INVESTIGATING SPACESUIT MOBILITY IN SPACEFLIGHT OPERATIONS USING MOTION CAPTURE TECHNOLOGY

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THE MISSION

The Spacesuit Utilization of Innovative Technology Laboratory (S.U.I.T. Lab) research at Embry-Riddle Aeronautical University aims to investigate methods for recording, analyzing and optimizing motion capture data for spacesuit mobility.

Understanding how spacesuits restrict astronaut mobility allows the S.U.I.T. Lab to gain hands-on experiential learning and support industry with the standardization of procedures for spacesuit operations. Mobility analysis includes upper body motions such as flexion, extension, abduction, and adduction of the arms as well as intravehicular and extravehicular activities. The lab makes use of a professional-grade motion capture system and the David Clark Company U2 Pressure Suit to collect preliminary motion data. Lessons learned will be applied to range of exploration activities including mobility for planetary exploration, emergency capsule egress, and the creation of virtual reality simulations. The lab research will provide future spacesuit manufactures and spaceflight operators with a greater understanding of spacesuit mobility restrictions, and how to improve designs.

JOINT ANALYSIS

- When pressurized, the protective layers of a spacesuit cause astronaut mobility limitations. Movement at the joints is task-critical for practically all intravehicular activities (IVA). Reaching for controls, objects, or handrails require comfortable adduction and abduction of the elbow joints, along with rotation of the shoulder joint. The ability to bend over to collect samples, repair components, or adjust fixtures during both IVA and extravehicular activities (EVA), or spacewalks, requires a wide range of rotation in the abdominal and knee planes of motion.
- Simple walking gait can require a detailed capture of the entire body. Walking without wearing a suit can be compared to walking in a pressurized suit to make the restrictions of the suit on certain joints more visible. This will be important to study for EVA suits that will be used on other celestial bodies in the future.
- Partnership with analogue researchers at HI-SEAS (Hawai'i Space Exploration Analog and Simulation) allows the Spacesuit Utilization of Innovative Technology Laboratory (S.U.I.T. Lab) to gather feedback from field tests on numerous tasks, including time data, video recordings, and suit information for certain motions. Motion data will allow for the calculation of various metrics for different parts of a suit such as: torque, velocity, acceleration, range of motion, metabolic cost (energy loss), and dexterity.

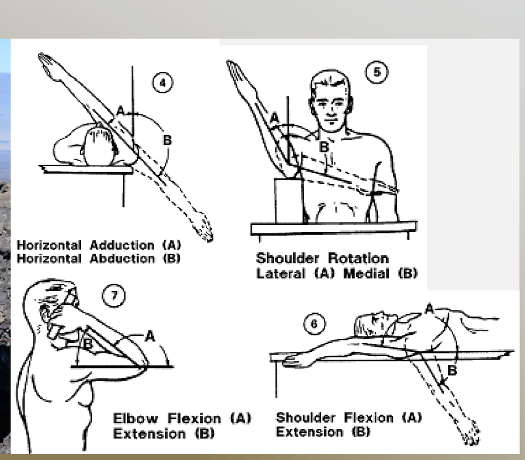

IMAGE SOURCES:
European Space Agency (ESA), Final Frontier Design (FFD), Hawai'i Space Exploration Analog and Simulation (HI-SEAS), HTC, National Aeronautics and Space Administration (NASA) , Opti-Track, Spacesuit Utilization of Innovative Technology Laboratory (S.U.I.T. Lab)

SUIT DESIGN AND ACTIVITIES

- As the current resurgence in the space industry moves towards human spaceflight again, many companies will look towards creating their own solutions for keeping pilots and passengers safe.
- Spacesuits are being designed for various applications and many suits specialize in different aspects of EVA and IVA operations. However, the S.U.I.T. Lab is working to create a standardized checklist for crews to utilize during their activities inside or outside a vehicle. Results from motion capture analysis will determine which activities are most critical for suit testing.
- The checklist can be used before, during, and after any activity involving a spacesuit. It is intended to provide a crew with the ability to identify any problems or inconsistencies when operating with the suit. The checklist will be applicable to all pressurized suits and intends to work across all manufacturers of spacesuits.
- By standardizing checklists, new spacesuit designers such as Final Frontier Design can keep them in mind when creating their products. The use of motion capture before or during spacesuit manufacturing and testing will allow designers to confirm nominal suit performance that is in accordance with the tasks on standard checklist.

