NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
HEADQUARTERS
SPACE TECHNOLOGY MISSION DIRECTORATE
300 E Street SW
Washington, DC 20546-0001

SPACE TECHNOLOGY RESEARCH GRANTS PROGRAM,

EARLY STAGE INNOVATIONS APPENDIX

to

NASA Research Announcement (NRA): Space Technology – Research, Development, Demonstration, and Infusion 2023 (SpaceTech–REDDI–2023), 80HQTR23NOA01

APPENDIX NUMBER: 80HQTR23NOA01-23ESI-B2

Appendix Issued: *May 3, 2023*
Notices of Intent Due: *June 7, 2023* (5 PM Eastern)
Proposals Due: *July 6, 2023* (5 PM Eastern, 2 PM Pacific)

NASA Assistance Listing Number 43.012

OMB Approval Number 2700-0092

Summary of Key Information

Appendix Name: Early Stage Innovations (ESI), hereafter called “Appendix”, to the SpaceTech-REDDI-2023 NRA, hereafter called “NRA.”

Goal/Intent: ESI is focused on the development of innovative, early-stage space technology research of high priority to NASA’s Mission Directorates.

Eligibility: Accredited U.S. universities are eligible to submit proposals; teaming and collaboration are permitted as per section 3.0.

Key Dates:

Release Date:	May 3, 2023
Notices of Intent Due:	June 7, 2023
Proposals Due:	July 6, 2023
Selection Notification:	early-November 2023
Award Date:	mid-January 2024

Selection Process: Independent subject matter expert peer review

Typical Technology Readiness Level (TRL): TRL 1 or TRL 2 at the beginning of the effort.

Award Details:

Anticipated Total Number of Awards:	6
Award Duration:	Maximum of three years
Award Amount:	Maximum of $650K

Type of Instrument to be used for awards: Grants. Cost sharing is not required.

Selection Official: NASA Space Technology Mission Directorate Director of Early Stage Innovations and Partnerships.

Point of Contact: Matthew Deans
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Significant Change:

- The Space Technology Research Grants (STRG) Program will use Dual Anonymous Peer Review (DAPR) for the review and evaluation of proposals submitted under this Appendix. This requires that proposers provide anonymized and non-anonymized proposal documents as per the instructions in this Appendix.

TABLE OF CONTENTS

Note: The organization and section numbering of this Appendix mirror the SpaceTech-REDDI-2023 NRA for convenience when cross-referencing content between the two documents.

Early Stage Innovations

1.0 SOLICITED RESEARCH/TECHNOLOGY DESCRIPTION

1.1 Program Introduction/Overview

NASA's Space Technology Mission Directorate (STMD) hereby solicits proposals from accredited U.S. universities for innovative, early-stage space technology research of high priority to NASA's Mission Directorates.

This specific Appendix is titled Early Stage Innovations (ESI) and is one of five calls for proposals from STMD's Space Technology Research Grants (STRG) Program. Early Career Faculty (ECF), Space Technology Research Institutes (STRI), NASA Space Technology Graduate Research Opportunities (NSTGRO), and Lunar Surface Technology Research (LuSTR) Opportunities appear as Appendix B1, Appendix B3, Appendix B4, and Appendix B5, respectively, under the SpaceTech-REDDI NRA.

This Appendix seeks proposals on specific space technologies that are currently at low Technology Readiness Levels (TRL). Investment in innovative low-TRL research increases knowledge and capabilities in response to new questions and requirements, stimulates innovation, and allows more creative solutions to problems constrained by schedule and budget. Moreover, it is investment in fundamental research activities that has historically benefited the Nation on a broader basis, generating new industries and spin-off applications.

Our Nation's universities couple fundamental research with education, encouraging a culture of innovation based on the discovery of knowledge. Universities are, therefore, ideally positioned to conduct fundamental space technology research and to diffuse newly found knowledge into society at large through graduate students and industry, government, and other partnerships. STMD investments in space technology research at U.S. universities promote the continued leadership of our universities as an international symbol of the country's scientific innovation, engineering creativity, and technological skill. These investments also create, fortify, and nurture the talent base of highly skilled engineers, scientists, and technologists to improve America's technological and economic competitiveness.

The ESI Appendix challenges universities to examine the theoretical feasibility of new ideas and approaches that are critical to making science, space travel, and exploration more effective, affordable, and sustainable. It is the intent of the STRG Program and this Early Stage Innovations opportunity to foster interactions between NASA and the awarded university Principal Investigators (PIs)/teams. Therefore, interaction with NASA researchers should be expected while conducting space technology research under these awards.

1.2 Program Goals and Objectives

The STRG Program within STMD is fostering the development of innovative, low-TRL technologies for advanced space systems and space technology. The goal of this low-TRL endeavor is to accelerate the development of groundbreaking, high-risk/high-payoff space technologies. These technologies, although not necessarily directed at a specific mission, are being developed to support the future space exploration and science needs of NASA, other government agencies, and the commercial space sector. Such efforts complement the other NASA Mission Directorates' focused technology activities, which typically begin at TRL 3 or higher. The *starting* TRL of the efforts to be funded as a result of this Appendix will typically be TRL 1 or TRL 2; typical end TRLs will be TRL 2 or TRL 3. See Attachment 2 of the NRA for TRL descriptions.

This Appendix seeks proposals to develop unique, disruptive, or transformational space technologies that have the potential to lead to dramatic improvements at the system level — performance, weight, cost, reliability, operational simplicity, or other figures of merit associated with space flight hardware or missions. The *projected* impact at the system level must be substantial and clearly identified. Although system-level demonstrations are likely not possible or expected under an ESI award, meaningful TRL advancement is required. This Appendix does not seek literature searches, survey activities, or incremental enhancements to the current state of the art (SOA).

This Appendix exclusively seeks proposals that are responsive to one of the three topics described in 1.3. Proposals that are not responsive to any of these topics, as specifically described, will be considered non-compliant and will not be submitted for peer review. NASA anticipates addressing other topics in future Appendix releases.

The topics described in 1.3 are aligned with the 2020 NASA Technology Taxonomy and are also consistent with the 2022 NASA Strategic Plan.

1.3 Topics

Topic 1 – Advancing Radiation-Hardened Photon Counting Sensor Technologies

The goal of this topic is to advance the development of radiation-hardening technologies for single-photon detector systems, including their readout electronics, in space platforms.

Ultrasensitive photon detectors are an enabling technology for ultraviolet, visual, and near-infrared wavelengths in strategic astrophysics space science applications as well as in high-bandwidth space optical communications. A key challenge for these detectors is to increase tolerance to spurious signals from particle radiation in space environments and limit longer-term susceptibility to radiation degradation over the duration of the mission lifetime.

Many of NASA Science Mission Directorate's future missions are anticipated to perform ultrasensitive observations of low photon flux sources in ultralow backgrounds, demanding substantial improvements in sensing performance over what is currently possible. For example, future space observatories in distant orbits, such as around L2, will be equipped with coronagraphs and/or external starshades to seek evidence of life on other worlds [1, 2]. Once some promising exoplanets in the habitable zones are identified, the attention will shift to assessing their potential habitability using spectroscopic biosignatures and other information [3].

The ultraviolet, visible, and near-infrared wavelengths are particularly rich in biosignatures. However, the in-band photon flux from such exoplanets is predicted to be extremely low, with only a few photons per hour per spectrometer resolution element [4, 5]. Better detectors and readout electronics than the ones in existence today are needed to achieve this level of sensitivity. Ideally, a single photon detector must count individual photons with zero dark (spurious) counts and zero readout noise. In practice, low spurious counts (false detections) and readout noise still exist due to non-idealities such as 'dark current' in semiconductor devices (e.g., EMCCD, CMOS, APD) and noise from amplification in the readout chain of both semiconducting and superconducting detectors.

