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3D PRINTING ASSISTIVE SOFT ROBOTICS AND SENSING SYSTEMS FOR HUMAN SPACEFLIGHT

Abstract

Long-duration spaceflight poses many physiological health risks to astronauts consisting of dangerous environmental conditions, muscular atrophy, and low medical accessibility. One of the most common notions of human health and survival in space is associated with spacesuits. Current NASA spacesuit supplies oxygen, pressure compensation, and thermal management in the radiative vacuum of space. However, the spacesuits used cause moderate mobility impairment that could endanger the user in a time of crisis and do not mechanically assist astronauts while performing Extra-Vehicular Activities (EVA) outside of climate-controlled environments. While not performing EVAs, astronauts encounter muscular atrophy for extended times in space from the low-gravity environment, which exacerbates fatigue. There have been studies that confirm a 20% musculoskeletal mass loss within 5-11 days while in space. These health risks call for advanced manufacturing techniques to produce customizable medical devices for astronauts while in space. This study develops 3D printing technologies using biocompatible composites to produce assistive health-related soft devices. Our materials selection focuses on PDMS silicone as the elastomeric structural matrix and liquid metal eutectic gallium-indium as the composite ink conductive filler because of their success in soft robot design. 3D printing is the primary manufacturing method due to its on-demand production capabilities necessary for long supply lines and adaptable designs frequent in space travel. The 3D printing method used will be Direct Ink Writing because of its ambient extrusion of customizable composite inks and the use of suspension gel vat support which allows for resilience to environmental effects such as movement and gravity on the uncured printed structure's geometry. The assistive gloves comprise printed compartments using multi-stiffness 3D printed elastomers to mimic physiological hand movements using fluid actuation. Whereas the biometric sensors combine printed thermally and electrically conductive with conventional multi-layered hardbody sensing units to gather a stream of astronaut health data. Both the actuator and sensing pathways are constructed in a single print procedure using multiple Direct Ink Writing inks. The skin-to-sensor from the gloves contact provides live astronaut health data for confronting both anomalous and long-term health events while in space. The development of these health-centric technologies is essential for the near-term Artemis generation spacesuit development, specifically for lunar surface expeditions as well as the future of long-term interplanetary human habitation.