NM NASA EPSCoR Research Showcase

Structural Health Monitoring Payload for Experiments on International Space Station
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Structural integrity assessment is essential for spacecraft exposed to severe mechanical loads during launch, in-orbit operations, and reentry. For reusable vehicles, reliable evaluation of structural condition between missions is critical to ensuring flight safety and operational readiness. Structural health monitoring (SHM) technologies enable continuous assessment of vehicle integrity using embedded sensors and data processing. However, SHM system performance under extreme temperature cycling and radiation exposure in space environment remains inadequately characterized.

This work describes the development of an SHM payload for deployment on the MISSE-22 platform aboard the International Space Station. The payload was designed to evaluate active ultrasonic sensing techniques and assess piezoelectric sensor performance under prolonged low Earth orbit conditions. The experimental hardware consists of two instrumented aluminum plates with integrated piezoelectric sensors to study elastic wave propagation and high-frequency structural vibrations in space. Practical damage detection capabilities are evaluated through controlled structural anomalies including a machined notch simulating crack damage and intentionally loosened bolted connections. The mechanical design prevents hardware from escaping the payload compartments in the event of complete fastener failure due to spacecraft vibration.

The payload incorporates both active and passive experiments. Active experiments use piezoelectric sensors for ultrasonic wave generation and reception, enabling damage detection through time-domain signal analysis. The data acquisition system measures sensor resonance characteristics in real time, allowing calculation of piezoelectric material constants and tracking of sensor degradation over the mission duration. Passive experiments expose piezoelectric sensors directly to the space environment through an aluminum enclosure with access ports and an externally mounted sensor, providing data on radiation and atomic oxygen effects on sensor materials.

The results from the proposed half-year orbital mission will provide fundamental understanding of SHM system performance in space, guide development of smart space structures with embedded sensing capabilities, and support design of reconfigurable structures and on-orbit servicing operations for future space missions.

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From Heat to Sound to X-rays: Quality Monitoring for Reliable 3D Printing
Borys Drach, NMSU

This presentation provides an overview of research conducted within the collaborative project “Next Generation Additive Manufacturing for Space Applications” between New Mexico State University, New Mexico Tech, and the University of New Mexico. Additive manufacturing (AM), or 3D printing, enables the production of parts with complex shapes directly from digital models with minimal tooling and setup. For space systems–where mass reduction is essential–the benefits of 3D printing are especially compelling. However, AM can yield variable quality even between parts made on the same machine, so process monitoring and non-destructive evaluation are essential for reliable, high-performance, and mission-critical use.

The first part of the talk highlights infrared imaging of fused filament fabrication (FFF) using a nylon/chopped carbon fiber composite and the development of a numerical model of transient heat transfer during printing. Two modeling approaches are introduced and validated against experiments. Micromechanical modeling is used to represent the composite's directional thermal conductivity. With an accurate model available, we can simulate common printing defects, such as under-extrusion, layer delamination, and nozzle clogs, and identify their infrared signatures. These signatures help translate raw infrared video into practical indicators for in-process monitoring, early detection, and potentially even corrective action.

The second part examines ultrasound as a tool for probing mechanical properties and directly detecting changes in material density and material discontinuities such as cracks and pores during printing. We describe progress toward in situ ultrasound testing integrated into the build plate of an FFF printer and discuss practical challenges. A systematic study explores how the speed of sound through the printed material varies with printing parameters, such as nozzle speed, nozzle temperature, and layer height, and how those changes affect monitoring. We also address the limited acoustic transparency of typical composite print beds and evaluate an alternative.

The final part presents a case study on non-destructive quality evaluation of AISI 316L stainless steel produced by laser powder bed fusion. High-resolution X-ray computed tomography is used to capture as-printed porosity and its evolution under load at multiple stages, providing insight into how defects interact, grow, and lead to ultimate failure in the presence of common metal AM features such as pronounced surface roughness, lack of fusion, and gas porosity. We also explore mitigation of detrimental effects of as-printed surface roughness by machining the surface prior to testing and assess the impact of improved surface finish on failure progression.

Together, these research efforts create pathways for monitoring and quality assurance in AM. The objective is to reduce uncertainty, detect problems early, and connect what we measure during fabrication to how parts perform under intended conditions. By advancing these capabilities, the project moves AM closer to the reliability of traditional manufacturing and supports broader adoption in space and other demanding applications.

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Fiber Optics-based Spectroscopic Sensing of Battery Systems

Dongchang Chen, UNM

In battery-based energy storage systems for space missions, storing and delivering the electrochemical energy in a safe, reliable, and predictable manner is vital for the success of the space missions, and the premise for applying any new battery technologies for aeronautics-related applications. For these purposes, a battery management system is a critical component to manage and utilize the electrochemical energy. Monitoring the chemical information within the cells of practical battery packs, however, has been a long-standing challenge. Such a challenge mostly lies in the fact that battery cells for realistic applications are a fully sealed system that intrinsically forbid measurements of chemical properties in the cells without interrupting the operation.

With the support of the NASA EPSCoR R3 project, Dr. Dongchang Chen (the Sci-I)'s group at the University of New Mexico aims to address such a needed, by incorporating fiber optics-based spectroscopy and battery technologies. In this presentation, First, we will present our newly constructed experimental platform, the first fiber-optics-based fluorescence/Raman spectroscopic sensing system for batteries, with optimized reliability and applicability. It enables live-collection of fluorescence and Raman spectra in battery cells and live-correlation between electrochemical and spectroscopic properties. Second, we will present our effort on refining the type of optical fiber for in-battery implantation, which allows us to realize maximal compatibility between optical-fiber-based spectroscopy and battery cells. Furthermore, relying on the system, we have studied the evolution of chemical information of battery electrolytes as a function of operating status for a few compositions, including commercially available ones and high-energy-density materials systems. The obtained spectral evolution, data correlation, and mechanistic analysis strongly supported the feasibility of the experimental approach and resolved the longstanding need of probing the chemical status of realistic batteries. In addition, we have integrated the developed spectroscopic sensing platform with optical switch technologies and greatly enhanced the throughput of the system. Such an optimization will be especially helpful for multi-cell battery packs, such as the system used in terrestrial energy storage or batteries of eVTOLs, and opens the possibility for parallel cell-to-cell comparison and correlation.

In parallel with the technical advancements, the project has provided a significant development for the Jurisdiction’s Research Infrastructure. It synergistically incorporates important concepts and approaches related to light, matter, and energy and has helped the Sci-I to construct an educational program to connect these fundamental subjects to space technologies. During the project period, we have organized a few guest lectures in local New Mexico high schools and achieved fruitful results. All these activities have greatly helped the Sci-I to deliver this research project to a broader group of audience, which will make a valuable contribution to the STEM education of New Mexico.

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