APPENDIX NUMBER: 80HQTR19NOA01-19ECF-B1

Appendix Issued: March 13, 2019
Notices of Intent Due: April 3, 2019 (5 PM Eastern)
Proposals Due: May 1, 2019 (5 PM Eastern, 2 PM Pacific)

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Summary of Key Information

Appendix Name: Early Career Faculty (ECF), hereafter called “Appendix” to the SpaceTech-REDDI-2019 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: March 13, 2019
- Notices of Intent Due: April 3, 2019
- Proposals Due: May 1, 2019
- Selection Notification: September 4, 2019 (target)
- Award Start Date: October 15, 2019 (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 and cooperative agreements. Cost sharing is not required.

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

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Note: The organization and section numbering of this Appendix mirror the SpaceTech-REDDI-2019 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), and Space Technology Research Institutes (STRI) in applicable years, appear as Appendix B2 and Appendix B3, respectively, under the SpaceTech-REDDI NRA, and NASA Space Technology Research Fellowships (NSTRF) is a separate solicitation.

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.

This 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 Appendix 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 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 Technology Roadmaps (http://www.nasa.gov/offices/oct/home/roadmaps/index.html).

NASA developed a set of Technology Roadmaps in order to facilitate the development and demonstration of space technologies that address the needs of NASA's exploration systems, earth and space science, space operations and aeronautics mission areas, as well as those that contribute to critical national and commercial needs in advanced space technology. Each of these roadmaps focuses on a technology area. The 2015 NASA Technology Roadmaps expand and update the 2012 roadmaps, providing extensive details about anticipated NASA mission capabilities and associated technology development needs.

The 2012 Technology Roadmaps were reviewed by the National Research Council (NRC). The NRC's review resulted in findings, recommendations, and priorities – within and across the technology areas – intended to inform NASA's space technology investments. Proposers may refer to the NRC final report (http://www.nap.edu/catalog.php?record_id=13354) for additional context.
The topics described in 1.3 are also consistent with the NASA Strategic Space Technology Investment Plan (http://www.nasa.gov/offices/oct/home/sstip.html#.UowA2XemYRc).

1.3 Topics

**Topic 1 - Advancing Human-Robot Teams for Space Exploration**

The objective of this topic is to develop technologies that enable high-performing human-robot teams for space exploration. Future human missions to the Gateway, Moon, Mars, and other distant worlds offer many new opportunities for exploration. However, astronaut time will always be limited and some work will not be feasible, practical, or efficient for humans to do manually. Robots can complement human explorers, performing work autonomously and under remote supervision from Earth.

Future human-robot teams need not be limited to the traditional model of "robot as tool". Instead, future human-robot teams may work in a loosely-coupled, yet interdependent manner where robots operate independently for extended periods of time from humans. Such human-robot teams can perform a wide range of tasks in space or on planetary surfaces. These include in-situ resource utilization, assembly of large structures or systems, food production, reconnaissance, and sample collection/return.

Since the coordination of a distributed team of humans and robots is complex, a major challenge is to develop tools and techniques that allow each team member to operate effectively with each other. Another challenge is to develop human-robot interaction methods that enable humans (both ground control and astronauts) and robots to communicate clearly about their capabilities, intent, state, and accomplishments. Finally, a third challenge is to enable human-robot team members to coordinate and collaborate to solve problems, especially when situations exceed autonomous capabilities.

To address these challenges, this topic specifically seeks proposals to develop new technologies for human-robot teams. Proposals should address one (or both) of the following research areas:

- **Methods, design principles, and technology** to produce highly effective and efficient user interfaces for distributed human-robot teams. Research that addresses improving objective workload metrics, developing workload detection methods, creating workload prediction models, or applying workload management strategies to user interfaces are particularly encouraged.

- **Techniques and tools** to facilitate human understanding of autonomous robot actions, particularly: (1) in the presence of poor (intermittent, bandwidth-limited, and/or high-latency) communications for distributed teams, or (2) when co-located humans and robots operate with limited or intermittent interaction.
Research in explainable artificial intelligence, summarization, and notification to enable robots to concisely explain their activity to humans are particularly encouraged.

