Office Of The Secretary Of Defense (OSD)
Deputy Director Of Defense Research & Engineering
Deputy Under Secretary Of Defense (Science & Technology)
Small Business Innovation Research (SBIR)
FY2003.1 Program Description

Introduction

The Deputy Under Secretary of Defense (Science & Technology) SBIR Program is sponsoring two technology area initiatives in this, the first of two FY2003 solicitations, Software Protection and Space Propulsion technology initiatives.

The Air Force Research Laboratory acts as our OSD Agent in the management and execution of the contracts with small businesses awarded as a result of this solicitation. The Air Force Research Laboratory invites small business firms to submit proposals under this Small Business Innovation Research (SBIR) program solicitation. In order to participate in the OSD SBIR Program this year, all potential proposers should register on the DoD SBIR website as soon as you can, and should follow the instruction for electronic submittal of proposals. It is required that all bidders submit their proposal cover sheet, company commercialization report and their firm's technical and cost proposal form electronically through the DoD SBIR/STTR Proposal Submission Website at http://www.dodsbir.net/submission. In addition, a signed copy of the entire proposal should be mailed to the service point of contact as follows:

For the Software Protection Technology Topics; **OSD03-001 through OSD03-005**, please mail a signed hard copy to:

Marleen Fannin
AFRL/SNOX
2241 Avionics Cl
Bldg. 620 Rm. N2-D18
Wright Patterson AFB, OH 45433-7320
Phone: (937) 255-5285 X4117 Email: Barbara.Fannin@wpafb.af.mil

For the Space Power and Propulsion Technology Topics, **OSD03-006 through OSD03-014**, please mail a signed hard copy to:

Deborah Spotts
AFRL/PROI Propulsion Directorate
5 Pollux Drive
Bldg 8353, Room 114B
Edwards AFB CA 93524-7048
Telephone: (661) 275-5617 Email: Deborah.Spotts@edwards.af.mil

If you experience problems submitting your proposal, call the help desk (toll free) at 1-866-724-7457. You must include a Company Commercialization Report as part of each proposal you submit; however, it does not count against the proposal page limit. Please note that improper handling of this form may result in the proposal being substantially delayed. Information provided may have a direct impact on the review of the proposal. The DoD SBIR Proposal Submission Website allows your company to come in any time (prior to the proposal submission deadline) to edit your Cover Sheets, Technical and Cost Proposal and Company Commercialization Report.

We <u>WILL NOT</u> accept any proposals which are not submitted through the on-line submission site. The hard copy submission is not considered a replacement for the on-line submission, it is only considered a signed copy. The submission site does not limit the overall file size for each electronic proposal. However, file uploads may take a great deal of time depending on your internet server connection speed. You are responsible for performing a virus check on each technical proposal file to be uploaded electronically. The detection of a virus on any submission may be cause for the rejection of the proposal. We will not accept e-mail submissions.

Firms with strong research and development capabilities in science or engineering in any of the topic areas described in this section and with the ability to commercialize the results are encouraged to participate. Subject to availability of funds, the Air Force Research Laboratory, acting on behalf of OSD, will support high quality research and development proposals of innovative concepts to solve the listed defense-related scientific or engineering problems, especially those concepts that also have high potential for commercialization in the private sector.

Objectives of the DoD SBIR Program include stimulating technological innovation, strengthening the role of small business in meeting DoD research and development needs, fostering and encouraging participation by minority and disadvantaged persons in technological innovation, and increasing the commercial application of DoD-supported research and development results.

The guidelines presented in the solicitation incorporate and exploit the flexibility of the SBA Policy Directive to encourage proposals based on scientific and technical approaches most likely to yield results important to DoD and the private sector.

The topics are presented in two technology areas: Software Protection and Space Power and Propulsion. The topic descriptions, that follow this program overview section, are listed below.

The five Software Protection Technology Topics follow this section and are:

- OSD03-001 Differential Analysis Software Protection
- OSD03-002 Idiosyncratic Computer Signatures used for Software Protection
- OSD03-003 Reconfigurable Processors for Software Protection
- OSD03-004 Protecting Software Binaries from Reverse Engineering
- OSD03-005 Tools to Aid in Protection of Application Software During Development

The nine Space Power and Propulsion Technology Topics are:

- OSD03-006 High Power Hall Thruster Technology Development
- OSD03-007 Decomposition Characterization and Optimization for Monopropulsion Systems for Spacecraft
- OSD03-008 Micropropulsion Thruster for Low Power Satellites
- OSD03-009 Advanced Cooling Techniques for Hydrocarbon Liquid Rocket Engine Components
- OSD03-010 Advanced Injector Designs for Hydrocarbon Liquid Rocket Engine Components
- OSD03-011 Advanced Manufacturing Techniques for Liquid Rocket Engine Components
- OSD03-012 Advanced Modeling & Simulation (M&S) of Complex Non-Equilibrium Plasma Flows for Microsatellite Propulsion
- OSD03-013 Novel Analysis Tools for Rapid Evaluation of New Propulsion Systems
- OSD03-014 Innovative Applications of Plasma Discharge for Power and Propulsion Technology

OSD SBIR Three Phase Program

Phase I is to determine, insofar as possible, the scientific or technical merit and feasibility of ideas submitted under the SBIR Program and will typically be one half-person year effort over a period not to exceed six months, with a dollar value up to $100,000. We plan to fund 3 Phase I contracts, on average, and downselect to one Phase II contract per topic. This is assuming that the proposals are sufficient in quality to fund these many. Proposals should concentrate on that research and development which will significantly contribute to proving the scientific and technical feasibility of the proposed effort, the successful completion of which is a prerequisite for further DoD support in Phase II. The measure of Phase I success includes evaluations of the extent to which Phase II results would have the potential to yield a product or process of continuing importance to DoD and the private sector. Proposers are encouraged to consider whether the research and development they are proposing to DoD Components also has private sector potential, either for the proposed application or as a base for other.

Subsequent Phase II awards will be made to firms on the basis of results from the Phase I effort and the scientific and technical merit of the Phase II proposal. Phase II awards will typically cover 2 to 5 person-years of effort over a period generally not to exceed 24 months (subject to negotiation). Phase II is the principal research and

development effort and is expected to produce a well defined deliverable prototype or process. A more comprehensive proposal will be required for Phase II.

Under Phase III, the DoD may award non-SBIR funded follow-on contracts for products or processes, which meet the component mission needs. This solicitation is designed, in part, to encourage the conversion of federally sponsored research and development innovation into private sector applications. The small business is expected to use non-federal capital to pursue private sector applications of the research and development.

This solicitation is for Phase I proposals only. Any proposal submitted under prior SBIR solicitations will not be considered under this solicitation; however, offerors who were not awarded a contract in response to a particular topic under prior SBIR solicitations are free to update or modify and submit the same or modified proposal if it is responsive to any of the topics listed in this section.

For Phase II, no separate solicitation will be issued and no unsolicited proposals will be accepted. Only those firms that were awarded Phase I contracts, and have successfully completed their Phase I efforts, will be considered. DoD is not obligated to make any awards under Phase I, II, or III. DoD is not responsible for any money expended by the proposer before award of any contract. For specifics regarding the evaluation and award of Phase I or II contracts, please read the front section of this solicitation very carefully. Every Phase II proposal will be reviewed for overall merit based upon the criteria in section 4.3 of this solicitation, repeated below:

a. The soundness, technical merit, and innovation of the proposed approach and its incremental progress toward topic or subtopic solution.
b. The qualifications of the proposed principal/key investigators, supporting staff, and consultants. Qualifications include not only the ability to perform the research and development but also the ability to commercialize the results.
c. The potential for commercial (Government or private sector) application and the benefits expected to accrue from this commercialization.