Current implementations of semiconducting single-photon detectors are close to fulfilling these demanding requirements, but only in low-radiation laboratory environments. Under radiation doses typical for missions in orbits favored for low background applications [6, 7, 8, 9, 10, 11], they still have operational limitations and are susceptible to performance degradation. Superconducting single-photon detectors, such as kinetic inductance detectors (KID) [12, 13], and superconducting nanowire single-photon detectors (SNSPD) [14, 15] are emerging technologies that surpass the sensitivity of silicon-based detectors and can even provide energy resolution or photon number information in certain implementations. However, similar to semiconductor detectors, they require further investigation to better understand their radiation tolerance limitations.

Particle radiation can negatively impact two key sensor subsystems: 1) the detectors and 2) the requisite readout electronics. In subsystem 1, exploring the impact of radiation on the photo-sensitive active regions, such as the silicon layers or superconducting films, or passive regions that may allow generation and/or propagation of unwanted signals (photons, phonons, or electrons) into the active region, is very valuable to determine the limits of radiation that could be the difference between a positive or a null detection of a faint science signal. In subsystem 2, designing and testing associated readout electronics (e.g., ROIC, FPGA, RFSoC, ASIC, etc.) for tolerance to single-event upsets (SEU) or any other negative radiation effects is very valuable.

This solicitation topic seeks proposals for ultrasensitive photon detector technologies that increase tolerance to particle radiation in space environments and limit long-term susceptibility to radiation degradation. Possible solutions and approaches to mitigate or overcome space radiation may include, but are not limited to:

- Nanofabrication improvements, use of new materials, and architecture modifications to shield or decrease the susceptibility of the sensor arrays to radiation
- New readout electronics architectures or upgrades to existing electronics for these arrays to make them radiation tolerant
- Software and post-processing advancements in analyzing the detected signals that could alleviate, eliminate, or distinguish some of the variable and/or single-event radiation effects

Proposed approaches should:

- Consider the effects of long-term radiation (> 5 years) in degrading performance as well as transient error signals due to single particle events.
- Consider relevant space environments (e.g., Suborbital, LEO, HEO, Cislunar, L2, Deep Space) with corresponding anticipated radiation levels.
- Include laboratory and appropriate testing in irradiating environments and provide justification for the radiation levels and choice of environmental factors.

Proposals are encouraged to:

- Include quantitative improvement metrics
- Use physics-based models to assist in providing accurate solutions
- Demonstrate the effectiveness of the proposed solutions.

References:

[1] National Academies of Sciences, Engineering, and Medicine, "Pathways to Discovery in Astronomy and Astrophysics for the 2020s", Washington, DC: The National Academies Press (2021). https://doi.org/10.17226/26141

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[4] Stark, C. C. *et al. "ExoEarth yield landscape for future direct imaging space telescopes,"* JATIS. 5, 1–20 (2019).

[5] Wang, J. et al. "*Baseline Requirements For Detecting Biosignatures with the HabEx and LUVOIR Mission Concepts*," JATIS 4, 1–9 (2018).

[6] Harding, L. K. et al., "*Technology advancement of the CCD201-20 EMCCD for the WFIRST coronagraph instrument: sensor characterization and radiation damage*," JATIS, Volume 2, id. 011007 (2016).

[7] Bush, N., et al., "*Cryogenic irradiation of an EMCCD for the WFIRST coronagraph: preliminary performance analysis*," Proceedings of the SPIE, Volume 9915, id. 99150A 18 pp. (2016).

[8] Effinger, R. et al., "*WFIRST coronagraph detector trap modeling results and improvements*," Proceedings of the SPIE, Volume 10709, id. 1070917 13 pp. (2018).

[9] Dunford, A., Stefanov, K., & Holland, A., "*Ageing and proton irradiation damage of a low voltage EMCCD in a CMOS process,"* Journal of Instrumentation, Volume 13, Issue 02, pp. C02059 (2018).

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[13] Zobrist, N. et al., *"Improving the dynamic range of single photon counting kinetic inductance detectors,"* J. Astron. Telesc. Instrum. Syst. 7(1) 010501 (2021).

[14] Shaw, M. et al., *"Superconducting nanowire single photon detectors for deep space optical communication (Conference Presentation),"* Proc. SPIE 10096, Free-Space Laser Communication and Atmospheric Propagation XXIX, 100960J (2017).

[15] Srinivasan, M. et al., "*The Deep Space Optical Communications project ground laser receiver*", Proc SPIE 12413, Free-Space Laser Communications XXXV; 124130R (2023).

Please refer to 7.0 – Points of Contact for Further Information of this Appendix if you have technical questions pertaining to this topic. Please note that NASA is unable to comment on whether a proposed area of research is responsive to this topic.

Topic 2 – Advancements in Predicting Plume-Surface Interaction Environments During Propulsive Landings

The goal of this topic is to advance the capability to predict plume-surface interaction (PSI) environments through development of a physics-based framework and models from analysis and application of unique, modern data products from a recent NASA ground test campaign.

The use of rocket propulsion by spacecraft near the surface of the Moon or other planetary bodies poses risks to the vehicle and other vehicles or surface infrastructure in the vicinity as result of the complex interaction between rocket exhaust plume(s) and the regolith underneath the vehicle. Results from this research will be used to further validate and improve predictions of PSI as well as contribute to applications informing the risks imposed by PSI on propulsive landing and ascent systems for the Moon and other planetary bodies.

In 2021 and 2022, NASA conducted a series of 2D, inert gas, subscale experiments under vacuum to obtain parametric validation and model data for erosion and ejecta due to PSI. In these tests, a supersonic, heated nitrogen plume impinged onto multiple regolith simulants, ranging in complexity from glass beads and monodispersed silica sand to Black Point 1 (BP-1) lunar regolith simulant. Tests were conducted at a range of nozzle heights and both Martian- and lunar-relevant ambient pressure. These tests have generated a substantial volume of video and other diagnostic data, which are challenging to reduce in a manner that extracts important physics and facilitates future code validation efforts. Representative data and detailed descriptions of this NASA test campaign can be found in references [1-4].

These data represent the state of the art for plume-surface interaction testing collected with high-speed optical diagnostics for erosion and ejecta physics, and represent some of the first parametric, scaled-from-flight PSI data since the Viking tests in the early 1970s. Empirical relations and engineering models at present are still largely based on ground and flight data from the 1960s and 1970s and have not yet incorporated much of the data currently being collected for PSI. Data products developed from these data may be used to inform the validation of these and higher-fidelity computational models. Advancements in understanding of erosion regimes and mechanisms, ejecta dynamics, and scaling from ground test to flight are needed to improve the capability to predict PSI for lunar and planetary environments and mitigate associated risks. Potential impacts to future NASA missions may include reduced uncertainties in prediction of PSI effects, tools of progressive fidelity that can be used to answer engineering and design questions, advancing the theoretical basis for scaling from terrestrial ground testing to flight, and improvements to evaluation and mitigation of PSI risks through a physics-based framework. Quantities such as erosion rate, crater depth and diameter, and ejecta velocity and energy flux are critical to the design, performance, and risk mitigation for exploration systems with PSI. The classification and taxonomy for PSI behaviors should be examined critically in light of previous work [5-9], as future missions will press beyond the experience from the Apollo, Mars Science Laboratory, and Mars 2020 landings.

