A.41 ADVANCED INFORMATION SYSTEMS TECHNOLOGY

NOTICE: Amended November 14, 2016. This Amendment releases the final text for A.41 Advanced Information Systems Technology, which replaces the placeholder text provided in ROSES-2016 in its entirety. Notices of Intent are requested by December 21, 2016, proposals are due February 16, 2017.

1. Introduction

The Earth is a vast, complex, dynamic, interconnected system. Information systems technologies play an essential role in our ability to understand, to forecast, and to predict the Earth system's behavior through the generation, management, and scientific exploitation of the very large amounts of data and information from space-, airborne-, and ground-based sensors, as well as model output. Advances in information systems impact all Earth Science focus areas:

- Atmospheric Composition
- Climate Variability and Change
- Carbon Cycle & Ecosystems
- Earth Surface and Interior
- Water and Energy Cycle
- Weather

The Earth Science Technology Office (ESTO) manages the early development of advanced technologies and applications that are needed for cost-effective NASA Earth Science Division (ESD) missions. ESTO plays a major role in shaping Earth science research and application programs of the future. These important technology investments enable promising scientific and engineering concepts to be explored. ESTO ensures its technology programs create an effective balance of investments by coordinating across missions and science focus areas to define technology needs of NASA's Earth Science Division.

1.1 Background

The NASA Earth Science Division's (ESD) Research and Analysis (R&A), Applied Sciences, and Flight Programs are described in Appendix A.1 of the overall ROSES Announcement. NASA Earth Science's overarching implementation plan is defined in the 2010 Climate-Centric Architecture document (https://smd-prod.s3.amazonaws.com/science-green/s3fs-public/atoms/files/Climate_Architecture_Final.pdf) and the NASA Strategic Plan (https://www.nasa.gov/sites/default/files/files/FY2014_NASA_SP_508c.pdf). Consistent with these plans, the Advanced Information Systems Technology (AIST) program has the responsibility for providing advanced technologies to enable science measurements, make use of data for research, and facilitate practical applications for societal benefit by directly supporting each of the core functions within NASA's Earth Science Division: Research and Analysis, Flight, and Applied Sciences.

2. Goals of the Advanced Information Systems Technology program

The goals of the Advanced Information Systems Technology (AIST) program are to identify, develop, and demonstrate advanced information system technologies that:

- Reduce the risk, cost, size, and development time for Earth science space-based, airborne, and ground-based information systems,
- Increase the accessibility and utility of science data, and

- Enable new observations and information products.

The AIST is focused on maturing technology projects early in the Technology Readiness Level (TRL) cycle (2 to 4) and to mature the technologies (typically TRL 6) for potential infusion into the appropriate science, applications, and mission communities.

3. Proposal Research Topics

Key technical themes being solicited are grouped into core topics (refer to Section 3.1):

- Operations Technologies
- Computational Technologies
- Data-Centric Technologies

Three additional special subtopics are being solicited to address more specific needs of the Earth Science Division (refer to Section 3.1.4). For each area, the investments are intended to reduce the risk and cost of evolving NASA information systems to support future Earth observations and to transform those observations into Earth information. The topics encompass both hardware and software for space-based, airborne, or ground-based systems.

Automation in any of these topics is of interest to NASA. There is an ongoing requirement to operate, manage, and exploit an increasing number of diverse missions and large and varied data and models. Automation allows NASA to operate large numbers of spacecraft safely with an affordable mission operations workforce. Automated data product generation is expected to accelerate the availability of data products from a growing inventory of data sources. Automation of instrument controls permits rapid mode changes in response to changes in the observed conditions. Of course, the needs of the observing strategy and the science community must dictate the degree and type of automation which is appropriate.

Recent ESTO investment strategy studies on Lidar (https://esto.nasa.gov/LidarStrategies/index.html) and Microwave (https://esto.nasa.gov/MicrowaveStrategies/index.html) instruments identify needs for information technology advances to support future capabilities in those instrument types.

3.1 Core Topics

3.1.1 *Operations Technologies*

Operations information systems technologies broadly support the future challenges of operating NASA's Earth Science space-based, airborne, or ground-based systems. New developments, (i.e., Unmanned Aerial Vehicles (UAVs) and small satellites) are being coordinated with other more mature observing systems platforms and sensors to advance how scientific observations are performed. Opportunities exist to improve observation strategies and to enable new types of observations. These advances will increase the degree of coordination among different platforms and sensors. Platforms and sensors of interest, with examples of areas of application, include:

- Spacecraft - traditional multiinstrument systems, small satellites, and U-class satellites, both as individuals and as constellations;
- Aircraft – automation of mission coordination and instrumentation operation and inflight reconfiguration based on observations of opportunity;

- In-situ sites and instruments – platform networking; automated management, and data polling;
- Models – automated execution of models with varying inputs to support studies of science sampling strategies, mission design trade studies and/or scientific investigations;
- Sensor Web – integrated multinode systems which may be composed of homogenous or heterogeneous nodes.

Innovative approaches are required to advance a variety of goals, such as:

- managing increasing numbers of remote sensing measurements;
- handling a variety and uncertainty of data;
- handling volume and analysis of data for improved operations;
- event-driven operations;
- autonomous remote sensing management.

Technologies in this category are intended to increase the operations effectiveness of Earth observing instruments, software, and missions.

