A technical report requesting no-cost project extension

Project Title: An efficient plant production system for eXploration habitat demonstration module

Submitted to: X-Hab 2012 Academic Innovation Challenge program
Topic area: Food Production Systems

Principal Investigator: Peter P. Ling

a. Narrative description of the project

The National Aeronautics and Space Administration (NASA) annually provides an academic challenge to colleges around the United States. The goal of this XHab project was to design, enhance and implement a monitoring and control network for a plant production system. This project emphasized on hands-on design, research, development, and manufacture of a functional prototype subsystem. This prototype is to be integrated onto an existing NASA built habitat prototype. The originally scheduled system integration date was May 31, 2012. Due to technical difficulties, we are requesting a no-cost extension of three month till August 31, 2012 to complete the project.

Through dimensions and sketches provided by NASA, the team designed a cardboard replica of one unit in the atrium. The sensors being used, their location and specifications are outlined in the following report along with the positioning and design of the blinds and camera. The irrigation system is to be automated and all parts obtained. This design and all the parts are detailed in Appendix A.

Sensors and actuators were analyzed and specifications obtained through guidance with the NASA team. The design uses eight total sensors, including a digital camera, and two actuators. Data acquisition and irrigation control uses LabView software user interface, data collection, and control of two irrigation valves. The hardware that has been utilized includes a data acquisition and control system, solid state relays, solenoid valves, and USB communication. The seven sensors, excluding the camera, send obtained data through the software for analyses. The crew display shows only the necessary data and controls for operation and observation. The type of camera and its location, track, and mount have all been identified.

Sensors have been incorporated into the irrigation system. Many factors were determined to influence irrigation initiation and quantity and all have been taken into consideration when formulating the LabView programs. Polyethylene tubing is being used to supply water from a 50-60 psi source of the Habitat Demonstration Unit.

Blinds are installed to improve lighting in the atrium plant production area. The blinds are made from metalized film which allows for reflection of light and still maintains visibility. Additionally, the blinds offer a form of reducing light pollution in order to use the light in the most effective manner. Hanging from above, the blinds can be pulled down and raised via a spring roller which increases ease of operation.

Our accomplishments to date include a blind system to reduce light pollution from plant growing area. Software tools have been developed to control irrigation and to monitor plant growing environment. The software can be run in either simulated mode, for training exercises, or field control mode for real-time sensing and irrigation control of the plant production system.

The automated irrigation control has manual override capability, and emergency water shut-off without electrical power requirement. For water leakage protection, a water flow cross checking algorithm is implemented. The amount of incoming water and the actual amount collected by the plant production system are compared to check for possible water leakage in real time. The incoming water is monitored with a flow meter. The collected water is determined using the weight differences of the plant production tray at different times. Disagreements between the amounts of incoming water and the collected water trigger water leakage alert when the water supply is turned off by shutting off the irrigation valve as well the master valve and sending an alert to the crew display. No more watering event will be enabled until the water leakage alarm is cleared by a crew member. The software is also capable of monitoring the plant production system's environmental and cultural parameters including air temperature, air relative humidity, PAR (photosynthetic active radiation) light intensity, canopy temperature, soil moisture, water flow, weight of the plant production system.

Attached in Appendix A is the final report submitted to the Capstone Design Course that the student team members took in partial fulfillment of the XHab Academic Challenge requirement.

b. Numbers and demographics of design team participants.

A total of ten Ohio State personnel participated in this X-Hab academic challenge project including four undergraduate students, three staff members, and three faculty members. The students are Robert Bourchele, Mason Young, Deborah Bleasdale, and Anupriya Chetal. Each of them has earned their Bachelor Degree in June, 2012. University technical staff members are Michael Klingman, Christopher Gecik, and Chad Draper. Faculty members are Dr. Jay Martin, Dr., Kaletunç, Gönül and Dr. Peter Ling.

c. **Contact information of all design team participants and any other participant related information that the Foundation may require by notification at that time.**

Listed below are participating member's expertise area, role in this project, and their contact information.

- Student
  - **Bleasdale, Deborah**: Biological Engineering. Deborah led the blinds design and evaluation effort and initiated outreach through OSU campus open house activities.