This topic seeks proposals to develop both 1) a physics-based framework for the analysis and categorization of PSI phenomena; and 2) rapid and engineering fidelity modeling tools for PSI phenomena. Research areas include:

- *Physics-Based Framework for PSI Phenomena* – Advancements in the understanding of the physical mechanisms that govern PSI phenomena and their effects during landing and other near-surface operations, based on analysis of existing PSI data sets [1-4]. Areas of interest include, but are not limited to:
    - Elucidation of observed features and phenomena
        - Classification and taxonomy of the observable behaviors
        - Identification of boundaries, limits, and transitions as functions of induced surface environments
    - Methodologies to identify, extract, derive, and assess quantities of interest for erosion and ejecta physics, with characterization and quantification of (required):
        - Crater evolution including boundaries and profiles

        - Erosion mechanisms and regimes
        - Velocity of moving particles, near-field and far-field
    - Definition and quantification of uncertainties in the experimental data (required)
- *Modeling Approaches and Tools* – Development of PSI modeling tools, guided by framework research areas outcomes, including uncertainties, to support risk characterization, mitigations, and other relevant products to be used in broader vehicle performance evaluations:
    - Rapid tools such as semi-empirical scaling relationships
    - Engineering-level modeling approaches
    - Granular mechanics models
    - One-way coupled computational modeling

Proposals should develop context for the NASA-provided data products relative to historical and modern PSI data in the literature while identifying and critically assessing significant parameters governing observable PSI effects. Additionally, proposers are encouraged to apply the following elements as appropriate:

- Novel image processing to improve data return from PSI image data.
- State-of-the-art methods for ingesting large volume, highly parametric data sets and deriving physics-informed models from those data

If NASA successfully acquires flight data from the Stereo Cameras for Lunar Plume Surface Studies (SCALPSS) payload [10] within the timeframe of this award, it may also be made available.

Proposals with a primary focus on the development or application of high-fidelity coupled computational modeling tools or additional experiments will be considered non-responsive. However, minor expansions of scope in these areas may be considered if such contributions are justified to achieve the advancements sought under this solicitation topic.

References:

[1] Korzun, A.M. et al., "Design of a Subscale, Inert Gas Test for Plume-Surface Interactions in a Reduced Pressure Environment", AIAA 2021-1808, January 2021.

[2] Rubio, J.S., et al., "Plume-Surface Interaction Physics Focused Ground Test 1: Setup and Preliminary Results", AIAA 2021-1809, January 2021.

[3] Diaz-Lopez, M.X. et al., "Plume-Surface Interaction Physics Focused Ground Test 1: Diagnostics and Preliminary Results", AIAA 2021-1810, January 2021.

[4] Eberhart, C.J. et al., "Overview of Plume-Surface Interaction Data from Subscale Inert Gas Testing at NASA MSFC Test Stand 300 Vacuum Facilities", AIAA 2021-1811, January 2021.

[5] Metzger, P.T. et al., “Cratering and Blowing Soil by Rocket Engines During Lunar Landings”, ed. By Haym Benaroya (CRC Press, 2010), pp. 551-576.

[6] Metzger, P.T. et al., “Phenomenology of Soil Erosion by Rocket Exhaust on the Moon and the Mauna Kea Lunar Analog Site”, *Journal of Geophysical Research – Planets 116*, E06005 (June 2011).

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[9] Land, N.S. and Scholl, H.F., “Scaled Lunar Module Jet Erosion Experiments”, NASA TN D-5051, April 1969.

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Please refer to 7.0 – Points of Contact for Further Information of this Appendix if you have technical questions pertaining to this topic. Please note that NASA is unable to comment on whether a proposed area of research is responsive to this topic

Topic 3 – Advancing the Performance of Refrigeration Systems Based on the Elastocaloric Effect

The goal of this topic is to develop advanced materials and approaches that provide performance improvements in refrigeration systems for NASA exploration applications that are based on elastocaloric effect using shape memory alloys (SMA).

The use of refrigerants in spaceflight applications can impose hazards, requires leak monitoring and replenishment, and results in tight operational temperature constraints. As such, efficient and safe methods of refrigeration are of interest to NASA. Advanced life support systems, food preservation systems, sample return concepts, NASA’s In-Situ Resource Utilization approaches, and cryogenic fluid management efforts could all potentially benefit from improved refrigerator technology. NASA applications range from cryogenic all the way to 300K or higher. For instance, food refrigeration can benefit most from a range ~ 250 – 300K, while biological/medical samples often favor a cold temperature of ~190 – 200K. For instance, in the case of conditioned stowage, there is a need for cold stowage that must accommodate sample requirements for a given mission; example sample types and temperatures range are given in Figure 1. Refrigeration system improvements across all these temperature ranges are expected to yield large benefits, and even more so in the less-studied cryogenic regimes, where new solutions can be game changer.

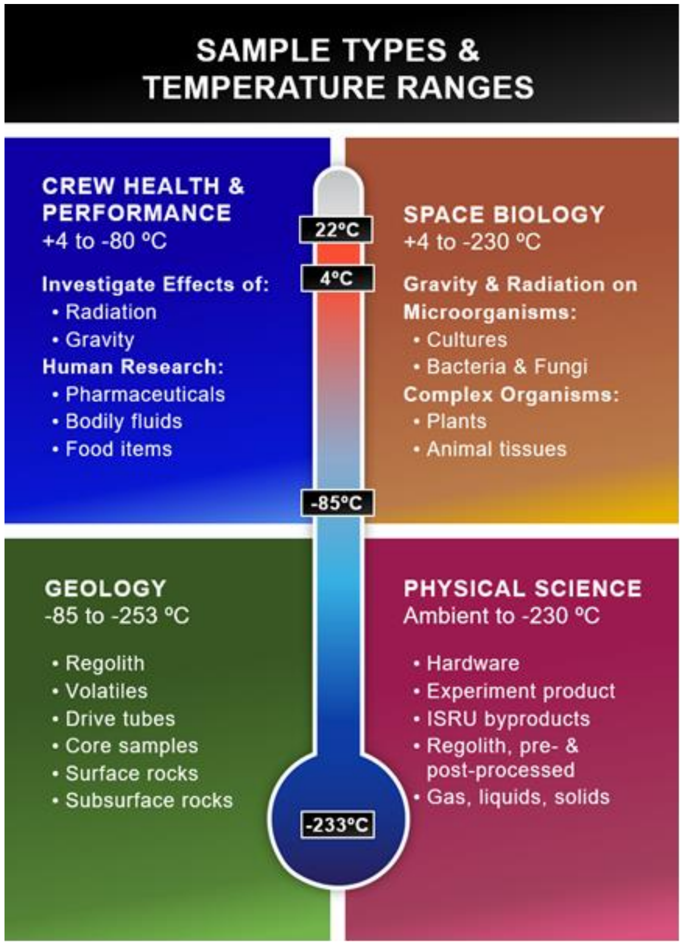

Figure 1: Examples of Conditioned Samples and Stowage Temperatures (Based on Human Exploration and Operations Mission Directorate (HEOMD)-006, Rev. A, Table AN1.2-1)

Elastocaloric materials have emerged as a promising refrigeration technology with high efficiency, low form factor, and low environmental impact, as outlined by the U.S. Department of Energy [1], the EU Commission, and other sources [2]. Elastocaloric technology is classified as having a ZERO global warming potential (GWP) as it does not use harmful fluids, such as Hydrofluorocarbons (HFCs), commonly used in refrigeration applications. Elastocaloric materials are solids capable of stress-induced reversible phase transformations during which latent heat is released or absorbed [3]. Refrigeration systems based on these materials have the potential to be more efficient than vapor-compression-based systems, or other caloric approaches such as electrocaloric or magnetocaloric technologies.

