Thermo-structurally optimized lattice materials and structures for large-scale space applications

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Research Objectives

- Novel approach for optimal design and fabrication of multi-functional ceramic and metallic lattice materials for aerospace structures over large areas (~10m^2) or volumes (~1m^3)
- Minimum-weight lattice core panels satisfying thermo-mechanical and M/D HVI shielding requirements.
- The key scientific innovation is the integration of models and experiments at multiple scales to elucidate the dependence of mechanical/thermal properties of ceramic lattices on manufacturing parameters and topology.
- Advantages over SOA: Superior specific stiffness and strength, HVI performance, low thermal conductivity, high-temp capabilities and formability over curves surfaces.
- TRL from 1 (start) to 2-3 (finish).

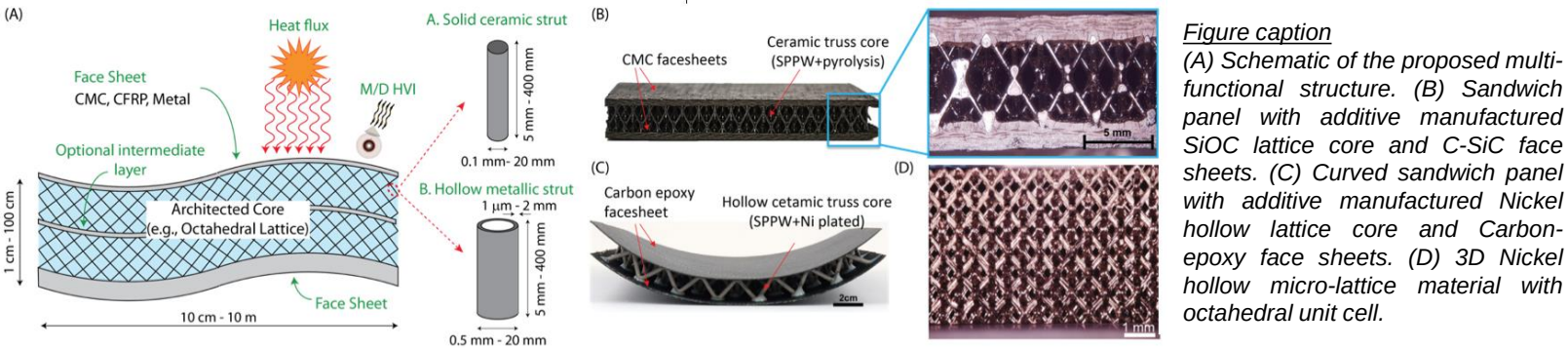

Figure caption
(A) Schematic of the proposed multi-functional structure. (B) Sandwich panel with additive manufactured SiOC lattice core and C-SiC face sheets. (C) Curved sandwich panel with additive manufactured Nickel hollow lattice core and Carbon-epoxy face sheets. (D) 3D Nickel hollow micro-lattice material with octahedral unit cell.

Approach

- **Fabrication** of lattices and panels by a combination of novel additive manufacturing processes.
- **Characterization and modeling** at 3 scales: *strut (material) scale* (microstructure, stiffness, strength and thermal conductivity), *lattice scale* (stiffness, strength, fracture toughness, thermal conductivity), *panel scale* (stiffness, strength, failure modes, heat loss, HVI resistance). Integration of manufacturing imperfections in models via stochastic tools.
- **Optimal design**: development of semi-analytical algorithms for multi-objective geometry optimization of octahedral lattice designs, and development of formal topology optimization tools for optimal lattice architecture design.

Potential Impact

- If the technology is successful, the weight of large-scale secondary structures subjected to thermo-mechanical load and M/D HVI will be greatly reduced.
- If the technology is successful, highly curved and topologically complex 2D ceramic and metallic lattice materials will be available for a wide range of applications relevant for space exploration.
- The experimentally validated multi-objective optimization approach for lattice core sandwich panels developed here can be applied to a variety of secondary and primary multi-functional structures subjected to thermo-mechanical loads.