NASA SBIR 2022 Phase I Solicitation

Z4.05 Nondestructive Evaluation (NDE) Sensors, Modeling, and Analysis

Lead Center: LaRC

Participating Center(s): GSFC, MSFC

Scope Title
Nondestructive Evaluation (NDE) for In-Space and Additively Manufactured Materials/Structures

Scope Description
NASA’s NDE SBIR subtopic will address a wide variety of NDE disciplines with a focus on in-space inspection. This SBIR solicitation will focus on aerospace structures and materials systems, including but not limited to Inconel, titanium, aluminum, carbon fiber, Avcoat, Alumina Enhanced Thermal Barrier (AETB), Phenolic Impregnated Carbon Ablator (PICA), and thermal blanket structures. Development efforts should target any set of these materials in common aerospace configurations, such as micrometeoroid and orbital debris (MMOD) shielding, truss structures, and stiffened structures. NDE can target material and material systems in a wrought state or additive manufacturing (AM). In-process or postproduction NDE techniques that could be used to inspect additively manufactured components will be favored. As NASA strives for longer duration space missions, these new tools need to be developed to support in-space manufacturing and assembly.

NDE Sensors and Data Analysis:

Technologies enabling the ability to perform automated inspections on large or complex structures are encouraged. Technologies should provide reliable rapid assessments of the location and extent of damage or defects. Methods are desired to perform inspections in areas with difficult access in pressurized habitable compartments and external environments for flight hardware. Many applications require the ability to see through assembled conductive and/or thermal insulating materials without contacting the surface.

Techniques that can dynamically and accurately determine position and orientation of the NDE sensor are needed to register NDE results to precise locations on the structure with little to no human intervention. Advanced processing and displays are needed to reduce the complexity of operation and interpretation for astronaut crews who need to make important assessments quickly. NDE inspection sensors are needed for potential use on free-flying inspection platforms. Integration of wireless systems with NDE may be of significant utility. It is strongly encouraged that proposals provide an explanation of how the proposed techniques and sensors will be applied to a complex structure. Examples of structural components include but are not limited to multiwall pressure vessels, batteries, tile, thermal blankets, micrometeoroid shielding, International Space Station (ISS) radiators, or aerospace structural components, including the lunar gateway.

Additionally, techniques for quantitative analysis of sensor data are desired. It is also considered highly desirable to develop tools for automating detection of material foreign object debris (FOD) such as lunar dust and/or defects and evaluation of bondline and in-depth integrity for ablative materials, like a heat shield. Typical internal void
volume detection requirements for ablative materials are on the order of less than 6 mm, and bondline defect
detection requirements are less than 25 mm.

Additive manufacturing is rapidly becoming a manufacturing method capable of producing fracture-critical
components; as such, NDE requirements will become more stringent. Additively manufactured components
represent a novel challenge for NDE due to the layering nature of the process and its effect on diffracting energy
sources. Development of NDE techniques, sensors, and methods addressing these issues would be highly desired.
Additionally, in situ inspection systems that support assessment of AM builds will be considered desirable. Most of
the aerospace components will be metallic in nature, and critical flaws can be volumetric or fracture-like in nature.

In-Space Inspection:

Technologies sought under this SBIR include those related to in-space NDE. This includes on-orbit NDE (e.g., ISS
or Gateway) as well as for future lunar, Mars, or other planetary missions. This could include new NDE tools for
astronauts to use in a habitat or in the space environment (i.e., on an extravehicular activity (EVA)) or for
automated inspection. Technologies may include fully functional NDE tools developed based on ground-
use/laboratory equipment. Consideration will also be given to particularly promising technologies that may not
provide turnkey operation, but enable the advancement of future NDE inspection capabilities in space (i.e.,
enabling technologies). Fully functional NDE “tool” designs must address considerations related to size, mass,
power, safety, environment, operation and/or automation, and data transfer related to their proposed application.
For example, an NDE tool designed for ISS must ultimately be able to meet (after final development) ISS design
requirements, launch mass/payload limitations, operational guidelines for crew, etc. If no specific application is
outlined in the design, or if the proposal is for development of an enabling technology, then consideration must still
be given to system size, mass, power, and data rate, to the extent that it makes the technology feasible in the
within the next decade. To that end, consideration may be given to technology developments that are specifically
focused on minimizing (or optimizing) these system parameters (e.g., low-mass, compact microfocus x-ray
sources).

