SPACE TECHNOLOGY RESEARCH GRANTS PROGRAM,
EARLY CAREER FACULTY APPENDIX

to


APPENDIX NUMBER: 80HQTR22NOA01-22ECF-B1

Appendix Issued: February 02, 2022
Notices of Intent Due: March 02, 2022 (5 PM Eastern)
Proposals Due: March 31, 2022 (5 PM Eastern, 2 PM Pacific)

Catalog of Federal Domestic Assistance (CFDA) Number 43.012
OMB Approval Number 2700-0092
Summary of Key Information

Appendix Name: Early Career Faculty (ECF), hereafter called “Appendix” to the SpaceTech-REDDI-2022 NRA, hereafter called “NRA.”

Goal/Intent: ECF is focused on supporting outstanding faculty researchers early in their careers as they conduct space technology research of high priority to NASA’s Mission Directorates.

Eligibility: Accredited U.S. universities are eligible to submit proposals on behalf of their outstanding new faculty members who intend to develop academic careers related to space technology. See 3.0 of this Appendix for complete eligibility requirements.

Key Dates:

- **Release Date:** February 02, 2022
- **Notices of Intent Due:** March 02, 2022
- **Proposals Due:** March 31, 2022
- **Selection Notification:** August 05, 2022 (target)
- **Award Start Date:** October 01, 2022 (target)

Selection Process: Independent Peer Review

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

Award Details:

- **Award Duration:** Maximum of three years
- **Typical Award Amount:** $200K/per year

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

Selection Official: NASA Space Technology Mission Directorate Associate Administrator or designee

Point of Contact: Claudia Meyer
Space Technology Research Grants Program Executive
hq-ecf-call@mail.nasa.gov
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Note: The organization and section numbering of this Appendix mirror the SpaceTech-REDDI-2022 NRA for convenience when cross-referencing content between the two documents.

80HQTR22NOA01-22ECF-B1
Early Career Faculty

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 Career Faculty (ECF) and is one of five calls for proposals from STMD’s Space Technology Research Grants (STRG) Program. Early Stage Innovations (ESI), Space Technology Research Institutes (STRI), NASA Space Technology Graduate Research Opportunities (NSTGRO), and Lunar Surface Technology Research (LuSTR) Opportunities appear as Appendix B2, 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 both conduct fundamental space technology research and 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 ECF Appendix seeks to tap into that talent base, challenging early career faculty 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 Career Faculty opportunity to foster interactions between NASA and the awarded university Principal Investigators (PIs) and their teams. Therefore, collaboration/interaction with NASA
researchers should be expected while conducting space technology 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 science and exploration 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 ECF 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 NASA’s 2020 Technology Taxonomy and are consistent with the NASA Strategic Plan.

1.3 Topics

Topic 1 – Development of Lightweight Solar Sail Attitude Control Technologies

The objective of this topic is to develop advanced technologies for solar sail control to enable future large solar sail mission with high science return for Heliophysics and other deep space science missions.

As solar sail technology matures, larger sails are being constructed and this trend will continue well into the future. There is a critical need to further develop lightweight actuators that scale with the sail and distance from the sun, primarily those that use the light pressure from the sun in some way.
A primary example of the capability to scale actuators with sail size are Reflectivity Control Devices (RCDs) [1] which are thin-film polyimides with a Liquid Crystal Diode layer LCD with tunable optical properties in response to an applied voltage. RCDs were originally demonstrated for solar sailing by JAXA on the IKAROS (Interplanetary Kitecraft Accelerated by Radiation of the Sun) mission [2] and are currently being further developed by NASA for the Solar Cruiser mission [3].

The Solar Cruiser solar sail is 1,684 m² and employs state-of-the-art attitude control actuators. Disturbance torque requirements for these actuators are listed in the table below. Note that the torques are for two different sail Sun Incidence Angles (SIAs). While both in-plane and out-of-plane torque should be considered, out-of-plane torque is a higher priority. For clarity, “out-of-plane” is synonymous with “normal axis of the sail”. Additionally, the table below includes torques for a larger sail necessary for a mission called Solar Polar Imager (SPI).

