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Mapping of IVA Spacesuit Mobility – Design Observations and Functionality

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The SUIT Lab at Embry-Riddle Aeronautical University is a joint student-faculty project utilizing multiple high altitude pressure garments to investigate suited crew capabilities within a spacecraft during simulated spaceflight missions. The testing environment within the SUIT lab includes the use of suits in a low-fidelity capsule cabin mockup with a horizontally situated launch-positioned chair simulator. Standard videography and analytical video software are used to determine levels of achievement in ergonomic range of motion and comfort design across multiple spacesuits. Comparative analysis and testing provide data supporting the requirement for the use of particular spacesuits inside proposed commercial launch vehicles. Results of the study have indicated that the use of ergonomic and standardized dexterity tests coupled with methods for quantifiable range-of-motion data collection via motion capture and analysis, provide a useful basis for evaluating spacesuit performance for future spacecraft integration. This study presents the relevance and means for developing an academic-based suit testing environment, and the processes of providing recommendations for adjustments that may need to be considered with respect to both nominal and off-nominal crew activities while in IVA spacesuits.

Nomenclature

\[\begin{align*}
AAS &= \text{Applied Aviation Sciences} \\
DCC &= \text{David Clark Company} \\
ERAU &= \text{Embry-Riddle Aeronautical University} \\
EVA &= \text{Extravehicular Activity} \\
FAA &= \text{Federal Aviation Administration} \\
FFD &= \text{Final Frontier Design} \\
IVA &= \text{Intravehicular Activity} \\
OTS &= \text{Off-the-Shelf} \\
opsy &= \text{Ounces per Square Yard} \\
psid &= \text{pounds per square inch, differential} \\
scfm &= \text{Standard Cubic Feet per Minute} \\
SRV &= \text{Suborbital Reusable Vehicle} \\
SUIT Lab &= \text{Spacesuit Utilization and Innovative Technology Laboratory}
\end{align*}\]

I. Introduction

Embry-Riddle Aeronautical University’s (ERAU) Department of Applied Aviation Sciences (AAS) has been developing space systems operations laboratories that provide undergraduates opportunities for research in the emerging specialized fields of space traffic management, life support and environmental systems, and payload development. This document will serve as an academic study and literary preview of the testing underway in the Spacesuit Utilization of Innovative Technology Laboratory (SUIT Lab), with emphasis on the functional characteristics of certain Intravehicular Activity (IVA) spacesuits. Suited participants perform a series of tasks under varying operational modes within hardware simulations. The testing procedures and analytical tools are used to focus on pressure garment constraints and comfort variations that will familiarize students for future research and design considerations.

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A. Background

The commercial space industry and associated space vehicles in development have generated new demand for innovation and growth in spacesuit systems and subsystems. The manufacturing and design of IVA spacesuits lack variability, indicating disregard for both the complexity of private space tourism and the human systems integration requirements posed by commercial spaceflight participants. Some advances in private IVA suit development are reflected in the work of industry leaders such as Final Frontier Design (FFD), the David Clark Company, Inc. (DCC), and Orbital Outfitters. Private entities like FFD have been developing operative training suits and fully functional IVA suits that are much more lightweight, cost-effective, and customizable than standard garments currently available on the market.\textsuperscript{1,2} Growth in the private and commercial space industry means growth in the understanding of redundant environmental systems in flight operations, yet suits tend to remain vehicle specific while development is focused on craft specifications. As an academic facility, the SUIT Lab at Embry-Riddle has begun observation and testing of suit characteristics within controlled simulated scenarios to further understand the constraints of commercially available IVA suits.

Students will be able to utilize equipment and mockups to effectively measure performance aspects of pressure garments during specific modes of operation. All suits used in testing are considered viable, and may be used for most training practices in general applied astronautical activities in accordance to manufacturing standards. The SUIT Lab has access to a DCC U-2 high altitude pressure garment (Figure 1) and FFD’s 4\textsuperscript{th} generation IVA Terra-suit (Figure 2). FFD uses NASA’s Technology Roadmap as guidance for Technical Readiness Level (TRL) advancement in determining effectiveness and viability.\textsuperscript{1} The U-2 is maintained in-situ, and FFD suits are available during scheduled intervals of use at Embry-Riddle facilities.

