eXploration Habitat (X-Hab) 2011-2012
Academic Innovation Challenge:
Horizontal Habitability Layout Studies

FINAL REPORT

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Outreach Partner:

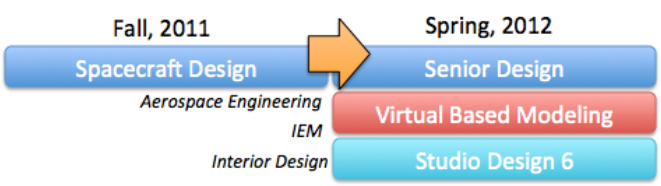
Interdisciplinary National Science Project
Incorporating Research and Education Experience

Synopsis

As our efforts in the *2011-2012 X-Hab Academic Innovation Challenge* we designed, developed, constructed and tested a deployable horizontally oriented habitat system for use as an Earth analog. The goals of the project included a short-term goal of an interdisciplinary senior design project to design, build and evaluate a horizontally oriented habitat and a long-term goal to develop capabilities in education, research, and outreach in field of space habitat design. This included both technical engineering and outreach efforts. In the 2011-2012 year, the program involved the following schools at OSU: The Schools of Mechanical and Aerospace Engineering (MAE) and Industrial and Engineering Management (IEM) within the College of Engineering, Architecture and Technology and Design, Housing and Merchandising (DHM) in the College of Human Sciences. We also included the School of Aviation Education (AvED) in the College of Education through the ISNPIRE (Interdisciplinary National Science Project Incorporating Research and Education Experience) program of as part of our outreach efforts.

Program Description

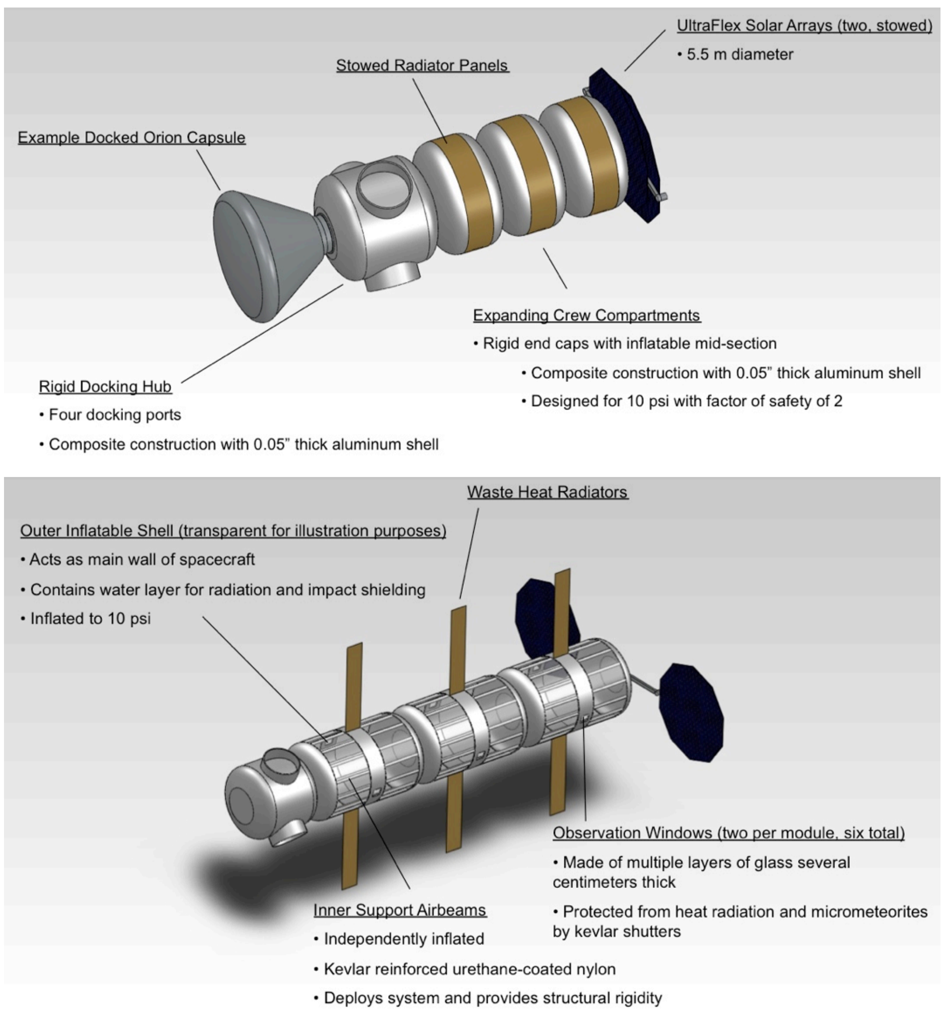
Development of the educational component was built around the previous interdisciplinary design project for X-Hab in 2010, but included expanded roles for interior design and human factors. Sequences of two semester courses at OSU were used as the delivery vehicle, including courses in the College of Engineering, Architecture and Technology and the College of Human and Environmental Sciences. This sequence included MAE 4213: *Spacecraft Design* taught Fall 2011 and MAE 4374: *Aerospace Capstone Design* taught in Spring 2012. Senior design courses in MAE, IEM and DHM were used as the respective course vehicles. Prof. Rick Bartholomew was responsible for the Studio Design courses. These courses offer enormous flexibility in contact and allow in depth interaction with other course projects. All courses are project based and included a design/build/test component. The final course deliverable for Fall 2011 was an engineering design of the system including a prototype and structural analysis while the deliverables for Spring 2012 included a complete systems set for delivery or presentation to NASA as shown below (the Daedalus module).



