A.58 ADVANCED INFORMATION SYSTEMS TECHNOLOGY

NOTICE: Amended November 30, 2023. This amendment releases final text that was previously "TBD." This element now uses a two Step proposal submission process that replaces a Notice of Intent (NOI) with a Step-1 proposal submitted by the proposing organization's Authorized Organization Representative. For more information see Section 4.1 of this program element. Step-1 proposals are due January 12, 2024, and Step-2 proposals are due April 4, 2024. Though no "Open Science and Data Management Plan" is requested for this program element, an Open-Source Software Plan is required, see Section 4.2.4. Step-2 proposals must include other non-standard components such as a Quad Chart and Research/Application readiness plan, see Section 4.2.3.

1. Scope of the Program

NASA's Advanced Information Systems Technology (AIST) Program identifies, develops, and supports adoption of software and information systems, as well as novel computer science technologies expected to be needed by the Earth Science Division in the 5-10-year timeframe, as described in ROSES-2023 A.1 Earth Science Research Overview.

Technology innovation, Earth observation missions, and the data from those missions serve as the foundation for growing scientific understanding of the Earth's systems, improve predictive capabilities, and deliver actionable science and applications to inform decisions. Within that end-to-end strategy, the AIST Program focuses on advanced technologies and innovative concepts with three main objectives:

O1. Enable new observation measurements and new observing systems design and operations through intelligent, timely, dynamic, and coordinated distributed sensing.

O2. Enable agile science analyses that fully utilize the many diverse observations using advanced analytic tools, visualizations, and computing environments, and that interact seamlessly with relevant observing systems to request additional observations and improve the final results.

O3. Enable the development of integrated Earth Science frameworks that represent the Earth with state-of-the-art models (Earth system models and others), timely and relevant observations, and analytic tools. This thrust will provide technology for enabling near- and long-term policy and science decisions by delivering actionable science and information.

AIST objectives aim at optimizing Earth Science mission return – Novel Observing Strategies (NOS) from an observation point of view and Analytic Collaborative Frameworks (ACF)/Earth System Digital Twins (ESDT) from an information analysis and utilization point of view. The assets and data accessed and utilized in these systems may come from NASA and non-NASA sources, as described in the National Academy of Sciences (NAS) 2017 Earth Science Decadal Survey.

AIST has been previously organized around three primary thrusts: NOS, ESDT, and ACF. These three thrusts are described below, and more information is available on the ESTO AIST website and in the AIST-23 Reference Documents.

This opportunity is mainly focused on the NOS and ESDT thrusts; novel ACF capabilities will only be considered if they provide new ways to seamlessly connect ACF and NOS systems or if they are required to develop ESDT systems.

Additionally, all proposed capabilities and systems must demonstrate significant innovation, especially in the areas of information systems Intelligence and Autonomy. Proposed technologies must have an Entry Technology Readiness Level (TRL) between 1 and 4. Projects at a higher TRL level or not including significant AIST-related innovation will not be considered relevant.

More information about autonomy is available in the report of the 2018 Workshop on Autonomy for Future NASA Science Missions.

Relevance to this opportunity is detailed in the Decision Chart posted under other documents on the NSPIRES page for this program element.

1.1 NOS Technologies

NOS Technologies, which respond to Objective O1, concentrate on optimizing measurement acquisitions by using diverse observing and modeling capabilities, that represent various resolutions, that are dynamically coordinated and collaborate to provide complete representations of Earth Science phenomena. The observing assets can be in space, in the air, or *in situ*, and the observed phenomena may exist on a variety of spatial or temporal scales (e.g., real-time tracking of hazards and disasters or long-term asset coordination for continuous ecosystem monitoring). Depending on the application, NOS can be described as a federated Observing System, a generalized SensorWeb, or more generally as an "Internet-of-EarthThings (IoET)" concept in which each node can be a sensor, a group of sensors, a constellation of satellites (e.g., Earth System Observatory concept), a model or integrated models, or even database(s) or any other source of relevant information, that have varying degrees of coordination to achieve a common science objective. The two main NOS goals are:

(1) Measurement-driven, i.e., design and develop future observation concepts at the request of a new measurement, for example as identified in the latest Decadal Survey or as the result of a model or other science data analysis (e.g., to reduce data volume, or for cross-calibration); and/or
(2) Event-driven, i.e., dynamically respond to science and applied science events of interest, not only focusing on sudden- or slow-onset events, but also considering the risks of these events at various scales and area coverages (e.g., distressed vegetation and drought leading to food insecurity, potential landslides due to runoff with marine consequences, etc.).

Some of these ideas are detailed in the Summary Report from the New Observing Strategies (NOS) 2020 Workshop.

To validate and demonstrate NOS technologies and concepts, the AIST Program has funded the development of an NOS-Testbed (NOS-T) framework that allows users to perform meaningful comparisons and trade-offs and to retire the risk of infusing these

technologies by raising their Technology Readiness Level (TRL). More information on NOS-T can be found in the NOS-Testbed Architecture Framework documentation. This testbed will be made available to proposers, as described in Section 3.6.

1.2 Earth System Digital Twins

Earth Systems Digital Twins (ESDTs) represent an emerging capability for understanding, forecasting, and conjecturing the complex interconnections among Earth systems, including anthropomorphic forcings and impacts to humanity.

