AIR FORCE
STTR PROPOSAL PREPARATION INSTRUCTIONS

The Air Force proposal submission instructions are intended to clarify the DoD instructions as they apply to AF requirements

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 18 Feb 08), 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 (19 Feb – 19 Mar 08), 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.

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.

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 technical 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 19 March 2008** 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 March, 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 proposals must be submitted electronically at www.dodsbir.net/submission. The complete proposal - Department of Defense (DoD) cover sheet, entire technical proposal with appendices, cost proposal and the Company Commercialization Report – must be submitted by the date indicated in the invitation. The technical proposal is **limited to 50 pages** (unless a different number is specified in the invitation). 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.) The preferred format for submission of proposals is Portable Document Format (PDF). Graphics must be distinguishable in black and white. **Please virus check your submissions**.

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. If selected for a Phase II award, we will match only the outside funding for Phase II

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

PHASE II ENHANCEMENT POLICY

The Air Force currently does not participate in the DoD STTR Enhancement Program.

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.

PHASE I SUMMARY REPORTS

In addition to all the Phase I contractual deliverables, 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 08.A Topic Index

AF08-T001 TITLE: A large size, 300x300 mm updatable, 3D holographic display using photorefractive polymers

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a large size 300x300 mm updatable 3D display with photorefractive polymers for battlefield and command and control applications.

DESCRIPTION: Battlefields require operations in complex urban and mountainous terrain. Currently available 2D visualizations are dynamically updatable but require manual paging to achieve a decision-grade understanding of the full dimensionality of the situation within the time available. Quicker understanding of the battle space can be provided with a spatial 3D map that is updatable in near real time (4D). Such a good 4D display system is needed to enable warfighters to more effectively visualize the Battlespace, evaluate terrain (including buildings, tunnels), and perform force movements. Such a 3D map would also allow modeling for mission rehearsal, mobility prediction, visibility assessment, and helicopter/plane landing zone evaluation. One emerging approach to the development of such a system of near real time 3D map involves photorefractive polymers that have the properties that can satisfy the challenging requirements imposed on the material platform. These properties include high diffraction efficiency, rewritability, fast writing time, long image persistence, controllable erase, wide viewing angle, and possibility for full color implementation. Photorefractive polymers, unlike photorefractive inorganic materials such as lithium niobate that are limited to sizes on the order of square centimeter, can be manufactured with sizes on the order 300 x 300 mm and larger. Photorefractive polymers have been extensively investigated for over a decade and their processing costs are generally lower than inorganic materials. The primary goal of this program is to utilize advanced photorefractive polymers to fabricate large-area 3D updateable display devices that can be used for command and control applications in today's battlefields.

PHASE I: Design and analyze large area 3D updateable display devices that incorporate photorefractive polymers, demonstrate the capability of achieving monochrome 3D display, with a pathway to color.

PHASE II: Construct and characterize a 300 x 300 mm prototype true 3-D display system. High diffraction efficiencies, wide viewing angles, fast writing times, long persistence of 1 hr or more, controlled erase, and 1000 write/rewrite cycle capability shall be demonstrated. Threshold goal is a monochrome green 3D display updatable within 10 min.; objective goal is a multicolor 3D display updatable within 5 min.

PHASE III / DUAL USE: Military application: Near real time true-3D map display system to enable terrain evaluation, battle space visualization, and force movements and in general command and control applications. Commercial application: A broad range of civil applications including manufacturing, mine and fire rescue, building design, and medical fields and specifically surgery planning and radiology.

REFERENCES:
1. Eralp, M., Thomas, J., Tay, S., Li, G., Schülzgen, A., Norwood, R.A., Yamamoto, M. and Peyghambarian, N., "Submillisecond response of a photorefractive polymer under single nanosecond pulse exposure," Applied Physics Letters, 89, 114105 (2006).

2. Eralp, M., Thomas, J., Tay, S., Li, G., Schülzgen, A., Norwood, R.A., Yamamoto, M. and Peyghambarian, N., "Photorefractive polymer device with video-rate response time operating at low voltages," Optics Letters, 31, 10, 1408-1410 (2006).

3. Thomas, J., Eralp, M., Tay, S., Li, G., Yamamoto, M., Norwood, R., Marder, S.R. and Peyghambarian, N., "Photorefractive polymers with superior performance," Optics and Photonics News, 16, 31 (2005).

4. Peyghambarian, N. and Norwood, R.A., "Organic Optoelectronics – Materials and Devices for Photonic Applications, Part One," Optics & Photonics News, 16, 2, 30-35 (2005), and Part Two, Optics & Photonics News, 16, 4, 28-33 (2005).

5. O. Ostroverkhova and W. E. Moerner
"Organic Photorefractives: Mechanisms, Materials and Applications" invited review, Chemical Reviews 104 (7), 3267-3314, 2004 (includes cover art).

KEYWORDS: Near real time 3D display, photorefractive polymers, electro-optic polymers, holographic display, high diffraction efficiency

AF08-T002 TITLE: Portraying Meta-Information to Support Net-Centric Command and Control

TECHNOLOGY AREAS: Information Systems, Human Systems

OBJECTIVE: Develop/evaluate methods for visualizing information, meta-information to enable faster, more effective C2 decision-making.

DESCRIPTION: The network-centric operational paradigm aims to provide unprecedented access to a wide variety of information from distributed, heterogeneous sources (Alberts & Hayes, 2003). The goal of such a paradigm is to ensure that needed information (i.e., actionable intelligence) is available to the commander. However, simply ensuring availability of information will necessarily result in information overload, as the volume of all possible information makes the challenge of determining what is "actionable" insurmountable. Numerous on-going efforts are addressing this challenge from a computational perspective by trying to create meta-data tags that become associated with the information (Marco & Jennings, 2004) and ensuring that critical details of information persist as it propagates through the chain of command. However, these efforts are not always grounded in a thorough understanding of what makes information "actionable" to the human commander. Doing so requires understanding the commander's decision-making process and how best to present information to facilitate a particular decision. One focus of this topic is on generating a basic understanding and definition of the characteristics of information (or meta-information (Pfautz et al., 2007)) that make it "actionable" (e.g., its authenticity, level of authority, pedigree) in particular operational contexts.
While many approaches to studying C2 decision-making to aid in system design are available (e.g., Scott, 2005; Schraagen, Chipman, & Shalin, 2000; Millitello & Hutton, 1998), of particular interest are approaches that result in concrete designs and prototype decision-aiding systems (Bisantz et al., 2003; Potter et al., 2002). Therefore, another focus of this topic is the development of specific methods or guidelines for communicating meta-information to a commander. These communication methods may include enhancements to standard C2 visual displays or innovative uses of multi-modal (e.g., audio, haptic) display methods. This effort could include, but does not require, the development of tools to aid in the prototyping of meta-information portrayal methods. The effort should, however, include plans for the systematic formal evaluation of the portrayal methods to not only develop an understanding of the fundamental cognitive and perceptual processes involved in communicating meta-information but also move any results towards operational environments. These evaluation plans should include the development of methods, procedures, and metrics that will clearly increase our knowledge of how commanders reason about qualified information.

PHASE I: Define a representative operational domain and identify a set of scenarios that exemplify challenges in identifying actionable information in a large set of data. Develop, prototype, and demonstrate methods for the portrayal of meta-information within the selected operational domain.

PHASE II: Develop and implement methods for the effective portrayal of critical information and meta-information to support network-centric C2 processes. Implement software for marrying display techniques to real or representative data sets in a sponsor-approved domain. Develop a report detailing prior work in the area of meta-information portrayal and define areas requiring future research efforts.

PHASE III / DUAL USE: Military application: Will involve development of generic versions of the meta-information portrayal strategies/tools developed to represent information and can be applied to a number of systems with information overload. Commercial application: This could include such things as tools for use by the banking/financial industry local/state emergency response systems, logistics/readiness chain evaluation, and business intelligence.

REFERENCES:
1. Alberts, D. S. & Hayes, R. E. (2003). Power to the Edge: Command and Control in the Information Age. C2 Research Program Publications.

2. Bisantz, A. M., Roth, E. M., Brickman, B., Gosbee, L., Hettinger, L., & McKinney, J. (2003). Integrating Cognitive Analyses in a Large Scale System Design Process. International Journal of Human Computer Systems, 58177-206.

3. Marco, D. & Jennings, M. (2004). Universal Meta-Data Models. New York, NY: Wiley.

4. Millitello, L. & Hutton, R. (1998). Applied Cognitive Task Analysis (ACTA): A Practitioner's Tool Kit for Understanding Cognitive Task Demands. Ergonomics Special Issue: Task Analysis, 411618-1641.

5. Pfautz, J., Fouse, A., Farry, M., Bisantz, A., & Roth, E. (2007). Representing Meta-Information to Support C2 Decision Making. In Proceedings of International Command and Control Research and Technology Symposium (ICCRTS).

KEYWORDS: Meta-Information, Information Visualization, Meta-Data Tagging, Multimodal Interface, User Interface Design, Command and Control, Actionable Intelligence

AF08-T003 TITLE: Solid Propellant Shock to Detonation Modeling and Formulation

TECHNOLOGY AREAS: Air Platform, Space Platforms, Weapons

OBJECTIVE: Develop and validate models that predict the shock sensitivity of solid propellant formulations.

DESCRIPTION: The shock to detonation transition (SDT) of a composite solid propellant is dependent on multiple formulation variables, such as individual ingredient sensitivity. Formulation approaches to reduce propellant detonability are often anecdotal and empirical, requiring significant testing in order to determine the correlation between formulation parameters and shock sensitivity. In order to minimize the detonation hazards of a solid propellant while improving propellant performance, development and validation of physics-based models on the SDT of solid propellants are being sought in order to aid in formulation of energetic solid propellants. Models should incorporate the interaction between propellant ingredients (binder, oxidizer, and fuel) with a shockwave as it travels through a composite propellant, including shock attenuation or augmentation. In addition to SDT modeling and as part of the validation effort, the model should be capable of simulating the Naval Ordnance Laboratory Large Scale Gap Test (NOL LSGT) results of representative 1.3 and 1.1 hazard class propellants based solely on individual ingredient properties and formulation variables, such as total solids loading.