    - **Boucherle, Henry**: Biological Engineering, Economics minor. Henry led the effort of irrigation system design.
    - **Chetal, Anupriya**: Biological Engineering. Anupriya focused her effort on the plant monitoring aspect of the project.
    - **Young, Mason**: Ecological Engineering. Mason addressed the camera aspect of the design as well as serving as the student team leader.

- Faculty
    - **Kaletunç, Gönül:** Food Engineering, Associate Professor. Gönül and Jay co-teach the Capstone Design Course that covers fundamental engineering design training.
    - **Ling, Peter**: Horticultural Engineering, Associate Professor. Peter is developing horticultural engineering teaching modules and provided XHAB project specific training and manages the project.
    - **Martin, Jay**: Ecological Engineering, Associate Professor. Jay and Gönül co-teach the Capstone Design Course that covers fundamental engineering design training.
- Staff
    - **Draper, Chad**: Computer programmer, software development,. Chad assists Labview program design, coding, and testing.
    - **Gecik, Christopher**: Electronic design engineer, electronic circuit design,. Christopher assists circuit design and construction.
    - **Klingman, Michael**: Senior mechanical engineer, mechanical fabrication. Michael assists with fabrication of load cell mounting brackets, weight plate, and other custom made mechanical fixtures.

d. Description of educational outreach activities and how the target goals were achieved.

Presentations were made throughout the development of the project to students, staff, faculty, and an advisory board of the Food, Agricultural and Biological Engineering Department, OSU. We have delivered two presentations to the Capstone Design class (approximately 16 senior students), two presentations to a Junior/Sophomore class of approximately 20 students, one presentation of the advisory board, consists of approximately 14 leaders of a wide range of industries. We also have received requests to display the prototype at the conclusion of this project as part of our departmental student recruiting program.

e. **Any other information that may showcase the success of the project and its achievement of overall project goals.**

The project provided rich and valuable experience in the system design and installation processes as well as appreciation of NASA’s Human Space Exploration Framework. Being a part of eXploration Habitat Demonstration for deep space habitat (XHAB-DSH) project, the team members have gained new experience and perspectives on many fronts including

1) some key technology needs for NASA’s Capability Driven Exploration approach and the latest roadmap of NASA deep space exploration program,

2) importance of a bioregenerative life support system for long term human exploration systems and key objectives of HDU-DSH Systems, including the atrium food production system, for sustained human presence in space,

3) NASA personnel’s enthusiasm in assisting all aspects of the sensing and control system development for the atrium food production system, and

4) a sustainable system design is necessary allowing maintenance and trouble shooting for long term operation.

We expect the project will have continuing impact to our future students as well as to local communities. Following the completion of the project, we will display and demonstrate a prototype replicate as part of our recruiting effort to prospective students, and to area high schools through their science program to promote Science Technology Engineering, and Mathematics education curriculum. The diverse ethnic background of the student team, including one Asian female, one Hispanic female, and two white males is an good example of our diversity that will be helpful to attract more minority students to our program as well as space related training programs.

We also like to acknowledge supports of NASA personnel who have provided valuable input throughout the project. Special thanks go to Gioia Massa, Simpson Morgan, Raymond Wheeler of KSC for their encouragement, and technical guidance in the area of plant production system. Colozza, Anthony of GSC provided power supply to our specifications, Amanda Lynch generously provided photos and dimensions of the plant production area, and arrangement of a JSC tour), Daniel Carrejo of JSC provided software integration assistance, and other NASA staff members’ assistance with on-site trouble shooting of the electronics.

Appendix A: Student Team Capstone Design Final Report

NASA X-Hab Design Report

May 25, 2012

Deborah Bleasdale, Henry Boucherle

Anupriya Chetal, Mason Young

FABE 725

Dr. Jay Martin, Dr. Gonul Kaletunc, Dr. Peter Ling

Ohio State University Design Team
590 Woody Hayes Ave.
Columbus, Ohio 43201

May 25, 2012

Dr. Peter Ling
Horticultural Engineering Associate Professor
Ohio State University
Wooster, Ohio, 44691

Dear Dr. Ling,

Attached is a copy of the Final Design Report for *"An Efficient Plant Production System for the eXploration Habitat Demonstration Module".* The following report summarizes the team's final design and development of a plant production system for the eXploration Habitat Demonstration Module. Included are finalized designs as discussed and approved by NASA.