Courses used for the multi-disciplinary XHab design project in 2011/2012 included students from Aerospace Engineering, Industrial Engineering and Interior Design. A joint meeting of the student design team in 2011.

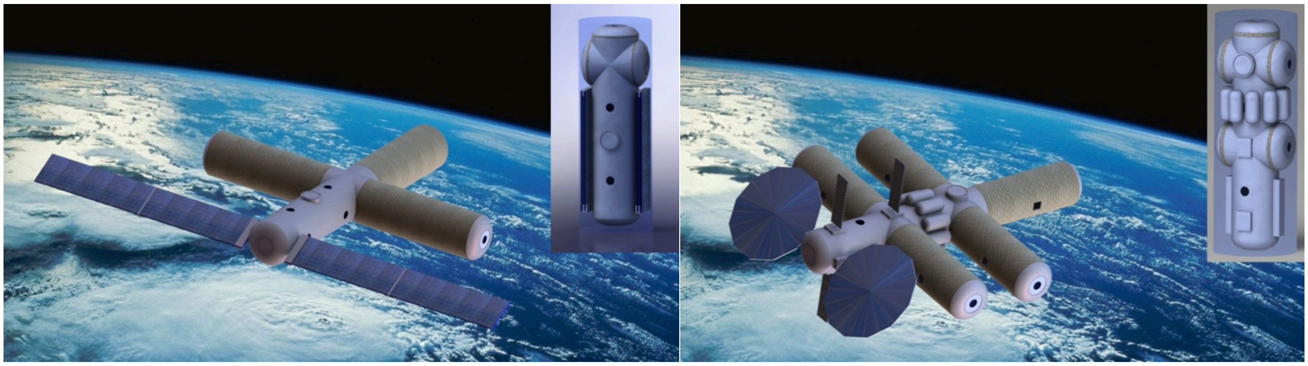
The Daedalus module in its stowed (left) and deployed (right) forms, which will be used as a teaching tool.

Two horizontally oriented concepts were developed in the MAE 4213: *Spacecraft Design* course. The first of these was the Spartan concept. This design was based around a series of individual horizontally oriented modules that could be attached end-to-end similar to the ISS, the benefit of which is that the number of modules could be varied based on the needs of the mission and capability of the launch vehicles. This is shown below.