PHASE I: Effort and deliverables include the following: 1) Identify and formulate a comprehensive SDT model including mathematical description of the model; 2)Develop code incorporating the formulated SDT model; and 3) Verify the model using representative literature data.

PHASE II: Effort and deliverables include the following: 1) Validate release version of SDT code, including user interface; 2) Formulate a less than 70 card propellant; 3) Perform NOL LSGT of the solid propellant demonstrating code predictive capability; 4) Document source code and its traceability to physics-based model description

PHASE III / DUAL USE: Military application: Solid rocket motors used in weapon systems as well as commercial space launch systems will be the primary beneficiary Commercial application: The explosives industry also may benefit in the area of safe storage, handling, and transportation.

REFERENCES:
1. Yang, V., Brill, T., Ren, W., Solid Propellant Chemistry, Combustion, and Motor Interior Ballistics, AIAA Progress in Astronautics and Aeronautics, Vol. 185, 2000.

2. Victor, A.C., “Insensitive Munitions Technology”, Tactical Missile Propulsion, AIAA Progress in Astronautics and Aeronautics, vol. 170, pp. 273-362, 1996.

3 “Hazard Assessment Tests for Non-Nuclear Ordnance”, Military Standard, Mil-Std-2105B, 1994.

KEYWORDS: Solid rocket hazards, shock to detonation transition, shock sensitivity, hazard classification

AF08-T004 TITLE: Creep Behavior of Ultra High Temperature Ceramics

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Topic seeks to develop test methods for measuring creep behavior of polycryst. ceramics in environments of extreme stresses and temp, 2200°C+. Composites or cermets based on refractory diborides.

DESCRIPTION: The need for high performance propulsion systems for rockets and missiles and leading edge structures for hypersonic and reentry vehicles has led to renewed interest in ultra high temperature ceramics. In these applications designers must know the creep behavior of materials at temperatures in excess of 2200°C, pressures up to 200 psi, for durations of hours. Current methods for measuring creep have severe limitations. The customary machinery uses tensile or compression configurations equipped with an electric or induction furnace. The ends of the creep specimen are held by a gripping fixture or a compression platen. Stress is applied by constant load dead weights or constant strain rate via hydraulic actuation. Isothermal testing is conducted up to about 1400°C depending upon the grip/specimen materials, their strength, creep rate, and chemical compatibility. For testing in the range of 1400°C to 1700°C, a thermal gradient design is required to cool the grips. This arrangement requires extremely long specimens which are expensive and time consuming to fabricate and finish. Because of these limitations, material scientists and designers often extrapolate low temperature creep data to higher temperatures. This is not always accurate, especially for dual-phased materials. Also, alloy development is impaired because of the lack of material characterization methods at extreme temperatures. To alleviate these problems, new approaches are required that that are capable of measuring the creep behavior to 2200°C, using small inexpensive samples and a non-contact design.

PHASE I: The proposal will modify existing commercially available equipment or design and build new equipment that is capable of ultra high temperature creep measurements. Demonstration tests will be conducted on at least two materials based on either ZrB_2 or HfB_2 SiC composites.

PHASE II: A successful Phase II project will expand the automation of equipment and procedures so that testing can be conducted cheaply and efficiently. A series of refractory diborides and cermets will be selected by contractor team and program manager and a standard test methodology will be developed. Data, analysis, and the test protocol or methodology will be deliverables.

PHASE III / DUAL USE: Military application: Refractory diborides and cermets have many applications for future air and space applications including hypersonic propulsion systems and rocket nozzles. Commercial application: Refractory diborides and cermets have many applications for future air and space applications including ground based turbine testing, and satellite rocket boosters.

REFERENCES:
1. Joan Fuller and Michael Sacks, Editors. Journal of Materials Science Vol 39, No 19, October 2004. Special Edition on Ultra High Temperature Ceramics.

2. F.R.N. Nabarro, H.L. Villiers, The Physics of Creep, Taylor & Francis Ltd., London, UK, 1995, p. 1-45.

3. L.W. Lherbier, R.W. Koffler, National SAMPE Technical Conference (1971) 169-182.

4. J.C. Zhao, J.H. Westbrook, MRS Bulletin 28 (2003) 622-627.

KEYWORDS: ceramics, solid rocket nozzles, creep, hypersonics leading edge materials, UHTC

AF08-T006 TITLE: GaN/AlGaN/AlInN Based THz Focal Plane Array Detectors, Ultraviolet (UV) Lasers, and HEMT High Power RF Devices on Low-Dislocation AlN and GaN Substra

TECHNOLOGY AREAS: Materials/Processes, Sensors

OBJECTIVE: Demonstrate AlGaN and AlInN materials improvement for compact and reliable ultraviolet (UV) lasers, high efficiency THz detectors, and HEMTs using nitride heterostructures.

DESCRIPTION: 1) GaN/AlGaN THz focal plane array detectors are to be explored for all-weather aircraft landing technology, improved space situational awareness, and space asset protection to support theater missile surveillance, chemical and biological agent detection, improved satellite communications, and environmental monitoring as part of Space Force Enhancement. In order to improve efficiency of detection, high quality materials with very low dislocation defect density are expected to play a major role.

2) Solid state ultraviolet (UV) laser diodes offer the possibility of short distance covert communication transmitters and receivers operating at relatively low power, and on-site detection of biological agents in a variety of locations. These applications demand compact, portable, and low cost systems. III-nitride materials can have energy bandgaps spanning from 0.7 to 5.2 eV, and are good candidates for next generation portable, compact deep UV lasers, although for deep UV emission a higher Al composition of AlGaN is required. For next generation ultraviolet (UV) laser diodes, this STTR topic seeks innovative approaches to develop efficient ultraviolet laser diodes. Innovative concepts are sought to address both material and thermal limitation, resulting in long-lifetime, cost-effective AlGaN ultraviolet laser diodes.

3) AlInN materials also offer improvements to conventional AlGaN/GaN HEMTs for high frequency, high power applications. Nitride ternaries can form lattice matched interfaces with GaN, potentially enabling a new class of GaN based devices without need of the piezo-electric charge carrier contribution. However, a greater understanding of the limitations of these films due to defects and growth dynamics is required to make use of the theoretically expected device performance and high frequency metrics. Successful materials development and characterization could enable unprecedented power and frequency performance in GaN and AlN-based devices.

PHASE I: Investigate single pixel AlGaN/GaN THz detector on low defect AlN substrate. Identify growth parameters, defects and control for AlInN and GaInN films. Identify role of defects and lattice mismatch on carrier density and mobility.

PHASE II: Fabricate, test and evaluate a 16x16 AlGaN/GaN or AlInN/AlN THz focal plane array and/or develop and fabricate prototype devices and demonstrate the operation of continuous wave ultraviolet (UV) laser diodes. Conduct comprehensive reliability tests to demonstrate long-term performance

PHASE III / DUAL USE: Military application: Increase the utility and performance of communication, sensor and satellite systems for military applications. Commercial application: Communications satellites, medical imaging, weather forecasting, and NASA interplanetary missions. Also applicable for high density optical storage systems and high efficiency lighting applications.

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KEYWORDS: ultraviolet (UV), laser diodes, biosensor, covert communication system, wide bandgap semiconductors, Ternary Nitrides, THz Detectors, FPAs, AlN substrates AlGaN, InAlN, AlInN, GaN, HEMT, power, defects, dislocations, growth, materials

AF08-T007 TITLE: <u>Distributed Conformal Actuation for Simultaneously Controlling Flow Separation and Transition</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Demonstrate a wall-conformal dynamically-switchable means of delaying transition and laminar separation.

DESCRIPTION: Control of turbulent boundary layers is perhaps the most celebrated problem in fluid mechanics. At typical aerospace engineering-scale Reynolds numbers, such those relevant to the airframe aerodynamics of manned aircraft and large Unmanned Air Vehicles, the principal problem is delaying laminar to turbulent transition, by attenuating or destructively interfering with the various transition mechanisms. The literature is replete with examples of passive means (contouring of airfoil shapes, compliant coatings, surface polishing – or, in precisely the inverse approach, particular distribution of surface roughness) and active means to delay transition, the latter also including schemes where fluctuating quantities such as pressure or shear stress are sensed, and a description of the flow state is fed back into a controller to optimize the actuation strategy.

Smaller Unmanned Air Vehicles, such as Micro Air Vehicles (MAVs) generally suffer from the opposite problem: laminar boundary layers separate in adverse pressure gradients, forming large and unsteady laminar separation bubbles closed by turbulent reattachments, or open separations with thick and unsteady wakes. Here the objective is to instead promote transition, thereby attenuating separation. This is beneficial since the turbulent skin friction drag penalty can outweigh the pressure drag penalty in the case of large separations. Again, there are many examples of passive means (roughness, trips, vortex generators, etc.) and active means (oscillating ribbons and patches, blowing/suction/synthetic jets, wall-jets produced by dielectric barrier discharges) to promote transition.

The ideal approach is to promote maximum laminar flow wherever there is no danger of boundary layer separation, but to induce transition near regions of incipient separations, thus actively managing the drag budget to minimize both pressure drag due to separation, and friction drag due to turbulent boundary layers. For smaller aircraft such as MAVs the benefit of such boundary layer management couples with improvement in flight dynamics: as flow separation causes loss of vehicle control, for example by wingtip stall, prevention of separation improves vehicle handling qualities and maneuverability, while promotion of large regions of attached laminar flow would improve the overall lift to drag ratio.

All passive flow control schemes are subject to the critique of questionable robustness to on-design and off-design conditions, while active flow control suffers from poor reliability and the often unfavorable balance between the input energy and the resulting output. The ideal approach is mechanically simple and self-adjusting to changing flowfield conditions, thus not requiring complex active control.

PHASE I: Theoretically describe and experimentally demonstrate a wall-conformal boundary layer control scheme capable of both attenuation and amplification of instabilities leading to turbulence.

PHASE II: Demonstrate a prototype boundary layer control scheme on a surface with compound curvature and a flow with large and time-varying pressure gradients; use canonical and flight-relevant problems such as an oscillating airfoil. Quantify experimentally the benefits of actuation. Demonstrate spatially distributed actuation, at appropriate temporal and spatial resolution.