SMA-based refrigeration concepts are mostly based on NiTi alloys and ternary derivatives, where an established transformation latent heat of approximately 10 J/g, a thermal conductivity of 12 W/m-k, and adiabatic temperature changes of approximately 25 K (at room temperature) are obtained. Other systems based on CuAl alloys, Fe-based alloys and NiMn alloys have been proposed with lower cost compared to NiTi, but also with lower performance compared to the latter. Some ternary NiTi alloys have shown latent heats up to 36 J/g, but the cost can be prohibitive (e.g., using Hf, Pd, Pt additions). Additionally, elastocaloric concepts and devices have been developed using mainly wires, foils or tubes loaded in tension or compression [4-5], bending, or some other multiaxial mode.

To date, several candidate elastocaloric materials have been explored [3], but none have been implemented in space systems where extreme environments present additional challenges that require improved systems with nearly 2 to 3 times the performance metrics compared to the state of the art. Material design approaches and technologies such as porous structures, additively manufactured alloys, gradient structures, grain refined alloys, and texture alloys have been proposed as potential means for achieving improved performance in refrigerant systems. From a device perspective, technologies using SMAs in the form of tube bundles, or wire bundles, or devices constructed with multi-stage, cascading-stages and other forms have been attempted with some success [3]. However, technology advancements are needed for elastocaloric materials and devices to provide the key performance metrics required to satisfy space system architectures. These emerging, novel materials may have the potential to enable efficient, non-toxic, technologies for refrigeration for NASA exploration mission needs, including food storage and the preservation of scientific samples.

This topic seeks proposals to develop novel materials and system approaches based on elastocaloric effects in shape memory alloys that can advance the performance of refrigeration systems for exploration applications. Proposals should address both of the following areas:

- *Elastocaloric Materials* – Novel materials and materials design for the development of elastocaloric refrigerants, based on SMAs/tailored SMAs. Proposed materials should offer performance metrics better than those currently provided by state-of-the-art materials (such as conventional Ni-Ti, Cu-Al, and Ni-Mn systems) with specific improvements in:
    - Latent phase transition energy, with performance goals larger than ~8 J/g to maximize latent heat.
    - Thermal conductivity, with performance goals larger than ~12 W/m-k.
    - Stress plateau for activation, with performance goals of less than 100 MPa.
    - Hysteresis, demonstrated via thermal or mechanical assessment, compared to baseline NiTi or CuAl based alloys or systems.
- *Refrigeration System Concepts* – Novel approaches for the development of elastocaloric-based refrigeration systems that fully exploit the unique materials

developed in the bullet above, including a path towards scalability and implementation of *refrigeration* cycle along with system performance metrics. Proposed approaches should address:

  - Cooling power target goal of at least 280 W and temperature spans of 15 to 25 K or higher.
  - Cyclic stability when subjected to relatively low stresses (to induce the martensitic transformation) with a target cycle life to exceed 1000s of cycles with relatively constant output or no worse than 90% from the initial cycle. This target life cycle goal is for testing purposes only, with the expectation that a device will experience many more cycles. Pre-training of SMA material or device is acceptable.

Proposals should:

- Identify viable shape memory alloy(s) and operational schema(s) in the context of matching or improving the efficiency of refrigeration systems such as
  - Liquid-gases, thermo-electric refrigeration, Stirling cryocoolers, phase change materials (PCMs)
  - Heat pipes [6-8]
  - Other caloric devices such as magnetocaloric, electrocaloric
  - Other systems, as deemed pertinent
- Articulate the benefits of the proposed development including:
  - Novel material and approach compared to existing SMA elastocaloric alloys
  - Performance metrics for the proposed system compared to state-of-the-art refrigeration systems to the proposed SMA alloys (refer to requirements)
- Provide a demonstration of cycle performance efficiency
  - As a function of refrigerant form factor (e.g., plate vs. wire vs. rod vs. 3D shapes, additive manufacturing, etc.)
  - Figures of merit adhering to the requirements listed above.
- Describe a path towards scalability and implementation of refrigeration cycle.

Proposers are encouraged to address:

- Potential cost implications, including but not limited to SMA material cost (e.g., NiTi ingot cost), fabrication cost (e.g., tube manufacturing, wire drawing), and overall device cost.
- Single stage versus multi-stage systems such as active regeneration, cascading or heat recovery.
- Packaging implications that consider minimizing system footprint per watt of cooling and anticipated system mass.

References:

[1] Goetzler, W., Zogg, R., Young, J., and Johnson, C. (2014). Energy savings potential and R & D opportunities for Non-vapor-compression HVAC technologies. US Dep. Energy 3673. https://doi.org/10.2172/1220817.

[2] https://www.caloricool.org/area/elastocaloric-effect

[3] Qian, Suxin, et al. "A review of elastocaloric cooling: Materials, cycles and system integrations. " *International journal of refrigeration* 64 (2016): 1-19. https://doi.org/10.1016/j.ijrefrig.2015.12.001

[4] Imran, Muhammad, and Xuexi Zhang. "Recent developments on the cyclic stability in elastocaloric materials." Materials & Design 195 (2020): 109030. https://doi.org/10.1016/j.matdes.2020.109030

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[6] Skipworth, A., Caskey, S. L., Brendel, L. P. M., Gomes, A., Chhajed, R., Phalak, S., ... & Groll, E. A. (2021). Zero Gravity Effects on Vapor Compression Cycle Performance for Cold Food Storage with Oil-Free Scroll Compression. In *Thermal & Fluids Analysis Workshop (TFAWS). Virtual*.

[7] Brendel, L. P., Caskey, S. L., Braun, J. E., & Groll, E. A. (2022). Effect of orientation on the steady-state performance of vapor compression cycles. *Applied Thermal Engineering*, *207*, 118174.

[8] Cheganças, J., Stephan, H., Jimenez, J., Campana, S., & Hutchison, S. (2013, January). Seven years of permanent running of MELFI-1 on board the ISS and utilisation of the three MELFI units refrigeration pool. In *64th International Astronautical Congress* (No. JSC-CN-28216).

Please refer to 7.0 – Points of Contact for Further Information of this Appendix if you have technical questions pertaining to this topic. Please note that NASA is unable to comment on whether a proposed area of research is responsive to this topic.

2.0 AWARD INFORMATION

As noted in 2.0 of the NRA, awards are authorized by The National Aeronautics and Space Act of 1958, 51 U.S.C. § 20113(e).

2.1 Funding and Period of Performance Information

NASA plans to make approximately 6 awards - across all topics - as a result of this Appendix, subject to the receipt of meritorious proposals. The actual number of awards resulting from this Appendix and for each topic will depend on the quality of the proposals received; NASA reserves the right to make no awards, or exceed 6, under this Appendix.

The ESI Appendix covers only proposals for new awards; continuations of existing awards are handled separately.

The total award value may not exceed $650K, and the amount in any one year may not exceed $250K. All amounts must be justified.

The maximum award duration will be three years, although proposals for less than three years are allowed. Initial funding will be for one year and subsequent funding will be contingent on the availability of funds, technical progress, and continued relevance to NASA goals. Annual continuation reviews – to assess technical progress and continued relevance – are required.