In addition, the OSD SBIR Program has a *Phase II Plus* Program, which provides matching SBIR funds to expand an existing Phase II that attracts investment funds from a DoD acquisition program. Private sector investments will also be considered for ***Phase II Plus*** funding. ***Phase II Plus*** allows for an existing Phase II OSD SBIR effort to be extended for up to one year to perform additional research and development. ***Phase II Plus*** matching funds will be provided on a one-for-one basis up to a maximum $250,000 of SBIR funds. All ***Phase II Plus*** awards are subject to acceptance, review, and selection of candidate projects, are subject to availability of funding, and successful negotiation and award of a ***Phase II Plus*** contract modification.

The Fast Track provisions in section 4.0 of this solicitation apply as follows. Under the Fast Track policy, SBIR projects that attract matching cash from an outside investor for their Phase II effort have an opportunity to receive interim funding between Phases I and II, to be evaluated for Phase II under an expedited process, and to be selected for Phase II award provided they meet or exceed the technical thresholds and have met their Phase I technical goals, as discussed Section 4.5. Under the Fast Track Program, a company submits a Fast Track application, including statement of work and cost estimate, within 120 to 180 days of the award of a Phase I contract (see the Fast Track Application Form on www.dodsbir.net/submission). Also submitted at this time is a commitment of third party funding for Phase II. Subsequently, the company must submit its Phase I Final Report and its Phase II proposal no later than 210 days after the effective date of Phase I, and must certify, within 45 days of being selected for Phase II award, that all matching funds have been transferred to the company. For projects that qualify for the Fast Track (as discussed in Section 4.5), DoD will evaluate the Phase II proposals in an expedited manner in accordance with the above criteria, and may select these proposals for Phase II award provided: (1) they meet or exceed selection criteria (a) and (b) above and (2) the project has substantially met its Phase I technical goals (and assuming budgetary and other programmatic factors are met, as discussed in Section 4.1). Fast Track proposals, having attracted matching cash from an outside investor, presumptively meet criterion (c). However, selection and award of a Fast Track proposal is not mandated and DoD retains the discretion not to select or fund any Fast Track proposal.

Follow-On Funding

In addition to supporting scientific and engineering research and development, another important goal of the program is conversion of DoD-supported research and development into commercial products. Proposers are encouraged to obtain a contingent commitment for private follow-on funding prior to Phase II where it is felt that the research and development has commercial potential in the private sector. Proposers who feel that their research and development have the potential to meet private sector market needs, in addition to meeting DoD objectives, are encouraged to obtain non-federal follow-on funding for Phase III to pursue private sector development. The commitment should be obtained during the course of Phase I performance. This commitment may be contingent upon the DoD supported development meeting some specific technical objectives in Phase II which if met, would justify non-federal funding to pursue further development for commercial purposes in Phase III. The recipient will be permitted to obtain commercial rights to any invention made in either Phase I or Phase II, subject to the patent policies stated elsewhere in this solicitation.

Contact with DoD

General informational questions pertaining to proposal instructions contained in this solicitation should be directed to the topic authors and point of contact identified in the topic description section. Proposals should be electronically submitted and a signed hard copy should be mailed to the address identified for this purpose in the topic description section. Oral communications with DoD personnel regarding the technical content of this solicitation during the pre-solicitation phase are allowed, however, proposal evaluation is conducted only on the written submittal. Oral communications during the pre-solicitation period should be considered informal, and will not be factored into the selection for award of contracts. Oral communications subsequent to the pre-solicitation period, during the Phase I proposal preparation periods are prohibited for reasons of competitive fairness. Refer to the front section of the solicitation for the exact dates.

Proposal Submission

Proposals shall be submitted in response to a specific topic identified in the following topic description sections. The topics listed are the only topics for which proposals will be accepted. Scientific and technical information assistance may be requested by using the DTIC SBIR Interactive Technical Information System (SITIS).

It is required that all bidders submit their proposal cover sheet, company commercialization report and their firm's technical and cost proposal form electronically through the DoD SBIR/STTR Proposal Submission Website at http://www.dodsbir.net/submission. In addition, a signed copy of the entire proposal should be mailed to the service point of contact identified for the topic. If you experience problems submitting your proposal, call the help desk (toll free) at 866-724-7457. You must include a Company Commercialization Report as part of each proposal you submit; however, it does not count against the proposal page limit. Please note that improper handling of this form may result in the proposal being substantially delayed. Information provided may have a direct impact on the review of the proposal. The proposal submission website allows your company to come in any time (prior to the proposal submission deadline) to edit your Cover Sheets, Technical and Cost Proposal and Company Commercialization Report. We **WILL NOT accept any proposals which are not submitted through the on-line submission site.** The hard copy submission is not considered a replacement for the on-line submission, it is only considered a signed copy. The submission site does not limit the overall file size for each electronic proposal. However, file uploads may take a great deal of time depending on your internet server connection speed. You are responsible for performing a virus check on each technical proposal file to be uploaded electronically. The detection of a virus on any submission may be cause for the rejection of the proposal. We will not accept e-mail submissions.

The following pages contain a summary of the two technology areas, which are followed by the topics.

I. SOFTWARE PROTECTION TECHNOLOGY FOCUS AREA

SUMMARY

In December 2001, the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)) established the Software Protection Initiative (SPI) to prevent the unauthorized distribution and exploitation of national security application software by our adversaries. This activity was initiated based on Presidential direction to "...identify and invest in additional measures for the protection of critical national security software codes." The Software Protection Initiative is executed under the oversight of the Deputy Under Secretary of Defense (Science and Technology) (DUSD(S&T)). The Air Force Research Laboratory (AFRL) was tasked to manage and execute the SPI with the following goals: 1) slow the acquisition of high-value DoD software by our adversaries, 2) make cost-prohibitive the exploitation of DoD software when it does "leak", and 3) ensure that technology and policy protection measures are appropriately applied, balancing mission requirements with security.

The focus of the DoD Software Protection Initiative (SPI) is to improve protections for critical scientific, engineering, and modeling and simulation software running on desktops through supercomputers. This type of software represents a significant portion of DoD's intellectual property (IP) and enables the development of next generation weapon systems. The SPI will develop software protection technologies; support the insertion of these technologies into application software; and define tools and methods for protected development and distribution of application software. The SPI will compliment the DoD Anti-Tamper Program, which addresses protections on weapon system hardware, subsystem hardware, and embedded software.

The US Air Force will act as the Office of the Secretary of Defense (OSD) Agent in the management and execution of these topics and resulting contracts with small businesses. Proposals in response to these topics (OSD03-001 through OSD03-005) must be submitted electronically (see previous pages for details).

