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 CAREER FACULTY APPENDIX

to


APPENDIX NUMBER: 80HQTR20NOA01-20ECF-B1

Appendix Issued: February 5, 2020
Notices of Intent Due: February 26, 2020 (5 PM Eastern)
Proposals Due: March 25, 2020 (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-2020 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 5, 2020
- Notices of Intent Due: February 26, 2020
- Proposals Due: March 25, 2020
- Selection Notification: July 30, 2020 (target)
- Award Start Date: October 1, 2020 (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
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Note: The organization and section numbering of this Appendix mirror the SpaceTech-REDDI-2020 NRA for convenience when cross-referencing content between the two documents.
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 four calls for proposals from STMD’s Space Technology Research Grants (STRG) Program. Early Stage Innovations (ESI), Space Technology Research Institutes (STRI) in applicable years, and NASA Space Technology Graduate Research Opportunities (NSTGRO) appear as Appendix B2, Appendix B3, and Appendix B4, 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 industrial, 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 universities/PIs. 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, not necessarily directed at a specific mission, 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 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. Although progress under an award may be incremental, the projected impact at the system level must be substantial and clearly defined. 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 four 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 (https://www.nasa.gov/offices/oct/taxonomy/index.html).

NASA developed the 2020 NASA Technology Taxonomy to articulate the technology developments needed to enable future space missions; the taxonomy identifies, organizes, and communicates technology areas relevant to advancing the agency’s capability needs. Each of these discipline-based taxonomies focuses on a technology area. The 2020 NASA Technology Taxonomy builds upon the technology roadmaps which were drafted in 2010, followed by updates in 2012 and 2015.

1.3 Topics

**Topic 1 – Coordinated Multi-Robots for Planetary Exploration**

The objective of this topic is to develop technology that enables multiple robots to work in a coordinated manner for planetary exploration. Recent demonstrations have shown that even small, lightweight platforms can exert significant forces on the environment and objects when they coordinate their actions and apply anchoring, tugging, and
controlled adhesion. In particular, coordinated multi-robot teams have been able to move and manipulate objects that are 40x their individual mass.

Future robotic missions will need to access and explore more challenging sites than have been reached to date, including steep and broken terrain, subsurface voids, and other extreme locations. Future missions will also need to perform tasks that far exceed the force and payload capabilities of current robotic systems. Coordinated multi-robots have the potential to address these challenges, while also increasing mission flexibility and robustness.

NASA currently employs planetary rovers, such as Curiosity and Mars 2020, to carry out surface missions. These rovers carry science instruments and perform limited sampling activities (rock coring, near subsurface drilling, etc.). Current rovers, however, do not have the capability to: explore extreme terrain (cliff walls, large craters, ejecta blankets, skylights, etc.); deploy and position large or massive objects; or carry out tasks that require applying significant forces to objects, payloads, or the local environment.

Early stage research is needed to understand how NASA can leverage such multi-robot teams to support exploration and science missions. Anticipated new capabilities include steep slope ascent/descent, skylight and lava tube exploration, terrain modification, large payload deployment and positioning, and collection of in-situ resources.

This topic specifically seeks algorithms, methods, and prototypes that enable coordinated and forceful environment/object interaction with small teams of robots. Proposals should:

- Focus on developing and demonstrating technology for coordinated physical action, rather than merely focusing on parallel task execution or distributed robot activity; and
- Consider how multiple robots working as a team, perhaps with heterogeneous autonomous capabilities, can exploit "mechanical advantage", and non-prehensile / grasp-less manipulation (pushing, pivoting, etc.) to accomplish tasks.

Proposals must:

- Create and systematically evaluate new technology rather than simply making incremental enhancements to the current state of the art;
- Include development of a "proof of concept" demonstration, preferably in a relevant analog environment; and
- Describe how technical advances could be integrated and applied to future NASA missions.

Proposals are particularly encouraged to develop technologies applicable to lunar and Mars exploration.
Proposals that focus primarily on the following will be considered non-responsive: (1) research that only develops system capability, but does not include metrics and systematic testing; (2) multi-robot systems that do not involve coordinated and forceful environment/object interaction; (3) large-scale swarm, cellular, or collective robotics.

