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

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

APPENDIX NUMBER: 80HQTR23NOA01-23ECF-B1

Appendix Issued: *February 16, 2023*
Notices of Intent Due: *March 16, 2023* (5 PM Eastern)
Proposals Due: *April 13, 2023* (5 PM Eastern, 2 PM Pacific)

NASA Assistance Listing Number 43.012

OMB Approval Number 2700-0092

Summary of Key Information

Appendix Name: Early Career Faculty (ECF), hereafter called "Appendix" to the SpaceTech-REDDI-2023 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 16, 2023
Notices of Intent Due:	March 16, 2023
Proposals Due:	April 13, 2023
Selection Notification:	August 2023 (target)
Award Start Date:	October 2023 (target)

Selection Process: Independent Peer Review

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

Award Details:

Anticipated Total Number of Awards:	6
Award Duration:	Maximum of three years
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 Director of Early Stage Innovations and Partnerships or designee

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

Early Career Faculty

1.0 SOLICITED RESEARCH/TECHNOLOGY DESCRIPTION

1.1 Program Introduction/Overview

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

This specific Appendix is titled Early Career Faculty (ECF) and is one of five calls for proposals from STMD's Space Technology Research Grants (STRG) Program. Early Stage Innovations (ESI), Space Technology Research Institutes (STRI), NASA Space Technology Graduate Research Opportunities (NSTGRO), and Lunar Surface Technology Research (LuSTR) Opportunities appear as Appendix B2, Appendix B3, Appendix B4, and Appendix B5, respectively, under the SpaceTech-REDDI NRA.

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

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

The ECF Appendix seeks to tap into that talent base, challenging early career faculty to examine the theoretical feasibility of new ideas and approaches that are critical to making science, space travel, and exploration more effective, affordable, and sustainable. It is the intent of the STRG Program and this Early Career Faculty opportunity to foster interactions between NASA and the **awarded** university Principal Investigators (PIs) and their teams. Therefore, interaction with NASA researchers should be expected while conducting space technology under these awards.

1.2 Program Goals and Objectives

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

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

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

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

1.3 Topics

Topic 1 – Novel Fluids for Spacecraft Thermal Control

The goal of this topic is to develop advanced fluids that provide performance improvements in active thermal control systems to meet NASA exploration needs via development and characterization of novel heat transfer fluids such as ionic liquids.

Single-phase (liquid) heat transfer fluids have been successfully used in a variety of active thermal control systems for human and robotic spacecraft [1-4]. Human spacecraft have historically used thermal control fluids in either one-fluid (Apollo) or two-fluid (Shuttle, ISS, Orion) architecture configurations [4]. Two-fluid systems have typically been driven by the need to minimize the risk of crew exposure to hazardous fluids within the vehicle, and simultaneously providing design robustness to varying heat loads and thermal environments external to the vehicle. While these two-fluid systems

increase mission flexibility and decrease risk to crew, they require additional system mass to accommodate support hardware associated with having multiple fluid loops. Novel fluids may allow systems to achieve increased operational flexibility, reduce system mass, and minimize hazards to the crew [5-8].

While several candidates have been explored and implemented for single-fluid human spacecraft thermal control systems in the moderate thermal environment of low Earth orbit, thermal systems for the lunar surface or deep space would benefit from improved fluids that are more capable of handling these extreme thermal environments. Tailored ionic liquids (ILs) represent an example of fluids considered to have potential for this application because of their thermophysical properties, such as thermal stability at high temperature and low vapor pressure [9, 10]. Careful consideration of systems-level implications of novel, candidate fluids is essential for efficient system functioning. For example, the use of nanofluids may be considered due to their increased thermal conductivity and improved heat transfer performance; however, an investigation into system-level effects for a previous spacecraft active thermal control system revealed that the inclusion of nanoparticles resulted in a heavier system or used more pump power than the baseline system due to the larger density and viscosity of the nanofluid [2].

This research area specifically seeks novel heat transfer fluids that offer thermophysical properties better than those currently provided by state-of-the-art external fluids (such as HFE 7200), reduce the pour point to preclude freezing during lunar night/low power periods, and minimize risks associated to potential crew exposure.