In addition, for each of these topics, please mail one signed copy of your proposal to:

Marleen Fannin
AFRL/SNOX
2241 Avionics Cl
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Phone: (937) 255-5285 X4117 email: Barbara.Fannin@wpafb.af.mil

The five Software Protection Technology Topics are:

- OSD03-001 Differential Analysis Software Protection
- OSD03-002 Idiosyncratic Computer Signatures used for Software Protection
- OSD03-003 Reconfigurable Processors for Software Protection
- OSD03-004 Protecting Software Binaries from Reverse Engineering
- OSD03-005 Tools to Aid in Protection of Application Software During Development

II. SPACE POWER AND PROPULSION TECHNOLOGY FOCUS AREA

SUMMARY

The Deputy Under Secretary of Defense (Science & Technology) SBIR Program is sponsoring a Space Systems Technology Initiative in the areas of spacecraft power and propulsion in support of the DDR&E aerospace initiatives. It constitutes a broad based technology program needed for reusable launch vehicles, incorporating many technologies that are common to hypersonic vehicles. The DDR&E aerospace area will address critical technology gaps in airframes, propulsion, flight critical subsystems, operations and payloads. Specific efforts will include propellants, tanks, air frame structures, thermal protection systems, liquid rocket engines, materials, design and analysis tools, actuation, vehicle management and health monitoring systems, autonomous ground operations, and

upper stages. These OSD SBIR topics focus on enabling technologies for advanced, low cost, reliable rocket engines and on enabling technologies for advanced spacecraft propulsion and power.

The US Air Force will act as the Office of the Secretary of Defense (OSD) Agent in the management and execution of these topics and resulting contracts with small businesses. Proposals in response to these topics (OSD03-006 through OSD03-014) must be submitted electronically (see previous pages for details).

In addition, for each of these topics, please mail one signed copy of your proposal to:

Deborah Spotts
AFRL/PROI Propulsion Directorate
5 Pollux Drive
Bldg 8353, Room 114B
Edwards AFB CA 93524-7048
Telephone: (661) 275-5617 Email: Deborah.Spotts@edwards.af.mil

The nine Space Power and Propulsion Technology Topics are:

- OSD03-006 High Power Hall Thruster Technology Development
- OSD03-007 Decomposition Characterization and Optimization for Monopropulsion Systems for Spacecraft
- OSD03-008 Micropropulsion Thruster for Low Power Satellites
- OSD03-009 Advanced Cooling Techniques for Hydrocarbon Liquid Rocket Engine Components
- OSD03-010 Advanced Injector Designs for Hydrocarbon Liquid Rocket Engine Components
- OSD03-011 Advanced Manufacturing Techniques for Liquid Rocket Engine Components
- OSD03-012 Advanced Modeling & Simulation (M&S) of Complex Non-Equilibrium Plasma Flows for Microsatellite Propulsion
- OSD03-013 Novel Analysis Tools for Rapid Evaluation of New Propulsion Systems
- OSD03-014 Innovative Applications of Plasma Discharge for Power and Propulsion Technology

All of the 14 OSD DUSD(S&T) topics are on the following pages.

OSD 03.1 Topic List

OSD03-001	Differential Analysis Software Protection
OSD03-002	Idiosyncratic Computer Signatures used for Software Protection
OSD03-003	Reconfigurable Processors for Software Protection
OSD03-004	Protecting Software Binaries from Reverse Engineering
OSD03-005	Tools to Aid in Protection of Application Software During Development
OSD03-006	High Power Hall Thruster Technology Development
OSD03-007	Decomposition Characterization and Optimization for Monopropulsion Systems for Spacecraft
OSD03-008	Micropropulsion Thruster for Low Power Satellites
OSD03-009	Advanced Cooling Techniques for Hydrocarbon Liquid Rocket Engine Components
OSD03-010	Advanced Injector Designs for Hydrocarbon Liquid Rocket Engine Components
OSD03-011	Advanced Manufacturing Techniques for Liquid Rocket Engine Components
OSD03-012	Advanced Modeling & Simulation (M&S) of Complex Non-Equilibrium Plasma Flows for Microsatellite Propulsion
OSD03-013	Novel Analysis Tools for Rapid Evaluation of New Propulsion Systems
OSD03-014	Innovative Applications of Plasma Discharge for Power and Propulsion Technology

OSD 03.1 Topic Descriptions

OSD03-001 TITLE: Differential Analysis Software Protection

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: To conduct research into developing technologies that eliminate or drastically reduce the Differential Analysis Software Threat.

DESCRIPTION: Over the past three decades, the Department of Defense (DoD) has made significant investments in applications software that employs high performance computing (HPC) for critical national challenges in the areas of scientific research, engineering analysis, modeling, simulation, training, and operations. In the DoD HPC Modernization Program (HPCMP) this software is critical to computational technology areas (CTAs) such as Computational Electromagnetics and Acoustics (CEA), for radar signature predictions, Signal/Image Processing (SIP), for processing sonar and radar data, Computational Fluid Dynamics (CFD), for fluid dynamics simulations of aircraft and ships, and Computational Structural Mechanics (CSM), for armor and projectile design.

In December 2001, the DoD established the Software Protection Initiative (SPI) to prevent the unauthorized distribution and exploitation of these types of software applications by our adversaries. The SPI requires a strategy that balances the need for application software control and security with the need to develop, enhance, test, and validate software as it is shared with authorized end users. The SPI must be able to effectively develop, leverage, and exploit software investments while still protecting software technology from unauthorized distribution or use.

Due to the complexity and componentization of software applications, developers only rewrite portions of programs when updating applications. As such, when new versions are released, a differential analysis of the new and old version would indicate where differences in the code exist. There is great concern that if software protection hooks were added to applications already being widely used, then a differential analysis would locate the position of those hooks in the source, object, or binary code, allowing it to be defeated. An expensive and impractical solution would be to incorporate software protection hooks in an application, and rewrite the entire application in a different programming language. Research is needed to develop technique(s) to effectively counter differential analysis. The SPI is in need of tools and methodologies that are optimized for the following:

1) Operates on standard processors (e.g., ADM, Intel, Motorola, etc.) used in any computer system
2) Minimizes performance degradation of the application software
3) Robust
4) Low cost

PHASE I: The proposal for Phase I will consist of:
1) Researching various differential analysis techniques and identifying the strengths and weaknesses of each technique
2) Identifying innovative tools and methodologies that are optimized, as discussed above, to counter those differential analysis techniques
3) Recommendations as to what set of tools and methodologies would counter most or all of the differential analysis techniques

PHASE II: Phase II would consist of:
1) Developing prototypes of one or more of the most promising tools and methodologies identified in Phase I
2) Developing a “test bed” for testing various programming language executables for the purpose of measuring performance and security metrics
3) Selecting several software “test-cases” of different programs in several different programming languages
4) Demonstrating prototype(s) using the “test bed” as a proof of concept
5) Producing full documentation of Phase II efforts

PHASE III DUAL-USE COMMERCIALIZATION: Development of tools and methodologies for the protection of high-value software against differential analysis would be highly marketable in both the DoD and commercial

sectors. Any computer application where software security is a concern would benefit from this technology. This technology would also be applicable to any software already in widespread use (DoD or Commercial) where protection is desired for newer versions.

References:
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2. René R. Klösch, “Reverse Engineering: Why and How to Reverse Engineer Software,” Proceedings of the California Software Symposium, University of Southern California, pp. 92–99, April 1996. 1996, URL:
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3. B. Cogswell and Z. Segall; “Timing Insensitive Binary-To-Binary Migration Across Multiprocessor Architectures;” Proceedings of the Third Workshop on Parallel and Distributed Real-Time System, pages 193–194, Santa Barbara, CA, USA, Apr. 1995. IEEE Computer Society Press.
4. M. V. Emmerik, “Signatures for Library Functions in Executable Files,” Technical Report 2/94, Faculty of Information Technology, Queensland University of Technology, GPO Box 2434, Brisbane 4001, Australia, Apr. 1994.
5. Cristina Cifuentes & Antoine Fraboulet, “Intraprocedural Static Slicing of Binary Executables”, Dept. of CS Univ. of Tasmania, Australia, 19975, URL:
http://citeseer.nj.nec.com/cache/papers/cs/2550/http:zSzzSzwww.cs.uq.edu.auzSz~cristinazSzicsm97.pdf/cifuentes97intraprocedural.pdf
6. P. Aiken, A. Muntz, and R. Richards, “A framework for reverse engineering DoD legacy information systems,” In [Waters and Chikofsky1993], pages 180-191, 1993. Gives an overview of the reverse engineering methodology used inside the DoD for the reengineering of information systems.
7. http://dlsuperc.com/

KEYWORDS: Binary, Pattern, Software, Reverse, Engineering.