PHASE III / DUAL USE: Military application: Distributed surface actuation for reducing laminar separation can improve range/endurance of small UAVs; increase of attached laminar flow along lifting surfaces is beneficial to all flight vehicles. Commercial application: Drag reduction in fluid piping (oil, water, etc.) where separation causes losses in total-pressure. Aerospace applications include airliner and general-aviation drag reduction and stall delay.

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KEYWORDS: boundary layer control, turbulence, transition, laminar separation, roughness, flow control, distributed actuation, surface actuation

AF08-T008 TITLE: Integrated sensing, control and modeling for agile Micro Air Vehicle platforms

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Integrate novel sensors and control effectors for micro air vehicles to demonstrate agile flight control.

DESCRIPTION: Micro Air Vehicles (MAVs) – typically UAVs with wingspan on the order of 15cm or less – are fast becoming commonplace for meeting a wide range of current and future military missions. A MAV's small size offers potential benefits in maneuverability, sensor placement and operational robustness, but small vehicle size and low inertia also makes fine-scale control of MAVs difficult. Precision operation of MAVs in highly cluttered environments is still a challenge, in part because of difficult to characterize aerodynamics and poorly understood structural-aerodynamic interactions, and in part because of the limited attention thusfar paid to the sensing-control issues required to overcome these gaps in our knowledge. A typical sensor suite for a MAV consists of GPS, MEMs-based linear accelerometers, angular rate sensors, magnetometers, and barometric-altimeters. While this is adequate for waypoint navigation, the potential of MAVs to replicate the flight agility of natural fliers (e.g., birds, bats, insects) remains elusive, especially in complex terrain such as city streets or forests.

The desire to engineer the agility of natural fliers has led researchers to the study of flying organisms to learn how animals combine sensory input with control output to achieve flight maneuverability. Biologists are beginning to understand how visual information is integrated with mechanosensory information in biological systems for flight stabilization, landing, and prey/mate pursuit. Studies are also underway to discover how proprioceptive sensory feedback is used for fine-scale control the movement of wings, legs, etc. during aggressive maneuvers (e.g., obstacle or collision avoidance). These sensory modalities are combined with olfactory or auditory information for predator avoidance and prey/mate pursuit. The fact that animals such as fruit flies exhibit such remarkable flight agility with many sensory inputs and modest onboard "processing" suggests a particular kind of coupling between sensing, control and dynamics altogether qualitatively different from that of engineered systems.

Advancements in flow control have made it possible to control the separation of flow around wings, either to inhibit separation for higher cruise lift-to-drag ratios or to promote it for large transients in aerodynamics loading for aggressive maneuvers. Natural flyers have anatomic features which probably act as flow control devices (e.g., covert flaps) and may act as aerodynamic sensors. Rigorous system modeling that can accurately capture the vehicle dynamics, sufficiently accounting for uncertainties in aerodynamic and structural models, remains primitive even for engineered vehicles, let alone for natural flyers. Uncertainty arises both in the veracity of particular models in describing a given flow or dynamics phenomenon, and in unknowns in the inputs, such as wind gusts and their time-dependent effect on the vehicle. While on-going research efforts are addressing some of the critical limitations in this area, significant uncertainties in the dynamics models of MAVs are unlikely to be completely eliminated. With inspiration from the study of animals, the use of appropriate sensory feedback needs to be explored in order to mitigate the adverse effects of these large uncertainties in system models.

The preceding leads one to believe that agile flight of MAVs will require the integration of sensors and actuators that go above and beyond present-day avionics suites. New kinds of sensors and control effectors will need to be integrated on MAV platforms with advanced control methodologies to achieve reliable, agile flight. Given the small size and low cost of these platforms, these sensors and control effectors are likely to have lower and more variable performance than those of larger vehicles. This leads to additional uncertainties in our mathematical models of these systems which challenges state-of-the-art control methodologies. The principal task, therefore, is development of sensor-actuator systems that, with suitable controller designs based on appropriate models, adequately address the various uncertainties while yielding the desired agile flight performance.

Notional physical dimensions of candidate MAVs will be: a nominal cruise speed of 10 m/s and wingspan of no greater than 15 cm.

PHASE I: Identify state-of-the-art, off-the-shelf sensors and control effectors for integration with MAVs that will lead to quantifiably increased flight agility. Identify the limitations of such sensors & effectors for use with MAVs. Explore controller synthesis methodologies necessary for integration of such sensors and actuators.

PHASE II: Develop flight control models for MAVs with innovative sensors & actuators. Develop and validate a simulation environment with high-fidelity modeling of MAVs with innovative sensors and actuators. Develop, characterize, and demonstrate a prototype MAV with innovative sensors and actuators clearly showing increased agility over conventional MAVs. Identify sensors, actuators, control design methods and processing necessary for autonomous flight.

PHASE III / DUAL USE: Military application: Surveillance, tracking, targeting by MAVs within cluttered environments such as city streets (so-called urban canyon). Unobtrusive ISR in urban environments, forests/mountains, rough terrain, etc. Commercial application: For MAVs capable of precision flight in cluttered environments: search for victims in collapsed buildings(earthquake and hurricane damage), pipeline inspection, and survey of damage downed powerlines.

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KEYWORDS: MAV, Micro Air Vehicle, low Reynolds number, integrated sensors, integrated control

AF08-T009 TITLE: <u>Efficient High-Power Tunable Terahertz Sources using Optical Techniques</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop high-power, highly efficient optically driven sources of terahertz radiation for imaging, sensing, and analysis.

DESCRIPTION: There is a potential for using terahertz (THz) waves for numerous applications including real-time imaging, non-destructive evaluation, stand-off sensing and chemical detection & analysis. Parametric frequency down-conversion of optical pulses is an established way of generating THz radiation. Principal barriers to application of this technique to THz generation are (i) intrinsically low conversion efficiency, because of fundamental scaling law of optical-to-terahertz conversion efficiency, and (ii) absence of efficient compact sources of optical radiation, suitable for THz generation. For many practical applications, especially stand-off applications, one needs a compact, yet sufficiently powerful (>10 mW) source of tunable THz radiation working at room temperature. The proposed program should address the development of new optical approaches to compact, efficient, high-power, robust THz source, tunable in the 0.5-5 THz range. The goal is to substantially increase efficiency and average power of existing THz sources in a compact system. This will imply new optical schemes of THz generation, including resonant-cavity-enhanced optical generation of THz waves [1], cascaded down-conversion [2], THz optical parametric oscillators [3], intracavity difference-frequency generation [4], frequency mixing and frequency conversion in waveguides. Also, developing new electrooptical materials suitable for efficient THz generation are considered, including periodically-structured GaAs, GaP, LiNbO3 , LiTaO3, etc, plus micro- or nano-structured optical materials such as photonic crystals for which one can vary the refractive index and enable phase matching. Approaches addressing long-term reliability and maintenance-free operation of proposed THz sources are highly encouraged.

PHASE I: Demonstrate the feasibility of the approach to portable, efficient, high-power, tunable THz generation. This includes both the optical driver and THz emitter. Demonstrate power scaling showing that greater than ten milliwatt power (>10 mW) 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 >10 mW THz source. Perform analysis, characterization, and optimization of system. Demonstrate improved signal and image acquisition rates in applications.

PHASE III / DUAL USE: Military application: Military application: Communications on the battlefield or in space, in the field 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, THz, parametric frequency down-conversion, resonant-cavity-enhanced optical generation, cascaded down-conversion, optical parametric oscillators, frequency mixing, frequency conversion, waveguides, intracavity difference-frequency generation, sub-millimeter, terahertz radiation, imaging, sensing, sub-surface imaging, spectroscopy, high-power, THz waveguides, optical rectification, photonic crystal, non-destructive evaluation, NDE, security inspection

AF08-T010 TITLE: Characterizing the dynamic behavior of novel energetic materials for space propulsion.

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: Characterization of dynamic behavior and delivery methods of high-energy-density propellants under realistic rocket conditions.

DESCRIPTION: As energy density increases in a combustion chamber, the propensity for more severe dynamic system behavior increases. This ranges from ignition transients to high-frequency combustion instability. Understanding and control of such events has been a focus and a significant part of all engine developments as it can lead to the loss of life in manned missions or loss of payload in unmanned missions. Controlling the propensity for more severe dynamic system behavior is expected to be even more critical with the future high-energy-density propellants. This topic would develop and put in place methods for characterizing the dynamic behavior of novel energetic materials that could be used in military or commercial applications of booster or upper-stage engines or micropropulsion engines used in satellites. Examples are optical and other diagnostics, experiments and modeling for characterizing the dynamic behavior of these materials under realistic rocket engine conditions (booster, upper-stage, micropropulsion) such as high pressures/temperatures (~ 1000 psi/3000K) and fast transient behaviors. Optical diagnostics may include, but not limited to, ultra high-speed multi-spectral diagnostics to capture fast transient phenomena, techniques insensitive to pressure broadening, methods capable of operation within highly-sooty/particle-laden environments. Modeling may include combustion in presence of nano-sized particles, breakup of gelled fuels, and transient phenomena for rocket engines. Novel delivery methods for energetic materials, such as solid propellants and injection/atomization issues with liquid, slurries, or gels with/without nano additives would be considered.

PHASE I: Identify transient characterization and/or delivery approaches for high-energy density propellants in high-pressure rocket engine environments. Evaluate these potential approaches for the efficiency and effectiveness in solving the selected problems and justify an approach most likely to succeed.

PHASE II: Develop, validate, and demonstrate the methods for characterizing the transient and dynamic behavior and/or delivery approaches of novel energetic materials. The methods shall be characterized under realistic rocket conditions of high pressure and temperature. These conditions should be applicable to booster, upper-stage, or micropropulsion engines that are used in military or commercial applications.

PHASE III / DUAL USE: Military application: Methods for characterizing the dynamic behavior of novel energetic materials would be used in military or commercial booster or upper-stage engines or micropropulsion engines used in satellites. Diagnostics can be used in commercial power combustors to optimize performance and minimize emissions. Novel delivery methods for energetic materials can be used on commercial satellites to extend the on orbit life or reduce the over all weight of the propulsion system.