The anticipated type of award instrument is grants, subject to the provisions of the 2 CFR (Code of Federal Regulations) 200, 2 CFR 1800, and the NASA Grant and Cooperative Agreement Manual (GCAM). Contracts will not be awarded as a result of this Appendix.

3.0 ELIGIBILITY INFORMATION

3.1 Limitation on Number of Proposals Per Organization

Only accredited U.S. universities are eligible to submit proposals to this solicitation, and teaming is permitted, subject to the eligibility of offerors (see 3.2 of this Appendix). There is no limit on the number of proposals which may be submitted by an accredited U.S. university.

3.2 Eligibility of Offerors and Limitation on Number of Proposals Per PI/Co-I

The PI on a proposal must be either a tenured faculty member or an untenured faculty member on the tenure track from the proposing university. Teaming is permitted, subject to the following restrictions:

- In order to facilitate broad, nationwide participation in this opportunity, a PI or Co-Investigator (Co-I) may participate in no more than two proposals in response to this Appendix. When more than one proposal is submitted on behalf of a PI or Co-I, each proposal must be a separate, stand-alone, complete document for evaluation purposes. More than two submissions may result in all being deemed non-compliant;
- At least 50% of the proposed budget must go to the proposing university;
- At least 70% of the proposed budget must go to accredited U.S. universities;
- Industry and non-profit entities are permitted to partner, subject to the above restrictions;
- Other government agencies and non-NASA FFRDCs are permitted to collaborate (see definition of collaboration below) only; therefore, they are not permitted to receive any funds through an award resulting from this Appendix;
- NASA Centers and JPL are not permitted to collaborate on proposals submitted to ESI23.

Diversity and inclusion are integral to mission success at NASA (see the *NASA Equity Action Plan*. The agency recognizes the benefits of having diverse and inclusive scientific, engineering, and technology communities and expects the reflection of such values in the execution of its funded efforts. Research effort leadership or participation from U.S. universities and organizations that support and serve under-represented groups, including Historically Black Colleges and Universities, Hispanic-Serving Institutions, Tribal Colleges, and other Minority Serving Institutions (MSIs), is strongly encouraged. NASA encourages submission of ESI proposals on behalf of tenure-track or tenured faculty members at all U.S. universities and especially encourages proposals submitted on behalf of women, members of underrepresented minority groups, and persons with disabilities. (See 1.0 of the NRA)

Other Proposal Personnel

Co-Investigators, postdoctoral associates, consultants, and collaborators are permitted, subject to restrictions listed above and explained below. As specified in Appendix B of the *2022 NASA Proposer's Guide*, a collaborator is not critical to the proposal but is committed to providing a focused but unfunded contribution for a specific task. The Scientific/Technical/Management Section of the proposal must document the nature and need for all collaborations; see Section 4.3.5 for specific requirements. If research collaboration is a component of the proposal, it is presumed that the collaborator(s) have their own means of research support; that is, an ESI proposed budget may not include any expenses for the collaboration effort.

This ESI Appendix is seeking to fund the best research proposed to the solicited topics from *outside* of NASA. NASA civil servants and JPL employees may not appear as collaborators on submitted proposals**,** and there may be no solicitation-related communications with NASA (including JPL) personnel from the time this Appendix is released until proposal selections are final. Although interaction with NASA researchers under these awards is expected, the proposer is *not* permitted to include potential specific interactions with agency experts (including JPL) in any part of the proposal. In addition, possible future interactions may not be discussed with NASA (including JPL) personnel while the solicitation is open, and letters of commitment from NASA (including JPL) are not permitted. NASA interactions will be addressed after proposal selection.

Failure to meet an eligibility requirement will result in NASA returning the proposal without review.

3.3 Proposals Involving Non-U.S. Organizations

Collaboration by non-U.S. organizations in proposed efforts is permitted as specified in 3.3 of the NRA.

3.6 Cost Sharing

Cost sharing is not required and is not considered a part of the evaluation.

4.0 PROPOSAL SUBMISSION INFORMATION

4.1 Introduction

The following information supplements the information provided in 4.0 of the NRA. Note that in instances where this Appendix and the NRA or *2022 NASA Proposer's Guide* differ, the Appendix takes precedence.

Proposals submitted to in response to this Appendix will be evaluated and selected through a one-step process.

4.2 NSPIRES Registration

In order to submit a proposal, all team members and their institutions must be registered in the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES). Therefore, every organization (including Co-I and collaborator organizations) that intends to participate in a proposal submitted to NASA in response to this solicitation, whether submitting through Grants.gov or the NSPIRES system, must be registered in NSPIRES. See 4.2 of the NRA for NSPIRES registration requirements.

4.3 Proposal Content and Submission

A full proposal includes the Proposal Cover Page and the following three proposal documents: an "Anonymized Proposal Summary Chart," an "Anonymized Proposal" document, and an "Expertise and Resources – Not Anonymized" proposal document.

Introduction to Dual-Anonymous Peer Review

The Space Technology Research Grants Program is strongly committed to ensuring that proposal review is performed in an equitable and fair manner that reduces the impacts of any unconscious biases. To this end, this Appendix will employ a Dual-Anonymous Peer Review (DAPR) process. Using DAPR, not only are proposers not told the identities of the reviewers, but the identities of the proposers (personnel and organization names) will not be shared with the reviewers until after the technical review of all anonymized proposals has been completed.

As described in detail below, proposers will provide an "Anonymized Proposal" document for peer review and a separate "Expertise and Resources – Not Anonymized" proposal document that contains identifying expertise and resource information.

Proposers must adhere to instructions in this Appendix on how to prepare proposals that enable dual-anonymous peer review. Further instructions for the preparation of proposals are provided in the "Guidelines for Proposers Responding to SpaceTech-REDDI Dual Anonymous Peer Review Appendices" document available under "Other Documents" on the NSPIRES page for this Appendix.

DAPR represents a major shift in the preparation of ESI proposals and, as such, STMD recognizes that there may be minor errors in writing anonymized proposals. However, STMD reserves the right to return without review proposals that are egregious in terms of violating the DAPR requirements described in this Appendix and the accompanying "Guidelines for Proposers Responding to SpaceTech-REDDI Dual Anonymous Peer Review Appendices" document on the NSPIRES page for this Appendix.

4.3.1 Electronic Proposal Submission

Offerors may submit proposals via NSPIRES or Grants.gov. See the "Guidelines for Proposers Responding to SpaceTech-REDDI Dual Anonymous Peer Review Appendices" document for additional information on Grants.gov.

The electronic proposal must be submitted in its entirety by an Authorized Organizational Representative (AOR) no later than 5 PM Eastern (2 PM Pacific) on July 6, 2023. Proposals submitted after the proposal deadline will be considered late and may be rejected without review.

See 4.3.1 of the NRA for details.

4.3.2 Notice of Intent (NOI) to Propose

NOIs are strongly encouraged by June 7, 2023. The NOI is submitted via NSPIRES. The information contained in an NOI is used to expedite the proposal review process and is, therefore, of value to both NASA and the offeror.

The NOI summary must include the following:

- A full title of the anticipated proposal (which should not exceed 254 characters and is of a nature that is understandable by a scientifically trained person); and
- A brief description of the primary research area(s) and objective(s) of the anticipated work (in the Summary field) (Note: the information in this item does not constrain in any way the Proposal Summary that must be submitted with the final proposal).

