EXPLORATION HABITAT (X-HAB) 2013-2014 ACADEMIC INNOVATION CHALLENGE

Space Cowboys

FINAL REPORT

<u>Principal Investigator:</u>

Jamey D. Jacob

School of Mechanical & Aerospace Engineering

Oklahoma State University

jdjacob@okstate.edu

Phone: 405-744-3208

<u>Oklahoma Space Grant Consortium</u>

Profs. Victoria Duca Snowden, Director and Andrew Arena, Deputy Director

<u>Outreach Partner:</u>

Prof. Steve Marks, OSU NASA Education Projects

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OSU XHab team with astronaut John Herrington.

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<u>**Outreach**</u>

Outreach activities were coordinated with OSU's NASA Education Office and focused around the Space Habitat Innovation Challenge. Two challenges were developed for this year: the ***Rapidly Prototyped Tool Challenge*** (RaPTC) and the ***Space Habitat Airlock Challenge*** (SHAC). RaPTC was open to eligible high school student teams while SHAC was open to eligible community college student teams. Teams involved 3-6 students from 12 states across the country and submitted videos or virtual presentations.[1] Entries were judged by the OSU XHab students and were provided with feedback on feasibility and design. Three groups in each challenge were selected as finalists for a final virtual presentation and interview with students and professors in the engineering program at Oklahoma State University. Three groups total were selected to present their design to engineers and astronauts at a NASA JSC. Judges included astronauts Joe Acaba, Nicole Stott, and Dottie Metcalf-Lindenburger.

Finalists at NASA JSC.

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[1] Entries posted at http://nasaweb.nasa.okstate.edu/nepemails/SpaceHabsubmissions.html

Technical Introduction

Oklahoma State's X-Hab team has performed eXploration Habitat (X-Hab) Academic Innovation Challenges for the past 4 years. This year a reconfigurable human in-the-loop volume study for a Mars lander was completed. The habitat has two stories with 3 different personal living quarters in the upstairs as well as hygiene and food preparation in the upper floor. The lower floor consists of 3 work stations and storage space. The walls of the lower story are reconfigurable, each wall can adjust inwards changing the volume of the habitat. This change in total volume can be seen below with comparison to other habitats and the volume per person versus time spent inside the habitat.

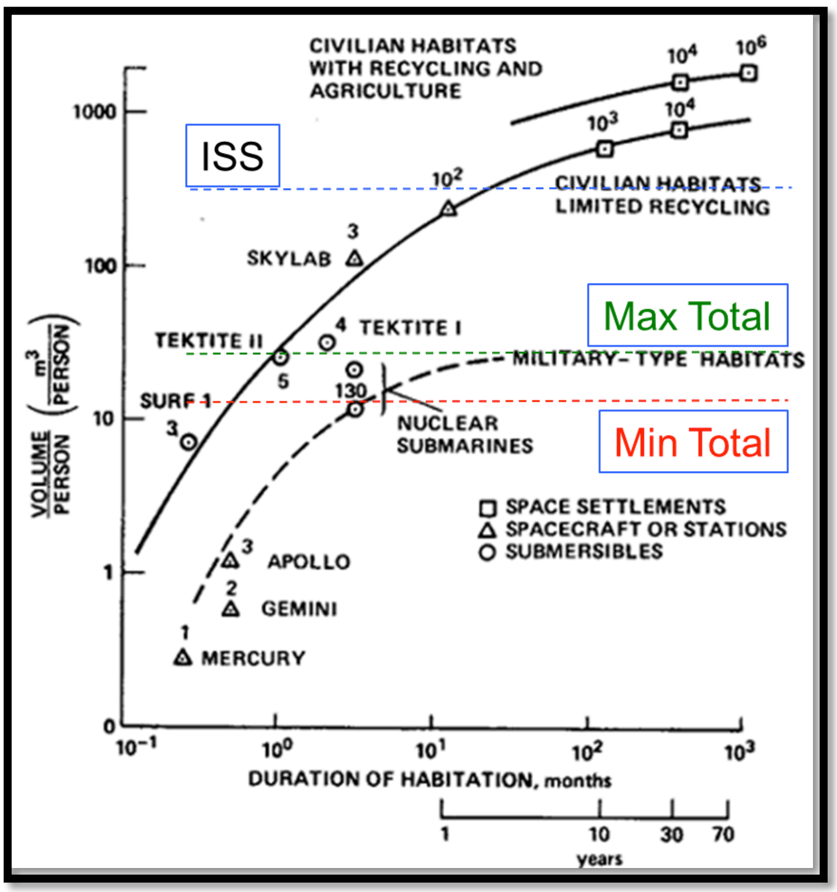

Figure 1: Volume versus Duration of Habitation

Project Background

The following paragraphs give some background information on the X-Hab project. "The eXploration Habitat (X-Hab) Academic Innovation Challenge is a university-level competition designed to engage and retain students in Science, Technology, Engineering and Math (STEM) disciplines. NASA will directly benefit from the competition by sponsoring the development of innovative concepts from universities which may result in innovative ideas and solutions that could be applied to exploration habitats.

The challenge is run by the National Space Grant Foundation for the Habitation Systems Project team at Johnson Space Center, which is part of NASA's Advanced Exploration Systems Program. The challenge is for a senior and graduate level design course in which students will design, manufacture, assemble, and test an inflatable loft that will be integrated onto an existing NASA built operational hard shell prototype" (NASA, 2014).

X-Hab Team

The X-Hab team is comprised of eleven seniors majoring in Aerospace Engineering, many of whom have previous experience working on NASA-related projects. Oklahoma State University offers a course known as "Spacecraft Design," in which students learn about space environments and their implications regarding spacecraft design. This serves as a precursor to the X-Hab senior design course. Alternatively, some may have volunteered to assist with prior X-Hab projects. As a result, the individual knowledge and experience of the members has coalesced to form the backbone of the 2014 X-Hab team, shown in Figure 2.

Figure 2: X-Hab Team

Design Schedule

The design schedule for the completion of Oklahoma State's X-Hab project is shown below.

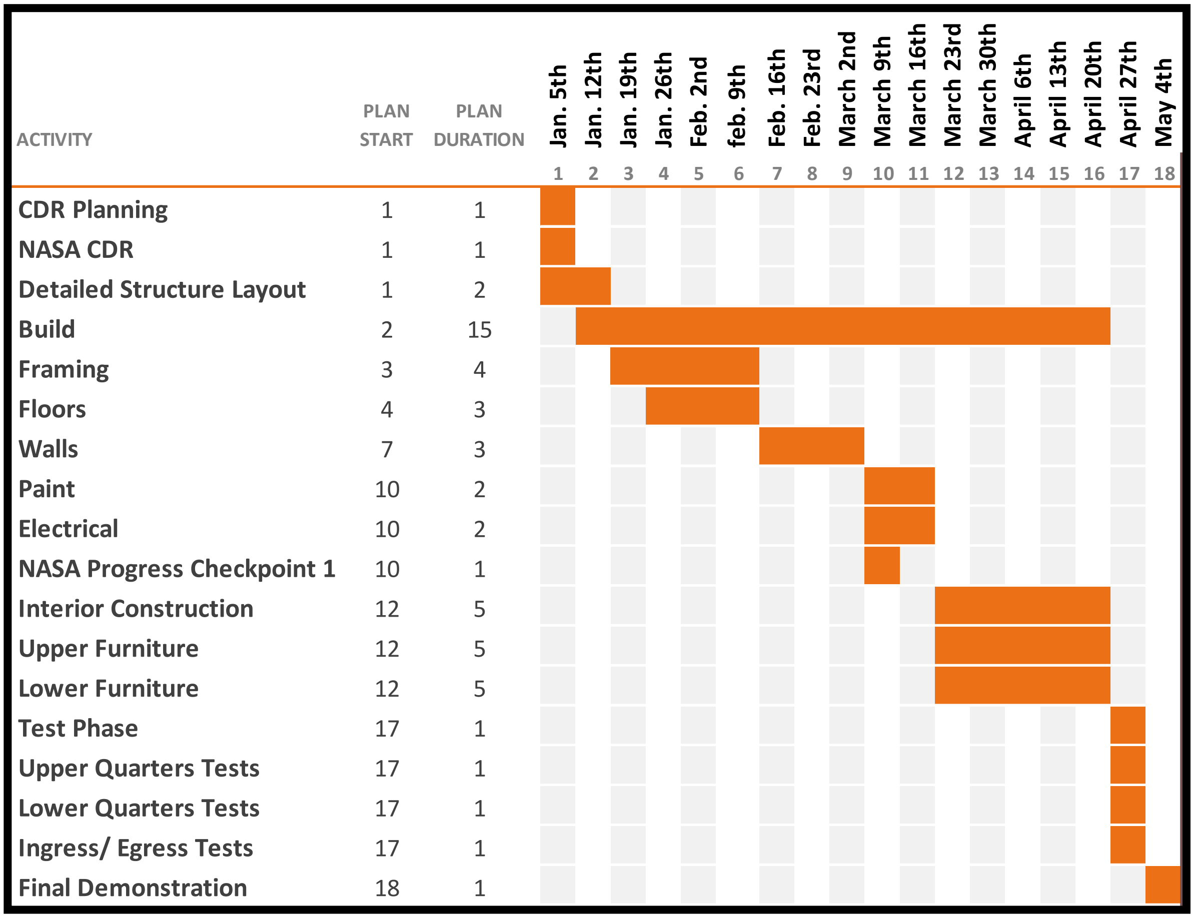

Figure 3: Gantt chart

Space Rated Design

The space rated design consists of a two-story cylindrical layout with an external airlock (See Figure 4 and Figure 5). Originally, this design had a 21 ft. external diameter and a 15 ft. pressurized diameter. It also had a 2437 ft^3 pressurized volume and a 1094.7 ft^3 unpressurized systems volume. The actual dimensions will be determined by the habitability study. The first floor is 6.5 ft. tall while the upstairs is 6ft. tall.