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 – Advanced Plant / Food Production Technologies for Space Exploration**

The goal of this topic is to advance the capabilities needed to effectively grow plants as a source of food for space exploration missions.

Providing life support for human crews for space missions requires nutritious and safe food. This is currently done through stowage and resupply of packaged, stabilized foods for the International Space Station (ISS), but for longer missions, such as the lunar surface, Mars transit, and the Mars surface, the impacts of stowing all food for an entire mission increase significantly. For example, some estimates for the amount of food and packaging needed to support a crew of 4 humans for a Mars landing and return mission are as high as 10 metric tons. In addition, packaged food diets would not have components such as fresh vegetable and fruits. Such fresh foods can provide micronutrients that are difficult to add in packaged diets (e.g., Vit. K and potassium) or that degrade with time (e.g., Vit. C and Vit. B1), while adding flavors, textures, and aromas to the meals.

An approach to provide dietary nutrients and augment the variety of foods would be growing plants in situ for space missions. Even if the plants only provided a fraction of the overall dietary needs for early stages of a mission, such fresh foods could reduce human nutritional risks, add diversity to the diet, and provide experience for expanding plant growth systems for future missions.

To date, some leafy vegetables such as lettuce, mizuna, pea, and pak choi have been grown on the ISS and the Russian Mir Space Station. Future plans include growing small fruiting crops such as tomato and pepper. This in-space ‘agriculture’ is typically done in small plant chambers, like NASA’s Veggie unit, that provide lighting with LEDs, use arcillite (calcined clay particile) with time release fertilizer, and use cabin air to provide chamber cooling and the CO2 needed by the plants. But these approaches are limited by size, volume, power, and water management constraints; in addition, the microgravity environment such as in the ISS and on a Mars transit poses an additional challenge.

As a result, advancements are needed in: 1) identifying and selecting appropriate food crops for space environments; 2) capabilities to monitor the plants and their
environment; 3) understanding the physiological, biochemical, and genetic properties of food crops for optimizing growth, nutrition, and plant health, and 4) understanding the interactions between crop plants and their associated microbiome. These goals are similar in many ways to basic goals for controlled environment agriculture on Earth, except that space systems are atmospherically closed, have fractional or microgravity, and are limited with regard to volume, mass, and energy inputs.

This solicitation topic specifically seeks proposals to advance technologies for plant and food production for human spaceflight that address one or more of the following research areas:

- **Selection, breeding, or genetic engineering of dwarf or short stature crops** with a high harvest index (ratio of edible to total biomass) for food production systems in space. These could include, but are not limited to, vegetables, legumes, grains, tuberous crops, fruiting crops, and even dwarf fruit trees and brambles with little or no dormancy requirements for flowering. The desired outcome would be high value, productive crop(s) / genotype(s) that could be used for future space missions.

- **Improved photosynthetic efficiencies**, which include genetic modification and horticultural improvements for light capture, more efficient energy conversion of light, efficient crop canopy architectures, and improved carbon capture and conversion, for lunar, Martian and deep space environments.

- **Advanced methods for remotely sensing** the status of plants in controlled environments of space to assess their overall health, growth, performance, and plant stress. Example methods include hyperspectral sensing of crops, use of bio-indicators in the crops themselves, or sensing of volatile compounds that provide information on the crop growth and development.

- **Identification and use of beneficial microbes or microbial consortia** for increasing crop growth, yield, improve food safety, and resilience to stress. The beneficial effects of candidate organisms or microbial consortia should be validated with crops in controlled environment settings.

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 3 – Enhanced Diagnostics for Characterizing Entry Aerothermal Environments in High-enthalpy Impulse Facilities**

The goal of this topic is to develop diagnostic techniques to provide detailed measurements of flowfield properties for high-enthalpy impulse facilities, such as shock tubes, used to simulate aerothermal environments experienced by spacecraft during atmospheric entry.

