HAESH Final Report

1.0 Introduction

The HAESH project was designed to a demonstration of off the shelf parts being used to create biological environmental life support systems. The purpose of our project was to ascertain the feasibility of low cost biological closed environmental life support systems through a modular approach. This work is important to validate the ability of grassroots space exploration organizations to mobilize citizen scientists and engaging the public to promote space access.

2.0 Problem Statement

We investigated the feasibility biological ECLSS using off the shelf parts, commonly available tools and techniques, within an accelerated timeline and very modest budget.

3.0 Procedures and Methods

Our approach was to split the system into different modules that could still have use outside of the scope of this project. The modules are as follows: Infrastructure Module, Atmosphere Module,

3.1 Infrastructure Module

Tank and Stand - The tank is a giant agriculture tank with 5000 gallon capacity. We were donated the tank from a local algae farm here on Maui and allowed to modify the tank for our project. The tank stand is constructed of steel and made for the tank and allows for the tank to stand vertically stationary under load.

Gantries and Platforms - The gantry for the tank is a tank gantry system made for the tank. We modified the gantry and pulled it out in front of the tank to create framing for our platform. The platform is constructed from sheets of plywood and screwed together across the top of the gantry frame.

Utilities Ports - utilities ports are two existing 4" ports on the top of the tank. The ports and have been fitted with bulkhead fittings and sealed. The ports allow for electricity, air conditioning, and water to travel into the habitat while remaining under pressure and sealed from the outside atmosphere.

Entry Port - The entry point is constructed with the installation of a locking hatch door purchased from the boating store for an airtight seal and tinted window to see out. The entry port is small but large enough to comfortably move in and out through the ladder inside. The hatch has been sealed with silicon to ensure air tight seal.

Internal Platform - The internal platform was constructed from a modular steel beam product known as unistrut. Unistrut can be used to make just about anything and we used it to build a cube inside the water tank. This cube is what the inhabitants will live on while inside the habitat, plants and people alike. We also used plastic decking boards for the floor surfaces on the upper and lower decking.

3.2 Atmosphere Module

Algae - Chlorella is a genus of single-cell green algae. Through photosynthesis, it multiplies rapidly, requiring only carbon dioxide, water, sunlight, and a small amount of minerals to reproduce. Many people believe Chlorella could serve as a potential source of food and energy because its photosynthetic efficiency can, in theory, reach 8%, comparable with other highly efficient crops such as sugar cane.

Bio-reactor Domes - We acquired two Plastic domes and glued them together one on top of the other to create a spherical dome bioreactor. The domes created a three inch space between them for the algae to grow. Fittings were added to transfer air and water between storage and the system. Under each dome is a led grow light array for night time production. The two lights we are testing are a 300 watt led array and the other is a 90 watt unit with the third dome having no lights underneath it. This experiment will allow for testing the production with supplemental lighting. The air from the bioreactors is pumped from and to the habitat for 02 generation and co2 sequestration.

Sensors - Ardunios, sensors, and labview are used to monitor co2, o2, humidity, air temperature, and VOCs, while calculating dew point, and triggering toxic gas level warnings.

Air Conditioning - A commercial air conditioning unit was used to control humidity and temperature. Condensed humidity was then transferred to the fresh water storage tanks on board. We gathered roughly a gallon of water in a few hours of testing

3.3 Freshwater Module

AC Condenser - Air conditioning condensate is collected in a tank from atmosphere inside the habitat

Tank - Our tank is constructed with two 5 foot 4" diameter pipes that were connected and serve as the collection tank.

RV Diaphragm Pump - This pump pressurizes the system to 60 psi.
Sediment Filters - This filters out any dust that washed off of the AC condenser and other micro particulate suspensions in the water.

Pressure Tank - Pressure tanks help to elongate the pumps lifespan because they allow them to run when they are needed without continuous running requirements for power management efficiency. Pressure tanks will also reduce water hammer instances helping to keep the water in the lines at a constant pressure.

UV Cleansing - Once past the filter and tank water passes through the UV disinfection unit where 99.99% of bacteria, viruses, etc are killed.
Re-mineralization - Once the valve is opened pressurized water is pushed through a mineralization pump and into the drinking vessel. Re-mineralization is necessary to maintain the proper proportion of minerals, salts and pH in your body and maintain health.

