Thermal Vacuum Spacesuit Component Level Testing

Chamber D Actuation System

Syracuse University
College of Engineering & Computer Science

Background:
For over 60 years, NASA has led U.S. civilian space exploration and scientific discovery. NASA's Crew and Thermal Systems Division Systems Test Branch of Johnson Space Center (JSC) in Houston, Texas has tasked a Syracuse University mechanical engineering senior design team with designing, building, and testing a system to support uncrewed spacesuit glove and boot testing for upcoming Artemis missions. Mechanical actuation is a well-known problem in space environmental testing and currently, no uncrewed test chamber for these components exists at JSC.

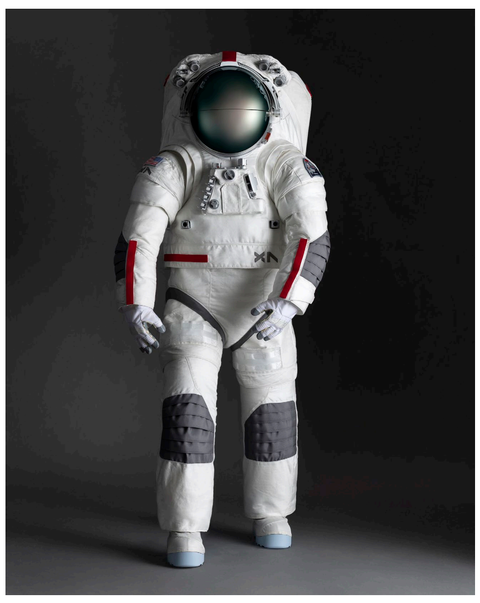
Project Description:
The team will develop a test stand, a contact plate, and a mechanism for linear actuation for the cryogenic vacuum testing of spacesuit components in Chamber D that will fulfill all requirements including

- Applying a 120 lbf load to the test article for up to eight hours within the chamber
- Reaching various contact test points on boots and gloves to analyze the effects of cryogenic temperatures on different anatomical points.
- Withstanding extreme environmental conditions including chamber operation between 16 K and ambient temperature as well as a test contact requirement of 48 K and a 40 K thermal environment.

Progress-to-date:

- Requirements Documented
- Research and Trade Studies completed on motion, contact surface, and stand subsystems
- Preliminary Design Review
- Obtained preliminary CAD model of test article with plans to integrate into system CAD model to conduct FEA simulations

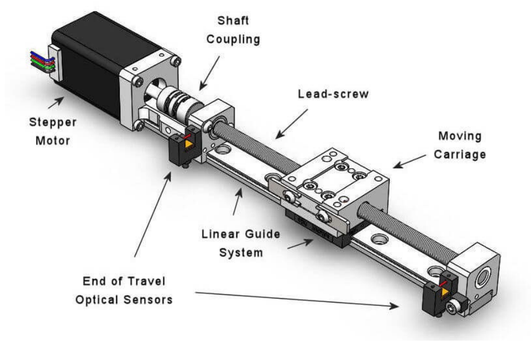
Chamber D Thermal Vacuum Chamber



Prada x Axiom "AxEMU Spacesuit"