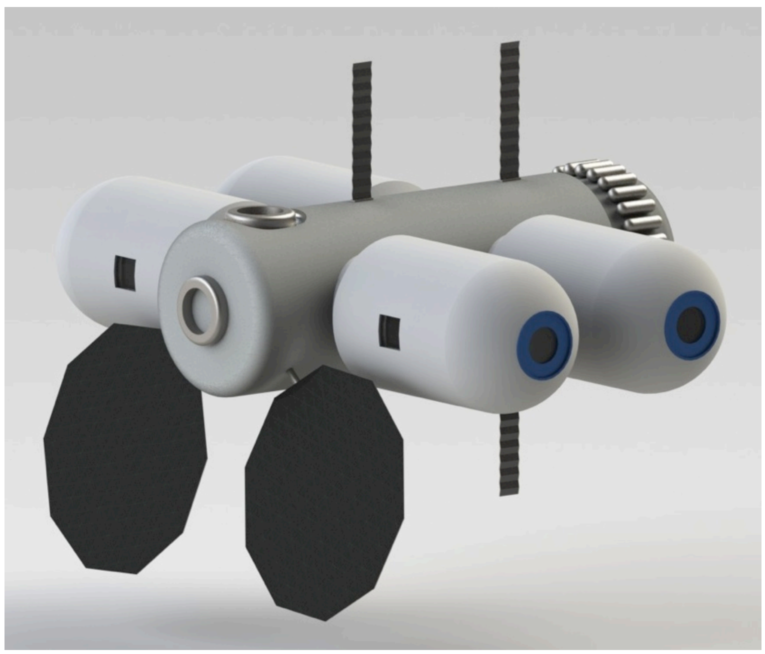


Spartan concept. Stowed (upper) and deployed (lower).

The second concept was the high expandable module (HEM). This is based around a rigid center module with deployable wings. The benefit is that the modules could be adjusted based upon the mission requirements and individual modules could be separated for either safety or privacy concerns, unlike the Spartan concept. This is shown below for two design variants, one each for 3 and 5 modules.



HEM concept. Stowed (upper) and deployed (lower).

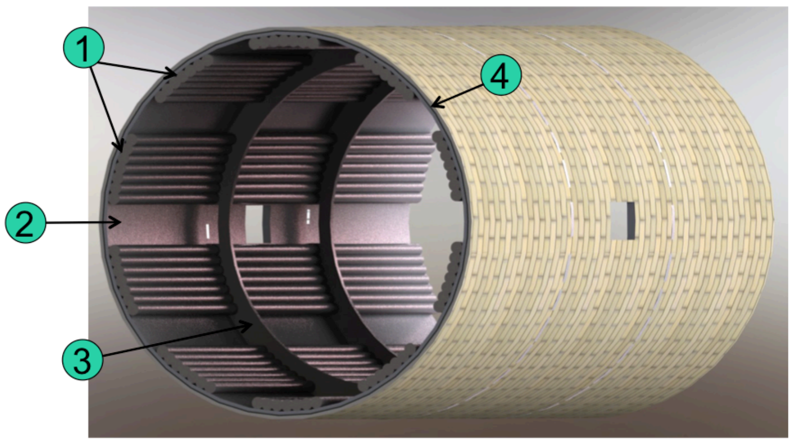


Final design configuration.

Earth analog interior panorama shot.

Both concepts were constructed around a baffled wall beam concept. While this concept has merits for space rated designs, in that the deployment and support system are separate from the pressure of the atmosphere gases within thus serving as a backup system, it also provides the Earth analog a much simpler deployment mechanism than inflation pressure alone.

1. 8 baffled air beam sections around the tube
2. HVAC, Electrical, Plumbing runs between the airbeam sections
3. 2 bulkheads in each inflatable section (one every ~6.5 ft)
4. Inflatable wings will have multiple layers

