved accounting system**. Get your DCAA accounting system in place prior to the AF Phase II award timeframe. If you do not have a DCAA approved accounting system this will delay / prevent Phase II contract award. If you have questions regarding this matter, please discuss with your Phase I contracting officer.**

All Phase II proposals must have a complete electronic submission. **COMPLETE** electronic submission includes the submission of the Cover Sheet, Cost Proposal, Company Commercialization Report, the **ENTIRE** technical proposal with any appendices via the DoD submission site. The DoD proposal submission site at http://www.dodsbir.net/submission will lead you through the process for submitting your technical proposal and all of the sections electronically. Your proposal **must** be submitted via the submission site on or before the Air Force activity specified deadline. Phase II Technical proposal is limited to 50 pages. Phase II Cost Proposal information should be provided by completing the on-line Cost Proposal form. The commercialization report, any advocacy letters, and the additional cost proposal itemized listing (a through h) will not count against the 50 page limitation and should be placed as the last pages of the Technical Proposal file that is uploaded. (Note: Only one file can be uploaded to the DoD Submission Site. Ensure that this single file includes your complete Technical Proposal and the additional cost proposal information.)

PHASE I SUMMARY REPORTS

All Phase I award winners must submit a Phase I Final Summary Report at the end of their Phase I project. The Phase I summary report is an unclassified, non-sensitive, and non-proprietary summation of Phase I results that is intended for public viewing on the Air Force SBIR / STTR Virtual Shopping Mall. A summary report should not exceed 700 words, and should include the technology description and anticipated applications / benefits for government and / or private sector use. It should require minimal work from the contractor because most of this information is required in the final technical report. The Phase I summary report shall be submitted in accordance with the format and instructions posted on the Virtual Shopping Mall website at http://www.sbirsttrmall.com.

SUBMISSION OF FINAL REPORTS

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

AIR FORCE STTR PROGRAM MANAGEMENT IMPROVEMENTS

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

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Air Force STTR 07 Topic Descriptions

AF07-T001 TITLE: Miniaturized Thermal Energy Harvesting System

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a miniaturized thermal energy harvesting system to provide electrical power for remote wireless sensor networks

DESCRIPTION: The Air Force currently has an immediate need for powering various remote wireless sensor networks (WSN) on aircraft platforms. These WSN systems are needed for monitoring engine emissions/conditions, evaluating structural integrity, and supplying remote sensing capabilities in support of ongoing battlefield activities. The miniaturized WSN systems contain processing, sensing and communication capabilities that require average power on the order of 1-10 mW over a 5-10 year life span. While several different WSN systems are commercially available, a mechanism to remotely power the system over the required time period is unavailable. That is WSN systems typically rely on battery systems requiring periodic replacement, an approach unacceptable at inaccessible aircraft locations. To meet this concern, an approach to harvest electrical energy in-situ from the surroundings is needed.

This program focuses on developing new concepts and associated manufacturing processes to harvest electrical energy from thermal energy. In general classical thermoelectric power generation technology (available since the 1950's) has had a singular focus on improvements in peltier devices (standard p and n-type materials exposed to a thermal gradient). To date commercially available thermoelectric are capable of providing on the order of 10 mW/cm2. An approach that increases this amount by an order of magnitude is desired. New devices relying on other active/smart materials to transfer energy between states (such as multiferroic materials) represents a unique opportunity to develop entirely new approach for harvesting thermal energy that may be superior to classical thermoelectrics. The focus of the proposed program is to study, characterize and subsequently implement an array of thermoelectrics for converting thermal energy into electrical energy. The size scale will be at the MEMS level with sufficient power to support a wireless sensor network (10 mW on average). The work must demonstrate the advantages of the new thermoelectric approach when compared to classical peltier devices.

PHASE I: Demonstrate a new approach producing an order of magnitude more power per unit volume than current thermoelectric devices. Build a bread board version demonstrating the fundamental components of the device.

PHASE II: Develop and fabricate a small scale (i.e. less than 0.1 cc) thermal energy harvesting system that can be integrated into commercial rechargeable battery systems for prolonged energy production.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Military applications for the source include a wide range of wireless sensor systems including structural health monitoring systems and jet engine monitoring systems. Commercial application: Commercial applications include but are not limited to powering remote sensing for automotive exhaust emissions and the soon to be mandated pressure sensors in tires.

REFERENCES:
1. J. A. Paradiso, T. Starner, " Energy Scavenging for Mobile and Wireless Electronics," IEEE Pervasive Computing, Jan.-Mar., pp. 18-27 (2005)

2. W.B. Green, Thermoelectric Handbook, Youngwood: Westinghouse Electric Corp., 1962

3. J.M. Gordon, "Generalized Power Versus Efficiency Characteristics of Heat Engines: The Thermoelectric Generator as an Instructive Illustration," Am. J. Phys., vol. 59, no.6, pp. 551-555, 1991

4. H. A. Sodano, D. J. Inman, G. Park, "A Review of Power Harvesting from Vibration Using Piezoelectric Materials," The Shock and Vibration Digest, Vol. 36, No. 3, pp. 197-205 (2004).

5. S. Roundy, E.S. Leland, J. Baker, E. Carleton, E. Reilly, E. Lai, B. Otis, J. M. Rabacy, P. K. Wright, "Improving Power Output for Vibration-Based Energy Scavengers," IEEE Pervasive Computing, Jan.-Mar., pp. 28-36 (2005).

KEYWORDS: Energy Harvesting, Energy Storage, Thermoelectrics

AF07-T002 TITLE: Materials Discovery for High Temperature Sensors

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Design, synthesize and characterize novel materials for use as sensors in high temperature environments (>1600 C).

DESCRIPTION: A new area of interest is the development of materials for sensors that are useful beyond 1600 C. Such applications would be in the hot areas of engines (2500 C), or the leading edges of hypersonic craft (2000 C) in which the sensor materials will be required to withstand the extreme temperature loads and chemical environments. Measurement of temperature, gas flow, strain, and crack detection are areas of special interest. Sensors may be acoustic, electronic, optical, magnetic, etc. There are two avenues of research for this topic: a.) Explore new concepts for rapid selection, screening and assessment of novel high temperature sensor materials b.) Refine and improve current sensor systems for use at temperatures above 1600 C. The recent advent of high-throughput screening techniques for multi-component materials allows for the synthesis and screening of tens of thousands of multi-component samples a day. An added advantage to the combinatorial synthetic methodology is that all the samples experience identical experimental conditions (strain, reactants, temperature and pressure) that often poise challenges when attempting to sort out variability in the property data when comparing samples prepared individually. The combinatorial material synthesis allows large libraries to be prepared for systematic study and identification of promising materials for specific applications. This methodology might be expected to accelerate the identification and optimization of new sensor materials with enhanced properties at temperatures above 1600 C. Note that while substantial progress has been made in developing more efficient methods for generating complex libraries of materials, the challenge remains in the identification of a high throughput-screening tool (i.e. fast analytical methods, like spectroscopic, thermal, acoustic,, mechanical, or chemical) for temperatures above 1600C and relevant sensor environments as well as the creation of a structure/property database that can be data mined for subsequent attributes such as detection sensitivity or robustness.

PHASE I: Focus on development of combinatorial approaches for screening and selecting materials for use as sensors above 1600¢XC or on the exploitation of the current class of sensor materials for temperatures above 1600C. Focus on synthesis of novel materials or manipulation of existing sensor materials.

PHASE II: Demonstrate the performance of the sensor material in-situ at 1600 C in an aggressive chemical environment and/or high acoustic loads. Develop as needed high temperature, in-situ analytical tools required for studying temperature, gas flow, creep, stress/strain and crack propagation of sensor under thermal or mechanical stress; characterize sensor sensitivity and reliability in-situ.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Cost effective routes to reliable sensors in high temperature environment applications is extremely important for military hypersonic leading edge and engine communities. Commercial application: Cost effective routes to reliable sensors in high temperature environment applications is extremely important for commercial airframe and engine communities.

REFERENCES:
1. O.J Gregory et al, Surface and Coatings Technology 88 (1996) 79-89.

2. K. Radhakrishnan et al, Mat. Sci. Eng, B57 (1999) 224-227.

3. K.Rajan in Workshop Report on a Future Information Infrastructure for the Physical Sciences- The Facts of Matter: Finding, understanding and using information about our physical world - DOE Panel report: http://www.osti.gov/search-cgis/dexpldcgi?qry1110673211;1 Report 2, pg 27.

KEYWORDS: High temperature sensors, combinatorial science, materials discovery, acoustic sensors, optical sensors, electronic sensors, magnetic sensors

AF07-T003 TITLE: Mo-Si-B-XX Alloys for High Temperature Service

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop and verify a deformation model for a multiphase Mo-Si-B-XX alloy for high temperature (1300degC - 1500degC) service.

DESCRIPTION: In an elevated temperature environment such as a gas turbine engine or thermal protective system, the essential requirements for a structural material include high temperature strength, stiffness and oxidation resistance at low density. They also require adequate room temperature mechanical properties and cost effectiveness. The most significant payoffs in terms of advanced aerospace applications and engine uses require temperatures approaching the range of 1300degC - 1500degC. The successful application of high temperature structural materials is reflected in a variety of mechanical and thermochemical properties: strength, ductility, toughness, fatigue resistance, creep resistance and oxidation resistance. A multiphase design based on a refractory metal and an intermetallic offers an effective strategy for the required balance of properties and performance.

To address the critical challenges of high temperature service, new materials are necessary. An attractive option is a multiphase Mo-Si-B alloy. Most of the attention has been directed to the three phase (Mo + Mo5SiB2 (T2) + Mo3Si) alloys that offer an effective balance of high temperature performance in terms of creep resistance and oxidation resistance. There has also been some effort on three phase (T2 + Mo5Si3 (T1) + Mo3Si) alloys. New microstructures based upon Mo + T2 + T1 three phase combinations have been developed by applying alloy design concepts that are based upon geometric factors and electronic structure. In addition, structures containing carbide, silicide phase strengthening constituents and additions such as Re have been established to partition preferentially to the Mo solid solution. Altering the possible modifications provides materials that address specific requirements. One key attraction of the Mo-Si-B system is the important opportunity to develop multiphase microstructural designs where specific phases, phase distributions and microstructural scales can be employed to impart oxidation resistance, creep resistance and toughness.

Due to the extensive alloying potential in the system, there are a number of attractive multiphase options that can be designed. In addition, unlike most other high temperature multiphase systems (e.g. SiC + Zr/HfB2), the inclusion of the ductile BCC phase allows for a much greater degree of damage tolerance and impact resistance at ambient temperatures. This is a powerful materials design tool that can be applied at ultrahigh temperatures. In multiphase microstructure designs, not only is the individual phase behavior important, but also the morphology, size scale and distribution of the phases in a microstructure play a key role in determining the overall alloy response in terms of ambient temperature toughness and elevated temperature creep performance. In order to achieve phase and microstructure stability at high temperature, it is evident that the initial alloy processing and microstructure synthesis is the main option that is available to develop the desired microstructure designs.

There is an important need to fully characterize and optimize the deformation mechanisms of these alloys to provide the basic understanding required to produce high temperature, oxidation resistant, and high stiffness materials. This material would provide a vital link in the development of thermal protective systems and high temperature combustion systems.

PHASE I: Phase I would identify a candidate Mo-Si-B-XX alloy class using advanced phase stability models and experimental data. In addition, the microstructural models would provide deformation mechanisms for initial alloy processing and synthesis.

PHASE II: Using the deformation models, alloy samples would be produced and mechanically tested to optimize processing conditions and validate mechanistic models. The resulting microstructures would be optimized for specific environmental conditions relating to elevated temperature exposure.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Apply full processing map to the selection of optimized processing avenues for an alloy suitable for acreage thermal protection system and metallic structure components for a hypersonic vehicle. Commercial application: Apply full processing map to the selection of optimized processing avenues for an alloy that could potentially replace current lower temperature nickel-based superalloys in gas turbine engines.

REFERENCES:
1. Sakidja, R, Perepezko, JH
Phase stability and alloying behavior in the Mo-Si-B system
METALL MATER TRANS A 36A (3): 507-514 MAR 2005

2. Schneibel JH, Liu CT, Easton DS, Carmichael CA
Microstructure and mechanical properties of Mo-Mo3Si-Mo5SiB2 silicides MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING 261 (1-2): 78-83 MAR 15 1999F

KEYWORDS: Heat resistant metals, refractory metal alloys, material forming, physical metallurgy, grain structures (metallurgy), segregation (metallurgy), crystal-structure, electronic-structure

AF07-T004 TITLE: Force Fields for Modeling of Ionic Liquids

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a robust, flexible, reliable, and efficient method for generating atomistic force fields for performing condensed phase simulations of ionic liquids (ILs) to predict their bulk properties.