The SUIT Lab was initiated in the summer of 2016 through the efforts of AAS Assistant Professor Dr. Erik Seedhouse, who oversaw the development and construction of the launch-positioned chair simulator. With consultation and guidance by FFD, several student volunteers constructed a horizontal launch position chair to simulate body positioning for crew activities within the cabin during standard launch and reentry phases of flight. Certain vehicle configurations will dictate the positioning of the astronauts during launch and reentry, therefore the horizontal chair will only simulate particular flight/vehicle characteristics.

In January of 2017, oversight of the SUIT Lab was transferred to Dr. Ryan Kobrick, who has since directed the development of testing systems and managed lab end items. The lab operates under jurisdiction of two hired undergraduate technicians and a number of student volunteers that oversee departmental needs of research and related deliverables. The lab has since put together a collection of low fidelity mockup simulators that demonstrate fundamental properties of cabin environment and crew activities in both nominal and off-nominal scenarios. Performance quality of the suits with each recorded movement will determine how suit architecture is analyzed, with the goal of converging differentiation amongst suit components into a more universal system. Pressurized operations are conducted under close supervision, and mechanical pressure vessels are in an isolated location from the air supply source. Technician supervision is

Figure 1. DCC U-2 “Dragon Lady” Pressure Suit.

Figure 2. The FFD IVA Terra-Suit is being utilized in the Project PoSSUM Scientist-Astronaut training program in partnership with the AAS Department at ERAU.
mandatory for both air pump and suit locations. The capsule hatch design and related suit lab operational hazards have been reported and documented for damage of both personnel and suits, and are awaiting departmental safety approval.

B. Testing Methods

This study uses IVA suits, which are designed to act as redundant life support in case of loss of cabin pressure to the craft. The mockup simulations have the user connected to an air pump by an external umbilical system that is capable of providing the suit and user with enough air ventilation and flow rate so that there is adequate temperature regulation and breathable constituents present by appropriate parts-per-million (ppm). This acts like the Life Support System (LSS) supplied by a spacecraft to the spacesuit during testing phases. While the mockup design is constructed for maximum user comfortability, the chair is not built to accommodate any particular suit. The chair only acts as functional hardware to test general movements in a horizontal seated position.

Crew positioning in the craft would be seated during nominal operations of launch and reentry launch phases, unless mission task specifies otherwise. Common actions when in the seated position include hand movement and tactile use of instrumentation, elbow flexion, and abduction and adduction shoulder and arm movements. Cross-body reaching is also included in testing, however may be unlikely in any aircraft/spacecraft control scenario.

Ingress and egress of vehicle refer to the crew safely entering and exiting the cabin respectively, without damage to suit. Regarding the mockup structure within the SUIT Lab, ingress and egress testing is performed exiting the horizontal chair and structure framework. Figure 3 shows a chair egress test procedure being tested in microgravity with participants wearing FFD pressure suits. NASA’s technology roadmap emphasizes importance on ingress and egress motions for both suited and unsuited users. Ergonomic modeling is imperative to consider overall dynamic movement so to properly assess tasks and differentiate severity levels for all suits used in testing.