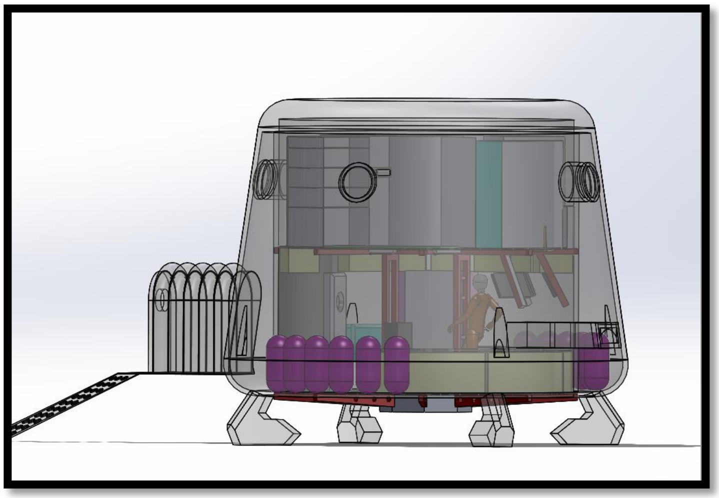

Figure 4: Space rated design with exterior shell

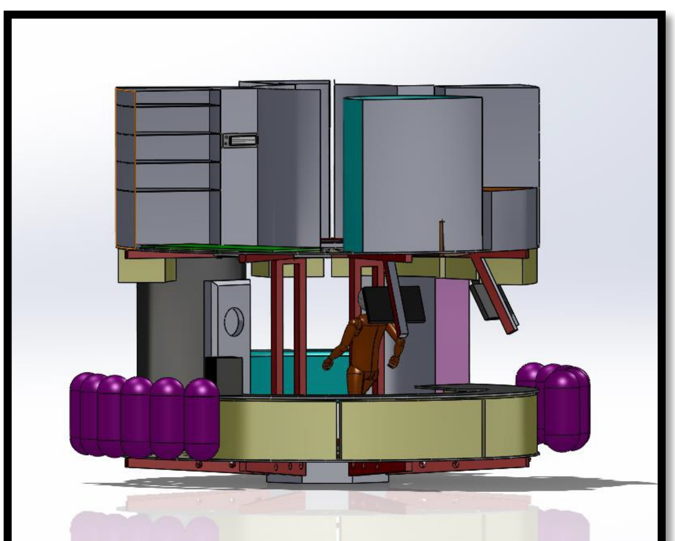

Figure 5: Space rated design without exterior shell

Also, Figure 4 and Figure 5 do not show the 1.5 ft. storage space between floors. This space will be utilized to store food for the duration of the mission. Astronauts will be able to access this space from both the top and bottom floors. The bottom floor consists of three work stations: geology station, medical/biology station, and the control station. The top floor contains a hygiene station, food re-hydration area, common table, and three bedrooms. Shelving units will be used to separate the work stations. The following paragraphs will go into detail about each feature of the space rated design.

First Floor

Outer Shell

The outer shell of the habitat will contain the life support systems, fuel, other electrical equipment, insulation, and radiation prevention system. The shell was shaped to improve the habitat's aerodynamics while landing on Mars (Figure 6).

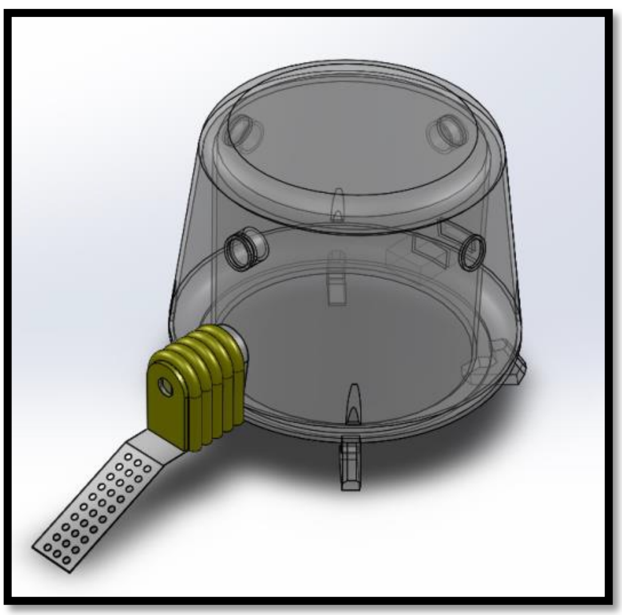

Figure 6: Outer Shell

External Airlock

To save space inside the habitat, we decided to utilize an external and inflatable airlock (Please see Figure 6). Inside this airlock, the astronauts will clean, store, take on, and take off their space suits. Because of this, the airlock will double as a dust mitigation room to prevent contaminating the inside of the habitat.

Medical/Biology Station

The astronaut assigned to this station is assumed to have a medical and biological background. Therefore, this station, shown in **Error! Reference source not found.**, is designed to accommodate an injured astronaut. This station will contain a medical box to treat minor wounds, syringes to draw blood, and storage units to properly store the blood for testing. Other equipment used to measure vital signs will be present as well.

Command Station

The command center will consist of a 3-D Printer and a computer with four monitors. This station will be utilized to communicate with the orbit vehicle, Earth, and astronauts on EVA missions. It will also be used to control the rover and monitor the habitat's life support and other systems. To save space and weight during lift off, the 3-D printer will be utilized to create tools as needed.

Geology Station

The geology station contains a sterile glove box that will be used to analyze rock samples under vacuum. To prevent contamination of the habitat and rock samples, rocks will be deposited into this box using a hatch located on the outside of the habitat. Various geological instruments will be located inside the glove box to analyze the samples. Next to the glove box, the geologist has a place to work and write down information.

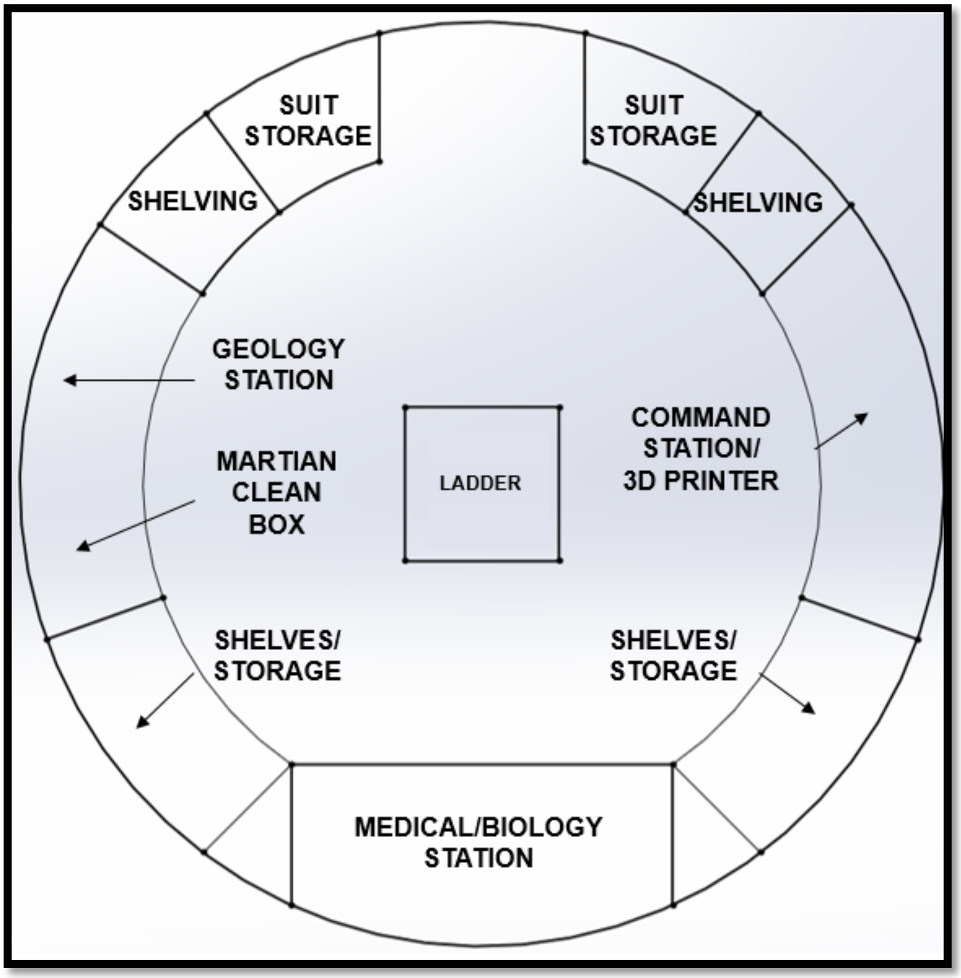

Figure 7: Theoretical first floor layout without internal airlock

Internal Airlock

We design a separate first floor layout to incorporate an internal airlock for suit repair and storage. This is to provide NASA with an alternative to Figure 7.