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KEYWORDS: High-energy density materials, optical diagnostics, high pressure rocket engine, propellant delivery systems, modeling, transient

AF08-T011 TITLE: Heterogeneous Network Management

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: To develop mathematical and design methods of managing heterogeneous networks using an information-structured theoretic approach.

DESCRIPTION: Many networks in the Air Force today have multiple uses including sensor and ISR information, voice, text, video, and data traffic approaches. These networks can be fixed or mobile wireless or wired networks that are used for tactical, theater or strategic purposes. Existing models for these networks are widely varied in both their statistical formulation as well their model for distribution of data. We wish to encourage modeling and characterization approaches that encompass both different physical layer and network topologies as well as diversity of applications on the network. These approaches are designed to enable a global management structure for the network [1-16]. In order to accomplish such global management, methods such as stochastic [3] and information geometric [1] modeling and characterization approaches are encouraged. These methods are central to many different fields including neural processing, biological and materials modeling, and quantum information processing. The objective of these approaches is to directly link the structure of the information on the network to the structure of the network itself thereby allowing one homogeneous representation of the network rather that multiple disparate network models that do not interoperate. We then wish to enable a management structure on the network with a basis in dynamic, linear, or geometric programming [2] that is able to bound the performance of the entire network state and show specific quality of service metrics in terms of application performance over the network. We then wish to use this management strategy to demonstrate specific performance goals in network operation policies.

PHASE I: Complete development of theoretical management model and demonstrate how it can be applied to real network policies. Develop metrics of performance.

PHASE II: Implement management model with a functional architecture in a basic simulation that can be translated onto an actual computer network. Use real network traffic data to show the functional performance of the implementation.

PHASE III: Implement functional approach in software that can be deployed on an actual network. Test the software on a platform that can emulate the performance of real network such as a high performance computer cluster.

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KEYWORDS: Network, Heterogeneous, Management, Information Structure

AF08-T012 TITLE: <u>Large Area Microcavity Plasma Arrays</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Study and demonstrate efficient, visible and ultraviolet emitting, large area, lightweight microcavity plasma arrays.

DESCRIPTION: Microcavity plasmas have been demonstrated over the past several years to have unique characteristics, including the ability to operate at extremely high power loadings (hundreds of kW/cm3) and pressures up to and beyond one atmosphere. Arrays of microcavity plasma devices have been realized with cavity dimensions as small as 10 μm, and have been fabricated in several materials systems, such as silicon, ceramics, and even plastic sheets. Recently, arrays of Al/Al2O3-based devices, with radiating areas as large as 200 cm2, were reported and, when operated in conjunction with a phosphor, produced luminous efficacies of ~15 lumens/W. The lightweight and low potential manufacturing cost of these thin (<1.5 mm) arrays make them of interest for Air Force and commercial applications. Ultraviolet-emitting arrays, for example, would be valuable for germicidal applications, phototherapeutic treatments, and the photochemical repair of tissue. Coupled with a phosphor, these arrays would provide portable, inexpensive, flexible and lightweight lighting sources that are potentially scalable to areas of several m2. The ability to address individual pixels in flexible microplasma arrays would be of considerable value as portable displays.

This topic is intended to lead to prototype devices demonstrating the full utility of microplasma array technology. Specifically, the value of these arrays for DOD applications requiring lightweight, portable and flexible lighting is contingent upon the realization of improved luminous efficacies. Values of the efficacy achieved to date equal or exceed that available from incandescent lighting but significant improvements are necessary to realize the full benefit of portability through reduced power consumption. Furthermore, the route to manufacturability of arrays having at least 400 cm2 of radiating area should be identified and prototypes fabricated and benchmarked.

Similarly, the proposed program must develop an inexpensive means for addressing individual pixels in a large (¡Ý100 cm2) array of microplasma devices. Cost of manufacturing and the scalability of the fabrication process to arrays with areas of thousands of cm2 will be critical considerations in the evaluation process.

PHASE I: Demonstrate 4" x 4" (100 cm2) arrays, having device packing densities no less than 103 cm¨C2, and producing a luminous efficacy of 20 lumens/W. Overall (sealed) thickness of the array must be small, no more than 1.5 mm. Develop a design for addressing arrays of microplasma devices, with an interconnect network with potential for economical manufacturing.

PHASE II: Demonstrate arrays no smaller than 8" x 8" (400 cm2) in radiating area, having a luminous efficacy of at least 25 lumens/W. Demonstrate a fully-addressable 4" x 4" array capable of displaying monochrome video imagery. The pixel density must exceed 2 x 103 cm¨C2 and a fully-manufacturable fabrication process should be developed.

PHASE III / DUAL USE: Military application: Heads-up displays, portable displays, sterilization and disinfection, lightweight portable and specialized lighting, treatment of infectious disease Commercial application: commercial and residential lighting, flexible signage, sterilization, phototherapeutic treatments.

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KEYWORDS: Microplasma arrays, lighting, displays, addressability, manufacturing, luminous efficacy, flexible

AF08-T013 TITLE: <u>Robust Model for Behavior of Complex Materials during Spin Testing</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Accurately model spin tests of turbine engine disk shapes using location specific material properties.

DESCRIPTION: Current models for rotating components involve simplified constitutive equations to describe material behavior. In reality, spin-pit articles can have bulk residual stresses, defects/flaws, microstructural variations, and chemical-composition gradients. The effect of these factors on constitutive response needs to be included in simulations in order to predict the performance of real spin-test articles accurately. At present, the incorporation of various material effects in finite element codes is both cumbersome and time-consuming.

PHASE I: The team will define current capabilities to model plastic growth of complex disk shapes during spin tests incorporating location-specific material properties. The team will outline a program to create a robust and accurate method describing materials in realistic spin-pit conditions.

PHASE II: The team will modify commercial software (e.g. DEFORM) to incorporate location-specific material properties. Realistic material properties will be derived from experiment along the radial direction of the disk. The software and data will be used to model room and elevated temperature spin tests. Predicted plastic strain distributions and burst criteria will be compared to experiments.

PHASE III / DUAL USE: Military application: Design and optimization of advanced turbine disk shapes, structure gradients and chemical composition profiles. Commercial application: Design and optimization of advanced turbine disk shapes, structure gradients and chemical composition profiles.

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KEYWORDS: turbine disk, spin pit testing, finite element models, material properties

AF08-T014 TITLE: Autonomous Aerial Recovery of Micro Air Vehicles

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop, implement, and demonstrate technology for aerial recovery of micro air vehicles (MAVs)using larger UAVs.

DESCRIPTION: Recent military conflicts have demonstrated the effectiveness of large UAVs in performing wide field-of-view area surveillance, as well as the effectiveness of using micro air vehicles in gathering narrow field-of-view imagery. Large UAV assets do not have the option of flying below cloud cover, whereas MAV platforms are much less restricted. In addition, MAVs have the ability to get low level, detailed information, look under vertical obscuration, and operate in difficult terrain with minimal risk to human safety. However, with limited range and speed, the use of MAVs by themselves for recovery of timely information is very limited.

Future ISR systems will likely be built on multi-layer sensor technology that combines the benefits of high altitude sensor platforms with low altitude, low speed, platforms. One concept of operations calls for a high altitude mothership to dispense several micro air vehicles [1]. Such a concept allows the extension of the MAVs unique data gathering capability far beyond the range of the MAVs themselves. To minimize cost, reduce the risk of MAV technology falling into enemy hands, and to facilitate refueling and redeployment, it is desirable that the MAVs be recovered at the end of the mission. Since ISR missions are often executed far from ground stations, there is a need for aerial recovery of the MAV by the mothership.

A significant challenge in aerial recovery is the large discrepancy in the relative speeds of vehicles that could function as the mothership (large UAVs or manned aircraft) and speeds of MAVs. Cruise speeds for most military manned aircraft is well above 100 knots, and cruise speeds of large UAVs are on the order of 70 knots. The average airspeeds for most MAVs are 20 to 30 knots, and many MAVs are incapable of flight above 40 knots. The purpose of this program is to develop technology that will enable air-to-air recovery of a MAV by larger UAVs. This program will assume open communication links between the MAV and the mothership. Technologies that are scalable to the recovery of multiple MAVs are particularly desirable.

Beyond the direct military applications, this method of recovering MAVs will be of great value in collecting information in disaster relief situations, forest fire monitoring, chemical plume detection and tracking, and for border patrol. In these applications, there is a need to obtain detailed views near ground level. In these situations, this detailed information can’t be obtained from high flying assets due to the vertical obscuration of weather, trees, smoke, buildings, the clutter of damage from natural disasters, or in the case of chemical plumes, the sensor may need to be inside the plume. For these applications there is no substitute for low flying small vehicles, and the range and requirement and need for timely information mean they will require air launch from other air vehicles. The fact that the sensor suites involved may be very expensive makes the concept of vehicle recovery desirable. This combination of factors makes the concept of air recovery of MAVs from larger UAVs a technology worthy of exploration.

PHASE I: Develop proof-of-concepts hardware and algorithms and determine system requirements for implementation in existing flight vehicles including weight and drag limitations. Conduct low fidelity simulations that estimate reliability of the recovery process, and potential failure modes and rates.

PHASE II: Implement and demonstrate the technology on scaled flight platforms using commercial off –the-shelf autopilot and RC airplane technology. Conduct high fidelity simulations that estimate reliability of the recovery process, and potential failure modes and rates. The focus in Phase II will be the recovery of a MAV by a small UAV (SUAV) with speeds on the order of 70-100 knots.

PHASE III / DUAL USE: Military application: Intelligence Surveillance Reconnaissance (ISR) for detection of camouflaged, or hard to detect and classify targets; ISR over large regoins, ISR for aircraft self-protection Commercial application: collecting information in disaster relief situations, forest fire monitoring, chemical plume detection and tracking, and for border patrol, fish school tracking, wildlife monitoring

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KEYWORDS: MAV, Guidance, Control, Navigation, recovery systems

AF08-T015 TITLE: Integrated Chemically Sensitive Transistors

TECHNOLOGY AREAS: Chemical/Bio Defense, Sensors

OBJECTIVE: Develop a sensor array in which the analyte can be identified by changes in the electronic properties of the sensor material due to analyte absorption or binding. The target analytes should be vapors from explosive devices or chemical weapons.