We would like to thank you for your support of the Capstone program and of our design team.

Sincerely,

Mason Young ____
Deborah Bleasdale ____
Anupriya Chetal ____
Henry Boucherle ____

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Executive Summary

The National Aeronautics and Space Administration (NASA) annually provides an academic challenge to colleges around the United States. The goal of this project was to design, enhance and implement a plant monitoring and control network for an experimental habitat, X-Hab, to be used on future manned space missions. This project emphasized hands-on design, research, development, and manufacture of a functional prototype subsystem. This prototype is going to be integrated onto an existing NASA built habitat prototype at the end of May.

Through dimensions and sketches provided by NASA, the team designed a cardboard replica of one unit in the atrium. The sensors being used, their location and specifications are outlined in the following report along with the positioning and design of the blinds and camera. The irrigation system was automated and all parts obtained. This design and all the parts are described in detail throughout the report.

Sensors were analyzed and specifications obtained through guidance with the NASA team and Dr. Peter Ling. The design uses seven total sensors along with a camera for image processing. The sensors use the LabView software for control and user interface. The hardware that has been utilized includes a data acquisition system, solenoid and USB. The seven sensors send obtained data through the software for analyses. The crew display shows only the necessary data and controls for operation and observation. The type of camera and its location, track, and mount have all been identified.

Sensors have been incorporated into the irrigation system. Many factors were determined to influence irrigation time and quantity and all have been taken into consideration when formulating the LabView programs. Polyethylene tubing is being used to supply water to the trays and the water is being pumped into the trays via a 30-40 psi pump.

The blinds are made from metalized film which allows for reflection of light and still maintains visibility. Additionally, the blinds offer a form of reducing light pollution in order to use the light in the most effective manner. Hanging from above, the blinds can be pulled down and raised via a spring roller which increases ease of operation.

The report contains an updated literature review and finalized designs for all aspects: sensing, lighting, and irrigation systems. An updated budget of the design along with the team's qualifications are also included within the report.

Introduction

The main aim of this project was to automate a plant production system for use in the X-HAB's artificial environment. Challenges included monitoring plant stress and environmental conditions and controlling aspects of the plant growth environment while minimizing energy and crew labor and developing protocols that are easily followed by an untrained crew.

If plants can be a part of any off-Earth habitation scenario, they can provide fresh produce to supplement a stored diet and generate oxygen. The goal was to maximize productivity and minimize interference in a small space with minimal crew labor inputs. A plant atrium with eight 10" x 18" growth trays has been integrated into the atrium of the habitat demonstration unit. In preliminary designs, lettuce was grown in these units, as it was easy to grow by untrained crew and can be eaten without cooking.

The original system consisted of eight trays of eight potted plants per tray which must be manually irrigated by astronauts. Few aspects of the environment were monitored, such as temperature and relative humidity. This system poses a problem of light pollution to crew members, with its red and blue LED lights. To fix this problem, a system of movable blinds have been implemented to prevent light from escaping out of the atrium when unwanted. To improve the irrigation system, sensing technology and feedback control has been applied to a computer controlled irrigation system. Plant monitoring was done using sensors and cameras that have been linked to software to record data and display it on the crew's computer interfaces in the main area of the unit. These design aspects have all been considered in the context of minimizing system cost.

The deliverable portions of this project included a working sensor network, irrigation system, and blind for one plant growth tray, along with plans for expanding the system to the remaining trays.

