

Statement of Objective(s) (SOO)
17 Oct 23

**Lab-to-Orbit: A University Center of Excellence Accelerating the
Development and Testing of Materials for Low Earth Orbit (LtO CoE)**

1.0 SCOPE OF WORK.

1.1 The objective of this program is the establishment of a university Center of Excellence (CoE) to develop knowledge and skills critical to future needs in the Department of the Air Force (DAF) for aerospace materials in low earth orbit (LEO) technologies. Proposals must not contain any proprietary information. This center is a joint project between the Air Force Office of Scientific Research and the Air Force Research Laboratory Materials and Manufacturing Directorate (AFRL/RX) and Space Vehicles Directorate (AFRL/RV), referred to collectively as “we”, “our”, “us”, or “AFRL” in this announcement. The center will extend the research capabilities of AFRL and provide opportunities for a new generation of United States scientists and engineers to address the basic research needs of the United States Air Force (USAF).

2.0 GENERAL TECHNICAL OBJECTIVES.

2.1 The purpose of this University Center of Excellence (CoE) is to develop researchers grounded in the crucial basic research foundations necessary to address fundamental challenges in the correlation between ground-based experimentation and on-orbit performance to improve forecasting of material and components lifetime and accelerate their insertion into the development cycle of space technologies. Through collaborations with AFRL scientists and engineers (S&E), the CoE researchers will broaden their understanding of DAF mission requirements, AFRL in-house research efforts, and the DAF S&T enterprise. This will enhance the CoE researcher’s perspectives, thereby enabling acceleration of national defense relevant research within AFRL, the defense industrial base, and US academic intuitions. New approaches to integrate and validate models of the space environment, ground-based experimental facilities, materials response, and uncertainty in life-time performance forecasts are needed to answer key questions regarding how materials behave in the combined environmental effects of LEO including, but not limited to ionizing radiation, ultraviolet (UV) radiation, ultra-high vacuum, atomic oxygen (AO), electrostatic charging/discharging, microparticle collisions and extreme thermal cycling.

2.2 The combination of extreme environmental factors, demanding mission requirements, and the lack of physical access for maintenance create a unique set of challenges to ensuring the performance and reliability of DAF systems operating in space. It is imperative that we develop design tools that can analyze the tradeoffs between orbit conditions, maneuvering, power requirements, and the subsystem degradation. Understanding fundamental material response to individual and combined space factors, including changes in basic material properties over time, is the key to our ability to design a “performance budget” for space systems. 2.3 Since the dawn of the space age, space environmental effects on materials, structures, and devices have been studied in two ways: laboratory experiments that probe the effects of a particular environmental factor, and direct exposure to the total space

environment. Direct exposure to space, such as through NASA's Materials International Space Station Experiment (MISSE) or the Long Duration Exposure Facility (LDEF), is cost-prohibitive for a rapid development cycle, which impedes the DAF's ability to field new technologies or to build and deploy proliferated space assets in mass. In addition, on-orbit testing delivers combined effects testing (exposure to UV, AO, radiation, thermal cycling, etc.) with no means to decouple the effects and understand which effects are dominant, or how multiple effects together could enhance and/or accelerate materials degradation. Ground based testing has serious limits in this regard, as most testing only accounts for one variable at a time and assumes the effects of exposure to multiple environmental effects are additive in nature. Modeling of material response under the influence of multiple space environmental factors has indicated the possibility of complex, non-linear interactions.

2.4 For example, there exists a large body of knowledge regarding the effect of ionizing and non-ionizing radiation on polymers. However, it has been demonstrated that at least some effects of radiation on polymers are fundamentally different in high vacuum, and exposure to ambient (earth) conditions reverses those effects. Thus, the ability to probe the chemical and mechanical changes in polymers via in-situ optical and mechanical interrogation during irradiation in vacuum is a critical capability that is not widely accessible. Alternatively, stochastic simulations capable of capturing the physical and chemical evolution of polymer properties at relevant time scales are needed to be able to validate the environment- and time-dependent properties of irradiated polymers using available laboratory techniques. As another example, the reactivity of materials with AO may change as a result of differences induced by ionizing radiation, as well as stresses induced by thermal cycling. Local beams of atomic oxygen have been used to measure material degradation, but the influence of thermal cycling and mechanical strain are expected to modify those reaction rates in as-yet unknown ways. Experimental methods that combine thermal, mechanical, and electrostatic loading during exposure to atomic oxygen would give greater confidence to material response predictions used to design space systems. As a final example, perovskite solar cells are a promising power generation technology for LEO, but reports of the effects of ionizing radiation on solar cell performance are inconsistent, and there is a lack of understanding of the fundamental damage mechanisms. In-situ and in-operando structural characterization during irradiation would provide this understanding but is currently not available.