DESCRIPTION: Condensed phase modeling and simulation studies of ILs utilize a force field which attempts to capture the essential physics of these materials within the framework of a computationally efficient mathematical model. Typical approaches to constructing such a force field for ILs include utilizing and/or empirically adjusting the force field parameters in existing simulation codes such as AMBER or CHARM. Some of the drawbacks associated with this approach include the following: (a) the AMBER and CHARM force fields were not specifically constructed or optimized for ILs, and (b) there is no unique approach or standard hierarchy of methods for systematically constructing and refining force field parameters. Therefore, modelers of ILs generally develop their own system-specific, ad-hoc force fields which may give reliable predictions for a limited set of bulk properties, but in general are not applicable to a broader range of ILs and properties. These factors severely reduce the efficiency of force field-based simulation methods for ILs.

PHASE I: Develop an approach for systematic construction and optimization of atomistic force fields for simulation of ILs and prediction of their properties. Apply this approach to a suitable set of ILs and demonstrate the capability to use the force fields in simulations to predict several key properties.

PHASE II: A robust, reliable, computationally efficient method for the construction of atomistic force fields for computer simulations of ionic liquids shall be developed to permit the accurate prediction of bulk properties such as density, viscosity, phase transitions, and thermal conductivities. The force field shall be capable of being easily interfaced with existing condensed phase simulation codes.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: This methodology will positively impact the development of new energetic materials for advanced rocket and missile propulsion applications, high energy explosives, and insensitive munitions. Commercial application: This methodology will be useful for commercial and research applications in “green” synthesis, catalysis, lubricants, gas generation, and energetic materials.

REFERENCES:
1. Wang, Y.; Voth, G.A. J. Am. Chem. Soc. 2005, 127, 12192.

2. Yan, T.; Burnham, C.J.; Del Popolo, M.G.; Voth, G.A. J. Phys. Chem. B 2004, 108, 11877.

3. Morrow, T.I.; Maginn, E.J. J. Phys. Chem. B 2003, 107, 9160.

KEYWORDS: Computational Chemistry, Force fields, Ionic Liquids

AF07-T005 TITLE: Broad Band Optical Multi Pass Cell

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Demonstrate the operation of an optical multi pass cell for laser sources from UV to near IR wavelength region for measurement environments with high levels of background emission.

DESCRIPTION: Multi-species measurements, as can be obtained with spontaneous Raman scattering, are invaluable for understanding complex environments such as those involving plasmas and/or combustion. For example, nonthermal plasmas recently have been demonstrated to enhance/modify hydrocarbon-air combustion operating over a wide range flow conditions in atmospheric to sub-atmospheric pressure conditions [1-2]. However, the detailed understanding of the mechanisms that lead to combustion enhancement by nonthermal plasmas are not currently completely understood due to the lack of quantifications of the effect of electron kinetics on the internal energies of the air/hydrocarbon molecules and also on the speciation of the radical densities. The development of laser spectroscopic measurement techniques, such as Raman scattering, which can quantify species concentrations and even the vibrational/rotational energies of constituent molecular species under the aforementioned reacting conditions (i.e., with plasmas and/or combustion) will aid in the physical understanding of these complex processes and in the development of computational models. Time-resolved measurement requires that a single laser pulse excited vibrational/rotational Raman spectrum be acquired. Also, in order for such measurements to be nonintrusive, the laser power density must be kept below the local self breakdown in the plasma medium. A multi pass cell design with combined retro-reflective and refractive elements can be used to improve the signal to noise ratio by nearly two orders of magnitude [3]. Similar or a variant design needs to be developed, which will allow pulsed laser wavelengths from 240 nm to 900 nm range for Raman scattering measurements. This multi pass cell design should be usable with experiments that require at minimum of 30 cm clearance between the optical components of this multi pass cell and the test set up.

This multi pass cell design should be reconfigurable for experiments requiring beam focusing for Raman scattering, as well as beam collimation for pulsed/CW laser absorption measurements of radical species line density over a minimum 30 cm working distance. A scalable multi pass cell design that permits its use up to 100 cm working distance is desirable.

PHASE I: Design and demonstrate a proof of principle multi pass cell that can be used with CW/pulsed lasers from 240 nm up to 900 nm for measurement environments with high levels of background emission, such as those with plasmas and/or combustion.

PHASE II: Demonstrate the operation of a multi pass cell hardware that can improve signal to noise ratio by orders of magnitude compared to a single pass beam configuration for either Raman scattering measurement or laser absorption of radical line density in a reacting as well as in a non-reacting flow. The contract deliverable will include the detail optical design and one multi pass cell hardware.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: The multi pass cell design should be useful for optical diagnostics of both reacting and non-reacting flows. Commercial application: The multi pass cell design should be useful for optical diagnostics of both reacting and non-reacting flows.

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KEYWORDS: Optical instrumentation, Raman spectroscopy, laser absorption spectroscopy, atmospheric pressure nonequilibrium reactive plasma, air breathing combustion.

AF07-T006 TITLE: Physics-Based Identification and Management of Aeroelastic Limit-Cycle Oscillations (LCO)

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop and successfully test a system for evaluating and expanding air vehicle flight envelope by LCO identification and management

DESCRIPTION: High-performance aircraft, existing and planned, are generally susceptible to a variety of LCO phenomena. Triggering situations for LCO include the inertial and aerodynamic presence of stores, control surface free-play, and rigid-body interactions (such as in flying wings). The potential presence of LCO greatly increases the cost of system development, certification, and operational support. Costs are driven by over-design, testing, and lifetime maintenance issues. No proved methodology exists by which root causes of LCO (flowfield or structural nonlinearities) can be identified and managed. Management activities include LCO suppression, prediction and potential expansion of safe envelope, and use of the methodology within existing and/or future Mil-specs.

A proved methodology is needed to carry out three principle tasks: (1) model reliably the key phenomenological characteristics of relevant LCO, as validated by experimental testing; (2) predict safe-operational envelopes; (3) simulate operation of, or participate within, an LCO-management process. Nonlinearities captured through nonlinear system identification and observation should be consistent between model and experiment. The methodology should consist of a computational framework suitable for simulation of nonlinear, dynamic processes. Attention can be given to individual LCO mechanisms provided that the methodology is shown to be sufficiently flexible to discern other LCO phenomena. The methodology should be able to predict operational envelopes for flight at safe levels of LCO, with or without modification of LCO behavior through a tested management system.

As guided by modeling and experimental testing of key nonlinear behaviors, LCO management is needed to decrease costs, increase performance, and increase operational readiness. LCO suppression encompasses passive and active measures to reduce LCO amplitude and potentially delay its occurrence. Passive measures include the addition of essential nonlinearities to the vehicle that robustly provide energy transfer out of emergent LCO. Active measures would seek to negate LCO triggers: for example, body freedom flutter through new aeroservoelastic capability. These measures need to be robust to targeted nonlinearities, as demonstrated by modeling and validated by testing. In addition to hardware systems, emphasis of LCO management can be given to incorporating new methodological capability for LCO assessment into certification practice; for example, obtaining relief from existing MIL-SPEC free-play requirements by safety demonstration via analysis and extensive validation.

Rigorous and comprehensive treatment of LCO, through identification, analysis, characterization, and modification of full-system behavior, will continue to be a cost-avoidance driver for air vehicle systems. As systems continue to carry increasing numbers and types stores, use articulated and conformal control surfaces, and seek to achieve higher levels of performance, LCO will be a negative characteristic system behavior requiring management.

PHASE I: Develop LCO analysis methodology and use to prove LCO management concept, involving either suppression or plan to modify an LCO-related specification. Validate methodology using existing literature data, and demonstrate applicability of methodology to different LCO phenomena

PHASE II: Mature methodology into a certification-quality tool. Validate for specific LCO behavior using wind tunnel and/or flight tests. Develop and validate a scalable process involving either a prototype LCO-suppression device for a generic configuration, and/or a more comprehensive methodology by which an LCO-related specification (e.g., MIL-SPEC) can be alleviated for a complete configuration.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Installation of prototype device in air vehicles to suppress LCO and extend flight envelope; provide safe relief from MIL-SPEC burdens. Commercial application: Free-play prediction tool and limit methodology adopted by FAA; commercialization of methodology software and use in consulting services.

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KEYWORDS: Limit-Cycle Oscillation, Aeroelasticity, Free-play, Aeroservoelasticity, Nonlinear Flutter, Transonic Flutter

AF07-T007 TITLE: Nanophotonic modulators based on functional polymeric materials

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop a nanophotonic modulator based on functional polymeric materials for optical interconnects.

DESCRIPTION: Future defense systems will employ advanced photonic devices for communications and sensing. The sophistication of next generation photonic systems on air-borne platforms will require individual components to have smaller size, lower power consumption, and lighter weight. As the design and fabrication technologies for photonic devices become mature, little room remains for significant improvement within the conventional technological frame. Innovative approaches are desired for a technological leap toward next generation photonic devices that can meet the needs of future air-borne defense. The beginning of the new millennium is accompanied by the pervasive presence of nanotechnology. In the area of photonics, photonic crystal has emerged as a new class of artificial materials that may provide revolutionary avenues to generate, guide, and manipulate light on a scale much smaller than conventional photonic approaches. Recent progress reveals broader potential of photonic crystals as an artificial material platform. Particularly, the high-dispersion and slow group velocity of photonic crystal waveguides promise significant enhancement of nonlinear optical effect far beyond the intrinsic limit of natural materials, which has been exploited for optical modulation applications. Meanwhile, Recent years witnessed escalating interests in utilizing polymeric materials for integrated photonics applications. Unlike silicon and III-V materials that require stringent lattice matching to the substrate, polymeric materials can be applied on the surface of virtually all genres of materials, which offers an ideal material platform for photonics integration.

The ability to modulate light is crucial to all active photonic applications. Polymer integrated modulators have been extensively investigated for over a decade. The merits of polymer optical modulators lie in an inherent velocity match of the radio-frequency wave and the optical wave in polymer materials, and high integration potential with both silicon and III-V materials based electronic or photonic devices. In addition, the material and processing costs of polymeric materials are generally lower than semiconductor materials. Although significant progress has been achieved in the past decade, the half-wave voltage (Vð) and device size of polymeric integrated modulators see little reduction. The primary goal of this program is to utilize advanced functional polymeric materials to form nanophotonic devices that can modulate light with lower driving voltage through enhanced optical nonlinear effect provided by photonic crystals.

PHASE I: Design and analyze photonic crystal based modulators that incorporate functional polymeric materials, demonstrate the capability of achieving lower voltage or high modulation efficiency through the enhancement effect provided by photonic crystal based structures.

PHASE II: An electro-optic modulator prototype shall be constructed and fully characterized. The driving voltage, speed, power consumption, and extinction ratio of the modulator shall be evaluated against the future need of air-borne defense applications.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: High Speed compact devices for communications, signal processing and in general C4I applications. Commercial application: Can have application in a broad range of commercial applications including optical communication, optical interconnects, optical sensing, and display technology.

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KEYWORDS: nanophotonics, photonic crystals, polymeric photonic crystals, electro-optic polymer, dispersion, slow photon

AF07-T008 TITLE: Micro Chemical Propulsion

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and demonstrate an innovative, highly efficient and compact micro-chemical propulsion system for miniaturized and small satellites.

DESCRIPTION: Two developing technology areas in the field of microelectromechanical systems (MEMS) are micropower generation and micropropulsion. Microthrusters, because of their simplicity, have received significant attention during the last few years, although early development in the MEMS field began approximately 10 years ago. The principle applications of microthrusters are for primary propulsion and attitude control of microspacecraft, but they may also be applied to any process requiring small quantities of directed gas flows. For example, the same technology necessary for the successful development of micro-thrusters is currently being applied to micro gas generators for usage in airbags and in microactuators. An important example of small-scale thrusters used on a micro-spacecraft is the US Air Force’s XSS-10 microsatellite experiment, which flew on 29 January 2003 as a secondary payload to a Global Positioning System navigation satellite aboard a Delta 2 rocket. The micro-satellite weighed 31 kilograms, and represented the first work in space involving micro-satellites that can autonomously approach other objects in space. The XSS-10 was classified as a microsatellite because it weighed in the range of 10 to 100 kg. As research and development of smaller scale satellites progress, such as nanosatellites (1 to 10 kg) and picosatellites (0.1 to 1 kg), smaller and more efficient propulsion systems will be required. Depending upon the propulsion function, different types of propulsion systems are currently envisioned. For example, low impulse bit functions are generally considered as a good fit for electric propulsion, whereas high trust missions are a good fit for chemical systems. Compared to macroscale thrusters, microthrusters potentially have a gain in thrust-to-weight ratio (F/W) with downsizing. Thus, if a one-meter macro-scale thruster has a thrust-to-weight ratio of 10, a thruster with a length scale of 1 cm could potentially have a thrust-to-weight ratio of 1000 and a thruster with a length scale of 1 mm could have a thrust-to-weight ratio of 10,000. If achievable, the applications of microthrusters could be numerous, ranging from distributed propulsion in macro-scale systems to primary propulsion in micro-scale systems. Although potential gains are expected with scaling of macroscale thrusters, such scaling is not as simplistic as described above and it is generally understood that for micropropulsion evaluation, the traditional measures of thrust-to-power ratio and specific impulse are not the drivers for microsatellites. At very small scales, the power of valves, heaters, and other auxilIary equipment becomes comparable to the total propulsion system power. Furthermore, the mass of electronics, structure and cabling will generally dominate over the propellant mass. Consequently new metrics of evaluation, such as the total impulse to the total system mass ratio and the total thrust to the total system input power ratio, will need to be considered. As a result, microthrusters will inherently become integral to the microsatellite design.

