42nd International Conference on Environmental Systems
15 - 19 July 2012, San Diego, California

AIAA 2012-3617

CHELONIA: Development and Manufacturing of an Earth Analog Habitat Evaluation Facility

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The University of Maryland Space Systems Laboratory (SSL) was awarded a NASA X-Hab 2012 grant for the design and construction of a new Earth analogue habitat for habitability research. This work builds on the past ECLIPSE and X-Hab projects at the SSL, by combining these elements with a new habitat module in order to create a single research platform for habitability studies. The "Crew Habitat Evaluator for Long-duration Orbital, Near-earth, and Interplanetary Applications" (CHELONIA) will deliver a much more flexible architecture than the previously developed mock-ups, allowing facilitating faster modification of the interior layouts and available total volume. This will enable the investigators to evaluate crew assessments and task performance as a function of the interior layout, functional area allocation and total available volume.

This paper documents the design of this new infrastructure, and includes the details of the manufacturing of a new habitat mock-up module and modifications to the existing elements. The paper also includes a brief discussion of possible future research goals.

Initial layouts are implemented using foam-core volumetric mock-ups for internal equipment and outfitting. These low fidelity mock-ups constitute a "library" that will allow a very rapid evaluation of a multitude of layouts. CHELONIA is also suitable for higher fidelity functional mock-ups, as well as short to medium-duration mission simulations.

This new facility will enable the examination of habitat layouts for both partial gravity and microgravity environments. While partial gravity systems will be easily evaluated with the habitat currently in development, microgravity subsystems will be studied by utilizing low fidelity volumetric neutral buoyancy mock-ups in order to determine if commonality in the design for these two environments is appropriate.

Finally, this new facility is being integrated into the SSL Moonyard planetary surface simulation center. The Moonyard simulates a planetary surface by means of a large sandbox, and is used primarily for rover field trials and suit systems evaluation. This new facility will be a prime element in future Earth analog simulations at the University of Maryland in support of NASA exploration objectives.

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Acronyms

CHELONIA	Crew Habitat Evaluator for Long-duration Orbital, Near-earth, and Interplanetary Applications
HAVEN	Habitat Analog with Variable Environments
ECLIPSE	Extensible Concept for Live-In Pressurized Sortie
HDU	Habitat Demonstration Unit
D-FLEAS	Desert Field Lessons in Engineering And Science
EVA	ExtraVehicular Activity
LASER	Lunar Advanced Science and Exploration Research
MX-3	Maryland eXperimental spacesuit, mark III
NBRF	Neutral Buoyancy Research Facility
SSL	Space Systems Laboratory
UMd	University of Maryland

I. Introduction

On March 14, 2011, the National Space Grant Foundation and the NASA Exploration Systems Mission Directorate released the 2012 X-Hab Academic Innovation Challenge.[1] The Space Systems Laboratory (SSL) at the University of Maryland responded with a proposal to fabricate a habitat module mock-up. This is the third habitat project undertaken by the SSL for NASA. The first was the Minimum Functional Lunar Habitat Element study, in which the SSL performed a detailed parametric study of space habitats configurations.[5] This study concluded that the ideal form of a habitat for a planetary surface is a vertically oriented cylinder. The second was the 2011 X-Hab project, for which a UMd student team designed and manufactured a vertically oriented inflatable habitat. Following up on this work, the UMd group proposed under X-Hab 2012 to focus on the design of a vertically oriented habitat module.

The team decided to use the 2012 X-Hab project as an opportunity to build a highly reconfigurable habitat facility. The UMd group will incorporate the new module in the SSL's Moonyard facility. Once complete, it will be joined with previously developed habitat elements to create a new habitat mock-up facility, dubbed the Crew Habitat Evaluator for Long-duration Orbital, Near-earth, and Interplanetary Applications (CHELONIA). This facility has been designed from the outset to be highly modular, in order to enable rapid reconfiguration of internal layouts including reconfiguration of hatches, windows, and other interfaces to the exterior. This will allow UMd researchers to implement a wide variety of internal habitat layouts with minimal set-up times, and give them the ability to conduct comparative habitability studies.

A major goal of the X-Hab Academic Challenge program is to get students involved in solving engineering problems, and to inspire them to pursue education and careers in Science, Technology, Engineering, and Mathematics (STEM) fields. As such, participation in X-Hab is predicated on incorporating the established design task into existing design courses at the university and to maximize involvement of students throughout the process. Since the beginning of the Fall 2011 semester, more than 40 students ranging from freshman to graduate students, a faculty advisor, and three graduate student mentors from the SSL have been involved in the design and fabrication of CHELONIA.

This work will describe in detail the design and manufacturing of UMd's CHELONIA facility. This includes the design of the new habitat module, as well as refurbishment of old habitat elements. This paper will also include a brief discussion of future research goals and conclude with other possible future work involving this facility.

A. Details and Requirements

The original call for proposals envisioned a transportable habitat module which could be packed into a standard shipping container. The module could then be easily transported to a field trial site, unpacked and deployed at a low cost. The sponsors also required a platform for testing internal layouts. After awards, the original requirements were modified by NASA, however: the new requirements no longer included any accommodation for transport. The habitat will be permanently located at UMd, with the stated hope by the sponsor that it will encourage long-term research and teaching interest in space habitat design. The team was granted \$ 28,000 for construction of the habitat, and for foamcore and other materials for initial implementations of interior layouts.