<table>
<thead>
<tr>
<th>Case</th>
<th>Out-of-Plane (Roll) Torque (N-m)</th>
<th>In-Plane (Pitch/Yaw) Torque (N-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Cruiser (1684 m²)</td>
<td>0° SIA</td>
<td>4.7x10⁻⁶</td>
</tr>
<tr>
<td>Solar Cruiser (1684 m²)</td>
<td>35° SIA</td>
<td>4.9x10⁻⁵</td>
</tr>
<tr>
<td>SPI (7000 m²) 0° SIA</td>
<td></td>
<td>7.7x10⁻⁵</td>
</tr>
<tr>
<td>SPI (7000 m²) 35° SIA</td>
<td></td>
<td>6.4x10⁻⁴</td>
</tr>
</tbody>
</table>

RCDs are not the only approach to scaling up actuators. Combinations of devices are of interest, provided they can remain lightweight and effective. For example, one possible design is a combination of ‘vanes’ (small sails that rotate like an aircraft elevator) near the CG for sail normal axis control with extensible booms for the other two axes. [4]

This topic specifically seeks proposals to develop advanced actuator technologies for solar sail control in one or more of the following areas:

- **Improvements to optical surfaces that increase optical efficiency and/or reduce mass.** (e.g., Reflectivity Control Devices, metamaterials [5], or other advanced materials)
  - Proposed approaches may include increases in the amount of light altered per unit area or an optimization in the direction light is reflected
- **Improvements in actuator designs that provide attitude control by altering the CG of the spacecraft**
  - Proposed improvements can include reducing the mass of the actuator and/or increasing its range of motion
Any proposed shifting of the CG should limit the rate of motion so that any resulting transient dynamic torque is less than 0.1% of the values listed in the table above.

- **Improvements in vane designs which reduce the mass of supporting structure and/or motors and mechanisms.** Proposed approaches may consider, but are not limited to:
  - Increasing the optical efficiency of the vanes in combination with metamaterials or RCDs
  - Attaching vanes to the bus with a smaller moment arm than vanes attached to the tips of the booms for the specific purpose of out-of-plane control torque [4]

For the areas listed above, the performance metric shall be actuator control torque per unit mass, and the actuator or actuators must meet the minimum control torques specified in the table above.

The proposed actuator or actuators should scale with both sail size and distance from the sun and at a minimum be sized to the two sail sizes in the table above.

Proposals may:

- Propose an actuator not listed in the areas above.
- For actuators mounted on the tips of sail booms (e.g., vanes or RCDs), suggest novel ideas for provision of power and command to the actuators (e.g., wireless commanding or local thin film solar arrays).

Proposals are encouraged to offer development and testing of prototype devices to verify analysis. Proposals are also encouraged to suggest other applications for this technology.

Research products at the conclusion of the award are expected to include:

1. Estimated performance using the metric and torque requirements defined above.
2. Documentation of the design including mass, dimensions, volume, area, materials, method of controlling the actuator, and power.
3. Analysis to demonstrate requirements are met including simulations integrated with a sail disturbance torque model.
4. Test results of any prototypes developed.

References:


Please refer to Section 7 – 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 – Hibernation and Recovery of Solar-Powered Systems for Lunar Missions

The goal of this topic is to advance power systems to tolerate and operate in extreme cold and enable spacecraft to hibernate through a lunar night when energy resources are low and reliably restore operations when solar illumination returns at lunar dawn.

Extreme cold in the lunar environment is inescapable. The 354-hour lunar night will see temperate drop to 70K to 90K. Polar region darkness may last 5 months, and temperatures drop to 50K. Currently, no small lunar spacecraft claim to survive the lunar night without relying on scarce and costly radioisotope materials. Until now, batteries have been assumed to be the weak link to surviving the extreme cold. However, recent tests show that common Li-Ion 18650 cells can tolerate cryogenic temperatures and will recover when warmed up to normal temperatures. This implies that a solar powered spacecraft can potentially survive by ‘hibernating’ until solar illumination returns.