PHASE I: Preliminary design and engineering studies, supported by detailed models and experiments based on the following key features: 1) choice of propellants and scaling issues 2) the use of environmentally friendly liquid propellant formulations 4) micro-scale combustion and fluid dynamics

PHASE II: demonstrate the technology with bench-scale experiments; fabricate micro uni-body combustion chambers and nozzles from novel materials; measure efficiency and thrust; determine scaling and potential longevity; demonstrate feasibility of non-propulsive applications such as power generation, identify and implement commercialization plan.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Military application: enables many nano to macro satellite missions, from satellite servicing to rapid re-constitution of space-based surveillance, navigation and communication networks. Commercial application: applications may be found in the civilian and commercial satellite market for Earth sensing and monitoring or communications. Applications include micro gas generators and compact power generation.

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KEYWORDS: Reference Dr. Mitat Birkan, microthruster,microcombustion,ignition

AF07-T009 TITLE: Advanced Window Materials for High Energy Propulsion

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop & demonstrate advanced windows materials for solar and/or laser-heating of high-pressure propellants, or other advanced propulsion concepts.

DESCRIPTION: Windows materials are an essential component of some advanced propulsion concepts relying on the transfer of radiative energy from one location and its coupling to flowing propellants in a vehicle’s propulsion system at a remote location. Examples of such concepts include solar heating, beamed energy (microwave and laser) propulsion, or even the nuclear light-bulb concept. High-performance propulsion requires high pressures, high temperatures, low energy losses and low weights. The window material must therefore be able to combine properties such as high mechanical strength, high melting point, high transparency in spectral ranges of interest, low density, and good resistance to the operating environment. The window will be exposed to a plasma at high density and high temperature (10,000 – 20,000 oK), which principally emits radiation in the visible and near-UV range; the optical transmission capability must therefore be at least as good and preferentially better than UV-grade fused silica in the 0.18 – 3 ìm range. The window should be able to withstand peak pressures of the order of 300 MPa. Relative ease of manufacture for moderately complex shapes is also desirable. Cylindrical window shapes are of special interest, for which high tensile and flexural strengths at high temperature (2 x sapphire at 1000 oC) are desirable. Nano-scale alumina ceramics [1] are of potential interest if their current properties can be improved [2]. Another example of a state-of-the-art material is Aluminum oxynitride [3] or ALON™, a transparent polycrystalline ceramic material that appears to have optical and mechanical characteristics potentially attractive for the types of applications mentioned above; however, a complete assessment of its potential for these various propulsion concepts still needs to be achieved, through key laboratory tests and measurements. Another approach may consist of reinforcing materials with carbon nanotubes (CNT) [4], if transparency can be obtained.

PHASE I: Phase I work may include any or all of the following: a) preliminary studies to improve material properties; and, b) preliminary testing of materials under conditions of interest, relevant to one or more propulsion concepts.

PHASE II: Development of improved materials, sample manufacturing, and testing of the material for transparency, mechanical strength, temperature stability, corrosion resistance to most common propellants, and irradiation.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Efficient and innovative propulsion systems using transfer of very high-intensity radiative energy; windows for sensors or laser communication devices exposed to extreme aero-thermal environments. Commercial application: Large-scale commercial applications in the lightning industry, from light-bulbs to high-intensity industrial light sources; power generation (solar concentrators) applications are also possible.

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KEYWORDS: Transparent Ceramics, High-Temperature Windows, ALON™, CNT, Radiative Energy Transfer, Beamed Energy Propulsion, Plasma Propulsion

AF07-T010 TITLE: High Flexibility Aircraft Primers

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a VOC-compliant aircraft primer coating with superior flexibility, elongation, and adhesion to maintain barrier properties across seams and fasteners.

DESCRIPTION: Aircraft coating systems utilize both corrosion prevention and corrosion control to protect against environmental damage. One aspect of corrosion prevention is for the coating to provide barrier properties which prevent the metal (e.g., aluminum alloy) surface from being exposed to the corrosive environment. Currently used coating systems also include corrosion inhibitors to slow the rate of corrosion when the coating barrier properties compromised through a coating defect or physical damage.

Historically the Air Force used a polysulfide primer purchased to MIL-P-87112 on large aircraft. This primer had excellent flexibility/elongation properties and did not crack despite the flexure experienced with large aircraft due to pressurization, wing flexure, landings, and takeoffs. Most coating systems fail around seams and fasteners due to the lack of coating flexibility, however, the polysulfide primer was flexible enough to maintain a continuous barrier coating film. When coating failure occurs due to cracking, water (i.e., electrolyte) can come in contact with the metallic substrate, forming a corrosion cell. At this point, the corrosion inhibitors present in the film are used to reduce the corrosion rate.

The implementation of more stringent emission regulations, stated in the 1998 National Emission Standards for Hazardous Air Pollutants (NESHAP) created under the 1990 Clean-Air Act, restricted the use of the polysulfide primer due to excess volatile organic compounds (VOCs). Past efforts to manufacture a NESHAP compliant version of the polysulfide primer have not been successful. Generally, the problems have centered on slow cure under high humidity conditions and reduced weatherability of the system due to unreacted sulfur compounds in the primer interacting with the topcoat.

The goal of this effort is to develop a new primer system with enough flexibility to maintain a barrier across seams and fasteners while still having a low VOC content. The resulting coatings will be evaluated to ensure they have sufficient flexibility, adhesion, and compatibility with currently used topcoats and corrosion inhibitor systems.

PHASE I: Demonstrate a viable approach to generate HVLP sprayable high flex primers that are compatible with current corrosion inhibitors and have a minimum of 60% G.E. impact flexibility. Coating shall meet MIL-PRF-23377J primer requirements (adhesion & corrosion)& be compatible with MIL-PRF-85285D topcoat.

PHASE II: Develop the coating system formulated under the Phase I effort to maximize corrosion inhibition for AA2024-T3 and AA7075-T6 substrates. Further develop the formulation with an emphasis on VOC/HAPs reduction as well as potential elimination of the use of Cr(VI). Evaluate compatibility with various surface pre-treatments and topcoats. Provide 10 gallons to the USAF for testing and evaluation.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Qualification of a VOC compliant MIL-PRF-23377J coating with MIL-P-87112 properties for use on the outer mold line of large aircraft to reduce cost and increase aircraft availability. Commercial application: Flexible VOC compliant aircraft primers will be of interest to the commercial aircraft industry.

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KEYWORDS: MIL-P-87112, MIL-PRF-23377, coating, primer, polysulfide, flexibility, non-chrome, corrosion, AA2024-T3

AF07-T011 TITLE: Protective conformal coatings for spacecraft polymers and paints

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop and characterize conformal coatings and coating methods which will prevent or minimize degradation of spacecraft polymers and paints by atomic oxygen attack, and ultraviolet and vacuum ultraviolet light while maintaining electric conductivity to prevent static buildup.

DESCRIPTION: Polymers and paints on spacecraft are subject to erosion by high energy atomic oxygen attack was well as photodegradation by ultraviolet (UV) and vacuum ultraviolet (VUV) light. Currently atomic oxygen attack is mitigated by coating with silicon oxide (SiO_2) deposited on the substrate by Plasma Enhanced Chemical Vapor Deposition (PECVD). This method requires a plasma generator and typically is limited to line-of-sight deposition. The problem of photodegradation of paints and polymers currently does not have a viable solution. Further, ions in orbit can lead to a build-up of static charge. This can pose a danger to astronauts, as well as a hazard to electronic circuits and sensors.

Atomic Layer Deposition (ALD) has shown promise in developing conformal, non-line-of-sight deposition coatings. Deposition of 30Å thick Al_2O_3 coatings have been shown to significantly protect polymer substrates from atomic oxygen attack. This thin alumina coating itself needs to be protected from mechanical damage and wear however. Additionally, it is known that titanium oxide (TiO_2) and zinc oxide (ZnO) absorb and reflect UV and VUV radiation. These materials may also be deposited by ALD technique and may, when deposited at sufficient thickness, serve to protect the substrate from photodegradation. Finally, ZnO/Al_2O_3 alloys have been shown to exhibit semi-conductor electrical properties, where the resistivity of the alloy can be made to vary up to 18 orders of magnitude as the alloy composition is varied.

Coatings and coating methods which can protect spacecraft paints and polymers from atomic oxygen erosion, UV and VUV photodegradation, and can dissipated static charge are sought. The coatings should be conformal and be able to be rapidly applied with a non-line-of-sight deposition method. Multiple layers of various materials may be necessary to achieve chemical, photo, and mechanical durability and substrate protection.

PHASE I: Identify candidate materials and non-line-of-sight deposition methods to achieve conformal protective coatings to provide static discharge capability; atomic oxygen protection; and UV, and VUV protection for spacecraft paints and polymers. Develop experimental and theoretical program for Phase II.

PHASE II: Demonstrate coating deposition and performance on Kapton coupon. Characterize protection and static discharge capabilities for candidate materials and coating methods. Develop secondary materials and coatings as necessary to protect against mechanical damage. Characterize protection against incidental damage (scratching) as well as long term wear.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Will extend lifetime of space assets by protection from atomic oxygen attack and UV, VUV degradation of polymers and paints. Will also protect delicate sensors from harmful static discharge. Commercial application: Longer life space assets through reduced degradation. Terrestrial benefits may also include reduced maintenance of painted assets through reduced fading and degradation of coatings.

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KEYWORDS: atomic layer depositon, atomic oxygen, ultraviolet degradation, static discharge coating

AF07-T012 TITLE: Cognitive Models for learning to control dynamic systems

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop fast yet robust algorithms for learning to control dynamic systems based on online experience with action, event, and outcome sequences.

DESCRIPTION: Developments in neural networks and machine learning have made substantial progress toward learning to control dynamic systems based on experience with action, event, and outcome sequences (see Ioannou & Sun, 1995; Michalski, Carbonell, Mitchell, 1983; Miller, Sutton, Werbos, 1991; Sutton & Barto, 1999). However, these learning algorithms learn rather slowly in comparison with humans, especially in navigational tasks, and they have difficulty working in non-stationary environments or scenarios with rapidly changing goals. These limitations are blocking the development of autonomous systems for controlling dynamic decisions in military scenarios. The existing algorithms lack the ability to construct online mental models of dynamic systems from experience, fail to make adequate use of prior knowledge from experience with analogous tasks, and lack the ability to generalize to new conditions or demands. New fast yet robust learning models need to be developed that are informed by cognitive science research on human learning in dynamic decision making tasks.

PHASE I: Develop new mathematical/computational models based on cognitive science principles that are capable of rapid learning for dynamic control problems. This requires testing and evaluation based on previously established experimental research with human dynamic decision tasks

PHASE II: Employ a synthetic task environment designed to study dynamic control problems to provide a test bed for evaluating the learning models, and develop the software for application of these learning models to the selected synthetic task environment. Conduct human experiments to generate data sets, and perform model comparisons and model evaluations on the basis of models ability to predict and match human behavior in these tasks.

PHASE III DUAL USE APPLICATIONS: Military: This technology will support the development of robust, cognitively realistic agents for learning to rapidly and robustly controlling UAV type of dynamic systems.
Public: This technology provides the foundation for developing learning algorithms for dynamic control problems in robotics for industrial applications.

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KEYWORDS: Computational cognitive model; mathematical cognitive model; learning to control; dynamic systems; mental models

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AF07-T013 TITLE: VARTM Processing of High Temperature Polymer Matrix Composites

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop and demonstrate affordable vacuum assisted resin transfer molding (VARTM) processes for fabricating high temperature polymer matrix composites (HTPMC)

DESCRIPTION: Composite materials are being considered for use as replacements for conventional materials in high-temperature applications. Hand lay-up prepreg/autoclave techniques used to fabricate polymeric composites for applications that require high-temperature resistance have high manufacturing costs that limit their usage. Compared to such conventional processing techniques, manufacturing high-quality, large composite parts using the VARTM technique should significantly reduce costs due to its low cost tooling and capability of making larger part dimensions. However, VARTM has traditionally been used for making composites for normal temperature applications. Processing high temperature („d600„aF) PMC using VARTM faces some technical challenges due to its inherent low processing pressure (maximum full vacuum or 14.7 psi), the high viscosity of high-temperature resin matrices, and the processing difficulty of eliminating solvents and subsequent voids during processing. Furthermore, high processing temperatures, low processing pressures, potential preform spring-backs and large part sizes may lead to large dimension variations in the composite parts.