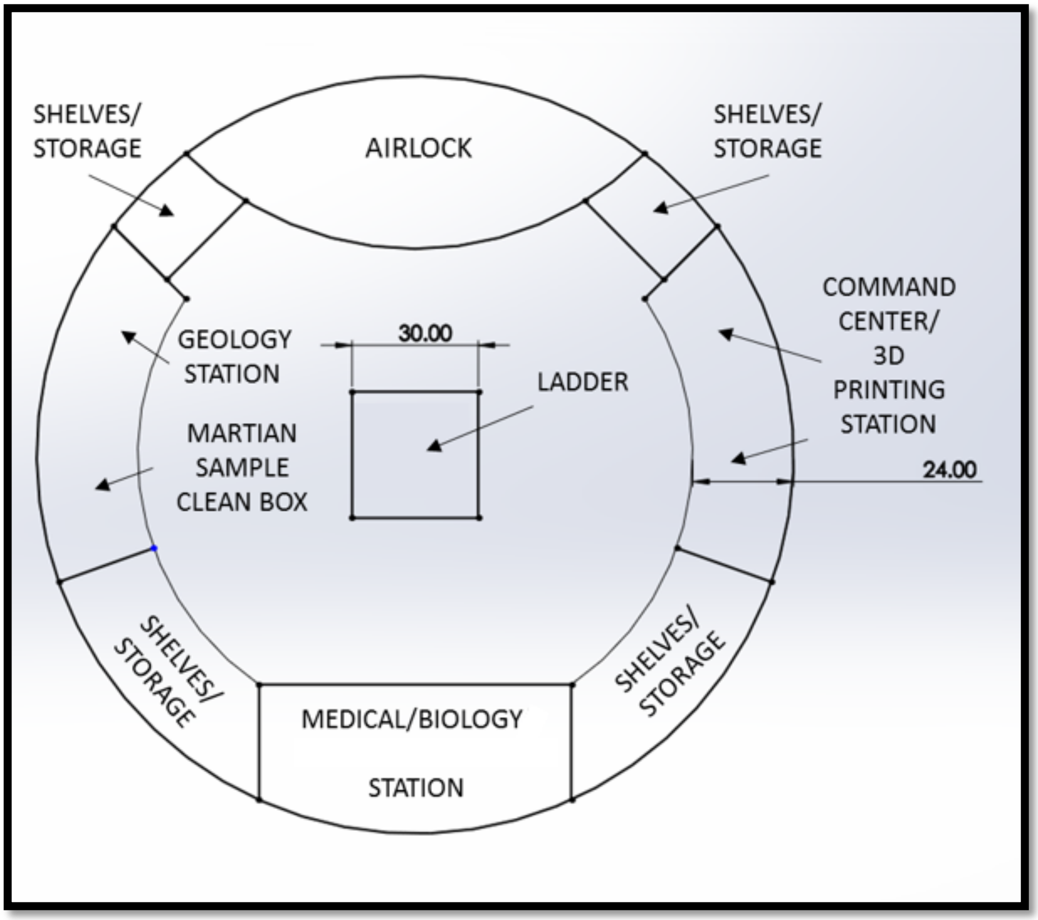

Figure 8: Theoretical first floor layout with internal airlock

Second Floor

Personal Living Quarters (PLQs)

Each living quarter will contain a bed, personal storage space, and a work area. The bed size is fixed at a 6 ft. length, but the type of bed and work space will be determined by the habitability study.

To add a sense of privacy, the rooms will be divided by solid walls and shelving units (See Figure 10). Astronauts will also be able to draw curtains across the front of the PLQ (represented by dashed lines in Figure 10). These curtains will be thick enough to block out light and sound. Windows overlooking the Martian landscape will be placed inside each PLQ to increase the mood of the astronaut, as well. Astronauts will be able to adjust the lighting conditions in their PLQ with their personal IPad or remote. A rough design can be seen below in Figure 9.

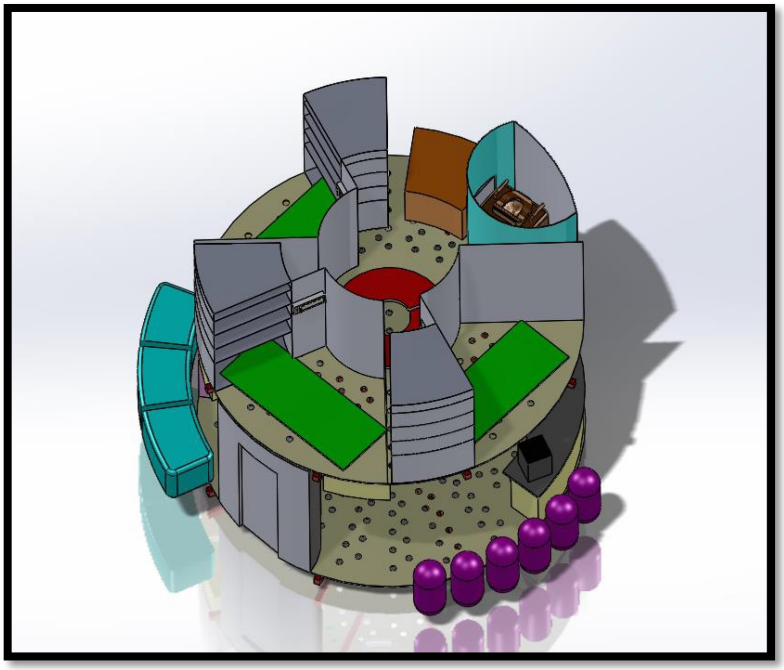

Figure 9: Second floor of the space-rated design

Food Prep

Since we planned on using de-hydrate food for the entire Mars mission, we incorporated a re-hydration station in the food preparation area. This station is relatively small compared to the first floor work area, but there will still be storage below and above this station for food and equipment. Please see Figure 10 for reference.

Community Table

On the other side of the ladder from the food prep area, a community table was included. This common meeting place will foster group cohesion and provide them with a place to meet during team meetings. Please see Figure 10 for reference.

Hygiene

The hygiene station will contain a toilet and a dry shower. It will be located next to the food preparation area, but separated by a hard wall. The entrance to the hygiene station will also be a hard door to prevent contamination of the food and to reduce the release of unpleasant odors and sounds. Since Mars is 1/3 Earth's gravity, the toilet will be lightly suctioned to prevent a potential mess. There will also be a space in front of the toilet for astronauts to take a dry shower. Please see Figure 10 for reference.

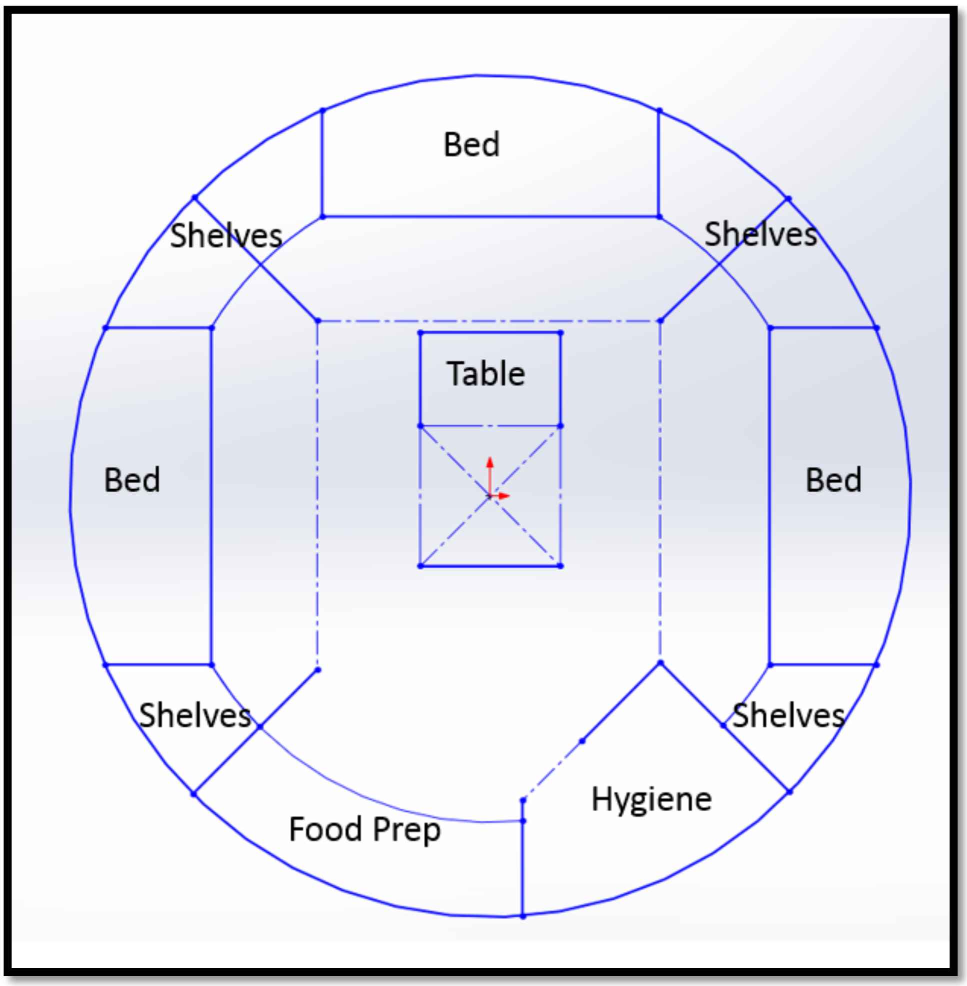

Figure 10: Theoretical second floor layout

Earth Analog

The theoretical, space-rated design is what would actually be sent to Mars. For the scope of this project, however, building the space-rated design is unreasonable. Due to monetary and time constraints, along with limited resources, certain compromises had to be made. The earth analog was designed to accommodate the limitations at hand and to allow for a wide range of variability in the habitability studies. After all, the purpose of the earth analog is to refine the theoretical, space-rated design.