Example technology areas and challenges include, but are not limited to:

- Technologies for automated real-time operations of individual platforms or collections of platforms and instruments.
- Tools for operations planning, scheduling, data acquisition, product distribution, and/or archiving from distributed and high data rate observations.
- Technologies for real-time data acquisition and control for science analysis and decision support applications.
- Technologies for efficient and/or automated equipment operation and control of small satellites, UAVs, and in-situ devices.
- Technologies for coordinated operation and data management of distributed, heterogeneous, and dynamic Earth observing assets (e.g., sensor webs and/or distributed mission operations), including small satellites, airborne platforms, UAVs, and in-situ sensors and instruments, in order to support science objectives.
- Technologies for improving and accelerating generation of low latency data products from the growing number of instruments supporting real time and near real time science objectives and applications.
- Reusable and rapidly reconfigurable ground data systems technologies.
- Operations technologies specific to aircraft missions, such as goal-directed planning, model driven replanning, vehicle health and monitoring, and on-board processing to support such capabilities.
- Operations technologies specific to small satellites (e.g., processing, compression, storage, downlink, autonomous operations, and attitude determination and control) to meet operational pointing requirements.
- Technologies supporting Synthetic Aperture Radar (SAR) science data processing, calibration and validation.

3.1.2 *Computational Technologies*

Computational technologies refer to innovations in computer architectures, computing hardware, algorithms, and novel approaches to software programming and software engineering. It also includes software developments that improve computing performance or provide new or improved functionality. Technologies in this category are intended to improve or enhance the science value of the data. As a consequence, they have the potential for improving the overall cost effectiveness of a mission or science research effort and reduce the end product latency. Computational Technologies include information systems technologies that operate directly on the following:

- Information extracted from the data stream or model outputs
- Measurements to be acquired by a new mission or science campaign
- Researchers' tools for analytics

Example technology areas include, but are not limited to:

- Data mining and visualization to enable analysis (e.g., data immersion approaches to enable real-time interaction with the models, and visualization of highly complex systems).
- Data exploration that significantly advances state of the art in Earth Science research, such as virtual or enhanced reality aiding in the understanding and evaluating of model output or earth science data.
- Enhancements of workflows, automation, data accessibility, multiple computing paradigms, and collaboration that accelerate model runs or data production.
- Techniques to exploit specialized processing units or accelerators and cloud computing technologies for large-scale on-demand data processing, mining, and distribution.
- Tools to manage and to accelerate the assessment and validation of model-data inter-comparisons (e.g., to more easily evaluate new algorithms and/or quantify data and product uncertainty).
- Tools to broaden the applicability and reduce the cost of simulations (e.g., Observing System Simulation Experiment, OSSE) for evaluating instrument, mission, sensor networks, and field campaigns.
- Tools to expand the integration of Quantum Computing into applications for analysis of Earth Science data and model output.

3.1.3 *Data-Centric Technologies*

Data-centric technologies are those that broadly support the science and applications communities in conducting the sequence of activities needed to transform Earth science mission's observational data, model output and other related datasets to

- improve information reuse, facilitate collaboration within the research community,
- increase the speed of production and publication of results.

AIST focus includes the design of novel and innovative technologies that advance the discovery, access, and use of NASA's Earth Science data within rapidly developing community architectures (e.g., interagency efforts) including:

- the Global Change Information System (https://data.globalchange.gov/),
- the Climate Data Initiative (https://www.whitehouse.gov/the-press-office/2014/03/19/fact-sheet-president-s-climate-data-initiative-empowering-america-s-comm),
- EOSDIS community APIs (https://earthdata.nasa.gov/api)
- global architectures (e.g., the Internet of Things, Smart Cities, and Smart World).

Once matured to Technology Readiness Level (TRL) 6, these technologies lay the foundation for adoption through the Earth Science Division data management programs and projects. They also yield data fusion products that serve to advance Earth science research and resulting publications, and aid decision-making within the research and application communities.

The scope of data-centric technologies includes, but is not limited to, the following sample technology areas:

- Big data analytics applied to the large volumes of Earth science observations' data and metadata and the use of other data-centric technologies.
- Tools and techniques for data fusion and data mining, particularly among files of different formats, sources, and internal data structures. Of particular interest is the use of these tools leveraging cloud computing economics, elasticity and scalability.
- Software architectures and frameworks that support the incorporation of scaling, models, data, sensor webs, data mining algorithms, and visualization by leveraging and/or enhancing interoperability standards.
- Tools and techniques to ease the incorporation of data quality, provenance, semantics, and any relevant metadata into Earth observation data.
- Capabilities to implement, discover, and consolidate/integrate shared services for effective use and management of data and metadata in the science and applications communities (e.g., data provenance mechanisms, uncertainty quantification methods, data quality metrics).
- Storage, management, and processing techniques for large data volumes (e.g., cloud computing, data distribution services and service migration) to enable near-real time end product delivery.
- New and/or enhanced customized tools for managing the development, reuse, and evolution of large scientific codes (e.g., enhancements to open source tools).
- Tools to enable software applications to execute functions and autonomously share results with one another, without compromising system security or violating associated data policies.
- Technologies that provide opportunities for more efficient interoperations with the observations data systems, such as high end computing and modeling systems.
- Tools, workflows, and techniques for formulating and testing families of hypotheses from a seed hypothesis.
- Capabilities that enable discovery and access to Service Oriented Architecture (SOA) components and services.