Proposals should focus on creating and evaluating (via analysis and/or systematic testing) new technology rather than simply making incremental enhancements to the current state of the art. Proposals must describe how technical advances in the above areas could be applied to future NASA missions. Proposals are particularly encouraged to develop technologies applicable to robots of similar archetypes and capabilities to NASA robots such as Astrobee, Curiosity, or Robonaut 2.

Proposals that focus primarily on the following will be considered non-responsive: (1) Research that only demonstrates system capability and does not include models, metrics, or theory; (2) Augmented reality, telepresence, or virtual reality interfaces without experimental evidence justifying the quantitative benefit of such interfaces; and (3) Direct teleoperation (manual control).

Please refer to Section 7 – Points of Contact for Further Information of this Appendix if you have technical questions pertaining to this topic.

**Topic 2 - Terrain Mapping and Processing Algorithms**

The objective of this topic is to develop algorithms for processing terrain data in real time to improve the probability of successful landings on NASA’s exploration missions.

Recent NASA projects have developed technologies to allow precise, controlled, and safe landing for future robotic and human missions to the Moon and Mars. While advances in guidance and navigation algorithms facilitate precise and controlled landings, a safe landing depends on the ability to accurately map the terrain surrounding the target landing site, quickly identifying terrain features that are hazardous to a lander, and determining safe landing locations.

Some of the safe and precise landing technologies currently under development, including sensors, processors, and guidance, navigation and control (GN&C) algorithms, have been tested both in high-fidelity simulation environments and onboard sub-orbital flight vehicles. However, advances are needed in onboard terrain mapping and processing technologies to both reduce the computational complexity of the algorithms and provide comprehensive knowledge of safe landing regions.

There are two steps to processing terrain data before it can be incorporated into the spacecraft’s GN&C system. The first step is obtaining a digital elevation map (DEM) of the surface through optical cameras and/or LIDAR. The second step is to analyze that DEM to identify terrain hazards and safe landing zones. While obtaining a high-quality DEM depends on the accuracy and precision of the sensors, successful identification of terrain hazards and transferring the information to the GN&C system depends on
algorithms. Machine learning or pattern recognition methods quickly assess the 3D maps and define a probability of safe landing associated with potential landing zones. Such algorithms utilize pre-defined parameters such as lander geometry and touchdown-related landing tolerances. Additionally, integrating safety maps with path planning algorithms could potentially yield more fuel-efficient divert maneuvers.

NASA has been making steady progress in the development of space-qualified sensors and processors for future hazard detection systems. The state of the art for terrain processing algorithms is the Autonomous Landing Hazard Avoidance Technology (ALHAT) project which included a complete suite of sensors and algorithms that mapped a 100m X 100m surface area within 5 seconds and provided its host lander vehicle with a safety map and a list of discrete landing points within another 5 seconds, onboard and in real time during the descent. The ALHAT hazard detection algorithm performed extremely well both mapping the surface and constructing a probabilistic safety map, and it will serve as the benchmark for comparison with future efforts. The ALHAT algorithm calculated local safety information using basic roughness, slope and hazard size constraints to provide only a list of discrete landing locations; it did not implement an integrated system-based selection of landing zones to make inflight divert maneuvers.

This solicitation topic specifically seeks proposals for algorithms that (1) rapidly process real time terrain data; (2) generate a map of potential landing zones with an associated probability of safety; and (3) differentiate and prioritize safe landing zones based on system level parameters (see list below).

- Proposals must focus on the algorithmic aspects of hazard detection (terrain mapping is not the key aspect of this solicitation).
- Proposers can start with an existing digital elevation map or use camera/LIDAR sensors to capture images of synthetic/relevant terrain.
- Example parameters to consider when defining a safe landing zone are:
  - Lander footprint size and navigation uncertainties
  - Terrain slope and hazard sizes
  - Terrain map errors
  - Lander keep-out zones
  - Optimal propellant use
  - Proximity to other safe sites

Proposed methods must consider the following:
- Assume that terrain mapping and processing occurs between 0.5-2km above the surface while on a near-vertical (+/- 10 deg) descent trajectory between 20-30m/s.
Assume that slopes greater than 5 degrees and surface features larger than 20cm are hazardous to a lander.