The team was given a set of guidelines and assumptions about the characteristics of a deep space habitat.[4] The UMd team translated this list to requirements wherever they were relevant to the habitability of an Earth-analog mock-up. The requirements are as follows:

1. Shall accommodate a crew of 4
2. Shall provide 42 m^3 pressurized volume per crewmember
3. Shall have at least 4 windows with a diameter of 0.5 m
4. Shall have at least 3 hatches
5. Shall have at least 4 docking interfaces
6. Shall be no larger than 5 m in diameter

It should be emphasized that the module itself was envisioned as a reconfigurable platform for testing various habitat interior layouts, and is not a mock-up of any particular habitat design. The team sought to ensure that this platform could be used to simulate a wide variety of designs based on these requirements.

B. Background

The SSL has fabricated several full-scale habitat element mock-ups in the past, two of which were considered for inclusion in the CHELONIA facility. These are existing elements, so their development will not be documented in depth in this paper. Instead, a brief overview will explain their purpose and how they might be integrated into CHELONIA.

The Extensible Concept for Live-In Pressurized Sortie Elements(ECLIPSE) was developed by the SSL as part of the Minimum Functionality Lunar Habitat Element study.[5] It is shown in the SSL's Moonyard facility in Figure 1. It is a vertically oriented, two-story, 3.65 m diameter habitat. The main cylindrical body is a fiberglass shell. All other structural elements are dimensional lumber.

Figure 1. ECLIPSE in the SSL Moonyard

The X-Hab inflatable loft was developed by a UMd student team as part of the 2011 X-Hab Academic Innovation Challenge. It was designed to simulate an inflatable space habitat module that could be mounted on top of NASA's Habitat Demonstration Unit (HDU) in order to provide additional habitable volume. Its intended purpose was to give additional habitable volume to the HDU during the 2011 Desert-RATS field trials.[3] Figure 2 shows the loft installed and deployed on top of HDU at Johnson Space Center. It consists of a fabric envelope, simulating an inflatable space habitat. However, instead of pressurization of the internal volume, the X-Hab is supported by a structure of inflatable beams.[2]

Figure 2. UMd's X-Hab Inflatable Loft mounted on top of NASA's HDU

C. CHELONIA Design Motivation and Research Goals

When NASA decided not to follow through on the concept of modular transportable habitats as specified in the X-Hab 2012 solicitation, extensive discussions took place between the sponsors and the UMd X-Hab mentor and team leaders. Since the original X-Hab 2012 design was modular for transport, the team was interested in retaining modularity for reconfigurability and a wider potential range of research applications. As this was the third NASA-supported habitat design for the SSL, this was also viewed as an opportunity to integrate previous habitat simulations to improve the utility of the final product. Indeed, since the sponsor's primary interest was in a habitat mockup for four crew with a minimum "pressurized" volume of 168 m^3, reusing the previous habitat elements was the only feasible way to meet the desired characteristics within the extremely limited budget.

The CHELONIA facility was designed with modularity and flexibility in mind as its primary requirements in order to allow the investigators to address several key questions on habitat design and interior solutions. While interiors can be easily changed in most habitat mockups, practical limitations are imposed by the habitat shell itself. For example, the NASA HDU has four hatches at 90° intervals, and past NASA designs have had to design around the existing hatches, or block them to allow installation of interior elements.

Having observed this limitation from past interactions with the NASA habitat team, the UMd design team decided to push for interchangeable wall segments in the habitat. This approach would allow variation of the number, type, and location of exterior interfaces (such as hatches, windows, and airlocks) to minimize constraints on future reconfigurations.

Over and above inspiring student involvement with a hands-on habitat development project, the SSL investigators are interested in developing a modular, reconfigurable habitat facility to support human factors studies on habitat design relevant to future human exploration missions to the Moon, Mars, or small bodies in the solar system. Some specific issues which are not well quantified include the impact of key design parameters and interior layouts (e.g. volume per crew member, mission duration, space distribution and allocation, logistics managment, robotic support, mission objectives, etc.) on crew performance, morale, and response. As part of this research, the University of Maryland Space Systems Laboratory is planning a series of rigorous evaluations with the completed CHELONIA facility where a sample crew of variable size (composed most likely of UMd students) will be given mission objectives, and will conduct a simulated mission in the facility.

Between trials, the investigators will vary mission objectives, duration, crew size, composition, internal available volume, and internal layouts. Trials will vary from very short, several-hour simulations to week- or month-long evaluations where the crew will be monitored remotely though CCTV cameras and a ground support team. Several metrics such as canonical survey protocols (e.g., AHP, NASA TLX, Cooper-Harper), interviews, journals and psychological evaluations will be recorded and analyzed during and after the trials. Several other metrics are also being considered such as overall time allocation and specific task execution time but those will have to be defined on a case-by-case basis.

The investigators will also attempt to identify whether partial or full gravity habitat design solutions still apply in the microgravity environment by reproducing lower fidelity habitat interior mock-ups for neutral buoyancy. Those simulations will provide first hand experience, and will potentially drive innovative alternatives to concepts drawn from Earth architectural experience. Overall, the CHELONIA facility will largely enhance the SSL research and simulation capabilities in habitat design, allowing an unprecedented level of flexibility aimed at quantitatively understanding the consequences of the many design choices that characterize the definition of space habitats.

II. Preliminary Design and Prototype Construction

Both X-Hab 2012 teams were required to complete a Systems Design Review (SDR), a Preliminary Design Review (PDR), a Critical Design Review (CDR), and two progress update reviews. All three design reviews occurred during the early months of the program, limiting the degree to which extensive trade studies could be performed and emphasizing driving to solutions which would allow immediate construction to start at the beginning of the Spring 2012 term.

