Work Term Assignment Spring 2017

Mallory Sico

Pathways Intern – ER5

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List of Acronyms

NASA - National Aeronautics and Space Administration

JSC – Johnson Space Center

ARGOS - Active Response Gravity Offload System

SDTS - Six Degree of Freedom Test Stand

SAFER - Simplified Aid for EVA Rescue

HAL - Habitable Air-Lock

ECLSS - Environmental Control and Life Support Systems

Section I: Introduction

Spring 2017 was my third co-op tour with National Aeronautics and Space Administration (NASA) – Johnson Space Center (JSC) in Houston, Texas. Johnson Space Center was founded in 1961 as the Manned Spaceflight Center. It served as mission control for Gemini, Apollo and Space Shuttle missions. It is currently the home of Mission Control Center, leading operations and missions for the International Space Station, and houses the Orion Crew Vehicle. The center also participates strongly with the Commercial Crew program.

Johnson Space Center is divided into six directorates and other program organizations. These directorates include Engineering, Safety and Mission Assurance, and Flight Operations. Johnson Space Center is the leading center for manned space flight in the agency. Johnson Space Center has 15,000 employees; 3,000 of which are civil servants. One hundred and ten of these are astronauts. The vision statement for NASA is “We reach for new heights and reveal the unknown for the benefit of all humankind.” This vision has been carried out in the past by putting some of the first men in space and finally on the moon in 1969. It is currently being carried out using the International Space Station to learn more about science and humans in space as well as telescopes like Hubble and Kepler to reveal unknown parts of the universe. This vision will continue to be carried out in the future in exploration missions using the Orion Crew Vehicle and the Space Launch System to move humans into deeper space.

This spring, I worked in the Dynamic Systems Test Branch in the Engineering Software, Robotics, & Simulation Division (SRSD) within the Engineering Directorate. There are 5 branches within the SRSD. These are Flight Systems, Robotics Systems

Technology, Spacecraft Software Engineering, Simulation and Graphics, and Dynamics Test Systems branches. The Dynamic Systems Test branch designs, builds and operates multiple engineering projects including the Active Response Gravity Offload System (ARGOS), Six Degree of Freedom Test Stand (SDTS), Cable Robot, Simplified Aid for EVA Rescue (SAFER), and the Habitable Air-Lock (HAL).

Section II: Work Environment

During my time in the Dynamic Systems Test Branch, I have had the opportunity to work with many engineers of different backgrounds. I worked with mostly mechanical and aerospace engineers. This spring my main projects centered on the Habitable Air Lock (HAL). For this project, I worked with Josh Sooknanan (mentor), Nathan Howard, Fernando Zumbado, and Derek Willingham. Through this project, I collaborated with the Human Factors branch and the largest machine shop at NASA. Canaan Martin worked with me to design the floor layout for the nose of the HAL. I also worked with Lenny Price and Charles Kellerman in the machine shop to procure and begin to assemble the materials needed for the HAL nose. Outside of this project I worked with Paul Valle and Mike Amoroso as a test subject for the Active Response Gravity Offload System (ARGOS).

Over the course of my tour, I had the opportunity to attend many presentations and meetings. These meetings included weekly HAL project tag-ups on Monday mornings facilitated cross-branch participation and a group design effort. I also participated in weekly HAL meetings for design reviews of various HAL systems, including the Environmental Control and Life Support Systems (ECLSS) and lighting. I attended weekly branch meetings as well. At the beginning and end of my tour, I presented my introduction and exit pitch during these branch meetings.

Outside of my division, I served on the Tours and Lectures Committee for all co-ops and interns. This committee plans tours of JSC facilities including the ECLSS lab, and the Lunar Lab where all moon rocks are stored and maintained. Organizing and arranging lectures were delegated to committee chairs. We saw lectures from Sonny White, a physicist working on electric propulsion and Gene Kranz, the Flight Director during Apollo 11 and 13. I planned a tour for the interns of the robotics sections of my building's high bay. The tour was for over 40 interns who rotated to see ARGOS, the cable robot, HAL, SDTS, SAFER, and Robonaut.