Due to DAPR, the names and institutions of the PI and any Co-Is and/or collaborators as known at the time of NOI submission may not be included in the NOI summary. Rather, Co-I, collaborator, and other known participant names and institutions should be provided in response to one of the Program Specific Data Questions.

The proposal number restriction described in 3.0 of this Appendix – a maximum of two per PI or Co-I – does not apply to NOIs. However, prospective offerors are encouraged to consider this restriction as early in the proposal window as possible, ideally prior to the NOI submission due date.

NASA is unable to provide feedback on NOIs.

4.3.4 Proposal Cover Pages

The Proposal Cover Pages for each proposal shall include the proposal team, the proposal summary (abstract), responses to program specific data questions, and the budget. Instructions for completing the Proposal Cover Pages are specific to the electronic proposal submission system used by the offeror (NSPIRES or Grants.gov).

Additional information can be found in the "Guidelines for Proposers Responding to SpaceTech-REDDI Dual Anonymous Peer Review Appendices" document.

See 4.3.4 of the NRA for NSPIRES and Grants.gov instructions.

4.3.5 Proposal

The proposal must include the following sections, as needed, and in the order listed (please note frequent references to 2. Proposal Preparation and Organization of the *2022 NASA Proposer's Guide*). Proposals that fail to meet the requirements specified herein may be rejected without review.

All proposal documents – whether anonymized or non-anonymized – must be formatted as unlocked PDF files containing the elements enumerated in the tables below. The "Anonymized Proposal" document must not contain any information pertaining to the identity of the proposal team members or their organization(s). Failure to submit unlocked PDF files may result in the proposal being deemed non-compliant.

Reviewers will not consider any content in excess of the page limits specified in the Tables below.

Anonymized Proposal Summary Chart

The proposal summary chart is intended to provide a quick sense of the proposed effort and should stand alone (i.e., not require the full proposal to be understood). **The proposal summary chart shall be uploaded to NSPIRES as a separate document.**

The chart must include the following information:

- The proposal title and a representative graphic with caption;
- The objectives of the research, a comparison to the SOA, discussion of the innovation, and start TRL and projected end TRL;
- A high-level summary of the research approach, including methods to be employed;
- The potential impact of the research (i.e., benefits, outcomes).

The chart should not include any proprietary or sensitive data (see 4.3.4.1 of the NRA).

The proposal summary chart should be organized as illustrated in Figure 1 – Template for Required Proposal Summary Chart and must be oriented as shown (i.e., landscape mode). Font size 10 or above must be used.

Title • Graphic Depicting Proposed Technology (with caption)	**Research Objectives** • What will be accomplished? • What is the innovation? • How does your effort compare to the SOA? • What are the start and end TRLs (with justification)?
Approach • Methods to accomplish goals	**Potential Impact** • Benefits of the proposed space technology research to future space science and exploration needs if the technology is eventually successful • Other benefits and outcomes of proposed work

Figure 1 - Template for Required Proposal Summary Chart

Anonymized Proposal Document

NASA Proposer's Guide Section	*Anonymized Proposal Document Section*	*Maximum Page Length*
2.12	1. Table of Contents	1
2.13	2. Scientific/Technical/Management Plan	10
2.11	3. Data Management Plan	1
2.14	4. References and Citations	As needed
2.18	5. Proposal Budget with Budget Narrative and Budget Details	As needed

The proposer must make sure that Sections 1-5 do not contain information pertaining to the identity of the proposal team members or their organizations. Team members, including collaborators, and their organizations must be referred to by role (e.g., modeler, experimentalist, etc.) or be given a set designation (e.g., Co-I 1, Co-I 2, Collaborator 1, Collaborator 2, Org 1, Org 2, etc.).

Section 1: Table of Contents

See 2.12 of the *2022 NASA Proposer's Guide*.

Section 2: Scientific/Technical/Management Plan

The Scientific/Technical/Management Plan, the main body of the proposal, is limited to 10 pages with standard (12 point) font, and the text must have 1-inch margins. This page limit includes illustrations, tables, figures, and all sub-sections.

The Scientific/Technical/Management Plan must cover the following sub-sections in the order given.

a) The **relevance** of the proposed research to the specific ESI Appendix goals and objectives and topics, as described in 1.2 and 1.3.
   i. Please note that the NRA and this Appendix describe how ESI is relevant to the NASA Strategic Plan; therefore, it is not necessary for individual proposals to show relevance to NASA's broader goals and objectives. The proposal should instead focus on demonstrating **responsiveness** and relevance by discussing how the proposed investigation is directly responsive to one of the topics and how the proposed space technology could lead to dramatic improvements at the system level — performance, weight, cost, reliability, operational simplicity or other figures of merit associated with space flight hardware or missions;
   ii. A comparison between the proposed effort and the existing **SOA**, including a discussion of the perceived impact of the proposed research to the state of knowledge in the field;
   iii. A clear statement of the proposed **innovation** as well as how the proposed technology might make space science, space travel, and exploration more effective, affordable, and sustainable;
   iv. A discussion of **next-step technology development;** specifically, a clear description of a path for further development and exploitation for space science and exploration needs and any crosscutting potential of the technology.

b) The **technical approach** and methodology (types of analyses, testing, experimentation, and other research activities) to be employed in conducting the proposed research. This section should describe, in an anonymized manner, the need for and utilization and salient capabilities of the facilities and equipment required to execute the proposed research. Access to NASA facilities should not be assumed during the course of the ESI effort, nor should NASA facilities be included in the proposal.

c) A general **work plan**, including schedule and anticipated key milestones for accomplishments. The proposal must identify the planned work for all years for which support is sought and include a discussion of the potential risks and mitigation strategies.

d) A discussion of the current **TRL** of the proposed technology (see Attachment 2 of the NRA) as well as the projected TRL at the end of the research.

e) The **management approach** for the proposal team members, referred to by roles or generic designations (see examples above), any substantial collaboration(s) and/or use of consultant(s) that is (are) proposed to complete the investigation, and a description of the expected contribution to the proposed effort by each proposal team member, regardless of whether or not they derive support from the proposed budget.

   It is not permissible to include biographical information; discussion of years of experience or prior efforts of team members and/or their organizations may not be included as part of the management approach or any other section of the "Anonymized Proposal" document. The qualifications, capabilities and experience of the proposal personnel should be submitted as part of the "Expertise and Resources – Not Anonymized" proposal document (see below).

Section 3: Data Management Plan

One of NASA's missions is to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof. It is NASA's intent that all data/metadata and as many of the research products as possible developed under this Appendix be shared broadly through dissemination of the results.

Therefore, all proposals submitted under this Appendix are required to submit a Data Management Plan (DMP), in accordance with the *NASA Plan for Increasing Access to the Results of Scientific Research*. Award recipients are subject to reporting requirements under this plan, including submitting peer-reviewed manuscripts and metadata to a designated repository and reporting publications with progress reports. More information can be found here.

The DMP is limited to 1 page and applies to any data needed to validate the conclusions of peer-reviewed publications, including data that underlie figures, maps, and tables. Other data, models, software, and hardware designs that would enable future research must be addressed in the DMP. The DMP must discuss how research products will be made available to NASA and the public and include evidence (if any) of past research product sharing practices. Sound rationale must be provided for any open access limitations.

The DMP must be written in an anonymized manner that does not explicitly identify the names of the team members or their institutions. It must include information on how the proposal team plans to archive research products, including details on types of products, where products will be archived, schedule for archiving products, how the DMP will enable long-term preservation, and roles/responsibilities of team members to accomplish the DMP. For information about data rights, and other aspects of intellectual property such as invention rights resulting from awards, see 2.4 of the NRA and Appendix J of the *2022 NASA Proposer's Guide.*

Also see 2.11 of the *2022 NASA Proposer's Guide*.