All entry, descent, and landing (EDL) missions have wrestled with uncertainties that stem from modeling the thermochemically non-equilibrium plasma generated during atmospheric entry. Modeling is crucial for the entry phase, in particular, because no ground test facilities are capable of simultaneously reproducing all aspects of the flight environment. Design margins used during mission planning are directly proportional to modeling uncertainty. Too much uncertainty can either result in excessive thermal protection system (TPS) mass, which in turn could drive a reduction in delivered payload in order to meet spacecraft mass constraints. Alternatively, if the payload mass is already allocated, significant resources must be expended in order to confidently close the design without impacting payload. The latter scenario has occurred at various points during the designs of the Mars 2020, Mars InSight, and Artemis entry vehicles.

Key barriers to uncertainty reduction are (1) difficulty in properly characterizing ground test experiments, which provide much of the benchmark data for model construction and validation, and (2) extrapolating the resulting models to flight. Typical facilities for generating high-enthalpy, non-equilibrium environments include shock tubes, arc jets, and other arc and plasma sources. Outputs of such facilities are typically integrated quantities of interest, such as radiance or heat flux, that may be used to assess the overall accuracy of a model but which give limited insight into specific sources of modeling error. By probing detailed non-equilibrium processes of the flow with new diagnostic techniques, data will be available to better characterize the flow and improve model validation. Having well-validated models at fundamental physical and chemical scales will enable development of more accurate, physics-based tools, and thereby reduce uncertainty in extrapolation to flight environments.

Current state-of-the-art (SOA) diagnostics to measure species populations often exhibit poor signal-to-noise and/or large uncertainties when applied at time scales relevant to
high-enthalpy impulse facilities. As such, capabilities are sought to provide significant improvement (2x or better) upon SOA diagnostics and/or new measurement techniques that extend the SOA to more states/species. In addition, capabilities are sought to measure multiple temperature components simultaneously, extend operational capability to new test gases, and/or provide significant (2x or better) reductions in measurement uncertainty when compared to SOA. Pitot measurements provide estimates of flow uniformity, but generally do not have sufficient resolution to measure the boundary layer thickness. In the case of shock tubes, shock velocity is typically measured to within 1% accuracy by monitoring time-of-arrival through pressure sensors embedded in the tube wall.

This solicitation topic seeks proposals for new or significantly enhanced diagnostics that enable access to additional species or state populations, enable simultaneous measurement of multiple temperatures, and/or improve understanding of fluid dynamics with sufficient spatial and temporal resolution as outlined below. Proposals should specifically address one or more of the following:

- **Population measurements** of electronically/vibrationally excited states and ground states for atoms, molecules, and ions, as well as measurements of electron number density.
- **Measurement of translational, rotational, vibrational, electronic, and electron temperatures.**
- **Measurement of the boundary layer thickness** of the shocked test gas within 20%.
- **High accuracy measurements of shock velocity** within 1% (based on the current standard using piezoelectric elements). Velocity measurements of the test gas behind the shock front using non-intrusive techniques are also sought.

Proposals must consider the unique constraints imposed upon diagnostic techniques due to the environments and time scales associated with high-enthalpy impulse facilities. To be considered responsive, proposed diagnostic techniques must meet the following requirements:

- Data must be obtained as time or space-varying quantities, with:
  - Temporal resolutions on the order of nanoseconds to microseconds.
  - Spatial resolution on the order of millimeters.
- Sufficient signal-to-noise must be demonstrated to provide validation data for model refinement.
- Non-intrusive diagnostics, or the capability to survive the passing of the shock in a repeatable fashion (i.e., > 10 experiments) without significantly altering the flow.
Furthermore, for relevance to atmospheric entry, this topic is focused on the ability to measure temperatures and populations for any of the following species: N, O, C, NO, N₂, N₂⁺, CN, CO, CO₂, H and He.

Proposals should identify the corresponding state of the art for their diagnostic(s) and how the proposed technical approach will advance diagnostic capability. Proposals should also present a plan for verification of diagnostic performance. Although it is not a requirement to include testing specifically in a high-enthalpy facility, proposers are strongly encouraged to consider such testing as a means of verification in the target environment. If high-enthalpy testing is not feasible within scope of the proposed effort, proposals should identify facilities for follow-on testing under application-relevant conditions.