Piping - Pipes are copper for its natural antibiotic properties.

3.4 Waste Water Treatment

Biogas - An Anaerobic Biogas Reactor is a chamber or vault that facilitates the anaerobic degradation of blackwater, sludge, and/or biodegradable waste. It also facilitates the separation and collection of the biogas that is produced. The residence time of the fluid in the reactor should a minimum of 15 days in hot climates and 25 days in temperate climates. For highly pathogenic inputs, a residence time of 60 days was factored for test conditions in the habitat. Thermophilic conditions allow for pathogen disinfectant of the waste products within the habitat (i.e. a sustained temperature over 50°C). Once waste products enter the digestion chamber, gases are formed through fermentation. The gas forms in the sludge but collects at the top of the reactor, mixing the slurry as it rises. The system will produce nutrients for the wetlands, algae and hydroponic gardens.

Hydrostatic Filter - Centrifugal force creates transverse flow patterns in a curved channel, which under certain circumstances manifest themselves as a pair of Dean vortices. As particles flow down the channel, they spiral around the Dean vortex cores while a combination of drag and shear-induced forces move them toward the channel center. Under the correct conditions (specified by channel geometry and flow rate), this dynamic causes the particles to focus into a band near the outside wall. At the end of the length of the channel, the single flow is separated into two flows: the concentrate and effluent outputs.

Although HDS technology leverages centrifugal force, it is different than centrifuges and hydrocyclones. Instead of relying on density differences between particles and fluid, HDS technology is solely based on hydrodynamic forces, resulting in a particle size dependent separation that allows for direct concentration of particles of any density, including neutrally buoyant ones. This component is still under R&D.

UV - The UV filtration unit is a small stainless steel tank that has a inner housing with a UV bulb that allows the passing of water around the bulb for sanitizing and treatment of water collection systems.

Wetland - The bottom of the habitat has a constructed wetland to utilize several plants species to consume the nutrients produced by the bio gas reactor is producing from human excrement, plant wastes and broken down consumables and biodegradable habitat waste products.

3.5 Food Module

Aquaponics - Aquaponics is a food production system that combines conventional aquaculture, (raising aquatic animals such as snails, fish, crayfish or prawns in tanks), with hydroponics (cultivating plants in water) in a symbiotic environment. In normal aquaculture, excretions from the animals being raised can accumulate in the water, increasing toxicity. In an aquaponic system, water from an aquaculture system is fed to a hydroponic system where the by-products are broken down by nitrogen-fixing bacteria into nitrates and nitrites, which are utilized by the plants as nutrients. The water is then recirculated back to the aquaculture system. In our system we have removed the fish and replaced them with human waste streams; Humiponics...

Aeroponics - The aeroponics system was designed to utilize the same water feed as the humiponics. Aeroponics is the process of growing plants in an air or mist environment without the use of soil or an aggregate medium. Typically it uses high pressure misters which when used with organic effluent streams tend to clog. Our process uses the ein gedi process, utilizing centrifugal misters that are not susceptible to clogging.

Microwave Pressure Cooker - The decreased cooking time required for foods cooked in a pressure cooker results in proportionally reduced consumption of energy. A pressure cooker is energy efficient and can save up to 70 % of the fuel used for cooking purposes. So we use a pressure cooker in our microwave to decrease power consumption and time cooking to its minimum.

3.6 Command And Control Module
Computer - MSI GP60 (ram and HDD upgrade max.) laptop for data management, database, sensor monitoring, and psychological wellness.

Software - labview software for monitoring all arduinos, sensors, and systems with monitoring capabilities (PSI)

Entertainment - Internet Access, Netflix media, Email, News, TV and Documents.

Lab View/ Ardunio/Sensor Interface - CO_2, O_2, Humidity, Temperature, Pressure, VOCs

4.0 Results

4.1 Infrastructure Module
Tank and Stand - Tank and stand were pre exisiting. The tank is waterproof and was modified to be air tight on the top fittings as well. The tank actually flooded due to a water valve malfunction so we know it can still hold 5000 gallons even with our equipment inside.

Gantries and Platforms - Platforms were compiled from scrap resources found nearby composed of steel, wood, etc.. They performed as designed. One of our tents was poorly mounted to the structure and blew away in the wind. Thus we recommend projects properly prepare for worst case scenario events with respect to weather.