With recent advancements in the development of high temperature resin systems, such as AFR-RTM and PETI-330, the processing of HTPMC with VARTM may now be feasible. A systematic investigation of feasibility and capability of HT-VARTM is high desirable. This proposed project should focus on developing and demonstrating the VARTM process for fabricating high quality HTPMC. The Tg of the resultant composite should be over 600„aF, which should be significantly better than the traditional medium-to-high temperature PMCs (such as BMI/carbon fiber or PMR-15/carbon fiber). The proposer should systematically investigate HT-VARTM processing techniques and advance processing science for high temperature VARTM. Specifically, the proposer should develop a robust VARTM processing method and demonstrate the capability of making high quality HTPMC: high fiber volume, low void content, and good part surface. Of the specific interest is to develop an effective flow and curing processes for HT-VARTM for large, complex shaped part fabrication. Various methods of resin infusion process should be explored to enhance the processing efficiency and part quality. In addition, the proposer should compare the mechanical, thermal and dimensional properties of the resultant HTPMC to those made by the traditional autoclave process to prove the feasibility of HT-VARTM.

PHASE I: Demonstrate HT-VARTM processing of PMC with high Tg („d600„aF). Fabricate flat test parts with high fiber volume, low void content and good surface. Characterize mechanical and thermal properties of test panels. Benchmark the HT-VARTMed PMC parts with those by the traditional autoclave process.

PHASE II: Develop a fundamental understanding of major processing issues in HT-VARTM. Develop and test optimum processing techniques to further reduce dimension variations and void contents. Develop and demonstrate affordable and robust HT-VARTM process to fabricate large and complex shaped test parts. Establish data- and knowledge-bases for HT-VARTM processing of high temperature PMC.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Apply the HT-VARTM processes to various military and commercial applications, including fabrication of selected high temperature PMC test articles, such as supersonic aircraft and engine components. Commercial application: This process can be used in commercial aircraft components near engine exhausts.

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KEYWORDS: High Temperature Polymer Matrix Composite, Vacuum Assisted Resin Transfer Molding, Dimension Variation.

AF07-T014 TITLE: High Frequency Surface Pressure, Shear Stress and Heat Flux Measurements for High Temperature Applications

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop flush-mounted, high frequency response devices for direct measurement of surface pressure, shear stress and heat flux distributions in extremely high temperature environments.

DESCRIPTION: Future USAF capabilities demand system operation in extreme temperature environments. Examples of such systems include high speed reentry vehicles, hypersonic transports, high performance gas turbine engines and scramjets. Crucial system components are exposed to extremely high temperature flow fields, necessitating understanding of the dynamics of the associated flow fields and the effects on exposed aerodynamic surfaces. Inexpensive, high temperature, high bandwidth thermal, shear stress and pressure sensors are desired for ground-based and flight testing of metallic and composite components in turbomachinery and hypersonic vehicle applications, in which few sensors can survive such extreme environments. Instrumentation must acquire data at a high enough rate such that changes due to fluctuations in the ground test environment and/or vehicle maneuvers are resolved.

Boundary layer transition measurements are critical parameters in ground and flight test programs. Surface pressure, shear stress and heat transfer rate measurements are desired to identify transition locations and unsteady thermal loads in shock boundary layer interactions found on hypersonic vehicles and in turbomachinery flows. Multi-point measurements from arrays of sensors would permit the spatial identification of unsteady processes, such as boundary layer instability waves and shock unsteadiness.

Sensor applications also include wind tunnel flow calibration efforts. Measurements of total pressure fluctuations in large DoD hypersonic ground test facilities require sensors with high frequency response and high temperature capability to survive the thermal environment at stagnation points. Long arrays of high frequency sensors are of interest to uniquely locate nozzle wall boundary layer transition during the calibration of large nozzles.

Recent advancements in micro- and nano-fabrication techniques may now enable development of such inexpensive, robust and flush-mounted sensors. The ideal sensor would have 1 MHz frequency response, with sub-millimeter spatial resolution and survivable in temperatures above 1600 degrees Celsius.

PHASE I: Identify and define innovative high frequency devices for measuring unsteady surface pressure, shear stress and heat flux distributions. Define equipment and processes required for ground and flight test data acquisition and reduction. Fabricate and demonstrate proof of concept in canonical flows.

PHASE II: Prototype Phase I technology and integrate with acquisition, analysis and support equipment. Demonstrate sensor integration, extreme environment survivability, ease of use and cost effective manufacturing. Develop and execute a test in a government facility with established flow characteristics to evaluate high frequency sensors and measurement processes. Provide required sensors and equipment.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: The technologies developed in this application can be used for testing and data acquisition for military systems. Commercial application: The technologies identified developed for the Air Force are also relevant in commercial aviation and automotive applications.

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KEYWORDS: High frequency response, hypersonic vehicles, turbomachinery, extreme temperature environment, pressure, shear stress, heat flux, sensors

AF07-T015 TITLE: Short-Wavelength Countermeasure for Circadian Desynchrony

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a scientifically-grounded approach to adjust human circadian phase through photic stimulation of the melanopsin photoreceptor system.

DESCRIPTION: Exposure to visible light is known to affect the phase of the endogenous circadian rhythm. The action spectrum for a variety of associated neurobehavioral effects has been shown to be wavelength-dependent. Photic suppression of melatonin depends substantially on a non-imaging photoreceptor system based upon melanopsin, with maximal sensitivity near 460nm. Effects on heart rate, core body temperature, and plasma cortisol also show short-wavelength sensitivity. Recent research has suggested that this non-imaging photoreceptor system, which has retinal projections to the suprachiasmatic nuclei, the ventromedial preoptic area, and other brain areas, also has a role in regulating human alertness. These findings suggest the possibility of a safe, non-aversive method of delivering optimal photic stimulation to reset human circadian phase and promote alertness.

An effective photic stimulus could mitigate the problem of asynchrony between an individual's endogenous circadian phase and the requirements for alert human performance on imposed environmental schedules (e.g., facilitate adjustments to "jet lag," or shift work, etc.). Research is needed to more fully understand the photic entrainment mechanism, and to define the "optimal dose," in terms of its spectral blend, timing, duration, and method of delivery. This Topic should therefore not be construed as a call for trial-and-error testing of methods or devices. Instead, a solid scientific foundation is needed to understand the role of such factors as pupillary transduction, photometrics, photic exposure history, state of visual adaptation, spatial and temporal neural integration and/or neural opponency. Consideration should also be given to issues of exposure safety.

PHASE I: Perform biophysical and/or neurobehavioral measurements to elucidate and quantify how human alertness can be enhanced through phototransduction mechanisms that affect changes in circadian phase. Develop modeling tools to optimize stimulus parameters.

PHASE II: Refine the measurements and theoretical tools developed in Phase I. Using this scientific background, develop and test novel approaches to optimize photic regulation of human circadian phase. Develop prototype algorithms or devices for potential use in countermeasure technology to mitigate the effects of circadian desynchrony.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: This technology may aid in scheduling command-and-control activity to optimize human performance during adverse circadian phase, and as a countermeasure for fatigue from transmeridian deployments. Commercial application: New techniques for photic stimulation may be useful to treat circadian and affective disorders, for workplace lighting design, and to prevent fatigue in commercial aviation and transportation sectors.

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KEYWORDS: Alertness, Circadian Pacemaker, Melanopsin, Biological Rhythm, Human Performance

AF07-T016 TITLE: Radio Frequency Identification Sensor for Tracking Biological Warfare Agents

TECHNOLOGY AREAS: Biomedical, Sensors, Human Systems

OBJECTIVE: Develop the capability for the Air Force to identfy, track, and engage biological warfare agents

DESCRIPTION: Small chains of DNA (aptamers) have been developed and patented which attach to biological warfare agents. Currently additional molecules have been attached to the aptamers which permit line of sight tracking of the aptamer/biological warfare agent (BWA) complexes. The limitation of this technology is the inability to identify and subsequently track the aptamer/BWA complexes behind walls and inside of containers.
To enable the aptamer/biological complexes to be followed behind walls, a miniature Radio Frequency Identification sensor (RFID) is needed. The RFID must be small enough to attach to an aptamer without affecting the binding properties of the aptamer. The RFID would be inert until the aptamer attaches to the biological warfare agent (BWA). The attachment of the aptamer to the BWA would activate the associated RFID. The RFID would be queried with a specific radio frequency and if it were activated by the aptamer/BWA complex it would return a radio frequency of a different wavelength. The return signal could then be “read” through walls and from inside of containers. The BWA could be located and tracked using the return radio signal.

PHASE I: Research the proof of concept of developing radio frequency identification (RFIDs) nano-particles that when challenged with one frequency of radio energy will emit a signal on a 2nd frequency. The RFIDs must be able to emit a signal indicating aptamer the has attached to a biological warfare agent.

PHASE II: Develop (RFIDs) nano-particles that when challenged with one frequency of radio energy will emit a signal on a second frequency and can be attached to aptamer. The RFIDs must be capable of emitting a radio signal that indicates that the aptamer has attached to a biological warfare agent. Demonstrate RFIDs that can be attached to a aptamer will function with a simulated biological warfare agent.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Infectious Biological Warfare Agents (BWAs) are very deadly to personnel. The RFIDs will give the Air Force the capability to locate, track, and engage BWAs behind walls and inside of containers. Commercial application: Nano-RFIDs could be use used to track valuable industrial material shipments or could be used by law enforcement officers to find and track illegal drugs or other illicit materials.

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KEYWORDS: radio frequency identification devices, RFID, biological warfare agents, taggants

AF07-T017 TITLE: Algorithm Development for Reconfigurable Computing Architectures

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: To develop advanced algorithms with reconfigurable computing paradigm for modeling and simulation based on non-von Neumann computer architecture.

DESCRIPTION: The availability of modern reconfigurable hardware technology brings an unprecedented opportunity for the acceleration of complex computations in engineering applications. Reconfigurable hardware-oriented algorithms implemented in field-programmable gate arrays (FPGAs) perform 10 to 1,000+ times faster than traditional serial or parallel algorithms, and can usually be developed for a fraction of the cost of a supercomputer or computer cluster. Reconfigurable computing is fast-approaching maturity as a robust technology for high–performance computing [1]. However, there are still relatively few people who understand it deeply enough for algorithm research and development. In order to unleash the full potential of reconfigurable computing in a vast array of scientific computing applications where faster numerical computation is a crucial necessity [2], research is needed to understand algorithm development with particular emphasis on scientific computing (i.e., solving differential equations of physics). Algorithm design under the reconfigurable computing paradigm requires an understanding of FPGA architecture, VHDL (hardware programming or “description” language), compiling, debugging, and synthesis tools. The present initiative seeks innovative algorithm development for reconfigurable computing. This should include developing a set of criteria for defining model test problems of a multidisciplinary nature and evaluating existing computational tools for comparison with the methodology developed. Specifically, the solution of differential equations and stochastic (e.g., Monte-Carlo) techniques on a large-scale are of utmost importance for Air Force scientific computing needs. Examples of such problems include electromagnetic wave propagation, computational fluid dynamics, particle transport and radiation transport.

PHASE I: Develop & demonstrate computationally effective solutions to problems of mathematical physics with innovative algorithms for (i) solving differential equations and/or (ii) simulating the physics via stochastic techniques with parallel and distributed computing. Formulate R&D plan for Phase II

PHASE II: Expand the capability of selected algorithms for multidisciplinary computing into a production–level product capable of solving complex problems in fluids, structures, and electromagnetism taking full advantage of reconfigurable computing architecture.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Applications for modeling and simulating realistic analysis, design, and optimization challenges. This includes but not limited to integration, structural analysis, and signature optimization. Commercial application: Commercial applications apply to any system or sub-system level optimization where detailed multidisciplinary computational analysis is required.

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KEYWORDS: Reconfigurable computing, field-programmable gate arrays, parallel computing, computational mathematics, computational physics.

AF07-T018 TITLE: Monitoring Activities and Trends to Determine Suspicious Entities

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop an automated technique enabling Air Force users to determine suspicious entities within a given dataset, with high accuracy.

DESCRIPTION: This capability will assist the intelligence analyst to obtain the essential understanding they need of given networks in datasets. It will allow them to discover and determine suspicious entities (people, places, events, objects, etc.) and the relationships that exist.

An entity is defined as something that is perceived or known, or inferred to have its own distinct existence (living and non-living). Examples of an entity can be a person (George W. Bush), a location (Air Force Research Laboratory Information Directorate Headquarters), an event (G8 Summit), an organization (Al Qaeda), and an object (weapons grade uranium).

As the fight against asymmetric threats continues to grow, it’s become increasingly important to identify suspicious entities, however it’s extremely complex to make the distinction between suspect and non-suspect entities. A technology needs to be available that determines red forces from grey forces. For example, if a vessel has veered off its scheduled path and has not communicated before it enters its destination port, it can be considered to be suspicious. The actual pattern of these events is more detailed and attempting to draw this conclusion from the given datasets is complex. This is just one example of how this technology could be applied.

Given this background, the objective of this STTR Topic is to develop an automated technique to determine suspicious entities. This technique should leverage social network analysis, especially link analysis and group detection. There needs to exist a capability that will allow analysts the ability to determine links, groups, and networks amongst entities. Then, taking this information and developing an understanding for this and what it means to the given situation. This technique also must be able to be flexible and reason over multiple data formats and schemas, per the analyst’s needs.

PHASE I: Develop an innovative approach to meet the STTR Topic requirements, and assess its feasibility. Develop the initial design for a prototype and demonstrate its application.

