



NASA SBIR 2018 Phase I Solicitation

H7.02 In-situ monitoring and development of in-process quality control for in-space manufacturing (ISM) applications

Lead Center: MSFC

Participating Center(s): KSC, LaRC

Technology Area: TA12 Materials, Structures, Mechanical Systems and Manufacturing

The ability to ensure production of parts with repeatable quality is critical for ISM implementation. There are essentially two approaches to ensure consistency in the parts and the manufacturing process: a traditional qualification and certification (which may be difficult for ISM due to constraints on crew time and equipment size limitations) and online quality control (i.e., process monitoring, where in-situ monitoring of process signals provides information about the quality of the part produced by the process).

Qualification and certification processes for ISM require better machine and feedback control than is currently available with off the shelf printers and other small manufacturing systems. While traditional approaches to qualification and certification are also being pursued, a more immediate solution is that of online/off-line quality control techniques that are adaptable to ISM.

This SBIR seeks approaches to real-time, in-situ quality assurance of parts manufactured in the space environment and specifically focuses on manufacturing platforms similar to those used on ISS. The solicitation seeks methods that can be demonstrated for FDM or nonmetallic additive processes initially but are also broadly applicable to other candidate manufacturing processes for ISM, including AM of metallics and potentially even CNC machining. The latter technologies will likely be incorporated in to the Fabrication Laboratory in some capacity.

Development of in-situ techniques for quality control applicable for ISM may utilize the following approaches or leverage other techniques not listed here:

- Online layer/trace monitoring would allow for rapid identification of defects as they are generated and well before the part is finished. In turn, this would allow for stoppage of the production run (thus conserving feedstock and lowering processing/recycling energy) or for the correction of defects by introducing layer compensation algorithms. Ideally, evaluation should occur with every layer (enabling corrective actions to be taken right away) but can also be done after a batch of layers. This approach may require:
 - A multi-sensor approach and the ensuing data fusion and signal processing to extricate sensor data signatures that point to anomalies in the current print layer. This might include a combination of vision, structured light profilometry, thermography (IR), temperature, etc. Sensors and measurement methods are needed for:
 - Dimension and geometry.
 - Roughness and general surface finish.
 - Defects, porosity and flaws.
 - Feedstock tolerance.

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- Energy source.
 - Microstructure and mesostructured.
 - Strength of the interlayer bonding.
 - Residual stresses.
 - Collection of extensive data that will help develop feedback systems, predictive processing and modeling capabilities. Defect taxonomies (type, frequency and size quantification) and algorithms will be needed to map the functional correlation between the type and size of defects and the potential impact on material composition and microstructure (thus mechanical and functional properties).
 - Validation of modeling with process measurements to enable robust process control (e.g., vision system identifies a defect/pore and process control system corrects and eliminates defect).
 - Use of statistical process control.
 - Measurement of in-situ materials properties.
 - In-situ, monitoring of operating conditions (e.g., temperature management and others) to reduce and control residual stresses and distortion.
 - On-demand/adaptive post-processing based on actual thermal history of part
 - Off-line quality control (nondestructive testing), including traditional finished part inspection and verification. Less desirable because it is *post-mortem*. Must be non-destructive testing. Computer Tomography (CT) and X-Ray analyses have become the norm for aerospace components. Others include visual and instrument-based inspection of dimensional accuracy, surface finish and perhaps some mechanical/physical properties. Likely to be intensive on crew time and limited by size of equipment.

Phase I is a feasibility demonstration and should provide:

- Approach for in-situ quality control and verification of parts manufactured in space with clear adaptability to current and future ISM systems.
- Demonstration of approach:
 - Sensors integrated into a ground based AM system (can be FDM initially), but has high extensibility to other processes that operate in a similar volume.
 - Demonstrate that process signals acquired during build are correlated with and predictive of material outcomes (density, mechanical properties, other metrics) through a combination of material testing and statistical analysis.

Phase II would focus on integration of the system in a NASA ground-based ISM platform as a demonstration and development of closed-loop control systems. Phase III would integrate the technique/NDE system into an ISM platform on ISS and verify its efficacy for V&V applications.