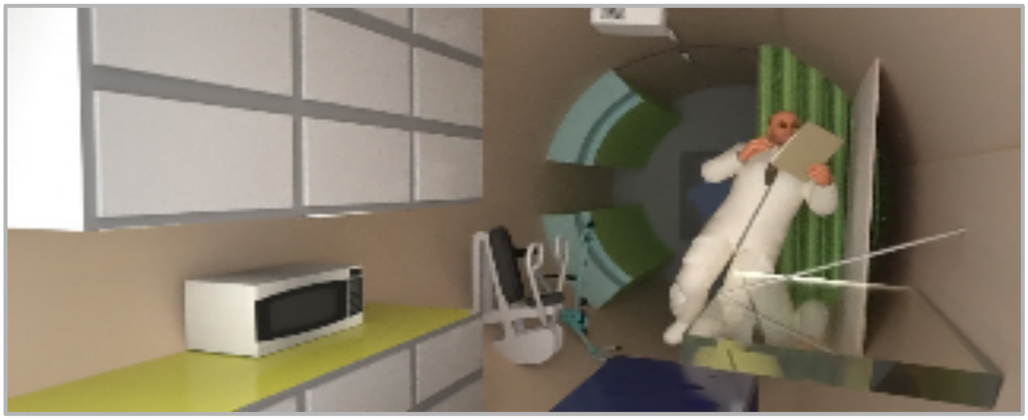


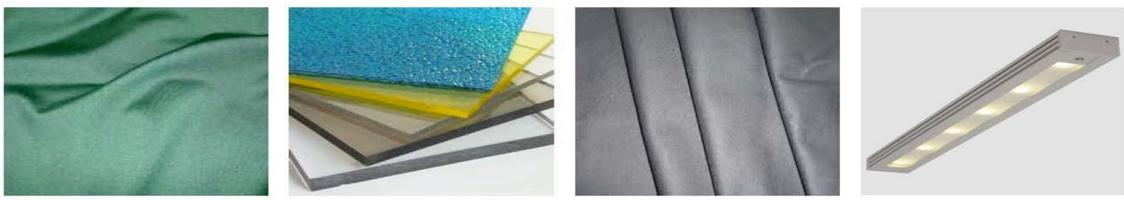
Baffled beam concept.

The Human Science interior design students paired together with the engineering students to coproduce the interior living environment for the X- Hab. Within the X- Hab there are three module units. These modules include storage and equipment, living and sleeping quarters, as well as, work and recreational space. Within the X-Hab unit zones were created to allot for testing, air quality control, spacesuit repair, medical aid and physical exercise.

Design challenges within the project include the implementation of ergonomics for the users, multifunctional spaces/furnishings, as well as, compactable and durable materials to fit within the "deployable" interior. These flexible materials include PVC coated nylon and Velcro. The hard surfaces are composed of magnetic strips and polycarbonate work surfaces. Effective space planning was an important element of the design process as the inhabitable space is an approximate 20'- 0 length x 7' 2" diameter.

By providing personalization of space, chroma-therapy, and a "home like" environment fulfill the psychological needs of the astronauts. A ceiling mounted projector will display photos of family, friends, and nature on an image display panel to provide the inhabitants with reminders of home. Color therapy is a method of incorporating different lighting and color attributes within the space to balance energy mentally. Various materials and colors are further used to create a sense of warmth in the living environment.