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 4 – Micro or Nano-structuring Multi-layer Insulation Shields for Ultra-low Emissivity**

The goal of this topic is to develop and demonstrate novel manufacturing and fabrication techniques to improve thermal performance of thin film reflective foils used in multi-layer insulation (MLI) systems for spacecraft.

The purpose of an MLI system is to increase the overall thermal resistance (or decrease the heat load) to a component or fluid of interest. Protection of satellites and manned and un-manned spacecraft, as well as long term storage of cryogenic fluids such as liquid hydrogen or liquid oxygen, depends on the performance of these passive thermal insulation systems in combination with the structural design and operational environment.

In order to achieve superior performance in harsh space environments where radiation heat transfer from the Sun and Earth is high, an MLI system is generally composed of highly reflective thin film radiation shields separated by a low thermally conductive spacer material. Traditional thin film metalized foils employed in MLI systems have been used for over 60 years. However, there has not been a significant improvement in performance despite numerous advancements in micro- and nano-structuring manufacturing and fabrication techniques. Improving the performance of MLI can result in a reduced heat load, passive insulation system mass, and ultimately increased mission duration.

MLI radiation shields typically consist of a lightweight Mylar base coated on both sides with highly reflective metalized substances such as aluminum. Radiation heat transfer of these metalized thin film foils is directly proportional to the ratio of incident to reflected
incident radiation, and is typically referred to as the “reflectivity” or “normal reflectivity” in the context of mid-infrared radiation (i.e wavelengths on the order of 10 μm). The current state of the art for normal reflectivity of aluminized mylar foils is 96-97%, and silver-ized and gold-ized foils can achieve ~97-98%. However, the ratio of incident-to-reflected solar radiation is much lower for these materials due to the addition of ultraviolet, visible, and near-infrared wavelengths. Therefore, in-space reflectors must be designed to deal with a wavelength band from roughly 0.2 to 4 μm, which encompasses 99.99% of the solar emittance.

An approach to improve MLI performance for future spacecraft is through the radiative properties of materials that can be somewhat tailored to specific requirements by manipulating characteristic length scales of surfaces with which the electromagnetic radiation interacts most. For example, in a material in which the incoming and outgoing electromagnetic waves peak at different wavelengths, designing a surface that is spectrally selective (highly reflective over part of the spectrum and high absorbing at other wavelengths) is particularly suitable.

For MLI applications, altering the surface finish on the micro- or nano-scale can lead to changes in properties such as emissivity, reflectivity, and absorptivity. Techniques that could be used, but are not limited to:

- Coatings
- Spectrally selective materials
- Grooves
- Patterns
- Ordered colloidal micro- or nano-particle three-dimensional arrays
- Photonic crystals
- Porous metallic nanostructures
- Periodic or micro-machined gratings
- Birefringent polymers
- Dielectric films

This solicitation topic specifically seeks proposals to design, fabricate, and demonstrate higher performance, ultra-low emissivity, low mass, metalized thin film foils for use in MLI systems that utilize novel micro- or nano-structuring techniques (examples cited above) to alter the surface finish of thin film reflectors for infrared wavelengths.

Proposed approaches should:

- Develop and demonstrate fabrication techniques that lead to a gain in thin film reflectivity (reduction in emissivity), with a target goal of a full order of magnitude.
- Experimentally characterize critical parameters in order to assess and optimize performance of the novel MLI prototype materials, including measurement of:
- Emissivity/Reflectivity as a function of wavelength and temperature (minimum of 0.2 µm to 10 µm)
- Mechanical strength (drapability, stiffness, mechanical handle-ability, general mechanical modifications related to use as a multi-layer stack-up of films)
- Physical characteristics of interest, such as thickness, mass per unit area, and in-plane electrical conductivity (static dissipation)

- Provide preliminary evaluation of the basic feasibility of commercial production of thin film material. The film needs to be structurally and mechanically sound for use in future insulation systems. This assessment of manufacturability is of interest for both sub-scale (for example, 0.3-m by 0.3-m) and full-scale product (for example, 1-m width roll goods)

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

2.1 Funding and Period of Performance Information

NASA plans to make approximately 8 awards 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 typical annual award value is $200K; smaller amounts may be proposed. The amount in any year may not exceed $220K and is subject to a maximum limit of $600K for three years. 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 the 2 CFR (Code of Federal Regulations) 200, 2 CFR 1800, and the NASA Grant and Cooperative Agreement Manual (https://prod.nais.nasa.gov/pub/pub_library/srba/).
3.0 ELIGIBILITY INFORMATION

Eligibility of Applicants

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.

