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A PROPOSED PHOTOELASTICITY-BASED ENHANCED VISUAL INSPECTION TOOL FOR ASTRONAUT EVA

Abstract

Space debris micrometeor impacts pose a significant threat to the ISS, as evident by the continuous barrage of damage sustained throughout its operation. Though critical systems have not yet been affected, active monitoring, damage assessment, repair and recovery options are high priority items in ISS operations. ISS solar arrays are especially vulnerable to impacts due to their large deployed area and minimal cover glass protection, which necessitates routine monitoring of array health. Only direct visual inspection can confirm the full extent and location of possible cracks, torsions and penetrations. The concept architecture for an Enhanced Visual-Inspection System (EVIS) for use by astronauts during EVA and IVA is proposed that promises to expand astronauts' visual senses. Current inspection methods employed by astronauts, as well as notable inspection and repair EVAs to date, are surveyed and compared. The proposed EVIS system is a direct line-of-sight visual tool that uses simple optical elements to locate abnormal stress, strain and thermal patterns in certain exposed, semi-transparent materials in real-time. The EVIS concept is comprised of two separate packages: a passive photoelastic inspector and an active thermal infrared imaging inspector. The photoelastic inspector is a simple, low mass system comprised of an easily manipulable view-finder screen of layered polarizer quarter-wave-plate films. Using the EMU spacesuit lights and solar illumination, the device takes advantage of an observed material's birefringence properties by using photoelasticity to visualize the induced stress geometry. The process renders a colorful isochromatic contour map depicting lines of constant maximum sheer stress, which trained astronauts may use to identify anomalous stress gradients indicative of possible damage. This allows the structural integrity of critical components (such as solar cells, truss structures, panels and windows) to be verified in-situ. Certain distressed components may be identified prior to failure so that appropriate action may be taken by the crew. The thermal infrared inspector is a streamlined, self-contained low-power device based on existing FLIR systems that enable quick assessment of the thermal conditions of exposed radiators and components. Both inspectors are hand-held, and may be attached to the EMU spacesuit through appropriate hooks and scars. Potential future enhancements such as helmet visor integration are also explored. The EVIS concept promises astronauts advanced situational awareness that enhances the quality, quantity, and rate of acquisition of visual inspection data during both routine and emergency operations, with the potential to significantly reduce the duration of inspection EVAs.