Proposed approaches may include but are not limited to tailored ionic liquids. The ideal coolant for active thermal control systems would provide the thermophysical and hazard control properties of water but never freeze.

Proposals are expected to focus on development, characterization, and demonstration of novel fluids tailored for the application, not design mitigations for existing fluid candidates (heaters, etc.). Proposed approaches should focus on single-fluid or improved multi-fluid, single-phase (liquid) fluids. Proposals should clearly articulate system-level implications of the proposed heat transfer fluid(s) and their potential benefit.

Target goals for desired thermophysical properties of the novel heat transfer fluids for crewed vehicles are provided below:

Note that proposals must provide estimates of anticipated thermophysical properties metrics (per the target goals cited below) of the fluids to be developed. Where the anticipated metrics exceed and/or fall short of the stated target goals cited below, proposals must justify the trade-offs that have been selected.

- Liquid temperature range: 100 K – 373 K:
    - Operational exposure limits are expected in the range of 150 K to 323 K,
    - Stability over 1000s of temperature cycles,
    - Changes in liquid density, phase and characteristics over the temperature range must be characterized; however, no specific design metric is offered in this regard.

- Thermophysical properties:
    - Specific heat ≥ 2000 J/kg K at 293 K,
    - Thermal conductivity ≥ 0.1 W/m K at 293 K,
    - Viscosity:
        - Provide viscosity low enough to maintain turbulent flow in key heat transfer sections such as radiator tubing (nominal tubing diameter: 1/8 - 1/2 inch),
        - Result in viscosity increase at 243 K≤ 2.3x (when compared to viscosity at 293 K),
        - Result in viscosity increase at 193 K≤ 5.5x (when compared to viscosity at 293 K),
        - Result in viscosity increase at 153 K≤ 65x (when compared to viscosity at 293 K).

Proposals are encouraged to discuss:

- Considerations for crew safety, including toxicology hazards (fluid vapors must be non-reactive and breathable at its saturation pressure, Tox 3 or lower) [8, 11, 12], and minimization of risks associated with oxygen displacement and flammability.
- Operational considerations including materials compatibility (with aluminum alloys, stainless steels, titanium, and common soft goods and seal materials Teflon, silicone, Viton, etc.), any potential risks with tight tolerance components, such as positive displacement or centrifugal fluid pumps, and where applicable inhibition of microbial growth. Target goal for operational life is > 10 years.

In addition to computational/theoretical techniques, empirical tests to demonstrate the ability to provide the desired thermophysical properties and characteristics of any fluid/mixture are encouraged although not required.

It is recognized that the target goals represent a significant challenge. Expected outcomes include identification, synthesis, and characterization of several promising candidates and rationale for further consideration, based on comparison with current thermal control system fluids [3].

References:

[1] Birur, G., et al, *From Concept to Flight: An Active Fluid Loop Based Thermal Control System for Mars Science Laboratory Rover*, AIAA International Conference on Environmental Systems, San Diego, CA, 2012, https://trs.jpl.nasa.gov/bitstream/handle/2014/42754/12-2473_A1b.pdf;jsessionid=82FB35BC1549374676BEFBCD127714A1?sequence=1

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

Topic 2 – Hypersonic Transition and Turbulence Modelling for NASA Entry, Descent and Landing Applications

The goal of this topic is to develop and validate higher-order/higher-fidelity computational models for transition and turbulent heating modeling relevant to NASA Entry, Descent and Landing (EDL) Vehicle Configurations and Mission Trajectories.

NASA's portfolio of current and future EDL applications encompasses missions to multiple destinations, including Earth, Mars, Titan, and Gas Giant planets, in which vehicles flying at hypersonic speeds experience boundary layer transition and turbulent convective heating. Accurate prediction of the boundary-layer state and resultant heating environment is critical to the design of the Thermal Protection Systems (TPS) which protects a vehicle during atmospheric entry. The modelling of these aspects of hypersonic flight is complicated by the effects of TPS roughness and surface features, non-equilibrium chemical kinetics, and/or separated wake flow.

