Range of Motion Evaluation of a Final Frontier Design IVA Spacesuit using Motion Capture

Principal Investigator: Ryan L. Kobrick, Ph.D.
Researchers: Nicholas Lopac, Michael Fornito, Chase Covello, & Benjamin Banner

EMBRY-RIDDLE Aeronautical University
DAYTONA BEACH, FLORIDA

RESEARCH OVERVIEW

Embry-Riddle Aeronautical University's Spacesuit Utilization of Innovative Technology Laboratory (S.U.I.T. Lab) is focused on improving human performance in spaceflight by concentrating on spacesuit research for intravehicular activities (IVA) and extravehicular activities (EVA). The design and execution of range of motion (ROM) protocols in an experimental setting will provide insight on the functions and restrictions of spacesuits, aiding in current and future designs or modification. The S.U.I.T. Lab worked with Final Frontier Design (FFD) to provide a quantitative analysis protocol for seated arm mobility of their NASA Flight Opportunities Program (FOP) IVA spacesuit. The lab used reflective tracking markers on three test subjects and recorded a set of arm ROMs using OptiTrack's infrared motion capture system including: shoulder abduction/adduction; vertical and horizontal shoulder flexion/extension; and vertical and horizontal full-arm carveouts. All motions were recorded in three spacesuit conditions including: unsuited; suited unpressurized; and suited pressurized (2.5 psid).

Motion capture data was edited and filtered for mobility analysis calculations. Programs were developed in MATLAB to analyze and plot angular metrics as well as three-dimensional reach envelopes. These programs allow the spacesuit manufacturer to visualize the mobility of their spacesuit design and associate qualitative mobility characteristics with quantitative results in the form of angular and volumetric data. The percentages of mobility retained between all spacesuit conditions reveal a quantifiable reduction in mobility going from unsuited to suited unpressurized to suited pressurized. Based off the performance of this investigation, FFD gathered preliminary data regarding the mobility of their NASA FOP spacesuit. Improvements to the equipment and protocol used by the lab for motion capture and analysis have been implemented since this study. Expanding from four to nine motion capture cameras, the lab has been able to capture spacesuit mobility data with far greater accuracy and completeness. Updated prescribed motion protocols instruct subjects to maintain straight arms reaching as far as comfortable and across their body in some cases, which is done to characterize shoulder mobility and is not reflective of the spacesuit's maximum mobility.

FINAL FRONTIER DESIGN (FFD)

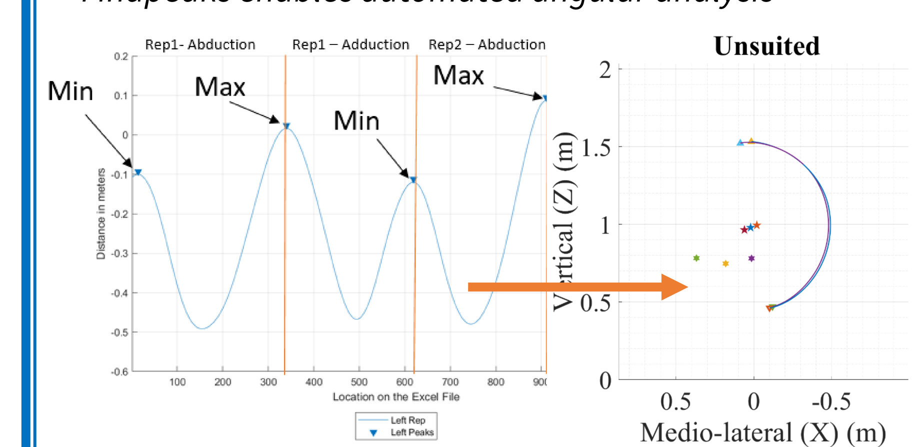
NASA FLIGHT OPPORTUNITIES PROGRAM
FFD IVA SPACESUIT SN#008

ICES-2019-99: **Range of Motion Evaluation of a Final Frontier Design IVA Spacesuit using Motion Capture**