OSD03-002 TITLE: Idiosyncratic Computer Signatures used for Software Protection

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: To conduct research into locating new idiosyncratic physical signatures emanating from any standard computer platform for software protection purposes.

DESCRIPTION: Over the past three decades, the Department of Defense (DoD) has made significant investments in applications software that employs high performance computing (HPC) for critical national challenges in the areas of scientific research, engineering analysis, modeling, simulation, training, and operations. In the DoD HPC Modernization Program (HPCMP) this software is critical to computational technology areas (CTAs) such as Computational Electromagnetics and Acoustics (CEA), for radar signature predictions, Signal/Image Processing (SIP), for processing sonar and radar data, Computational Fluid Dynamics (CFD), for fluid dynamics simulations of aircraft and ships, and Computational Structural Mechanics (CSM), for armor and projectile design.

In December 2001, the DoD established the Software Protection Initiative (SPI) to prevent the unauthorized distribution and exploitation of these types of software applications by our adversaries. The SPI requires a strategy that balances the need for application software control and security with the need to develop, enhance, test, and validate software as it is shared with authorized end users. The SPI must be able to effectively develop, leverage, and exploit software investments while still protecting software technology from unauthorized distribution or use.

One of the requirements for protecting software executables is the ability to “lock-down” a particular application to one computer system. Tools such as FlexLM, hard-disk volume IDs, and hardware dongles have been used with modest success. Recently, there has been some interest into utilizing the idiosyncratic signatures emanating from standard magnetic medias such as hard disk drives and swipe cards to explicitly link the software with specific

computer platforms. The software uses the "noise signatures" of the system's hard disk drives or swipe cards to determine if it is still operating on the same computer platform. If not, the software will not run or erases itself. The end result is a "locked-down" version of the software that helps prevent illegal uses of the software application.

PHASE I: The proposal for Phase I should identify potential idiosyncratic signatures for securing software application programs and the strength and weakness of each signature. Criteria for evaluating the potential signatures should include, but not be limited to:

1) The robustness and repeatability of the signature
2) Number of different frequencies and bandwidths signature can be detected
3) How common the device is that produced the signature is across various computer platforms
4) The need for extra internal or external hardware
5) If external hardware required, size of form factor
6) Potential costs for extra hardware
7) Impact on computer performance due to additional hardware/software

Proposals should include documentation of:
1) Test sensors and processing circuitry/equipment used
2) List of components tested
3) List of test frequencies

PHASE II: Phase II would consist of developing one or more prototypes to exploit the most promising signatures identified in Phase I and demonstrating the prototype(s) on a computer platform running a standard software application. During this phase, a centralized database would also be developed to record the various digitized signatures.

PHASE III DUAL-USE COMMERCIALIZATION: Identification and development of idiosyncratic signatures for the protection of high-value software and anti-piracy assurances would be highly marketable in both the DoD and Commercial sectors. Any computer application where software security is a concern would benefit from this technology. Additionally, this technology would have application in failure analysis and preventive maintenance by identifying and tracing subtle changes in signatures.

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1. "BIOMETRIC USER AUTHENTICATION," February 2000,
http://www.euro.dell.com/downloads/global/vectors/biometrics.pdf
2. Michael Grant & Ganesh Pai, "A Report for EE 686: Embedded Computer Security," Department of Electrical and Computer Engineering, University of Virginia, Charlottesville, 22903,
http://www.ece.virginia.edu/~gjp5j/EE686ProjectReport.pdf
3. "Cyber-SIGN – Electronic Signature Technology Background," http://www.cybersign.com/tech.PDF

KEYWORDS: Remnant, Noise, Software, Protection, Idiosyncratic, Security, Fingerprints

OSD03-003 TITLE: Reconfigurable Processors for Software Protection

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: Develop new processor technologies specifically designed to support software security protection of and intellectual property.

DESCRIPTION: Over the past three decades, the Department of Defense (DoD) has made significant investments in applications software that employs high performance computing (HPC) for critical national challenges in the areas of scientific research, engineering analysis, modeling, simulation, training, and operations. In the DoD HPC Modernization Program (HPCMP) this software is critical to computational technology areas (CTAs) such as Computational Electromagnetics and Acoustics (CEA), for radar signature predictions, Signal/Image Processing

(SIP), for processing sonar and radar data, Computational Fluid Dynamics (CFD), for fluid dynamics simulations of aircraft and ships, and Computational Structural Mechanics (CSM), for armor and projectile design.

In December 2001, the DoD established the Software Protection Initiative (SPI) to prevent the unauthorized distribution and exploitation of these types of software applications by our adversaries. The SPI requires a strategy that balances the need for application software control and security with the need to develop, enhance, test, and validate software as it is shared with authorized end users. The SPI must be able to effectively develop, leverage, and exploit software investments while still protecting software technology from unauthorized distribution or use.

SPI is concerned about attacks on our critical national security applications by highly motivated, foreign government funded organizations who have virtually unlimited resources to conduct their software attacks. Tools such as compilers, dissemblers, debuggers, and utilities may be used to reverse engineer facsimiles of application source code from processor-specific executable files. Consequently there are a number of software applications that are vulnerable to these organized attackers. The most crucial element for these types of attacks is the availability of the opcode instruction set for a specific processor. To operate properly, the attacker must utilize the instruction set of the processor that the software and operating system was designed to operate on. Only then can they conduct a successful reverse engineering attack of the binary executable by converting the binary code back into its equivalent neumonic code to for the purpose of extracting legible information. Or, they can dynamically monitor the activity of the software executable during real time operation. However, it would be virtually impossible for the attacker to gleam any information if the opcodes were made specific to one unique processor. The benefit of this technology could potentially be enormous. For example, this technology would automatically eliminate the “Differential Software Analysis Threat” since the each version of the binary software would be totally different from its previous version. Specifically, the SPI is interested in conducting research into the practicality of designing such a processor whose opcode instruction set would be programmable.

PHASE I: The proposal for Phase I will consist of:
1) Conducting research into existing reconfigurable processors specifically for application software protection purposes
2) Determine the practicality of designing such a processor whose opcode instruction set would be programmable during software compilation
3) Insuring these processor will operate successfully inside either parallel or serial processing platforms
4) Identification of innovative tools and techniques sufficient to design such a processor
5) Recommendations as to what set of specifications would be necessary to design such a processor taking into account tradeoffs between both speed and software protection features

PHASE II: Phase II would consist of:
1) Designing a reconfigurable processor using the specifications and tradeoffs identified in Phase I
2) Developing a working prototype of the reconfigurable processor
3) Developing a “test bed” for testing various programming language executables for the purpose of measuring performance and security metrics
4) Demonstrating prototype(s) using the “test bed” as a proof of concept
6) Testing these prototype processors on both parallel and serial processor platforms
5) Producing full documentation of Phase II efforts

PHASE III DUAL-USE COMMERCIALIZATION: Development of reconfigurable processors for the protection of high-value software against anti-piracy assurances would be highly marketable in both the DoD and commercial sectors. Any computer application where software security is a concern would benefit from this technology.