Section 5: References and Citations

References must be in the [1], [2] format when cited in other sections of the "Anonymized Proposal" document. References will necessarily require names, but proposers must take care not to explicitly reveal information that would compromise DAPR.

Also see the "Guidelines for Proposers Responding to SpaceTech-REDDI Dual Anonymous Peer Review Appendices" document and 2.14 of the *2022 NASA Proposer's Guide*.

Section 7: Proposal Budget with Budget Narrative and Budget Details

An anonymized budget justification must include details adequate to substantiate the requested funding. The proposal must provide planned budgets for all years for which support is sought. Additional restrictions for this ESI Appendix include:

- The maximum annual and total award values are detailed in 2.0 of this Appendix. All amounts must be justified.
- Funds may be used for student (undergraduate or graduate) and postdoctoral fellow support, provided these individuals are directly involved in the proposed research and any costs related to such individuals are allowable and allocable according to governing cost principles.
- Funds may be used for research expenses, such as costs incurred in experiments, purchase of equipment and/or supplies, computing, travel, etc.
- If research collaboration is a component of the proposal, it is presumed that the collaborators have their own means of research support; that is, an ESI award may not include any expenses for the collaboration effort.

Also see 2.18 of the *2022 NASA Proposer's Guide.*

Expertise and Resources – Not Anonymized Proposal Document

In addition to the "Anonymized Proposal" document described above, proposers must submit a separate "Expertise and Resources – Not Anonymized" proposal document; this document contains identifying expertise and resource information.

NASA Proposer's Guide Section	***Expertise and Resources – Not Anonymized Proposal Document Section***	***Maximum Page Length***
2.12	1. Table of Contents	1
N/A	2. Team Member Qualifications and Capabilities	1
2.15	3. Biographical Sketches	Dependent on the number of Co-Is, with page limits as specified in *2022 NASA Proposer's Guide*
2.16	4. Current and Pending Support	As needed
2.17	5. Statements of Commitment and Letters of Resource Support	1 page each, if needed
2.19	6. Facilities and Equipment (optional)	2 pages, if needed

Section 1: Table of Contents

See 2.12 of the *2022 NASA Proposer's Guide*.

Section 2: Team Member Qualifications and Capabilities

Identifies all involved team members and organizations, revealing the roles and/or designations used in the "Anonymized Proposal" document (e.g., Dr. John Doe (Co-I 1, ABC University), ABC University (Org 1)). Any prior or current work that demonstrates that the proposal team has the skill, expertise, and experience needed to successfully execute the proposed technical approach should be described. The relationship between strongly related and/or leveraged resources involving any PI or Co-I and the proposed research must be described in this section.

Section 3: Biographical Sketches

See 2.15 of the *2022 NASA Proposer's Guide*.

Section 4: Current and Pending Support

Information must be provided for all ongoing and pending projects and proposals that involve the proposing PI or Co-I, even if the PI or Co-I would receive no salary support from the project(s).

All current project support from any source (e.g., Federal, State, local or foreign government agencies, public or private foundations, industrial or other commercial firms) must be listed. This information must also be provided for all pending proposals already submitted or submitted concurrently to other possible sponsors. Do not include the current proposal (i.e., the proposal in response to this Appendix) on the list of pending proposals unless it has also been submitted to another possible sponsor.

For pending research proposals involving substantially the same kind of research as that being proposed to NASA under this Appendix, the proposing PI must immediately notify the NASA Program Officer identified for this Appendix of any successful proposals that are selected any time after the ESI proposal due date and until the time that NASA's selections are announced.

Also see 2.16 of the *2022 NASA Proposer's Guide*.

Section 5: Statements of Commitment and Letters of Resource Support (if needed)

Each team member identified as a participant on the proposal's cover page and/or in the proposal's Scientific/Technical/Management Section must acknowledge their intended participation in the proposed effort. This acknowledgement of commitment is expected to occur through NSPIRES (see 4.3.1 of the NRA).

- NSPIRES allows for participants named on the Proposal Cover Page to acknowledge a statement of commitment electronically; acknowledgement via NSPIRES is considered sufficient for this Appendix. In the event that a Co-I or collaborator is unable to confirm participation through NSPIRES, the proposer should include a statement of commitment (one page maximum each) in the body of the proposal.
- Any proposal submitted via Grants.gov must include signed statements of commitment (one page maximum each) in the proposal.

In addition, a letter of support (one page maximum each) is required from the owner of any facility or resource that is not under a team member's direct control, acknowledging that the facility or resource is available for the proposed use during the period of performance.

The letter(s) may not include statements of affirmation (that endorse the value or merit of a proposal). NASA does not solicit, permit, or evaluate such endorsements for proposals. The value of a proposal is determined by peer review using the evaluation criteria defined in 5.0 of this Appendix.

Statements of commitment and/or letters of support from NASA civil servants and JPL employees are not permitted.

Also see 2.17 of the *2022 NASA Proposer's Guide*.

Section 6: Facilities and Equipment

The optional Facilities and Equipment section is limited to 2 pages. Access to NASA facilities should not be assumed during the course of the ESI effort, nor should NASA facilities be included in the proposal.

Also see 2.19 of the *2022 NASA Proposer's Guide*.

4.3.7 Proposal Funding Restrictions

The funding restrictions and requirements given in 2 CFR 200, 2 CFR 1800, 14 CFR 1274, and the GCAM are applicable to this Appendix and are detailed in 4.3.7 of the NRA.

Pre-award costs, expenses incurred within the 90-day period preceding the effective date of the award, may be authorized but such expenses are made at the proposer's risk. NASA will not pay any pre-award costs incurred for unfunded proposals.

4.6 Collection of Demographic Information

See 4.6 of the NRA.

5.0 PROPOSAL REVIEW INFORMATION

5.1 Administrative Review

In addition to steps described in 5.1 of the NRA, proposals will be pre-screened for compliance with DAPR requirements (see 4.3 of this Appendix). NASA reserves the right to return, without review, proposals that are egregious in terms of violating the DAPR requirements described in this Appendix and the accompanying documents on the NSPIRES page for this Appendix.

5.2 Review Process

5.2.1 Evaluation Criteria

The technical review criteria considered in evaluating proposals under this Appendix are given below. The questions associated with each criterion are provided to elaborate on the meaning of each criterion; the order of the questions does not indicate order of importance. The three primary evaluation criteria are 1) Relevance (40%); 2) Technical Approach (50%); and 3) Management Approach and Proposal Cost (10%).

Relevance (40%)

Evaluation includes consideration of the following:

- **Responsiveness to Topic**: Does the proposed effort specifically address a technology topic identified in this Appendix? Could the proposed space technology lead to dramatic improvements at the system level — performance, weight, cost, reliability, operational simplicity, or other figures of merit associated with space flight hardware or missions?
- **State of the Art (SOA):** How does the proposed effort compare to the existing SOA? Does the proposal state how the research might impact the direction, progress, and thinking in relevant fields of research?
- **Innovation**: Is the proposed research innovative? Does it have the potential to lead to revolutionary or breakthrough improvements in performance, new approaches, or entirely new missions?
- **Next-Step Technology Development**: Does the proposal clearly describe a path for further development and exploitation for space science and exploration needs? Does the technology have the potential to be crosscutting?