C. Market Valuation

The commercial spaceflight industry has developed under large influence of the rapid emergence of suborbital reusable vehicles (SRV’s). SpaceShipOne flight 15P in 2004 introduced the feasibility of suborbital human transport, provoking the industry need for commercially available IVA spacesuits. Recent market analysis performed by the Federal Aviation Administration Office of Commercial Transportation has displayed human spaceflight experiences for tourism or training to make up approximately 80% of suborbital reusable vehicle opportunities. Figure 4 illustrates SRV industry growth vs. time for the prediction of commercial human transport compared to other lucrative industry possibilities over a 10 year timescale. It should be noted that even with the largest growth occurring in basic and applied research, the projected need for human spaceflight is the driver for market turnout, and likely success. The human
transportation submarket demand incorporates: in-situ personnel training for private entities requiring staff training procedures, and human spaceflight experiences for space tourism. It is projected that 3,600 participants will fly within the next 10 years, an increase in human presence in space by about 650%. Nearly 1,000 individuals already have reservations on SRVs.

As a consumer market, human transportation dominates the SRV realm. The operating environments for SRVs encourage the development of other aerospace hardware. Human interfacing remains a crucial component of human spaceflight, regardless of any guarantee of shirt-sleeve environment by commercial launch providers. NASA’s Criteria for Thermal Regulation for Manned Spacecraft Cabins defines shirt-sleeve environments as physiological conditions that maintain air, skin, and surrounding wall temperatures to be “sweat-free.” With regard to commercial spaceflight for human spaceflight participants, the desire to engineer comfortable and stress-free environments during flight is essential for marketing space tourism as an easily accessible service.

The FAA commercial space transportation regulations currently state that a launch provider must include some form of redundancy in case of cabin depressurization, and must prevent incapacitation of flight crew and participants, according to 14 CFR Part 460.11(c). Launch providers will need to provide proof of effective means of life support redundancy beyond that of hull safety and cabin gas supply redundancy to ensure spaceflight participant safety, which would insinuate use of a pressure garment as no other technology has yet presented itself. The off-the-shelf (OTS) readiness of commercial spacesuits is crucial in reinforcing the development of specific subsystems to promote commercial access to space for human spaceflight, as a support to the fragile nature of young industry focused on new technologies and minimum guidelines. Commercial launch providers would benefit purchasing variable, easily integrated, and affordable IVA suits designed for effectiveness and operator simplicity.

D. Design Characteristics

The SUIT Lab will be making use of two suits: The David Clark Company (DCC) U-2 “Dragon Lady” high altitude pressure garment, and the Final Frontier Design (FFD) Terra-suit.

DCC S1034 and S1034E Helmet

The U-2 pressure suit (schematics in Figure 5) is worn by high-altitude pilots in the U-2 reconnaissance aircraft. The first generation of the suit was developed in 1951, the Model 4 full pressure suit. The design concept has undergone decades of improvement, of which in 2015 the AAS department acquired the DCC S1034 (manufactured in 1998). Suits are available in 12 sizes; the ERAU suit is a small-long. The coverall and gloves weigh 12.5 lbs, the retainer 7.5 lbs, and S1034E helmet 7.5 lbs. The suit requires up to two technicians to assist user in donning and doffing procedures.

Desired operating pressure is +3.5 psid, with operating altitudes of up to 100,000 ft, and helmet hold-down pressure of +5.0 psid. The helmet is an improvement to the S1031L, primarily the two-ply visor: polycarbonate for the inner ply as shatter resistance and outer acrylic layer. The gloves for the S1034 ERAU suit are the S1031 model (Figure 6). The outer garment of the suit is a gold-dyed Nomex, with a 5.5-ounces-per-square-yard (opsy) poplin weave for the coveralls and 5.9 opsy gabardine weave for the leg restraint. The glove and neck o-rings are anodized aluminum, with interior rubber lining for compressive sealing.

Figure 5. DCC U-2 S1034 overall architeture. Courtesy of David Clark Company, Inc.

Figure 6. DCC U-2 S1031 gloves.
**FFD Terra-Suit**

Final Frontier Design describes their Terra-Suit (as seen in Figure 7) to incorporate five primary end items that represent the system as a whole: the inner pressure garment, pressure gloves, outer garment, under garment, communications hardware/cap. The suit is considered an analog spacesuit meant for training purposes only. The purpose is to provide the option of a cheaper, more easily obtainable suit with identical characteristics to that of a flight-ready IVA suit, for a reduced cost that can be used in high fidelity simulations.