During the SDR, the UMd team proposed an initial concept for a habitat mock-up in order to address the newly-applicable top level requirements. The initial concept made use of a new primary habitat module, combined with existing habitat elements previously built at UMd. The new habitat module, named the Habitat Analogue with Variable ENvironments (HAVEN), would mate with the ECLIPSE module at ground level. The X-Hab inflatable would be mounted on top of the new module, much like the configuration in the 2011 X-Hab Academic Challenge. The resulting complex would be a highly modular facility. This configuration stipulated that the new module be a cylindrical structure with a flat roof and mating ring, much like NASA's Habitat Demonstration Unit (HDU). This module was sized such that the entire facility would meet or exceed the volume requirement of 42 m^3 per crew member. The result was a 5 m cylinder with a ceiling height of 2.67 m. Extremely tight budget constraints precluded the selection of anything other than standard lumber as the primary building material for the HAVEN module.

A. Modular Approach

The CHELONIA complex is envisioned to be suitable for a wide variety of habitat mock-ups. During SDR and PDR, the UMd group proposed several features to accommodate this flexibility. The most apparent is a result of the chosen configuration. It is possible to simulate habitats with varying module numbers, simply by closing off areas in CHELONIA. For example, UMd researchers would be able to isolate HAVEN and ECLIPSE and consider smaller habitats, and habitats with fewer modules. The ECLIPSE and HAVEN modules would also have different diameters, 3.65 and 5 m, respectively. This difference would allow the examination of the influence of module diameter on habitat layout.

The UMd group also proposed two vertical hatch locations to allow access from the HAVEN module to the loft. One hatch would be located in the center of the module, while the other would be close to the wall. The two passageways can be seen in Figure 3. A given internal layout would only make use of one of the two hatches, but having two hatches would allow researchers to mock-up layouts incorporating either option. The central hatch location would accommodate interior layout choices previously developed for the HDU Loft during the 2011 X-Hab Challenge, while the side-located hatch was shown from the ECLIPSE habitat to free up valuable floor space in the center of the habitat.

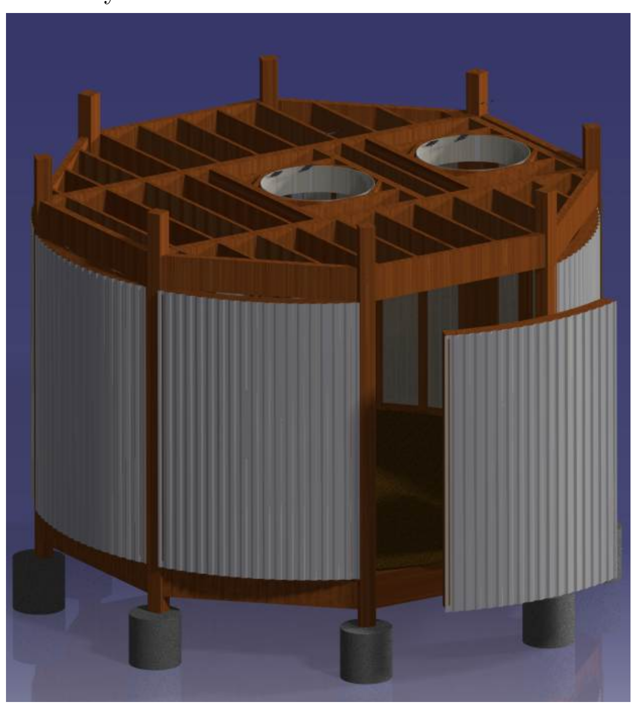

Figure 3. Preliminary Design of HAVEN Module

Another feature proposed for the HAVEN module was interchangeable wall segments. The team did not want interior layouts to be restricted by permanently located hatches, windows, and other features installed in the module's wall. This feature also enables the researchers to vary the number of windows, hatches, and other fixtures with ease. This ability enables mock-ups of a wide variety of habitats that fall within NASA's current assumptions.[4]

The module would be split into 8 wall segments. Each wall segment could be plain, or have a feature such as a hatch, window, scientific airlock, suitport, etc. Researchers would then be able to reconfigure the habitat to best fit the desired interior layout. Figure 3 also illustrates how a wall segment would fit into the main structure of the module. The wall sections themselves would be designed for rapid installation of interior mock-up components and equipment. Interior pegboard walls would allow easy installation anywhere on the wall, while metal rails (e.g. 80-20^{TM} prototyping extrusion) would provide hard mounting points for heavier equipment and furniture.

B. Prototypes and Hardware Evaluation

Major elements of the HAVEN module were first built as prototypes, in order to evaluate manufacturing techniques and verify the feasibility of various aspects of the design. The most important design feature to evaluate was the interchangeability of the walls. Figure 4 shows a test section of the main structure, into which a wall section would fit, and Figure 5 shows a prototype wall section being test-fit into the section of the main structure. The wall fits between two radially aligned 4x4 posts, and rests on the beam that connects the posts. This test fitting verified that the walls mated properly along the vertical edges. This also helped to determine the clearance necessary between the horizontal edges to allow the installation of weather-proofing foam and flashing. The team also installed sample siding materials, which can also be seen in Figure 5. The interior of a wall section can be seen outfitted in Figure 6. Students installed a notional computer station using the pegboard and 80-20 modular extrusion as mounting points.

Figure 4. Section of main structure

Figure 5. Wall section inserted into main structure element

The team also assembled a prototype of the inter-level hatches, as seen in Figure 7. The test article revealed that the original design had unacceptable deflections under nominal loads, such as a person standing on the center of the hatch when closed. The new hatch design features a complete bearing surface around the entire circumference of the hatch, as well as a thicker plywood base.