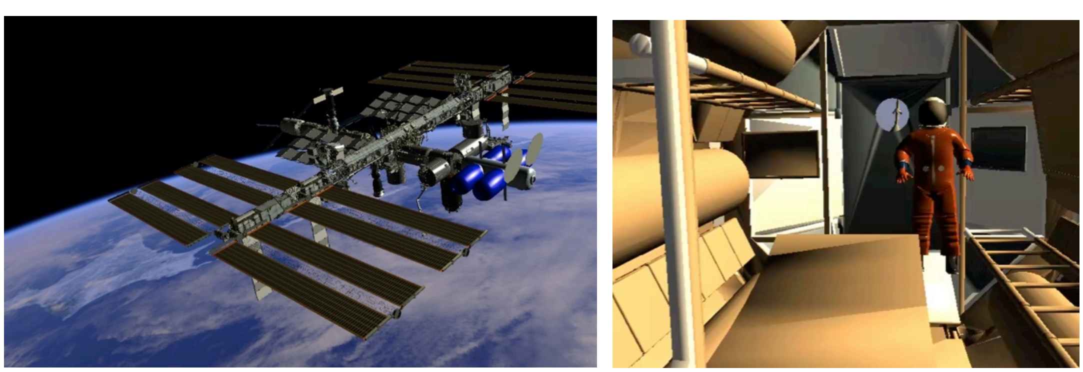




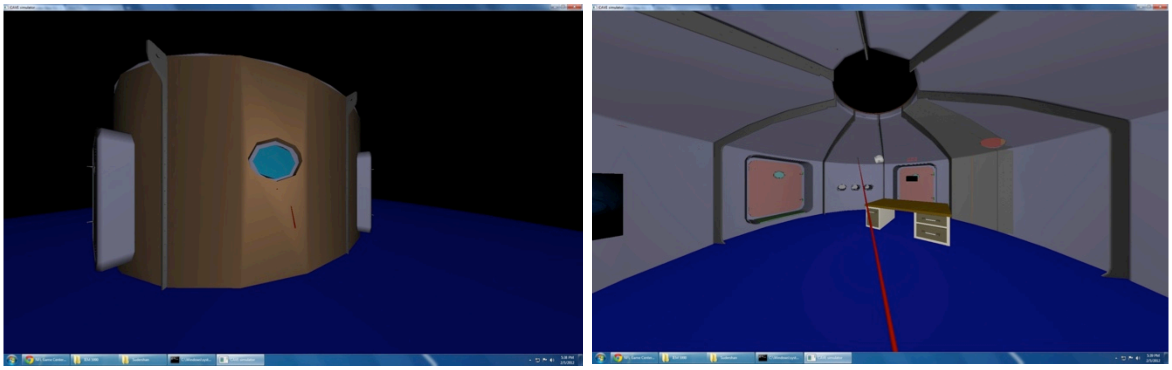
Sample interior design elements.

Due to limited room in the unit, it is important that everything in the unit be collapsible and able to be stored away. Some ways to accomplish this are through fabric storage compartments, inflatable structures, and foldable hard surfaces. In order to address the issue of zero gravity, handles and straps have been located throughout to allow for maneuverability. Stirrup-style restraints allow astronauts to stable themselves when standing or sitting. A neutral color palette keeps the astronauts from being overstimulated while in such a small area for extended periods of time. Accents of red and blue are reminiscent of homey Americana decor. Solid surface Corian allows is durable and has low off-gassing qualities.

To explore the interior design elements, the exterior and interior modules were created in a virtual environment. A detailed CAD model was developed and was brought into the virtual environment. The size of the CAD model was considerably large due to the detailing provided. The pictures below show the outside and the inside view of the habitat. As a development training tool, a virtual and interactive 3D model of the HDU was developed as shown below.



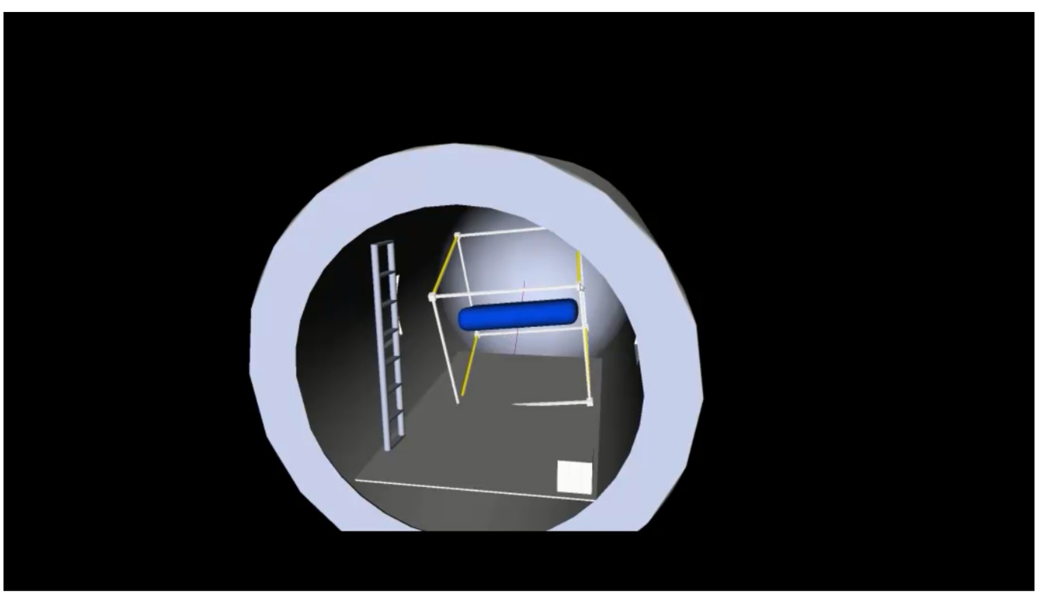
Habitat simulation using EDGE, IDEF0 SE model of X-Hab, and interior simulation of the Daedalus module.