An Earth System Digital Twin or ESDT is a dynamic and interactive information system that first provides a digital replica of the past and current states of the Earth or Earth system as accurately and timely as possible; second, allows for computing *forecasts* of future states under nominal assumptions and based on the current replica; and third, offers the capability to investigate many hypothetical scenarios under varying impact assumptions. In other words, an ESDT provides the integrated What-Now, What-Next, and What-If pictures of the Earth or Earth systems.

An ESDT dynamically integrates: relevant interconnected models; Earth system models and simulations as well as other relevant models (e.g., anthropomorphic, socio-economic and related to the world's infrastructure); continuous and timely (including near real time and direct readout) observations (e.g., space, air, ground, over/underwater, Internet of Things (IoT), socioeconomic); long-time records; as well as analytics and artificial intelligence tools and using advanced computing and visualization capabilities. Effective ESDTs will scale up the actionable information that is delivered and will enable users to run hypothetical scenarios to improve the understanding, prediction of and mitigation/response to Earth system processes, natural phenomena and human activities as well as their many interactions.

As a complex integrated information system, an ESDT enables continuous assessment of impacts between naturally occurring and/or human activities. ESDT technologies requested in AIST respond to Objective O3. They also respond to NASA Earth Science strategy using NASA’s end-to-end capability as a space and science agency to quicken the pace of scientific discovery, broaden the impact of Earth science to benefit humanity, and better enable decision makers to use that science to address pressing challenges posed by our changing planet – and help more people visualize and understand the Earth. ESDTs will advance and integrate Earth science knowledge to empower humanity to create a more resilient world and will deliver trusted information to drive Earth resilience activities.

The AIST ESDT thrust will develop capabilities toward the development of future digital twins of the Earth or of subcomponents of the Earth, as well as working prototypes that will address one of the use cases described in the ESDT Workshop Report and on the AIST ESDT webpage. These prototypes will also be developed with an architecture following the framework described in AIST’s Earth System Digital Twin Architecture Framework document.

1.3 ACF Technologies

Although the development of ACF systems is not in the scope of this solicitation, this section gives a brief background on ACF technologies and how they could be used to

develop more efficient NOS and ESDT systems.

ACF technologies respond to AIST Objective O2 and address the challenges associated with observing systems such as NOS systems which will acquire an increased variety and volume of data over various geographical scales, latencies, and frequencies. The ACF thrust is designed to facilitate access, integration, and understanding of large amounts of disparate datasets. Its purpose is to harmonize analytics tools, data, visualization and computing environments to meet the needs of Earth science investigations and applications. The ACF thrust integrates new or previously unlinked datasets, tools, models, and a variety of computing resources together into a common platform to address previously intractable scientific and science-informed application questions.

In the context of this solicitation and of the development of NOS and ESDT systems, the interest in ACF technologies is two-fold:

- ACF systems will autonomously determine which additional observations would be needed to improve a model or a science analysis and will query NOS systems for new observations from direct broadcast or from agile observing systems.
- ACF will provide capabilities that can be used to build digital replicas. Then, working in concert with NOS, ACF will originate the requests to continuously update those digital replicas in a real-, near-real-time, or timely fashion. ACF and NOS both represent some of the most important building blocks needed to build future ESDT systems.

From an AIST point of view, ESDT capabilities will integrate Earth observations analysis and understanding capabilities provided by ACF-type systems and on-demand and timely IoT and IoET data using NOS capabilities, while taking advantage of advanced Machine Learning (ML), Big Data Analytics, impact assessment, and uncertainty quantification methods, all using powerful computational and visualization capabilities.

2. Research Topics Solicited

This program element is part of Appendix A; therefore, if not addressed in this program element, the default rules in ROSES-2023 A.1 Earth Science Research Overview apply to Step-2 proposals. Similarly, as Appendix A is part of ROSES, if not addressed in this program element or in A.1, the default rules in the *ROSES-2023 Summary of Solicitation* apply. Finally, if not addressed in the documents above, default Agency rules in the 2023 *NASA Proposer's Guide (formerly the Guidebook for Proposers)* apply.

This element solicits proposals that fall into one (and only one) of three distinct sub-element topic areas:

1) Early-Stage Technology (EST), or
2) Advanced and Emerging Technology (AET), or
3) Demonstrations and Prototypes (D&P).

2.1 Early-Stage Technology

The Early-Stage Technology (EST) sub-element topic area seeks proposals for 12- to 18-month projects to develop and mature cutting-edge tools and models that have an entry TRL between 1 and 3, and that are relevant to future Earth Science missions and

programs, including but not limited to NOS and ESDT. The value of each award will be approximately $300-400K per year.

Technologies of highest interest for this sub-element include:

- "Beyond Deep Learning" advanced AI and autonomy methods for Intelligent Systems
- Emerging state-of-the-art AI and ML concepts including but not limited to:
  - Novel Earth science applications of Visual Transformers and Foundation Models, including computational performance and accuracy assessments and comparison to traditional methods and other ML methods
  - Physics-based and physics-inspired AI, Probabilistic Programming, Composite AI, Hyperdimensional Computing, Liquid Neural Networks, and others, especially addressing issues related to generalization, explainability, extensibility, validation, and reproducibility of the results
  - Causal AI, especially as it relates to decision-making and ESDTs
- General methods for validation, assessment, explainability and understanding of AI and ML systems
- General methods for creating Analysis Ready Data (ARD)
- Ontologies and capabilities to develop a common model or object schema for describing space and non-space sensors to create an "Internet-of-Earth-Things"
- Quantum computing and quantum-inspired algorithms that would enable and improve any aspect of Earth system science
- Algorithm performance optimization (onboard or on the ground) by using a combination of at least two or more state-of-the-art computing capabilities, including but not limited to quantum, GPU, brain-inspired neuromorphic, FPGA, etc., especially when applied to mission concepts including sensors with very-high dimensionality such as hyperspectral and SAR
- Note: ML tools already widely available are not of interest in this sub-element and using ML over traditional methodologies must be justified.