Literature Review

Sensing and Monitoring

For monitoring all the plant growth factors, there are two kinds of sensing techniques, Contact sensing and non-Contact sensing. In the contact sensing, the sensors have to be in contact with the plant all the time and there placements need to be changed with the growth of the plant. Whereas the non-contact sensing technique does not interfere with the growth of the plants, does not damage the plant and gives more accurate data (Kacira, Ling, 2001). The data that is recorded by the sensors can be displayed with computer software. There are many software options available to analyze and record data. Some software can also generate control signals that can be output to other components. For example, LabView software can acquire data and generate signals (Deshpande, et al, 2004). The decision for the software to be used depends on a number of factors. It is based on its efficiency of integrating to a computer, cost of the software and how user friendly it is (Pecan et al, 2004). Computer software cannot directly read common analog sensors, but requires a device in between to acquire signals and convert it into a readable form for the software. These devices are called Analog-to-Digital Converters (ADCs) and are required by most sensors (Kacira, Ling, 2001). Because of the complexity of the input, cameras often require their own software to acquire data (Boyd, Hopkins, et al, 2004). Plant stress is one of the most important aspects to monitor, because it directly affects the lighting and irrigation of the plant. (Kacira, Ling 2001). To measure plant stress, however, more than one sensor is required. There are many measureable factors that can indicate plant stress, such as, soil moisture, light intensity, and leaf canopy temperature. Soil moisture, light intensity temperature, and relative humidity sensors are often used to measure plant stress (Pardossi 2008).

Irrigation

There are currently many different methods for artificially growing plants in industry. In hydroponic techniques, sub-irrigation is most commonly used, and instead of water, a nutrient solution is delivered to the plant root zone (Jones 2005). With sub-irrigation there are several common techniques, including “ebb-and-flow”, where water is pumped in only as needed and remains in the root zone until absorbed, and recirculating “nutrient film technique” where the solution is continuously pumped through the root zones and back to a reservoir to maintain the high oxygen levels necessary in the root zone (Pardossi 2008). With hydroponic techniques, however, this nutrient solution must be mixed and carefully pH-controlled to ensure the plant's ability to absorb nutrients. A pH around 5.5 is optimal and much higher or lower will hinder nutrient uptake and stunt plant growth (Jones 2005). In lieu of hydroponic techniques, another option is to use a growth medium which contains the necessary nutrients and requires only water irrigation. The two most commonly used media in today's plant production facilities are rock wool and natural soil, although other materials such as coconut fiber are being investigated (Pardossi 2008). In techniques with growth media, methods of irrigation are more diverse. Some facilities use sub-irrigation with flooded-floor technique, meaning the plant pots have holes in the bottom and absorb the water from the surface they rest on, and other common methods include drip tubing and spray irrigation. In ebb-and-flow systems, an important question is when and how much to water, and there are several techniques currently in use to determine the answer. These include determination by human inspection, automatically timed irrigation, and methods relying on data collected from the plants and environment including soil moisture and pot weight (Pardossi 2008).

Blinds

The current design of the XHDU food production system involves eight plant production units that include a growing tray containing growth media and plants, a LED lighting bank positioned over the growing tray, and a water reservoir (Stutte et al, 2011). A smart lighting design for deep space life support plant production was recently reported (Poulet et al, 2011). Lighting units are custom designed consisting of LEDs providing light for plant growth and photo-sensors to detect canopy coverage. Each of the lighting units is turned on only when a plant is detected underneath. Each lighting unit covers an area of approximately 3" x 3" (Morrow, 2011). Thus, 12 of the lighting units are required for a growing area of 12" x 9". Alternatively, a simplified plant sensing approach is proposed in this project using only one off-shelf imaging sensor to detect all plants in the same 12" x 9" area from seedlings to full grown plants.

Previously, red and blue lights were used in the atrium to maximize plant growth. These created problems with the crew and to reduce light pollution in the form of unwanted light from the atrium above, blinds have been implemented. Several blind materials and substitutes were researched. The Sunteca reflective blinds are created with a mylar material sandwiched between aluminum. This material creates a sunglasses affect for those in the area, minimizing light pollution. This type of blind was available to be motorized for $ to $ (*Sunteca*, 2009). The second blind material was made of the same material and provided an option for a cassette cord actuated roller blind. This blind material reduces glare from 91-97%. Dependent on the specific film chosen, heat gain can be reduced from anywhere between 50 and 80% (*Witworx*, 2006). A two way mirror was also presented as an option. This offered varying thicknesses which would fluctuate costs and also affect heat transfer coefficients. Additionally, it allows for minimal breathability which is an important aspect due to heat created from the lights. With minimal breathability, the heat transfer would need to be evaluated and maintained so that the plants do not overheat within the atrium. Although it is entirely solid, it allows for complete visibility. The product is offered in both acrylic and glass. Benefits to this product would be easy manipulation of price depending on thickness, type of material and size ("Two-way or See-through Mirrors",). All of these materials' benefits and disadvantages were taken into consideration when determining which material would be best for this project.