Design varies, with the primary exclusion being the carbon fiber waist ring that was present in the 3rd generation model, known as the 3G. The Terra-Suit has a semi-soft helmet with a pylocarbonate visor neck ring. The suit and helmet is all one component, rather than the suit-to-helmet disconnect functionality of the U-2. The recommended operating pressure is +3.5 psid, but should not be used in true hazardous environments beyond training parameters. The outer garment is a flame retardant material, with multiple access points for suit sizing along the inside and outside of the extremities. The suit comes in two sizes: medium and large, with variability and customizability between each. The gloves are single layer nylon material coated with urethane, and coated fingertips for durability and improved tactility, as well as touch-screen capable. The suit is capable of self-donning and doffing, and is a front-entry garment. The umbilical system can be attached via hose junctions to an air source to provide pressurization and ventilation, so to exceed the suit leak rate of 1 standard-cubic-feet-per-minute (scfm).

**II. Test Development**

**A. Equipment Setup**

The SUIT Lab currently holds a reclining launch-positioned chair with an attached space capsule hatch and door frame mockup to simulate ingress and egress procedures both suited and unsuited. The following items were developed in-house, and on a minimal budget.

**Launch Position Chair**

Under direction of Dr. Erik Seedhouse, undergraduate volunteers began development of the horizontally situated chair for launch simulations and seated anthropometric studies. The framework for the test rig sits upon a plywood base with plastic tiling sealed at the surface of walking area, with corrugated plastic adhered to the bottom to maximize structural longevity. The design concept was influenced by FFD’s launch position chair (as seen in Figure 8) utilized in range-of-motion and tactile simulations, as well as those who participate in FFD’s Space Suit Experience. The cushion material is sourced from various chair components constructed to provide lumbar support and as much comfortability in a natural laying and seated position. The outer layering is a black...
spandex material that form-fits over the chair, head rest, and leg positions (seen in Figure 9).

The platform dimensions are 77” x 53” for length and width, respectively. From foot to headrest the chair length is 64” and can extend outward to a length of 67.5” by protracting the foot holds on the test rig. The skeletal framework holding the chair into place is cut from black aluminum square deck railing segments, at 1” x 1” in height and width. The headrest is slightly elevated for minimal straining of the neck and spine in a natural laying position. For suits such as the DCC U-2 with the hard helmet, it is imperative to provide further support for vulnerable extremities in what would be high G environments, as the weight of the helmet can be hazardous and may result in injury to the user if not properly secured. This is not as much of a concern with the FFD design, as the semi-soft helmet is lightweight in fabric and visor material, and center of gravity of the suit is not as upward toward the neck as the DCC suit is in the horizontal position. Side railing provides additional support to simulation monitors and tablets that are mounted during testing, as well as overall seat structure.

Capsule Hatch Mockup

For the purpose of testing egress and ingress maneuvers while suited, SUIT Lab personnel completed the development of an attachable capsule hatch mockup. The design resembles structural dimensions of flagship commercial capsule vehicles with respect to flight-readiness, thereby the most relevant vehicles to simulate. The design model was planned and detailed according to the hatch opening dimensions similar to that of the Boeing CST-100 Starliner vehicle, and SpaceX’s Dragon V2. The purpose was to attach the siding of what would be an entry point to the launch position chair, hitch at the railing to illustrate a more complete testing scenario.
The primary frame for the mockup is a plywood skeleton, with the backboard being 38” in width and 47” in height. The cut opening for the hatch door and entry way for the backboard, is 33” in width and 28.5” in height, with the orthogonal opening on the outside at 30.5”. The framing of the hatch was reinforced with medium-density fibreboard, and curvature of mockup achieved by riveted sheetmetal fastening wetted wood. Figure 10 shows the completed original framework of the hatch opening. The hatch door was constructed with lightweight wood-based materials to ensure there would be minimal weight constraints to overall hatch frame support the door, and general use during testing. A port hole is integrated to allow visual confirmation from outside rig during testing scenarios. The latching system of the hatch supports the weight of test users by counter-torque of the user to the framework of the launch position chair. Additional feet segments support the weight of research participants and technicians.