First, while the pressurized portion of the space-rated design is cylindrical, the earth analog is octagonal. The motivation behind this is twofold. It allows for much more simplified construction. With an octagonal shape, all of the walls could be constructed with standard framing practice, ensuring proven structural rigidity. The walls of the lower story were framed 16 inch on center while the walls of the upper story were framed 24 inch on center. The walls of the upper story serve no structural purpose other than a mount for the walls, so less substantial frames were acceptable.

In order to enhance the variability of the habitability studies that can be conducted in the earth analog, additional, non-structural walls were installed in the lower floor that can move in and out. This allows for a wide range of volumes (from 1291 ft^3 to 336 ft^3 on the lower floor). Our maximum and minimum volume in comparison to the Habitat Demonstration Unit (HDU) can be seen in the figure below.

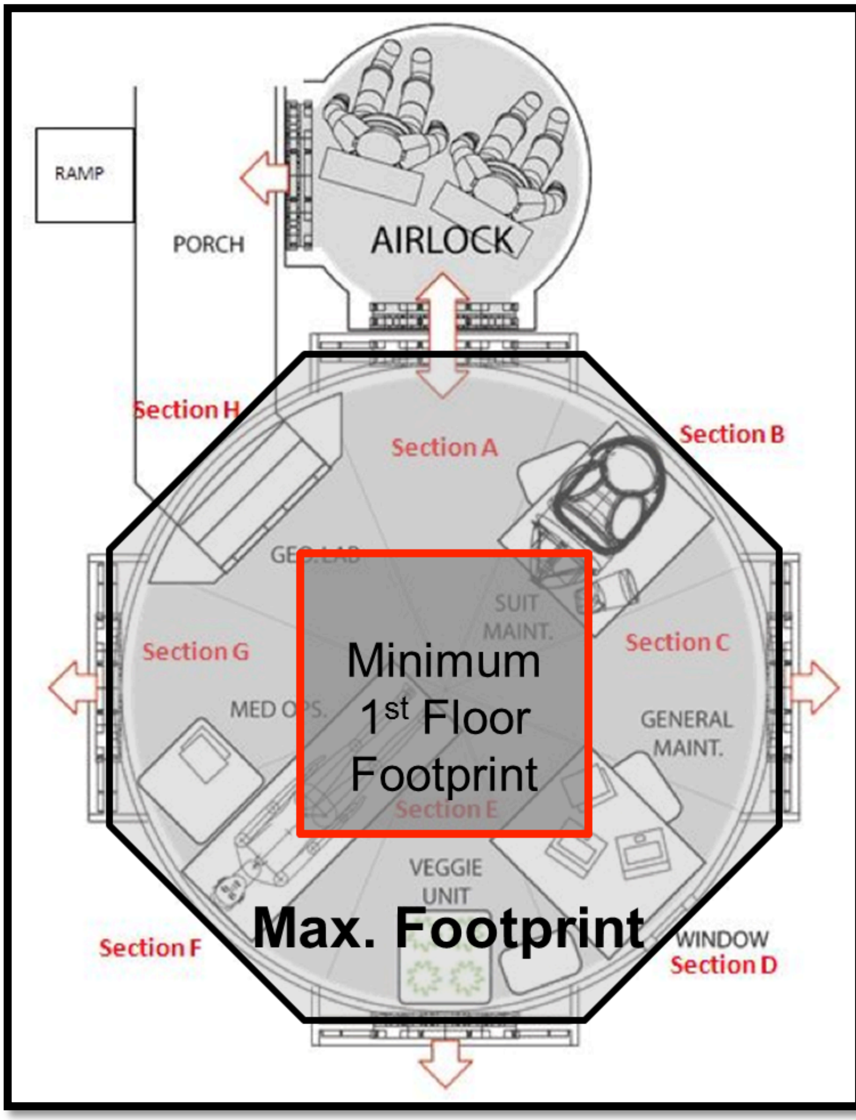

Figure 11: Minimum and Maximum Footprint Comparison

Moreover, all of the furniture in the lower floor is modular to accommodate the variable volume. Because of the octagonal shape, the floor plan approaches a square shape as the volume is decreased. The walls parallel and perpendicular to the entrance (termed "major walls") move in first while the other walls (termed "minor walls") move in behind those. The modularity of the design allows students to experiment with different volumes and find the smallest realistic volume for the 30-day mission with three people.

Another compromise incorporated into the earth analog is build materials. The structure itself is made entirely of wood. Wood was chosen because is cheap, easily accessible, and easy to work with. It is not, however, optimal in terms of weight and bulkiness. The space-rated habitat would undoubtedly incorporate more appropriate materials, such as aluminum, Kevlar, and carbon fiber.

Upper Level

The upper story of the Earth analog consists of three different PLQ designs, a common table, hygiene station, and a food preparation area. Unlike the first floor, the walls are not reconfigurable.

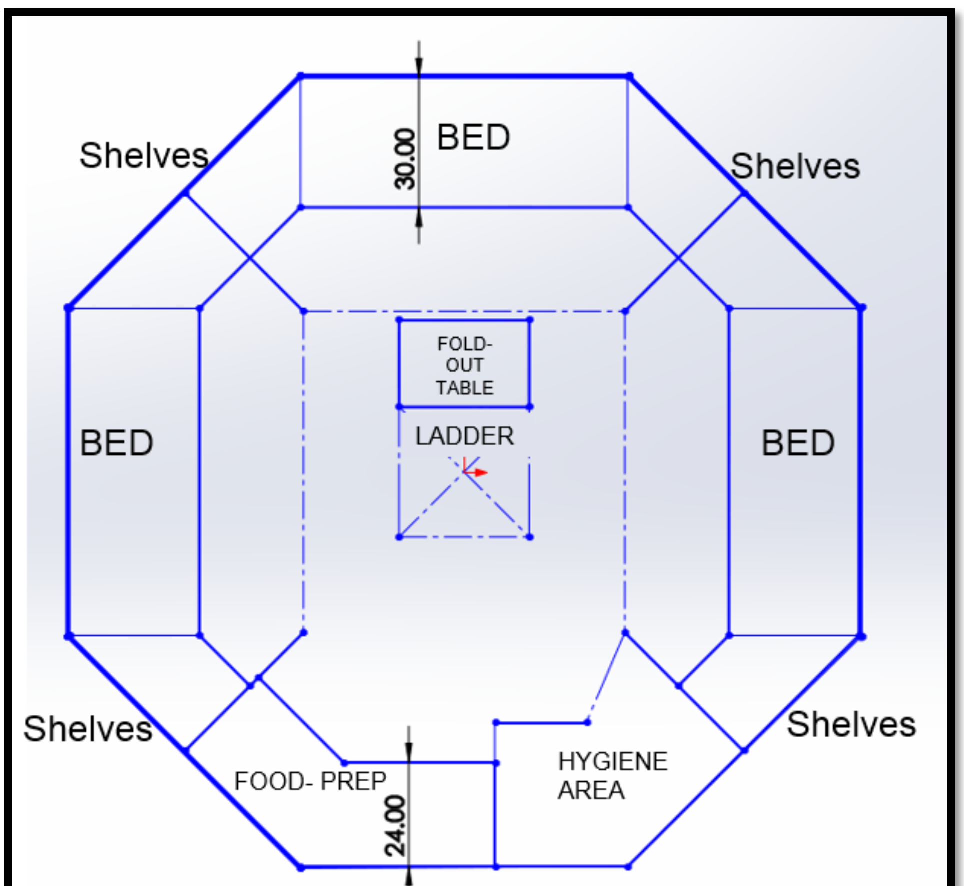

Figure 12: Earth analog second story layout

Personal Living Quarters

We developed three different PLQ options to study in our habitat. All beds are designed to be 6ft. long and 2.5 ft. wide with a minimum of 2.5 ft. overhead clearance. All bed options possess personal storage space, work station, sleeping area, and a window. For safety, the beds are stapled to the frame to prevent the bed and person from slipping off. All work stations are designed so that the astronaut will not have to remove or rearrange their work or equipment before going to bed. The lights in each PLQ can be individually controlled by personal remotes, as well. Also, Blackout curtains were installed in each PLQ to provide privacy, block out light, and muffle sound (see Figure 13). Shelves were placed between each PLQ to stabilize the hard walls and add storage space (see Figure 14).