Exterior and interior views of the HDU.

A wand was included to assist the user with the sense of direction. Also, interaction was allowed with several objects in the habitat. The user can pick and place some of the objects or just click on it and see an action performed. This program also allowed the easy navigation and also the graphics and the texture of the model made the environment reasonably close to the actual one. This program can be used to view and investigate any model and any person with or without any software background can use and explore the model.

A unique program was developed in this attempt. This allows the user to select the coordinates according to his/her choice and the simulation is generated that makes the user decide whether or not it would be a valid position. The user enters the desired coordinates using a text file and the program reads the coordinates and then generates the simulation accordingly. Several other factors like that of the how the function of each part is changed if it is moved and how it would affect other parts can be given a thought about. How a particular part needs to be assembled can also be visualized. This program proved to be useful as after several trials the user can come up with a reasonable design. Another program was also generated to allow the user to make or change an assembly layout, but in a more interactive way. A screen shot of the use of this interactive way is provided below.

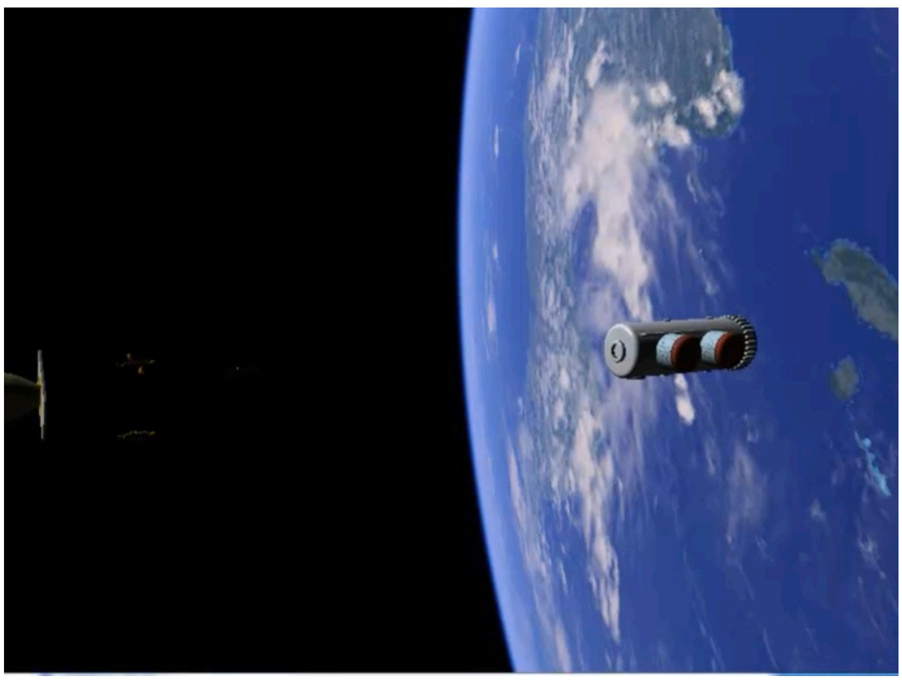


Interactively rearranging the objects.

The program allows the user to select any object with the help of a mouse and then he/she can drag, scale or rotate the object according to his choice. This program can be concurrently used by engineer of any department and come up with a layout that they think can be a valid. The entire design layouts can be compared and finally the best layout can be selected for manufacturing. This can also be applied to exterior assembly and similar decision and models can be created. The only area that was left unanswered here was collision and needs further study and programming to include it in this.