Section III: Technical Summary

Project I: Habitable Air-Lock Nose

The Habitable Air-Lock is a project within the Deep Space Gateway program. It is intended to be used as a multi-functional space vehicle. The cabin is designed for use as a cis-lunar space vehicle as well as a rover cabin. The vehicle will have different noses on the front for each of these different purposes. The current nose design is intended for a cis-lunar air-lock vehicle. This nose will be used to house the astronaut work stations, hold the Orion Docking Hatch and stow ECLSS systems in the ceiling and floor.

My assignments for this nose were to work with the machine shop in building 10 to manufacture and assemble the nose, update the parts document for the foam stack up and create drawings for all parts and nose versions.

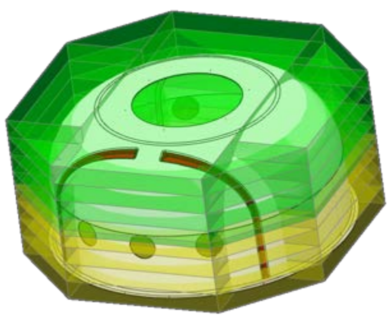

Figure 1: HAL Nose shape embedded in foam stack

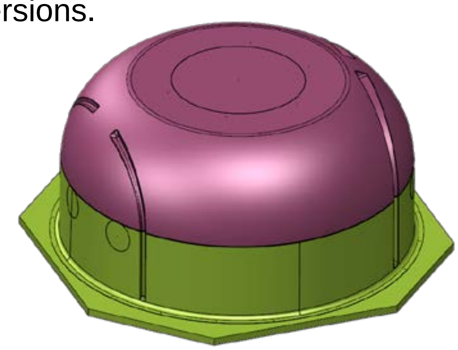

Figure 2: HAL Nose outer cut before finished

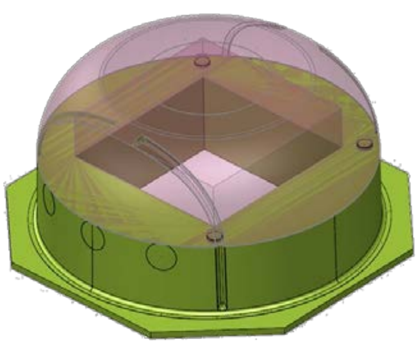

Figure 3: HAL Nose outer cut with transparent top showing corner keys

Figure 4: HAL Nose final shape

The figures above show the nose shape embedded within a foam stack in Figure 1, the foam stack after initial cut in Figure 2, the foam stack with a transparent top in Figure 3, and the final nose shape to be installed in the HAL mock-up in Figure 4. This represent the manufacturing process of the nose.

To begin the manufacturing process, the team met with the machine shop techinicians to discuss how the design would need to be altered to meet manufacturing constraints. Initially, the nose was going to be cut as one large piece that was completely hollow in the middle rather than having solid top layers. Each of these designs changed after meeting with the technicians to enable machining. To fit within the height of the Thermwood CNC machine, the nose needed to be cut in half. This called for a redesign of the nose to include two halves each with keys in the corners to be used for orientation and gluing. The top layers were also changed from hollow to solid in order to ease the cutting of the hole on top during the machining process.