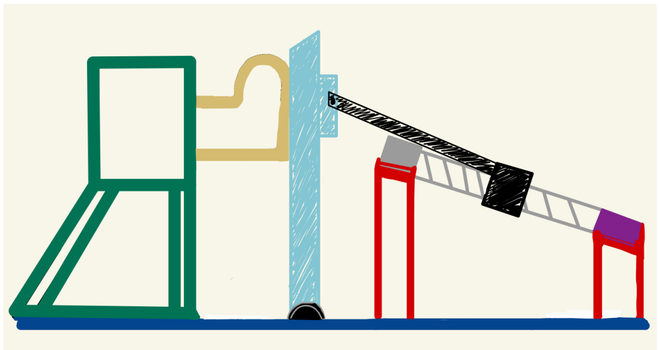
Design Concepts

Motion Mechanism



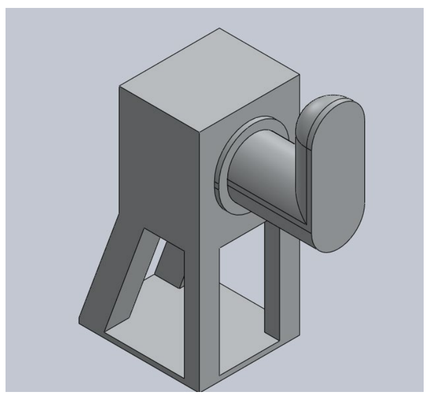
Ball and Screw Actuation

A Ball and Screw Actuator will be used to position the Contact Plate and apply the required force. The Actuator will be powered by a Servo or Stepper Motor housed in a MLI (Multilayer Insulation) thermal wrap. A pair of plates will be attached to the lateral sides of the Moving Carriage. These two plates will connect to the Contact Plate by a pin and hinge support. The Actuator will be fixed to a raised Stand. To minimize heat transfer with the Cold Plate and increase efficiency by decreasing the angle of force application.



Concept Drawing

Test Article Stand

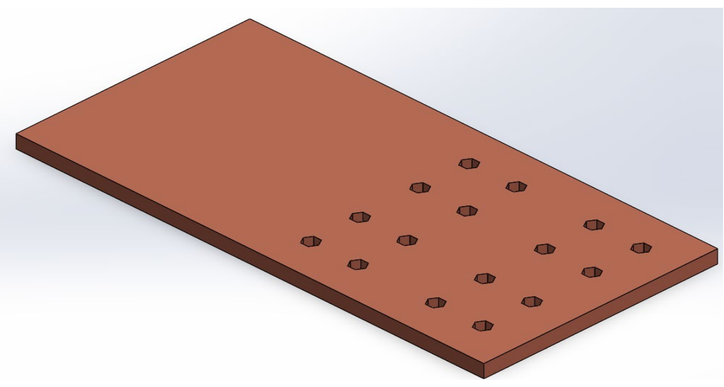


Preliminary Test Article Stand

The initial design concept of the test article stand is engineered to meet all requirements necessary to withstand the extreme environment during chamber testing. With its minimalistic and durable design, the structure can bear 120 lb force for the duration of the testing periods. It will also house a water heating system in the upper component to maintain the test article temperature to that of a human appendage. The stand's modular design allows for quick removal, enabling efficient article replacements in under 24 hours to minimize downtime during testing.

xEMU Lunar Boot

Contact Plate



Preliminary Copper Contact Plate CAD Model

The team is examining heat transfer concepts of thermal conductivity, diffusivity, and expansion while considering overall heat load and thermal mass to maintain below 48K contact and 40K radiative environment temperature requirements.

Material considerations for the plate mainly compared aluminum and copper for usage in thermal vacuum environments. Oxygen-free high conductivity (OFHC) copper was preferred in this application. This material also must withstand the 120 lbf applied onto the test article.

A bolt pattern is necessary for compatibility with grasping objects to complete three glove contacts: one fingertip, one mid finger, and one mid palm contact. The boot contact will be made without modification to the bolt pattern. A hinge will connect the contact plate to the preinstalled actively cooled chamber plate.

Deliverables:

1. Develop a visual representation of the mechanism and stand as a CAD model
2. Evaluate the effects of the system in cryogenic temperatures through FEA analysis and report our findings
3. Thermal Simulation and Analysis to demonstrate even thermal gradient from contact
4. Construct and test a prototype of the designed stand and actuation framework
5. Deliver a comprehensive drawing package and fully integrated hardware solution to the Johnson Space Center

Faculty Mentor: John Dannenhoffer III

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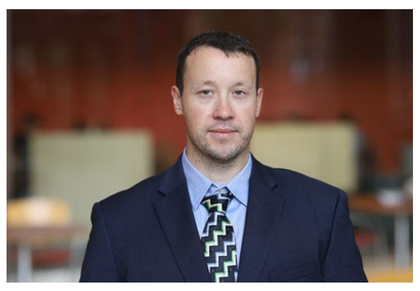

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