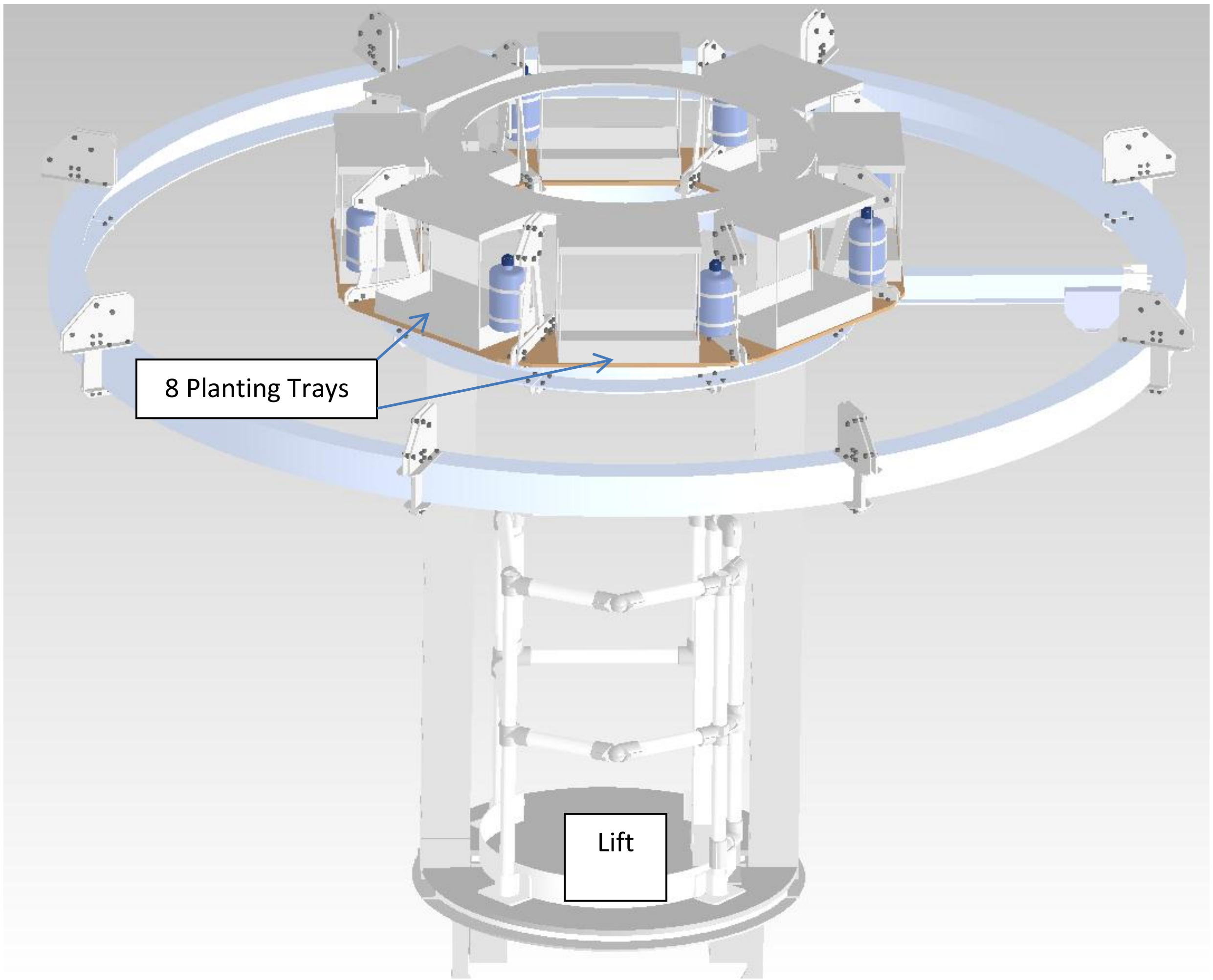
Final Design

The design is described in four categories: irrigation, blinds, sensing and monitoring, and camera. Each of these components and the overall existing structure are explained below.