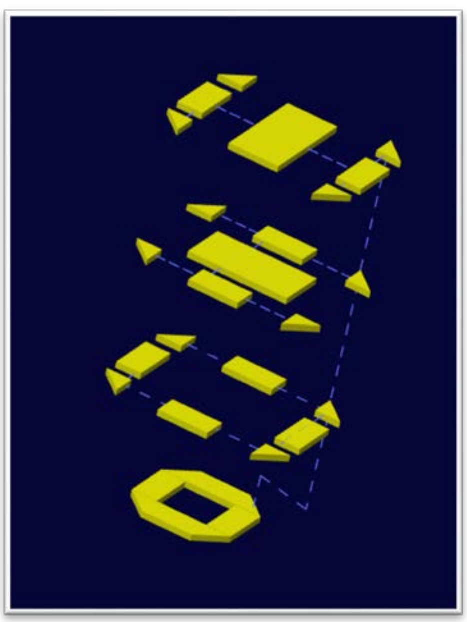

Figure 5: HAL Nose foam stack top half assembly model in exploded view

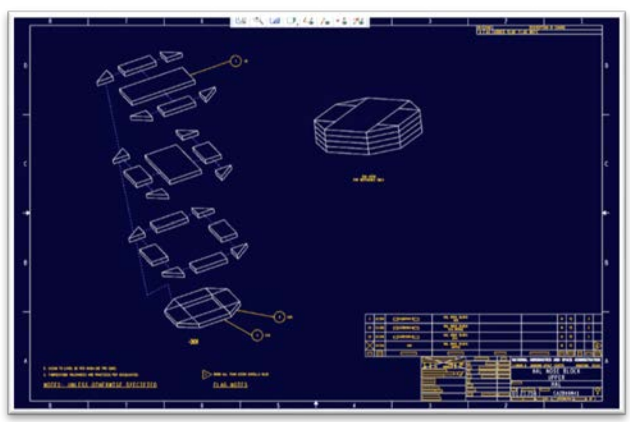

Figure 6: HAL Nose top half assembly drawing

Following these discussions, I was assigned to update and create drawings using Creo 2.0 for delivery to the machine shop for execution. Figures 5 and 6 show the updated assembly for top half of the HAL nose foam stack and the final drawing for the top half of the nose. To start, I updated the assembies for the nose according to the specifications made by the machine shop techinicians. This required me to create the center part for the top two layers as shown in Figure 5. I also added a ring layer, as shown at the bottom of Figure 5, to the top and bottom half assemblies. These layers were later removed to fit the final design specifications. This process gave me an introduction to the standard for NASA assemblies and drawings. After finishing all updates and drawings, these were sent to building 10 to begin production.

Figure 7: Foam stack edges during gluing process

The nose design called for the shape to be cut out of foam and covered with 16 plys of fiber glass. The foam began as large 4’X8’X.5’ pieces and were cut into 2’X4’X.5’ rectangles for the edges and 2’X2’X.5” triangles for the corners. After cutting these parts using a bandsaw, they were glued together with Gorilla Glue. This process consisted of covering edges completely with water and glue. Immediately after this, the foam was set in place and covered with large weights to prevent the glue from expanding and pushing them apart. After the gluing process is finished, the top piece and bottom piece of the nose will be cut using the Thermwood CNC machine into the shape shown in Figures 3 and 4. After all cutting is finished the top and bottom will be glued together. All fiber glass plys will be overlayed at a 45 degree angle to the last layer. Finally, the shape will be brought to vacuum and Tygon tubes will be used to pull in resin to set the fiber glass.

During my tour, I was able to participate in some of the manufacturing processes. I worked in buidling 10 to cut the triangle corner pieces using the bandsaw. I also participated in the gluing process which is shown in Figure 7. I have spoken with Lenny Price, one of the technicians in the machine shop, and he will continue to send updates on the rest of the of the manufacturing. The will give me the opportunity to see the process of CNC cutting, and fiber glass application.

Project II: HAL Hatch 3D Print

The second project I worked on was the simplification of the Orion Docking Hatch for 3D printing. This hatch is to be installed in the hole at the end of the nose. In order to complete the design for the hatch, I needed to simplify the docking hatch for 3D printing in fewer parts, print and assemble the hatch, and conceptualize an attach and lock mechanism for nose installation.