Utilities Ports - Waterproofing worked well with a combination of foam expanding foam and silicone inside bulkhead fittings for utilities ports.

Entry Port - Entry port was a boat hatch and worked perfectly. Couldent have gotten luckyer for cost and functionality.

Internal Platform - Internal platform was constructed from uni strut. The unistrut was assembled inside the tank. We settled on unistrut because it was the only building material that was strong, fit through the hatch, was modular, and had low outgassing. It worked well.

We build ours with little planning due to time constraints. In hindsight we recommend building it outside first to acquaint yourself with the process in a less stressful environment.

4.2 Atmosphere Module

Algea - Chlorella Algae was cultured in beakers for use in the domes but has not been used for full production due to lack of funding for electricity.

Bioreactor Domes - Bioreactor domes were constructed from leftover parts from the fuji algae facility. The domes were cleaned, sterilized, and retrofitted. We developed a novel method for cleaning the tanks that involved a bottle brush and a electric drill. This method allowed us to sterilize the tanks very effectively. We removed the PVC drain lines from the set up due to concern of microporous plastic harboring contamination. Overall we significantly increased the maintainability of the fuji style domes through innovative techniques and methods.

Sensors - We constructed a module that used sensors, hooked to arduinos, that communicated to a PC running labview software. The labview software then provided post processing capabilities. We found that although this hardware software combination is possible, it is not ideal. Labview cannot be trusted with the safety of the occupants. There were issues with syncing the arduino clock to the labview clock causing irregular readings every 2 or three minutes. From a technical sense it worked but from a practical standpoint it was unable to provide clean reliable data for use in visual media. Post processing capabilities worked great and allowed us to calculate dew point from sensor data. Overall we decided that programming the sensors and data directly into c, java or some other text based platform may be more stable. More research and development needs to be done on opensource sensor interfaces and opensource graphical programing as labview community and labview staff was generally not interested in supporting these low cost options directly but rather allowing the community to “figure it out”. This did not help our project. It seems like making arduinos work with labview is not well supported or developed. Its in beta and no one is testing from the manufacturer. Due to time constraints however this method was effective in providing a proof of concept prototype.

Air Conditioning - The air conditioning was used to cool the habitat and also provide freshwater supplies. It worked sufficiently in our tests for its intended use and pulled over a gallon of water approximately every 4 hours. It also reduced the temperature to below 75 degrees in full sun from a non cooled temperature of 115 degrees fahrenheit. The AC unit electronics inside the habitat suffered catastrophic failure when the habitat was flooded as mentioned above. We are in the process of repairing the electronics via the manufacturer's instructions. Overall in its short life this unit more than exceeded our expectations for cost, ease of use, and performance.

4.3 Freshwater Module

AC Condenser - Ac unit made a considerable amount of condensate before its failure due to water damage. The amount well exceeds that required by a human. More testing is needed during full sealing of the dome.

Tank - We used large diameter PVC for water storage due to issues with fitting anything in the top hole.

RV Diaphragm Pump - We used a pump with PVC fittings that broke during construction, testing will resume when new parts are ordered.

Sediment Filters - Attached but not tested

Pressure Tank - Attached but not tested

UV Cleansing - Attached but not tested

Re-mineralization - Attached but not tested

Piping - Attached but not tested

4.4 Waste Water Treatment

Biogas - The dual stage biogas unit was constructed. We used 55 gallon drum for the second stage and a 10 gallon jug for the 1st stage. The first stage has an aquarium heater for the tank. We tested the heater with water and it was able to hold the temperature at 110f as required.

Hydrostatic Filter - Unable to construct due to budget and time constraints. Development is ongoing.

UV - UV was attached to the biogas directly. Biological water testing will be required once the system is turned on to ascertain effectiveness without hydrostatic filter. .

Wetland - The wet land is simply the inside of the habitat module and holds water well as evidenced by the water valve incident.

4.5 Food Module

Aquaponics - Aquaponics module was constructed from flexible hose. We noticed that getting a proper grade.

Aeroponics - We developed a super high power atomizer utilizing high power brushless rc motors. Atomization performance was similar to existing prototype using simple dremel knock offs. Also the device was highly overpowered and the extra force had little or no effect on mist production. More testing is needed on lower power motors, although it may be difficult to beat the price point of the off the shelf rotary disk tools. One major issue with our high power device was shaft alignment. Even using precision RC shaft couplings, microscopic imbalances proved fatal to several test disks and they were destroyed by the ensuing centrifugal forces.