Figure 6. Wall section - Interior outfitting

Figure 7. Prototype of Vertical Hatch

III. Final Design and Manufacturing

The UMd group presented its Critical Design Review, detailing the final design of CHELONIA, on February 6, 2012. The UMd team presented the final design of the HAVEN module, plans for the modification of ECLIPSE, and a preliminary design for a new airlock module. Following PDR, the UMd team abandoned the plans to reuse the X-Hab loft from the 2011 X-Hab competition. This was a result of high shipping costs, timing, and nontrivial modifications to the X-Hab envelope that would be necessary in order to integrate it into the CHELONIA facility as a permanent module. Instead, the team decided to build the HAVEN module as a two-story module. The end result is a more versatile system with less operational overhead and maintenance, albeit at additional requirements in development cost and labor. Figure 8 shows the final configuration of the various habitat modules.

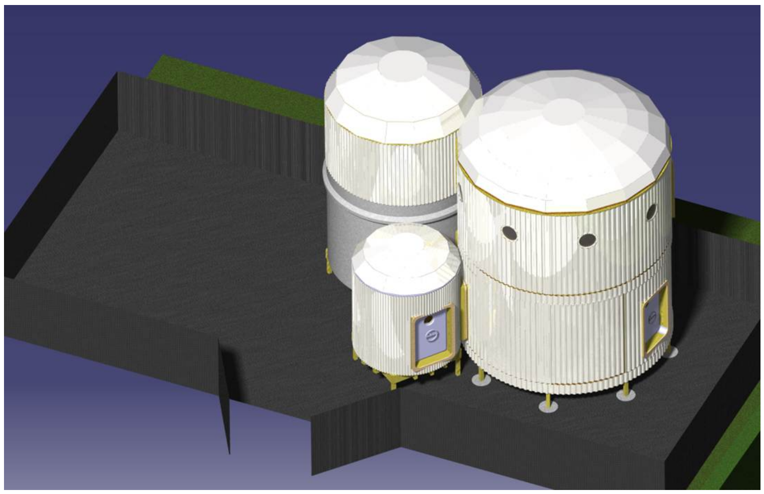

Figure 8. CHELONIA Model

A. HAVEN Module

In the final design, HAVEN is a two-story, cylindrical module with an ellipsoidal dome roof. It is the largest of the modules shown in Figure 8. Each wall section on the first level is removable, whereas the wall sections on the second level are fixed.

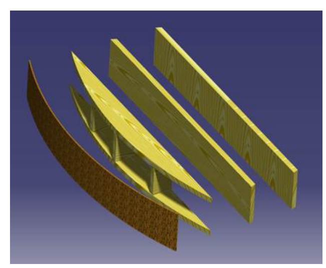

Figure 9. HAVEN Beam - Expanded

The main structure of HAVEN is supported by 8 pressure treated (PT) No.2 grade 4x4 posts. Each post is connected to the adjacent posts by two built-up beams constructed of two PT No.2 grade 2x12s, forming an octagonal structure. Curved plates attached to these beams add roundness to the module and provide its cylindrical shape. The beam assembly can be seen in Figure 9.

The posts are all anchored to cement footings, which extend below the local frost line. The posts are anchored to the cement using Simpson Strong-Tie (SST) PBS44A connectors. Each floor is supported by 2x12 joists, which transfer loads to the beams connected to the posts. The joist spacing is nominally 16 inches on-center, which is typical of basic wood structure construction. Each joist is secured to the beams with either SST LUS210 or SUR/L210 joist hangers. Joist span tables were employed to ensure that the floor's strength meets typical building code prescriptions. The subfloor is 0.75 inch Advantech$^{\mathrm{TM}}$ boards, which is similar to oriented strand board (OSB), but with higher strength and increased water-resistant properties.

Given the particular nature of the dome structures, construction guidelines and common practices in the building codes were not available, therefore the designers had to perform their own structural analysis in order to ensure a safe structure. Finite Element Analyses (FEAs) were conducted on Finite Element Models (FEMs) of the HAVEN and ECLIPSE domes. Since FEA results are particularly susceptible to model constraints, a great deal of attention was given to imposing the right constraints and loads. The dome