The current state of the art for NASA EDL applications generally ignores the boundary-layer transition question by assuming fully-turbulent flow, a level of conservatism that may not be acceptable for future missions. The modelling of turbulent environments is generally limited to smooth-surface, attached flow fields - usually employing algebraic turbulence models, which are validated for simple blunt-body aeroshell forebody geometries and robust in application. Empirical and/or experimental models are typically used to estimate the effects of roughness or separated wake flows on turbulent heating.

It is recognized that the general topic of higher-order transition and turbulence modelling is being addressed in academia, however, the focus there is mostly on applications for slender-body configurations flying in Earth's atmosphere at relatively modest (in comparison to EDL missions) hypersonic speeds. Investments have been provided by commercial and defense funding sources to address those requirements. The intent of this solicitation is to leverage those investments to extend model development activities by providing funding to focus on NASA-specific applications.

This solicitation topic specifically seeks proposals that will develop robust and validated computational models for the prediction of boundary-layer transition and turbulent heating for NASA EDL vehicle configurations. Proposals should address one or more of the following specific elements of transition and turbulence modelling:

- Boundary-layer transition and turbulent heating augmentation in the presence of TPS surface roughness, including distributed (e.g., sand-grain), pattern (e.g.,

hexcomb or weave), deformation (e.g., flexible TPS), and/or surface features (e.g., fences or gaps between TPS blocks).
- Turbulent heating prediction for non-earth atmospheres in the presence of high-enthalpy flow field chemistry effects. CO_2 atmosphere effects for Martian atmosphere are of primary interest, but N_2 models for Venus and/or Titan and H_2/He modelling for gas giant atmospheres may be of interest.
- Shear layer transition and turbulence modelling in the separated wake flow behind blunt-body EDL configurations.
- Effects of surface mass flow (either from TPS ablation or enforced blowing) on boundary-layer transition and convective heating.

For transition model development, proposals must focus on the “bypass” modes of transition that are relevant to blunt-body vehicle boundary layers perturbed by large-scale (i.e., roughness) features, rather than transition models applicable to smooth-wall, slender body vehicles.

Proposals should:

- Be based on the use of an existing computational fluid dynamics (CFD) toolset that has a demonstrated record of validation/application to the prediction of laminar, hypersonic heat transfer environments on blunt-body, EDL configurations.
- Clearly define which of the above listed area(s) of hypersonic transition/turbulence physics for which new models will be developed (e.g., surface roughness effects on transition, high-enthalpy reacting flow effects on aeroheating, etc.).
- Identify data set(s) that will be used in the validation/assessment of the computational model(s) being developed.
- Define an implementation plan through which new methods and models can be incorporated into existing CFD toolsets (including LAURA, DPLR, US3D, and/or FUND3D) that NASA currently employs to define environments for its EDL missions.

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

Topic 3 – Non-Traditional Orbital Debris Remediation

The goal of this topic is to advance enabling technologies for remediation and repurposing of orbital debris.

The U.S. economy depends on space for critical infrastructure, from communications and financial exchanges to national security, transportation, and climate monitoring. Orbital debris created by objects such as abandoned vehicle stages, non-functional satellites, and fragments of launched materials impedes our ability to use space by increasing the cost of space operations (maneuvering around debris), threatening the safety of astronauts and satellites, limiting the ability to launch spacecraft, and potentially rendering entire orbits unusable. In accordance with national priorities, STMD

is pursuing advanced enabling technologies for breakthroughs that may lead to low-cost services for bulk remediation of orbital debris.

Debris remediation services are those that move, remove, or reuse orbital debris to reduce the risks associated with it. The National Orbital Debris R&D Plan identifies the major challenges associated with debris remediation, including two major technological challenges [1]. Specifically, remediation technologies are often tailored to particular types of debris, making it difficult for a single technology to scale from remediating one piece to many pieces of debris. Likewise, the costs and benefits associated with various remediation methods are not well characterized. New remediation concepts that push the boundaries of low-cost capabilities are needed to ensure benefits exceed costs. The National Orbital Debris Implementation Plan articulates actions required to address the hazards posed by orbital debris [2].