Microwave Pressure Cooker - The microwave pressure cooker worked well for preparing meals from unrefined foods in short times. We cooked vegetables and brown rice in a soup. Plain but edible, cook time was 10 minutes. We used a nordic ware microwave tender cooker.

4.6 Command And Control Module

Computer - A MSI laptop computer was used for this project for software and hardware development. The computer had several softwares installed with windows 7 operating system and installed in windows we used labview, arduino loader, Microsoft Publisher,

Software - User interfaces were developed via labview. It was determined that labview performed poorly for applications where the data is critical to survival. For quick easy applications in the lab it will work, further development will be done via method used in BIOMONSTARR Project instructable.

Entertainment - Lab View/ Ardunio/Sensor Interface - We constructed a module that used sensors, hooked to arduinos, that communicated to a PC running lab view software. The labview software then provided post processing capabilities. We found that although this hardware software combination is possible, it is not ideal. Labview cannot be trusted with the safety of the occupants. There were issues with syncing the arduino clock to the labview clock causing irregular readings every 2 or three minutes. From a technical sense it worked but from a practical standpoint it was unable to provide clean reliable data for use in visual media. Post processing capabilities worked great and allowed us to calculate dewpoint from sensor data. Overall we decided that programming the sensors and data directly into c, java or some other text based platform may be more stable. More research and development needs to be done on opensource sensor interfaces and opensource graphical programing as labview community and labview staff was generally not interested in supporting these low cost options directly but rather allowing the community to “figure it out”. This did not help our project. It seems like making arduinos work with lab view is not well supported or developed. Its in beta and no one is testing from the manufacturer. Due to time constraints however this method was effective in providing a proof of concept prototype.

5.0 Timelines

blue X is planned
red X is actual

Tasks Month	1	2	3	4	5	6	7	8
Develop resource flow chart	X							
Design prototype modules	X	X						
Construct prototype modules	X	X			X	X		
Test prototype modules		X	X				X	
Design control system	X		X	X	X			
Integrate control system with modules		X	X	X				X
Install module network into closed habitat				X	X	X	X	X
Documentation and Instructable	X	X	X	X	X	X	X	X

6.0 Conclusions and Discussion

The HAESH project served to better understand the mechanical and financial limitations involved with a project of such magnitude and scope. We have learned through the construction of HAESH ECLSS and module designs that these systems are easy to construct from common existing parts and materials. Through collaborative learning and development with in small groups allows for troubleshooting, problem resolution, and breadth of materials and resource acquisitions by having an array of diverse people together towards a common goal created through hackerspace crowd-sourcing.

Crowd sourcing for materials donations to our project served as an invaluable resource for achieving our goals realistically for HAESH project. A better understanding of where possibilities are, how we create through innovation and imagination breakthroughs a firm call to action on further inquiry into HAESH project or more importantly small scale ECLSS management systems. Not all our goals were achievable by the funding allocations and labor costs and material expenses associated with this endeavor as well as time delays due to uncontrollable circumstance (postal, freight, stock). Hawaii is a place a limited resource, materials, people and skillsets creating a difficult environment for fostering the innovative, and nurturing the imagination. Projects with underreperesented labor budgets are less likely to succeed and 100% crowd sourced hardware is much more difficult that crowdsourced software and media.

We learned furthermore that it is possible to acquire, assemble and implement such a system for most people in the US and likely many other developed countries simply through being creative and adaptive to each unique situation and through many minds compile the best answer among the (crowd) organic and social sourcing. Collaborative efforts among several people across virtual spaces and transposed into tangible real life invention created the ability to make it happen even in the remote and isolated islands of Hawaii. We have set an example of how small groups of community innovators and dreamers of tomorrow through innovation, adaptation, and critical examination and implementation to create sustainability for a single human as bar set for people to understand resource and possibility.

Our project in perspective of the maker movement made us realize more work needs to be done to create a framework for makerspaces to become professional organizations and less anarchistic. This will lead to more cooperation with various government entities, which are crucial to national development. I think that makerspaces need this resource as a service from a 3rd party or association.