NASA SBIR 2011 Phase I Solicitation

S6 Information Technologies

NASA Missions and Programs create a wealth of science data and information that are essential to understanding our Earth, our solar system and the universe. Advancements in information technology will allow many people within and beyond the Agency to more effectively analyze and apply these data to create knowledge. In particular, modeling and simulation are being used more pervasively throughout NASA, for both engineering and science pursuits, than ever before. These are tools that allow high fidelity simulations of systems in environments that are difficult or impossible to create on Earth, allow removal of humans from experiments in dangerous situations, and provide visualizations of datasets that are extremely large and complicated. In many of these situations, assimilation of real data into a highly sophisticated physics model is needed. Information technology is also being used to allow better access to science data, more effective and robust tools for analyzing and manipulating data, and better methods for collaboration between scientists or other interested parties. The desired end result is to see that NASA science information be used to generate the maximum possible impact to the nation: to advance scientific knowledge and technological capabilities, to inspire and motivate the nation's students and teachers, and to engage and educate the public.

Subtopics

S6.01 Technologies for Large-Scale Numerical Simulation

Lead Center: ARC

Participating Center(s): GSFC

NASA scientists and engineers are increasingly turning to large-scale numerical simulation on supercomputers to advance understanding of complex Earth and astrophysical systems, and to conduct high-fidelity aerospace engineering analyses. The goal of this subtopic is to increase the mission impact of NASA's investments in supercomputing systems and associated operations and services. Specific objectives are to:

- Decrease the barriers to entry for prospective supercomputing users.

- Minimize the supercomputer user's total time-to-solution (e.g., time to discover, understand, predict, or design).

- Increase the achievable scale and complexity of computational analysis, data ingest, and data communications.

- Reduce the cost of providing a given level of supercomputing performance on NASA applications.

- Enhance the efficiency and effectiveness of NASA's supercomputing operations and services.

Expected outcomes are to improve the productivity of NASA's supercomputing users, broaden NASA's supercomputing user base, accelerate advancement of NASA science and engineering, and benefit the supercomputing community through dissemination of operational best practices.

The approach of this subtopic is to seek novel software and hardware technologies that provide notable benefits to NASA's supercomputing users and facilities, and to infuse these technologies into NASA supercomputing operations. Successful technology development efforts under this subtopic would be considered for follow-on funding by, and infusion into, NASA's high-end computing (HEC) projects: the High End Computing Capability project at Ames and the Scientific Computing project at Goddard. To assure maximum relevance to NASA, funded SBIR contracts under this subtopic should engage in direct interactions with one or both HEC projects, and with key HEC users where appropriate. Research should be conducted to demonstrate technical feasibility and NASA relevance during Phase I and show a path toward a Phase II prototype demonstration.

Offerors should demonstrate awareness of the state-of-the-art of their proposed technology, and should leverage existing commercial capabilities and research efforts where appropriate. Open Source software and open standards are strongly preferred. Note that the NASA supercomputing environment is characterized by: HEC systems operating behind a firewall to meet strict IT security requirements, communication-intensive applications, massive computations requiring high concurrency, complex computational workflows and immense datasets, and the need to support hundreds of complex application codes - many of which are frequently updated by the user/developer. As a result, solutions that involve the following must clearly explain how they would work in the NASA environment: Grid computing, web services, client-server models, embarrassingly parallel computations, and technologies that require significant application re-engineering. Projects need not benefit all NASA HEC users or application codes, but demonstrating applicability to an important NASA discipline, or even a key NASA application code, could provide significant value.

Specific technology areas of interest:

Efficient Computing

In spite of the rapidly increasing capability and efficiency of supercomputers, NASA's HEC facilities cannot purchase, power, and cool sufficient HEC resources to satisfy all user demands. This subtopic element seeks dramatically more efficient and effective supercomputing approaches in terms of their ability to supply increased HEC capability or capacity per dollar and/or per Watt for real NASA applications. Examples include:

- Novel computational accelerators and architectures.

- Enhanced visualization technologies.

- Improved algorithms for key codes.

- Power-aware "Green" computing technologies and techniques.

- Systems (including both hardware and software) for data-intensive computing.