Algorithms must work properly at the rates and distances listed above regardless of real-time or synthetic mapping. If testing is performed at laboratory scales, it must be shown that the algorithms can scale to the rates and distances above.

Algorithms that employ artificial intelligence or non-deterministic approaches must produce an associated confidence level along with the safety map information, and methods for validating the safety results.

Processing time to obtain safe landing areas from 3D map data should be less than 5 seconds.

Proposed algorithms must be demonstrated in real-time on a processor equivalent to the High Performance Spaceflight Computing (HPSC) processor under development within NASA or an equivalent space-qualified field-programmable gate array (FPGA) with path to spaceflight. Low-fidelity optical cameras and/or LIDARs are suggested for mapping in laboratory environments. Proposals should identify any facility requirements if a NASA lab environment is proposed for testing algorithms.

Innovative approaches are encouraged, rather than incremental improvements to the ALHAT methodology.

Please refer to Section 7 – Points of Contact for Further Information of this Appendix if you have technical questions pertaining to this topic.

Topic 3 – Intelligent Calibration of Constellations of Sensors

The objective of this topic is to develop the capability to rapidly calibrate various sensors distributed across a spacecraft constellation, both individually and relative to each other.

NASA’s planetary surface observation and exploration objectives are achieved by combining information from various sensors which might be in situ, e.g., collecting surface and/or atmospheric data, and/or distributed on constellations of orbiters collecting remote sensing data which provide support for navigation, communication, and feature detection.

The remote sensing portion of planetary observation and exploration is undergoing a revolution with the emergence of small satellites (e.g., CubeSats) provisioned with high-quality sensors. This architecture creates the opportunity to develop new data acquisition strategies, based on constellations of small satellites, which combine data to create actionable information for scientific discovery and exploration guidance. This new approach has the potential to enable the measurement of physical process characteristics that previously were inaccessible. However, the use of multiple sensors on different platforms requires new supporting processes. Specifically, a constellation of spacecraft consisting of multiple platforms, each supporting identical or complementary
sensors, requires an innovative inter-spacecraft and inter-instrument calibration (inter-calibration) process to fully exploit data gathered from multiple locations and various viewpoints, as well as at different or identical times.

Historically, NASA observing spacecraft have performed data fusion and inter-calibration using techniques that involve substantial processing on the ground and long after the observations occurred. While the current approach is reliable, well-accepted, and provides sufficient single spacecraft sensor calibration and inter-spacecraft calibration for traditional missions, these techniques do not meet the needs of time-sensitive co-observations and of exploration missions. They are expensive and require extensive pre-flight ground calibration. They also do not provide a unified estimate of sensor errors and uncertainties, in situ and in real- or near real-time.

The following three use cases are particularly demanding in terms of producing networked sensor data with low latency:

- Observation of a given event or feature of interest (e.g., water detection) by a succession of orbiters separated by short intervals, with each spacecraft providing directions to where the next spacecraft should take measurements;
- Detection of an event of interest by one sensor and re-direction (e.g., re-targeting) of other sensors to that location;
- Observation of a given event or feature of interest by an array of sensors (in loose or tight formation), at different vantage points or from different viewing angles and on different platforms;

A logical approach to mitigating the challenges above is greater autonomy in the operation and control of sensor suites. However, many of the difficulties with the autonomous re-direction of a sensor, whether in situ or in-orbit, have barely been conceptualized. Control theory, measurement theory, uncertainty quantification, and the statistics and applied mathematics needed to use the output from sensors (both local and remote) to direct sensors and platforms have only started to be applied in a learn-by-doing approach. In particular, inter-calibration among sensors, both spatially (observing site registration) and spectrally (sensor output), requires substantially more attention to the theoretical and algorithmic underpinnings. In addition, performing this inter-calibration in real-time requires improved or novel techniques.