DESCRIPTION: At present, the ideal handheld chemical sensor is envisioned as a multitude of individually highly selective sensors. The standard method to achieve selectivity is to synthesize sensing materials that selectively bind analyte molecules. Unfortunately, this is rarely possible since for many small molecule toxins and biochemical systems, there is weak specificity. For small molecules, the functional groups (hydroxyls, carboxylics, etc) determine the binding energy and there are only subtle differences between molecules with nearly identical functional groups. Therefore, it is desirable to develop sensor molecules with higher selectivity.

An alternative approach is to have an array of very small sensors in which the analyte changes the electronic properties of the sensors. This STTR topic seeks proposals to develop a sensor array in which the analyte is identified by the changes induced in the electronic properties of the sensor material. Possible analyte induced changes in the electronic properties of the sensor films include the: (a) carrier mobility; (b) impedance; (c) fluorescence intensity; (d) fluorescence lifetime; (e) trap lifetime; and (f) analyte desorption time. The sensor array must have the following characteristics: 1) At least 6 independent sensors should be included 2) Each sensor should draw less than 10 microwatts of power, 3) The 6 sensor elements should occupy less than 1cm2 area, 4) The sensor array should be packaged with amplification, logic, and wireless communication to a PDA, 5) Basic research studies at the academic institute should identify the mechanisms by which the analyte changes the electronic properties of the sensing material.

PHASE I: In Phase 1, the contractor should prove the ability of the sensor arrays to detect and distinguish analytes based on the changes the analyte induces in the electronic properties of the sensor material. Explosive simulants and chemical weapons simulants can be employed. An array with at least 6 sensors is required. Preliminary models of analyte/sensor material interaction should be developed.

PHASE II: In Phase 2, the grantee should develop a working prototype for evaluation of selective analyte detection with live agents and realistic evaluation of power consumption and signal/noise ratio with pre-amplification and signal processing. The contractor should develop a fundamental understanding of how the analytes induce changes in the electronic properties of the sensor films.

PHASE III / DUAL USE: Military application: The proposed sensor arrays would have wide use in the detection of pathogens and chemical explosives wherever the Air Force and the Armed Forces are operating in a hostile environment. Commercial application: Compact sensor packages powered by ambient light with wireless communication will be used to secure both military bases and domestic transport hubs such as airports, bus stations and rail/subway stations. Compact sensor packages are also required for monitoring shipping containers. The total domestic market probably exceeds 1 million devices.

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KEYWORDS: chemical sensor, ChemFET, phthalocyanine

AF08-T016 TITLE: Dynamics-based Nondestructive Structural Health Monitoring Techniques

TECHNOLOGY AREAS: Air Platform, Materials/Processes

OBJECTIVE: Develop robust structural health monitoring techniques using vibration response and elastic wave propagation data and supporting theories.

DESCRIPTION: Metallic and composite materials are used in advanced aerospace structural systems, thus the damage in these structures can occur through both normal wear and tear as well as extraordinary circumstances. Efforts needed to detect those damages and the following corrective actions constitute most serious and costly problems that the Air Force faces. This problem is compounded by the fact that damage can occur in many different forms, such as fatigue cracks, corrosion, and dents in metals; delamination, debonding, and fiber breakage in composites; and battle damage. Large external damage can be detected by the naked eye, and small external and/or internal damage need conventional Non-Destructive Evaluation (NDE)/I techniques. However, conventional Non-Destructive Intrusion (NDI) techniques are based on the use of eddy-current, ultrasound, radiography, thermography, etc., and they are limited to certain kinds of materials and structural geometries, and usually have difficulties in quantifying the damage. Moreover, very often they require the structure to be at least partially disassembled and a skilled technician to interpret the observations, which increase labor costs and add to the time needed to complete the inspection. Besides, they are "local" methods in the sense that they can only find flaws in a small area in each test. Recent developments [refs. 1, 2, and 3] suggest that an approach based on analyzing the micro-amplitude high-frequency vibrations at the surface of a structure, such as those that can be measured by a scanning laser vibrometers with supporting theories that include techniques like perturbation methods, frequency domain numerical methods, innovative techniques to obtain baseline data, methods to separate baseline data from data due to damage can lead to a damage-detection technology that avoids some of the current limitations of NDE/I.

PHASE I: Develop combined theoretical/experimental techniques capable of assessing damage to aerospace structures. Demonstrate the proof-of-concept on composite and metallic test articles; determine location and extent of damage (small delaminations; small cracks at fastener holes; hidden corrosion…)

PHASE II: Develop a portable system for on-site use. Demonstrate the damage-detection system on actual metallic and composite aircraft structures with known flaws, similar to those found in practice, placed in the structures. Evaluate the efficacy of the damage-detection system by comparison with conventional NDI techniques.

PHASE III / DUAL USE: Military application: Structural health monitoring of metal/composite structures of fixed wing aircraft, rotorcraft, ships, land vehicles, bridges and building structures with military applications Commercial application: Structural health monitoring of metal/composite structures of fixed wing aircraft, rotorcraft, ships, land vehicles, bridges and building structures with commercial applications

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KEYWORDS: Vibration-based damage detection, surface evaluation, cracks, delamination, composite and metallic structures

AF08-T017 TITLE: Expert system for coherent feature detection in high-fidelity fluid dynamic simulations

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop data-mining expert system for automated concurrent coherent feature analysis in multi-physics simulations.

DESCRIPTION: New high-resolution numerical approaches, coupled to widespread access to scalable computer systems, have greatly facilitated the simulation of problems of previously unattainable magnitude. For example, direct numerical simulations of turbulent flows in complex configurations are increasingly feasible at ever higher Reynolds numbers. Extraction of physical insight from such simulations can not only help predict and understand key physics in all speed regimes, but can also trigger new and unconventional breakthroughs in control approaches. Such analysis is however a daunting task because of the broad spectrum of spatio-temporal scales encountered, typically spanning several orders of magnitude. Mature present approaches to interpreting the data typically require massive storage, a priori decisions based on extensive human experience and often, wasteful repetitive simulations for statistical analysis. Technologies to automatically and intelligently mine the data, either concurrently with the evolving simulation or as a post-processing step, are only in embryonic stage. This gap can be filled by developing an expert system to mine massive real-time data, which can then be coupled to commercial and research codes with suitable integration procedures, thus realizing the full promise of high-speed computing. The effort should 1) develop and demonstrate techniques predicated on relevant mathematical tools such as spectral analysis, wavelets, vortex identification, topological theory among others in an expert system environment for turbulent flows and 2) develop a versatile, robust, scalable and expandable framework that can be incorporated into industrial, commercial and research codes.

PHASE I: Develop range of feature detection and interaction techniques, data mining and machine intelligence implementation strategy. Demonstrate approach on representative flowfields.

PHASE II: Extend the work of Phase I to develop prototype of a comprehensive framework that can be linked to existing simulation methods. Test and document scalability. Demonstrate applicability in high Reynolds number flows.

PHASE III / DUAL USE: Military application: By extending the analysis beyond the traditional focus on thermo-mechanical loads to include phenomena that drive the physics, including for example coherent structure dynamics which influence aeroacoustic and aerooptic interactions, these new simulations have the potential to revolutionize simulation-led, physics-based advanced vehicle configuration evolution and design. Better understanding of turbulence and transition will have pervasive impact in extending the envelope of current aircraft and in the development of new unmanned vehicles which will operate under highly maneuverable conditions where present experience is inadequate. Commercial application: Applications are anticipated in broad areas where turbulence plays a key role, including commercial aircraft, weather prediction and industrial and biomedical devices.

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KEYWORDS: Turbulence, feature extraction, data-mining, artificial intelligence

AF08-T019 TITLE: Efficient Kinetic/Continuum Simulations of Hypervelocity Gas Flows in Nonequilibrium Dissociation and Ionization for Earth Atmospheres

TECHNOLOGY AREAS: Air Platform, Space Platforms

OBJECTIVE: Employ gas kinetics approaches for three dimensional, hybrid kinetic/continuum modeling capability in steady and transient conditions for hypersonic flight emphasizing accurate heat transfer.

DESCRIPTION: The flight envelope of the next generation of hypervelocity aerospace vehicles powered by air breathing propulsive devices includes extended dwell time at relatively high altitudes. The design space of such vehicles can only be analyzed by acquiring a detailed understanding of a broad spectrum of spatio-temporal time scales ranging from continuum to rarefied flows. Hypervelocity flows are distinctive in the high temperature regime because of the finite rates at which the energy modes in the atmospheric air get excited and eventually dissociate and ionize. Since these processes take place at finite rates, their accurate computation impacts surface heat transfer prediction accuracy, and consequently the design of the thermal protection system. Currently, numerical methodologies to address the continuum and rarefied regimes are often distinct. However, unified kinetic and continuum solution methods with proper domain decomposition algorithms offer a viable method to simulate gas flows with a wide range of time scales inherent in Air Force applications. Cartesian grids offer distinct advantages including advanced automatic grid refinement and adaptation algorithms and obtaining a fast turnaround of the solutions on today's computers. These advantages for Cartesian grids, however, are offset with the difficulty in resolving the boundary layer and the proper prediction of heat transfer on the surface of the vehicle. Thus, there are considerable numerical and physical challenges in the realization of a kinetic/continuum solver for viscous hypersonic flows.

PHASE I: Develop capability for viscous/inviscid problems solving full Boltzmann equation in kinetic regions and Euler/Navier-Stokes equations in continuum regions. Provide a computational strategy for the kinetic/continuum algorithm to compute heat transfer for dissociating and ionizing hypersonic flows.

PHASE II: Incorporate theoretical advances into a user-friendly computer code with user manuals. Code validation exercises comprise heat transfer on Cartesian mesh, and implementation of existing turbulence models in continuum models. Finalize and validate benchmark cases, viz. (1) heat transfer predictions on a Mach 15.6 flow past biconic body in Ref. 4. (2) Dissociation and Ionization levels in Ref. 2.

PHASE III / DUAL USE: Military application: The computational capability developed for Air Force systems is equally applicable for use in commercial nanotechnologies. Commercial application: The computational capability developed for Air Force systems is equally applicable for use in commercial nanotechnologies.