Corrugated plastic sheets line the outside of the hatch framework providing an added layer of protective coating to ensure no damaged to the suit and suited users. Styrofoam railguards line the corners of the hatch entry point, and grip tape for user assistance in general test maneuvering. Serious Steel® workout straps are positioned at the entry point in two locations of the entry point to allow for free movement support when navigating the suit in and out of the testing chair. There can be as many straps as needed for test protocol, and can translate along test rig railing for mission-specific positioning. Figure 11 shows the current hatch model attached to the launch position chair. The workout straps are visible in the image, with the attached door and port hole window for visual conformation of research participants in the simulator. The lightweight material is fastened by riveted metal framing, with common OTS gate hinges. The port hole is a flexible plastic, stain resistant material, and the handles cut from standard PVC piping. Spandex fabric lines the inside surface of the hatch door.
B. Testing Tools and Data

This section will discuss techniques used to collect sampling of data for suited users within the testing environment. All of the testing described in this document will be performed in the SUIT Lab at Embry-Riddle Aeronautical University, located in the College of Aviation. The hardware specified in the previous section will also be considered tools, in addition to the number of instruments to collect data to determine user performance and interaction inside the spacesuit.

Videography

The primary method of anthropometric study and observation is the video recording of basic movements across varied operational modes of the suits. The procedure described in this section is a generic ergonomics test conducted as an assessment as arm flexion from rest until reaching a stopping point upwards above the shoulder. The end items in use within the SUIT lab include all stated end items in prior sections of this study, and adherence to specific suit operations manuals and Bullard air pump users guide. All hardware in location is under jurisdiction of associated codes enforceable by Embry-Riddle Aeronautical University, and relevant safety departments. The primary equipment for all testing procedures are the spacesuit, the horizontal laying chair rig, the umbilicals for ventilation provision, and the Bullard Free-Air Pump model EDP10, which is used as the air source for ventilation and pressurization.

The arm flexion observation was recorded with a Panasonic™ Lumix G7 camera, which captured video of the research participant performing the flex unsuited, suited, and pressurized with the FFD Terra-suit. For the DCC U-2 suit, the user was only able to perform while unpressurized due to the suit's operational condition. During testing, the SUIT Lab personnel are comprised of the following three positions:

**Test Subject.** The suited individual undergoing suit performance assessments.

**Suit Technician.** Designated spacesuit technician assisting in donning and doffing procedures, as well as maintenance inspections and comrotability checks. Ensures safety of the subject and the suit.

**Videographer/Analyst.** Assigned technician monitoring video hardware or motion capture software to ensure test equipment functionality and data collection.

Only two operational modes of the suits will be used within the SUIT Lab: Nominal flight mode, and Visor-up, as no spacecraft simulator with self-providing air supply exists within AAS testing laboratory locations. The test subject will be suited in the SUIT Lab specified area, with the umbilical attachment running from the air pump source located in the adjacent confined electrical closet. Potential hazards were identified in a conducted hazard analysis document. The document presented the major hazards associated with the use of the U-2 pressure suit and the FFD Terra-suit, as well as the required ancillary support equipment for both pressurized and unpressurized testing. After assessment of constructed hazard analysis worksheets, all hazards were considered to be of controlled disposition. A full protocol was developed for the occurrence of emergency scenarios that may/may not render the user unresponsive. General policy of the SUIT Lab emergency guidelines state that all emergency supplies are to be in a secured kit or location that are readily accessible during all SUIT Lab operative hours. Local factors such as anticipated Emergency Medical System (EMS) response time, the availability of a physician and the ability of trained personnel to initiate an emergency procedure in the event of asphyxiation, and/or an acute anaphylaxis/allergic reaction will determine the need for supplies beyond the minimum and expanded protocol/procedure for the SUIT Lab. Emergency plans and procedures are coordinated with the local EMS office and responders.