The current state of the art is focused on capturing trackable debris that is about 100 kg in mass in low Earth orbit (LEO). For example, the European Space Agency (ESA) is supporting the development of a capability to remove multiple ESA-registered derelict objects; the first step is a removal mission targeting a 100 kg object in 2025. Provided the space object is not rotating too quickly, recent missions such as the U.S. MEV-1 and Chinese SJ-21 missions have demonstrated the capability to capture large, defunct satellites and maneuver them to new locations.

For this solicitation topic, “traditional” active debris removal (ADR) systems have the following features:

- physically capture and remove large (>10cm) legacy debris via atmospheric entry or relocation to a disposal orbit;
- capture “prepared” or legacy spacecraft and remove them via atmospheric entry or relocation to a disposal orbit (end-of-life services).

Traditional ADR approaches are well explored in the literature and end-of-life services based on those concepts are emerging in commercial industry [3-]. However, these approaches may not address the scalability and cost-benefit challenges identified by the National Orbital Debris R&D Plan. Advancements are needed to:

- Increase the scalability of remediation options;
- Explore remediation approaches that focus on reducing risk to operational spacecraft, such as nudging debris to avoid collisions, rather than reducing the number or mass of debris objects in space;
- Reduce the costs associated with debris remediation; and
- Enable the remediation of debris that is currently not trackable by existing space situational awareness capabilities.

This solicitation topic specifically seeks proposals for the development and maturation of non-traditional, innovative, potentially breakthrough technologies for ADR. Proposals must:

- Focus on innovative technologies that address one or more ADR approaches (see additional information below);
- Clearly describe the technology development plan;
- Identify and provide a rationale for the anticipated size range of debris that would be addressed by the technology, and if applicable, extensibility to other sizes;
- Describe how the proposed technology addresses a path to scalability for bulk orbital debris remediation;
- Articulate and justify the anticipated benefits of the considered approach(es). Benefits include, but are not limited to:
    - overall reduction of collision risk for spacecraft operators and for debris-on-debris collisions;
    - reduction of close approaches requiring spacecraft to perform collision avoidance maneuvers;
    - generated benefits, where applicable, such as potential revenue considerations from salvage operations or resources generated by salvage/recycling operations.

Proposals that focus primarily on “traditional” approaches as identified above would be considered non-responsive.

ADR approaches sought include, but are not limited to, one or more of the following:

- Just-in-time collision avoidance (JCA) and Debris Traffic Management [6] – maneuvering or nudging pieces of debris to avoid collisions via contact means or remote application of force (e.g., modeling ground-based lasers [7, 8] and space-based lasers [9,10] for debris removal, and nudging and architectures for nanotugs [11] to tend debris);
- Remediation in place – systems that do not require atmospheric entry, such as salvage, recycling, agglomeration, or redistribution to reduce collision risk. Approaches in this area must include detailed assumptions for how the debris are collected and brought to the downstream process;
- Rapid response capabilities for individual debris generating events (e.g., on-orbit break-ups or collisions), in order to capture and remove the debris while it is still relatively concentrated (responsive post-fragmentation cleanup) [12]. Analysis in this area should include evaluation of the sensitivity of outcomes to the time delay between fragmentation and the initiation of remediation activities;
- Other approaches that could yield highly efficient debris remediation. This may include, but is not limited to, remediation specific to small debris, debris that are

large enough to cause damage (greater than 4 mm), but too small to track (<10 cm) and are a threat for which there are few proposed solutions. Potential solutions for small debris remediation include, but are not limited to, lasers, physical sweepers [13, 14], and dust [15].

Expected outcomes include a notional roadmap of how the developed technology could be incorporated into a debris remediation mission.

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

2.0 AWARD INFORMATION

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

2.1 Funding and Period of Performance Information

NASA plans to make approximately 6 awards – across all topics - as a result of this Appendix, subject to the receipt of meritorious proposals and the availability of funds. The actual number of awards will depend on the quality of the proposals received; NASA reserves the right to make no awards, or exceed 6, under this Appendix. The ECF Appendix covers only proposals for new awards; continuations of existing awards are handled separately.