Overall

The shuttle consists of two floors with lift access to the second floor. The food production unit is located around the lift, between the two floors inside the ceiling of the first floor/floor of the second floor. This means the outside of the unit is solid material. A water source with pressurized water of 30 to 40 psi along with any power source needed will be provided by NASA.

Figure 1: The existing lift and the location of the atrium where the food production unit will be placed. There are 8 trays surrounding the lift to be used for growing plants.



Sensing and Monitoring

Table 1 gives a list of the factors that will be monitored for the plants. It includes the sensors that will be used for each factor. The table also gives details about the quantity of the sensors, its dimensions and weight.

Table 1: Sensors used to measure different factors of plant growth and specifications.

Telemetry name	Units	Sensor Type	Quantity	Dimensions	Weight
Temperature 1 & Humidity 1	degC	RH/Temp	1	Length= 2.8 in Diameter=0.47 in	23 g

Temperature 2	degC	Leaf/Canopy Temperature	1	Length= 6 cm Diameter= 2.3 cm	190 g
Soil Moisture	%water/volume	Soil Moisture Probe	1	8.9 X 1.8 X 0.7 cm	55 g
Holding Tank Weight	kg	Load Cell	2	1 X 3 X 0.75 in	50 g
Water Flow	gal/min	Flow Sensor	1	1.3"dia,3"long	500g
Light Intensity	µmol/m2/sec	PAR sensor	1	1 X 1 X 2 in	100 g
Image	---	Webcam	1	Φ: 105 mm X 124 mm H	406 g

The data collected from the Temperature/RH sensor, Leaf Canopy Temperature Water flow sensor and the PAR Sensor, will be used to control the lighting and the irrigation of the plant. The control actions generated for the amount of water delivered to the plant will be automated, but the crew will be able to completely stop the water flow if required. The readings from the soil moisture sensor, load cells and the float sensor will be used to alert the crew about any water leakage in the system. The data collected for leaf canopy temperature will be used to turn off/on the fan over the tray. The amount of light given to the plant will be under the control of the crew present. Table 2 summarizes the activities that will be controlled by the crew. The crew will be using Labview program for the control

Table 2: Factors that will be controlled by the crew member.

Command Name	Function
Fan Speed	The fan will maintain the air flow in the tray
Water on/off	There will be a switch in Labview that can be used to completely turn off the water supply
Light on/off	This will be controlled by a switch in Labview
Light intensity	If the light increases the temperature for the plant, it can be controlled by the crew

Table 3 gives all the specification of the hardware that will be used to integrate the sensors to the unit. The DAQ is a data acquisition system, which is required for integrating the sensor to the Labview software. The solenoid valve is used to control the flow of the water from the tank.

Table 3: Hardware used to integrate sensors into the plant unit.

Name	Function	Quantity	Dimensions	Weight
DAQ	DAQ for PAR sensor, temperature, etc.	1	79 mm (L) x 82 mm (W) x 25 mm (H)	200 g
DAQ	DAQ for load cell, moisture sensor, canopy temp	1	Approx. 2 X 4 X 6 in	300 g
Solenoid	Control water flow to tray	2	Approx. 2 X 2 X 3 in	500 g
Master Solenoid	Emergency cutoff	1	Approx. 2 X 2 X 3 in	500 g
Relay	Send control signal to solenoid	2	Approx. 1 X 1 X 0.5 in	100 g

Table 4 gives the specification of all the software's that will be used for the sensors. The Labview software will be used to integrate all the sensors and record the data from them. The Labview software will be running on a laptop computer with Windows software.

Table 4: Software used for Sensing and Monitoring.

Name	Version	Function
Windows	7, XP	operating system for host PC
Instacal	6.22	data acquisition software
LabVIEW	8.5	data processing and control software

Table 5 gives the information of the interfaces that are required between the softwares and the sensors. Some of the sensors do not directly connect to the Labview or DAQ and they require some interface. Also the table gives the information of the voltage sources that are required for some sensors.

Table 5: Interface required for some sensors.