REFRENCES:
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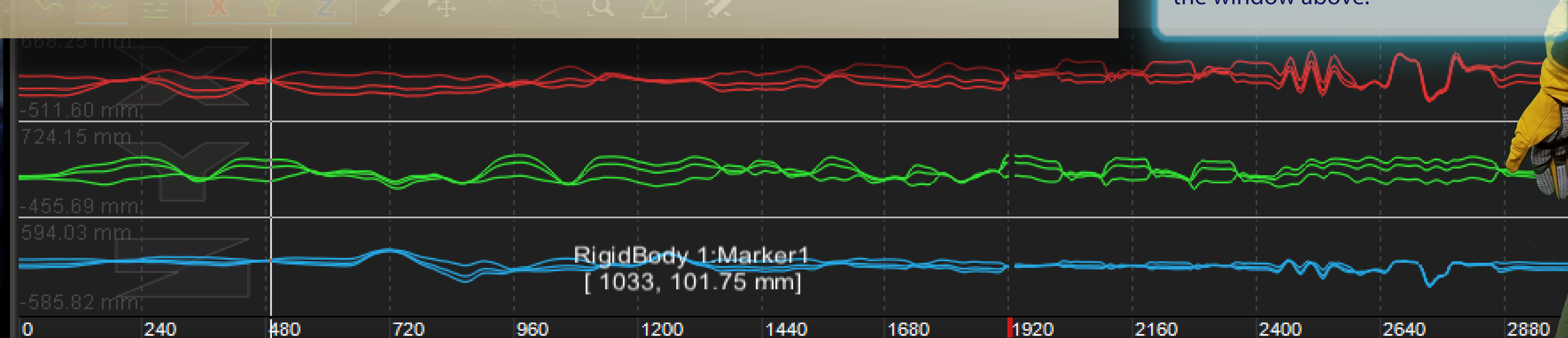
Astronaut Edward H. White II, pilot for the Gemini-Titan 4 space flight, floats in space during America's first spacewalk. The extravehicular activity (EVA) was performed during the Gemini 4 mission on June 3, 1965. (Image courtesy NASA)

SIMULATION

- 3-Dimensional (3D) data is applicable in various software environments ranging from animation, interactive virtual reality simulation, and data visualization. With captured movements, 3D spacesuit models can be rigged and animated within professional software. Real movements can be mapped into virtual movements to create a true to life astronaut avatar that can be used in high detail concept designs and instructional media.
- Software development for virtual reality has the power to create endless amounts of scenarios for continuous testing and rapid development of spacesuits and the systems they utilize. The S.U.I.T. Lab's spacecraft cabin mockup has the potential to become an immersive platform for simulated capsule testing. The physical rig can remain constant, while any number of virtual capsules can be loaded for user testing within a virtual reality simulation, for example SpaceX's Dragon V2, Boeing's Starliner CST-100, or Lockheed Martin's Orion.
- The positional tracking hardware of modern day Virtual Reality (VR) headsets will allow fully tracked head, hand, and object tracking within an expandable 3D space. This will allow accurate full scale testing of a simulated capsule. Users can interact with the simulation wearing a pressurized suit while the lab technicians monitor user performance during testing.
- A VR study will allow the S.U.I.T. Lab to simultaneously monitor effects of spacesuit characteristics on IVA performance and the human factors involved in the system in which the user interacts with. Improvements can then be made to both the suit, and the system to identify the conditions for nominal performance during IVA operations.

Below is a waveform graph detailing the X, Y, and Z coordinates of the markers tracked by the two cameras above. Makers placed on the David Clark U2 Pressure Suit can be detected by infrared reflection in the window above.



Astronaut James B. Irwin, lunar module pilot, uses a scoop in making a trench in the lunar soil during Apollo 15 extravehicular activity (EVA). August 2, 1971. (Image courtesy NASA)