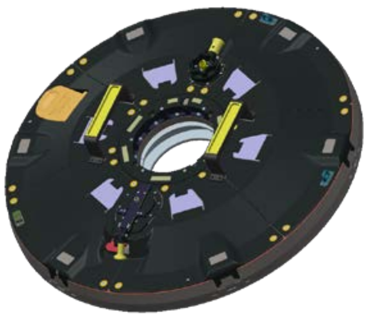

Figure 8: Hatch Final Assembly

Figure 9: Hatch Bottom Part

Initially, I was given the model for the official Orion Docking Hatch containing over seven hundred parts. The first task was to eliminate all unnessecary or proprietary parts. After finishing this, I was to change the whole assembly into one or a few parts for 3D printing. There were many steps in simplifying the assembly into a part. NASA uses Creo 2.0 for 3D modeling therefore I utilized many of its tools to modify the hatch. The first attempt was to alter the assembly into a part by exporting the simplified assembly as an IGES file and to import the file back as a part. When this was attempted, some parts in the assembly were adjusted perpendicular to their original orientation while others were not causing mismatched orientation of the part. This was not successful and required a change in simplification method. The next idea was to use the shrinkwrap tool. This tool takes the shape of the outer surfaces and changes them into one infinitely thin surface. This attempt was also unsuccessful because the volume of the hatch was hollow and there were holes in the edges leading to an open outer surface. After this attempt, we realized the importance of filling the center hatch volume in order to simplfy the assembly into a part. With this information, I started to use the extrude feature on the inner bottom surface to extrude “to next”. The next surface was the inner surface of the top panels. Figure 8 and 9 show the hatch final assembly and the hatch bottom part to portray the surfaces used in the attempted extrusion. This attempt was also unsuccessful because in Creo an assembly cannot extrude or revolve to add material. It can only remove material. From this information, I next began to create a part with the shape of the inner volume. Once I started this process, I realized I would be taking the shape of both the bottom part and the section view of the hatch assembly geometry. Instead of creating a new part, I used the extrude tool to modify the bottom part shown in Figure 9. This was the successful way chosen to fill the volume.

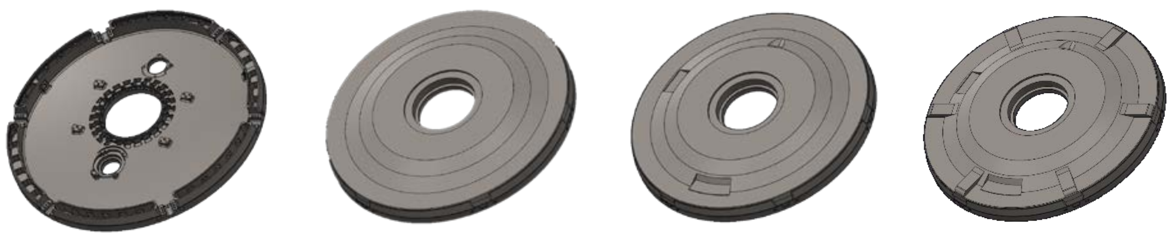

Figure 10: HAL Hatch bottom part modification process. Left to right shows original part to final simplified part

The above figure shows the process of filling the volume. The first model is the original shape of the hatch bottom part. The second model shows the part after using the revolve tool to fill the volume. This was done by creating a section view of the hatch assembly model and sketching the open volume geometry. The sketch was copied into the part model and used for the revolve tool to match the shape. After the modification shown in the second model in Figure 10, there were still large protrusions where handles were placed and open volumes where locking mechanisms had been removed. The third figure shows the extrudes and revolves made to cut out the protrusions for a clean shape on the outer surface. The last model shows the hatch with added volumes around the edge. These were placed using the pattern feature to fill even volumes under the top panels. After modifications to this part were finished, the inner volume of the hatch was suitably filled and all parts began the process of print procurement.

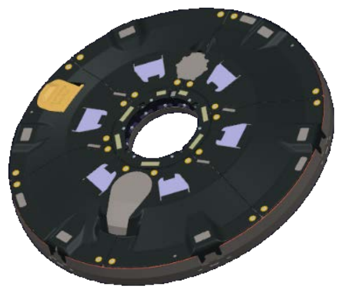

Figure 11: HAL Hatch Main Body

Figure 8 shows the hatch with all pieces connected. The main body of the hatch without separate pieces is shown in Figure 11. This part was originally intended to be printed as one large part. I reached out to large 3D print commercial vendors about printing this part. These printers, such as Cincinnati BAAM and Titan Robotics, have printed cars and small scale space vehicle mock-ups. Due to the size of the parts they make, the bead on the printer is large. Because the hatch is very detailed on the outside, the large-scale printers would not be able to guarantee that the detail would make it into the final part. With this information, the hatch was split into 6 separate parts. These parts each have a lip on the side edges of .468” to allow for orientation of the pieces after printing. The six separated parts are shown below in Figure 12.

Figure 12: HAL Hatch in final six parts

Other parts printed included two handrails on the top, two handle mechanisms on top with similar attachments on the bottom. A window part will also be attached to the bottom. Each of these parts were printed separately to be attached to the main body. The handles on top and bottom will be attached with glue.