2.2 Advanced and Emerging Technology

The Advanced and Emerging Technology (AET) sub-element topic area seeks 2-year proposals to develop technologies and tools for use in NOS and ESDT systems (as previously defined) with an entry TRL of 3 or 4 (higher TRLs will not be considered for this sub-element). The value of each award will be approximately $500-700K per year.

Such projects must include at least one or two Earth Science use cases and significant transdisciplinary expertise from all relevant domains, Earth Science, and Computer/Computational/Data Science.

- Example high-level NOS use cases are provided in the NOS Workshop Report. All NOS proposed technologies must be compatible with the NOS-Testbed Architecture Framework and interoperable with the corresponding software available at https://github.com/code-lab-org/nost.
- Example ESDT use cases are provided in Section 5.1 of the ESDT Workshop Report and in the ESDT Science Use Cases webpage. All ESDT proposed technologies must represent modular components compatible with the

architecture framework described in the ESDT Architecture Framework Document.

Technologies needed to support the following phases of strategic observing, analysis, and prediction development include but are not limited to:

2.2.1 *NOS systems capabilities*

- Semantic representations, ontologies, and AI- and knowledge-based agents used to represent an NOS/IoET system and its various nodes, including node discovery, node communications and situational awareness
- NOS technologies for onboard high-level autonomous decision making, including deliberative/deduction AI (e.g., heuristic search, probabilistic reasoning) and Hybrid AI (reflexive plus deliberative)
- Edge Intelligence: Pushing both data and intelligence to analytic platforms either on, or close to, where the data originated, enabling faster data-driven decision making and reducing latency and reliance on traditional platforms to analyze NOS data
- NOS technologies focusing on the design of new observing system concepts or on the timely observation of specifically mid- and long-term science events ("timely" being commensurate with the type of events being observed). Of particular interest are:
  - Development of novel trades addressing heterogeneous sensing capabilities
  - Metrics to evaluate/compare alternative observing strategies
  - Concepts applicable to NASA Earth System Observatory (ESO), particularly for focus areas at a level of maturity appropriate to potentially facilitate infusion, e.g., Planetary Boundary Layer (PBL), Surface Topography and Vegetation (STV)
  - Other NOS capabilities as described in the NOS Workshop Report. Of particular interest are NOS capabilities and concepts integrating the use of hyperspectral and/or NISAR data.
- Capabilities needed to evolve toward Earth System Digital Twins, including “ACF-to-NOS capabilities” to continuously ingest data (including physical, biogeochemical, and socio-economic) into an ESDT framework in response to analytic tools and science models results.

2.2.2 *ESDT systems capabilities*

- Integration of Uncertainty Quantification in all components of an ESDT
- ACF-like capabilities for ESDT that will form the foundational capabilities to build digital replicas:
  - Multi-discipline analytic concepts, e.g., enabling analysis of cascading impacts such as rainfall-triggered landslides or air quality impacts due to fires, elevation-dependent warming, biodiversity conservation solutions at landscape-to-regional scales
  - Analytic concepts enabling the interconnection of Earth science models with anthropomorphic and human models and systems. For example, studying how climate change is changing the impacts of disasters

    - Technologies necessary to move from custom-built ACF systems to true reusable ESDT framework components
    - Analytic and workflow management tools capable of characterizing natural phenomena or physical processes from extremely large amounts of diverse data and information, including non-traditional and unstructured data (e.g., IoT, socioeconomic, social media, health data)
- Digital Thread, provenance and/or trustworthiness concept developments to link all digital twin capabilities, to track system requirements and performance, records, provenance, and system reorientations, and to address any questions related to the behavior or the results of the digital twin system
- Concepts and technologies for developing "federated ESDTs" in which multiple individual ESDTs interact and can be integrated as the layers of broader ESDTs
- Intelligent system techniques enabling ESDTs to quickly request, integrate, and fuse diverse and timely Earth observations
- Investigative technologies to facilitate "what-if" investigations inherent to ESDT systems, including but not limited to:
    - Multi-scale simulations, statistics, uncertainty quantification, and causality methodologies (including causal AI)
    - Seamless integration of cloud- and high-end computing into what-if investigations to enable running large permutations of what-if scenarios using large amounts of data and high-resolution and high-fidelity models
    - Statistical methodologies (including surrogate models) that optimize the computational efficiency of "what-if" investigations
- Innovative, interactive, and user-friendly interfaces and visualization methods, including but not limited to Augmented Reality (AR) and Mixed Reality (MR) techniques, and capable of visualizing all three aspects of an ESDT, What-Now/What-Next/What-If
- Concepts applicable to NASA's Climate Action which is described in "*Advancing NASA's Climate Strategy (2023)*" and that represent a multiplier to generate greater scientific discovery, to engage more users of NASA data and research, and to deliver more applied Earth science
- Note that all ESDT technologies developed in this sub-element must be architecturally agnostic as described in the ESDT Architecture Framework Document.