The total award is subject to a maximum limit of $600K for three years. The typical annual award value is $200K; smaller amounts may be proposed. The amount in any year may not exceed $220K. All amounts must be justified.

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

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

3.0 ELIGIBILITY INFORMATION

3.1 Limitation on Number of Proposals Per Organization

Only accredited U.S. universities are eligible to submit proposals on behalf of their outstanding new faculty members who intend to develop academic careers related to space technology (see 3.2 of this Appendix). There is no limit on the number of proposals which may be submitted by an accredited U.S. university.

3.2 Eligibility of Offerors and Limitation on Number of Proposals Per PI

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

The PI must be an untenured Assistant Professor on the tenure track at the sponsoring U.S. university at the time of award. If the PI's appointment is scheduled to change to Associate Professor (either tenure-track or tenured) on or before the award date, they are not eligible for an ECF award. At the time of selection, the university must provide, on behalf of a selected PI, confirmation that the PI 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 by the target award start date (October 2023).
- Note 2: The award will be terminated if, at any time, the PI transfers to a position that is not either tenure track or tenured.

The PI must be a U.S. citizen, U.S. national, or have lawful status of permanent residency (i.e., holder of a U.S. Permanent Resident Card, also referred to as a Green Card) *at the time of proposal submission*. The biographical sketch and department letter should specifically address the U.S. citizenship/permanent residency requirement.

The PI must be the primary researcher on the effort. Co-Investigators are not permitted. Collaborators are permitted. 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 information. The PI may not be a current or former recipient of an STRG Program ECF award.

Diversity and inclusion are integral to mission success at NASA (see the *NASA Equity Action Plan*). 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, and proposals submitted by Historically Black Colleges and Universities, Hispanic-Serving Institutions, Tribal Colleges, and other Minority Serving Institutions (MSIs). (See 1.0 of the NRA)

Collaborators are permitted but not required. As specified in Appendix B of the *2022 NASA Guidebook for Proposers*, a collaborator is an individual who is not critical to the proposal but is committed to providing a focused but unfunded contribution for a specific task. The Scientific/Technical/Management Section of the proposal (see 4.3.5 of this Appendix for additional information) should document the nature and need for all collaborations. If collaboration is a component of the proposal, it is presumed that the collaborator(s) have their own means of research support; that is, an ECF award may not include expenses for personnel or activities at collaborating institutions, nor salary costs for senior personnel, consultants, or subcontractors.

This ECF Appendix is seeking to fund the best research proposed to the solicited topics from *outside* of NASA. NASA civil servants and JPL employees may not appear as collaborators on submitted proposals, and there can be no solicitation-related communications with NASA (including JPL) personnel from the time this Appendix is released until proposal selections are final. The proposer is permitted to identify potential specific fruitful interactions with agency experts; however, these interactions may not be discussed with agency personnel *a priori* and will not be a factor in proposal evaluation; letters of commitment from NASA (including JPL) are not permitted. If a proposal is selected, any potential NASA interactions identified will be addressed at that time.

Relationship of ECF to PECASE

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

3.3 Proposals Involving Non-U.S. Organizations

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

3.6 Cost Sharing

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

4.0 PROPOSAL SUBMISSION INFORMATION

4.1 Introduction

The following information supplements the information provided in 4.0 of the NRA. Note that in instances where this Appendix and the NRA or *2022 NASA Guidebook for Proposers* differ, the Appendix takes precedence.

4.2 NSPIRES Registration

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

4.3 Proposal Content and Submission

4.3.1 Electronic Proposal Submission

Offerors may submit proposals via NSPIRES or Grants.gov. See 4.3.1 of the NRA for details.

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 April 13, 2023. Proposals submitted after the proposal deadline will be considered late and may be rejected without review.

4.3.2 Notice of Intent (NOI) to Propose

NOIs are strongly encouraged by March 16, 2023. The NOI is submitted via NSPIRES. See 4.3.2 of the NRA for details of the information to be included in the NOI. The information contained in an NOI is used to expedite the proposal review process and is, therefore, of value to both NASA and the offeror.