The proposed research must be led by a single, eligible PI:

- 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 or have lawful status of permanent residency (i.e., holder of a U.S. Permanent Resident Card, also referred to as a Green Card) no later than August 1 following the proposal submission deadline, and both 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.

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.
Cost Sharing

Cost sharing is not required.

Limitation on Number of Proposals Per PI/Organization

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

There is no limit on the number of proposals which may be submitted by an accredited U.S. university.

Collaboration

Collaborators are permitted but not required. As specified in Appendix B of the 2018 NASA Guidebook for Proposers, a collaborator is not critical to the proposal but who is committed to provide a focused but unfunded contribution for a specific task. The Scientific/Technical/Management Section of the proposal (see 4.0 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) researchers and managers 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 (see 4.0 of this Appendix); however, these collaborations may not be a priori discussed with agency personnel, they will not be a factor in proposal evaluation, and letters of commitment from NASA (including JPL) are not permitted. As stated previously, one objective of this Appendix is to foster interactions between NASA and the awarded universities/PIs. Therefore, collaboration/interaction with NASA researchers should be expected while conducting the space technology research under these awards. If a proposal is selected, any potential NASA collaborations identified will be addressed at that time.

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

Relationship of ECF to PECASE

Each year, 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.

4.0 PROPOSAL SUBMISSION INFORMATION

The following information supplements the information provided in 4.0 of the NRA. Note that in instances where this Appendix and the NRA or Guidebook differ, the Appendix takes precedence.

- Offerors may submit proposals via NSPIRES or Grants.gov. See 4.3.1 of the NRA for details.
- Notice of Intent (NOI) to Propose: NOIs are strongly encouraged by February 26, 2020. See 4.3.2 of the NRA for details.
  - 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 respondents are encouraged to consider this restriction as early in the proposal window as possible, ideally prior to the NOI submission due date, and focus efforts on the proposal they deem most likely to succeed.
  - NASA is unable to provide feedback on NOIs.
- Proposal Submission Deadline: 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 25, 2020. Proposals submitted after the proposal deadline will be considered late and may be rejected without review.
- Proposal Cover Pages: This Appendix has associated program specific data (PSD) questions. See 4.3.4 of the NRA for NSPIRES and Grants.gov instructions.
- Proposal Sections:

The Proposal must include the following sections, as needed and in the order listed (please note frequent references to 3. Proposal Preparation and Organization of the 2018 NASA Guidebook for Proposers):
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<td>7. Current and Pending Support</td>
<td>As needed</td>
</tr>
<tr>
<td>3.17</td>
<td>8. Letters of Collaboration</td>
<td>1 page each, if needed</td>
</tr>
<tr>
<td>3.18</td>
<td>9. Proposal Budget with Budget Narrative and Budget Details (including facility descriptions, if needed)</td>
<td>As needed (Note: facility descriptions, if needed, may not exceed 2 pages total)</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 3.12 of the *NASA Guidebook for Proposers*.

**Section 2: Overview Chart:**

The overview 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 key 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 overview chart should be organized as illustrated in Figure 1 – Template for Required Overview Chart and must be oriented as shown (i.e., landscape mode).

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**Figure 1 - Template for Required Overview Chart**

**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 11 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 technology transition; 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, as well as a description of any hardware proposed to be built
and any facilities and/or capabilities required to execute the proposed research.
(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.