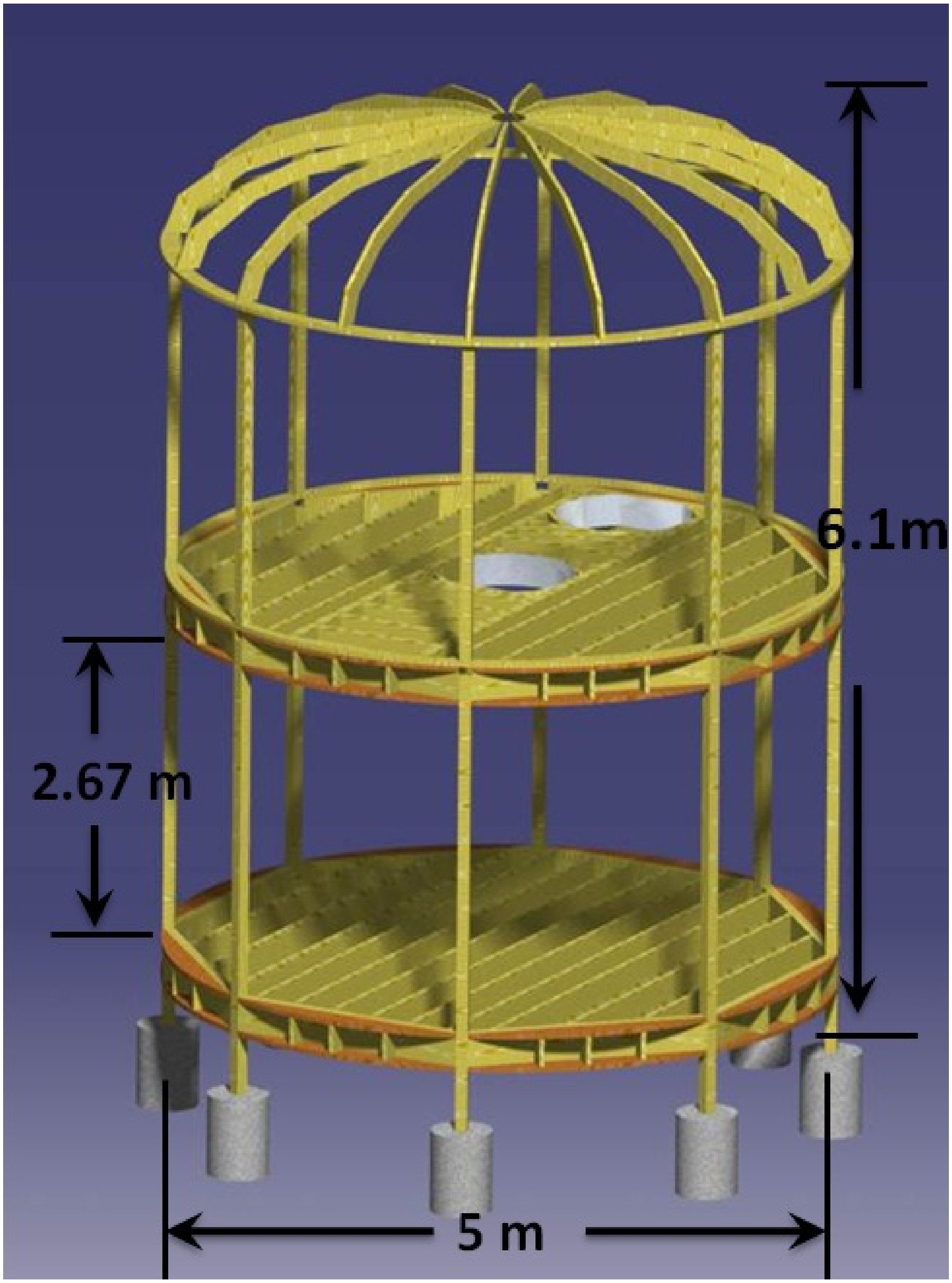

Figure 10. HAVEN Module Structure

structures were modeled using 2D triangular elements for the skin elements, and 1D beam elements for the supporting struts. The imposed loads had to simulate standard building code requirements for roofing. The modeled loads include gravity loads to simulate the actual weight of the dome element, and a distributed vertical surface load of 50 lbs/ft^2. In addition to the loads, the restraints on the dome model were reduced to a simple clamp restraint on the bottom ring, simulating the permanent connection, through screws and nails, of the dome element to the rest of the habitat. Figure 11 below shows the FEM of the CHELONIA module.

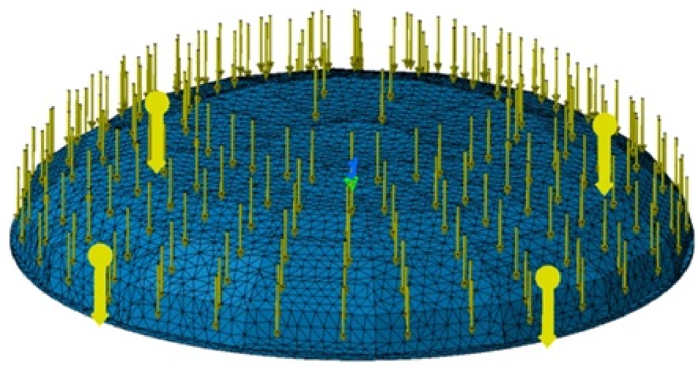

Figure 11. CHELONIA dome FEM

From the FEM models, an initial mass estimate was acquired resulting in a total mass of 323 kg for the CHELONIA dome and 147 kg for the much smaller ECLIPSE dome. Model nodes and elements were automatically generated, and the mesh was manually tuned where necessary resulting in a total number of elements/nodes for each model of 29200/9903 for CHELONIA and 17179/5892 for ECLIPSE. The material used in the simulation was pine wood with ultimate strength of 40 MPa and Young's modulus of 1.7×10^{10} N/m^2. Figure 12 shows the results of the FEA, where it is easy to see that the largest loads will be concentrated on the first ring beams.