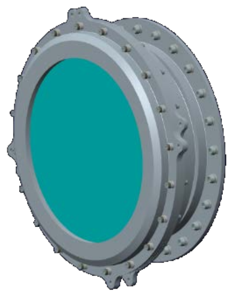

Figure 13: Hatch Window Assembly

The window assembly shown in Figure 13 has one outer ring that was manufactured out of aluminum. This piece will be bolted to the rest of the window attachment. The other piece is printed to be attached to the main body using bolts and helicoils. The window assembly was designed and assembled this way to allow for double pane window installation. This has the added benefit of easy removal in case of damaged or scratched panes in the future if necessary.

The last part of this assignment was conceptualizing the locking and attaching mechanism for the docking hatch. Magnets presented the best option for this mechanism for two reasons. The first reason is that there are no moving parts. The magnets will stay in place which allows for easy removal and replacement of the hatch. The magnets do not have switches or latches so the user can hold both handrails while pulling or twisting the hatch to break the magnetic connection. The second reason is that it would allow for hatch orientation. The magnets will be placed asymmetrically on the hatch to create one orientation in which it will set in the hole. There are 10 holes for magnets and not all of these will be needed. Extra holes were placed to allow the engineer who installs them to move them around for best orientation.

Project III: Secondary Structure

The secondary structure of the Habitable Air-Lock contains the floor, ceiling and bench panels and supports as well as side storage bins. My assignment for this project was to work on the redesign of the secondary structure of the floor for the HAL nose. The floor had been designed previously for a different more hemispherical nose shape. After alterations, the nose now has a cylindrical shape with a rounded cone at the end. This is shown in the Figure 4. My assignments for this project were to work with the Human Factors division to establish keep out zones for the floor and to design the floor panels and panel supports.

Human factors engineers discussed the idea of stowing the hatch in the floor while not in its place in the nose. This would mean the floor needed a hole for the hatch to fit into. This shaped the design work for the floor as it needed modification in structural support to carry the weight of people standing and working in the mock-up and continue to provide stowage room for the hatch.

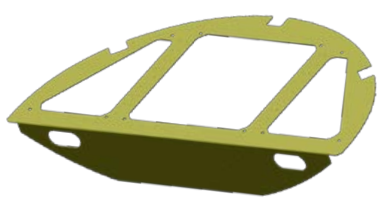

Figure 14: Hemispherical nose shape floor support design

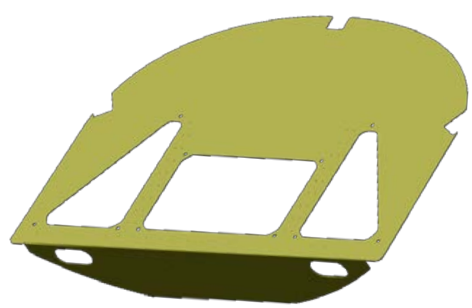

Figure 15: Final nose shape floor support design

Figure 15 shows the original floor support for the hemispherical nose shape. Figure 15 shows the redesigned shape. The project started with finding the original and using the copy geometry feature in Creo 2.0 to change and redefine all existing features. This was a new challenge because the floor was designed using sheet metal. Sheet metal modeling used many of its own tools for designing. Because of this, it was necessary to create a new floor and redefine all existing holes and cuts to the new floor. The second figure shows the shape after redefining without adding new cuts or holes.

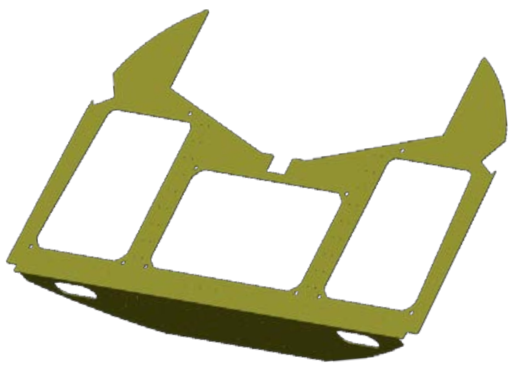

Figure 16: Nose floor support design with hatch cutout

The figure above shows a version of the final floor design. This design includes the addition of the hatch hole which can be seen at the top of the model. Cable cutouts were added at the bottom corners of the floor to allow electrical cables to run through. Lastly, the shape of the large cut outs for the panels were changed to rectangular shapes. The panels will be change to match this and fitted with correct ribbing on the bottom for structural support. After these modifications were made, the cutouts were all changed to the same size to allow for structural support to be placed between the panels and the hatch cutout. In the future, the floor will be further modified with vertical supports underneath to account for all loads on the floor in the mock-up.