2.5 These challenges apply across DAF space assets. In each subsystem, an understanding of the fundamental material response to the combined space environment is central to our efforts to accelerate technology development for space. Of particular importance, due to their pervasive criticality in space systems, are power generation and management, platform and payload control, sensors and data processing, propulsion, structural chassis, and surface films/coatings. Materials used in these subsystems comprise many different classes such as semiconductors, elemental metals, polymers, elastomers, lightweight alloys, high performance alloys, ceramics, etc.

3.0 SPECIFIC TECHNICAL OBJECTIVES.

3.1 To address pervasive challenges in predicting material response in the LEO environment, the technical objective of this CoE is to engage emerging researchers in developing novel approaches to increase the fidelity with which laboratory scale experimentation and modeling can predict the performance of materials in LEO. This will entail advancements in each of the following three core research vectors.

- I. Space environment science
 - a. Holistic models of the complex environment in LEO
 - b. Laboratory capabilities to replicate or simulate multiple space environmental effects
 - c. Approaches to validate and quantify uncertainty in terrestrial representations of the space environment
- II. Measurement science
 - a. In-situ measurement techniques to probe evolution of material properties during exposure to complex combinations of environmental factors.
 - b. Correlation of precision laboratory measurements with on-orbit observables
- III. Performance forecasting
 - a. Quantification (through a combination of experiment and validated models) material response to multiple space environment factors
 - b. Methods, to include both physics-based modeling and data-driven analysis (ie, AI/ML), for predicting subsystem performance

3.2 An integrated computational and experimental approach across each of the three research vectors will be critical to success. To create a focal point for collaborative and integrated research among the three core vectors identified above, the program will be framed in the context of a notional (generic) LEO satellite system (NSAT) that includes a structural chassis, power generation, energy storage, propulsion, visible and/or IR sensing, RF communications, and integrated control systems. While the goal of this CoE is not to create a new satellite architecture, advancements in the core research vectors should demonstrate the potential to accelerate technology development in one or more of these subsystems. An understanding of how combined space environmental effects contribute to the performance and reliability of these systems is critical.

3.3 The CoE should demonstrate how its innovations in modeling the LEO environment, replicating or simulating environmental factors in the lab, and measuring fundamental material response to the space environment can be used to quantify a performance budget for the NSAT and accelerate the development cycle for future DoD space systems. A successful CoE will reduce the operational risk for future DoD space systems by developing new skills and toolsets in the rising domestic work force to address the needs outlined in this announcement.

4.0 GENERAL REQUIREMENTS.

4.1 The successful offeror is expected to encompass a multidisciplinary team of investigators that includes experts in materials science, space environment, and data analytics.

4.2 Individual projects in the CoE will be co-led by investigators from the academic institution and from AFRL, and students supported by the CoE will be expected to perform some of their work at AFRL. AFRL will provide access to its research facilities, materials, and on-site expertise to facilitate the research and provide educational value for the students.

4.3 The successful institution is expected to facilitate technical workshops and other opportunities for AFRL researchers to participate in meaningful in-person interactions at the CoE for project execution and strategic planning. Faculty investigators at the CoE should plan for multiple visits to AFRL, including visits for project meetings and seminars. CoE faculty will benefit from exposure to real-world problems, meeting with government S&Es, and development of a new curriculum for training the next generation workforce.

4.4 The institution(s) shall provide a reasonable budget for supporting the various travel requirements for its investigators and students as described above.

5.0 Security Requirements - Information Regarding Non-US Citizens Assigned to this Project

5.1 Recipient employees requiring access to USAF bases, AFRL facilities, and/or access to U.S. Government Information Technology (IT) networks in connection with the work on this agreement must be U.S. citizens. For the purpose of base and network access, possession of a permanent resident card ("Green Card") does not equate to U.S. citizenship. This requirement does not apply to foreign nationals approved by the U.S. Department of Defense or U.S. State Department under international personnel exchange agreements with foreign governments. Any waivers to this requirement must be granted in writing by the Grants Officer prior to providing access. The above requirements are in addition to any other contract requirements related to obtaining a Common Access Card (CAC).

5.2 For purposes of paragraph (5.1) above, if an IT network/system does not require AFRL to endorse a contractor's application to said network/system in order to gain access, the organization operating the IT network/system is responsible for controlling access to its system. If an IT network/system requires an U.S. Government sponsor to endorse the application in order for access to the IT network/system; AFRL will only endorse the following types of applications; consistent with the requirements above:

(1) Recipient employees who are U.S. citizens performing work under agreement.

(2) Recipient employees who are non-U.S. citizens and who have been granted a waiver.