Type	Specification	Function
USB	2.0	interface from DAQ to host PC
voltage	12 VDC	power to sensors
voltage	2.5 V DC	power to soil moisture sensor
voltage	120 V AC	Power for laptop and camera

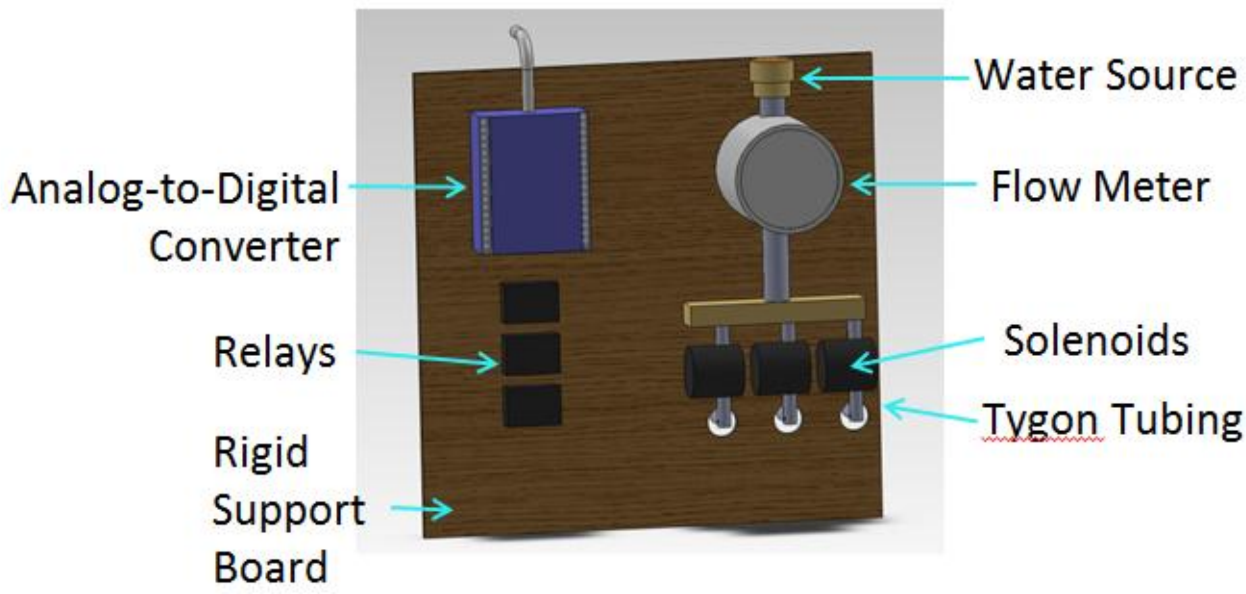
Blinds

The curtain will be made from metalized film. This allows for the camera to see through the blinds with little obstruction while still reducing light pollution. They are also rather durable so they will not have many issues being handled often. The blinds will be mounted from the top of the atrium by epoxy with universal mounting brackets and maintained on a spring roller. With this type of roller, the crew is able to choose any desired length for the shades, dependent on the temperature of the canopy and crew preference of how much light is desired. This will not protrude farther than a few inches and will not interfere with the lift processes. Specifics of the shade include a bronze exterior and grey interior allowing for light to be reflected back onto the plants instead of escaping into the habitation unit. Approximately 59 percent light is reflected with this shade and 25 percent of light is transmitted.

Irrigation

A CAD drawing of the irrigation control system is shown in Figure 2. In order to minimize the installation time, everything will be placed on a preassembled board which will be installed vertically to minimize the potential for water to come into contact with electrical components. Water will come in from the pressurized source provided by NASA, and travel through the flow sensor and solenoids before traveling through the tubing to the individual trays. Sensor voltage signals will be converted to digital by the Analog to Digital Converter (ADC). Using the data from these sensors, the irrigation program will determine when to open or close the solenoid valves to each tray. For each tray we will use two solenoid valves in series in case one valve fails. The control signal will come from the ADC to normally open relays, which separates the valve from the power source. Green polyethylene tubing will be used to supply the water to the trays because it is flexible, easy to install, and the coloration helps prevent algal growth. The flow sensor will record how much water is delivered to each tray in each watering cycle. In case of software malfunctions, there will be a float sensor in each tray so that if the water level gets high enough to spill out, the water supply will be automatically cut off and an alarm sounded to crew members.