2.3 Demonstrations and Prototypes

New with AIST-23, AIST seeks proposals for a very few larger 3-year awards in the Demonstrations and Prototypes (D&P) sub-element topic area culminating with either an NOS demonstration or an ESDT prototype. These systems of systems projects will have an overall entry TRL of 3 or 4, although some of their sub-systems could be at a higher TRL. The value of each award in this sub-element will be in the range of $1,200-1,400K per year per project, with no more than 4 or 5 projects funded. For D&P projects, annual demonstrations will be expected, and the composition of the awarded teams will need to show a well-balanced representation from at least 2 NASA Centers (including JPL), as well as from both academia and industry. The team composition requirement of D&P projects is driven by the need for all interoperability standards and

protocols of the proposed NOS and ESDT systems to be accepted and eventually adopted by the Earth community at-large.

NOS simulation demonstrations must:

- Describe one use case responding to either:
  - One of the general science use cases listed in Section 3 of the NOS Workshop Report, or
  - One of the upcoming ESO missions, e.g., Planetary Boundary Layer (PBL) or Surface Topography and Vegetation (STV), or
  - A Surface Biology and Geology (SBG) NOS concept including commercial assets and other government satellites, or
  - Integration of several ESO missions creating a "virtual mission", or
  - A combination of one or several ESO missions with targeted observations from a commercial remote sensing provider.
- Follow the standards defined by the NOS-Testbed Architecture Framework and integrate any new code with the open-source software provided at https://github.com/code-lab-org/nost. As described in Section 3.6, support for using the NOS-Testbed will be provided by AIST.
- Have a minimum of three independent nodes
- Be implemented in a modular, generalizable, evolvable and truly open-source fashion
- Demonstrate the entire operational concept, fully autonomous, and end-to-end in the NOS-T framework.

ESDT prototypes must:

- Select and address one of the 5 science use cases described in Section 5.1 of the ESDT Workshop Report and on the ESDT Science Use Cases webpage. These are: Wildfires; Ocean Carbon; Water Cycle; Central Africa Carbon and Biodiversity Corridors; Atmospheric Boundary Layer. Note: A Land-ESDT is not requested here; this topic will be addressed in a separate solicitation in ROSES-24
- Be coordinated with the relevant R&A Programs (see Section 3.3. below)
- Address the goals and the focus areas of the "Advancing NASA's Climate Strategy (2023)" (see also https://science.nasa.gov/earth/in-action/ and section 3.2 below)
- Address the key features and capabilities described in Section 3 of the ESDT Architecture Framework document
- Follow the framework described in Section 4 of the ESDT Architecture Framework document
- Provide a modular, generalizable, evolvable, and truly open-source architecture
- Address various spatial and temporal resolutions and at least 3 interconnected Earth systems and other models
- Include a dynamic, user-friendly, and interactive interface, responsive to the needs of multiple users, "from farmers to decision makers to scientists"
- Clearly define all standards and interfaces utilized in this prototype (for potential candidate standards, proposers can refer to the recent ESDT Standards for

Interoperable Digital Twins Workshop and in machine-readable common data and metadata formats such as the Earthdata Common Metadata Repository (CMR)), as needed

- Aim to achieve a system that:
  - Responds to user queries in real- or near-real-time, or in a timely fashion w/r to the Earth system being considered, as appropriate
  - Is as autonomous as possible, with a minimum of human intervention (i.e., does not include any "sneakernet" component)
- Include and demonstrate the three components of an ESDT: What-Now/What-Next/What-If.

3. Special Matters Related to Proposals

3.1 Diversity and Inclusion

NASA recognizes and supports the benefits of having diverse and inclusive scientific, engineering, and technology communities and fully expects the reflection of such values in the composition of all panels and teams, including peer review panels, proposal teams, science definition teams, and mission and instrument teams. NASA welcomes proposals from all qualified and eligible sources, and strongly encourages proposals from Historically Black Colleges and Universities (HBCUs) and other Minority Serving Institutions (MSIs), small-disadvantaged businesses, veteran-owned small businesses, service-disabled veteran-owned small businesses, HUBZone small businesses, and women-owned small businesses, as eligibility requirements apply.

To broaden the base of investigators involved in SMD-supported science and engineering, SMD especially seeks proposals from investigators who and institutions that have rarely if ever received funding from SMD. A resource that some proposers may find useful is the NASA MSI Exchange at https://msiexchange.nasa.gov/.

3.2 Climate Action and NASA Earth Science Applicability

One of the main objectives of the AIST Program is to provide technology advancements that will be essential in achieving several of the key priorities described in "*NASA – Advancing NASA's Climate Strategy*". Successful proposals will show strong relevance to at least one of these priorities. Of particular interest are:

- "1.1. Advance climate and Earth science through novel observations, including the Earth System Observatory, associated research and modeling, and the creation of societally useful applications"
- "1.2. Advance the development and use of aeronautics and space technologies that enable us to understand, mitigate, and adapt to climate change"
- "2.1. Increase discoverability, accessibility, and usability of climate and Earth science information"
- "2.2. Support communities and stakeholders in preparing for and responding to climate change by enhancing information, tools, applications, and resources that draw on NASA observations, models, and people to improve societal resilience"
- "2.3. Address climate change impacts in underserved and vulnerable communities by promoting equity in the collection and use of climate and Earth science information"

- "3.1. Help humanity understand and prepare for climate change by improving stakeholder and public awareness of and access to NASA climate discoveries, information, and technology."

Overall, successful AET and D&P proposals will demonstrate how their proposed technologies could accelerate scientific discovery and the use of Earth science by leveraging an end-to-end capability for the benefit of humanity – informing decisions ranging from a farmer assessing a single field, to global leaders weighing decisions impacting the entire world.