Figure 13: PLQ Curtains

Figure 14: PLQ Shelves

<u>Option 1: Bunk Bed</u>

This bed option puts an emphasis on work area. The bed slides up and out of the way of the work station providing the astronaut with a large space to store personal mementos and write reports. When it is time to sleep, the bed slides down and stops 1 ft. above the work area. Because of this, the astronaut will not have to put away his work before going to bed. To climb onto the bed, a person will have to use the front lip of the lower storage space as a ladder.

Figure 15: bunk bed

Option 2: Storage Bed

This bed option puts an emphasis on storage space. There is ample storage above and below the bed for personal items and equipment. A work table also folds up from the side of the bed. Figure 16 shows the table in an upright position.

Figure 16: Storage Bed

Option 3: Murphy Bed

The Murphy bed emphasizes sleeping area (Figure 17). Because it folds down from the wall, there is a large amount of clearance above the bed. As can be seen from the figure below, there is a small amount of room behind the bed against the wall that could be used for storage space. We did not add shelves there though due to time constraints. When the bed folds up, there is a large work station for an astronaut to use, but when the bed folds down the work station double as a bed support. Because of this, the astronaut will not have to put away his work before going to bed.

Figure 17: Murphy Bed

Food Prep

The food preparation station consists of a mock re-hydrator, microwave, and a computer (Figure 18). Theoretically, an astronaut will only utilize the computer and re-hydrator, but we included a microwave so that participants in the habitability would have a way to eat inside the habitat. There is storage below for equipment, food, and personal items, and space above the prep station for potential shelving units.

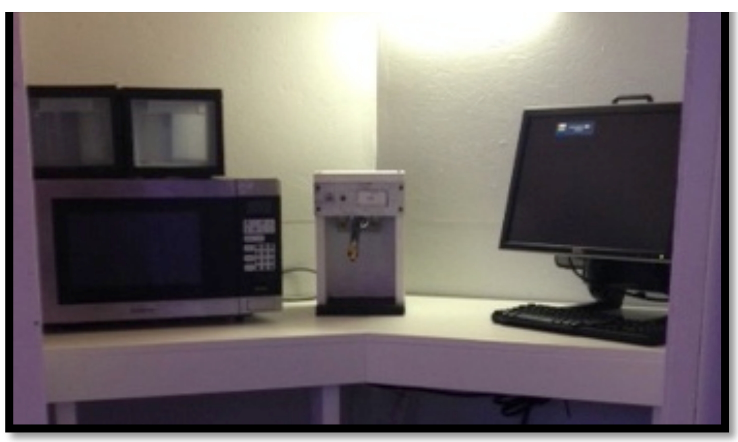

Figure 18: Food Preparation Station

Hygiene Station

The hygiene station (Figure 19) is surrounded by hard wooden walls to increase privacy. A curtain will be used to separate this area from the rest of the second floor. Also, the area in front of the toilet will be used to mock a dry shower. The toilet is roughly 18 in. deep with a fake hole drawn underneath the toilet seat. We chose not to make a hole for the toilet to prevent visitors from leaving trash.

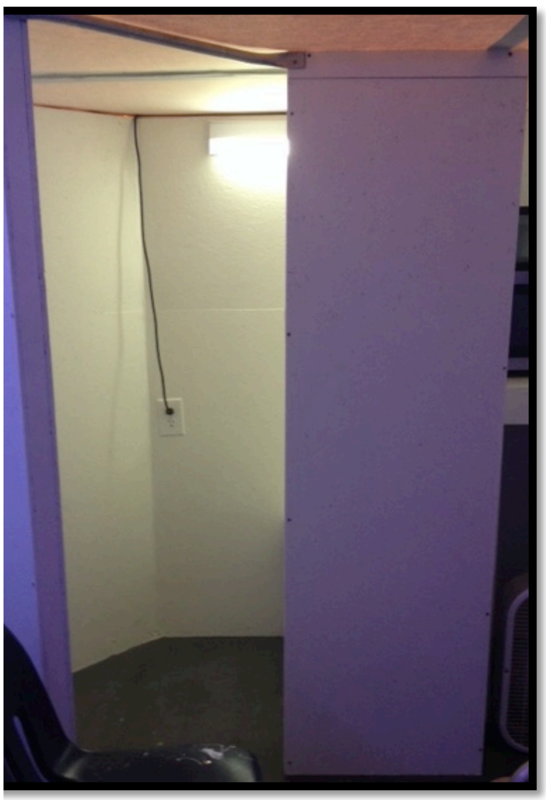

Figure 20: Toilet

Team Meeting Area

We created a small fold out table to simulate the common meeting area. Because we did not want to block the bathroom or food prep area, the table is located in front of the storage PLQ. To sit at this table, each person will have to use their own chairs located in their respective PLQ. When not in use, the table will fold against the safety rail (see Figure 22).

Figure 21: Fold-out table

Figure 22: Stored table

Lower Level

One of the challenges in building this habitat was keeping all of the interior components of the lower floor compatible with the moveable walls. The three major walls are the first to be brought in, so they remain a full six feet in width across the spectrum of variability. The minor walls, however, lose area as the major walls are brought in. Any components mounted to these walls must then be designed such that they can narrow accordingly.

As a result, the major stations are on the major walls, and storage is located on the minor walls. Each minor wall consists of three shelves that are four feet wide attached to a vertical track to allow for variability in the heights of the shelves. Also, more narrow versions of the shelves were built that will be installed once the four-feet-wide ones are too wide. On top of these shelving units sit soft, cubical storage bins. These can be easily rearranged or removed if larger items need to be stored on the shelves.

Figure 23: Panorama Lower Story

Command Station

The command station consists of 4 monitors ran off of 2 Dell desktop computers and a Makerbot 3D printer. The station is a 48 inch by 24 inch deep table with an additional 24 inch by 24 inch table, when the habitat is at its largest configuration. The command station would be used for communication with earth, the orbiting vehicle and the astronauts during EVAs. Along with the command station is the 3D printer station. At this station the supplies and storage for temporary tools would be kept near the 3D printer. Along each side of the command station are green storage boxes for other supplies that may be needed by the command specialist. The command station can be seen in the pictures below.

Figure 24: Command Station before 3D Printer

Figure 25: Command Station Monitors

Biology Station

In the space-rated design, the medical/biology station would be longer than the other two stations in order to comfortably hold an astronaut lying down. In the earth analog, space and geometric constraints resulted in a 6-foot wide station. The shelf along the back of the station holds four first aid bins. These would contain smaller pieces of medical equipment, ranging from bandages to scalpels. Larger pieces of equipment, such as an ultrasound unit, might be stored on shelving adjacent to the medical station. Additionally, the computer on the right side of the station could be used to access treatments for injuries/illnesses should the situation arise.

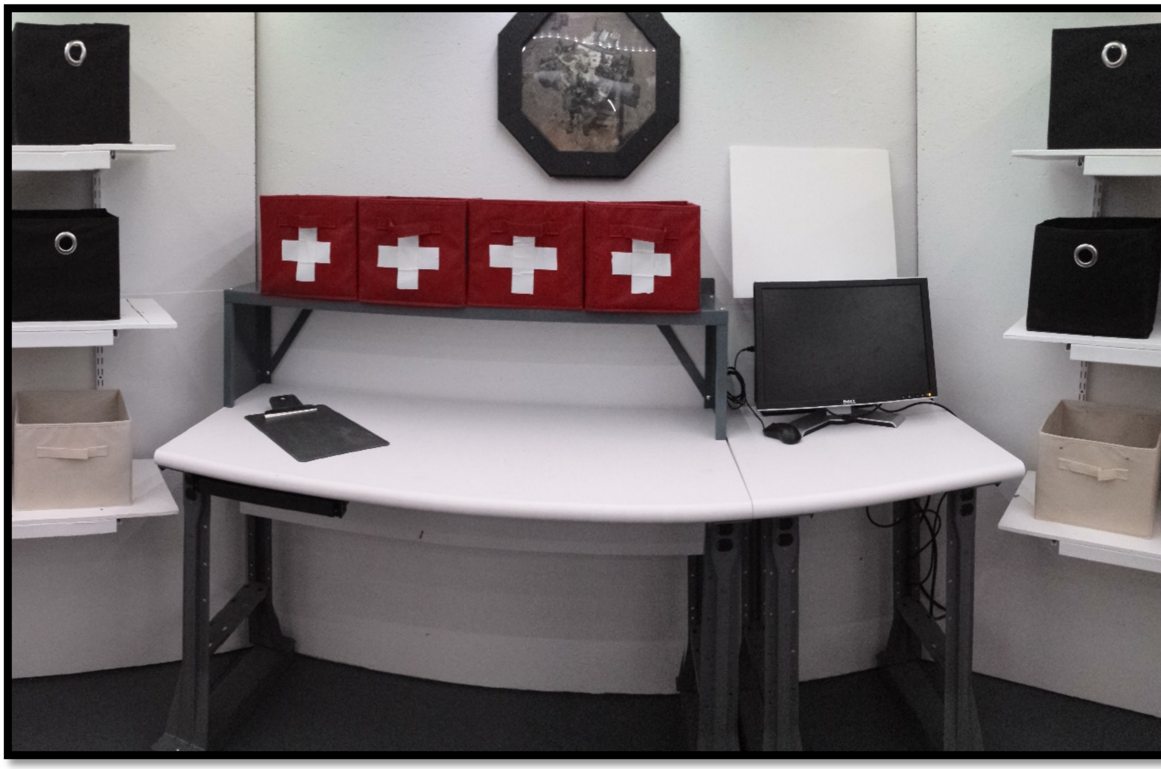

Figure 26: Biology/ Medical Station

The station would also be used to study life sciences on Mars. Astronauts might use it to house a cell culture unit to study microorganisms, as well as an aquatic habitat to study fish in a reduced gravity setting.