This solicitation topic specifically seeks proposals to develop algorithms, processes, and related strategies for the autonomous inter-calibration of constellations of satellites (computer vision and machine learning approaches are of particular interest). Proposed techniques must address all of the following elements:

- a mathematical or statistical formulation of the conceptual approach;
• an estimate of the accuracy of resulting consolidated datasets, based on the accuracy of the inter-calibration, to understand the effectiveness of the resulting strategies;
• a proof-of-concept of the scalability of the approach from a few to tens to hundreds of sensors;
• an estimate of the computational complexity of the algorithm(s);
• a laboratory-based demonstration of the approach including a series of experiments to characterize the performance of the approach and the validity of the assumptions and approach; and
• the software and its documentation needed to implement the approach.

The submission shall explain how the proposed approach addresses all of the following challenges:

• The required frequency of downlinking data or uplinking commands or calibration parameters between spacecraft and ground;
• The capacity of onboard processors to handle their task assignments and the processing required for near-realtime processing;
• The data retained onboard for calibration processing;
• The affordability of pre-launch, on-ground calibration to be performed on a large number of spacecraft (assuming ranging from 8 to 200) as part of their manufacturing, assembly and test cycle; and
• The capability of the technique to support inter-calibration to within 1% of any two sensors and the registration accuracy of the measurement within at least 0.1m.

Please refer to Section 7 – Points of Contact for Further Information of this Appendix if you have technical questions pertaining to this topic.

**Topic 4 – Advanced Thermal Control Materials for Exploration Spacecraft**

The objective of this topic is to identify, develop, and demonstrate novel technologies which address challenges in, and advance performance of, thermal control systems for both manned and unmanned spacecraft.

All spacecraft require thermal management in order to effectively complete their missions. As the fundamental component technologies and materials to provide thermal control have remained largely unchanged for many years, designers of new spacecraft are generally constrained to currently available material solutions to achieve the desired performance throughout different mission phases. Alternative solutions to thermal management are needed which can reduce spacecraft mass, volume, and overall complexity.
One approach is the expanded use of flexible thermal control materials which provide heat transfer across complex interfaces. These materials have traditionally been used in very specific locations that do not directly tie into the overall active thermal control systems (i.e., fluid loops). However, with the advent and successful demonstration of inflatable habitat structures on the International Space Station (ISS), the integration of flexible thermal material with an external active thermal system radiator may yield mass savings for deployable modules of future human exploration missions.

Another emerging approach is the use of tunable interface materials which have engineered properties to meet specific conditions. For example, many components envisioned for future missions to the Moon require some form of compact passive thermal switches to withstand the extreme surface temperature variations experienced throughout the lunar diurnal cycle. Such a technology would also benefit deep space missions where the vehicle’s trajectory may take it to 0.7 AU (near Venus) then to the outer planets, 3 AU and beyond. This is especially true for small vehicles that rely on non-nuclear power sources and have a relatively small overall mass to dampen temperature swings. Tunable interface materials could provide significant mass, volume, and complexity savings over current state-of-the-art practices such as louvers, paraffin heat switches, etc.

This solicitation topic specifically seeks proposals for novel thermal management technologies in one or both of the following areas:

- **Flexible materials** for use in a deployable habitat. For reference, the following characteristics are provided as goals:
  - Compatibility with an active pumped fluid loop;
  - Single fault tolerance to loss of coolant flow;
  - Fin efficiency greater than 0.85;
  - Dry mass/area ratio less than 11 kg/m2. A stretch goal of 6.5 kg/m2 is desirable;
  - Optical properties consistent with the current state-of-the-art end of life static coatings [e.g., optical solar reflectors, high IR emittance ($\varepsilon > 0.8$) low solar absorptance ($\alpha < 0.2$) coatings]; and
  - Compatibility with long duration exposure of the space environment including but not limited to UV radiation, atomic oxygen, and the temperature extremes experienced on the lunar surface during its diurnal cycle [approximately $-170 \, ^\circ C$ to $120 \, ^\circ C$]. Heat rejection is not required at elevated temperatures; however, the system must operate nominally after exposures to the provided limits.