The work plan should also include a brief data management plan - a clear
statement of how the proposer intends to publicly disseminate results as well as
evidence (if any) of past data sharing practices. 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 solicitation be shared broadly through
publication of the results. Award recipients may be subject to reporting
requirements under the NASA Plan for Increasing Access to the Results of
Scientific Research, including submitting peer-reviewed manuscripts and
metadata to a designated repository (currently PubMed Central) and reporting
publications with progress reports. For more details on public access to scientific
publications and digital scientific data resulting from NASA-funded research and
the above-mentioned plan, please see:
https://www.nasa.gov/open/researchaccess/public-access-results;

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 substantial
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, regardless of whether or not they derive support from the proposed budget. The relationship between strongly related and/or leveraged current support and the proposed research must be described in this section.

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 on submitted proposals**, and there can be no solicitation-related communications with NASA (including JPL) researchers and managers 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 in this section of the submitted proposal; however, these collaborations may not be a priori discussed with agency personnel, they will not be a factor in proposal evaluation (see 5.2 of this Appendix), 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.

**Section 4: References and Citations**

See 3.14 of the *NASA Guidebook for Proposers*.

**Section 5: 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 two pages in length. The biographical sketch must clearly address the citizenship/permanent residency requirement specified in 3.0 of this Appendix.

**Section 6: 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 two 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 3.0 of this Appendix.

Section 7: 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 3.16 of the NASA Guidebook for Proposers.

Section 8: Letters of Collaboration

If applicable, the proposal must include (one-page maximum each) signed letters of collaboration that specify the nature of the collaboration, such as intellectual contributions to the project, permission to access a site, an instrument or facility (that is not under the PI's direct control), offer of samples and materials for research, logistical support to the research program, and off-site interaction with students. The letter(s) should NOT include a personal endorsement or recommendation of the investigator, but should be limited only to the description of the support that will be offered. Letters of collaboration from NASA civil servants and JPL employees are not permitted. The Scientific/Technical/Management Section should document the nature and need for all collaborations (see above).

Also see 3.17 of the NASA Guidebook for Proposers.

Section 9: 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.

Please note that, if required, facility descriptions may be included in this section; however, they may not exceed 2 pages (total) in length.

Also see 3.18 of the *NASA Guidebook for Proposers*.

5.0 PROPOSAL REVIEW INFORMATION

5.2 Evaluation Criteria

The evaluation criteria (all equally weighted) considered in evaluating proposals under this Appendix are given below. The questions associated with each criterion are provided to elaborate on the intended meaning of each criterion; the order of the questions is not intended to indicate order of importance.

**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?
• **Technology Transition**: 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 (1-2) 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?

5.3 **Review and Selection Processes**
Both Federal and non-Federal 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 Associate Administrator or designee.
5.5 Selection Announcement and Award Dates

Selection notifications are anticipated on or about July 30, 2020. 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.

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 NASA Grants and Cooperative Agreement Manual (GCAM, accessible from https://prod.nais.nasa.gov/cgi-bin/nais/nasa_ref.cgi). 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, 2020, 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

Please see Section 5.10.1 of the GCAM for more information, including useful links.

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 Section 3.21 of the Proposer’s Guidebook for more information.

6.2 Award Reporting Requirements

The reporting requirements will be consistent with 2 CFR 1800.902 “Technical Publications and Reports” and Exhibit E - Required Publications and Reports of the NASA Grant and Cooperative Agreement Manual. Grants and cooperative agreements typically require annual and final technical reports, financial reports, and final patent
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 (templates will be provided):

**Quarterly Progress Reports.** The Principal Investigator (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.

**Year-End (Annual) Reports.** The year-end report will take the place of the fourth Quarterly Progress Report. In addition to the information described above, an annual summary of research chart is required.

**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. 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 research summary slide) at the end of the final grant year.


For information about data rights, and other aspects of intellectual property such as invention rights resulting from awards, see the file entitled "Award and Intellectual Property Information" under the section called "Grant and Cooperative Agreement Guidance" at https://prod.nais.nasa.gov/pub/pub_library/srba/.
7.0 POINTS OF CONTACT FOR FURTHER INFORMATION

Technical questions 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

Procurement questions and comments about this Appendix may be directed to:

Kimberly Cone
ECF Acquisition Official
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 19, 2020; 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.