- Approaches to effectively manage and utilize many-core processors including algorithmic changes, compiler techniques and runtime systems.

User Productivity Environments

The user interface to a supercomputer is typically a command line in a text window. This subtopic element seeks more intuitive, intelligent, user-customizable, and integrated interfaces to supercomputing resources, enabling users to more completely leverage the power of HEC to increase their productivity. Such an interface could enhance many essential supercomputing tasks: accessing and managing resources, training, getting services, developing codes (e.g., debugging and performance analysis), running computations, managing files and data, analyzing and visualizing results, transmitting data, collaborating, etc.

Cloud Supercomputing

Cloud computing has made tremendous promises, and demonstrated some success, for business computing. For operations, potential benefits include: resource virtualization, incremental and transparent provisioning, enhanced resource consolidation and utilization, automated resource management, automated job migration, and increased service availability, and others. For users, potential benefits include: out-sourced operations, on-demand resource availability, increased service reliability, customized software environments, a web user interface, and more. This subtopic element seeks technologies that enable Cloud computing to be used for efficient and effective supercomputing operations and services.

S6.02 Earth Science Applied Research and Decision Support

Lead Center: SSC

Participating Center(s): AFRC, ARC, JPL

The NASA Applied Sciences Program (http://nasascience.nasa.gov/earth-science/applied-sciences) seeks innovative and unique approaches to increase the utilization and extend the benefit of Earth Science research data to better meet societal needs. One area of interest is new decision support tools and systems for a variety of ecological applications such as managing coastal environments, natural resources or responding to natural disasters.

This subtopic seeks proposals for utilities, plug-ins or enhancements to geobrowsers that improve their utility for Earth science research and decision support. Examples of geobrowsers include Google Earth, Microsoft Virtual Earth, NASA World Wind (http://worldwindcentral.com/wiki/Main_page) and COAST (http://www.coastal.ssc.nasa.gov/coast/COAST.aspx). Examples include, but are not limited to, the following:

- Visualization of high-resolution imagery in a geobrowser.

- Enhanced geobrowser animation capabilities to provide better visual-analytic displays of time-series and change-detection products.

- Discovery and integration of content from web-enabled sensors.

- Discovery and integration of new datasets based on parameters identified by the user and/or the datasets currently in use.

- Innovative mechanisms for collaboration and data layer sharing.

- Applications that subset, filter, merge, and reformat spatial data.

This subtopic also seeks proposals for advanced information systems and decision environments that take full advantage of multiple data sources and platforms. Special consideration will be given to proposals that provide enhancements to existing, broadly used decision support tools or platforms. Tailored and timely products delivered to a broad range of users are needed to protect vital ecosystems such as coastal marshes, barrier islands and seagrass beds; monitor and manage utilization of critical resources such as water and energy; provide quick and effective response to manmade and natural disasters such as oil spills, earthquakes, hurricanes, floods and wildfires; and promote sustainable, resilient communities and urban environments.

Proposals shall present a feasible plan to fully develop and apply the subject technology.

S6.03 Algorithms and Tools for Science Data Processing, Discovery and Analysis, in State-of-the-Art Data Environments

Lead Center: GSFC

Participating Center(s): ARC, JPL, LaRC, MSFC, SSC

This subtopic seeks technical innovation and unique approaches for the processing, discovery and analysis of data from NASA science missions. Advances in such algorithms will support science data analysis and decision support systems related to current and future missions, and will support mission concepts for:

- All current operational missions (http://www.nasa.gov/missions/current/index.html).

- Future Earth Science Decadal Survey missions (http://science.nasa.gov/earth-science/decadal-surveys).

- The Landsat Data Continuity Mission (LDCM) (http://ldcm.nasa.gov/).

- The Joint Polar Satellite System (JPSS) (http://www.nesdis.noaa.gov/pdf/jpss.pdf).

- The Lunar Reconnaissance Orbiter mission (LRO) (http://lunar.gsfc.nasa.gov/).

- The Moon Mineralogy Mapper (M3) on Chandrayaan (http://moonmineralogymapper.jpl.nasa.gov/).

- The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) (http://crism.jhuapl.edu).

- The Visual Infrared Mapping Spectrometer (VIMS) on Cassini (http://saturn.jpl.nasa.gov/spacecraft/cassiniorbiterinstruments/instrumentscassinivims/).