  Note: When implemented in a habitat system (assuming a cylindrical form factor with diameters ranging from 3 to 5 meters and lengths from 4-8.5 meters), structural elements containing flexible materials must:
Be capable of pressurization up to 15 psid in the deployed configuration; and

Provide micrometeoroid and orbital debris shielding equivalent to 1 mm thick aluminum bumper spaced 4 inches from the pressure vessel in the deployed configuration.

- **Passive tunable/smart thermal interface materials** that provide high conductance turndown. The proposer is asked to consider the following performance property goals:
  - Have an ‘on’ or ‘high-state’ conductance of 2 W/K and a turndown ratio of at least 400:1 to the ‘off’ or ‘low-state’ condition. Higher turndown ratios are desirable when achieved with a lower ‘off’ state conductance. For example, an improvement from a 400:1 conductance ratio (2 W/K to 0.005 W/K) to 500:1 conductance ratio should target maintaining the ‘on’ state at 2 W/K while reducing the ‘off’ state to 0.004 W/K;
  - Capable of achieving full ‘on’ performance (high conductance) at temperatures above 15 °C. Full ‘off’ performance (low conductance) should be provided at temperatures below -15 °C.
  - Capable of providing switching function across a 4 cm x 4 cm contact area. A stretch goal of surface area coverage approaching 10 cm x 10 cm and greater is desirable; and
  - Total thicknesses < 1 cm as a goal.

Proposals must demonstrate proof-of-concept of the proposed technology and discuss the TRL advancement of the proposed novel technology.

Please refer to Section 7 – Points of Contact for Further Information of this Appendix if you have technical questions pertaining to this topic.

2.0 AWARD INFORMATION

2.1 Funding and Period of Performance Information

NASA plans to make approximately 6-8 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 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 are required.
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 anticipated type of award instruments will be grants and cooperative agreements, 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/). Cost sharing is not required.

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.

**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:

- 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 April 3, 2019. 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 May 1, 2019.
- Proposal Cover Page: 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>As needed</td>
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<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:**

This chart is different from the Proposal Summary described in 4.3.4 of the NRA. 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). 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
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).

**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 (see https://www.nasa.gov/open/researchaccess/data-mgmt) - as well as evidence (if any) of past data sharing practices;

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 (university support, such as release time or co-funding of graduate students, should be discussed here);
- 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 4.3.6 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 September 4, 2019. PIs and University AORs will receive notification via NSPIRES.

For those proposals being recommended for an award, the notification should not be regarded as an authorization to commit or expend funds. Research grants and cooperative agreements are expected to be awarded as a result of this announcement. Assuming the availability of appropriated funds, a mid-October 2019 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.
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

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 additional requirements will be incorporated into the ECF awards:

- **Progress Reports.** The Principal Investigator (PI) shall submit progress reports in the format to be provided by NASA. Reports are due every 90 days, with the first one due 90 days from the grant start date. The reports will provide a summary of progress against the work plan; discussion of upcoming activities; data related to publications, presentations, conferences, and inventions; student information; and any issues or concerns that should be brought to the attention of the program.

- **Year-End Reports.** The PI shall submit year-end reports in the format to be provided by NASA. Year-end reports are due at the end of each grant year and comprise three, separate documents:
  - Fourth Progress Report
  - Annual Summary Chart
  - Publications Summary

- **Continuation Review Package/Presentation.** If more than one year is proposed, annual continuation reviews are required. A continuation review package will be submitted in place of the third quarterly report in applicable grant year(s). 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). A corresponding annual presentation, at NASA Headquarters in Washington, D.C., of progress and plans will also be required. Note: if a no-cost extension is needed, a continuation review package will also be required.

- **Annual Technical Seminar.** The PI shall present a technical seminar at a minimum of one NASA center annually. 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. These seminars will be broadcast virtually to ensure broad exposure and the briefing will be posted on STMD’s external website. Awardees selected to perform research on the same topic area will be highly encouraged to participate in each other’s seminars.

- **Closeout Reports.** The PI shall submit closeout reports in the format to be provided by NASA. Closeout reports are due at the end of the final grant year.

### 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  
[hp-ecf-call@mail.nasa.gov](mailto:hp-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  
[hp-ecf-call@mail.nasa.gov](mailto:hp-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 April 25, 2019; 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.