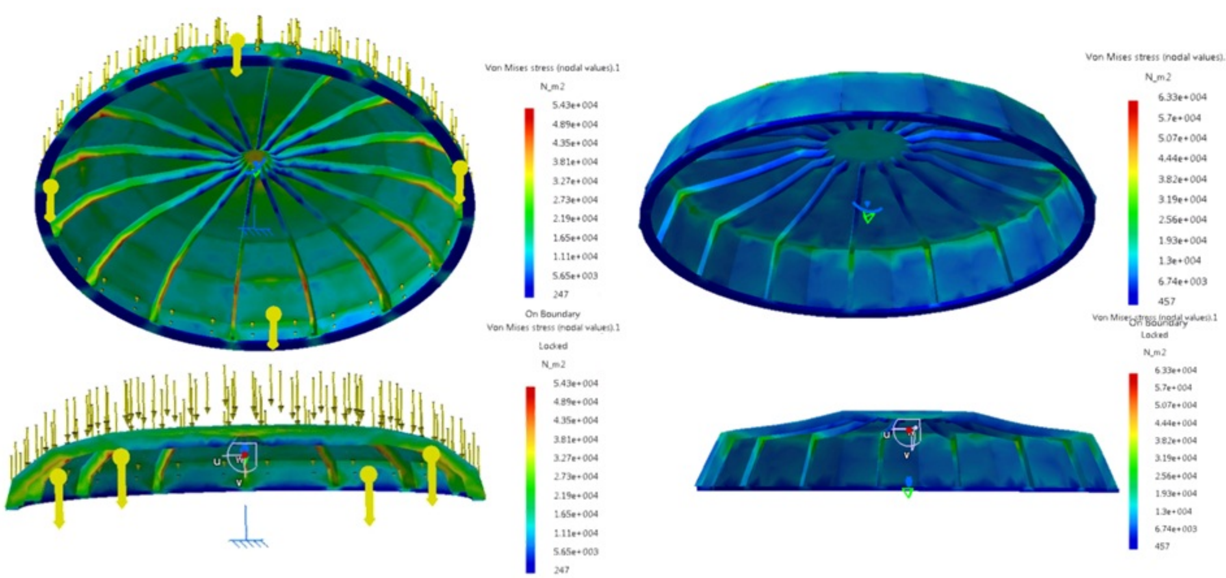

Figure 12. FEA results (CHELONIA on the left, ECLIPSE on the right)

The wall design was further developed from SDR and PDR. The basic wall structure is shown in Figure 13. Each component of the wall will be detailed, from the inside to the outside, as follows:

1. A pegboard/hardboard contours easily to the curvature of the module, as well as provides a flexible mounting options for interior components.

2. Fiberglass batt insulation is sandwiched between the studs, as seen in typical wooden structures. The batt insulation provides both thermal insulation and sound dampening.

3. The wall structure is also based on typical wall framing, with 2x4 studs spaced approximately 16 inches on-center. However, the top and bottom plates of the frame are curved. The proper curvature is achieved by cutting the plates from a larger piece of lumber.

4. A layer of sheathing is bent over the wall and screwed in place, providing lateral stability to the structure.

5. A layer of Tyvek house wrap creates a vapor barrier and provides weatherproofing for the module.

6. Aluminum flashing and an Ethylene Propylene Diene Monomer (EPDM) rubber skirt at the edges of the wall section prevent water intrusion at the interfaces between the wall and the main structure.

7. An outer layer of corrugated polycarbonate panels creates the first major barrier against the weather.

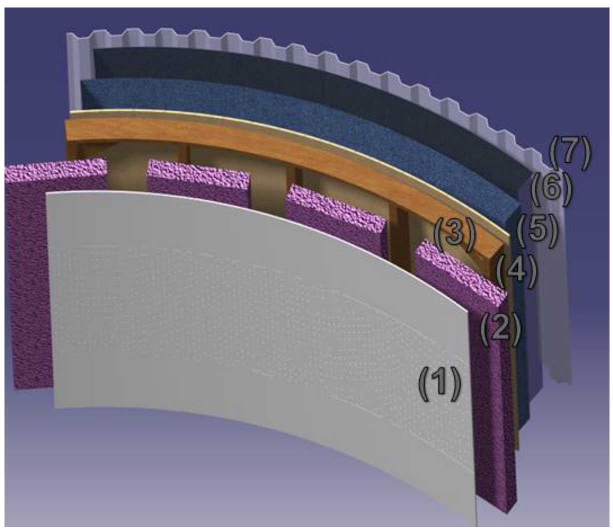

Figure 13. Expanded view of the wall components.

CHELONIA will initially have two wall sections with windows on the first level, and four on the second level. The upper level has more windows than the lower level because it would be more difficult to add additional windows to the permanently installed wall-sections. Extra windows can easily be covered if they are unused in a given layout. Several wall sections will be framed to allow the installation of a window. The windows consist of two plates of polycarbonate, attached to a sheet of oriented strand board (OSB) with two OSB mounting rings. Figure 14 shows the window assembly, and Figure 15 shows how the window will appear from the outside.

The passageway through each hatch is 40 inches wide and 60 inches tall. Figure 16 shows a UMd student passing through a hatch opening. The hatch doors themselves, as shown in Figure 16, are composed of two sheets of OSB, separated by approximately 1 inch to accommodate a latching mechanism. Additionally, each hatch has a window in order to increase the number of windows in the module.

The chosen configuration requires four passageways between modules. The passageways include a passageway from both HAVEN and ECLIPSE to the airlock module, and a passageway on both levels between HAVEN and ECLIPSE. In order to easily accommodate these passageways, the hatches on the ECLIPSE and