- The James Webb Space Telescope (JWST) (http://www.jwst.nasa.gov/).

Research proposed to this subtopic should demonstrate technical feasibility during Phase I, and in partnership with scientists show a path toward a Phase II prototype demonstration, with significant communication with missions and programs to ensure a successful Phase III infusion. It is highly desirable that the proposed projects lead to software that is infused into NASA programs and projects.

In the area of algorithms, innovations are sought in the following areas:

- Optimization of algorithms and computational methods to increase the utility of scientific research data for models, data assimilation, simulations, and visualizations. Success will be measured by both speed improvements and output validation.

- Improvement of data discovery, by identifying data gaps in real-time, and/or derive information through synthesis of data from multiple sources. The ultimate goal is to increase the value of data collected in terms of scientific discovery and application.

- Techniques for data analysis, that focus on data mining, data search, data fusion and data subsetting that scale to extremely large data sets in cloud, large cluster, or distributed computing environments.

In the area of tools, innovations are sought in the following areas:

- Frameworks and related tools such as open source frameworks or framework components that would enable sharing and validation of tools and algorithms.

- Integrated ecosystem of tools for developing and monitoring applications for high performance processing environments, including cloud computing, high performance cluster, and GPU processing environments, that support software development for science data discovery applications, including support for compilation, debugging, and parallelization.

- Integrated tools to collect, analyze, store, and present performance data for cloud computing and large scale cluster environments, including tools to collect data throughput of system hardware and software components such as node and network interconnects (GbE, 10 GbE, and Infiniband), storage area networks, and disk subsystems, and to allow extensibility for new metrics, and verification of the configuration and health of a system.

Tools and products developed under this subtopic may be used for broad public dissemination or within a narrow scientific community. These tools can be plug-ins or enhancements to existing software, on-line data/computing services, or new stand-alone applications or web services, provided that they promote interoperability and use standard protocols, file formats and Application Programming Interfaces (APIs) or prevalent applications. When

appropriate, compliance with the FDGC (Federal Geographic Data Committee) and OGC (Open Geospatial Consortium) is recommended.

S6.04 Integrated Mission Modeling for Opto-mechanical Systems

Lead Center: GSFC

Participating Center(s): ARC

NASA seeks innovative systems engineering modeling methodologies and tools to define, develop and execute future science missions, many of which are likely to feature designs and operational concepts that will pose significant challenges to existing approaches and applications.

Specific areas of interest include the following:

Low-cost Model-Based Systems Engineering (MBSE) methodologies (defined as some combination of tools, methods, and processes - refer to the "INCOSE Survey of MBSE Methodologies") for rapid and agile definition of mission architectures during the conceptual design phase. Here, "low-cost" is intended to capture multiple aspects of the investment in the methodology, including initial purchase, maintenance, and training/learning-curve. These methodologies must support requirements analysis, functional decomposition, definition of verification and validation methods, and analysis of system behavior and performance. Development of methods and applications based on, or supporting, standards such as UML and SysML is highly encouraged, as is tight integration with Microsoft Office and Microsoft Project.

Interfaces between existing (or proposed) MBSE tools and CAD/CAE/PM applications used to support NASA science mission development, which typically include (but are not limited to): Pro/E, NX, NASTRAN, ANSYS, ABAQUS, ADAMS (for MCAD and structural/mechanical systems analysis); TSS, SINDA, Thermal Desktop, TMG (for thermal systems analysis); Code V, ZEMAX, OSLO (for optical systems analysis); Hyperlynx Analog, Hyperlynx GHz, System Vision, DxDesigner, ModelSim (for ECAD and electrical systems analysis); Matlab, Simulink, STK (for guidance, navigation and control systems analysis); Excel, MathCAD, Mathematica (for general purpose numerical and symbolic analysis); DOORS (for requirements management); PRICE-H, SEER, SSCM, COSYSMO (for cost modeling)

S6.05 Fault Management Technologies

Lead Center: MSFC

Participating Center(s): ARC, JPL

As science missions are given increasingly complex goals and have more pressure to reduce operations costs, system autonomy increases. Fault Management (FM) is one of the key components of system autonomy. FM

consists of the operational mitigations of spacecraft failures. It is implemented with spacecraft hardware, on-board autonomous software that controls hardware, software, information redundancy, and ground-based software and operations procedures.