The concept of hibernation requires all electronics and batteries to tolerate extreme cold overnight and then recover and operate at Lunar Dawn. This capability to survive the extreme cold lunar environment would significantly improve the endurance and operational robustness of spacecraft in the lunar environment.

In a notional hibernation scenario, all systems, including batteries, are inactive and passively tolerate the cold. Batteries are isolated to prevent inadvertent charge or discharge damage. At lunar dawn, the coldest point in the cycle, solar arrays will be illuminated and start generating electrical power. As voltages rise, the main power system activates and regulates array output while routing power to controls that supply power to preheat essential functions such as batteries, control logic, and power regulators. Non-essential systems remain inactive at this point. Batteries are slowly heated until cells reach operational temperatures. Once diagnostics assure that cells are safely charged, the batteries are reconnected to the main power system. The
balance of the spacecraft systems is then preheated and progressively restarted until fully operational.

The current state of the art for spacecraft power systems is limited to a relatively modest temperature range typical of near-Earth operations. There is substantial published evidence that power devices can tolerate and operate at much lower temperatures.

Power hibernation technology extends the effectiveness of solar array power that, in the near term, applies to low-cost lunar robotic missions, but may be extensible to human lunar surface systems and in-situ resource utilization.

This solicitation topic specifically seeks proposals to advance the capabilities of solar powered systems to hibernate through lunar night and subsequently recover at lunar dawn. Proposals should address one or more of the following research areas:

- **Characterization of Lithium-Ion cells cycling through the freeze-thaw process down to 50K to support design and development of batteries capable of hibernation.**
  - Little is known about transition between normal and frozen states within Lithium-Ion cells and the effects on, electrolyte chemistry, thermal mechanical effects on cell structure, seals, “jelly roll” assembly, and built-in safety devices.

- **Develop and demonstrate cold cell fault detection and safing controls.**
  - Cell diagnostics that detect faults (internal shorts) while the cell is still frozen or in the thaw process enables a response while cells are still in a low energy state.
  - Safing controls that exploit cold environment to slowly dissipate energy from the faulty cell could prevent thermal runaway and improve spacecraft battery safety and fault tolerance.

- **Develop and demonstrate power regulators that tolerate poor power quality and operate over a 50K to 400K temperature range.**
  - Power controls and regulators that maintain steady output while tolerating low power-quality expected during dawn operations.
  - Power regulators that are insensitive to temperature due to effective temperature compensation techniques and/or by utilizing new semiconductor devices exhibiting a flat response over a wide temperature range (such as Gallium-Nitride).

- **Characterization and modeling of power devices throughout the 50K to 400K temperature range.**
  - Some electronic modelling and simulation tools can address low temperatures, but they are constrained by the lack of data beyond the common temperature range.
Proposals should:

- Strive to cover as much of the 50K to 400K range as possible; however, the low end of this temperature range is the higher priority.
- Consider that lunar missions may range from equatorial to polar regions.
- Consider lunar environment implications such as high vacuum and space radiation.

References:


LRO DIVINER Lunar Radiometer Experiment, https://www.diviner.ucla.edu/science


Please refer to Section 7 – 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 – Tailorable Composite Design Concepts towards Dimensionally Stable Structures**

The objective of this topic is to exploit structural composite tailorability and computational modeling to design and fabricate lightweight structures that remain dimensionally stable across a range of temperatures through innovative processing of combinations of materials including but not limited to polymers, fibers, ceramics, metals, and nanomaterials.

The recently released Astrophysics Decadal Plan [1] envisions a future where large telescopes enable the discovery of habitable exoplanets. Structural components of these instruments such as mirror supports and backplane require dimensional stabilities that exceed those of the Hubble and James Webb telescopes by three orders of magnitude. [2,3] However, the launch mass of these advanced telescopes remains a primary constraint. As such, structural design concepts that are optimized to provide the required functionality at minimum weight are desired.