REFERENCES:
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KEYWORDS: Reconfigurable, Processors, Software, Protection, Security

OSD03-004 TITLE: Protecting Software Binaries from Reverse Engineering

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: To conduct research into developing technologies that eliminate or drastically reduce software binaries from being reversed engineered.

DESCRIPTION: Over the past three decades, the Department of Defense (DoD) has made significant investments in applications software that employs high performance computing (HPC) for critical national challenges in the areas of scientific research, engineering analysis, modeling, simulation, training, and operations. In the DoD HPC Modernization Program (HPCMP) this software is critical to computational technology areas (CTAs) such as Computational Electromagnetics and Acoustics (CEA), for radar signature predictions, Signal/Image Processing (SIP), for processing sonar and radar data, Computational Fluid Dynamics (CFD), for fluid dynamics simulations of aircraft and ships, and Computational Structural Mechanics (CSM), for armor and projectile design.

In December 2001, the DoD established the Software Protection Initiative (SPI) to prevent the unauthorized distribution and exploitation of these types of software applications by our adversaries. The SPI requires a strategy that balances the need for application software control and security with the need to develop, enhance, test, and validate software as it is shared with authorized end users. The SPI must be able to effectively develop, leverage, and exploit software investments while still protecting software technology from unauthorized distribution or use.

There are a number of software applications that are vulnerable to reverse engineering. Specifically, the SPI is interested in protecting those COTS binaries and legacy applications, which are unfeasible or impractical to recompile or relink. Research is needed to develop techniques for processing software binaries to make reverse engineering unlikely or extremely difficult. The SPI is in need of a tools and techniques that are capable of:
1) Detecting hostile reverse engineering applications including debuggers and disassemblers
2) Detecting falsified operating environments
3) Memory and file protection
4) Obfuscation, as applied to executables

PHASE I: The proposal for Phase I will consist of:
1) Research into various reverse engineering techniques and identifying the strengths and weaknesses of each technique
2) Identification of innovative tools and techniques that have the capabilities discussed above, to counter those reverse engineering techniques
3) Recommendations as to what set of tools and techniques would counter most or all of the reverse engineering techniques

PHASE II: Phase II would consist of:
1) Developing a working prototype environment utilizing one or more of the most promising tools and techniques identified in Phase I for a new advanced integrated secure software processing system
2) Demonstrating the feasibility of the new system through analysis
3) Demonstrating the security features of the prototype by testing the protected software using normal hacking attacks (e.g., disassembling binary, debuggers conducting buffer overflows, etc.).

4) Demonstrating how the prototype operates on binaries and not source code using compliers from different venders.
5) Producing full documentation of Phase II efforts

PHASE III DUAL-USE COMMERCIALIZATION: Development of tools and technologies for the protection of high-value software against reverse engineering would be highly marketable in both the DoD and commercial sectors. Any computer application where software binary vulnerabilities are a concern would benefit from this technology.

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KEYWORDS: Reverse, Engineering, Software, Protection, Security.

OSD03-005 TITLE: Tools to Aid in Protection of Application Software During Development

TECHNOLOGY AREAS: Information Systems, Sensors

OBJECTIVE: Develop tools and methods for an enhanced software development environment that adds features to incorporate systemic protection of the intellectual property and national security. The environment should:
(1) Protect both binary and source against theft or piracy
(2) Preserve and document the version history (A.K.A. pedigree) and maintain a record of those who accessed the codes throughout the entire development process
(3) Ensure that the protection of an application is not compromised by the inadvertent distribution and reuse of an application component

DESCRIPTION: Over the past three decades, the Department of Defense (DoD) has made significant investments in applications software that employs high performance computing (HPC) for critical national challenges in the areas of scientific research, engineering analysis, modeling, simulation, training, and operations. In the DoD HPC Modernization Program (HPCMP) this software is critical to computational technology areas (CTAs) such as Computational Electromagnetics and Acoustics (CEA), for radar signature predictions, Signal/Image Processing (SIP), for processing sonar and radar data, Computational Fluid Dynamics (CFD), for fluid dynamics simulations of aircraft and ships, and Computational Structural Mechanics (CSM), for armor and projectile design.

In December 2001, the DoD established the Software Protection Initiative (SPI) to prevent the unauthorized distribution and exploitation of these types of software applications by our adversaries. The SPI requires a strategy that balances the need for application software control and security with the need to develop, enhance, test, and validate software as it is shared with authorized end users. The SPI must be able to effectively develop, leverage, and exploit software investments while still protecting software technology from unauthorized distribution or use.

A continuing difficulty encountered in software development is the total lack of software protection during the development process. While currently available software development tools may enhance productivity and accelerate the code-compile-test cycle, they do not provide any meaningful assistance to protect software during the

development process. Of particular concern is the security of a software application when it is assembled from components, subprograms, and/or objects. This issue is especially salient as most complex codes are developed using available subprograms or objects. Recently, object oriented software composition is increasingly viewed as a promising means for controlling development costs and for enabling the assembly of complex software applications. However, this same technique also permits one component/subprogram/ object to compromise the protection of an application during development, or later during execution. It is important to develop tools that assist programmers in establishing, tracking and maintaining the version history or "pedigree" of the software under development. The pedigree documents the history of those who have had access to the source code and unprotected binary application, and records all locations where the source codes and binary executables reside. The science of software protection will use an application's pedigree to determine which protection measures would be appropriate, as well as the vulnerability to various methods of attack like differential code analysis.

As a result, DoD is seeking investments in software development environments that protect the source code from unauthorized redistribution, while providing those who have authorized access a usable programming environment. Currently, software development environments are focused at programmer productivity and not software (source code) protection. This SBIR topic is the first real instantiation of such a proposed technology. The concept outlined in this topic is a critical theme of the SPI program – "Protecting software during the development stage while enabling use by appropriate parties." This technology is a very important component of the SPI's portfolio of R&D projects.

PHASE I: The proposal for Phase I should identify innovative tools and methodologies for one or more of the following:
(1) Protecting software from theft or piracy by providing protection of software during compilation and testing (potentially using virtual machines) and automatic encryption and protection of software from access while on physical storage media
(2) Documenting the application pedigree and maintaining lists of all whom have had access to the software throughout the entire development process
(3) Automatically scan developed software for viruses, Trojan horses, or worms that could be embedded within the software during development
(4) Protecting applications from being compromised through the inadvertent use of software components/subprograms/objects.

PHASE II: Phase II would consist of developing prototypes of one or more of the most promising tools and methodologies identified in Phase I. The tools and/or methodologies selected should be developed and coded for use in software development applications. Full documentation and demonstrations should be produced.

PHASE III DUAL-USE COMMERCIALIZATION: Development of tools and methodologies for the protection of high-value software and anti-piracy assurances during software development would be highly marketable in both the DoD and commercial sectors. This technology would also be useful for maintaining control of commercial intellectual property – used in object oriented applications – as well as aid in the development of enhanced protections for DoD applications.

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KEYWORDS: Tools, Obfuscation, Watermarking, Software, Protection, Security

OSD03-006 TITLE: High Power Hall Thruster Technology Development

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Design, develop, and validate innovative "high power" Hall thruster technologies that significantly improve thruster operating characteristics and/or reduce thruster life cycle cost.