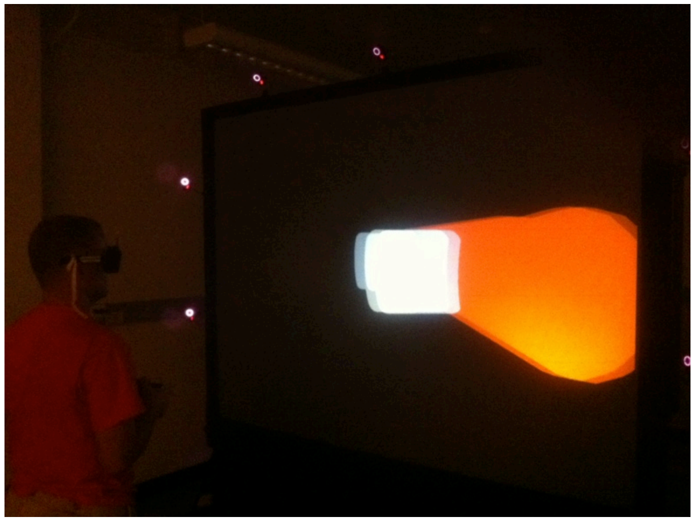
Two simulations were created using two software tools. One was a non-immersive simulation using EDGE software and the other was a semi-immersive simulation using COIN 3D software. MECHDYNE's Power wall was used as a tool for semi-immersion.

EDGE is a one of NASA's software used to train astronauts in space related environments. The software requires very little programming language but has an attractive graphics based engine. A picture of how the simulation environment would look using the software is illustrated below.



The deployment sequence in EDGE

But this software had issues while converting into immersion. COIN 3D was used to address this issue. This software is a C++ based engine that allowed the use of cave library file that allowed the program to be viewed on immersive wall. A picture of a user using the Power wall to view the deployment is shown below.



Deployment sequence viewed using Powerwall.

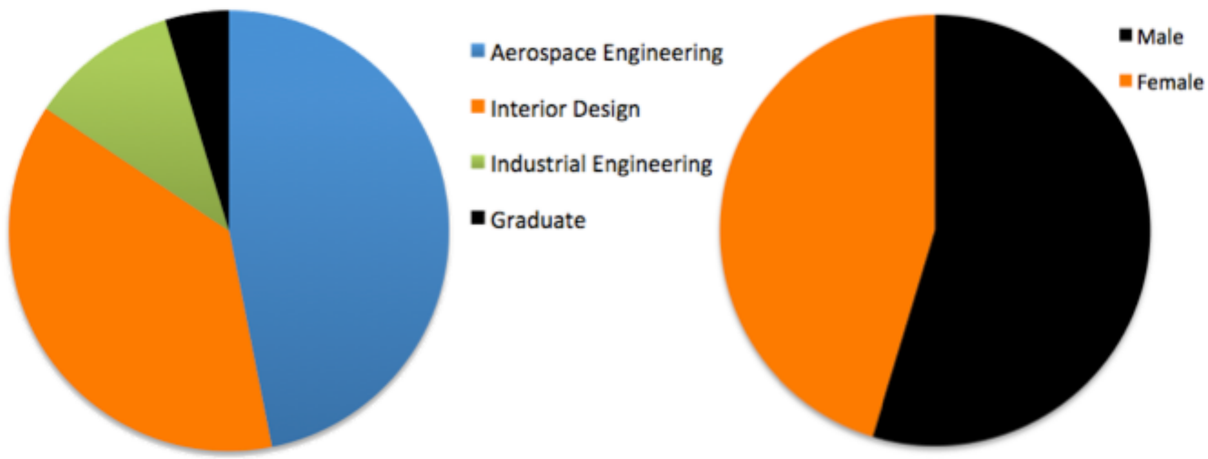
This also had several issues that were not addressed. The first thing is the texture mapping. Although, the software allowed adding texture to any model, the textured got stretched if it was not of the correct resolution. Also, the detail of the CAD model was very low when the object was brought from non-immersive environment to the semi-immersive one. These two issues were not been addressed in these simulations.