Composites offer the potential for design concepts that capitalize on combinations of various materials to achieve performance characteristics that may not be achievable otherwise. SoA composite designs tend to be limited only to high modulus fibrous reinforcement bound together by a matrix material [4]; however, limiting composite designs to modifications in fiber layups is not sufficient to yield desired intrinsic dimensional stability attained without assistance from active thermal control. With the advent of topology optimization, the range of emerging material systems, and methods in computational materials [5-7] there is opportunity to combine multimaterial systems to tailor performance of novel hybrid material systems in ways beyond those available only through laminate stacking sequences. Such innovations are needed to yield performance characteristics that enable new operational concepts such as on-orbit assembly.

Advancements in modeling-driven materials design are needed to explore large material property and processing parameter spaces to yield the required manufacturable structural designs. It is noted that composite materials performance is a complex function of physical and thermal properties and fabrication methods. Examples of challenges that need to be addressed include but are not limited to:

- Compatibility of multiple materials such as polymers, ceramics, metallic alloys and short and/or continuous fiber reinforcements, when combined to yield high modulus composite structures with effective coefficient of expansion as close to zero as possible.
- Validated models capable of predicting mechanical properties and thermal stability of proposed multimaterial design concepts to demonstrate limits in performance characteristics.
• Topologically optimized designs of multimaterial combinations amenable to manufacturing by commercial processes.

This solicitation topic specifically seeks proposals for design concepts that support the required dimensional stability without assistance from active control. In order to more efficiently narrow the design broad space, proposals that span model guided design to proof of concept to overcome the above challenges are sought. The proposed work should include:

• Development of design tools with predictive capabilities for the use of disparate materials to achieve performance characteristics not possible with current material designs. Performance parameters of interest are:
  o Effective CTE control of 1-10 ppb/°K
  o Material systems with tensile modulus in the range of 275 - 400 GPa
  o Creep rates of <10^{-13}/hr

• Processing methods to validate the design concepts suggested by the modeling tools.
  o Identification of multimaterial interfacial issues that may arise from the design concept suggested by the modeling tools
  o Development of processing methods to overcome compatibility issues at the interface of disparate materials to achieve desired performance.

• Validation of the design concepts through fabrication and testing at coupon scale for evaluation of the proposed design concepts. Testing must include but is not limited to:
  o Effective CTE with test data including isotherm at 270°K over several hours
  o Tensile modulus
  o Creep resistance

Proposals must demonstrate how computational tools can be used to design advanced structures with the desired mechanical and thermal performance and validate the design concepts experimentally.

Proposers are encouraged to explore:
• Material combinations that can be used in large scale applications such as structures for the next generation telescopes
• Viability for manufacturing of proposed material systems with scalable processes

Proposals that focus primarily on the following will be considered non-responsive: (1) research that only develops computational modeling with no consideration for experimental validation of material system designs. (2) material system designs limited solely to tailoring of carbon fiber configurations such as tow-steering or fiber stacking
sequences (3) conceptual material designs that are not scalable to produce lightweight structural components.

References:


Please refer to Section 7 – 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 and the availability of funds. The actual number of awards will depend on the quality of the proposals received; NASA reserves the right to make no awards under this Appendix. The ECF Appendix covers only proposals for new awards; continuations of existing awards are handled separately.

The total award is subject to a maximum limit of $600K for three years. The typical annual award value is $200K; smaller amounts may be proposed. The amount in any year may not exceed $220K. 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 will be grants, subject to the provisions of 2 CFR (Code of Federal Regulations) 200, 2 CFR 1800, and the NASA Grant and Cooperative Agreement Manual (GCAM). Contracts will not be award 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 on behalf of their outstanding new faculty members who intend to develop academic careers related to space technology (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 Number of Proposals Per PI

A PI may submit only one proposal in response to this Appendix. Multiple submissions may result in all being deemed non-compliant.