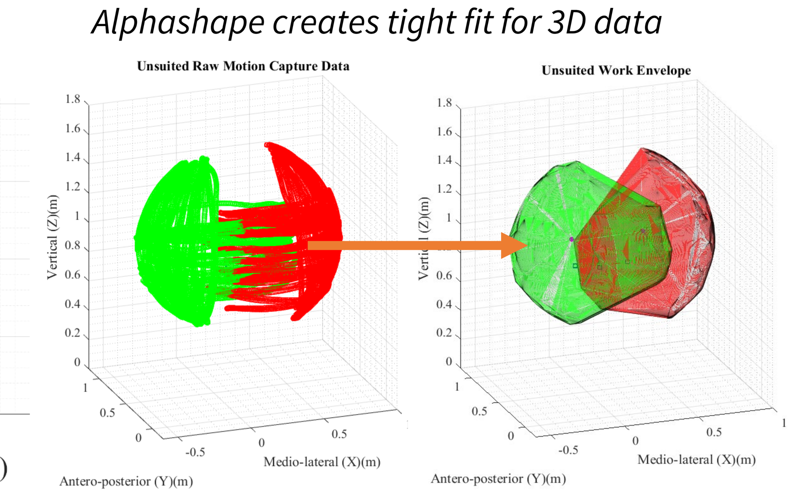
RESULTS

- **Custom Built MATLAB Mobility Processing and Analysis Tools**

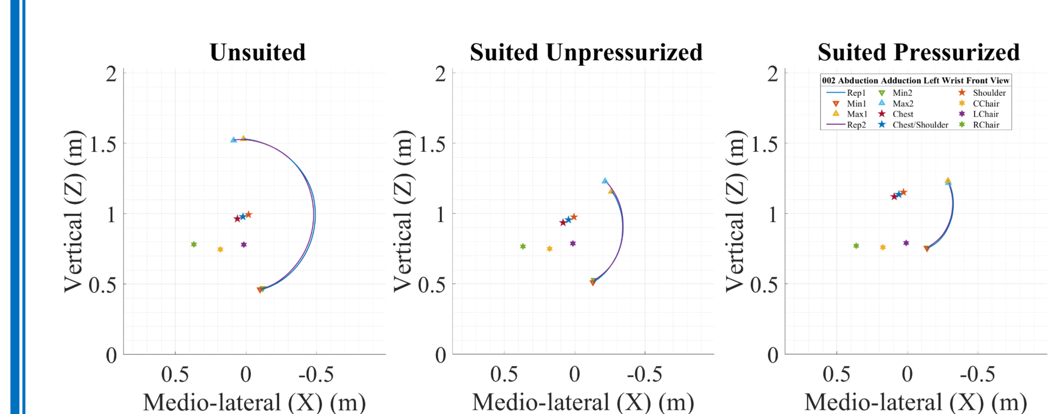
Findpeaks enables automated angular analysis