This solicitation is aimed at technologies for conventional NDE inspection of relevant components in space,
meaning detection of commonly known defects in materials (cracks, pores, delamination, FOD, impact damage,
etc.), rather than analytical tools aimed at determining chemistry, composition, or other properties of materials.
Relevant components to be inspected may include (but are not limited to) spaceflight hardware, protective gear,
core/rock samples, structural components, electronics/wiring, pressure vessels, thermal protection systems, etc. Of
particular interest are technologies that advance the inspection of AM parts in space. These parts may be
manufactured in an AM cabinet system that fits in an ISS EXPRESS (EXpedite the PRocessing of Experiments for
Space Station) rack, which results in parts on the scale of 6 in. AM technologies used in such a payload could
include fused deposition modeling, bound metal deposition, wire arc additive manufacturing, or other technologies
using wire feedstock. Large-scale space structures may be manufactured or assembled in the space environment
using AM techniques. Inspection technologies may involve x-ray technology (such as computed tomography),
ultrasonic imaging, thermography, or any other NDE methods adapted for space use. NDE tools or enabling
technologies that are compact, easy to carry (by astronauts), and work on low or accessible power will be
considered.

Expected TRL or TRL Range at completion of the Project

1 to 6

Primary Technology Taxonomy

Level 1

TX 08 Sensors and Instruments

Level 2

TX 08.X Other Sensors and Instruments

Desired Deliverables of Phase I and Phase II

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**Desired Deliverables Description**

Phase I Deliverables: For proposals focusing on NDE sensors: Lab prototype and feasibility study or software package, including applicable data or observation of a measurable phenomenon on which the prototype will be built. For proposals focusing on NDE modeling: Feasibility study, including demonstration simulations and data interpretation algorithms, proving the proposed approach to develop a given product (Technology Readiness Level (TRL) 2 to 4). Inclusion of a proposed approach to develop a given methodology to a TRL of 2 to 4. All Phase I proposals will include minimum of short description for Phase II prototype/software. It will be highly favorable to include a description of how the Phase II prototype or methodology will be applied to structures.

Phase II Deliverables: Working prototype or software of proposed product, along with full report of development, validation, and test results. Prototype or software of proposed product should be of TRL 5 to 6. Proposal should include plan of how to apply prototype or software on applicable structure or material system. Opportunities and plans should also be identified and summarized for potential commercialization.

**State of the Art and Critical Gaps**

NASA and the SBIR program are preparing for the next phase of human deep space flight. As such, much of the materials, structures, and subsystem will have to be built or assembled in space. Quantitative and qualitative inspection of these components and structures will be critical to ensure safe spaceflight. Additionally, NDE sensors will be used to determine the health of structures as they age in space.

**Relevance / Science Traceability**

Several missions could benefit from technology developed in the area of NDE. Currently, NASA is returning to manned spaceflight. The Artemis program's Orion spacecraft and Space Launch System have had inspection difficulties, and continued development and implementation of NDE tools will serve to keep our missions flying safely. Currently, Orion is using several techniques and prototypes that have been produced under the NDE SBIR topic. The Space Launch System is NASA's next heavy-lift system, capable of sending hundreds of metric tons into orbit. Inspection of the various systems is ongoing and will continue to have challenges, such as verification of the friction stir weld on the fuel tanks. As NASA continues to push into deeper space, smart structures that are instrumented with structural health monitoring (SHM) systems can provide real-time mission-critical information on the status of the structure. NDE of spaceflight hardware and parts manufactured in space will be key enabling technologies for constant crew presence and long-duration missions.

**References**

- Cramer, K. E.; and Klaassen, R.: Developments in Advanced Inspection Methods for Composites Under the