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USING INERTIAL MEASUREMENT UNITS FOR MEASURING SPACESUIT MOBILITY AND WORK ENVELOPE CAPABILITY FOR INTRAVEHICULAR AND EXTRAVEHICULAR ACTIVITIES

Abstract

Human spaceflight destinations are expanding to include a multitude of environments that will offer different mobility challenges to explorers due to varying gravity levels and surface operations. Intravehicular Activities (IVA) suits might include a basic "get-me-down" suit for suborbital spaceflight, or a high performance pressurized pilot suit where arm mobility and field of vision are particularly important. Extravehicular Activities (EVA) could require different spacesuit architectures including: a zero-gravity station/craft maintenance suit where hand dexterity is critical; a close proximity operation suit to asteroids where maneuverability and visibility are critical; and a surface suit for the Moon or Mars where leg mobility would be a key requirement. Spacesuit kinematics are currently measured using motion capture data or photo and video analysis. Although these methods retain great detail of the external motion of the suit, they do not capture the physical body motions within the suit and in the case of motion capture, they are restricted to a laboratory setting. Inertial Measurement Units (IMUs) use accelerometers and gyroscopes to estimate relative translation and rotation. IMUs systems exist that are mobile, low-powered, and economical solutions that can be used in a laboratory setting or in the field. In this paper a range of commercially available IMUs are presented, from which the Man-Vehicle Laboratory has selected APDM, Inc.'s Opal (TM) devices for research. A preliminary analysis was conducted of a subject's knee bend angle while walking comparing the IMUs to a Vicon motion capture system, which is considered the industry gold standard for data acquisition. The IMU knee joint angle mapped within 3 degrees of the Vicon data showing the potential of the new system. At the David Clark Company, the IMUs were used with the Contingency Hypobaric Astronaut Protective Suit (CHAPS) to measure elbow flexion/extension, shoulder flexion/extension, and shoulder abduction/adduction in the scenarios of unsuited, suited and unpressurized, and pressurized. Results from testing are presented in the paper showing the system's ability to capture range of motion in any environment. A brief discussion summarizes key findings in the study and identifies limitations in the IMU test configuration. Recommendations for future testing are outlined and conclusions are drawn on the usability of IMUs for exploration investigations of astronaut mobility and work envelope.