Alphashape creates tight fit for 3D data

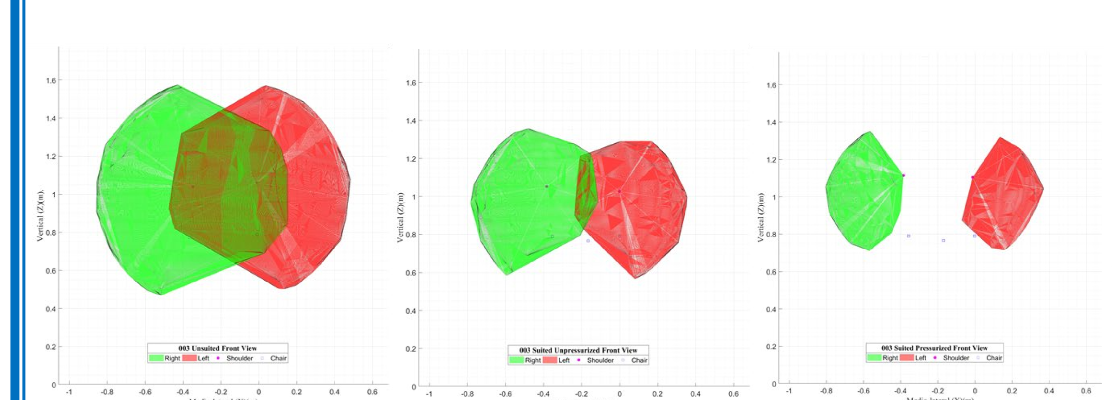


- **Two-Dimensional Joint Angle Analysis**



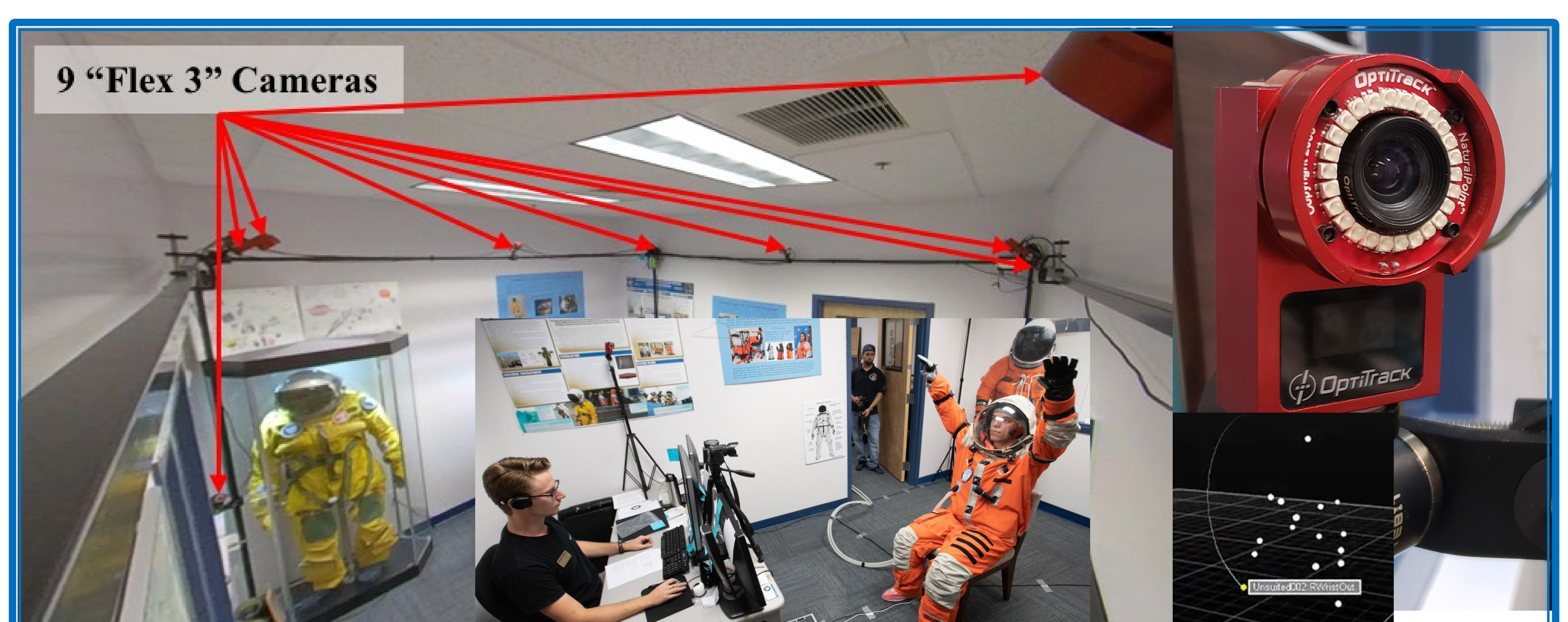
Angular Figure Analysis
- A noticeable occurrence in the angular figures was the change in position for the shoulder and chest points
- By using actual 3D data in motion capture, the slant (deflection) of the body can be measured