Geology Station

The geology station consists of a glove box, with electronic microscope, work space and a Dell desktop computer. The station is a 48 inch long by 24 inch deep table. The work station is positioned at a height that is comfortable to work at standing as well as sitting in a tall chair. The geology station would be used for analyzing mineral samples from the Mars surface. The glove in theory would have access from the outside of the habitat and be sealed shut. The earth analog is not vacuum sealed and does not have access through the outside of the habitat. The glove box contains a separately controlled set of LED lights that allow for total customization of the lighting within the glove box. As seen in pictures below the glove box has a tracing table style bottom that allows for light to shine through the working surface, eliminating most shadows. Above the glove box is a monitor that will link to a webcam inside the glove bow, allowing the user to see closer details of the minerals he or she is examining. Beside the glove box is the computer, for taking notes and performing other tasks as assigned. Along each side of the geology station are brown storage boxes for storing mineral samples and other supplies that may be needed by the geology specialist. The geology station can be seen in the pictures below.

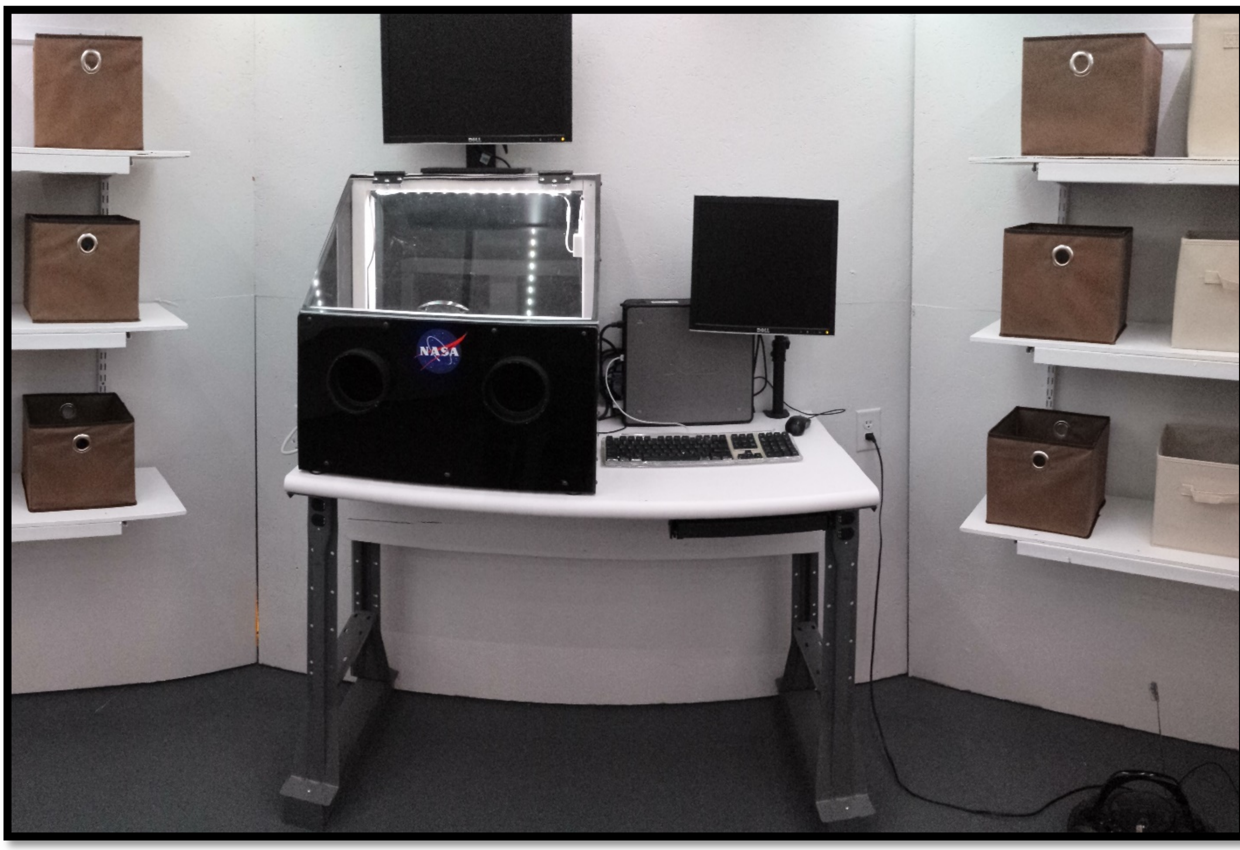

Figure 27: Geology Station

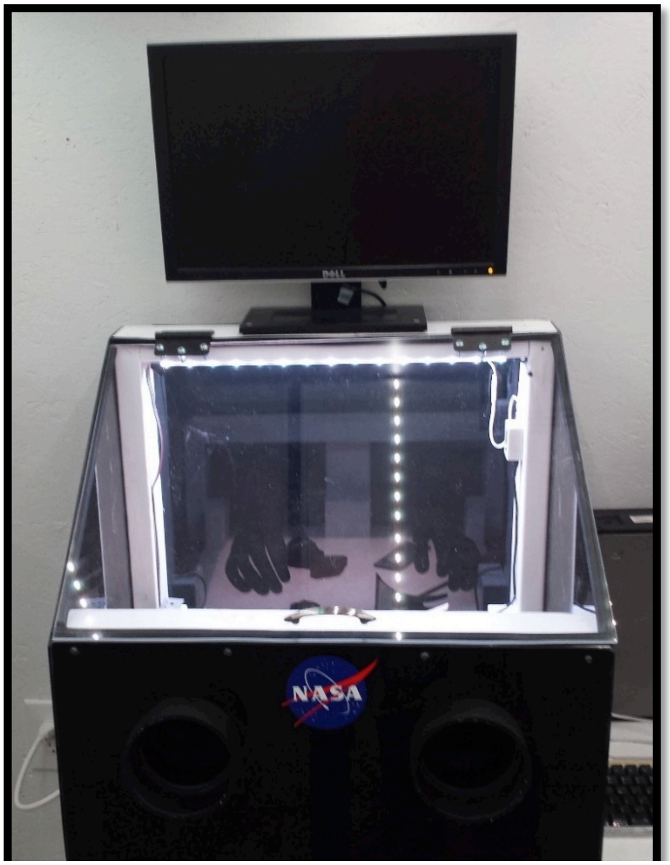

Figure 28: Exterior of Glove box

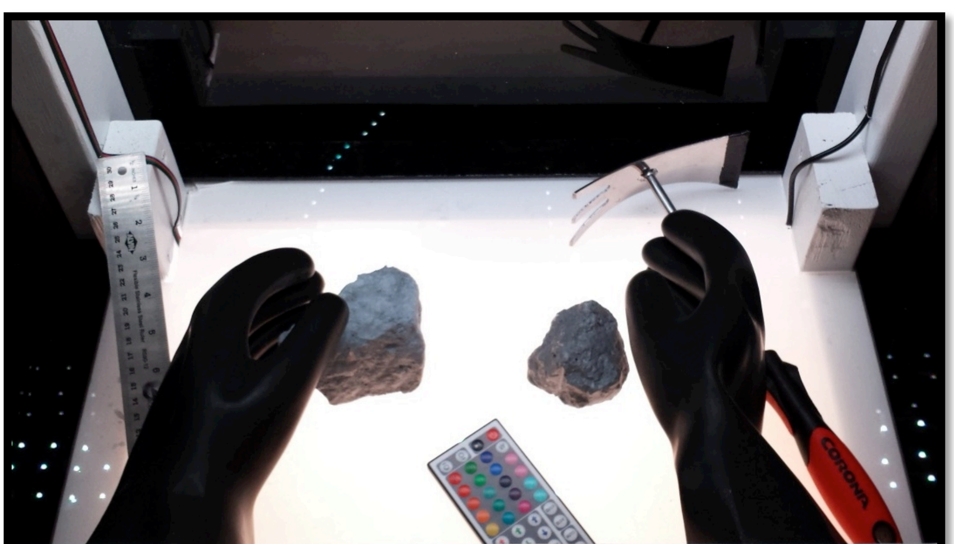

Figure 29: Interior of Glove box

Aeroponics

Aeroponics is the method by which plants can be grown without the presence of soil and with little water. The plants are grown in a nutrient-rich air/mist environment. This greatly reduces chances of contamination that conventional plants are exposed to through soil, pesticides, and residue (Dunbar). Also, there are no seasonal constraints as far as when plants can be grown – they can be grown any time.