The PI must be an untenured Assistant Professor on the tenure track at the sponsoring U.S. university at the time of award. If the PI’s appointment is scheduled to change to Associate Professor (either tenure-track or tenured) on or before the award date, he/she is not eligible for an ECF award. At the time of selection, the university must provide, on behalf of a selected PI, confirmation that he/she will remain untenured in a tenure-track Assistant Professor position until at least the award date (date the funding instrument is effective).

- Note 1: Universities may submit proposals on behalf of PIs who are being considered for a tenure-track position; however, the PI must be an untenured Assistant Professor on the tenure track at that university at the time of award.
- Note 2: The award will be terminated if, at any time, the PI transfers to a position that is not either tenure track or tenured.

The PI must be a U.S. citizen, U.S. national, or have lawful status of permanent residency (i.e., holder of a U.S. Permanent Resident Card, also referred to as a Green Card) at the time of proposal submission. The biographical sketch and department letter should specifically address the U.S. citizenship/permanent residency requirement.
The PI must be the primary researcher on the effort. Co-Investigators are not permitted. Collaborators are permitted. See “Collaboration” below for further requirements regarding collaborators. NASA civil servant and JPL collaborators are not permitted on submitted proposals. The PI may not be a current or former recipient of a Presidential Early Career Award for Scientists and Engineers (PECASE). Please see “Relationship of ECF to PECASE” below for further guidance. The PI may not be a current or former recipient of an STRG Program ECF award.

Diversity and inclusion are integral to mission success at NASA. NASA encourages submission of ECF proposals on behalf of early career 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)

Collaboration

Collaborators are permitted but not required. As specified in Appendix B of the 2021 NASA Guidebook for Proposers, a collaborator is an individual who 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 (see 4.3.5 of this Appendix for additional information) should document the nature and need for all collaborations. 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 ECF award may not include expenses for personnel or activities at collaborating institutions, nor salary costs for senior personnel, consultants, or subcontractors.

This ECF 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 can be no solicitation-related communications with NASA (including JPL) personnel from the time this Appendix is released until proposal selections are final. The proposer is permitted to identify potential specific fruitful collaborations with agency experts; however, these collaborations may not be discussed with agency personnel a priori. Potential collaborations will not be a factor in proposal evaluation, and letters of commitment from NASA (including JPL) are not permitted. If a proposal is selected, any potential NASA collaborations identified will be addressed at that time.

Relationship of ECF to PECASE

NASA selects its nominees for PECASE from the exceptionally meritorious awardees sponsored by its research programs. PECASE awards recognize outstanding scientists and engineers who, early in their careers, show exceptional potential for leadership at the frontiers of knowledge. The nominations are made by program officers at NASA Headquarters; NASA does not issue a special announcement for the PECASE award.
ECF awardees will constitute a source of nominations for PECASE by STMD. If an ECF awardee is selected for a PECASE award, the duration for the combined honor is five years. Conversely, current or former recipients of the PECASE award are not eligible to apply to ECF.

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 as 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 2021 NASA Guidebook for Proposers differ, the Appendix takes precedence.

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

4.3 Proposal Content and Submission
4.3.1 Electronic Proposal Submission
Offerors may submit proposals via NSPIRES or 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 March 31, 2022. 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 March 2, 2022. The NOI is submitted via NSPIRES. See 4.3.2 of the NRA for details of the information to be included in the NOI. 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 restriction on the number of proposals allowed as described in 3.0 of this Appendix – a maximum of one per PI – 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). See 4.3.4 of the NRA for NSPIRES and Grants.gov instructions.

4.3.5 Proposal Sections
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 2021 NASA Guidebook for Proposers). Proposals that fail to meet the requirements specified herein may be rejected without review.