3.2 Special Subtopics

The AIST program works closely with each of the Earth Science elements (Research and Analyaia (R&A), Flight, and Applied Sciences) to identify technology challenges and to designate special subtopics to help address their longer-term science needs. Offerors are

encouraged to submit proposals that advance novel, higher risk/return approaches to the stated challenges. Core topics proposals are not required to address the Special Subtopics.

3.2.1 Innovation Breakthroughs to Aid in Understanding the Impact of Global Change focusing on Climate Change and Changes in Biodiversity

Global change is threatening to push the Earth system through a range of tipping points threatening global sustainability (*A Safe Operating Space for Humanity*, Johan Rockstrom[7]). The need to understand global change is identified by the National Academy of Sciences (http://sites.nationalacademies.org/PGA/sustainability/PGA_048724) and various conferences, such as Planet Under Pressure (http://www.planetunderpressure2012.net/). Two significant global changes affecting life on Earth are occurring simultaneously: climate change and biodiversity loss. Currently, data from individual instruments and systems are first analyzed individually and then measurements of other parameters are computed from those results. The use of data fusion is growing, along with the analysis of the propagation of uncertainties. The placement of instruments at different vantage points from in-situ sensors up through geostationary satellites affords different measurement characteristics, including spatial resolution (e.g. grain size and extent), temporal resolution (e.g., revisit rate) and coverage of various areas along the electromagnetic spectrum. Climate change observations are typically taken at large regional to global spatial scales while biodiversity observations are often made at plot to landscape scales. The integration of observations of multiple types from all vantage points is required to improve our ability to understand both climate change and biodiversity loss and how each affects the other in space and through time.

The National Climate Assessment (http://nca2014.globalchange.gov) observed that "Impacts of climate change on ecosystems reduce their ability to improve water quality and regulate water flows. Rapid changes to ecosystems may cause the displacement or loss of many species. Timing of critical biological events is shifting, affecting species and habitats." It also pointed out that some scientific barriers present challenges to implement adaptive strategies. More accurate, timely and comprehensive information will be needed to reduce the uncertainties in the short-, medium-, and long-term and to help appropriately respond to these changes.

Advanced information technologies are prevalent across Earth Science R&A activities and are both an enabler and a major cost driver in supporting scientific breakthroughs. Recent results in several NASA programs (Cryosphere, Terrestrial Hydrology, Biodiversity and Ecological Forecasting, Terrestrial Ecology, Ocean Biology and Biogeochemistry) have identified the opportunity to apply recent advances in information technology (such as machine learning, cloud computing, workflow technologies) to enable scientific investigations to use much larger sets of data from dissimilar sources to improve support for their conclusions. Key science research questions are described in these ROSES announcements.

Improvements needed in the use of advanced information technology include:

a) the integration of output from sensors at varying observational levels (in-situ, airborne and orbital) into a more complete and more accurate picture of the spatial distribution and behavior of key populations of organisms, communities, and species.
b) the integration of output from sensors at varying observational level (in-situ, airborne and orbital) into a more complete and more accurate picture of the water distribution and hydrological processes.

c) the integration of instrument data into models with improved accuracy and reduced latency.
d) the correlation of time series measurements of key environmental parameters with the spatiotemporal distribution of organismal populations, communities, and species for improved understanding of the impact of climate change along with other drivers of change on biological systems.
e) the application of the principles of data-driven modeling to improve context for and selection of measurements.
f) the application of uncertainty estimates from machine learning and applied statistics to improve the understanding of the limitations on observational data and model output.
g) improving the ease with which the biology and ecology communities can understand, select and use appropriately NASA remote sensing data.
h) automated analytic techniques to scale the use of all relevant observational data in the understanding of patterns and processes in biodiversity.
i) tools which aid the researcher in formulating and evaluating hypotheses quickly.
j) the integration of automation and workflow tools into the analysis process to accelerate testing, repeatability and inter-organizational collaboration in analysis of data and model output.
k) the prediction and modeling of extreme water-related events, including droughts and floods.
l) the rapid preparation and update of disaster response products, consistent with the NASA's Disaster Response Program.

3.2.2 Alternative Approaches/Disruptive Technologies for Mission Planning and Operations

Developments in the employment of U-class satellites and smallsats to conduct scientific investigations or to supplement conventional orbital platforms is described in a recent report by the National Academy of Sciences (https://www.nap.edu/catalog/23503/achieving-science-with-cubesats-thinking-inside-the-box). New opportunities for integrated sensor webs involving coordination of sensors from in-situ, suborbital and multiple orbital vantage points, thereby permitting a more coherent picture of a phenomenon or event. It is anticipated that, as the number of these platforms expands, the pressure on conventional mission planning and operations capabilities will grow, adding to the cost of missions. Additionally, new measurement strategies could address transient and transitional phenomena by leveraging steerable instruments, coordination among multi-altitude devices and more flexibility in platform orbital dynamics. As key orbital paths become more crowded, planning and signaling among the various mission operations centers become essential to traffic control and critical to collision avoidance. Automation, responsive analytic capabilities and intuitive decision support tools are needed to manage effectively and efficiently these growing numbers of measurement assets.

Such advances include:

(a) integration of multi-satellite mission planning/design tools with multi-satellite tasking and operations capabilities.

(b) goal-oriented mission replanning to maximize the value of science gained.