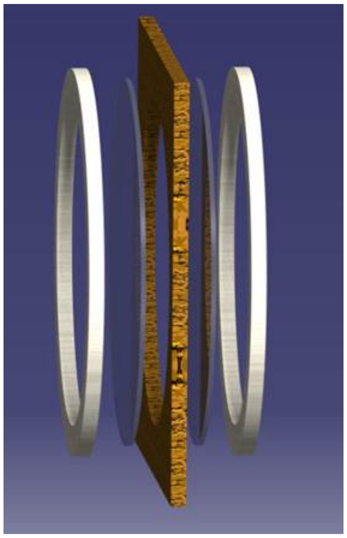

Figure 14. Window Design - Expanded

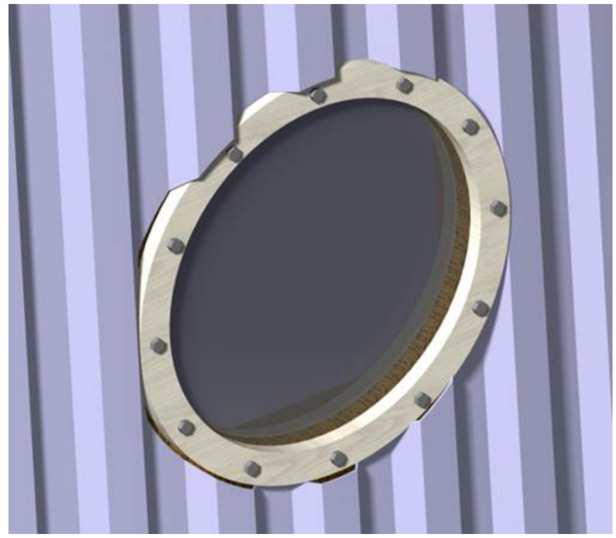

Figure 15. Window - External View

airlock modules are of the same design as the hatches on the HAVEN module. The modules are positioned such that the hatches on each module align. The gap at the interface is then sealed with EPDM tape to repel air and water. Figure 17 shows a cutaway view of two aligned hatches.

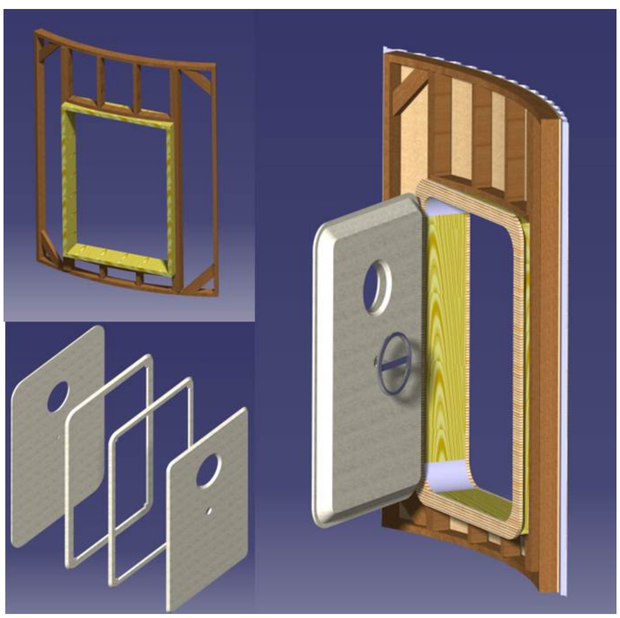

Figure 16. Hatch Design

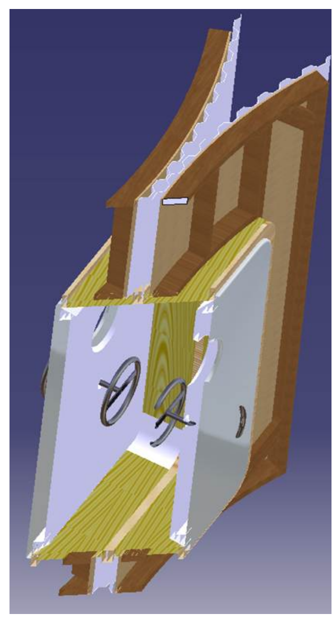

Figure 17. Passageway between Modules

The UMd team has completed construction of the first story of the HAVEN module, as shown in Figure 18. The team also implemented a notional interior layout to demonstrate the ease of reconfiguring the module. The layout employs modular furniture, such as stackable crew births. Figure 19 shows one of the rooms with births in a bunk-bed configuration. Each crewmember has an individual room in order to maintain privacy. The crewmember with this room sleeps in the top birth, and has the bottom of the bunk walled off. The crewmember in the adjacent room sleeps in the bottom birth. A notional common area is shown in Figure 20. This area features galley, storage accommodations, and a common work station which could be employed as a teleoperation station, crew eating space, or general work station.

Figure 18. HAVEN Module

Figure 19. Crew room with individual birth in a bunk bed configuration.

Figure 20. Common area, with joint general purpose and teleoperation work station, galley, storage area and plant growth area.

B. ECLIPSE Refurbishment

The ECLIPSE module requires several major modifications in order to be integrated into the CHELONIA facility. The UMd group's goal is to increase the versatility of ECLIPSE to nearly the same level as that of HAVEN. The first step will be to remove the current interior layout, which was not designed to be reconfigurable. Before the start of this work, ECLIPSE had been a static, low-fidelity mock-up, as seen in Figures 21 and 22. More details about ECLIPSE can be found in a previous work,[5] but this mock-up is one example of how the team might implement out an interior layout.

Figure 21. Lower Level of ECLIPSE Interior

Figure 22. Upper Level of ECLIPSE Interior

A new internal wall will be installed in the first floor. This wall will be framed with 2x4 No.2 grade lumber, similar in design to the previous walls. This framing will accommodate the installation of fiberglass batt insulation and an internal wall surface. The internal wall surface will also be pegboard. This will give ECLIPSE a level of versatility similar to HAVEN, as well as provide a smooth, flush wall surface, unlike the current state. Three new hatches must be cut into the fiberglass shell and framed in the new interior wall, as well.