<table>
<thead>
<tr>
<th>NASA Guidebook Section</th>
<th>Proposal Section</th>
<th>Maximum Page Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.12</td>
<td>1. Table of Contents</td>
<td>1</td>
</tr>
<tr>
<td>N/A</td>
<td>2. Proposal Summary Chart</td>
<td>1</td>
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<tr>
<td>2.13</td>
<td>3. Scientific/Technical/Management Section</td>
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<tr>
<td>2.11</td>
<td>4. Data Management Plan</td>
<td>1</td>
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<td>2.14</td>
<td>5. References and Citations</td>
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<td>2.15</td>
<td>6. Biographical Sketch</td>
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<td>7. Department Letter</td>
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<td>2.16</td>
<td>8. Current and Pending Support</td>
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<td>2.17</td>
<td>9. Statements of Commitment and Letters of Support</td>
<td>1 page each, if needed</td>
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<td>NASA Guidebook Section</td>
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<td>2.18</td>
<td>10. Proposal Budget with Budget Narrative and Budget Details</td>
<td>As needed</td>
</tr>
<tr>
<td>2.19</td>
<td>11. Facilities and Equipment (optional)</td>
<td>2 pages, if needed</td>
</tr>
</tbody>
</table>

Reviewers will not consider any content in excess of the page limits specified in the Table above.

**Section 1: Table of Contents**

See 2.12 of the 2021 *NASA Guidebook for Proposers*.

**Section 2: 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). As noted in 4.3.4.1 of the NRA, it should not include any proprietary or sensitive data as NASA intends to make it available to the public after selections are announced.

The chart must include the following information:

- A representative graphic with caption;
- The proposal title, the PI’s name, the PI’s institution and information (name and affiliation) of other team members, if any;
- The objectives of the research, a comparison to the SOA, discussion of the innovation, and start 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 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.
Section 3: Scientific/Technical/Management Section:

This is the main body of the proposal and must cover the following sub-sections in the order given. The Scientific/Technical/Management Section 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.

a) The relevance of the proposed research to the specific ECF 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 ECF 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 description of a clear 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 any hardware proposed to be built and discuss any facilities and/or capabilities that would be required to execute the proposed research. Access to NASA facilities should not be assumed during the course of the ECF effort, nor should NASA facilities be included in the proposal. (Note: facilities and proposer capabilities will be evaluated under the third evaluation criterion as described in 5.2 of this Appendix).

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 structure** for the proposal personnel, any collaboration(s) that is (are) proposed to complete the investigation, and a description of the expected contribution to the proposed effort by the PI and each collaborator or other team member, regardless of whether or not they derive support from the proposed budget. See 3.0 of this Appendix for restrictions. The relationship between strongly related and/or leveraged current support and the proposed research must be described in this section.

**Section 4: 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. Therefore, it is NASA’s intent that all knowledge developed under this Appendix be shared broadly through publication of the results.

All proposals 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 also 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 include information on how the proposer/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 2.5 of the NRA and Appendix J of the 2021 NASA Guidebook for Proposers.

**Section 5: References and Citations**

See 2.14 of the 2021 NASA Guidebook for Proposers.

**Section 6: Biographical Sketch**

The biographical sketch of the PI should include education and training, research and professional experience, synergistic activities, publications, book or book articles, patents, copyrights and software systems closely related to the proposed project. The sketch may also include collaborators and co-editors on research projects, and graduate and postdoctoral advisors and advisees. This section may not exceed 2 pages in length. The biographical sketch must clearly address the citizenship/permanent residency requirement specified in 3.0 of this Appendix.

See 2.15 of the 2021 NASA Guidebook for Proposers.

**Section 7: Department Letter**

The department letter shall be on the sponsoring university’s letterhead and include the department head's name and title below the signature. The letter may not exceed 2 pages in length and should contain the following elements:

- A description of the relationship between the proposed ECF effort, the PI's career goals and job responsibilities, and the goals of his/her department/organization;
- An indication that the PI's proposed research activities are supported by the department and that the department is committed to the support and professional development of the PI;
- The ways in which the department head (or equivalent) will ensure the appropriate mentoring of the PI; and
- Statements confirming that the PI meets the eligibility requirements (tenure track and untenured, U.S. citizen or permanent resident, no current or former PECASE award) specified in 3.2 of this Appendix.

