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RFA-028: 3D-printable regolith--shape memory polymer composites for long-term lunar habitats (SMD-BPS)

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Given NASA's strategic goal of extending human presence to the Moon and on toward Mars for sustainable long-term exploration, lunar habitats and permanent bases will need to be set up in the foreseeable future. 3D printing and polymers have emerged as promising choices for fabrication method and material, respectively, to build many structural and functional components of such habitats. Among polymers, shape memory polymers (SMP) offer an attractive choice especially for lightweight, selfdeployable structures owing to their ""active"" microstructure that dynamically responds to external stimuli such as thermal heating. Several SMP-based structures have already undergone spaceflight experiments.

Despite their promising aspects, SMPs suffer from poor thermal stability and low recovery stress, specific strength and stiffness. SMP-based composites can overcome these limitations by combining the superior thermo-mechanical properties of composites with the functional shape-memory and self-healing properties of SMPs. Motivated by the recent discovery by the co-I of a 3D printable hollow glass microsphere (HGM)--SMP composite that exhibited excellent thermal stability, mechanical properties, shape memory response, flame retardancy, and self-healing, the goal of this proposal is to develop an equivalent 3D printable regolith--SMP composite for application in lunar habitat constructure enabled by in-situ resource utilization (ISRU), and to generate fundamental understanding of the processing-structure--property--performance relationships of such composites.

In this study, we will synthesize an SMP-based particulate composite by mixing a lunar regolith simulant with a polymeric mixture of a high-temperature SMP and photo-initiator. Using our validated Digital Ink Writing method for such composites that features UV and thermal curing, we will 3D print regolith--SMP composite specimens. We will validate and optimize our composite fabrication method based on Scanning Electron Microscopy (SEM) of the printed samples. To understand the process--structure--property-performance relationships of this composite for the extreme lunar environment, we will conduct thermomechanical and materials characterization on a number of test samples fabricated with different regolith weight percentages and 3D printing parameters. The following tests will be conducted to evaluate the mechanical and shape memory performance: quasi-static and high strain rate compression tests in a wide range of temperatures from (-150°C--120°C) and under a wide range of loading rates (10-3--103 s-1), quasistatic and high strain rate tests after successive thermal cycling (0 to 60 cycles), quasi-static free shape recovery tests, CT scanning (to evaluate microstructural defects), impact damage tests, and SEM (to evaluate self-healing and crack closure after damage).