Many recent Science Mission Directorate (SMD) missions have encountered major cost overruns and schedule slips during test and verification of FM functions. These overruns are due to a lack of understanding of FM functions early in the mission definition cycles, and to FM architectures that do not provide attributes of transparency, verifiability, fault isolation capability, or fault coverage. The NASA FM Handbook is under development to improve the FM design, development, verification & validation and operations processes. FM approaches, architectures, and tools are needed to improve early understanding of needed FM capabilities by project managers and FM engineers, and to improve the efficiency of implementing and testing FM.

Specific objectives are to:

- Improve ability to predict FM system complexity and estimate development and operations costs.

- Enable cost-effective FM design architectures and operations.

- Determine completeness and appropriateness of FM designs and implementations.

- Decrease the labor and time required to develop and test FM models and algorithms.

- Improve visualization of the full FM design across hardware, software, and operations procedures.

- Determine extent of testing required, completeness of verification planned, and residual risk resulting from incomplete coverage.

- Increase data integrity between multi-discipline tools.

- Standardize metrics and calculations across FM, SE, S&MA and operations disciplines.

- Increase reliability of FM systems.

Expected outcomes are better estimation and control of FM complexity and development costs, improved FM designs, and accelerated advancement of FM tools and techniques.

The approach of this subtopic is to seek the right balance between sufficient reliability and cost appropriate to the mission type and risk posture. Successful technology development efforts under this subtopic would be considered for follow-on funding by, and infusion into, SMD missions. Research should be conducted to demonstrate technical feasibility and NASA relevance during Phase I and show a path toward a Phase II prototype demonstration.

Offerors should demonstrate awareness of the state-of-the-art of their proposed technology, and should leverage existing commercial capabilities and research efforts where appropriate.

Specific technology in the forms listed below is needed to increase delivery of high quality FM systems. These approaches, architectures and tools must be consistent with and enable the NASA FM Handbook concepts and

processes.

- FM design tools: System modeling and analyses significantly contributes to the quality of FM design; however, the time it takes to translate system design information into system models often decreases the value of the modeling and analysis results. Examples of enabling techniques and tools are modeling automation, spacecraft modeling libraries, expedited algorithm development, sensor placement analyses, and system model tool integration.

- FM visualization tools: FM systems incorporate hardware, software, and operations mechanisms. The ability to visualize the full FM system and the contribution of each mechanism to protecting mission functions and assets is critical to assessing the completeness and appropriateness of the FM design to the mission attributes (mission type, risk posture, operations concept, etc.). Fault trees and state transition diagrams are examples of visualization tools that could contribute to visualization of the full FM design.

- FM verification and validation tools: As complexity of spacecraft and systems increases, the extensiveness of testing required to verify and validate FM implementations can be resource intensive. Automated test case development, false positive/false negative test tools, model verification and validation tools, and test coverage risk assessments are examples of contributing technologies.

- FM Design Architectures: FM capabilities may be implemented through numerous system, hardware, and software architecture solutions. The FM architecture trade space includes options such as embedded in the flight control software or independent onboard software; on board versus ground-based capabilities; centralized or distributed FM functions; sensor suite implications; integration of multiple FM techniques; innovative software FM architectures implemented on flight processors or on Field Programmable Gate Arrays (FPGAs); and execution in real-time or off-line analysis post-operations. Alternative architecture choices could help control FM system complexity and cost and could offer solutions to transparency, verifiability, and completeness challenges.

Multi-discipline FM Interoperation: FM designers, Systems Engineering, Safety and Mission Assurance, and Operations perform analyses and assessments of reliabilities, failure modes and effects, sensor coverage, failure probabilities, anomaly detection and response, contingency operations, etc. The relationships between multi-discipline data and analyses are inconsistent and misinterpreted. Resources are expended either in effort to resolve disconnects in data and analyses or worse, reduced mission success due to failure modes that were overlooked. Solutions that address data integrity, identification of metrics, and standardization of data products, techniques and analyses will reduce cost and failures.