3.3 Technology Infusion

Funded investigations must demonstrate technology development that has potential to eventually be transitioned to or infused into a NASA Earth Science domain, either the Science Research and Analysis element's Thematic Focus Areas, the Climate Action strategy, or the Earth Science Data Systems Program, as described in the ROSES A.1 Earth Science Research Overview. Successful proposals will address technologies that are useful to at least one science or application community and have a realistic potential for acceptance by the community in the future. The degree to which that potential is clear is directly related to the exit Technology Readiness Level (TRL) of the project. Successful investigations must demonstrate a TRL increase of at least one level during the performance period of EST and AET projects, and of at least 2 levels during the performance period of D&P projects, Achievement of full infusion and broad community acceptance are not required during the proposal period of performance. The proposal must identify both the technology being developed and a collaborator or Co-Investigator from the domain into which the technology might be eventually infused. Optionally, letters of affirmation provide strong evidence of claims of potential for infusion or transition into external communities.

3.4 Agency Computing Resources

NASA's major computing environments available for use are summarized in Table A.58-1, below. Additionally, for quantum computing projects, proposers are encouraged to utilize various systems, such as D-Wave quantum annealers as well as other quantum model processors available through other government agencies, industry, and university partners. Funding for these computing resources (if needed) must be included in the proposal budget.

Table A.58-1: NASA Computing Environments

Resource	Additional Technical Information	Cost to Proposers
High End Computing	https://hec.nasa.gov/request/request.html See Section I(e) of the ROSES-23 Summary of Solicitation	No cost to selected Principal Investigators
Science Managed Cloud Environment	https://smce.nasa.gov/	Funded by awarded project. Include cost in proposal budget

3.5 Independent Testing

The AIST Program uses the Earth Science Information Partners (ESIP) to perform independent assessments of TRL and adoptability of AIST projects. This practice has

the additional benefit of improving the chances for adoption of projects or infusion of technologies by giving additional target audiences opportunities to evaluate the product and to influence final enhancements that might make the product more usable. Awarded AIST projects may participate in this assessment by coordinating with the AIST Program Manager during the final year of project development.

3.6 Integration with Existing Frameworks

The AIST Program encourages technology development that can be deployed into frameworks either commonly used by the NASA Earth science community; other government agencies, and commercial and educational organizations; or in frameworks previously developed under NASA- or AIST-funding. This includes consideration of the existing capabilities offered by the Earth Science Data Systems program, including the Common Metadata Repository (CMR) catalog, analytics tools developed by NASA Distributed Active Archive Centers (DAACs), and access to NASA Earth Science datasets. For previous AIST-funded projects, refer to the ESTO Technology Portfolio and to the AIST Overview and Recent Projects Document.

Another example is the use of commercial or open-source frameworks, e.g., Geographic Information Systems (GIS) and Model-Based Systems Engineering (MBSE) tools for research and applied science, which have been shown to enhance assembly, manipulation, simulation, and analysis of large data sets from a variety of sources. Investigations involving substantial development of visualization or analysis frameworks duplicating existing capabilities are discouraged.

Other examples are tools and capabilities provided through NASA ESDS Space Act Agreements with industry (e.g., NVIDIA, IBM, MS, AWS, Google, and Esri).

Additionally, support for using the NOS-Testbed for the development of NOS-T technologies or NOS-T demonstrations will be provided by the AIST Program, but request for this support will need to be specified in both Step-1 and Step-2 proposals with the proposer selecting either “Level-1 support” (for AET proposals) or “Level-2 support” (for D&P proposals): see the NOS-T Support Selection for more information. Proposers are encouraged to indicate their interest in any of those resources as part of their proposals.

3.7 ESTO Reporting Requirements

Several ESTO-specific reporting requirements must be incorporated in the work plan of AIST proposals, including semi-annual, annual, and final review presentations, as well as the ESTO Quad Chart. These reviews are required in addition to the Agency reports for grants and are detailed on the ESTO reporting requirements website. Proposals must demonstrate an understanding of these reporting requirements and these requirements must be included in the work plan of the AIST proposal.

4. Proposal Format, Content, and Submission

Proposers unfamiliar with ROSES should be aware that they may keep current with amendments to ROSES by, for example, subscribing to appropriate NSPIRES mailing lists (by logging in and checking the appropriate boxes under "Account Management"

and "Email Subscriptions"), using the Google calendars, or referring to the ROSES-23 blog.

4.1 Two-Step Proposal Submission Process

To facilitate the early recruitment of a conflict-free review panel, this program element will use a two-step proposal submission process (see Section IV(b)vii of the *ROSES Summary of Solicitation*). A Step-1 proposal is required and must be submitted electronically by an Authorized Organization Representative (AOR) prior to the Step-1 deadline. No budget, nor any attachments, are requested for the Step-1 proposal. Only proposers who submit a Step-1 proposal are eligible to submit a full Step-2 proposal. Step-2 proposals must address the same broad scientific goals as in the Step-1 proposal. The PI cannot be changed from Step-1 to Step-2. Addition of new funded investigators between the Step-1 and Step-2 proposals requires the PI to inform the point(s) of contact identified in the summary table of key information and cc: sara@nasa.gov at least two weeks in advance of the Step-2 due date. Additions of funded investigators within two weeks of the Step-2 deadline require explicit permission from the NASA point of contact. Submission of a Step-1 proposal does not obligate the proposer to submit a Step-2 (full) proposal.