PHASE II: Research and develop the required technologies and prototype, per the Phase I design. Develop and demonstrate prototype tools and techniques for monitoring activities and trends of entities in domains of interest for Air Force users using real-world data.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Rapid customization of monitoring activities and trends to a warfighter’s specific domain (Area of Responsibility), enabling more dynamic situation awareness. Commercial application: Identify insider threat amongst employees in commercial organizations.

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KEYWORDS: Situation Awareness, Knowledge Discovery, Asymmetric Threats, Social Network Analysis, Link Analysis, Group Detection

AF07-T019 TITLE: Scalable Formal Methods for Distributed Systems

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Advance theory to support scalable formal methods for distributed systems; develop tools that apply them.

DESCRIPTION: Distributed systems are ubiquitous in the infrastructure of our nation. Much is at stake in designing them well: our economy, safety and security. They are, however, difficult to understand and design, which can lead to unexpected behaviors ranging from innocuous to actually or latently catastrophic. Formal methods have had some success in ensuring the reliability and robustness of moderately complex systems. Yet their applicability is limited in two significant ways. First, the size and complexity of actual distributed systems challenges the theoretical foundations of formal methods. These must cope with the state-explosion problem inherent in concurrent systems, and accommodate different kinds of properties of these systems. Second, the practical application of formal methods requires tools that are general, flexible, useful and easy to use. This solicitation invites proposals that will transition the best of theory into the best of tools, to produce a significant incremental advance toward the goal of useful, scalable formal methods. The proposal must describe an innovative approach to achieve this goal. It must discuss how the theoretical component of the project will improve significantly the power and scalability of formal methods. It must describe and discuss a plan to exploit this theory in the design and development of tools and methodology to support the development of complex distributed systems. The discussion may describe a vision and philosophy of a research direction, but it will clearly scope out short-term tasks that are significant steps in investigating the described approach to the problem of scalability.

PHASE I: Significantly advance proposed approach to improve the scalability of formal methods for designing distributed systems: develop theory to be applied in tools and methodology that improve the flexibility and scalability of current methods; give evidence of effectiveness of this research direction.

PHASE II: Applying theory and methods developed in Phase I, develop tools and methodology that supports the development of distributed systems. The main criteria in judging this part of the project are flexibility and ease-of-use of the tools, and useful support to the design and development process of distributed systems.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Secure military applications require complex protocols that must behave as intended in all scenarios. Tools developed under this research program would support the development of these protocols. Commercial application: Complex commercial applications require dynamic, constant availability of accurate information, which means they must rely on well designed distributed systems.

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KEYWORDS: Scalable formal methods,design of distributed systems

AF07-T020 TITLE: Software Integration for Computational Cognitive Models in Virtual Environments

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a robust and general interface linking 3D simulation environments to computational cognitive modeling platforms

DESCRIPTION: Recent developments in computational cognitive modeling architectures have included implementation of perceptual and motor modules that allow models to interact directly with software (e.g., Anderson et al., 2004; Kieras & Meyer, 1997; Ritter, Baxter, Jones, & Young, 2000). However, the laboratory-based history of these systems means that they have not been designed to inhabit complex 3D environments of the sort that are typically used in military training applications. Technology that provides a link between 3D virtual environments and computational cognitive modeling architectures is lacking in the field of cognitive science and stands in the way of developing robust, cognitively plausible replicates to inhabit these training simulations. Ad hoc instances of these links have been developed (e.g., Best, Lebiere, & Scarpinatto, 2003), but lack the usability and generalizability required to make them appropriate for most applications. The agents that currently inhabit these environments are tailored to the application, and incorporate special-purpose mechanisms for interacting with the software. For computational cognitive models to function as robust and cognitively valid entities in these applications, a general, standardized approach to extracting visual and spatial information from simulation environments is necessary.

PHASE I: Develop an initial framework for processing data from candidate 3D virtual environments for use as inputs to a computational cognitive architecture. This requires analyzing the information available from the system as well as consideration of human information processing limitations.

PHASE II: Develop a software application to communicate between simulation-based virtual environments and computational cognitive agents implemented in a cognitive architecture, which is general enough to operate with multiple 3D simulation environments and multiple cognitive architectures. Information from the simulation environment should support psychologically plausible performance.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: This technology will support the development of robust, cognitively realistic agents for simulation-based training environments, reducing costs and personnel for conducting realistic training events. Commercial application: This technology provides the foundation for developing algorithms for spatial reasoning in robotics that are cognitively plausible, for use in applications where humanlike behavior is desirable.

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KEYWORDS: Computational cognitive model, cognitive science, simulation-based training, virtual environment, cognitive architecture, spatial, interaction

AF07-T021 TITLE: Platform routing and data fusion technologies for Cooperative ISR

OBJECTIVE: Investigate optimal platform routing techniques and algorithms to optimize collection for fusion metric benefits while satisfying collection and de-confliction requirements.

DESCRIPTION: The significant growth in UAV platforms and payload capabilities offer a challenge and opportunity to realize the benefits of cooperative Intelligence, Surveillance, and Reconnaissance (ISR). The combination of both (1) wide-body and UAV cooperative systems or (2) multi-UAV (ie all-UAV) cooperative systems have positive, but different benefits to improved ISR.. Among other technology challenges, the routing and data fusion requirements related to effective use of these cooperative platforms will require unique algorithmic techniques and methods for evaluation of these innovative approaches.

PHASE I: Select, research and define applications and appropriate optimization techniques for fusion of multi-source data from wide-body and UAV on-board sensors. Utilize Measures of Performance (MOPs) to determine fusion resultant improvements. Design an architecture to dynamically utilize the MOPs to enhance algorithm performance.

PHASE II: Optimize routing to satisfy a broad set of constraints and mission requirements. Utilize the architecture designed for optimizing fusion performance metrics. Analyze the resulting fusion process performance. Distributed data fusion processes, track management and methodologies for handling track duplication will be a technical challenge influencing design and testing of algorithm approaches.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Optimizing collection centers for increased information and situational assessment. Commercial application: Applications to Commercial agencies for the use of optimized collection and fusion plans could benefit the civilian population tremendously resulting in more efficient use of the nation's highways.

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KEYWORDS: Cooperative ISR, Data fusion technologies, UAV platforms

AF07-T022 TITLE: <u>Innovative, Renormalizable Numerical Approach to Multi-Scale Modeling</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: To develop a numerical method based on dynamic clustering of a hierarchy of spatial and temporal scales, with renormalized cluster interactions and accurate two-way inter-scale mappings, which allows efficient computations for multi-scale and multi-physics problems.

DESCRIPTION: A wide variety of problems of interest to the DoD that require scientific modeling involve multiple time and length scales, and even multiple physical models on each range of scales. Of particular interest here is the computation of complex non-equilibrium plasma, for which kinetic descriptions are applicable on micro-scales, while continuum fluid models are used on the large scales of interest. Typically, the micro-scale physics are considered through the definition of transport mechanisms and coefficients, assuming relatively simple, quasi-equilibrium configurations. This is also the case, for example, in turbulent flows, where an equilibrium Kolmogorov spectrum is assumed to yield transport coefficients for Reynolds-Averaged flow models. The case of non-equilibrium plasma is of particular interest, because the coupling to electromagnetic fields can induce very dynamic changes to the plasma and correlations across a wide range of scales. For example, kinetic effects can play a major role in the rate magnetic reconnection in MHD plasma, and affect the overall large-scale structure and stability of the plasma, while the micro-scale kinetics are themselves governed by "mean-field" properties of the plasma's larger scales. The approach of particular interest here is the dynamic partitioning into clusters as virtual structures of the phase space. Interaction with the dynamics of the next scale could be achieved, for example, through boundary integral solutions or moment expansions. In some aspects, the model of dissipative particle dynamics could be considered an example of this principle. A more general approach to multi-scale simulation can potentially be derived from the powerful theoretical tool of renormalization group (RNG), which was developed for condensed matter and quantum field theory. In essence, RNG provides the means of relating the dynamics of one scale to another through the re-definition of effective coupling constants and other parameters for scale-averaged micro-structures. While the original concept describes a mapping of one formulation (effective action) to another of the same type, one can also in principle generalize the procedure to yield different models on each scale. For example, the kinetic model at the smallest scales can project into a multi-fluid model on the next one, and then into a single-fluid MHD model in the next one; this allows a generalization of the procedure to multi-physics as it spans the range of scales.

The proposed effort should aim at developing a general mathematical and computational procedure based on the principles mentioned above, which can (a) dynamically separate sub-structures at different spatial and temporal scales; (b) efficiently solve the dynamics for each separate scale; (c) provide an accurate interface between the different scales; (d) provide a control mechanism to verify the accuracy of the scale separation and inter-scale mappings; (e) be extensible to various problems besides plasma physics (e.g. plasma-material interactions, materials for crack propagation and fatigue, or turbulent reacting flows). The approach should be computationally efficient, i.e. should dynamically resolve the fine scales only where and when necessary, be parallelizable, and should not be excessively memory intensive.

PHASE I: Develop simplified model with reduced dimensionality or reduced complexity in physical modeling, or develop complete solid theoretical foundation for the approach. Develop detailed plan for Phase II implementation and testing and validation.

PHASE II: Complete development of numerical procedure for multi-scale plasma simulation, in moderately complex configuration (at least 2D), using a well-chosen test-case for demonstration of the accuracy of the method and potential for applications to other physical problems. Demonstrate or measure computational efficiency.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Method can be used for plasma simulations of space weather, electric propulsion systems for satellites, space flow contamination, plasma discharge processing, magnetrons and beam propagation.
Commercial application: General approach can be used for materials modeling (crack, void, fatigue, aging), turbulent flows and combustion, weather modeling, etc, applications also of great significance to the DoD.

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KEYWORDS: Multi-scale, multi-physics, plasma, renormalization, interscale transfer, kinetics, treecode, moment closure, boundary integral.

AF07-T023 TITLE: Advanced Combat Simulation for More Effective Anti-Terrorist Operations

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Advance the state-of-the-art in user-friendly combat simulation software by enabling the realistic modeling of anti-terrorist operations.

DESCRIPTION: Today's asymmetric warfare environment demands a new generation of smart, user-friendly combat simulation software (wargames) that go beyond the historical premise of massive "force-on-force" operations. Current "battlefields" are less likely to have "front lines" separating our troops from well-armed enemy divisions. They are more likely to contain off-limits "civilian" populations of uncertain loyalties, suicide bombers and improvised explosive devices (IEDs) that can kill, maim, and/or demoralize our troops. Security forces at forward-deployed airbases, for example, must formulate doctrine and tactics to protect our personnel and assets against fanatical suicide bombers and against mortar shells lobbed from nearby civilian areas rather than against the coordinated armored assaults of the last century. Realistic strategy wargames can address that requirement if they could accurately model such elements of today's asymmetric warfare environment. The challenge for the wargame developer is to formulate new algorithms to capture the crucial nuances of these new threats while also maintaining flexibility for the real-time updating of emerging technologies and accounting for the subtle yet important cultural and social idiosyncrasies for different regions of the world. Finally, the software's artificial intelligence should actively "observe" the tactics employed by a given human opponent and thereby "learn" what concepts work best to defeat its human adversary. This capability would help to capture the patient scouting preparations and adaptive tactics often employed by seasoned terrorist organizations. Our tacticians would thus be forced to constantly rethink approaches to given terrorist scenarios. Overall, this would create a wargaming environment optimized for useful learning on the part of the human warfighter. To thereby maximize chances for formulating new operational doctrine that can realistically succeed with minimum casualties against a complex and intelligent foe, the "strategy" genre of wargames will take precedence to "arcade" style games.

PHASE I: Create a detailed research plan for Phase II explaining how combat simulation software can be enhanced so that it can realistically model modern asymmetric combat. Each new capability should be explained. Preliminary software enhancements should be implemented and tested.

PHASE II: Complete a user-friendly, PC-based, artificially intelligent asymmetric combat simulation system.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: The resultant wargame software will be immediately useful to war-fighters to combat the asymmetric threat in Iraq, Afghanistan, and other deployment scenarios. Commercial application: It could similarly be directly used by commercial "security services" seeking new tactics to better protect clients against both terrorist and criminal threats. Furthermore, the new software game engine can be used to create new commercial computer games to introduce into the domestic $1 billion+ per year entertainment game market.

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KEYWORDS: Wargame, Combat Simulation, Artificial Intelligence, Asymmetric Warfare

AF07-T024 TITLE: <u>Autonomous Precision Inertial Navigation System Using Cold Atom Chip Sensor</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Research sources of decoherence, environmental noise and errors, leading to the design and construction a microchip interferometer and platform.