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

NASA is unable to provide feedback on NOIs.

4.3.4 Proposal Cover Pages

The Proposal Cover Pages for each proposal shall include the proposal team, the proposal summary (abstract), responses to program specific data questions, and the budget. Instructions for completing the Proposal Cover Pages are specific to the

electronic proposal submission system used by the offeror (NSPIRES or Grants.gov). See 4.3.4 of the NRA for NSPIRES and Grants.gov instructions.

4.3.5 Proposal Sections

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

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

Proposals must be formatted as a single, unlocked pdf file containing the elements enumerated in the above table. Failure to submit a single, unlocked pdf file may result in the proposal being deemed non-compliant.

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

Section 1: Table of Contents

See 2.12 of the *2022 NASA Guidebook for Proposers*.

Section 2: Proposal Summary Chart:

The proposal summary chart is intended to provide a quick sense of the proposed effort and should stand alone (i.e., not require the full proposal to be understood). As noted in 4.3.4.1 of the NRA, it should not include any proprietary or sensitive data as NASA intends to make it available to the public after selections are announced.

The chart must include the following information:

- A representative graphic with caption;
- The proposal title, the PI's name, the PI's institution and information (name and affiliation) of other team members, if any;
- The objectives of the research, a comparison to the SOA, discussion of the innovation, and start and projected end TRL;
- A high-level summary of the research approach, including methods to be employed;
- The potential impact of the research (i.e., benefits, outcomes).

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

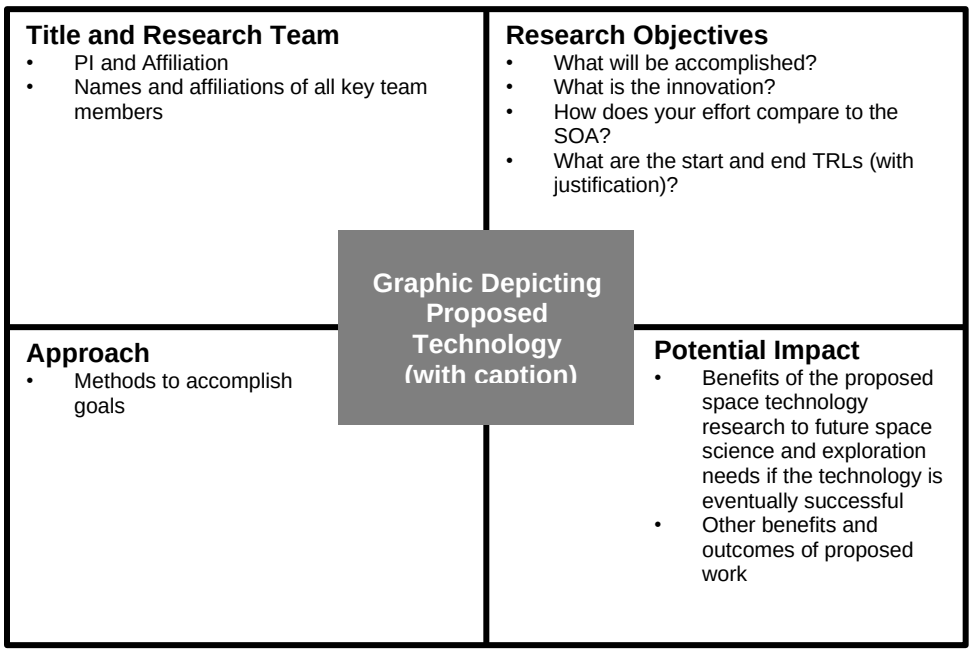

Figure 1 - Template for Required Proposal Summary Chart

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 10 pages with

standard (12 point) font, and the pages must have 1-inch margins. This page limit includes illustrations, tables, figures, and all sub-sections.