The Scientific/Technical/Management (S/T/M) section of a Step-1 proposal is submitted through several fields of the NSPIRES web interface cover pages, for a total of 16,000 characters divided over four 4,000-character text boxes, see below. PDF attachments will not be accepted through NSPIRES for Step-1 proposals to this program element.

4.1.1 *Step-1 Proposals*

Please refer to the "Step-1 Proposal Instructions document" under other documents on the NSPIRES page for this program element for basics on Step-1 proposals. The Step-1 proposals for this program element have four separate required sections and must cover the following topics, below. The first part, the Project Summary, must be entered in the Proposal Summary section of the cover page. The remaining three parts must be entered in response to the corresponding questions in the "Program Specific Data" section of the NSPIRES cover page.

- Project Summary (called ‘Proposal Summary’ in NSPIRES; 4000 characters), i.e., an extended abstract of the proposed work and its targeted outcomes
- Background and Justification (4000 characters): The proposers will describe the proposed work's background and current state-of-the-art. They will briefly describe science needs and associated technology development intention, in particular, why this project is important and why it is important now. This section will describe what the proposed investigation will enable or improve, and the manner in which it would advance current developments and capabilities. In particular, it will identify the reasons why the proposed work is responsive and relevant to the scope of the program element, and why this program element is the most appropriate for the work proposed.
- Task Description *(*4000 characters*)*: This section will describe the goals and objectives of the project, including its end goal and proposed output or product. It will give a general overview of the approach and methodology that will be used to address those goals and objectives; and identify and describe the main AIST

Technology innovation(s) or forward-reaching concept(s) or idea(s) that will be developed as part of this project, and how it/they are planned to be integrated in the Work Plan.
    - If the work is proposed as an EST: Describe how this effort will be "game-changing" (i.e., with an entry TRL smaller than 3)
    - If the work is proposed as an AET: Describe how this effort will improve on the state-of-the-art (i.e., with an entry TRL of 3 or 4)
    - If the work is proposed as a D&P: Describe how this effort will produce an operational demonstration or prototype concept for NOS or ESDT
- Proposed Team and Effort *(*4000 characters*)*: In general terms, describe the composition of the team, their responsibilities, and their level of effort for the proposed work.

Following the submission of a Step-1 proposal, most proposers will be notified through NSPIRES that the Step-1 proposal has been designated as "encouraged" or "discouraged," at which point the proposer will be able to create a Step-2 proposal. The proposer can expect a response back on Step-1 within 3 weeks of the Step-1 proposal due date. No evaluation of intrinsic merit will be performed on Step-1 proposals. The perceived relevance of the proposed work will be the main factor in deciding whether submission of a Step-2 proposal will be encouraged. Please note that the Step-2 proposal evaluation is independent of the Step-1 designation i.e., reviewers of a Step-2 proposal do not know whether a proposal was discouraged at Step-1.

In rare cases, for example, when the Step-1 proposal is not compliant with the requirements outlined above or the proposed work cannot be funded because of NASA, SMD, or Division policy, a Step-1 proposal may be declined by the selection official. In such a case, a Step-2 proposal cannot be submitted.

4.2 Step-2 Proposal Content

The Step-2 proposal comprises the elements given in Table A.58-2 of this program element, including some components particular to this opportunity such as the quad chart and Research/Application readiness plan. Other than that, or any other additional rules specified in this document, proposals are subject to the normal default rules and requirements for proposals described, e.g., in A.1 the Earth Science Research Overview, ROSES, or the Guidebook. Any questions about order of precedence of rules should be directed to SARA@nasa.gov and HQ-AIST@mail.nasa.gov.

The Science/Technical/Management (S/T/M) section of Step-2 proposals is limited to 15 nonreduced, single-spaced, typewritten pages and subject to the formatting rules in Section IV(b)ii of the *ROSES-2023 Summary of Solicitation*. Proposals that exceed the 15-page limit or violate the formatting rules may be returned without review or declined following review.

Table A.58-2 identifies the required proposal components of Step-2 proposals in the order in which they are to appear. Proposals that do not adhere to specified content and formatting requirements may be declined without review.

Table A.58-2: Step-2 Required Proposal Components in Order

Required Parts of a Step-2 Proposal	Reference
NSPIRES Proposal Cover Page • Proposal Summary (4000-character limit) • Select EST, AET or D&P • For AET: select NOS or ESDT • For D&P: select NOS Demonstration or ESDT Prototype • Domain(s) of science application • NSPIRES cover page budget • Proposal team members • Other required elements, see *Table 1 of ROSES-2023*	See NSPIRES Online Help, the *2023 NASA Proposer's Guide* and Sections 1 and 2 of this program element.
Table of Contents	See Section 2.12 of the *2023 NASA Proposer's Guide*
Scientific / Technical / Management Section • Goals and expected significance of proposed work • Perceived impact, applicability/relevance to NASA Earth Science (including Relevancy Scenario) • Technical approach and methodology of proposed technology • Comparative technology assessment • TRL assessment • Research implementation/management plan	Limited to 15 pages See ROSES-2023 for details and Section 4.2 of this program element for additional guidance (especially related to comparative technology assessment)
References and Citations	No page limit, see the ROSES-2023 *Summary of Solicitation*
Quad Chart	See above, Section 4.2 of this program element, and ESTO reporting requirements website
Research/Application readiness plan (as appropriate)	See above, Section 4.2.3 of this program element
Open-Source Software Plan	See above, Section 4.2.4 of this program element
Biographical Sketch(es)	See Table 1 of *ROSES-2023*
Table of Personnel and Work Effort	See Table 1 of *ROSES-2023*
Current and Pending Support	See Table 1 of *ROSES-2023*
Letter(s) of affirmation from target community, if any	See Section 3.3 of this program element

Budget: Narrative and Details (redacted)	See Section IV(b)iii of the *ROSES-2023 Summary of Solicitation*.