Technical Approach (50%)

Evaluation includes consideration of the following:

- **Technical Approach**: Are the research approaches technically sound, logical, and feasible? Are the conceptual framework, methods, and analyses well justified, adequately developed, and likely to lead to scientifically valid conclusions?
- **Facilities/Capabilities:** Are described facilities/capabilities appropriate for the proposed effort?

  Work Plan: Is the work plan complete and appropriate to successfully accomplish the proposed technology development? Is the schedule, including key milestones, appropriate and realistic? Does the proposal recognize significant potential problems and consider reasonable mitigation strategies?
- **Data Management Plan:** Does the data management plan ensure widespread dissemination of results? Does the proposal provide evidence of past data sharing practices?
- **TRL**: Is the proposed work at the appropriate entry TRL as stated in 1.2 of this Appendix? Does the proposal achieve meaningful TRL advancement?

Management Approach and Proposal Cost (10%)

Evaluation includes consideration of the following:

- **Management Approach:** Are roles, including those of any collaborators, clearly defined? Are the staffing levels adequate? Is the management approach sound with practices that are appropriate for the proposed work?

- **Budget**: Is the proposed budget reasonable for the scope of the effort? Is the budget of sufficient fidelity? Are the assumptions and components of the proposed budget defined?

5.2.2 Dual Anonymous Peer Review Process

A technical review panel will evaluate the proposals against the evaluation criteria noted in 5.2.1. The evaluation of the anonymized proposals will not take into account the qualifications and capabilities of proposers.

After the evaluation of *all* anonymized proposals has been finalized, the panelists will be provided with the "Expertise and Resources – Not Anonymized" proposal documents for a subset of proposals that scored highly (the cutoff being dependent on the distribution of evaluations and projected selection rate). For each proposal considered, the panel will verify that this document clearly confirms the team has the capabilities and resources required to execute the proposed technology development effort. If there are clear, compelling deficiencies in the expertise or resources required to execute the goals of the proposal, the panel may note this in its comments to the NASA Selection Official. This review may not be used to "upgrade" proposals for having particularly strong team qualifications, nor may it be used to reevaluate the proposals.

5.2.4 Additional Review and Selection Information

Both government (NASA and non-NASA) and non-government reviewers may be used, and submission of a proposal constitutes agreement that this is acceptable to the investigator(s) and the submitting institution. Peer reviewers are selected with regard to both their scientific expertise and the absence of conflict-of-interest issues.

The Selection Official for this Appendix will be the NASA Space Technology Mission Directorate Director of Early Stage Innovations and Partnerships or designee. The Selection Official may take portfolio balance and other programmatic considerations into account when making final selections.

5.3 Selection Announcement and Award Dates

Selection notifications are anticipated in early November 2023. PIs and university AORs will receive notification via NSPIRES.

Feedback to PIs will be provided upon written request; requests for feedback should be submitted as instructed in the notification letter and within 30 days of notification.

5.6 Risk Analysis

See 5.6 of the NRA.

6.0 FEDERAL AWARD ADMINISTRATION INFORMATION

All awards are subject to the terms and conditions, cost principles and other considerations described in 2 CFR 200, 2 CFR 1800, and the GCAM. This Appendix does not invoke any special administrative or national policy requirements.

6.1 Federal Award Notices

For those proposals being recommended for an award, the notification should not be regarded as an authorization to commit or expend funds. Research grants are expected to be awarded as a result of this announcement. Assuming the availability of appropriated funds, a mid-January 2024 award date is expected. If selected, NASA expects the grantee to commence with the proposed research on the award start date; deferrals will not be permitted.

<u>Research Terms and Conditions</u>

Awards from this funding announcement are subject to the Federal Research Terms and Conditions (RTC) located at http://www.nsf.gov/awards/managing/rtc.jsp. In addition to the RTC and NASA-specific guidance, three companion resources can also be found on the website: Appendix A— Prior Approval Matrix, Appendix B—Subaward Requirements Matrix, and Appendix C— National Policy Requirements Matrix.

<u>Environmental Impact</u>

All awards made in response to proposals to this Appendix must comply with the National Environmental Policy Act (NEPA). The majority of grant-related activities are categorically excluded (from specific NEPA review) as research and development projects that do not pose any adverse environmental impact. A blanket NASA Grants Record of Environmental Consideration (REC) provides NEPA coverage for these anticipated activities and it is expected that all awards resulting from this Appendix will be covered by this REC. Please see 2.21 of the *2022 NASA Proposer's Guide* for more information.

6.2 Award Reporting Requirements

The reporting requirements will be consistent with 2 CFR 1800.902 "Technical Publications and Reports" and Appendix F - Required Publications and Reports of the GCAM. Grants and cooperative agreements typically require annual and final technical reports, financial reports, and final patent/new technology reports. Electronic copies of publications and presentations should be submitted along with progress reports.

The following requirements will also be incorporated into the ESI awards:

Quarterly Research Performance Progress Reports (RPPRs). The PI shall submit progress reports every 90 days, with the first one due 90 days from the grant start date. The reports will provide a summary of progress against the work plan, discussion of upcoming activities, accomplishments, student information, and any issues or concerns that should be brought to the attention of the program. In addition, information related to publications, presentations, conferences, inventions, follow-on funding, and press received – referred to as grant visibility and impact data – must be provided. For detailed information on reporting project performance, please refer to the Post-award Phase Section of the GCAM.

Continuation Review Package/Presentation. If more than one year is proposed, annual continuation reviews are required. The continuation review package will be submitted in place of the third quarterly RPPR in applicable grant years. The package will consist of a more comprehensive report (i.e., a description of the research progress and findings to-date or since the last continuation review, discussion of relevance, and any updates to the overall work plan and associated schedule), in addition to the grant visibility and impact data and a research summary. An associated continuation review presentation, virtually or at a NASA Center, of progress and plans will also be required.

Technical Seminars. The PI shall present a minimum of two technical seminars at NASA Centers over the course of the grant award; seminar travel must be included in the grant budget. The purpose of these presentations is to promote excitement about the space technology research efforts being conducted under the award and to create opportunities for technical interaction and collaboration.

Final Performance Reports. The PI shall submit closeout report documentation (final technical report, final grant visibility and impact data, and final research summary) at the end of the final grant year.

Awards issued under this Appendix must comply with the provisions set forth in the *NASA Plan for Increasing Access to the Results of Scientific Research*; see 4.3.5 of this Appendix for more detailed information.

7.0 POINTS OF CONTACT FOR FURTHER INFORMATION

Questions (technical, programmatic, grants management, etc.) or comments about this Appendix may be directed to:

Matthew Deans
Space Technology Research Grants Program Executive
Space Technology Mission Directorate, NASA Headquarters
hq-esi-call@mail.nasa.gov

Questions to the manager of the NRA associated with this Appendix may be directed to:

SpaceTech-REDDI NRA Manager
hq-esi-call@mail.nasa.gov

Questions of a general nature may be added to the Frequently Asked Questions (FAQs) for this Appendix. The FAQs document will be located under “Other Documents” on the NSPIRES page for this Appendix.

All technical questions will be incorporated into one of the topic-specific Questions and Answers (Q&A) documents, also located under “Other Documents” on the NSPIRES page for this Appendix. When submitting a technical question, proposers are agreeing to have the question, and associated response, published in one of the Topic Q&A documents. Questions will be accepted through June 29, 2023; no technical questions will be accepted after this date. Please note that NASA is unable to comment on whether a proposed area of research is responsive to a topic described in 1.3.