(c) algorithms for integrating instrument output into mission commanding functions, both on the same platform and on related platforms.

(d) security measures to ensure all commands are appropriately originated, authorized, and authentic.

3.2.3 Technology Enhancements for Applied Sciences Applications

Proposals are sought that develop new and potentially "game changing" capabilities for decision support or end user applications through the use of Earth Science data and/or models in one of the Applied Sciences active applications themes (http://appliedsciences.nasa.gov):

1) Health and Air Quality
2) Disaster Response
3) Water Resources
4) Ecological Forecasting
5) Wildfires

Technology development activities in this topic area must target a public or private sector organization considered to be a value-adding entity or an end-user of NASA Applied Sciences data and services, and at least one member of the proposal team must be from this organization. A letter of endorsement supporting the technology development and committing to an evaluation of its longer term use if successfully demonstrated is required from the identified organization end user.

Proposers who are targeting the Disaster Response application theme should reference *GEOSS Architecture for the Use of Satellites for Disasters and Risk Assessment* (http://ceos.org/ourwork/workinggroups/wgiss/past-activities/ga4disasters/), a report issued by the Committee on Earth Observation Satellites Working Group on Information Systems and Services (CEOS-WGISS). This document should be used when describing the activities and rationale for the proposed technology.

Technology development to translate science and technology into useful tools to help with the response to flood, earthquake and volcano hazards, tropical and hazardous weather, and coastal hazards – including oil spill and chemical releases are particularly needed, including tools for teaming related to response to these hazard areas. Disaster project attributes, such as low latency data, data automation, visualization, monitoring and prediction, are also needed. Global disaster response efforts in support of or related to demonstration and pilot activities aligned with disasters community partners such as the CEOS Working Group for Disasters, the International Charter for Space and Disasters, and the AmeriGEOSS Plan on Water and Disasters are also germane.

4. Special Matters

The AIST Program is designed to bring information system technologies to a level of maturity that allows integration or infusion into existing or future NASA technology, science research and missions, to enable timely and affordable delivery of NASA information to users.

4.1 Technology Infusion

Technology developed with a target audience in mind is more likely to have important impacts on NASA's Earth Science Program. Proposals should address technology development that identifies specific community-based science problems to be solved.

AIST supports development of technologies to the point where they have been demonstrated and are ready to be adopted by NASA Earth Science elements (R&A, Flight, and Applied Sciences). The Earth Science elements influence AIST starting with the requirements definition through the technology infusion phase. Representatives of the relevant elements participate in the proposal review, ranking, and programmatic decisions. After award, element members participate in project reviews and continuation decisions. An early and ongoing influence by the target element ensures a technology will ultimately be useful to that element in the accomplishment of NASA Earth Science goals.

Projects are required to identify a target recipient element and understand their needs in order to produce impactful technology development. A representative of that element should be on the proposed team to ensure design and development decisions are made to support element acceptance. If a technology is potentially useful to multiple elements, they should pick one element where they will obtain effective collaboration.

4.2 Technology Community Resources:

4.2.1 *AIST Managed Cloud Environment (AMCE)*

The AIST Program has implemented a Managed Cloud Environment as a demonstration of how to supply inexpensive, elastic computational and storage services using Amazon Web Services (AWS). The AMCE service provides the AIST IT development community

- collaboration and infusion opportunities,
- flexibility for users,
- adherence to the NASA security requirements.

Successful projects are encouraged to explore this service as a means of obtaining information technology services and reducing their cost. Proposals should not be dependent upon this service for their computation. Upon award, information can be obtained through the AIST Program.

4.2.2 *Independent Testing*

The AIST Program uses the Earth Science Information Partners (ESIP) Federation to perform independent assessments of TRL and adoptability of AIST Projects. This has the additional benefit of improving the adoption of projects or infusion of technologies by giving additional target audiences an opportunity to evaluate the product and to influence final enhancements and make it more usable. Awarded projects may participate in this assessment by arranging it through AIST in the final year of their development.

4.2.3 *Quantum Computing*

Proposals for the development of quantum annealing/computing applications for Earth sciences will be given access to the NASA quantum annealing system located at the NASA Ames Research Center (see http://www.nas.nasa.gov/projects/quantum.html). Proposals must address NASA Earth Science problems that are suitable for solving via quantum optimization algorithms, such as clustering for pattern recognition, data fusion and image matching for remote sensing, structured learning for multiple label classification, and others.

Successful proposals need to describe the full cycle of research on the quantum system. This includes (1) the identification of the specific application embodying an optimization problem, (2) the strategy for mapping the problem into the quadratic unconstrained binary optimization (QUBO) format, and (3) the strategy for embedding the QUBO into the underlying Chimera graph of qubits of the quantum device.

4.3 Technology Best Practices

4.3.1 *Geographic Information Systems (GIS)*

The AIST Program encourages technology development that can be deployed into frameworks commonly in use in the NASA Earth Science community, other Government Agencies, and commercial and educational organizations. The use of commercial or open source Geographic Information Systems (GIS) for Research and Applied Science has been demonstrated to enhance the use of large data sets from a variety of sources, including NASA Distributed Active Archive Centers (DAACs) and field campaigns. The development of unique visualization or analysis frameworks duplicating work already in use is discouraged.