DESCRIPTION: The application of electric propulsion (EP) systems for orbit transfer of satellites will deliver larger payloads and provide greater mission capability when compared to chemical propulsion systems. Due to its high efficiency and appropriate specific impulse range, the Hall Effect Thruster (HET) is a strong candidate technology for stationkeeping, repositioning, and orbit transfer missions. Over 100 Russian Hall thrusters operating up to 1.35 kW have flown in space. Development of Hall propulsion systems with powers up to 10 kW is proceeding internationally, and on-orbit application of several 4.5 kW systems is projected within the next few years. To support future orbit transfer missions, multiple Hall systems operating at powers exceeding 20 kW are envisioned. These high power levels are especially applicable for communications satellites, where high on-board power availability enhances the primary mission. The development of innovative Hall thruster technologies that can significantly improve thruster operating characteristics and/or reduce thruster life cycle cost is expected to provide greatly increased mission capability and system application. Topics of interest include, but are not limited to: thrust-to-thruster mass ratio; thrust-to-thruster power ratio; efficiency; total impulse; thruster production cost; electromagnetic and contamination output and measurement; ground test cost. Research may focus on one or more improvement objectives. Since these characteristics are both interrelated and power dependent, it is necessary that such effects be accounted for when investigating technology improvements. Innovations may include, but are not limited to: thruster magnetic system; thruster geometry; thruster materials; thruster fabrication techniques; propellant type; ground test pumping system; thruster diagnostics. Research may focus on one or more innovations. Evaluation of technology improvements with respect to state of the art should occur throughout the effort.

PHASE I: The objectives of Phase I are the following: (1) identify and evaluate candidate technology improvements applicable to 10 kW and greater thruster power; (2) perform analysis to determine the feasibility of these concepts; and (3) perform analysis to estimate the impact of these candidate technologies on the spacecraft level.

PHASE II: The objectives of Phase II are the following: (1) demonstrate the feasibility of the design concepts created during Phase I by fabricating and testing hardware (sub-scale is acceptable); (2) as a result of the testing, incorporate changes and improvements as necessary to scale-up and demonstrate a full size prototype Hall thruster at a power greater than 10 kW.

PHASE III DUAL USE APPLICATIONS: Develop and qualify a flight quality Hall thruster for orbit transfer vehicle and space experiment applications. Deliver to Air Force for further testing and evaluation. Both mission capability and profitability will increase through the introduction of these thrusters into the marketplace. The outlook for commercialization therefore appears very strong.

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KEYWORDS: Electric Propulsion; Hall Effect Thruster; Anode Layer Thruster; Stationary Plasma Thruster; Orbit Transfer; High Power

OSD03-007 TITLE: Decomposition Characterization and Optimization for Monopropulsion Systems for Spacecraft

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Determine a means of initiating a repeatable exothermic decomposition of USAF developed monopropellants resulting in high efficiency rocket engine performance.

DESCRIPTION: Current approaches to initiation of an exothermic decomposition of advanced USAF developed high performance Hydroxy Ammonium Nitrate (HAN) based monopropellants utilize catalyst reactor configurations optimized for straight hydrazine (N2H4) for decomposition. The state of the art catalyst, Shell 405, used for N2H4 does not have the high temperature or oxidation resistance required by these USAF developed HAN based monopropellants. Expected temperature ranges for exothermic decomposition will range from 1900oC to 2200oC. Repeatable, reliable decomposition initiation over a range of demanding mission duty cycles, e.g., high pulsing operations with short exothermic decomposition delay times in the 5-10 millisecond range, as well as reliable and predictable performance over long storage times of up to 20 years are desired. The time increment of decomposition delay times is defined as that time starting from monopropellant introduction into the chamber to 90% design chamber pressure for a thrust range of 25 lbf to 100 lbf. Manufacturability and maintainability are to be considered, as these are the largest impacts to an overall system cost. We seek novel exploitation of exothermic decomposition initiation concepts to reduce to common practice USAF developed high performance HAN based monopropellants in rocket propulsion systems.

PHASE I: Demonstrate a feasibility concept that can potentially be scaled to flight weight applications in atmospheric static ground firings. The effort should clearly address and estimate propulsion system inert weight impact as well as overall flight system impacts.

PHASE II: Demonstrate proof of concept with flight scaled components in flight test or simulated flight conditions in static ground firings. Propulsion system inert weight and flight system impacts shall be optimized from those estimated in Phase I.

PHASE III DUAL USE APPLICATIONS: The Offeror shall develop viable demonstration cases in collaboration with the government or the private sector. Follow-on activities are to be sought aggressively throughout all mission applications within DoD, NASA, and commercial space platforms by Offeror.

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KEYWORDS: Ignition, Decomposition, Injection, Pressurization, Catalyst, Monopropellant

OSD03-008 TITLE: Micropropulsion Thruster for Low Power Satellites

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and validate innovative design concepts for “low power” electric propulsion thrusters for station keeping and orbit maneuvering of small satellites. Identify and validate means of improving small satellite thruster performance.

DESCRIPTION: Small satellites are extremely mass and power limited (250 kg down to 5 kg with satellite specific powers from 1 to 4 W/kg). These satellites are intended for missions including inspection, servicing, and sparse aperture formation flying. Propulsion system requirements for this class of satellite are high due to larger maneuvering requirements, higher precision attitude control, increased stationkeeping life, and higher drag make-up for low orbit satellites. Substantial improvements in both thruster performance and specific power are needed to provide this increased propulsion system capability while constrained by large mass and power limitations. The objective of this effort is to radically push the technological envelope in the field of electric propulsion. Proposed concepts must show promise of more efficiently utilizing the on-board electrical energy while maintaining high specific impulse operation. Primary interests are performance, thrust-to-weight ratio, minimal impact on spacecraft operations and systems, minimal spacecraft contamination, environmental compatibility, and lifetime. Projects proposing significant enhancements to existing systems will also be considered. A strong emphasis should be placed on the validation of the design that is expected to provide the stated performance enhancements; experimental and theoretical methods can be considered. Based on the results of these tests, thruster performance should be estimated and improvements quantified. Evaluation of technology improvements with respect to state-of-the-art should occur throughout the effort.

PHASE I: Perform analysis to determine the applicability of candidate electric propulsion microthruster concepts for small satellite applications.

PHASE II: Fabricate and demonstrate an electric propulsion microthruster based on the results of the Phase I analysis.

PHASE III DUAL USE APPLICATIONS: Develop and qualify flight quality electric propulsion systems for small satellite and space experiment applications. Deliver to the Air Force for further testing and evaluation. Both mission capability and profitability will increase through the introduction of these thrusters into the marketplace. The outlook for commercialization therefore appears very strong.

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KEYWORDS: Electric Propulsion; Micropropulsion; Microsatellite; Electrostatic; Electromagnetic; Electrothermal

OSD03-009 TITLE: Advanced Cooling Techniques for Hydrocarbon Liquid Rocket Engine Components

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop, model, and demonstrate advanced cooling techniques for hydrocarbon rocket engine propellants.

DESCRIPTION: Hydrocarbon rocket propellants are an excellent choice for boost rocket engines because of high thrust to weight and high propellant density. Heretofore, all hydrocarbon rocket engines in the U.S. have been for expendable applications. Current interest in both long life and highly operation rocket propulsion coupled with a renewed interested in hydrocarbon propellants such as RP-1 and other advanced fuels identify the need for innovative methods for combustion chamber cooling. Methods such as transpiration, film, and regenerative cooling have been proposed, but never fully explored for long life, highly operable hydrocarbon fueled rocket engines neither have new techniques been employed for low cost-expendable applications. Identify concepts and methods to reduce or eliminate coolant channel coking to extend engine life for 60 missions or greater. New techniques for combustion chamber cooling design, analysis, and verification are desired to improve the state of the art for hydrocarbon rocket propulsion.