Project IV: HAL Assembly

The final project I had the opportunity to work on was assembly tasks within the existing HAL mock-up. These tasks gave me hands-on experience using many new tools. The first task was working with Richard Pedersen to install the side hatch panels using an epoxy. This included mixing the epoxy and applying panels at correct angles on either side of the mock-up to allow for side hatches to face each other evenly. The next task was receptacle installation. The receptacles in the mock-up are used for side hatch hinge installation and setting. Once the hatch was set in the hinges, the other receptacles were used to lock it in place. The installation for these included drilling 78 holes through carbon fiber and bolting in the hinge receptacles. Once the panels and hinge receptacles were placed, it was realized the receptacles that would go near the ceiling and bench were not in line with the original design. Holes needed to be cut to create space for the receptacles to fit. Because the panel supports were made from sheet metal, I used a dremel tool to cut the holes in the ceiling and bench support panels. Lastly, I attached the hinges to the bench supports for bench panel installation. This process included cutting the hinges into 19” pieces from 5’ parts. These were cut with a cutting saw and sanded down using a belt sander. After cutting and sanding. I used a pneumatic rivet gun to attach the hinges with structural rivets. In the future, the bench panels will be riveted to the hinges for final installation.

Section IV: Conclusion

My tour in the Engineering Robotics directorate exceeded my expectations. I learned lessons about Creo, manufacturing and assembly, collaboration, and troubleshooting. During my first tour, last spring, I used Creo on a smaller project, but had limited experience with it before starting in the Dynamic Systems Test branch this spring. I gained valuable experience learning assembly design, sheet metal design and designing with intent for manufacturing and assembly. These skills came from working both on the hatch and the floor. I also learned to understand the intent of other designers on models I worked with. While redesigning the floor, I was modifying an existing part and worked to understand what the previous designer had done to make it fit with the new model. Through working with the machine shop and in the mock-up, I learned much more about manufacturing and assembly. I used a Dremel, rivet gun, belt sander, and countersink for the first time. Through taking multiple safety training for different machine shops, I learned new machine shop safety skills specific to each one. This semester also gave me new collaborative opportunities. I collaborated with engineers within my branch as well as with Human Factors and the building 10 machine shop. This experience helped me learn how to design for functionality and assembly, not only for what would be easiest in my designs. In addition to these experiences, I learned many lessons in troubleshooting. I was the first person in my office to use a Windows 10 computer. This caused unexpected issues with NASA services and programs, such as the Digital Data Management Server (DDMS). Because of this, I gained experience finding solutions to lockout and freeze issues as well as Creo specific settings. These will be useful skills to have in the future and will be implemented in future rotations.

This co-op tour has motivated me more to finish my degree and pursue my academic goals. I intend to take a machining Career Gateway Elective in the Fall to improve my skills in building as well as designing with manufacturing intent. I am also inspired to take more mechatronics CGE courses before I graduate to learn more about the crossover between mechanical and electrical engineering.

This semester, I worked on multiple projects and had the opportunity to learn from engineers of different disciplines. I became proficient in Creo 2.0, a program I had not used significantly before. I finished modifying the hatch for 3D print and made sizeable modifications to the nose floor support design. I also gained hands-on experience that will be useful in my engineering career in the future. I would consider all of these major achievements from this spring semester. Lastly, I learned to ask more questions and to search for the right people to find answers which I know will be a valuable skill in the future.

This summer, I will be completing my last rotation in the Flight Operations Directorate at Ellington Air Field. After this last tour, I will be returning to school for the Fall, Spring and Summer. I will graduate in August of 2018. I am looking forward to learning more about the different jobs available to engineers. This division works directly with many different types of aircrafts and I am excited to learn more about this focus of engineering. The Aircraft Operations Division values team work greatly and I intend to improve my interpersonal skills by working with them this summer.