4.3.2 *Software Engineering Practices*

The AIST Program encourages the use of quality software engineering practices. Proposals must address a software engineering and testing plan to describe the software engineering practice to be used by the project, including the use of software engineering standards and procedures. The proposal will be considered unresponsive without this plan. The plan should include the design and architecture documents to facilitate future expansion and maintenance of the software.

4.3.3 *Open Source Software*

The software developed under this ROSES Appendix must be designated and distributed to the public as open source software. Software developed may be created to run in conjunction with commercial or other restricted use software (such as MATLAB, Envi, arc-GIS), but must be separate from that software and should include a brief open sourcing plan and re-use license equivalent to the Apache License 2.0 (http://www.apache.org/licenses/LICENSE-2.0).

5. Proposal Content and Submission

Proposers are advised to periodically check the solicitation website (http://nspires.nasaprs.com/) for any amendments to the ROSES-2016 NASA Research Announcement (NRA), and consult the 2016 version of the NRA *Guidebook for Proposers*.

Notices of Intent (NOI) to propose are encouraged, but not required. Submit NOIs electronically via NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES) by the due date given in Section 9, Summary of Key Information. Please refer to the *Guidebook* for more information regarding NOIs.

The table below identifies the required proposal sections and identifies the appropriate Guidebook sections.

Required Proposal Section	Reference
Proposal Cover Page	2.3.2(a), (b)

Table of Contents	2.3.5
Scientific / Technical / Management Applicability to NASA Earth Science (Relevancy Scenario) Description of Proposed Technology	2.3.6 and additional elements (see Important notes below)
Comparative Technology Assessment TRL Assessment Research Management Plan	See important notes in section 5.3 below
References and Citations	2.3.7
Biographical Sketch	2.3.8
Current and Pending Support	2.3.9
Statements of Commitment and Letters of Support	2.3.10
Budget Justification – Narrative Details	2.3.11

5.1 Virtual Q&A

An online question form is available at https://esto.nasa.gov/AIST2016_VBC from release date thru December 20, 2016. Proposers may submit their questions regarding this solicitation at any point during that time period using the online form. Responses will be posted to that website and on the NSPIRES page for this program element under "other documents" by January 20, 2017. Please continue to check these websites periodically in case there are additional questions and answers posted.

5.2 Proposal Summary

The NSPIRES web page requires proposers fill in a text box with a proposal summary of no more than 4000 characters. The proposal summary includes: (a) objectives and benefits; (b) an outline of the proposed work and methodology; (c) the period of performance; and (d) entry and planned exit Technology Readiness Level (TRL).

5.3 Scientific/Technical/Management Section

This section is specific to this NRA and replaces Section 2.3.6 of the *Guidebook*. This section must include the following content information in subsections that use the same titles. Failure to provide any of this material may be cause for the proposal to be judged as noncompliant without further review. The Project Description is limited to 15 nonreduced, single-spaced typewritten pages. Standard proposal style formats shall be in accordance with Section 2.2 of the *Guidebook for Proposers*. Proposals that exceed the 15-page limit may be returned without review. The following subsections are required to be included and clearly identified in the Scientific/ Technical/Management section of the proposal.

To respond to the solicitation, proposers are required to identify exactly one core topic area to identify their proposal theme. If a proposer desires to address a special subtopic, then the

subtopic should be selected in addition to the core topic. Proposers are required to select one core topic and any subtopics on the NSPIRES cover page, or to explicitly name the topics in the abstract if the proposal is submitted through Grants.gov.

5.3.1 *Applicability to NASA Earth Science*

Describe the benefits to future Earth Science missions, research or applications that utilize the proposed technology including a relevancy scenario. In no more than one page, the offerors should provide a relevancy scenario (i.e., use case) that describes how the proposed technology will benefit NASA Earth Science and how the work links to the elements of the strategic planning documents mentioned above, and as appropriate, to the special topics in Section 2.2. The relevancy scenario is intended to sell the concept being offered and should provide clear examples of how the technology would be infused or integrated (i.e., if the technology is targeted at a flight program the applicable NASA mission or measurement should be identified). Involvement of Earth Science researchers who are familiar with NASA's Earth Science programs is highly encouraged. Projects are required to identify a target recipient community and understand their needs in order to produce impactful technology development; a representative of that community should be on the proposed team to ensure design and development decisions are made to support community acceptance. Proposals that fail to include a relevancy scenario may be rated significantly lower.

5.3.2 *Description of Proposed Technology*

Provide a description of the proposed element, system, or subsystem technology. Describe the technical approach and include an operational concept of the proposed technology that addresses Earth science needs. Explain and justify how the proposed technology enables science. Discuss any possible cross-cutting or commercial benefits. Include the use of any Open Source or commercial tools use and Open Source licensing for any software to be delivered. Each proposal shall:

a. Identify any proprietary software, software owned by a non-Federal entity, or open source software that is incorporated into the software being proposed, and an open source plan;
b. Indicate whether a license has been obtained in situations where proprietary software, software owned by a non-Federal entity, or open source software has been incorporated into the software that is the subject of the proposal and attach a copy of the license to the proposal, along with evidence of permission obtained from the software owner to release improvements or derivative works to the software as Open Source under the Apache License, Version 2.0.

Proposals will be evaluated for compliance with the above open source software requirements. A proposal that does not include documentation sufficient to satisfy NASA that the developed software will be open source may not be selected.