DESCRIPTION: Harnessing the unique properties of ultracold gases is revolutionizing inertial force sensing. This technology could make for very small, extremely precise sensors that consume very little power for many space-based applications including precise targeting, tracking, and pointing, all requirements for space-based C3ISR and space superiority (survivability, offensive and defensive counterspace, communications). Such a sensor could be made into a small, GPS-free, non-emanating, jam-proof inertial navigation system. This effort will focus on understanding the environmental sources of decoherence that disturb rotation measurements and provide appropriate solutions to minimize their impact, while integrating a controlled rotation to these devices. A thorough investigation into the sources of phase decoherence will be required to successfully mitigate their damaging effects on rotation measurements. Another research challenge will involve determining and understanding scale factor errors. Scale factor errors are the errors between the measured rate and the actual input rate increases as the input rate grows. Determining the physical analog to a "closed loop solution" would convert a rate gyro into a rate integrating gyro, perhaps mitigating this error source. Overcoming this research challenge is critical for achieving scale factors suitable for inertial navigation. To work these research issues a rotation platform is needed. In addition the platform itself has several scientific and engineering issues that must be addressed including analyzing vibration dampening during rotation, which is a major source of environmental noise with a sensitive rotation sensor

PHASE I: Research and understand sources of decoherence, environmental noise and errors. Design a suitable platform sufficient for mitigating these unwanted factors

PHASE II: Develop a prototype of the Phase I design of the sensor platform

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: GPS-free, jam-proof navigation; remote sensing of other space objects via gravitational or magnetic sensing; tracking; targeting; and pointing with inertial sensors for feedback. Commercial application: Commercial applications include satellite pointing for communications.

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KEYWORDS: Rotation sensor, Fiber optic gyroscope, Bose-Einstein condensation, atom interferometry.

AF07-T025 TITLE: Hybrid CMOS/Nanodevice Integrated Circuits

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Explore the possibility to design and fabricate high-performance hybrid semiconductor-nanodevice integrated circuits for a broad range of applications in digital and mixed-signal electronics.

DESCRIPTION: It is generally accepted now that the current exponential (“Moore’s-Law”) progress of semiconductor microelectronics will come to halt some time during the next decade, unless new concepts and/or devices are introduced to integrated circuits. It is also widely accepted [1] that none of the known nanodevices, which could be reproducibly fabricated at reasonable costs, has a functionality which might parallel that of the silicon technology workhorse, the field-effect transistor. Recent results [2, 3] indicate that this dead end situation may be overcome using hybrid CMOS/nano integrated circuits, in which a layer of simple (two-terminal) nanodevices with a very small footprint would work as an add-on for CMOS circuits fabricated using relatively crude (e.g., 32-nm) lithography. Especially promising seems the so-called CMOL concept [2] in which the CMOS/nano interface is provided by vertical pins distributed over all the chip surface. Calculations show that digital and mixed-signal CMOL circuits may enable an unparalleled circuit density (up to ~1012 active functions per cm2), creating an unprecedented potential for information storage and processing performance (up to 1020 bits per cm2 per second) at acceptable power dissipation, thus deferring the Moore’s Law demise for approximately 15 years. However, despite the recent demonstration (see, e.g., [4]) of two-terminal devices sufficient for the initial stage of CMOL technology development, several significant scientific and technological advances have to be made to make this technology practicable. The objective of this STTR effort is to implement in practice the basic CMOL circuit concepts and prepare this technology for the broad practical introduction.

PHASE I: Based on published results and preliminary experiments, select the most promising active device and passive interconnect technologies, and demonstrate experimentally the first CMOL circuit cells.

PHASE II: Build CMOL circuits of medium integration scale and optimize their performance, power and defect tolerance. Develop new CMOL circuit architectures scalable to sub-10-nm nanodevices.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: CMOL circuits may enable new ultra-compact, ultra-fast signal processing with minimal power dissipation. The impact on command and control, and on surveillance and communications, will be enormous. Commercial application: Development of the ultimate in compact circuitry with minimum power dissipation will have a huge range of applications: consumer electronics, digital signal processing; and biomedical applications.

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KEYWORDS: nanoelectronics; CMOL; integrated circuit; CMOS; nanodevice; nanosensor; digital electronics

AF07-T026 TITLE: Novel Crystal Growth Technology for Bulk Semiconductor Ternary Alloys – Modeling and Experiment

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To investigate, develop, and transition crystal growth processes to produce bulk ternary crystals of uniform composition and low defect density.

DESCRIPTION: The Air Force has an interest in high-speed electronics and long wavelength IR detectors based on bulk semiconductor wafers. Bulk crystal wafers are the foundation of advanced microelectronics, enabling a wide variety of electronic and photonic devices. Currently, thin-film device technology is dependent on the availability of substrate wafers that are lattice-matched to the device crystal structure. Without a lattice-matched substrate, the device design is problematic; very expensive steps must be taken to compensate for the resulting lattice strain. For the next generation of microelectronics and optoelectronics, semiconductor wafers of specified alloy concentrations are required. However, semiconductor bulk ternary alloy crystals are not available commercially. A new type of crystal growth furnace is needed in order to grow ternary alloys of uniform composition. The new furnace design requires electromagnetic stirring for better control of doping uniformity and interface shape. The application of external force fields during crystal growth must be designed to control the compositional uniformity of the crystal and to reduce dislocation density. Within the proposals, offerors must justify the theoretical advantage of applied external fields for improving the uniformity of ternary alloys, based upon solid scientific evidence, and must discuss the feasibility of implementing the new design in a crystal growth furnace for ternary crystals of relevance to Air Force interests.

PHASE I: A model shall be developed to justify the configuration of applied external fields to improve crystal uniformity, and a furnace design that enables significant improvement in the operation of ternary semiconductor bulk crystal growth shall be implemented.

PHASE II: The proposed furnace design shall be further developed, and a crystal growth furnace shall be fabricated to demonstrate the improved crystal growth technology. All necessary manufacturing processes for commercialization of the crystal growth furnace shall be developed as well.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Follow-on activities are expected to be aggressively pursued by the offeror, namely in seeking opportunities for integrating the improved crystal growth furnace into commercial activity. Commercial application: Commercial benefits would be for medical laser procedures, remote bio/chemical detection, and scientific instruments.

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KEYWORDS: Crystal growth, semiconductors, IR detectors, ternary alloys, lattice-matched alloys

AF07-T027 TITLE: <u>Wavelength and Polarization Agile Infrared Detector Materials</u>

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop new detector material structures that support passive spectral and polarization sensing at infrared wavelengths without external components.

DESCRIPTION: The performance and operational feasibility of passive spectral and polarimetric imaging sensors in the thermal infrared (nominally 2 to 14 micron wavelength) would be greatly enhanced by the ability to perform the spectral and polarization filtering within the detector materials, as opposed to using external means such as spectrometers, waveplates, and filters. This topic is intended to explore new material structures, such as quantum-confined heterostructures of III-V materials, that offer the possibility of achieving the needed spectral resolution (better than 100 nm) and polarization sensitivity (100:1 extinction ratio) for future remote sensors with the filtering performed inherently by the material absorption characteristics. It is further intended to explore means for both spatial (lateral and along the growth direction) and electrical control of the fundamental detector properties in order to ultimately obtain spatially and/or temporally tunable devices.

PHASE I: Develop new material constructs that support fine spectral and/or polarimetric tunability. Perform theoretical and analytical modeling of the material structures to estimate the expected sensitivity and filtering potential. Experiment with test structures to validate the key device concepts.

PHASE II: Fully design and fabricate spectrally and/or polarization agile detector array devices. Perform thorough device characterization, compare to model predictions, and resolve discrepancies. If possible, mate the detector array with a read-out integrated circuit and perform a sensor demonstration and evaluation.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: This technology has the potential for use in a wide range of military and civilian remote sensing applications, including geology, agriculture, surveillance, disaster relief, and drug enforcement.

Commercial application: This technology has the potential for use in a wide range of military and civilian remote sensing applications, including geology, agriculture, surveillance, disaster relief, and drug enforcement.

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KEYWORDS: Hyperspectral, Polarization, Infrared Detectors

AF07-T028 TITLE: Photonic Analog-to-Digital Converter

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop and demonstrate photonic technologies for high resolution (> 10 bits) and high speed (> 10 GigaSamples per second) analog-to-digital signal conversion.

DESCRIPTION: Rapid advancements in digital signal processing have had a tremendous impact on radar, surveillance and communication systems. CMOS chip capacity as described by Moore’s Law continues to double every eighteen months. Processing speed has also increased due to advancements in parallel computing architectures. However, this continual improvement in DSP capabilities cannot be fully exploited. The rate-of-improvement in analog-to-digital converters (ADCs) has not kept pace with the advancements in DSP. ADCs are a bottleneck in current receiver systems. For example, the average increase in ADC resolution for a given sampling rate over an eight year period was only 1.5 bits. Conversely each time the sampling rate is doubled there is a loss of one bit of resolution. ADC performance is limited by a number of factors including thermal noise, aperture jitter and comparator ambiguity. Improved ADC performance will have a tremendous impact on digital receivers. Current wideband receivers use standard frequency downconversion techniques prior to digitization due to limited ADC performance. These techniques require single or even multiple stages of mixing and filtering resulting in increased size, weight and power of receiver systems. Frequency downconversion also introduces additional nonlinearities resulting in a reduction in the system dynamic range or effective number of bits of resolution. Digital receiver functionality will be further enhanced by pushing these advanced ADCs closer to the antenna allowing more processing functions such as matched filter and out-of-band rejection to be performed in the digital domain.

Recent improvements in enabling photonic component and subsystem performance have renewed the interest and activity of using photonic techniques for high speed and high resolution analog-to-digital conversion. Photonic technology is an attractive candidate for ADC applications for a variety of reasons including its wide bandwidth, ultrafast switching speeds and its potential for integration resulting in significant size, weight and power savings. One such advantage is the use of a modelocked laser to precisely sample an analog signal. There has been much recent activity in achieving ultrastable pulse trains from modelocked lasers for this sampling process in order to maximize the accuracy and hence the resolution of the ADC. Optical sampling has been shown to exhibit ultralow timing jitter far surpassing state-of-the-art electronic sampling. In addition to ultralow timing jitter, optical sampling also offers narrow pulse widths, limited interaction with the electronic input signal and the ability for optical remoting over extremely long distances. These features are not possible with conventional electronic sampling. There has also been recent activity in the development of demultiplexing technology so that the high speed optically sampled signal can be quantized by a parallel bank of high resolution, low speed electronic quantizers. This demultiplexing has been demonstrated in both the time and wavelength domain. Alternatively, there has also been much interest in a wide variety of photonic quantization techniques following the optical sampling process. These techniques often require the use of an efficient, high contrast, and low loss optical switch.

This topic will build upon advances in enabling photonic technology and methods in order to develop and demonstrate photonic analog-to-digital conversion. Key areas to be investigated and researched include robust, ultrastable, high dynamic range optical sampling schemes. Novel electro-optic and photonic quantization schemes including enabling devices are also of key interest to this topic. Scalability in terms of both sampling speed and resolution is required to meet various military and commercial applications. Minimizing the loss within the photonic analog-to-digital converter is essential in meeting military and commercial system performance requirements and loss budgets. The viability of a photonic ADC system is severely compromised as its optical insertion loss and required power increases. A major component of this topic is to demonstrate device and subsystem technology that can be ultimately integrated in order to meet the restrictive volume constraints encountered in typical military and commercial receivers.

Novel schemes and devices for photonic quantization will also be investigated including nanophotonics, silicon based photonics, and fabrication of the key components.

PHASE I: Investigate, design, model and perform critical experiments to identify possible photonic device and subsystem approaches for photonic analog-to-digital converters operating at > 10 GigaSamples per second (GS/s) and with > 10 bits of resolution.

PHASE II: Develop and demonstrate prototype photonic analog-to-digital converters operating at > 10 GS/s and with > 10 bits of resolution. Perform laboratory testing of the prototypes to determine their utility in both military and commercial systems.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: The primary military use will be in radar, surveillance, electronic warfare and communication receivers as well as in digital beam forming techniques for phased array antenna systems. Commercial application: Commercial uses include high speed instrumentation including test and measurement equipment, cell phone bay stations, and phased array antenna systems. Low cost manufacturing will be a focus.

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KEYWORDS: photonic analog-to-digital converters, modelocked lasers, quantizers, multiplexing, analog-to-digital converters, optical switching, modulators, lasers, detectors, optical comparators, integration, optical sampling

AF07-T029 TITLE: Computer Aided Design for Rapid Development of Novel Optical Materials and Sensors

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Define and develop a computer aided design solver capable of shortening the time to development of novel optical materials and sensors.

DESCRIPTION: Computer aided design continually grows in importance to military and commercial users. At the same time, device fabrication using two photon-initiated microlithography requires variations of many chemical and laser parameters, particularly with recent significant advances in laser technology, such as shorter pulse durations (picosecond and femtosecond), high repetition rates, extended spectral range (visible to near infrared) and higher intensity. Together these systems possess unique characteristics for inducing structural change in solids of all types. The sensitivity of such phenomena to the local laser intensity gives them sharp and repeatable thresholds for producing damage and sub-damage modification. Additionally, infrared femtosecond photo-initiated microlithography using Ti:sapphire lasers is being used to create new structures such as gratings and a variety of photonic devices in other host crystals. Both applications involve complex chemical chromophores such as reverse saturable absorbers or two-photon absorbers. The current method of chemically synthesizing the materials and testing them in various optical geometries has shown limited success. The cost and fabrication time preclude performing all of the required variations of materials and optical parameters experimentally. A user-friendly computer aided design program is therefore needed. One of the key features for military and commercial applications is a sophisticated, user-friendly Computer Aided Design (CAD) program, which will shorten time to product development.