PHASE I: Demonstrate, analytically or otherwise, one or more advanced cooling techniques or concepts that are viable for the combustion chamber of a long life hydrocarbon liquid rocket engine chamber and/or low cost expendable hydrocarbon liquid rocket engines. Any effort should clearly understand the environment, issues, and trades of combustion chamber cooling with overall engine integration, engine level performance, and life. Engine level trades should be conducted against conventional cooling techniques to identify benefits and potential disadvantages.

PHASE II: Implement sub-scale/full scale testing and manufacturing experiments of the innovative cooling methods. Analytically or experimentally demonstrate the improvements attained.

PHASE III DUAL-USE APPLICATIONS: Both long life reusable and low cost expendable hydrocarbon rocket engines for the government and industry should be pursued in earnest by the offeror. Application to such other areas as combined cycle engines and thermal protection systems should be pursued if appropriate. Licensing of developed technologies to interested prime contractors should also be considered. Follow-on activities are expected to include transition of this technology to commercial and military engine systems.

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KEYWORDS: hydrocarbon rocket propellant, combustion chamber, cooling, film cooling, transpiration cooling, oxidizer cooling, high heat flux

OSD03-010 TITLE: Advanced Injector Designs for Hydrocarbon Liquid Rocket Engine Components

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop, model, and demonstrate advanced rocket main and preburner injectors for hydrocarbon rocket engine propellants

DESCRIPTION: Hydrocarbon rocket propellants are an excellent choice for boost rocket engines because of high thrust to weight and high propellant density. Heretofore, all hydrocarbon rocket engines in the U.S. have been for expendable applications. Further, past U.S. injectors for rockets has focused mainly on liquid propellant injection. Current programs are pursuing oxygen rich staged combustion cycles which will utilize supercritcal warm/hot hydrocarbon/oxygen combustion products for the oxidizing propellant instead of high pressure liquid oxygen. It is likely new preburners will continue to use liquid liquid propellant injection, but at far higher pressures than the U.S. experience base. We seek a stable combustion with high mixing efficiencies for both main and preburner injectors that are capable of engine life of 60 missions or greater. New designs, techniques, and modeling capabilities for combustion stability and performance modeling are required.

PHASE I: Identify and demonstrate, experimentally, analytically, or otherwise, promising advanced injector designs for existing and advanced hydrocarbon propellants in low cost expendable and/or long life, highly operable and reusable hydrocarbon liquid rocket engines. Consider cost, producibility, and performance constraints. The effort should demonstrate an understanding of the hydrocarbon liquid rocket engine environment and identify potential benefits and disadvantages. Clear understanding of the combustion stability and performance of hydrocarbon rocket fuels must be included in the effort.

PHASE II: Demonstrate the advantages of one or more proposed advanced injectors with actual testing in sub-scale environments.

PHASE III DUAL USE APPLICATIONS: Advanced injectors for both long life reusable and low cost expendable hydrocarbon rocket engines for the government and industry should be pursued in earnest by the offeror. Application to such other areas as aerospace combined cycle engines and terrestrial power generators should be considered. Licensing of developed technologies to interested prime contractors should also be considered. Follow-on activities are expected to include transition of this technology to commercial and military engine systems.

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KEYWORDS: hydrocarbon rocket propellant, injector, combustion stability, c-star, combustion efficiency

OSD03-011 TITLE: Advanced Manufacturing Techniques for Liquid Rocket Engine Components

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop affordable advanced manufacturing techniques for low production rate liquid rocket engine components.

DESCRIPTION: Current manufacturing techniques and production methods that achieve affordability through high production rates, such as injection molding of polymers and metal stamping, are not affordable for the small lot sizes (10 units) and low production rates (0.75/year) of liquid rocket engine components. An ability to produce small lot sizes economically, in shorter times, with advanced materials, would significantly reduce the cost of rocket engine research and development and shorten the overall engine development cycle. Manufacturing techniques and processes currently being developed for prototyping in other industries may be applicable to finished component production for the rocket industry. Embedded process models could reduce scrap rate, improve predictability of finished component behavior, and enhance insertion of new materials such as powdered metallurgy products and metal matrix composites. The payoff for this effort is more affordable rocket engines and shorter engine development times.

PHASE I: The purpose of the phase I activity is to identify and demonstrate promising fabrication technologies and/or process modeling methodologies which have the potential to greatly reduce both the cost and time required to produce liquid rocket engine components in quantities as small as one, but not to exceed 15, with predictable high quality results. The materials of interest include, but are not limited to, metal matrix composites, powder metallurgy products, and high strength superalloys. The extreme environments and structural requirements of rocket components can not be overemphasized. The power densities of rocket engine turbopumps are 100 times that of jet aircraft engines. Therefore, the quality of consolidation and structural integrity of resulting components are essential and should be assessed as part of phase I activities. Process limitations such as size, cross sectional thickness change, minimum detail size, and surface finish should be documented. Capability of, or requirement for, embedded modeling should be investigated. Needs for secondary processing should be defined. If process model development is proposed, a software/model demonstration, or a complete detailed description of how the new tool will be constructed, and implemented must be included in phase I activities along with an estimate of process cost reduction and repeatability/predictability improvement due to model implementation. The result of phase I effort should be a process demonstration of a suitable proof-of-concept article and/or a proof-of-concept demonstration of a process model, and a development plan for improving the technology. Proposal should demonstrate reasonable expectation that proof of principle can be attained within Phase I, and that both commercial potential and commercialization paths exist.

PHASE II: The purpose of phase II is to develop the process and/or computational techniques demonstrated in phase I and produce acceptable examples of typical rocket engine components. The required material properties, microstructures, predictability, and repeatability of the process must be demonstrated. Demonstrate significant cost and schedule reductions in the production of these parts.

PHASE III DUAL USE APPLICATIONS: Many industries require high reliability components that are made in small lot sizes. Automobile race equipment, specialized devices for aiding the handicapped, spacecraft, and petroleum drilling equipment are examples of such small production run products. Once a predictable process capability is commercialized, it can be employed by many industries.

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KEYWORDS: manufacturing technology, fabrication, no-tooling fabrication, direct manufacture, paperless production, process modeling, computational process tools

OSD03-012 TITLE: Advanced Modeling & Simulation (M&S) of Complex Non-Equilibrium Plasma Flows for Microsatellite Propulsion

TECHNOLOGY AREAS: Space Platforms

ACQUISITION PROGRAM:

OBJECTIVE: Develop Advanced Software Tools using Hybrid Numerical Methods for Simulation of Complex Multi-Scale and Multi-Dimensional Non-Equilibrium Plasma Flows.

DESCRIPTION:
The development of new, high-efficiency and scalable plasma propulsion systems involves plasma behavior on smaller time and length-scales, for which there can be a wide range of non-equilibrium conditions. Furthermore as the scale is being reduced for micro and nano-satellite propulsion, interaction with materials becomes increasingly important and may require physical models that take into account heterogeneous structures and atomic/molecular scale effects. The modeling of these phenomena for new classes of non-equilibrium plasma discharges would benefit the design of novel space propulsion systems, as well as high-power switches or high energy / high-intensity beam sources for directed energy weapons. These micro-scale and possible transient plasma flows are generally characterized by a high degree of departure from thermodynamic equilibrium, and can be difficult to model by a single numerical approach. Therefore, the M&S software is likely to involve a hybridization of several methods, such as continuum, multi-temperature Navier-Stokes (NS), magneto-hydro-dynamic (MHD), Direct Simulation Monte-Carlo (DSMC), and Particle-In-Cell (PIC). Furthermore, the material physics must be incorporated at various levels, from continuum dynamics (including phase change) to molecular dynamics, and the electromagnetic-field evolution must also be computed. A new M&S software capability is desired to model all of these multi-scale effects. The proposed research should go beyond the development of new algorithms, or simply the implementation of existing algorithms into a large, "multi-scale" code. All aspects of the problem should be addressed, starting with: database structure, geometry description and grid generation, code architecture, portability and maintenance issues, parallelization approaches, user interfaces, and documentation. The objective is to develop a complete design tool with the following properties: (a) the level of physical description of the problem can be variable; (b) the dimensionality can be varied; (c) the geometric complexity and grid structure can be variable; (d) the software can be easily extended and maintained; (e) the software can easily run on multiple computer architectures, and; (f) the software is efficiently and easily parallelized.