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KEYWORDS: Boltzmann Equation, Continuum, Rarefied, Transition, Cartesian, Heat Transfer, Transient

AF08-T020 TITLE: Efficient Multi-Scale Radiation Transport Modeling

TECHNOLOGY AREAS: Information Systems, Space Platforms

OBJECTIVE: To develop a numerical method for efficient computations of complex and multi-scale radiative transport problem, from the optically-thin to optically-thick regimes.

DESCRIPTION: Radiative transport can be an important feature of many physical configurations of interest to the Air Force, e.g. combustion flows in air-breathing engines and rockets, high-energy plasma discharges and high-velocity atmospheric re-entry. In turbulent combustion, radiation is coupled to the turbulent eddies and chemical kinetics in nonlinear ways, leading to complex flame dynamics. In the analysis of engine or rocket plume emissions, the detailed spectrum must be computed with high accuracy. In dense plasma discharges and aerodynamic flows with extreme thermal loads, the problem is compounded by the development of dense boundary layers with steep gradients, in particular for ablative surfaces. In the latter case, the radiative mean-free-path (mfp) can vary by several orders of magnitude over very short distances, and scattering by atoms, molecules or micro-particles also becomes important. Therefore, this becomes a multi-scale problem, requiring innovative and efficient numerical methods to be developed and applied. Radiation transport can be treated either through continuum (e.g. discrete ordinates) or stochastic methods (Monte-Carlo); both approaches (and hybrid) are of interest, as long as they have the potential to efficiently treat the multi-scale problem, i.e. applicable from optically thin to thick (diffusion) limits. In the case of deterministic methods, a particular challenge is the handling of the number of unknowns (for 3D problems with frequency and angular dependence) and non-cartesian grids. Partial moment methods [1], as well as "photon-free" methods [2] may be attractive in that case. For Monte-Carlo (MC) methods, the challenge is in the efficient (large time steps) treatment of the optically-thick regime [3]. Techniques such as symbolic MC [4,5] and discrete diffusion MC [6], if extended to the non-grey problem with real scattering, are of particular interest, as well as hybrid methods (e.g. [7]). Parallelization efficiency is also an important issue in determining the approach's effectiveness. The proposed research effort should be focused on demonstrating the accuracy and efficiency of the method for a typical multi-scale problem, i.e. with a large mfp variation such as, for example, an ablative flow layer. The ability to treat the detailed, frequency-dependent problem is also critical; for the purpose of this research effort the thermal properties of the fluid can be simplified (e.g. perfect gas), but the basic approach should be valid for real gases and flows with more complex equations of state.

PHASE I: Develop and demonstrate the basic approach on a simplified problem with reduced dimensionality and/or reduced complexity, 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-dimensional (preferably 3D) and frequency-dependent problem, preferably including real scattering. Verify method on known test-cases for demonstration of the accuracy of the method and potential for applications to physical problems of interest. Demonstrate or measure computational efficiency.

PHASE III / DUAL USE: Military application: Simulations of combusting flows in aircraft engines, hypersonic propulsion, re-entry flows, high energy density plasma discharges (DE, power applications), high-energy particles (space physics). Commercial application: General approach can be used for design of a variety of combustion and power devices, solar energy, and modeling of material-radiation interactions.

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KEYWORDS: Radiation Transport, Multi-scale, multi-physics, plasma, ablation, combustion

AF08-T021 TITLE: Sub-aperture based EO imaging systems

TECHNOLOGY AREAS: Sensors, Space Platforms

OBJECTIVE: Develop sub-aperture based EO imaging systems capable of being near conformal and of compensating for atmospheric effects. High efficiency non-mechanical, or micromechanical, steering of the field of view of the sub-apertures should be used.

DESCRIPTION: Next Generation Air Force platforms will require near conformal apertures. In addition as we push EO imaging systems to longer range we will need to be able to compensate for atmospheric effects. A sub-aperture based imaging approach allows sub-aperture sizes smaller then the atmospheric R0. In addition even if each sub-aperture is flat they can be small, so the over-all effect is almost conformal. Steering the field of view of the EO systems will require a non mechanical steering approach1,2. Diffraction limited resolution should be close to full aperture diffraction limit, at least on receive. As a goal we would like systems that require very little alignement. It is acceptable if the EO system only works with narrowband active EO imaging systems, but as goal it is desirable to be able to image both with active EO systems and with passive systems. Conformal, highly efficient, rapid, random access laser beam steering is needed for many sensing and directed energy applications, including pointing and tracking, imaging, and designation as well as for high average power laser applications. Such an approach has the potential to be scalable in size and is readily adaptable to many applications. For directed energy applications it is required that the sub-apertures be phased on transmit as well as receive.

PHASE I: Develop and digitially demonstrate at least one method of phasing multiple sub-apertures in order to obtain near diffraction limited resolution, based on the full sub-aperture array. As a goal conduct a rudimentary physical demonstration of at least one sub-aperture phasing approach.

PHASE II: Conduct a demonstration of at least one sub-aperture phasing approach. Create a high resolution image at least 128 x 128 pixels in size. Demonstrate update rates of > 1 khz. Show the ability to maintain this high update rate at long ranges, up to 100 km, while imaging a diffuse target that does not contain any significant specular scatterers.

PHASE III / DUAL USE: Military application: Potential phase 3 applications include sensing, free space laser com, and directed energy applications. 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: Imaging, Atmospheric optics, sub-apertures

AF08-T022 TITLE: <u>Novel energetic materials from new polyazide ingredients</u>

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

OBJECTIVE: Identify candidate polyazide compounds for use in as energetic materials.

DESCRIPTION: Poly-nitrogen and high-nitrogen containing energetic compounds have been sought by the DoD for use in propellants and energetic materials. Recently several new polyazide compounds have been synthesized [1,2]. While some of these compounds have been preliminarily characterized and shown to be highly energetic, a thorough characterization of these compounds has not yet been carried out. Further, it is not well understood which of these candidate materials, or potential new polyazides, is the best choice for use in propellant and/or munitions systems, nor is it understood what the best manner is in which to use these compounds (solid compound or solvated liquid/gel). Many of the salts formed from these compounds have been shown to be shock and friction sensitive and undergo rapid thermal decomposition at moderate temperatures [1]. Experimental and theoretical methods are sought which will 1) identify the best energetic polyazide compounds for use in propellant and munitions systems and 2) aid the researcher in the design and synthesis of future high-nitrogen compounds. It is envisioned that these tools will identify traits and trends of the polyazide compounds which can be used to direct future synthetic efforts.

PHASE I: Develop and implement experimental and theoretical approaches to evaluate and recommend the best candidate polyazide compounds for use as energetic materials. These approaches shall have some predictive capability to guide future research and synthesis efforts.

PHASE II: Identify, synthesize and evaluate current and potential new polyazide compounds with potential for use in propellant and/or munitions systems using the approaches and methods developed in Phase I. Evaluation criteria should include, but is not limited to: shock sensitivity, thermal stability, energy density, burn rate, toxicity (both compound and products), oxygen balance, and specific impulse.

PHASE III / DUAL USE: Military application: New polyazide energetic compounds will find military use in rocket propellant systems future munitions and increased energy density fuels. Commercial application: Commercial uses range from satellite station keeping and launch vehicle propulsion to airbag inflater and increased energy density fuels.

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KEYWORDS: polyazide, poly nitrogen, high nitrogen, energetic materials, propellants

AF08-T023 TITLE: High-order modeling of applied multi-physics phenomena

TECHNOLOGY AREAS: Air Platform, Sensors

OBJECTIVE: Develop mathematical techniques, and multi-physics software based thereon to create robust, efficient, high-order tool for phenomena described by the continuum approximation.

DESCRIPTION: Over the last several years, it has become clear that orders of magnitudes improvements in efficiency and accuracy can be achieved by replacing lower-order methods with high-order approaches. This recognition has opened previously unimaginable opportunities to tackle complex problems in aerodynamics, electrofluid interactions, aeroelasticity, structural mechanics, and other non-aeronautical areas such as bio- and nuclear engineering. These physics are characterized by broad-spectrum spatio-temporal scales arising from non-linear, thermal, chemical, structural and electromagnetic effects. However, the promise of these methods has remained to large extent unrealized because of difficulties associated with complex configuration discretization, boundary conditions and lack of robustness. This gap between potential and reality can be bridged by a) further evolution of the spatio-temporal mathematics of such methods for both non-linear as well as diffusive terms, coupled with b) a concentrated effort to rapidly port these advances into software platforms where they can c) be verified, validated and certified in the complex configuration environment. This solicitation seeks proposals to extend the capability of the current generation of multi-physics modeling software by developing and implementing the required mathematical extensions to current state-of-the-art. The effort should facilitate accurate and efficient modeling of phenomena such as diffusion, discontinuities (in material and field properties) and be suited for diverse same-order boundary conditions, including not only Dirichlet and Neumann conditions, but also to account for absorbing, variable catalycity and moving surface problems. Further, improvements in speed with respect to conventional solvers are sought, so that high-order solvers may be tightly integrated in practical design processes. For example, a flexible software system with high-order accuracy, h-p adaptivity and implicit temporal advancement methods incorporate new physics with relative ease and accommodate various types of boundary conditions of engineering interest. Specific needs exist at the present time in the application of these techniques in the areas of vortical flows, aeroelastic analyses, shock-boundary layer interactions, problems involving multiple shock reflections, and supersonic jet flows for thrust as well as mixing.

PHASE I: Develop methods and demonstrate their feasibility to accurately treat diffusion, discontinuous solutions and diverse boundary conditions in complex configurations. Document the improvements over second-order methods (minimum) in canonical problems such as shock/vortex interactions, as well as in sub-system components such as inlets and nozzles. Formulate research and development plan for Phase II.

PHASE II: Extend the methodology to develop and demonstrate a prototypical production-level software product capable of solving complex problems with multidisciplinary physics, taking full advantage of high-order accuracy. Address remaining challenges in robustness, speedup, parallelization, usability and solution-adaptive capability as needed.

PHASE III/DUAL USE: Military applications encompass efforts to model realistic (aircraft–level) analysis, design, and optimization challenges. This includes but is not limited to engine-airframe integration, lifting surface-structure analysis, and electromagnetic system control. Commercial applications include any system or sub-system level analyses and design cycles where detailed, highly accurate multidisciplinary scientific computation is required.