4.2.1 *Science/Technical/Management Section*

Below are a few clarifications related to the Science/Technical/Management (S/T/M) section:

- Applicability to Earth Science and Relevancy Scenario: The benefits to future Earth Science missions, measurements, research, or applications that will utilize the proposed technology need to be clearly stated. How would this project contribute to future missions or scientific investigations? This section must include a one-page relevancy scenario that describes how the proposed technology could be transitioned or infused (e.g., with a science use case and, if possible, identifying a specific flight program, mission, measurement, application, or scientific investigation). Collaborators or Co-Is who are Earth Science researchers or application developers familiar with NASA's Earth Science programs and/or representatives of the target recipient community are highly encouraged.
- In addition to the items specified in *Table 1 of ROSES-2023*, the S/T/M section must provide appropriate details on the following:
  - What is the technology innovation being proposed? Provide a detailed description of the proposed work, its goals and objectives, the proposed approach, the main AIST innovation(s), how it would be applied to the relevancy scenario, and how the proposed technology is game-changing for EST proposals and beyond state-of-the-art for AET and D&P proposals.
  - Comparative technology assessment: Describe the anticipated advantages of the proposed technology compared to those currently in use or enabling of a new capability not previously possible. Describe the current state-of-the-art, identify other competing technologies or previous and current efforts, and compare them to the proposed effort.
  - The S/T/M section must also include a table listing TRL Entry and anticipated Exit TRL for the entire technology, as well as for all subsystems or components to be developed, with a brief, relevant justification for each.
  - The Work Plan shall include clear, measurable, milestones throughout the project, including ESTO reporting requirements, as well as specific agency computing resources required to develop and test the proposed technology.
  - For work that is a continuation, extension, or follow on to work previously funded by NASA Earth Science (what is called "Successor" or "renewal" Proposals in Section 2.5 of the 2023 proposer's guide) the proposal must explicitly say that it is such a proposal and must explicitly address the extent to which the proposer was successful in the previously proposed work and, if not, why not.

4.2.2 *Quad Chart*

Immediately following the references and citations for the S/T/M section, the proposal shall contain a one-page ESTO Quad Chart (not included in the 15-page limit). A template and example of the quad chart can be downloaded from

http://esto.nasa.gov/files/EntryQuad_instructions_template.ppt. The Quad Chart is described in the reporting guidance in 3.7 above and on the ESTO reporting requirements website. It should contain no more than four key milestones.

4.2.3 *Research/Application Readiness Plan*

If applicable, immediately following the Quad Chart, the target mission or research/application transition area must be identified and potential cost reductions and/or science return improvements must be clearly stated and substantiated to the extent possible, with supporting analysis that indicates scalability. Letter(s) of affirmation from a mission or research/application area potential stakeholder/adopter/infusion program describing the envisioned impact represent strong support for this claim. This readiness plan will address how this transition will be approached after the AIST project has ended. This Research/Application Readiness Plan may be up to one page (not included in the 15-page limit).

4.2.4 *Open-Source Software Plan*

Since AIST Projects do not produce significant data products, an Open Science and Data Management Plan (DMP) is not generally necessary. However, an Open-Source Software Plan is required as part of the proposal. The software developed under this program element must be designated, developed, and distributed to the public as Open-Source Software (OSS). Software developed may be created to operate in conjunction with commercial or other restricted-use software (such as MATLAB, Envi, or arc-GIS) and environments, but must be licensed separately. The proposal must include a plan for open-source contribution of the software and, if applicable, a reuse license. In particular, among the many different types of open-source licenses that can be used, the proposer will describe which license will be utilized, if any; the proposer will also describe how the software will be made available, at which location, in its totality or partially. Examples of open-source solutions are described in the Resources section of on the NASA Software Catalog website (others examples include the GitHub and the IEEE websites, among others).

This Open-Source Software Plan may be up to a half-page (not included in the 15-page limit).

4.2.5 *Table of Personnel and Work Effort*

The proposal must also include the team's level of effort, see the example Summary Table of Personnel and Work Effort in Section IV(b)iii of *the ROSES-23 Summary of Solicitation*.

4.3 Questions and Answers

Proposers are strongly encouraged to submit questions regarding this program element during the first 30 days after this final text is released. Questions should be sent to HQ-AIST@mail.nasa.gov. Responses will be posted on the NSPIRES page for this program element under "other documents". Proposers should check this website periodically in case there are additional questions and answers posted.

5. Proposal Evaluation Criteria

For Step-1 proposals, the following evaluation criteria will be used:

- Responsiveness of the proposed work to NASA Earth Science goals, to AIST general objectives, and to this program element research topics
- Level of AIST Innovation and Impact/Return on Investment
- Multi-disciplinarity of the team: the team must contain at least one Earth Scientist and one of the following – Computer Scientist/Data Scientist/Computational Scientist
- Optionally, technical relevance, and as much as can be evaluated from the Step-1 input:
    - Technical Feasibility
    - Realism of level of effort within the proposed period of performance and with the proposed expertise
    - Potential for transition or infusion (if applicable and for AET proposals only)

For Step-2 proposals, the three basic evaluation criteria, Relevance, Intrinsic Merit, and Cost Reasonableness are defined in the *2023 NASA Proposer's Guide* and applied as described in Section V(a) of the *ROSES Summary of Solicitation*. Clarifications and additions specific to this program element are listed below.