a) The **relevance** of the proposed research to the specific ECF Appendix goals and objectives and topics, as described in 1.2 and 1.3:

   i. Please note that the NRA and this Appendix describe how ECF is relevant to the NASA Strategic Plan; therefore, it is not necessary for individual proposals to show relevance to NASA's broader goals and objectives. The proposal should instead focus on demonstrating **responsiveness** and relevance by discussing how the proposed investigation is directly responsive to one of the topics and how the proposed space technology could lead to dramatic improvements at the system level — performance, weight, cost, reliability, operational simplicity or other figures of merit associated with space flight hardware or missions;

   ii. A comparison between the proposed effort and the existing **SOA**, including a discussion of the perceived impact of the proposed research to the state of knowledge in the field;

   iii. A clear statement of the proposed **innovation** as well as how the proposed technology might make space science, space travel, and exploration more effective, affordable, and sustainable;

   iv. A discussion of **next-step technology development**; specifically, a description of a clear path for further development and exploitation for space science and exploration needs and any crosscutting potential of the technology.

b) The **technical approach** and methodology (types of analyses, testing, experimentation, and other research activities) to be employed in conducting the proposed research. This section should describe any hardware proposed to be built and any facilities and/or capabilities that would be required to execute the proposed research. Access to NASA facilities should not be assumed during the course of the ECF effort, nor should NASA facilities be included in the proposal. (Note: facilities and proposer capabilities will be evaluated under the third evaluation criterion as described in 5.2 of this Appendix).

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

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

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

Section 4: Data Management Plan

One of NASA's missions is to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof. Therefore, it is NASA's intent that all knowledge developed under this Appendix be shared broadly through publication of the results.

All proposals are required to submit a data management plan (DMP), in accordance with the *NASA Plan for Increasing Access to the Results of Scientific Research*. Award recipients are subject to reporting requirements under this plan, including submitting peer-reviewed manuscripts and metadata to a designated repository and reporting publications with research performance progress reports. The designated repository for this data is the NASA Scientific and Technical Information (STI) Repository. More information can be found on the STI website.

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

The DMP must include information on how the proposer/team plans to archive research products, including details on types of products, where products will be archived, schedule for archiving products, how the DMP will enable long-term preservation, and roles/responsibilities of team members to accomplish the DMP.

For information about data rights, and other aspects of intellectual property such as invention rights resulting from awards, see 2.5 of the NRA and Appendix J of the *2022 NASA Guidebook for Proposers*.

Section 5: References and Citations

See 2.14 of the *2022 NASA Guidebook for Proposers*.

Section 6: Biographical Sketch

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

See 2.15 of the *2022 NASA Guidebook for Proposers*.

Section 7: Department Letter

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

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

Section 8: Current and Pending Support

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

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

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

Also see 2.16 of the *2022 NASA Guidebook for Proposers*.

Section 9: Statements of Commitment and Letters of Support (if needed)

Every collaborator identified in the proposal's Scientific/Technical/Management Section must acknowledge their intended participation in the proposed effort. This acknowledgement of commitment is expected to occur through NSPIRES (see 4.3.1 of the NRA).

In the event that a collaborator is unable to confirm participation through NSPIRES, the proposer should include a statement of commitment (one page maximum each) in the body of the proposal.

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

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

Also see 2.17 of the *2022 NASA Guidebook for Proposers*.

Section 10: Proposal Budget with Budget Narrative and Budget Details

The budget justification must include details adequate to substantiate the requested funding. The proposal must provide planned budgets for all years for which support is sought.

Proposal funding restrictions are detailed in 4.3.7 of the NRA. Additional restrictions for this ECF Appendix include:

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

Also see 2.18 of the *2022 NASA Guidebook for Proposers*.

Section 11: Facilities and Equipment

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

Also see 2.19 of the *2022 NASA Guidebook for Proposers*.

4.3.7 Proposal Funding Restrictions

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

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

4.6 Collection of Demographic Information

See 4.6 of the NRA.

5.0 PROPOSAL REVIEW INFORMATION

5.2 Technical and Programmatic Review

The technical review criteria considered in evaluating proposals under this Appendix are given below. The questions associated with each criterion are provided to elaborate on their intended meaning of each criteria; the order of the questions is not intended to indicate order of importance. The three primary evaluation criteria – 1) Relevance, 2) Technical Approach, and 3) Suitability of PI/Team, Resources, and Cost – are all equally weighted.