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KEYWORDS: High-order accurate methods, Computational efficiency, Multiphysics modeling

AF08-T024 TITLE: Reconfigurable Materials for Photonic Systems

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Study new optical reconfigurability mechanisms in materials and nano/micro-scale structures for digitally controlled change between two or more states for redundant Reconfigurable Photonic Arrays.

DESCRIPTION: Reconfigurable cellular electronic and photonic arrays (RCEPAs) are of interest to the Air Force due to their great potential for directly implementing complex systems as software-defined emulations, configuring pre-built (but uncommitted) logic, interconnect, switching, memory and other resources to perform a desired set of functions. The success in design, utility, and implementation of RCEPA systems is tightly coupled to the materials and geometries used in these basic device cells, as well as the choice of layout and interconnect of such device elements to serve as a switch array. RCEPAs are malleable and, conceptually, infinitely reformable. In this program, new classes of reconfigurable photonics are expected to result in revolutionary expressions of pervasive morphability in warfighting systems of relevance to Air Force interests.

PHASE I: Investigate, analyze and design new basic electronic or photonic switching elements that will demonstrate multi-state/continuously controlled optical reconfigurability mechanisms, such as hysteresis, in novel materials and in micro- and nano-microelectro (opto)-mechanical (NEM/MEM/NOEM/MOEM) structures.

PHASE II: Further develop the proposed design concept, pertinent material and/or the relevant material processes. Fully demonstrate device functional properties and its utility for commercial and military applications. Perform preliminary life testing on individual switching cells and on prototype devices to determine reliability and significant failure mechanisms. Develop all necessary manufacturing processes for commercialization of the material and/or product.

PHASE III / DUAL USE: Military application: Follow-on activities are expected to be aggressively pursued by the offeror in seeking opportunities for integrating the improved reconfigurable materials into photonic-based switching systems. Commercial application: Commercial benefits would be for optical signal processing in telecommunications and scientific instruments.

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KEYWORDS: photonic switching, optical reconfigurability, slow light, light signal processing

AF08-T025 TITLE: Failure Initiation Predictors for Reliability-Based Design of Hybrid Composite Materials

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop Failure Initiation Theory and Models for Onset of Irreversible Behavior in Hybrid Composite Materials.

DESCRIPTION: Methodologies for reliability-based design of structural components are currently pursued by industry, academia, and government research laboratories. A current methodology explored by Advanced Structural Concepts Branch of AFRL/VA requires analysis to determine a damage initiation event, modeling & simulation of damage progression of the initial flaw, and determination of final failure of the structural component. These deterministic solutions are then linked to a probabilistic analysis framework to iteratively modify the structural design to achieve targeted reliability. This effort will provide new methodologies and analysis techniques for the initiation of irreversible behavior, which then can be utilized to design new composite and hybrid materials which have acceptable damage tolerance characteristics as measured by targeted reliability levels. Failure initiation in Hybrid Composite Materials will require physics-based models and chemistry-based models to adequately capture previously observed behaviors in metal, polymer, and ceramic material systems, as well as interactions of materials within a hybrid material system.

Onset of irreversible behavior in non-isotropic materials is currently determined at the macro-level, where damage initiation is determined through critical dilation or distortion measurements based on strain allowables. These strain allowables require measurements obtained from macro-level coupon testing. New hybrid composite material concepts designed to achieve targeted reliability levels must be formulated independent of experimentally derived quantities. Failure modeling based on physics and chemistry (interface, bonds, etc.) will enable revolutionary composite and hybrid materials designed at the nano- and micro- levels, without reliance on macro-level measurements to provide damage initiation criteria.

Physics and chemistry based failure theories will be subject to validation (solving the correct equations) and verification (solving the equations correctly). Validation can be met through measurement, or methods of measurement can be proposed to capture damage initiation at the micro-level.

PHASE I: Develop micro-models for hybrid composite materials suitable for failure prediction. Development of improved physics/chemistry based failure theory, not based on macro-level strain allowables, capture material interactions. Non-deterministic analysis development or link to probabilistic framework.

PHASE II: The physics/chemistry based failure theories will be linked to damage progression and component failure prediction software for reliability analysis of composite, hybrid, or meta-materials. Sub-component and component structures will be designed utilizing this methodology. Experimental validation of predictions on coupon, element, and sub-components composed of designed hybrid composite materials.

PHASE III / DUAL USE: Military application: This effort will culminate in industry standard reliability prediction and reliable structure design tools for safe life design of military air vehicles. Commercial application: This effort will culminate in industry standard reliability prediction and reliable structure design tools for safe life design of commercial vehicles, land, sea, or air.

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Ng, Stanley J. (Aerospace Materials Division, NAVAIR); Felsecker, Alan; Meilunas, Ray; Tsai, Hsi Chin Source: International SAMPE Technical Conference, 36th International SAMPE Technical Conference - Materials and Processing: Sailing into the Future, 2004, p 129-141

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Craig Collier and Phil Yarrington, Collier Research Corp., Hampton, VA 23669, 46th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics & Materials Conference, 18 - 21 April 2005, Austin, Texas, AIAA 2005-2366

5. Assessment Of Probabilistic Certification Methodology For Composite Structures,
Report # DOT/FAA/AR-00/74, Office of Aviation Research Washington, D.C. 20591, January, 2001

KEYWORDS: Physics-based Failure, Chemistry-based Failure, Reliable Design, Life Prediction

AF08-T026 TITLE: Stability and Performance Analysis of Turbine Engines under Distributed Control Architecture

TECHNOLOGY AREAS: Air Platform, Space Platforms

OBJECTIVE: Develop the theory and the tools to analyze the stability and achievable performance of Turbine Engines under Distributed Control Architecture.

DESCRIPTION: Current engine control systems still use centralized hierarchical control architecture. These centralized control systems have limited redundancy, lack flexibility , have limited diagnostic capability and need extensive cabling requirements. They incorporate analog input and output signals wired directly to the Full Authority Digital Engine Control (FADEC). A centralized hierarchical control architecture leaves the entire system susceptible to loss of all control channels . Thus there is need for replacing the centralized hierarchical control architecture with an autonomous distributed network. In this architecture, analog input/output signals are to be replaced with digital signals. Fixed redundancy is to be replaced with variable/adaptive redundancy. Hard wire cable connections are to be replaced with virtual software connections aided by digital technology resulting in weight and complexity reduction which in turn help in improving fuel efficiency and other performance metrics. These advanced control systems need to take into consideration the distributed nature of the various component controllers and the effective integration and coordination of these decentralized controllers to improve efficiency and health management of the overall propulsion system. This architecture consists of local controllers at the subsystem (component control) level and also a global component at a higher hierarchical level to achieve high performance (fuel efficiency and high thrust control) over as wide range of operating envelope as possible (adaptability to changing operating conditions). Under this distributed control architecture, one needs to study and evaluate the stability and performance characteristics of the overall system under a decentralized control scheme with each control channel having its own communication constraints such as finite bit rate, communication delays and noisy channels. Conditions have to be derived on the allowable finite bit rates and delays to accomplish the control objectives and synchronization issues have to be addressed.

PHASE I: Significantly advance the theory of distributed control under communication constraints, linking encoders, decoders and controllers into a single mathematical framework and develop theoretical/analytical metrics for assessing the achievable stability and performance characteristics for engine.

PHASE II: Apply the theory and methods developed in Phase I to a practical Turbine Engine data and develop tools and methodologies to determine the practical specifications of encoders, decoders and controllers to be employed in the turbine engine control system.

PHASE III / DUAL USE: Military application: Tools developed under this research program would support both military and commercial engine/flight control systems. Commercial application: Commercial turbine engine, civil and commercial UAV applications are also benefiting from this technology

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KEYWORDS: Distributed Control; Decentralized Control; Communication Delays; Finite Bit Rate; Sampling Period; stability

AF08-T027 TITLE: Polarization Imaging Sensors Based on Nano-scale Optics

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Fabricate polarization imaging sensors based on optical components employing subwavelength structures exhibiting particular polarizing, reflecting, and transmitting properties in the ultra-violet (UV) to terahertz (THz) spectral regions.

DESCRIPTION: In recent years, an exciting new class of nano-structured materials has emerged paralleled by novel nano-patterning tools to create these structures. The nano-scale optical properties of these materials can be engineered such that surface effects can produce a number of novel and useful phenomena. Examples include but certainly are not limited to surface gratings, two dimensional photonic crystals used in atypical oblique incidence angles, effective medium optical composites, and motheye coatings. The theoretical descriptions of these materials must include detailed solutions of Maxwell’s equations in order to cover the range of possible responses and applications. Typical bulk optical components do not necessarily require the same level of modeling sophistication for their description. The structures may be constructed with innovative nano-patterning techniques out of functional component materials to achieve the desired response and manipulation of polarization, phase, wavelength, and other optical properties.
Future battlefield systems will exploit highly sophisticated optical detection systems and communications networks connecting command and control with dense arrays of intelligent sensors, compact reconnaissance platforms, and manned and unmanned military assets. These environments will need ultracompact, lightweight, low-power, low-cost optical sources; antenna transmitters; and detectors. In turn, these technologies will require advances in the design of ultracompact microphotonic structures: the design and engineering of the electromagnetic properties of the materials will be on a sub-wavelength scale. Successful completion of this program will aid the development of scaled optical imaging systems and high quality, robust, photonic circuits that will serve as an integrating medium for optical components and networks and that will perform basic, on-chip functions (such as signal conditioning and signal processing).

PHASE I: Demonstrate feasibility of polarization imaging sensors which are based on, and in conjunction with a focal plane array, optical devices with nano-scale structures for the manipulation of light in UV to THz spectral regions that exhibit particular optical properties such as polarization, reflection, and transmission. Identify application, integration and performance parameters.

PHASE II: Build upon Phase I work and demonstrate a system of one or more variations of the components and implementation of a working prototype. Perform appropriate analysis and modeling, software integration, design the materials and other elements, fabricate the device and test its performance. Address the issues of integration into an optical system requiring the functionality provided by the prototype.