PHASE I: Define and determine an innovative computational design program for rapid development of novel optical materials and sensors. Describe potential numerical algorithm(s); develop initial concept, and model key parameters to compare with experiments.

PHASE II: Develop and demonstrate a software package that will permit a realistic computational program for design of optical materials and sensors. The software package should demonstrably show the benefits of its use for applications such as optical limiters and two-photon absorbers. Deliverables include description of algorithms used, definitions of all input and output parameters, and a prototype code

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: The military anticipates using such optical materials as protection for eyes and sensors against laser pulses, particularly ultrashort pulses. Commercial application: Commercial benefits include expanded and improved competitive opportunities for industrial applications in photodynamic therapy, communications, sensors, biotechnology, and medicine.

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KEYWORDS: Optical Materials, Ultrashort laser pulses, computer aided design

AF07-T030 TITLE: High Current Density Thermionic Cathodes For Future Vacuum Electronics Applications

TECHNOLOGY AREAS: Electronics, Weapons

OBJECTIVE: To develop and demonstrate reproducible, reliable operation of a thermionic cathode providing > 100 A/cm2 of pulsed current density with a lifetime of many thousands of hours (i.e. total time at operating temperature) for application in vacuum microwave, millimeter wave, and terahertz sources.

DESCRIPTION: Recent promising results in advanced scandate cathodes require additional examination. Modern preparation techniques have led to homogeneously porous bodies with sub-micron substrate grain sizes and nanometer-scale Sc-based dopants. Though there are reports of > 100 A/cm2 from some versions of scandate cathodes, these results are still not easily reproduced or fully understood. The goal of this research is to establish a firm understanding of the relevant physical mechanisms via surface science studies and any other pertinent techniques. In addition, this advanced understanding should be used to manufacture and test a thermionic cathode capable of emitting > 100 A/cm2 of pulsed current density at low duty (e.g. 10 microsecond duration pulses at 10 Hz repetition). The cathode should be designed and built with the intent that it will supply the electron beam for a vacuum microwave, millimeter wave, or terahertz device. It should be capable of emitting the required current density for many thousands of hours and should be compatible with potential continuous (dc) operation for future applications.

PHASE I: Analyze promising scandate cathodes to develop an understanding of the critical physical features required for long-lifetime, high current density operation. Determine appropriate manufacturing technique to accomplish the required features. Produce and test prototype scandate cathodes.

PHASE II: Perform pre-test and post-test analysis on the Phase I-manufactured scandate cathodes to further develop the understanding of the processes involved. Optimize the manufacturing to achieve > 100 A/cm2 of pulsed emission for lifetimes > 10,000 hours at operating temperature.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Such cathodes may supply the electron beam required in next-generation microwave devices for radar, communications, and, eventually, high power microwave devices for Directed Energy applications. Commercial application: These cathodes may be scaled to provide the electron beam for terahertz sources for applications such as medical imaging diagnostics, semiconductor device characterization, and combustion analysis.

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KEYWORDS: high power microwave, radar, vacuum electronics, electron beam, cathode, thermionic

AF07-T031 TITLE: Robust, Autonomus, Inexpensive Space Weather Sensors

OBJECTIVE: Develop robust, autonomous, low-cost sensors to deliver near real-time, three-dimensional space environmental data.

DESCRIPTION: Space weather impacts satellite health and operations, space situational awareness, and surveillance, reconnaissance, navigation, guidance and communication systems. An area of particular concern is the effect on radio signals that pass through, or reflect off the ionosphere and the associated impacts on the performance of operational space, air and ground systems. As the DOD has moved to more sophisticated applications that interact in more complex ways with the ionosphere and the space environment in general, the ability to specify, forecast, and mitigate the impact of space weather has lagged. One reason for this lag is that the space environment has been drastically under-sampled, compared to the tropospheric weather environment, because the high costs have prohibited wide deployment of the sensors capable of measuring the upper atmospheric, ionospheric, magnetospheric and heliospheric environments. A second reason for the lag is that very few of these instruments provide timely data in a format and quality ingestible by space weather models without exorbitant human intervention. Current space weather sensors range in cost from tens of millions of dollars for incoherent scatter radars, to the range of a hundred thousand dollar for ionosondes, coherent radars, low-light imagers and Fabry-Perot interferometers, and ten thousand dollars for multi-frequency GPS and beacon receivers. The number of instruments deployed and able to contribute to space weather efforts in each cost range is in general inversely proportional to the acquisition and operations costs, with only a few incoherent scatter radars around the world but networks of hundreds of GPS receivers now in operation. Inexpensive, field-deployable sensors representing further reductions in the cost of, and corresponding increases in the density of space weather measurements would revolutionize our ability to assess and exploit space weather impacts in a timely and meaningful way. Under this topic we seek to develop a new, innovative generation of more affordable space weather sensors capable of feeding quality measurements of both quiet and disturbed conditions to models in near real-time. Concepts for reducing weight, size, and power, while maximizing network connectivity and automation to reduce operating costs and data latency, are specifically desired. The total cost of the system, including procurement, installation, maintenance and operation should be considered. Sensors capable of remote, unattended operation are especially of interest. Proposals may include some modeling component for aggregation, interpretation, or quality control of sensor outputs, but the primary focus of the work should be on low-cost techniques or systems to significantly increase the density of real-time measurements. Responses to this topic may focus on, but are not limited to a single technique or instrument type, such as oblique ionospheric sounding, high-frequency magnetometer mapping of current systems, or optical or Global Positioning System (GPS) remote sensing.

PHASE I: Develop a concept for a measurement technique or system with the potential to greatly reduce the cost and increase the density of space weather measurements. Determine what parameters are potentially observable and develop concepts for measuring, providing quality control of, and reporting the parameters.

PHASE II: Develop, build, and test an actual space weather sensor or sensor system capable of being produced and deployed in large numbers and operated with minimal human intervention or maintenance. Demonstrate sensor capability in an appropriate field environment, including sensor operation and data hand-off to a third-party space weather model or archiving system. Validate sensor capability against present-generation ionospheric sensors.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Sensor networks to feed space weather specification and forecast models and data products. Commercial application: Space weather monitoring for civilian government systems (such as the FAA WAAS) or private enterprise applications affected by space weather (long-distance power transmission, semiconductor production, satellite communications, precision surveying, etc). Low cost sensor systems can also be expected to open up new applications such as operation of sensor networks from schools or other educational institutions.

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KEYWORDS: Ionosphere, ionospheric monitor, space weather, ionospheric impacts, space weather impacts, radio propagation, GPS, ionospheric sounding, ionospheric tomography

AF07-T032 TITLE: RADAR Moving Target Indication Interpretability Rating Scale (MTIIRS)

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop a rigorous theoretical framework for assessing Moving Target Indication (MTI) RADAR sensors.

DESCRIPTION: While prior work has made progress in estimation of MTI effectiveness, there is a large amount of work left for RADAR targeting performance to be estimated with the same accuracy as that of EO and IR systems. First, an image quality equation that provide RADAR MTIIRS as a function of imager characteristics is required. Second, a minimum resolvable contrast/minimum resolvable temperature (MRC/MRT)-type model must be developed for RADAR applications. MTIIRS will be a collection of scientific algorithms working together to establish moving target indication tracking and performance predictions. The MTIIRS technical approach should consist of the following main categories:

- Identification of key Air and Ground Moving Target Imager (MTI) performance requirements.
- Identification of key physical parameters.
- Establishment of performance figures.
- Performance estimate modeling.
- Probability of detection threshold determination.
- Minimum Detectable Velocity modeling.
- Revisit interval model development.
- Image quality model development.
- Model integration.
- User interface studies.
- MTIIRS validation.

A study of the fundamental physics involved will be required. This study will lead to the determination of the key parameters that will be used in the MTIIRS algorithms. Likely parameters include: probability of detection, false alarm rate, revisit rate, variation of the revisit rate, missed scans of the region, target recognition, target location, range rate accuracy, image build-up time, target density, target visibility, and minimum detectable velocity. Performance figures will be determined and will be ranked from 0 to 10. This scale is similar in principle to the NIIRS scale used for visible image performance. Examples of the MTIIRS scale include a rating of 0 = Limited Utility, 5 = Ability to Track a Battalion, and 10 = Track Individual Helicopter or UAV.

To best understand the approach to an MTIIRS design it will be required to query potential users and determine the key AMTI and GMTI performance requirements. The possible requirements include: detecting enemy targets of various types, identifying the intention to advance, identifying threats, identifying the enemy's direction of attack, and identifying enemy logistical movements.

PHASE I: Develop basic models and heritage to prior imagery interpretabilty scales and establish contacts with potential users in order to formulate phase II effort.

PHASE II: Develop a rigorous theoretical framework for assessing MTI RADAR sensors. This theoretical and mathematical understanding will be validated and refined through experimentation (real & modeled), exercises of opportunity, and operational user review.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: The USAF is actively pursuing the development of a space based RADAR (SBR) MTI satellite constellation. Existing platforms such the AWACS or E2C would be similar beneficiaries. Commercial application: Ground traffic management. Air traffic control systems.

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KEYWORDS: RADAR, NIIRS, MTI

AF07-T033 TITLE: Photochemical Tissue Bonding for Military Medical Applications

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Research on materials and devices to convert demonstrated capabilities of photochemical tissue bonding (PTB) into a clinical and military fieldable medical technology.

DESCRIPTION: PTB has been studied and demonstrated to be a promising technique for new or improved capabilities in trauma and other medical procedures. The technique uses a dye on the tissue to be bonded and a light source which cross-links the dye and makes a strong, leak-tight seal. Unlike prior tissue “welding” schemes PTB does not raise the temperature significantly at the bond, so does not denature the material at the bond. PTB has advantages over sutures in that it is faster and easier, is much less prone to leaking, and does not have foreign body issues. Potential for small PTB kits for important battlefield procedures by medics has been shown to be a possibility for procedures such as nerve and small blood vessel repair. The demonstrations to date, however, have involved laboratory equipment, for example large, costly lasers, and procedures not applicable for clinical or field use. For example, in vascular repair studies there is a requirement to avoid collapse of the vessel to ensure intimate tissue approximation of the vessel stumps during PTB. Demonstrations used a catheter approach in rat femoral artery repairs, but this involves secondary incision and placement of the catheter, which is problematic. Also in anastomoses of vessels and nerves the need is to seal tissue over the full 360 degrees of the cylindrical structure. Demonstrations have simply irradiated from one side, then manipulated the tissue to provide access to the other side. This is clearly sub-optimal.

PHASE I: Study materials and devices to make PTB viable for fieldable military medical procedures. Such studies might include: a disolvable vascular stenting device, a 300-500mW surgical solid state illumination device, and a cylindrical illuminator for isotropic dose delivery to tubular structures.

PHASE II: Integrate the results of phase I, perform further required studies, and demonstrate feasibility and prototype systems for fieldable and clinical kits for application of PTB for nerve, blood vessel, and other medical procedures relevant to military and civilian needs.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: The PTB devices and procedures, potentially in the form of deployable small kits, would enable earlier, faster, and more effective treatment of battlefield vascular, nerve and other injury. Commercial application: Practical PTB procedures and kits would benefit civilian vascular and nerve repair described above, as well as, potentially, corneal transplants, skin closing and grafting and other procedures.

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KEYWORDS: Photochemical tissue bonding, tissue bonding, nerve repair,vascular repair, anastomoses

AF07-T034 TITLE: Miniature Atom Chip Vacuum Systems for Sensing and Navigation

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: To develop miniature atom chip vacuum cells capable of producing and manipulating cold atoms and demonstrating dramatic reduction in size, weight, and power consumption.

DESCRIPTION: Cold atom technology has proven its merit in inertial sensing for navigation, magnetic field sensing, frequency standards, and atomic clocks. Devices and systems based on cold atoms have demonstrated orders of magnitude sensitivity improvement, for example, in measurements of local gravity. Similarly, atom gyroscopes have orders of magnitude greater sensitivity than their laser and fiber gyroscope counterparts. Nearly all demonstrated cold atom systems are currently large, and therefore their deployment is limited to platforms capable of accommodating the size and weight of these systems. At the same time, advances in cold atom chip technology have shown great promise to reduce the size, weight, and power consumption of ultracold atom systems dramatically. Devices and systems based on atom chip technology can make deployment of cold atom technology in a much wider range of platforms practical. Moreover, cold atom research currently requires significant expertise in a wide variety of scientific and engineering disciplines. Advances in atom chip technology can greatly simplify and enable further research into applications of ultracold atoms in the same way that advances in laser technology transitioned lasers from scientific laboratories to the engineering toolbox. In addition to sensing applications, atom chips enable the development of atom analogs of semiconductor devices such as “atom transistors”, which may lead to atom amplifiers, oscillators, and logic gates. The full potential of atom circuits can only be explored if the underlying ultracold atom technology is small, simple, robust and reliable.