Relevance

Evaluation includes consideration of the following:

- **Responsiveness to Topic**: Does the proposed effort specifically address a technology topic identified in this Appendix? Could the proposed space technology lead to dramatic improvements at the system level — performance, weight, cost, reliability, operational simplicity, or other figures of merit associated with space flight hardware or missions?
- **State of the Art (SOA)**: How does the proposed effort compare to the existing SOA? Does the proposal state how the research might impact the direction, progress, and thinking in relevant fields of research?

- **Innovation**: Is the proposed research innovative? Does it have the potential to lead to revolutionary or breakthrough improvements in performance, new approaches, or entirely new missions?
- **Next-Step Technology Development**: Does the proposal demonstrate a clear path for further development and exploitation for space science and exploration needs? Does the technology have the potential to be crosscutting?

Technical Approach

Evaluation includes consideration of the following:

- **Technical Approach**: Are the research approaches technically sound, logical and feasible? Are the conceptual framework, methods, and analyses well justified, adequately developed, and likely to lead to scientifically valid conclusions?
- **Work Plan**: Is the work plan complete and appropriate to successfully accomplish the proposed technology development? Is the schedule, including key milestones, appropriate and realistic? Does the proposal recognize significant potential problems and consider reasonable mitigation strategies? Does the data management plan ensure widespread dissemination of results? Does the proposal provide evidence of past data sharing practices?
- **TRL**: Is the proposed work at the appropriate entry TRL as stated in 1.2 of this Appendix? Does the proposal achieve meaningful TRL advancement?

Suitability of PI/Team, Resources, and Cost

Evaluation includes consideration of the following:

- **Qualifications and Capabilities of PI/Team**: What is the potential of the PI to conduct successful research? How well qualified are the PI and the research team to carry out the proposed research – do they possess sufficient technical knowledge and the capabilities required? Are roles, including those of any collaborators, clearly defined? (Note: potential NASA interactions identified will not be evaluated) Is the management structure appropriate?
- **University Support**: Does the university show long-term commitment to the Early Career Faculty researcher's career development?
- **Facilities**: Are facilities appropriate to complete the planned research? Does the proposal team have access to (commitment from) the appropriate facilities?
- **Budget**: Is the proposed budget reasonable for the scope of the effort? Is the budget of sufficient fidelity? Are the assumptions and components of the proposed budget defined?

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

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

5.3 Selection Announcement and Award Dates

Selection notifications are anticipated on or about August 2023. PIs and university AORs will receive notification via NSPIRES.

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

5.6 Risk Analysis

See 5.6 of the NRA.

6.0 FEDERAL AWARD ADMINISTRATION INFORMATION

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

6.1 Federal Award Notices

For those proposals being recommended for an award, the notification should not be regarded as an authorization to commit or expend funds. Research grants are expected to be awarded as a result of this announcement. Assuming the availability of appropriated funds, an October 1, 2023, award start date is expected. If selected, NASA expects the grantee to commence with the proposed research on the award start date; deferrals will not be permitted.

Research Terms and Conditions

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

Environmental Impact

All awards made in response to proposals to this Appendix must comply with the National Environmental Policy Act (NEPA). The majority of grant-related activities are categorically excluded (from specific NEPA review) as research and development (R&D) projects that do not pose any adverse environmental impact. A blanket NASA Grants Record of Environmental Consideration (REC) provides NEPA coverage for these anticipated activities and it is expected that all awards resulting from this

Appendix will be covered by this REC. Please see 2.21 of the 2022 *NASA Guidebook for Proposers* for more information.

6.2 Award Reporting Requirements

The reporting requirements will be consistent with 2 CFR 1800.902 “Technical Publications and Reports” and Appendix F - Required Publications and Reports of the GCAM.

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

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

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

Technical 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.

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

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

7.0 POINTS OF CONTACT FOR FURTHER INFORMATION

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

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

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

SpaceTech-REDDI NRA Manager
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 April 6, 2023; no technical questions will be accepted after this date. Please note that NASA is unable to comment on whether a proposed area of research is responsive to a topic described in 1.3.