5.3.3 *Comparative Technology Assessment*

Describe the anticipated advantages of this element, system, or subsystem technology compared to those currently in use, e.g., reduction of size, mass, power, volume or cost, improved performance, or enabling of a new capability not previously possible. Describe the current state of the art, identify other competing technologies or efforts and compare it to the proposed effort.

5.3.4 *TRL Assessment*

The TRL scale is used to assess the maturity of a particular technology. The AIST program accepts technology development at various stages of maturity and advances the TRL through appropriate risk reduction activities, such as requirements analysis, conceptual design, prototypes, and proof-of-concept demonstrations. Proposals are required to include an entry TRL estimate along with a brief justification, the planned exit TRL, and success criteria. Provide the current TRL assessment of the technology and the anticipated progression of TRL levels throughout the proposed effort based on the NASA software or hardware TRL definitions. Note that ESTO desires the TRL to advance by at least one during the two years of performance of the activity. For this solicitation, the entry TRL should be from 2 through 4. Past and ongoing work on the research activity should help to determine the entry TRL. TRL definitions and information can be accessed on the ESTO web page (https://esto.nasa.gov/technologists_trl.html). Technologies at a higher level may be considered as a lower priority for this solicitation.

5.3.5 *Research Management Plan*

The Proposer must provide a Statement of Work that concisely describes each task and milestone to be accomplished, the duration, and the responsible team member in the course of the research and development. Define the success criteria associated with each task or milestone. Also include a milestone schedule chart that identifies at least two critical milestones per twelve-month period.

Subcontracting portions of the research project is acceptable; overall management, reporting, and integration of the work to achieve the end state are the proposing organizations responsibility.

Proposals developing significant new datasets must include a data management plan.

5.3.6 *Personnel*

Provide a list of key personnel and identify experience related to the proposed activity. Proposers should include all relevant skills (i.e., science, technology development, and instrument development). The key personnel list is included in the overall page count and must include, at a minimum, the Principal Investigator (PI). Optionally, one-page resumes for Key Personnel may be supplied; these resumes are not included in the 15-page limit for the Project Description Section.

5.3.7 *Facilities and Equipment*

Describe significant facilities and equipment required to complete the work. Before requesting funding to purchase a major item of capital equipment, the proposer should determine if sharing or loan of equipment already available within the proposing organization is a feasible alternative.

For any of the topics, facilities needed for computation, testing, verification, or validation of components, subsystems, and/or systems can be included and priced as an integral part of a proposed technology effort, but should not be submitted as a stand-alone proposal. If any special purpose equipment is needed, the proposers should identify how such equipment would be acquired and how it would contribute to the overall effort.

5.3.8 *Quad Chart*

Provide a quad chart using the template and example at https://esto.nasa.gov/files/EntryQuad_instructions_template.ppt.
Note: This quad chart is not included in 15-page limit for the Project Description Section.=

6. Award Information

6.1 Funding

The Government's obligation to make award(s) is contingent upon both the availability of appropriated funds from which payment can be made and the receipt of proposals that NASA determines are acceptable for award under this program element. No additional funds beyond the negotiated award value will be available. NASA does not allow for payment of profit or fee to commercial firms under grant awards, and few fees are permitted (For example, see http://science.nasa.gov/researchers/sara/faqs/#16).

Proposers are encouraged to offer cost sharing. If a cost sharing arrangement is proposed, appropriate data rights that recognize the proposer's contributions, as well as the Government's rights to access, will be negotiated prior to award.

6.2 Period of Performance

The expected period of performance is 12-24 months. Proposals must define clear, measurable milestones to be achieved for each year of performance in order to warrant continuation.

6.3 Type of Award

All selected proposals will result in the award of grants, cooperative agreements, or intra- or inter-Government transfers, as appropriate. Grants and cooperative agreements will be subject to the provisions of the *Grants and Cooperative Agreement Manual* (GCAM) and Appendix D of the *NASA Guidebook for Proposers*. In the case of any conflict, the GCAM takes precedence. If a commercial organization wants to receive a grant or cooperative agreement, cost sharing is required, unless the commercial organization can demonstrate that it does not expect to receive substantial compensating benefits for performance of the work. If this demonstration is made, cost sharing is not required, but may be offered voluntarily (see references in Section III(d) of the *ROSES Summary of Solicitation*).

7. Evaluation Criteria

For this solicitation, the following important factors are included in the evaluation process (relevance, intrinsic merit, cost realism/reasonableness) and replace those given in the *Guidebook* Appendix C.2.

Relevance is defined as the applicability of the proposed investigation to Earth Science missions and technology needs and specifically includes the relevance to NASA's Earth Science scientific and technical areas of emphasis, as described in ROSES program element A.1. Endorsement by a representative from the target audience either participating in or advising the Project will be considered as part of relevance.