Upon completion of the recording, simple angular measurements were taken from the relaxation point to the peak point of flexion. Figure 12 below represents one of the capture videos used for analysis. For both the FFD and DCC suits, an attempt was made to try and maintain elbow placement when flexing upward. The figure illustrates how despite that effort, suit design will demand that torque be placed on the back tricep and shoulder of the arm, forcing it forward. This is due to lack of flexibility in the stitching in the garment patterns for irregular shapes such as elbows, armpits, and elbowpits.
The angles measured for the arm flexion were full range angles, forearm-bicep angle, and elbow translation. With these basic movements, each reactionary movement due to constraints are indicative of how designs may hinder or assist particular movements. For the Terra-suit, the full range of motion while suited was within 85 percent of the unsuited movements, and while pressurized was within 80 percent (Refer to Table 1). The DCC U-2 was is not operable under pressurized conditions, however its ability to achieve flexion unpressurized was 93% of full range motion.

<table>
<thead>
<tr>
<th></th>
<th>Full Range Angles (Degrees)</th>
<th>Forearm-Bicep Angles (Degrees)</th>
<th>Elbow Translation (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uns suited</td>
<td>133</td>
<td>32.56</td>
<td>0</td>
</tr>
<tr>
<td>Suited</td>
<td>113</td>
<td>31.35</td>
<td>9.96</td>
</tr>
<tr>
<td>Pressurized</td>
<td>106</td>
<td>34.47</td>
<td>12.07</td>
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</tbody>
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Table 1. FFD Terra-suit arm flexion angles.

<table>
<thead>
<tr>
<th></th>
<th>Full Range Angles (Degrees)</th>
<th>Forearm-Bicep Angles (Degrees)</th>
<th>Elbow Translation (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uns suited</td>
<td>140.12</td>
<td>40.03</td>
<td>0</td>
</tr>
<tr>
<td>Suited</td>
<td>130.42</td>
<td>44.65</td>
<td>13.24</td>
</tr>
</tbody>
</table>

Table 2. DCC U-2 arm flexion angles.

The capture of the entire arm movement demonstrates the specific constraints to each design of suit. The FFD suit achieves overall good movement and versatility in should to elbow flexion, with independence among joint movements. The U-2 garment has a notable full range, however, certain movements become constricted to movement of the entire arm with a lack of forearm independence, as is indicated by the elbow translation in the flexion tests. Further conclusions can be made once the U-2 suit is operational for pressurization.
Motion Capture System

The Optitrack: Motion Capture System® is used as a 3-dimensional tracking system that provides mapping capabilities and analytical opportunities of quantifiable data in movement and general motion sciences. The SUIT Lab currently has possession of two Flex 3 motion capture cameras. They operate with a 640 x 480 resolution and frame rate of ~100 fps, and is equipped with an LED ring at 850 nm IR to isolate spectral noise. There will be an in-suit sensor system that characterizes the physiological interactions and constraints of the user within the suit performing tasks within the mock-up test rig. The cameras are positioned above testing sites at surrounding planar locations. The cameras will locate and track sensor points for suit movement and triangulate positions in 3D space.

The supportive software used to capture the data points is OptiTrack Motive®. The reflective sensors are placed along joint locations using Velcro® adhesive material as a non-invasive method to augment the suit for collecting data. Figure 13 shows the placement of the reflective markers down the left arm on the outer garment of the U-2 pressure garment. Due to only 2 cameras being currently accessible, the motions being performed are rudimentary 2-dimensional movements. The movements are captured through the IR recognition by the Motive software, and modeled to illustrate the mapping of movement. The data collects in real-time, so movement achievement will be observable to a statistical point. The basic upperbody movements that will be performed are characterized by the MIT study conducted by Allie Anderson and colleagues analyzing human-space suit interaction. These movements include:

- Elbow Flexion/Extension
- Shoulder Flexion/Extension
- Shoulder abduction/Adduction
- Cross Body Reach
- Overhead Hammering

Figure 13. Sensor point locations on U-2 suit.
Figure 14. Flex 3 camera positioning in reference to mock-up.