Different suit configurations and different module designs were considered for this simulation. The first set of simulations was made with two kinds of suits but with an empty interior. A medium sized astronaut wearing both these suits would easily fit in this module and would be able to navigate around very freely. The next set of simulations was done on one of the arm modules but, this time completely populated. It showed that the not all suits were able to fit. Different positions of the astronaut were also considered but the result was the same. The only suit that can be considered was the escape suit. This is a best example to show that virtual technology can be used to analyze various environments and come up with a solution without wasting numerous and expensive resources. The picture below shows the astronaut with an escape suit in the fully populated environment.

Reachability analysis using an escape suit

Demographics

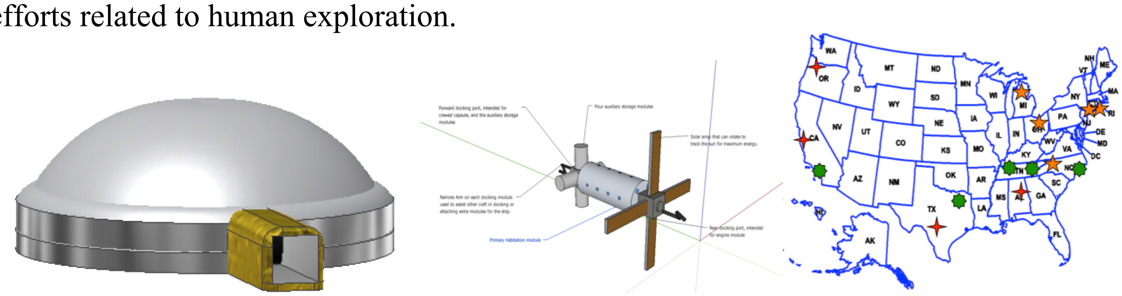
In the 2010-2011 OSU X-Hab program, 67 students were involved as part of class projects with a broad diversity of academic level, major, gender and race as shown in Figure 5. We intend to expand upon this in the 2011-2012 program, focusing on areas of weakness, particularly involvement of race and ethnicity, using the mechanisms discussed above.



OSU X-Hab student demongraphics.

Educational Outreach

The primary outreach effort was a *Space Habitat Innovation Challenge* aimed at students in grades 9-12 by using INSPIRE's (Interdisciplinary National Science Project Incorporating Research and Education Experience) nationwide network. This competition mirrored the university level *X-Hab Academic Innovation Challenge* and student teams competed in a virtual design competition. As part of the INSPIRE mission, the OSU X-Hab team provides a unique space habitat related challenge to encourage students to pursue STEM careers in both NASA and elsewhere. The *Space Habitat Innovation Challenge* will utilize the NASA Digital Learning Network (DLN). The DLN fosters the effective use of interactive instruction technologies through the delivery of NASA content. The DLN strives to reach targeted populations associated with the NES and to the educational community across the US. The DLN contributes to the professional development of internal and external educators through the delivery of face-to-face and distance learning-based events. Utilizing this capability in the 2011-2012 X-Hab effort, over 130 students on more than 25 distance collaboration teams from almost all 50 states participated. Sample high school designs are shown below. The winning team was awarded an all expenses paid visit to NASA JSC that included tours of engineering efforts related to human exploration.



Sample designs and location of students from the top 3 teams.

Winning high school team from 2012 visiting ARGOS and the Serenity module.

We are also used non-traditional media as part of our outreach. In addition to our traditional web-site, this included Facebook and Youtube pages to keep both team members and "fans" up-to-date with the progress of X-Hab and was used to promote both manned and unmanned space exploration to K-12 students. To date we have reached over 500 people in 15 countries.

Non-traditional media outreach includes Facebook and other tools.

Development of an Interdisciplinary Program

As part of this effort, a proposal was submitted by the team to OSU to develop a formal interdisciplinary program in Space Engineering and Architecture. This will include diverse specialties across the schools listed above with the goal of developing technology and designs to facilitate human habitation in outer space. The program was selected by the OSU Provost in June 2012 to be evaluated over a year long effort.