The scientific and practical challenges facing cold and ultracold atom chip technology arise from the need for large atom numbers and long atomic coherence times, particularly for interferometric systems. The science of continuous wave ultracold atom sources is immature, as such sources have not been demonstrated by any system, despite several research groups around the world specifically focusing on such sources. Additionally, the high atomic density typical of on-chip ultracold atoms leads to a trade-off in coherence time versus atom number. Open questions remain concerning the possibility of quantum wavefunction control to mitigate collisional effects. Other challenges include the requirement of ultra-high vacuum (less than 10^-9 Torr) with long life (greater than 1 year) in a small package (less than 1 liter) that incorporates an alkali vapor source, active and passive pumping elements, and provides substantial optical access for laser cooling and imaging. The chip itself must be capable of handling high currents, allow for the corresponding heat dissipation, and provide ultra-high vacuum compatible electrical bias and possibly optical bias. Moreover, standardized construction and chip features are needed for producing and manipulating coherent ultracold atoms (~200 microKelvin), to facilitate the development of interferometric atom devices and systems.

Miniature chip vacuum cells have high surface-to-volume ratios. Keys to long life and system robustness are a thorough understanding of materials, properties, and compatibility in the ultra-clean and ultra-high vacuum environment of the atom chip cell. In particular, alkali vapors such as rubidium are aggressive and can form compounds with impurities that deteriorate the vacuum quality over time. Ultracold atoms are particularly susceptible to surface interactions, and there are fundamental science issues concerning the limits of ultracold atom cloud lifetimes in the vicinity of atom chip surfaces and practical issues concerning the background hot (e.g., room temperature) alkali vapor arising from the chip surface.

Miniature systems also place special demands on alkali vapor sources and thus call for the development of isotropically enriched sources such as nearly pure 87Rb compatible with the ultrahigh vacuum environment.

Potentially useful approaches to atom chip technology may provide a means of allowing customization of the atom chip for specialized applications without substantial redevelopment costs. Thus "carrier chips" could provide standard electrical and possibly optical feedthroughs while also allowing a simple means of incorporating a customizable "device chip".

PHASE I: Demonstrate prototype miniature atom chip vacuum cell capable of sustaining cold atoms with a 10 s lifetime. Establish that the lifetime of high-vacuum performance will exceed 1 year by accelerated aging tests. Establish by theory and demonstrations a means to produce a continuous cold atom source.

PHASE II: Demonstrate a complete packaged miniature atom chip vacuum cell (volume: less than 1 liter; weight: less than 1 kg; pressure: less than 10^-9 Torr) capable of producing, sustaining, and manipulating ultracold atoms (i.e., a Bose Einstein Condensate) operating in a "breadboard" optical and electronic environment.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Miniature GPS-free, jam-proof precision inertial navigation; remote sensing; precision pointing and tracking. Commercial application: Satellite pointing for communications; more precise atomic clocks for time-keeping.

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KEYWORDS: atom interferometry, Bose-Einstein condensation, atom electronics

AF07-T035 TITLE: Optical Techniques Toward High-Power Terahertz Sources

TECHNOLOGY AREAS: Sensors, Electronics, Battlespace

OBJECTIVE: Develop high-average-power, high-repetition-rate optically driven sources of terahertz radiation for use in imaging, sensing, and analysis.

DESCRIPTION: Time-domain terahertz (TD-THz) technology is rapidly developing for many applications in both the civilian and military sectors. The TD-THz method uses ultrafast lasers to generate near-single-cycle sub-picosecond electromagnetic pulses with wide spectral content from below 100 GHz to greater than 3 THz [1-4]. The ultrabroad bandwidth allows spectroscopic measurements without tuning, and helps ensure penetration of absorbing materials. The use of pulses allows reflection tomography with sub-mm layer resolution, and enables simple measurement of index and the amount of material, orthogonal to the relative absorption of the material. Commercial systems have recently become available for both imaging and sensing (materials detection and identification via spectral signatures). A principal barrier to further application of TD-THz technology in many real-world situations is the available TD-THz average power from highly compact sources. The current state of the art employs table top conventional cavity mode locked lasers which are expensive and limited in oscillator power. Driving conventional photoconductive devices, the average pulse train energy is 1 microwatt or less at 80 MHz repetition rates. For many practical applications, such as inspection and screening, illicit materials detection, etc., the lack of power necessitates long signal acquisition times, and is insufficient to divide among an array for parallel detection or synthetic aperture imaging. High power is particularly critical for sub-surface imaging and spectroscopy applications, where the TD-THz beam may suffer considerable attenuation due to absorption and scattering as it propagates through material.

The proposed program should address the development of new optical approaches to compact, high-power, robust, real-world time-domain TD-THz sources. The goal is to increase the average power to greater than 1 milliwatt at a repetition rate between 3 GHz and 50 MHz in a source which is more compact and lower cost than traditional sources. The high repetition rate is critical for noise reduction and rapid waveform acquisition. The high power TD-THz source may include the integration and development of novel high-power compact pump sources (such as fiber lasers) with new conversion methods such as TD-THz waveguides for optical rectification sources, photonic crystal emitters, and resonant cavity or multi-pass emitters to increase efficiency. Approaches such as coded excitation in structured nonlinear materials may also be a powerful way to maintain the multi-THz bandwidth of time-domain systems while increasing the power and SNR.

PHASE I: Demonstrate the feasibility of the approach to high-power THz generation. This includes both the optical driver and the THz emitter. Demonstrate power scaling showing that milliwatt power levels will be achieved in the Phase II implementation. Perform design of components to implement in Phase II.

PHASE II: Build upon Phase I and demonstrate operation of >1 mW TD-THz source. Perform analysis, characterization, and optimization of system. Demonstrate improved signal and image acquisition rates in applications.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Communications on the battlefield or in space, explosives and chemical agent detection, non destructive evaluation , high sensitivity detection of thermal bodies, and flame spectroscopy. Commercial application: Atmospheric environment sensing, near object detection, security, material imaging and inspection, quality control will benefit from new technology in this part of the electromagnetic spectrum.

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KEYWORDS: terahertz,sub-millimeter,terahertz radiation,imaging, sensing,time-domain terahertz,THz,TD-THz,time domain techniques,ultrafast lasers,sub-picosecond pulses,sub-surface imaging,spectroscopy,high-power,fiber lasers, THz waveguides,optical rectification,photonic crystal, non-destructive evaluation,NDE,security,inspection

AF07-T036 TITLE: Satellite Propulsion Systems for Defensive Counter-Space (DCS)

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Demonstrate use of current or new satellite electric propulsion system against space debris or other objects with potentially hostile intent.

DESCRIPTION: Nano-satellites ("nanosats," less than 50 lbs) and pico-satellites ("pico-sats," less than 0.5 lbs) are small space platforms currently under intensive development within the space community worldwide. Such platforms characteristically include the state of the art in semiconductor and micro-mechanical devices, and provide unique opportunities for rapid and low-cost deployment of space-based space surveillance, navigation, and communication networks. However, the same technology can be used for hostile intents against US space assets, allowing many potential competitors with modest launch capabilities to covertly deploy nanosats and picosats for shadowing, monitoring and disabling critical US platforms. Since a significant amount of power, mass and volume in these platforms is devoted to propulsion, it is highly desirable to develop approaches and designs of propulsion systems with inherent capability to use these resources for defensive counter-space purposes. In particular, new electric propulsion (EP) systems in the next generation of medium and large satellites could be devised that can also be used to detect approaching nano-/pico-sats and deflect or disable them (collision protection, object detection, remote sensing, EMP shielding, sensor blinding). For example, this could be achieved by modifying the plasma stream at the exhaust to cover a wide area and illuminate potentially hostile objects, and subsequently focusing the stream onto the target for disabling (e.g. sensor blinding), deflection (off-axis net force from impinging plasma), or destruction (e.g. high-energy radiation, heating). Other approaches leading to similar results, e.g. collision protection, object detection, remote sensing, EMP shielding, sensor blinding, are of interest as well, and systems also capable of discriminating orbital assets from space debris would elicit particular interest. Innovative designs and methods are needed, which can produce the desired DCS effects without excessively sacrificing overall EP system performance, whether propulsive or packaging efficiency.

PHASE I: Phase I work consists of preliminary analytical or computer studies demonstrating the potential defensive aspects of the approach and propulsion system design, and/or early demonstration of some critical aspect of the technology.

PHASE II: Demonstrate the technology with bench-scale experiments for as many key aspects of the DCS counter-measures as possible. Develop dual-use propulsion system design and integrate with generic satellite design.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Dual-use EP propulsion system can lead to new fleet of US space platforms with inherent protection capability. Commercial application: Dual-use features of the proposed EP system could be applied in diagnostics and material manufacturing, while propulsive applications can be transferred to the private space sector.

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KEYWORDS: Space situation awareness, electric propulsion, defensive space, ion beams, radiation, sensor

AF07-T037 TITLE: Infrared Fiber for Conversion & Routing

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To investigate, develop, and transition materials and the associated material processes for fabricating either linear or nonlinear optical fiber (conventional or photonic crystal) that is suitable for multiwatt laser output at various infrared wavelengths in the 2 – 12 micron spectral region with strongest interest in the mid-infrared (2 – 5 microns) region.

DESCRIPTION: Fiber laser sources are of interest for a variety of Air Force applications including laser radar, guide star generation for imaging, and laser-based platform self defense. Amazing progress has been made in developing fiber lasers. However in order to more fully exploit this progress, optical fiber for both nonlinear wavelength conversion and beam routing would be useful. Areas of interest in materials science and technology include polymer science, basic glass science of chalcogenide or fluoride glasses, basic science of other materials relevant to infrared fiber optic products, or photonic band gap design concepts relevant to infrared fiber optic products. Within the proposals, offerors must justify the potential for improving the performance of infrared fiber, based upon solid scientific evidence, and must discuss the likelihood of transitioning the effort into fiber optic products of relevance to Air Force interests.

PHASE I: The behavior of materials for use in infrared fibers shall be explored and materials processing techniques shall be developed that enable significant improvement in the operation of either linear or nonlinear optical fiber with laser output at various wavelengths from 2 microns to 12 microns.

PHASE II: The proposed material and/or the relevant material processes shall be further developed, and the material properties and its usefulness for commercial and military applications shall be fully demonstrated.All necessary manufacturing processes for commercialization of the material and/or product shall be developed as well.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Follow-on activities are expected to be aggressively pursued by the offeror, namely in seeking opportunities for integrating the improved material into laser-based systems. Commercial application: Commercial benefits would be for medical laser procedures, remote bio/chemical detection, and scientific instruments.

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KEYWORDS: Laser, optical fiber, photonic crystal fiber, infrared fiber, fiber laser

AF07-T038 TITLE: <u>Advanced Friction Stir Processing for Ultra-refined Microstructure Development of Aluminum 7XXX Series Alloys</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a novel method of friction stir processing to create a nano-crystalline microstructure in Aluminum 7XXX series alloys.

DESCRIPTION: Ultra-refined microstructures have shown tremendous improvements in mechanical properties and processing capabilities. However, it is often difficult to develop the refined microstructures in selected areas where the smaller grains and increased grain boundary interactions are required. Bulk metallic glass and advanced extrusion processes produce materials with ultra-refined grain structures, but the processes are not applicable to large structures in situ, or to selected regions within larger structures. Friction stir processing provides a method for producing refined structures in selected regions where optimized processing conditions provide differing grain sizes. The Air Force has invested significant resources in the development of friction stir welding processes with the goal of developing an efficient low temperature joining process. The stir processing concepts differ from welding; there may not be any actual joining of materials. Although friction stir concepts have been investigated by different researchers, there is a tremendous need for basic research into the development mechanisms and interactions of the microstructures, including the refinement of structures due to the enhanced extrusion and stirring processes. In addition, there is a need to model and optimize this process for use in developing corrosion resistant, high strength aluminum alloy surfaces – specifically 7XXX series alloys. Successful completion of this effort would provide the basic understanding necessary to process the high strength alloy surfaces for a vast number of structural applications. It would also lead into the processing of titanium and other aircraft alloys where current microstructure refinement is needed.

PHASE I: Phase I would use microstructural models to predict required processing conditions to produce nanostructured grain sizes in the thermo-mechanical affected zone. Select friction-stir tool materials, dimensions and speeds.

PHASE II: Based on the results of the microstructural models, alloy samples would be produced using friction-stir processing and mechanically tested to optimize processing conditions and validate mechanistic models.

DUAL USE COMMERCIALIZATION POTENTIAL: Military application: Apply microstructural modeling and friction-stir processing for optimized processing avenues to produce a nanostructured aluminum 7XXX alloy for aerospace structural applications or lightweight armor. Commercial application: Apply microstructural modeling and friction-stir processing for optimized processing avenues to produce a nanostructured aluminum 7XXX alloy for commercial aerospace structural applications.

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KEYWORDS: FRICTION-STIR PROCESSING; MICROSTRUCTURAL MODIFICATION; DYNAMIC RECRYSTALLIZATION; NANOSTRUCTURED MATERIALS; MECHANICAL-BEHAVIOR; RESTORATION MECHANISMS; DEFORMED ALUMINUM; SUPERPLASTICITY