Figure 15. OptiTrack Motive® motion capture mapping software.

Other movements will include the maneuverability during ingress and egress procedures; different tasks while seated, such as interaction with analog controls and touch-screen tablets while in the launch position. OptiTrack Motive detects the 3-dimensional placement of each marker, and captures the exact wavelength frequency to focus tracking and minimize error. Currently the SUIT Lab only has 2 cameras at their disposal, however additional cameras are being pursued to achieve the desired capture vantage points as displayed in Figure 14. The visual display feedback illustrated in Figure 15 shows the points being recognized in the software. These locations are then recorded in realtime while performing any task.
The movements and data points for each axis exist within the file, but can be accessed through Motive. Analysis is approached with the software Visual 3D® by C Motion. The movement and pathways of the data points make rendering the motion possible. This can assist in seeing modeled constraints of the suit user during all testing phases. Each axis is recorded independently, and each wavefront represents the aberrant behavior of movement. In Figure 16, the screenshot shows the movement in progress by the arm segment, with the positioned cameras modeled as the prismatic shapings facing the sensor points. With additional cameras provides additional precision in spatial mapping, as well as precision of movement constraints.

III. Conclusions

A. Summary of Development and Testing

With the research space provided, a team of technicians and volunteers have been successful in developing low-fidelity test simulations with the appropriate level of tools to do anthropometric research and architectural analysis into understanding the components, materials, human factors, and overall operational concepts of spacesuits. The research goal of observing, analyzing, and reassessing suit designs is to promote the independent research and understanding of the importance of IVA and EVA spacesuit systems. The differences in constraints noted in the flexion testing for the FFD Terra-suit and DCC U-2 pressure garment demonstrate that in rudimentary sense, the suits have functional differences that may affect performance in a particular vehicle. The DCC U-2 suit internal umbilical system is woven in a protective cord fabric, that may induce stiffness to the joint locations of the suit. Final Frontier Design uses an integrated ventilation system comprised of rubber tubing that is durable, lightweight, flexible, and non-invasive. As development progresses, recommendations will address architectural layout and fabrication of suits in segmented locations where constraints differ with tested suits. The feedback provided by students under guidance of ERAU faculty will be a pivotal step into familiarizing younger minds in academia with the specialized fields of life support systems and suit engineering.
B. Future Work and Considerations

The SUIT Lab will continue to collect anthropometric data using the U-2 pressure garment, and the FFD Terra Suit upon scheduled arrivals. The integration of the Motion Capture camera system and supporting Visual 3D® software to analyze cycled data is necessary to continuing suit assessments. The need for proper research space and equipment is considered high-priority; the goal continues to be to provide the students involved with the tools necessary to have substantial findings and greater understanding of pressure garments. The completed acquisition of the Optitrack hardware and software integration into the lab is the next step for mapping IVA suit constraints. Development of analog controls within the launch position simulator is key to assessing tactile capabilities as a comparative study between glove designs, and to encourage future students, faculty, and enthusiasts to have innovative action in spacesuits and life support systems. Further interest in use of virtual reality is of interest to replicate cabin configuration for test users in all future flight simulations. The use of smartsuits is also a possibility as a full body motion capture studio that can cover full body motions, and will fit under the suit. At a cost-effective price, this would be crucial to the academic goal of the SUIT Lab to fully measure all body movements inside and affecting the suit.
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Virgil Calejesan – Final Frontier Design
Nikolay Moiseev – Final Frontier Design
Jason Reimuther – Integrated Spaceflight Services and Project PoSSUM.

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