An Aeroponics system is installed in the habitat, as shown in Figure 30. Though the space-rated design would contain multiple layers of Aeroponics systems around the ladder, the single layer installed in the earth analog gives a visual representation of the setup. The Aeroponics system makes good use of otherwise wasted space around the ladder. Also, its central location makes it easily visible to all astronauts while working. Green plants give the habitat a more earthly feel, which is important when living 225 million kilometers away from Earth (space.com).

Figure 30: Aeroponics Station

Storage

One of the challenges in building this habitat was keeping all of the interior components of the lower floor compatible with the moveable walls. The three major walls are the first to be brought in, so they remain a full six feet in width across the spectrum of variability. Eventually, the major walls collide with one another to form three sides of a small square, forming the smallest possible configurable volume. The minor walls lose area as the major walls are brought in. Any components mounted to these walls must then be designed such that they can narrow accordingly.

For the sake of simplicity, the habitat was designed such that the major stations are on the major walls, and storage is located on the minor walls. Each minor wall consists of three shelves that are four feet wide. They are attached to a vertical track to allow for variability in the heights of the shelves. If the inhabitant needs room to store a large tool he/she printed with the 3D printer, for instance, he/she can move the shelves accordingly to accommodate it.

Also, more narrow versions of the shelves were built. Once the major walls are brought in a few feet, the wider shelving will collide with them. The more narrow shelving, measuring 2 feet in width, will be installed at smaller volume configurations. On top of these shelving units sit soft, cubical storage bins, shown in Figure 31. These can be easily rearranged or removed if larger items need to be stored on the shelves.

Figure 31: Storage Bins

Maintenance

In order to open the habitat, both handles must be turned simultaneously

Figure 32: Front Hatch

General Start Up

To turn all of the habitat, follow these steps.

1. Locate Breaker box on rear side of habitat

Figure 33: Habitat Breaker Box

2. Open breaker and flip all breakers over to the on position.

Figure 34: Breakers in ON Position

3. Lights will now turn on to the last state they were in before shut down.

Figure 35: Interior Lights ON

4. Each computer throughout the habitat now must be turned on.

To shut down the habitat, follow the startup directions in reverse order.

Lighting

The lower story LED lighting are wired in series with amplifiers approximately every 4 strips. The lower story lights are controlled via WIFI with an App available on both Android and Apple products. The App allows for the brightness and color of the lights to be adjusted. The WIFI router can be found behind the west wall on the lower floor. Below are screen shots of the App as well as a link to the App.

Android: https://play.google.com/store/apps/details?id=com.lxit.wifi102

Apple: https://itunes.apple.com/us/app/wifi-102/id631496674?mt=8

Figure 36: LED Light Controller App Screenshot

Moveable Walls

The moveable walls are very simple. They are sheets of OSB reinforced with 2x4s. Two trolleys are attached to the top of each sheet, each of which can slide within an appropriately sized section of unistrut. The figures below show the maximum and almost minimum configurations, respectively. These are older pictures of the lower story before anything was painted, but the walls and the accompanying unistrut above them can be seen.

Figure 37: Moveable Walls, Max Configuration

Figure 38: Moveable Walls, Smaller Configuration

In order to move the walls, first disengage the stopper at the top of the wall. Then, firmly grasp the top of the wall and push or pull. It is important to push or pull at the top of the wall because applying force at a lower location mostly causes the walls to swing in and out. When the wall is at the desired location, engage the stopper.

If a wall will not slide freely, first ensure the stoppers at the top are disengaged. Then, check to make sure nothing on the floor is blocking the wall. Finally, check inside the unistrut to ensure that foreign debris is not blocking the path of the trolleys.

If the wall becomes damaged, the wall can be repaired or replaced. If it is a localized area, it would be advantageous to dismount the wall, set it on sawhorses, and cut out a square section around the damaged area. Then, cut a piece of OSB to fit within the removed section. Place it in the area, and place a 2x4 along the backside of the wall to which to mount the section. Screw the section to the 2x4, and the 2x4 to the wall itself.

If the wall is severely damaged, replacing the entire wall would be the best solution.

Future Development

Human in-the-loop Testing

Habitability studies will be utilized to test the functionality and versatility of the Habitat. Through these studies we hope to analyze the effectiveness of the layout, decide on which bed option is superior, and find the minimum habitable volume. There will be 10 different plans for each astronaut ranging from 2 to 36 hours. For test subjects, we will use students that are as small as 5ft 2in, and students as large as 6ft 4in. We will also use the JPATS cases to help choose test subjects that will properly test our habitat.

These studies will help us analyze different aspects of the habitat. To test the functionality of the layout, the participants in this study will have to perform different tasks at the same time on the same floor during a time crunch. To test how easy participants of different size can perform a task, they will have to accomplish various goals, such as: reach towards the back of tall shelves, perform maintenance, reach towards the ceiling to get food, and evacuate the habitat from the second floor. The participant will be able to rate the difficulty of each task on a scale of 1-10 and make suggestions on how to improve the ease of the task. Some example tasks include using the 3-D printer, prepare and eat food, analyze Mars sediment, maintain the habitat, use the command station, take blood samples, repair an injury, communicate through social media, and sleep.

Once the complete set of tests for the first floor is complete, the walls will be moved in closer. The tasks for the first floor would then be repeated. This process will continue until we reach the minimum volume allowed by our walls.

Repositioning the Habitat

In the original development of the Reconfigurable habitat, there were plans to make the habitat able to be deconstructed into 3 pieces for movement. This is no longer the case and it is strongly recommended to not attempt to move the habitat. The weight of the habitat has increased due to the habitat being mainly built out of wood. In order to take the habitat apart, all interior furnishing must be removed. Following emptying the habitat, additional supports would be required inside the habitat to prevent the structure from twisting and collapsing. Next, all the electrical wiring would have to be removed due to it spanning across the joints where the habitat would separate. The upstairs food station would have to be removed and the corners of the walls would be required to be cut. At this point the lower floor ceiling must be removed, which involves removing all of the lighting for the lower story. At this point the floor would be removed down stairs to access the bolts holding the three sections of the habitat together. To summarize, **do not attempt to separate the habitat into 3 pieces**. To accomplish this task, means total deconstruction of the habitat, followed by a complete rebuilding of the habitat. If movement inside the high bay is required, the habitat is raised to a height that allows for a forklift to be moved under. With a forklift lifting the habitat and several furniture dollies, the habitat could be repositioned within the high bay with minimal effort.

Conclusions & Recommendations

The students on the X-Hab team invested an enormous amount of time and effort in the spring 2014 innovation challenge. The point of the project is to design a Mars habitat, and the students at Oklahoma State University took it a step further by designing a Mars habitat with a large amount of variability incorporated. This variability allows students to test firsthand different layouts, volumes, and living arrangements, and, from there, formulate an optimized design.

From a structural standpoint, the habitat is complete. The first portion of the semester was spent designing and building the structure in such a way that it will survive many semesters to come. From an interior standpoint, it is mostly complete. The basic components are all present. Tables, shelving, PLQ components, electricity, and walls, to name a few, were all installed. Improvements upon some of them could be made, however. For instance, more storage bins could be purchased to better utilize the storage space. Future students could purchase space-appropriate items to place in the storage bins to get a better feel for the amount of storage necessary. This applies to upper-story storage, too. The shelving in the PLQs do not have many items on them, and clothing, food, electronics, etc. could be purchased to better represent an astronaut's belongings.

Finally, perhaps the most pressing recommendation is for future students to perform habitability studies. It was intended for this semester's students to perform a few of them, but finishing the interior ran a little late. Ideally, three students will live in the habitat and simultaneously perform pre-determined tasks. These students will live in the habitat for varying lengths of time (some will stay overnight) and perform tasks at different volumes. With their feedback, the optimized volume and configuration of the space-rated Mars habitat can be approximated and implemented into a final design.

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Appendix: Space Habitat Innovation Challenge Solicitation

Sponsored by NASA's National Space Grant Consortium through
Oklahoma State University's School of Mechanical and Aerospace Engineering and
NASA's Interdisciplinary National Science Project Incorporating Research and Education Experience (INSPIRE)

Purpose:

In partnership with NASA and the National Space Grant Consortium, Oklahoma State University (OSU) is conducting a competition among teams of high school students and community college students to design technologies for NASA's manned space exploration program with the goal of engaging and inspiring the next generation of innovative engineers and scientists.

There are two challenges for this year: the ***Rapidly Prototyped Tool Challenge*** (RaPTC) and the ***Space Habitat Airlock Challenge*** (SHAC). RaPTC is open to eligible high school student teams while SHAC is open to eligible community college student teams. Teams should involve 3-6 students, but may include more or less at the discretion of the organizer. All entries will be provided with feedback from Oklahoma State University's School of Mechanical and Aerospace Engineering on feasibility and design. Three groups in each challenge will be selected as finalists for a final virtual presentation and interview with students and professors in the engineering program at Oklahoma State University. One group will be selected as the winner of the each challenge making them eligible for a visit to present their presentation to engineers at a NASA center. All participating groups will be competing against each other during this challenge.