Currently, the base of ECLIPSE's dome sits approximately half a meter above the upper level floor. This

Figure 23. ECLIPSE - Second Story Wall Framing

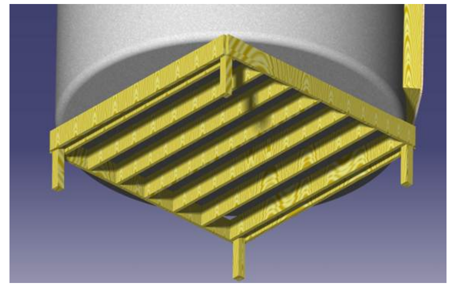

Figure 24. ECLIPSE - View of Base

limits the available vertical wall space on the second level, so the current plan is to remove the dome and extend the wall above the current level. The new wall, whose framing is seen in Figure 23 will employ the same circular wall-building technique as HAVEN. The new wall will be 8 feet high, giving a full 8 feet of vertical wall height. A new dome, of the same design as the HAVEN dome, will be installed at the top of this wall. The top level of Eclipse will also have a hatch installed, to enable a passageway to HAVEN on the upper level.

A base must be built to raise ECLIPSE to the proper height in order to mate with HAVEN and the airlock. This base, shown in Figure 24 is based on standard deck construction. It was not necessary to design curved elements for this base to distribute the loads, due to the circular floor already present inside ECLIPSE. The base will have 4x4 support posts at the corners of the frame. These posts will placed directly underneath the 4x4 posts inside Eclipse.

C. Airlock Module

The team designed the module in Figures 25 and 26 to serve as both the airlock for crew ingress and egress, as well as for use as a connecting node between the HAVEN and ECLIPSE modules. The team selected a diameter of 2.5 m so that this module may also be used as a logistics/storage module, hygiene module, or other small docked habitat element. It will employ similar wall-framing techniques as used in other parts of the CHELONIA design. Curved wall plates will be cut from OSB, with 2x4 studs to frame the walls. The base will be a square, similar to that of ECLIPSE, with cantilevered supports to support the weight of the circular wall at all points. The wall will be framed for 3 hatch locations, but no windows. The airlock roof will be of the same design as shown for HAVEN, but on a smaller scale.

IV. Conclusions and Future Work

When complete, the CHELONIA facility will be a highly modular habitat mock-up facility. Its addition to the Space Systems Laboratory will enable UMd researchers to implement a wide variety of habitat layouts with a minimum of constraints imposed by the facility itself. Key parameters, such as habitat volume, diameter, hatch and window location, etc. may be varied within CHELONIA. This flexibility will allow researchers to gain a great amount of insight into the design of space habitats.

In addition to the flexibility granted by CHELONIA for habitat studies, the facility will also serve as a useful platform for other research at the SSL. To that end, researchers will install a teleoperation workstation in the habitat, which will be useful for a number of the SSL's robotics projects. The Desert Field Lessons in Engineering And Science (D-FLEAS) field trials, for example, are conducted by the SSL and a group from Arizona State University (ASU) to study the interaction of robotic systems and human crew members. Researchers based inside CHELONIA will remotely operate a rover at the test site during the 2012 D-FLEAS field trials. The details of the testing and results will be the subject of a future publication.[6,7]

CHELONIA will also be used in conjunction with the SSL's Moonyard facility. The facility will be

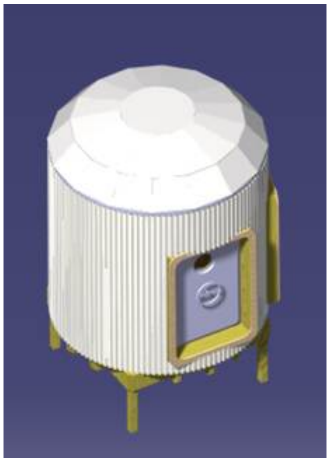

Figure 25. Airlock Module

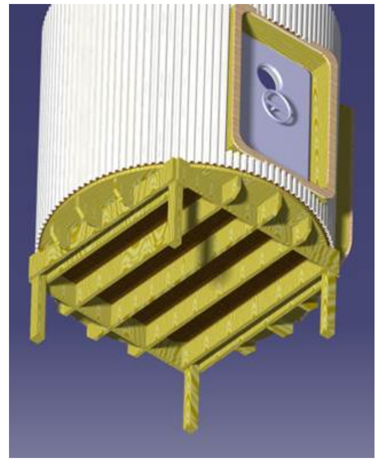

Figure 26. Airlock Module - View of Base

outfitted with equipment to support simulated EVA operations, including pressure suit operations. Future plans include the design and installation of a suitport, as well. It will also be possible to simulate pressurized rover docking. SSL researchers will be able to simulate a wide variety of mission operations using this facility.

Acknowledgements

This work was supported by NASA, and administered through the National Space Grant Foundation. The dedication and enthusiastic contributions of the entire NASA team, especially A. Scott Howe, Larry Toups, Terry Tri, Kriss Kennedy, and Tracy Gill is gratefully acknowledged.

The authors wish to thank all the students of the 2011 ENAE100 X-Hab group and the students of 2011/12 ENAE 483/484 for their great contributions to this project. Our most heartfelt thanks goes to Megan Bentley, Derek Cooper, Matt Horowitz, Rebecca Foust, Yosef Fasehah, Ryan Felton, Duarte Ho, Amar Kulkarni, Sahin Kunnath, Sarin Kunnath, Max Martin, Grant McLaughlin, Kayvan Nejad, and Robert Smith for their admirable dedication, hard work and support; without them all this would not have been possible. Last but not least we wish to thank the entire SSL personnel for their help in times of need.

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