PHASE III / DUAL USE: Military application: Applications of the nano-optical elements include remote smart sensors, spectrum analysis, signal processing and communications. Commercial application: Enable fabrication and design of optical components using nano-scale surface structures, which lead to highly functional optoelectronic (OE) circuits in the ultraviolet to infrared to terahertz range.

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KEYWORDS: optical components, optical subcomponents, nanotechnology, imager,polarimeter, optical properties, nano-structured materials, nano-patterning, plasmonics, sub-wavelength components, integrated devices, integrated components, optical networks, light waves, nano-fabrication, detectors, sensors, near-field optics, optical interactions at the nanometer scale, near-field optical memory, nano-scaled optical imaging, infrared, terahertz, photonic crystal and subwavelength optical elements

AF08-T028 TITLE: Nanotailored Carbon Fibers & Forms

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To synthesize and characterize nanotailored carbon fibers for use as advanced multifunctional materials or as a constituent in polymeric matrix composites. Existing carbon fibers based on polyacrylonitrile (PAN) or pitch precursors are constrained in that trades between structural properties and thermal or electrical conductivity properties must be made. A new area of interest is the tailoring of carbon fibers with carbon nanotubes. Such an approach offers the potential for the development of fiber forms that have superior strength, stiffness, thermal conductivity, electrical conductivity, and strain to failure. A viable approach for continuous processing/fabrication is necessary. The characterization of process-morphology and morphology-property is of special interest.

DESCRIPTION: The synthesis of carbon nanotubes has been demonstrated through various techniques. Today the interest in how these materials may change material-property trade spaces typically of conventional materials is of interest. The incorporation of single wall carbon nanotubes and multiwall carbon nanotubes into host matrices or the assembly of them into devices is today's technical challenge and opportunity. Many have tried to disperse various nano-forms of carbon into polymers with inconclusive results. Models have not been fully developed to guide research towards the most promising nanotailored fiber forms. In addition, direct characterization of their properties is often challenging. Yet the promise of multifunctional and superior properties motivates the need to benchmark the capability of some of these new materials. Spinning carbon nanotubes into fibrous forms offers an approach that, if successful, offers near-term applications.

PHASE I: Research should focus on the development of continuous processes that can combine carbon nanotubes into a microscopic fiber form. The resulting fiber must be able to be used at or above temperatures of 120°C. Research should focus on development and scale-up of a process that can continuously form nanotailored carbon fibers. A process that provides a fiber with a minimum strength of 550 ksi, modulus of 75 Msi, density on the order of 1.2 g/cc and high thermal or electrical conductivity is the goal. Potential to reach this must be demonstrated. Morphological characterization to investigate internal structure and towards development of structure-property relationships as well as process control is critical.

PHASE II: Demonstration of scale-up and repeatability of the process. Demonstration of stable properties. Development of experimental and analytical tools for the prediction of performance under mechanical stress. Assessment of interface between developed fiber and thermosetting polymers.

PHASE III / DUAL USE: Military application: New Nanotailored materials can enable ultralight weight structures and advanced thermal management materials for advanced electronics and direct energy systems. Commercial application: New carbon fiber forms have applications in civilian and commercial satellites and electronics.

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KEYWORDS: Carbon nanotubes, carbon fibers, nanotailored fibers

AF08-T029 TITLE: Ultrashort Pulse Manufacturing Technology

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Study high throughput systems for 2- and 3-D, micron and sub-micron structuring of materials.

DESCRIPTION: It is generally recognized that processing materials with pulses of ultrashort duration (defined as pulses with Full Width Half Maximum duration of < 10-12 seconds) is an emerging technology capable of producing high quality structures on the scale of the very small either by ablation, multiphoton photopolymerization, or direct material deposition. Unlike structuring with longer pulse lasers, the physics of ultrashort pulse material modification results in very reduced heat affected zone, splatter, recast layer, delamination, and spalling. Of special relevance to both military and commercial applications is that ablation with ultrashort pulses of light is very deterministic and thus very repeatable. This in turn results in higher yield and lower cost. Current manufacturing systems using ultrashort pulses of light are based on a Ti:Sapphire oscillator/amplifier technology designed originally for use in the scientific research market. This system architecture is suboptimal for producing the highest quality results at the high material removal rates needed to make this technology viable when manufacturing low-cost components.

PHASE I: Research and develop an innovative approach for a high quality, high throughput manufacturing system capable of micro-structuring a variety of materials using ultrashort pulses of light. Design a prototype and explore its anticipated impact on several representative applications.

PHASE II: Construct and commission a prototype innovative manufacturing system detailed in Phase I, and demonstrate its utility in several representative applications.

PHASE III / DUAL USE: Military application: Direct-write structuring of materials on the micron and nanometer scale is of importance for, for example, advanced microsystems with sensors, actuators, and advanced electronic systems. Commercial application: Similar applications as military, including, for example, inexpensive, low power displays.

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KEYWORDS: Direct-write, ultrafast structuring, ultrafast micromachining

AF08-T030 TITLE: Nanodielectrics with Nonlinear Response for High Power Microwave Generation

TECHNOLOGY AREAS: Materials/Processes, Sensors, Electronics

OBJECTIVE: Nanoscale control of dielectric properties demonstrating nonlinear response to E fields, high permittivity (1000's) and very low losses (< 0.0005) at frequencies of 100's MHz to 1 THz.

DESCRIPTION: Delivering Precision Effects and Full Battlespace Awareness are capabilities that are crucial for maintaining the superiority of the U.S. Air Force into the future. Critical technologies for enabling these capabilities require the development of devices that are robust, highly efficient, compact, powerful (> 10 MW) and can easily select operational frequencies ranging from the high rf to terahertz. To realize the full potential of these devices, the development of new, high performance, nonlinear dielectrics materials with electrical properties far exceeding those of existing dielectrics are needed. Tailoring the dielectric material on the nanometer scale by nanostructuring and/or nano-engineering offers the opportunity to make revolutionary advances in the area of nonlinear dielectrics by providing tremendous improvements in electrical, mechanical and thermal properties.

Conventional ferroelectrics are known for high permittivites and strong, non-linear response to an applied electric field under certain conditions. Their response is controlled both by the lattice dynamics of the material and the presence of defects. The loss tangent of the material typically exceeds 0.005 and dielectric response decreases at frequencies in the range of interest (100's MHz to 1 THz). Innovative approaches utilizing unique capabilities enabled by nanostructured dielectrics are needed to provide the unique combination of electrical properties at frequencies within the 100's MHz to 1 THz range. Developing a fundamental understanding of the interactions and physical processes that may develop between molecules, atoms and small clusters of atom (10^3 to 10^6 atoms) in nanometric scale regimes such as quantum confinement effects, defect dipoles and space charge polarization will be critical to the optimization and reproducibility of new nanodielectric materials. Thus, the development and/or utilization of models and simulations that enable an understanding of how the enhancement of the macroscopic properties such as dielectric constant, losses, breakdown strength and nonlinear response at high frequencies (100's MHz – 1 THz) arise from engineering the material on the nanometric scale, and validating them with experimentation will be essential to a successful program. Mechanical properties, thermal stability, compatibility with materials used for device fabrication, lifetime and packaging issues need to be considered as well.

Potentially useful approaches may explore theoretical and experimental aspects of developing nano-engineered nonlinear dielectrics utilizing techniques such as electronic or ionic self-assembled monolayer deposition, atomic layer deposition (ALD), or sol-gel deposition, nanoparticle dispersion processes. Some examples of nanomaterial technologies that may be of interest include, but are not limited to; hybrid nanocomposite materials or nanoengineered films consisting of polymers/ceramics, multi-phased (ferroelectric, paraelectric, antiferroelectric), multi-composition ceramics or nanometric layered structures with dielectric gradients.

PHASE I: Demonstrate nanoscale manipulation of dielectric properties through both simulation & electrical testing. Demonstrate feasibility of forming capacitor structures with combined high permittivity, low losses, high breakdown strength & non-linear E field response at 100's MHz to 1 THz operation.

PHASE II: Demonstrate performance of packaged, prototype capacitors fabricated from optimized, nano-engineered, nonlinear dielectric materials operating at frequencies in the 100's MHz to 1 THz range, Weibull statistics, E field dependence curves, permittivity and losses.

PHASE III / DUAL USE: Military application: Directed energy applications, ultra wide band radar, voltage controlled oscillators, phased array antennas, tunable filters, phase shifters, compact, tunable(narrowband and wide band) microwave device Commercial application: phased array antennas, tunable filters, phase shifters, compact, tunable (narrowband and wide band) microwave devices, communications and cellular telephones.

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KEYWORDS: Nanodielectrics, nanotechnology, nanocomposites, ferroelectrics, paraelectrics, anti-ferroelectrics, nanostructured dielectrics, nonlinear dielectrics, nonlinear transmission lines

AF08-T031 TITLE: Improved Soft Magnetic Materials for High Power Density Electrical Machines

TECHNOLOGY AREAS: Materials/Processes, Electronics

OBJECTIVE: Develop new soft magnetic materials for high power density electric machinery.

DESCRIPTION: Higher aircraft electrical power requirements and replacement of centrally-fed hydraulic actuators has led to a need for higher performance soft magnetic materials. To increase power density these soft magnetic materials will need improvements in operating temperature, mechanical strength, and/or saturation magnetization while retaining acceptable losses [1,2]. Operating temperatures for high power density electrical machines fall into three classes. Room temperature operation is needed for terrestrial applications. An operating temperature of 300 C is needed for use in aircraft power conversion devices, actuators and external generators, with 550 C operation needed for internal turbine engine actuators and bearings.

PHASE I: Identify approaches and determine the best method to improve mechanical strength and/or saturation magnetization of soft magnetic materials. Magnetic losses must remain acceptable. Initial mechanical and magnetic characterization of candidate soft magnetic materials is expected.

PHASE II: Fabricate new magnetic materials that improve on the mechanical, electrical and thermal characteristics of current state-of-the-art magnetic materials.

PHASE III / DUAL USE: Military application: Military applications can include armatures and stators of compact, lightweight generators, pulse transformers, magnetic bearings and electric power conversion components. Commercial application: Commercial applications include high power density electrical machines for civilian aerospace and electric vehicles.

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KEYWORDS: Soft magnetic materials, saturation magnetization, mechanical strength, Curie temperature