- **Three-Dimensional Range of Motion Analysis**



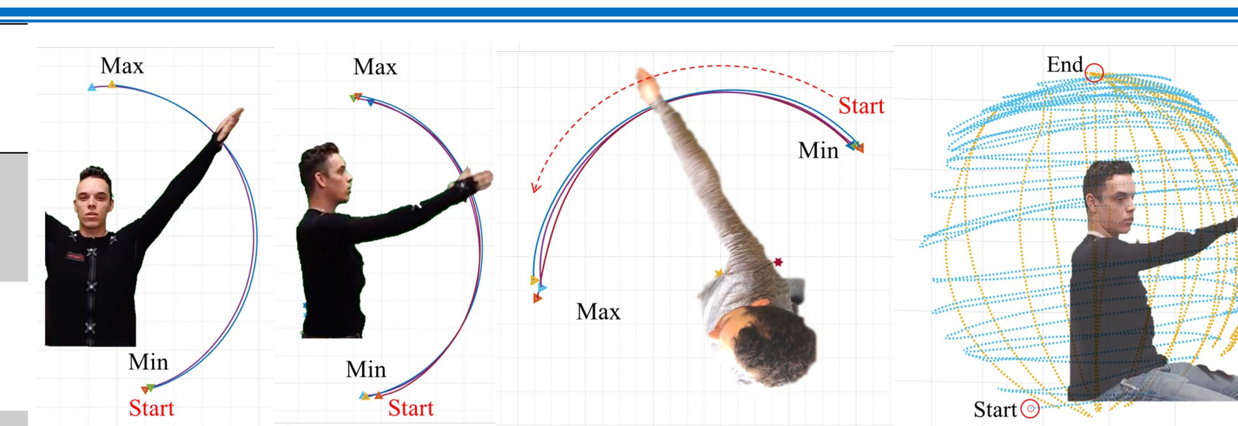
Reach Envelope Observations
- Difficulty reaching while their arms are fully extended
- Loss of overlap volume for unpressurized and pressurized
- The reduction of volume in the suited reach envelopes appear to be larger than expected. This may be due to MATLAB alpha shape generation and positioning.

S.U.I.T. LAB EQUIPMENT



BIOMECHANICS

Shoulder AA (Abduction and Adduction)
Shoulder VFE (Vertical Flexion and Extension)
Shoulder HFE (Horizontal Flexion and Extension)
Right Arm: Vertical Carveout
Left Arm: Vertical Carveout
Right Arm: Horizontal Carveout
Left Arm: Horizontal Carveout



Left to Right: AA, VFE, HFE, Vertical & Horizontal Carveouts

- Range of motion activities recorded in 3 repetitions for all test cases
- Participants were instructed to move to a comfortable minimum and maximum without straining shoulders or bending elbows for each activity
  - This is done to characterize shoulder mobility and is not reflective of the spacesuit's maximum mobility (Excludes elbow mobility)

CONCLUSION

- First attempt in developing procedures and data analysis
- Collected 3D data focused on shoulder mobility of the FFD FOP IVA spacesuit
- Analyzed quantitative mobility data which yielded statistical insights
- Angular ROM revealed the degradation of shoulder mobility
- These procedures can be replicated and updated for future applications in spacesuit design, vehicle layout, human performance and safety analysis

ACKNOWLEDGMENTS

Embry-Riddle Aeronautical University - 2017-2018 FIRST Award & 2018-2019 FIRST Award – ERAU Applied Aviation Sciences Department and College of Aviation - Spacesuit Utilization of Innovative Technology Laboratory students, volunteers, and test subjects. This project was supported by the National Aeronautics and Space Administration through the University of Central Florida's NASA Florida Space Grant Consortium and Space Florida (2017-2018 Florida Space Research Program Award).