PHASE I: Demonstrate capabilities of novel algorithm(s) and/or other software elements; evaluate multi-processor scaling performance; design overall code architecture and identify validation cases; develop commercialization plan.

PHASE II: Develop M&S software tool with one or more hybrid models and with pre- and post-processing tools, user interfaces, automatic parallelization, and complete documentation. Perform code validation. Analyze performance and scaling issues.

PHASE III DUAL USE APPLICATION: Dual-use and commercial applications of the software are significant. Commercial development of the M&S tool can lead to its application to design and design improvement of sensors, switches, microwave generators, accelerators, lasers, advanced material fabrication or treatment. The need for commercial software of this kind was mentioned, for example, in a National Academy of Sciences report.

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KEYWORDS: none.

OSD03-013 TITLE: Novel Analysis Tools for Rapid Evaluation of New Propulsion Systems

TECHNOLOGY AREAS: Space Platforms

ACQUISITION PROGRAM:

OBJECTIVE: Develop Advanced Software Tools for Rapid Performance Analysis of Novel Space Launch Concepts.

DESCRIPTION: As part of the DDR&E aerospace initiative, new concepts for affordable and safe access to space must be designed and evaluated. These concepts may involve conventional rocket propulsion, air-breathing propulsion and combinations thereof. Furthermore, non-conventional propulsion cycles may also need to be considered, including unsteady operation (such as Pulse Detonation Engine -PDE or Pulse Detonation Rocket Engine - PDRE) or magneto-hydro-dynamic (MHD) concepts. The evaluation of a wide range of propulsion systems is further complicated by the overall vehicle integration requirements. Therefore the evaluation of performance benefits must take into account issues such as fuel storage requirements, weight distribution, aerodynamic properties, power requirements, etc. The detailed analysis of the propulsion systems generally requires the application of advanced Computational Fluid Dynamics (CFD) methods. Such methods are routinely capable to model multi-phase and combustion flows inside and around complex body shapes, and can be used to evaluate both aerodynamic and propulsion performance. System design could be accelerated if one were able to couple the performance characteristics from the flow behavior with other components. For example, the heat transfer to the walls of an air-breathing hypersonic vehicle provides an input to the cooling requirements, which in turn feed into the total fuel mass flow requirements and the total vehicle mass for a given mission. In other examples, fuel injectors, turbo-pumps, material structure are coupled to the combustion chamber pressure and propulsive performance. The coupling becomes more difficult to analyze when additional physics (e.g. MHD) and unsteady effects must be taken into account. The research should yield a Modeling & Simulation (M&S) tool that can easily achieve this coupling between various system components and automatically evaluate the design characteristics of the overall system. Furthermore this software should be able to seamlessly transition between various levels of performance analysis for rapid evaluation to more detailed and complete (e.g. 3D CFD and coupled structural analysis) for design refinement. Variable dimensionality and complexity are therefore essential elements of the software design. This requires a novel and advanced software structure than can also interact easily with a variety of well-established legacy codes, such as CFD flow solvers, structural finite-element solvers, and in-house system performance software for various components (e.g. turbo-pumps, injectors, etc). The software should be designed for easy maintenance and extension (to incorporate additional physics), able to run on any platform, and be highly efficient. The ability to model unsteady cycles is considered a key requirement. Furthermore, the software should be robust and simple to operate, such as designers do not require expertise in the numerical methods involved.

PHASE I: Demonstrate capabilities of novel software architecture on a problem of reduced scope, i.e. with limited coupling to system components, yet still capable of analyzing air-breathing, rocket and unsteady cycles; design overall code architecture and approach for Phase II development; identify validation cases.

PHASE II: Develop M&S software tool for automatic analysis of propulsion systems with coupling to system component performance, coupling capability to legacy codes or with own CFD code, along with pre- and post-processing tools, user interfaces, automatic parallelization, and complete documentation. Perform code validation. Develop commercialization plan.

PHASE III DUAL USE APPLICATION: The system performance analysis of complex systems has dual-use and commercial applications in the aerospace and energy industries. Some system components (turbo-machinery,

injectors,..) and some of the flow physics (combustion, aerodynamics, structural analysis) are similar in both the design of aerospace vehicles and power plants.

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KEYWORDS: Performance Analysis; System Modeling; Aerospace Propulsion; Access to Space

OSD03-014 TITLE: Innovative Applications of Plasma Discharge for Power and Propulsion Technology

TECHNOLOGY AREAS: Space Platforms

ACQUISITION PROGRAM:

OBJECTIVE: To develop new classes of plasma-based devices leading to significant advances in space power and/or propulsion technologies.

DESCRIPTION:
The development of new, innovative plasma-based devices can lead to revolutionary advances in propulsion and power technologies. Hollow cathode and pseudospark discharges provide good examples of such technology. Pseudosparks are distinguished by very high current rise rates (up to 1012 A/s), a high intensity electron beam transient (with power density of the order of 109 W/cm2), and a super-dense glow discharge (ne > 1015 cm-3) capable of sustaining current densities as high as 104 A/cm2. With such operating characteristics, pseudosparks can have a profound impact on technologies for space propulsion systems, particle accelerators, laser and high power microwave discharges, plasma switches, and material processing. To increase practicality, it is extremely desirable to be able to scale down some of the characteristics of the pseudospark, i.e. size and applied voltage. However, the physics involved in the operation of hollow cathodes and pseudosparks are complex and have resisted complete analysis, thus so far preventing the design of micro-sized devices with similar characteristics. The design of efficient and reliable advanced power and propulsion systems based on the operating characteristics of pseudosparks or the next generation of similar devices will require a better understanding of the physics of such devices. The proposed research is aimed towards developing, or supporting the development of advanced plasma-based devices (including micro-discharges), that can have a significant impact on war-fighting capabilities. Power conditioning, plasma accelerators, lasers (including FEL) and HPM weapons are of special interest, as well as advanced space propulsion systems. The research should focus on novel concepts of scalable or micro-discharges with properties (e.g. conductivity, beam generation) of interest to such applications.

PHASE I: Provide engineering analyses or small-scale experimental demonstration of the potential of the proposed device or the validity of the proposed approach; identify key requirements for validating the technology, potential problems and propose approach for Phase II demonstration; identify dual-use and commercialization potential.

PHASE II: Demonstrate the technology with bench-scale experiments; provide detailed plan for scaling-up and additional testing; construct commercialization plan.

PHASE III DUAL USE APPLICATION: Commercial development of the technology, either for military applications and/or other applications. Plasma propulsion systems have applications in both military and commercial sectors. Plasma switches, high quality particle beams and high-power microwave devices also have commercial applications in the power, health and advanced manufacturing industries.

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KEYWORDS: Pseudospark; Micro-Discharges; Plasma Switches; Plasma Accelerators; HPM