Important Challenge Dates:

Challenge start date: February 10, 2014
Notice of intent to participate: February 17, 2014 (optional, but encouraged)
Submissions Due: **March 31, 2014**
Finalists Selected: April 7, 2014
Winner Announced: April 21, 2014

Video Presentation of the Design:

Creation of a 3-D model of the design is necessary detailing the design concept, pre-assembly and final states and operating configuration. A variety of programs are available with which to create 3-D CAD renderings such as Google Sketch-Up or Rhino3D. All models should be displayed graphically in the final presentation (i.e., demonstrating that a final CAD model has been generated).

Each group will create a video presentation uploaded to YouTube designed to demonstrate the group's design. Teams may use *PowerPoint* or *Prezi* as part of their presentation. Presentations must include the following:

- Team name along with hometowns of team members and their school
- Design concepts including brainstorming
- A 3-D rendering of the proposed design
- Rationale behind design
- Overview of materials, construction, and cost
- Explanation of adherence (or lack thereof) to specified guidelines

Teams may be creative in their presentation and judges may award additional consideration based upon the video originality. Videos may include humor, music or other artistic expressions. YouTube links of the presentation must be submitted by March 31, 2014 at 12:00pm (noon) Central Time to be eligible for consideration. Selected finalists may be asked to present their design via Skype. Participants should e-mail their links to jdjacob@okstate.edu with the subject line of either XHab RaPTC or XHab SHAC.

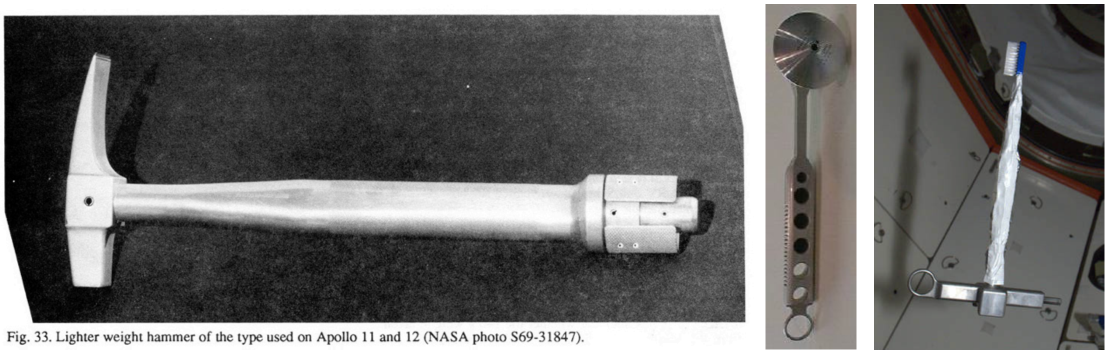
RaPTC:

Deliver of items into space requires enormous resources. A kilogram of material may costs thousands of dollars into orbit and its final destination. As such, engineers and scientists take great care in minimizing the weight of items sent into space, and designing and optimizing tools for everyday or special use in manned missions is an important task that is often overlooked. The recent advent of 3D printing or rapid prototyping will revolutionize the way tools are designed for manned space flight. Instead of requiring specialized tools for certain tasks, crew members may now "print" items from a library, generating tools and replacement parts as needed then recycling them for use in future print jobs, saving valuable weight.

RaPTC teams are tasked with designing a multi-purpose tool for manned space exploration. This tool may be designed for any specific tasks related to a deep space mission with a destination of the moon, Mars, or an asteroid. The tool functionality may include science and/or engineering tasks such as geologic exploration, medical emergencies, space suit or vehicle repair, farming, etc., or any combination thereof.

Restrictions include the following. The tool should be no larger than 20 cm in any one dimension and should use no more than 25 cm^3 worth of material (remember that material weight, hence volume, is at a premium). The tool may use multiple parts that can be printed separately and assembled as long as the total tool volume remains below the maximum allowed value. The tool may also include moving parts as long as no additional parts are required for operation outside of those that can be printed.

The selection will be equally judged based on practicality, creativity, and efficiency. For practicality, the teams should address how the item will be used. Is it a sensible design? Will it do its intended job? Is the tool something that is needed for a deep space mission? For creativity, the teams address how the item was designed. Does it simply replace something already designed (i.e., a screwdriver or hammer) or is it novel? Does the design take full advantage of 3D printing? For efficiency, the team should address the build and operation of the tool. Does it make efficient use of materials? Can the tool be used for more than one purpose? The teams should also come up with an appropriate name or acronym for their tool.



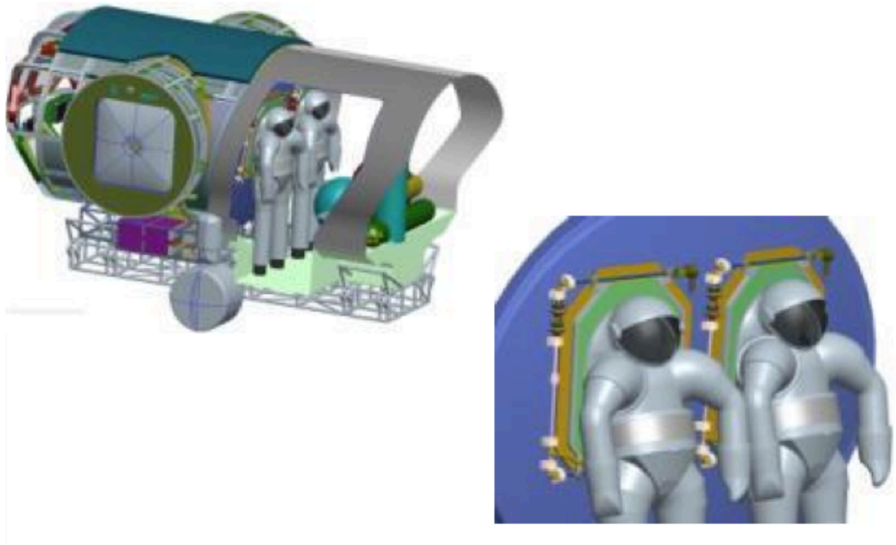
Early Apollo rock hammer (left), STS EVA ratchet (center) and a modified toothbrush used on an EVA aboard the ISS (right).

SHAC:

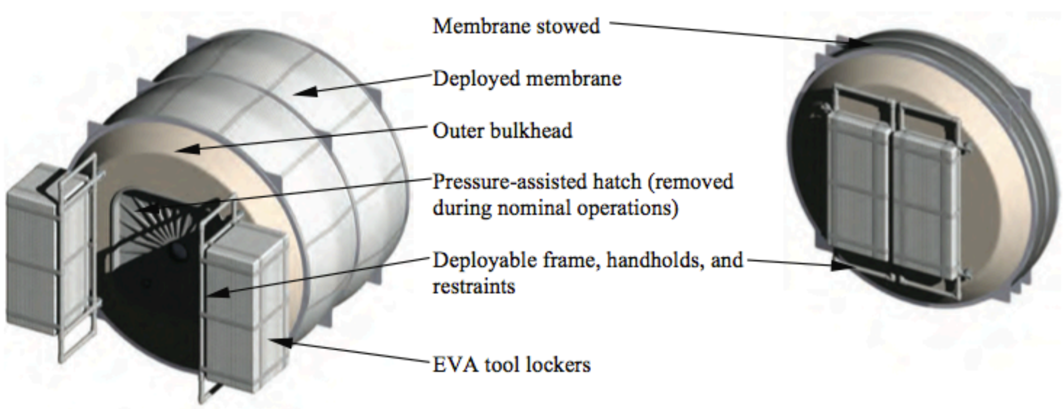
For deep space exploration on the moon, Mars or NEOs, future missions will have a need to egress from the habitat to the surface in an airlock for Extravehicular Activity (EVAs). However, there is little design experience to draw from. The Apollo mission, for example, lacked any airlock and required that the lunar module be completely depressurized and repressurized for excursions on the lunar surface. Upon reentry into the module, moon dust adhered to the spacesuits would contaminate the module interior with possible risks to crew health and equipment functionality. In future missions, this must be avoided. Crew members may be need to ingress and egress from either habitats or pressurized rovers. Thus, there is a need for compact airlocks that provide ingress/egress with minimal air loss during pressurization and also provide a measure of dust mitigation.

Based on specifications from NASA (Cohen), the airlock design should address the needs for minimal volume, rapid ingress and egress, minimal air loss during depressurization and repressurization, robustness, and shirt sleeve environment maintenance. The technology must be resistant to dust and other foreign bodies. The system should be applicable to both planetary surfaces and NEOs with varying atmospheric pressure from partial (Mars) to none (moon and NEO) and be usable on both partial-g planetary surfaces (moon and Mars) to zero-g environments (NEOs). Additionally, the ideal system will compact for transportation, minimizing the stowed volume during launch and transit. Suitlock or suitport concepts (see for example, Howe et al.) provide a novel mechanism for providing dust mitigation, but at the cost of suit maintainability since access to the suits for repair and maintenance are limited.

The SHAC teams will present an airlock design that address the above requirements for a deep space mission with the capability to simultaneously allow up to 3 astronauts on an EVA at one time. The concept should include provisions for dust mitigation, storing air used during pressurization, connecting with other pressurized systems, and storing suits. Additional consideration will be provided for those teams that include designs that stow the airlock during transit. The designs will be judged based on completeness of the design, engineering soundness, practicality, and creativity.



Pressurized rover suitlock concept (from NASA).



Dual-chamber hybrid inflatable airlock concept (from Howe et al.)

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