**Section 8: Current and Pending Support**

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

All current project support from whatever 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 the Appendix of any successful proposals that are awarded any time after the ECF proposal due date and until the time that NASA’s selections are announced.

Also see 2.16 of the 2021 NASA Guidebook for Proposers.

**Section 9: Statements of Commitment and Letters of Support**

Every collaborator identified 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).

In the event that a 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.

In addition, a letter of support (one page maximum each) is required if there is a facility or resource essential to the proposal not under the control of a proposal team member listed on the NSPIRES Cover Page. The letter(s) may not include a personal endorsement or recommendation of the investigator or the proposed research but should be limited only to the description of the support that will be offered. The Scientific/Technical/Management Section should document the nature and need for all collaborations (see above).

Statements of commitment and/or letters of support from NASA civil servants and JPL employees are not permitted.
Section 10: Proposal Budget with Budget Narrative and Budget Details

The 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.

Proposal funding restrictions are detailed in 4.3.7 of the NRA. Additional restrictions for this ECF 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 ECF award may not include any expenses for the collaboration effort.

Also see 2.18 of the 2021 NASA Guidebook for Proposers.

Section 11: 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 ECF effort, nor should NASA facilities be included in the proposal.

Also see 2.19 of the 2021 NASA Guidebook for Proposers.

4.3.7 Proposal Funding Restrictions

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

5.2 Review Process

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 their intended meaning of each criteria; the order of the questions is not intended to indicate order of importance. The three primary evaluation criteria – 1) Relevance, 2) Technical Approach, and 3) Suitability of PI/Team, Resources, and Cost – are all equally weighted.

Relevance

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 demonstrate a clear path for further development and exploitation for space science and exploration needs? Does the technology have the potential to be crosscutting?

Technical Approach

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?

- **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? 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?
Suitability of PI/Team, Resources, and Cost

Evaluation includes consideration of the following:

- **Qualifications and Capabilities of PI/Team**: What is the potential of the PI to conduct successful research? How well qualified are the PI and the research team to carry out the proposed research – do they possess sufficient technical knowledge and the capabilities required? Are roles, including those of any collaborators, clearly defined? (Note: potential NASA collaborations identified will not be evaluated) Is the management structure appropriate?

- **University Support**: Does the university show long-term commitment to the Early Career Faculty researcher’s career development?

- **Facilities**: Are facilities appropriate to complete the planned research? Does the proposal team have access to (commitment from) the appropriate facilities?

- **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?

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 and the submitting institution. Peer reviewers are selected with regard to both their scientific expertise and the absence of conflicts of interest.

The Selection Official for this Appendix will be the NASA Space Technology Mission Directorate Associate Administrator 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 on or about August 05, 2022. 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, an October 1, 2022, award start 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.

Research Terms and Conditions

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.

Environmental Impact

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 (R&D) 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 2021 NASA Guidebook for Proposers 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 ECF awards:

**Quarterly Progress Reports.** The PI shall submit progress reports every 90 days, with the first one due 90 days after the grant start date. The reports will provide a summary of progress against the work plan; discussion of upcoming activities; student information; any issues or concerns that should be brought to the attention of the program; and data related to publications, presentations, conferences, inventions, follow-on funding, and press received. These data are referred to as grant visibility and impact data.
**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 report 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, discussion of relevance, and an update to overall work plan and associated schedule), in addition to the grant visibility and impact data and summary of research slide. An associated continuation review presentation, virtually or at a NASA Center, of progress and plans will also be required.

**Technical Seminar.** 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.

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

### 7.0 POINTS OF CONTACT FOR FURTHER INFORMATION

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

Claudia Meyer  
Space Technology Research Grants Program Executive  
Space Technology Mission Directorate, NASA Headquarters  
*hq-ecf-call@mail.nasa.gov*

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

Kimberly Cone  
SpaceTech-REDDI NRA Manager  
Office of Procurement, NASA LaRC  
*hq-ecf-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 March 25, 2022; 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.