The evaluation of the Relevance criterion is defined as the applicability of the proposed investigation to Earth Science Division missions and technology needs, and specifically includes the relevance to this Program Element, including an appropriate relevancy scenario, see Section 4.2. A Letter of affirmation by a representative from the target audience who is not on the proposed project team will be considered as strong support for the relevance factor (see Section 3.3).

The definition of Intrinsic Merit is given in Appendix D of the *2023 NASA Proposer's Guide*. Below are clarifications and details about some of the factors described in Appendix D which will be important in the evaluation of Merit (i.e., will be a strength if present and a weakness if absent, except Criterion (j) which will be a strength if present but not a weakness is absent):

a) The potential for the proposed technology to effectively enable new observing systems, maximize science mission return, facilitate science investigations and/or enable the development of future ESDTs.
b) The high degree of innovation of the proposed study or technology development concepts and an approach that has potential for high impact.
c) The past performance and the proven expertise and experience of the team in all areas of the proposed technology.
d) The qualifications of key personnel, including at least one relevant Earth Science domain scientist and one Computer Scientist/Computational Scientist/Data Scientist on the proposed team.
e) A substantiated justification and appropriateness of the entry and anticipated exit TRL. These TRLs will also be utilized to assess innovation and potential impact of the proposed technology.
f) The feasibility of making a demonstrable TRL increase of at least one level during the performance period of EST and AET projects, and of at least 2 levels during the performance period of D&P projects.
g) The potential for the technology development to improve the ability to do Earth System Science.

h) The potential to reduce any of the following aspects of Earth science systems development: risk, time, or cost.
i) The potential of the technology and tools to be integrated, once matured, into a NASA Earth science mission, Research and Analysis activity, or Applied Sciences activity.
j) The potential integration opportunities with existing ESDS capabilities and data tools. Optionally, the potential for the technology to have commercial benefits, if any.
k) The clarity and comprehensiveness of the plan for releasing open-source software.
l) For D&P proposals only, a well-balanced representation from at least 2 NASA Centers, as well as from both academia and industry.

In addition to the evaluation of cost reasonableness described in the *2023 NASA Proposer's Guide* (e.g., the reasonableness of the level of effort and the cost of goods and services), AIST evaluation will include the following:

a) The adequacy and achievability of proposed milestones and associated success criteria.
b) The adherence to sound and consistent management practices appropriate to the TRL of the proposed task.
c) The commitment of the organization's management to the proposed technology development. For example, as part of the cost justification, proposers will identify any previous investment by the organization/program that will be leveraged towards the proposed work (e.g., Internal Research & Development projects).

5.1 Follow-on Proposals

For follow-on proposals, consistent with the requirement in the last bullet in Section 4.2.1, the peer review panel may take into account the extent to which the proposers have successfully accomplished the previously proposed work and NASA may take into account whether the financial management was satisfactory.

6. Award Information

Awards to non-governmental organizations will be as grants or cooperative agreements, as appropriate. Further information regarding Awards is provided in Section II of the *ROSES-2023 Summary of Solicitation*.

6.1 Period of Performance

The expected period of performance for EST proposals is 12-18 months.

The expected period of performance for AET proposals is 24 months.

The expected period of performance for D&P proposals is 36 months.

7. Summary of Key Information

Expected program annual budget for new awards	~$18 million yearly
Number of investigator awards pending adequate proposals of merit	~6-8 EST awards and ~10-12 AET awards and

	~4-5 D&P awards
Maximum duration of awards	18 months for EST; 2 years for AET; 3 years for D&P
Due date for Step-1 proposals	See Tables 2 and 3 of ROSES
Due date for Step-2 (full) proposals	See Tables 2 and 3 of ROSES
Planning date for start of investigation	Six to eight months after due date for Step-2 proposals
Page limit for the central Science/Technical/Management section of Step-2 proposal	15 pp; see also Section 4.2.1
Relevance	See Section 5. This program is relevant to the Earth Science questions and goals in the NASA Science Plan. Proposals relevant to this program are, by definition, relevant to NASA.
General information and overview of this solicitation	See the *ROSES-2023 Summary of Solicitation*
General requirements for content of proposals	See A.1 Earth Science Research Overview and Section IV and Table 1 of ROSES-2023
Detailed instructions for the submission of proposals	Please see NSPIRES Online Help, *the 2023 NASA Proposer's Guide* and Section IV(b) of the *ROSES Summary of Solicitation*
Submission medium	Electronic proposal submission is required; no hard copy is permitted
Web site for submission of proposal via NSPIRES	https://nspires.nasaprs.com See NSPIRES Online Help (help desk available at nspires-help@nasaprs.com or (202) 479-9376)
Web site for submission of proposal via Grants.gov	https://www.grants.gov/ (help desk available at support@grants.gov or (800) 518-4726)
Funding opportunity number for downloading an application package from Grants.gov	NNH23ZDA001N-AIST
Point of contact concerning this program to whom questions should be submitted	Jacqueline Le Moigne Earth Science Technology Office Science Mission Directorate NASA Headquarters Washington, DC 20546-0001 Email: HQ-AIST@mail.nasa.gov