Intrinsic merit is defined as:

a) Feasibility and merit of the proposed technical approach to achieve the technology development objectives.
b) Degree of innovation of the proposed study or technology development concepts and approach.
c) Past performance and related experience in the proposed area of technology development.
d) Qualifications of key personnel, and adequacy of facilities, staff, and equipment to support the proposed activity as it contributed to cost realism.
e) Substantiated justification and appropriateness of the entry and exit TRL. For this solicitation, the entry TRL is constrained to be between 2 and 4 inclusive, with the exit TRL no higher than 7. Higher entry TRL technology can be proposed but will be considered as a lower priority.
f) Feasibility of obtaining the potential reduction in risk, cost, size, and development time with the proposed technology, and the feasibility of making a demonstrable TRL increase of at least one level during the performance period.
g) The potential for the technology development to reduce the risk, cost, size, and development time of Earth science systems. The mission or research area should be identified and potential cost reductions should be clearly stated and substantiated to the extent possible, with supporting analysis that indicates scalability. A Letter of Support endorsing the value from a mission or research area potential adopter must be included.
h) The potential of the technology to be integrated, once matured, into an Earth science mission, research activity, or a product for use by the Applied Sciences function. A Letter of Support from an appropriate representative of the science team and/or direct participation in the Project must be included.
i) The potential for the technology to have commercial benefits, and if applicable endorsed by a potential commercial adopter including an appropriate Letter of Support.

Cost realism and reasonableness is defined as:

a) Adequacy and realism of proposed milestones and associated success criteria.
b) Realism and reasonableness of the person time to successfully achieve the proposed task, proposed cost of procurements and (by NASA) comparison of costs to available program funds.
c) Adherence to sound and consistent management practices appropriate to the TRL level of the proposed task.
d) Commitment of the organization's management to the proposed technology development (evidenced by prior teaming arrangements, etc.). Proposers should identify any previous investment by the organization/program and provide supporting documentation.

8. Technical Reporting Requirements

Proposers should be aware that technology programs require more extensive reporting than many other ROSES elements and these costs should be taken into account in submitted proposals.

Once awarded, submit all status information, presentation material, and report deliverables applicable to this AIST program element to the web-based ESTO Reporting System (ERS). A user account on the ESTO ERS will be provided to the PI upon award. Due to NASA IT security requirements, all PIs must register with the Identity Management and Account Exchange

(IdMAX) system before a user account on ERS will be established. To create an IdMAX account, some personal information will be required.

The following deliverables are required of awarded proposals. In cases where subcontract arrangements exist, consolidated project reports are the responsibility of the PI. The proposed budget should provide for these reporting requirements. In this context, "Annual" refers to a twelve-month task effort that commences at award.

8.1 Initial Plans and Reports

Within 15 days of award, provide an updated Project Plan, initial Quad Chart, and initial TRL assessment. Also, provide a monthly cost plan for the entire period of performance. The project plan, initial (entry) Quad Chart, cost plan, and initial TRL assessment (and supporting data) should be created in the ESTO ERS.

The project plan shall identify plans for all technical, schedule, and resource activities for the proposed life of the project.

The initial quad chart shall follow the template and example at https://esto.nasa.gov/files/EntryQuad_instructions_template.ppt

Proposers are required to update the Quad Chart and TRL assessment at least annually and more often, if appropriate. This can be done on the ESTO ERS under the "Quad Chart" section and "TRL" section respectively.

8.2 Quarterly Technical Reports

The quarterly technical report shall focus on the preceding three months' efforts. Address the following in each report:

1. Technical status: Summarize accomplishments for the preceding three months, including technical accomplishments (trade study results, requirements analysis, design, etc.), technology development results, and results of tests and/or demonstrations.
2. Schedule status: Address the status of major tasks and the variance from planned versus actual schedule, including tasks completed, tasks in process, tasks expected to complete later than planned, and tasks that are delayed in starting, with rationale for each and recovery plans, as appropriate.

Upload the Quarterly Technical Reports to the appropriate location in the ESTO ERS at three-month intervals, starting on the third-month anniversary date of the start date specified in the award vehicle. In months for which the PI is providing interim or annual review, the requirement for a quarterly report is superseded by the interim or annual review requirements discussed in the next two sections.

Reports may be submitted in PDF, Microsoft Word, or Microsoft PowerPoint compatible file formats by the required due date, or by close of business of the first workday following the due date if the due date falls on a weekend or a holiday. A teleconference or brief meeting may be conducted between the ESTO and the PI to review and discuss each report.

8.3 Interim Reviews

An Interim Review occurs at the end of the first six-month calendar period commencing from the date of award and at twelve-month intervals thereafter. The PI must provide a presentation summarizing the work accomplished and results leading up to this Interim Review and must:

1. Describe the primary findings, technology development results, and technical status, e.g., status of design, construction of breadboards or prototype implementations, results of tests and/or proof-of-concept demonstrations, etc.;
2. Describe the work planned for the remainder of the project and critical issues that need to be resolved to successfully complete the remaining planned work;
3. Summarize the cost and schedule status of the project, including any schedule slippage/acceleration. Create and maintain a schedule milestone chart of all major task activities and show at all reviews. Also, create and maintain a cost data sheet that shows total project costs obligated and costed, along with a graphical representation of the project cost profile to completion;
4. Provide a summary of anticipated results at the end of the task; and
5. At the second review and subsequent reviews, address the comments and recommendations prepared by the reviewers participating in the most recent review.

The Interim Review will be conducted via teleconference and uploaded to the appropriate location in the ESTO ERS at least three (3) working days prior to the review. Following the review, the presentation, updated in accordance with comments and discussion resulting from the review, shall be uploaded to the appropriate location in the ESTO ERS within ten days after the review.

