Diffuse field ultrasonics for *in situ* material property monitoring during additive manufacturing using the SMART Platform

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ABSTRACT:

Additive manufacturing (AM) technology has potential to revolutionize manufacturing operations and significantly disrupt the conventional handling of new and replacement parts in all industries, including nuclear. Major positive disruptions in the nuclear industry will occur when: (1) AM can be leveraged to accelerate deployment schedules of nuclear assets and, (2) understanding of the AM process allows the part microstructure to be controlled and optimized with respect to radiation tolerance. Once fully implemented, these innovations will enable new levels of agility, leanness, and overall efficiency in the nuclear industry. This project is designed to develop, test, and provide the essential *in situ* sensing technology to achieve the outcomes of rapid part quality assessment and microstructural characterization of the part during the build. These two outcomes support the Advanced Methods for Manufacturing program goal of reducing cost, accelerating the development of nuclear relevant laser additive manufacturing (LAM) alloys, and rapid deployment of reactor technologies.

The major deliverable in this project is the development of a SMART (Sensing Microstructure using Acoustics in Real-Time) AM build platform that seamlessly integrates an array of harsh environment ultrasonic sensors into a powder bed fusion system. Two primary hypotheses are posed: (1) the SMART Platform, together with the measured response of diffuse ultrasonic scattering from material microstructure, will be capable of sensing part and/or build failure prior to failure and (2) the SMART Platform will be able to accelerate the development of new laser additively manufactured (LAM) alloys. The major tasks are designed to answer these hypotheses.

Affirming the first primary hypothesis provides the opportunity to correct the build process to avoid damage. This outcome will inevitably lead to higher efficiencies in manufacturing high-quality parts, which will reduce material costs and accelerate deployment of AM parts into nuclear systems. The second hypothesis is based on the expected measurement sensitivity to the AM part's microstructure. To answer this hypothesis, the *in situ* testing of the SMART Platform will focus on building parts composed of 9Cr-1Mo-V-Nb steel (Grade 91). This particular steel is under consideration as a potential LAM alloy as it contains desirable high-temperature creep resistance and associated radiation tolerance. However, these properties are only observed if the alloy obtains a particular microstructure during manufacturing. Testing of the SMART Platform will indicate the degree of sensitivity to various realizations of the part's microstructure. Affirming this hypothesis could lead to accelerated LAM alloy and AM component development.