8.4 Annual Review

An Annual Review occurs at the end of the twelve-month calendar period commencing from the date of award. The Annual Review is similar to the Interim Reviews and include all of the products required at an Interim Review with the following exceptions:

1. The review is held at the PI's facility or a mutually agreed to location.
2. An independent technical reviewer from an organization separately funded by ESTO participates in the review.
3. The PI may provide a laboratory demonstration, if appropriate, to show technical results and status.
4. Report any educational and outreach components of the project, e.g., graduate degrees, educational activities; technology infusion or patents applied for or granted; journal or conference publications; presentations at professional conferences, seminars and symposia; demonstrations; media exposure; and, other activities that contributed to the overall success of the research project.
5. The Annual Review should be comprehensive, and should cover the progress over the previous twelve months.

Upload the review package to the appropriate location in the ESTO ERS at least three (3) working days prior to the review. The presentation, updated in accordance with comments and discussion resulting from the review shall be uploaded to the appropriate location in the ESTO ERS within ten days after the review.

8.5 Final Review and Final Report

The Final Review occurs at the completion of the activity. The Final Review is similar to the Annual Review and includes all of the products required at an Annual Review. In addition, the final review must provide conclusions of the work performed and make recommendations for follow-on activities that should be pursued, with estimates of the cost and schedule to advance the TRL to the next level.

Include the following in the written Final Report:

1. Background of the project, including the science rationale for conducting this technology development;
2. Results of all analyses, element, subsystem, or system designs, breadboards and/or prototyping implementations and designs;
3. Performance analysis results of tests and/or demonstrations; estimation of reduction(s) in size, mass, power, volume and/or cost; improved performance; description of newly enabled capability; and documentation of technology dependencies;
4. Tables, graphs, diagrams, curves, sketches, photographs, and drawings in sufficient detail to comprehensively explain the results achieved;
5. An updated TRL assessment, including a rough order of magnitude cost and a description and estimate of the duration of the follow-on activities necessary to advance the TRL to next level;
6. Updated Quad Chart; and
7. At the end of the period of performance, the PI shall create a final Accomplishments Chart which contains the following information (a template is available in the ERS):
    - Upper Left: "Objective"
    - Upper Right: A visual, graphic, or other pertinent information.
    - Middle: "Accomplishments."
    - Bottom: "Co-Is" (name and affiliation), "Entry TRL" and "Exit TRL."

The Final Report and updated Final Review presentation shall be uploaded to the appropriate locations in the ESTO ERS within thirty days of the final review. Also, update the Accomplishment Chart and TRL assessment on the ESTO ERS under the "Quad Chart" section and "TRL" section respectively.

8.6 Earth Science Technology and Other Relevant Forums

The awardee is encouraged to make the community aware of their work by participating in relevant technology forums and other conferences and meetings related to Earth Sciences (please note slots are limited for NASA civil servant and contractor personnel for such events). Offerors must include travel costs in their proposals. The awardee should be prepared to make a presentation, provide a paper, or create a poster providing a description of the project, the objectives, approach, technical status, and schedule information. Such events may include, but are not limited to, the NASA discipline Science Team Meetings, the AGU Annual Meeting, the AMS Annual Meeting, relevant IEEE and ACM conferences, and the semi-annual ESIP Federation meetings.

PIs or their representatives are also expected to participate in the ESTO Earth Science Technology Forum to advance information sharing of their work. Follow-on efforts are

envisioned to identify candidate Earth science scenarios that will benefit from information systems technology concepts, and approaches and that can be prototyped to demonstrate those benefits through collaboration and science participation.

9. Summary of Key Information

Expected program budget for first year of new awards	~ $12.5 million
Number of new awards pending adequate proposals of merit	~ 18-20
Maximum duration of awards	2 years
Virtual Q&ASite	https://esto.nasa.gov/AIST2016_VBC Open from release date through December 20, 2016
Due Date for Notice of Intent to Propose (NOI)	December 21, 2016
Due date for delivery of proposals	February 16, 2017
Planning date for start of investigation	5 months after proposal due date.
Page length for the central Science- Technical-Management section of proposal	15 pages; see also Chapter 2 of the *NASA Guidebook for Proposers* and Section 5.2.2 of this solicitation.
Relevance to NASA	This program is relevant to the Earth Science questions and goals in the NASA Science Plan. Proposals that are relevant to this program are, by definition, relevant to NASA.
General information and overview of this solicitation	See the *ROSES Summary of Solicitation*.
Detailed instructions for the preparation and submission of proposals	See the *NASA Guidebook for Proposers* at http://www.hq.nasa.gov/office/procurement/nraguidebook/.
Submission medium	Electronic proposal submission is required; no hard copy is required or permitted. See also Section IV of the *ROSES Summary of Solicitation* and Section 3 of the *NASA Guideline for Proposers.*
Web site for submission of proposal via NSPIRES	http://nspires.nasaprs.com/ (help desk available at nspires-help@nasaprs.com or (202) 479-9376)
Web site for submission of proposals via Grants.gov	http://grants.gov (help desk available at support@grants.gov or (800) 518-4726)
Funding opportunity number for downloading an application package from Grants.gov	NNH16ZDA001N-AIST

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[1] National Research Council, Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, http://www.nap.edu/catalog.php?record_id=11820, 2007.

[2] 2012 Midterm - National Research Council, Earth Science and Applications from Space: A Midterm Assessment of NASA's Implementation of the Decadal Survey, https://www.nap.edu/read/13405/chapter/1 .

[3] *A Safe Operating Space for Humanity*, Nature 461, 472-475 (24 September 2009).