Figure 2:Irrigation Control System



Camera

There will be one camera which will not be located in a fixed position throughout the atrium. The camera will be capable of being relocated via magnets since a track was impractical and incapable of being incorporated into the system without interfering with the lift. The camera will be responsible for monitoring any single designated tray from any position in the atrium as shown in *Figure 3* and *Figure 4* below. It will have a sampling rate of 2 images/day/tray and these images will be stored on a hard drive so they can be accessed at any time by the crew or by ground control. The live feed as well as the camera controls will be accessed through a web browser either by the crew or by ground control. The camera is meant for recognizing the health of the plants and if the plants are ready for harvest.

Table 6: Camera Specifications.

Dimensions	Ø: 105 mm Ø x 124 mm H
Weight	406 g
Power	12V DC 1A
Certification	CE, C-Tick, FCC, LVD, VCCI
Operating temperature	0° to 50°C
Viewing system	OS: MS Windows 2000/XP/Vista/7; Browser: Firefox, Internet Explorer 6.x or above
Operating humidity	20 - 80%, noncondensing
Storage humidity	0% to 90%, noncondensing
Pan	± 150°
Zoom	10x
Tilt	-45° (down) to +90° (up)
Illumination	2.76 lux @ f1.8, 0.06 Lux @ F1.8 (low light mode)
Focal length	4.2-42 mm, minimum focusing distance of 2.5 cm
Field of view	4.15° horizontal; 2.77° vertical
Video resolution	720x480
Frame rate	Up to 30 frames per second

Figure 3: Camera position. The camera (gray box) will have the capability of monitoring the designated tray.

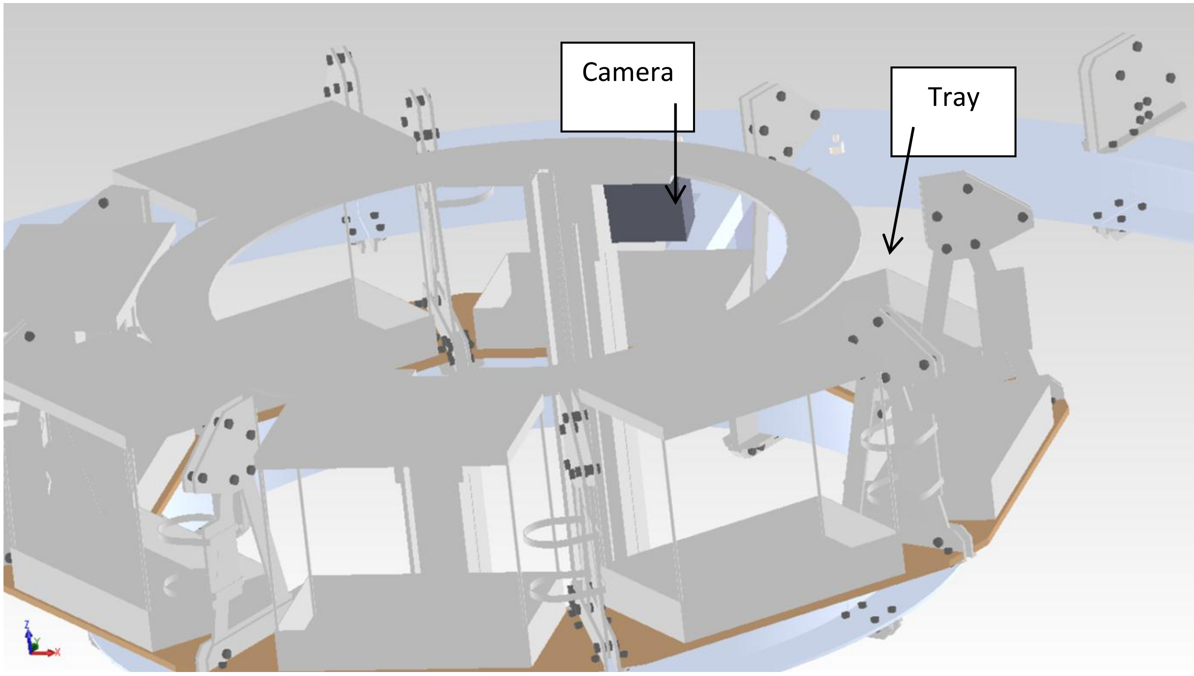
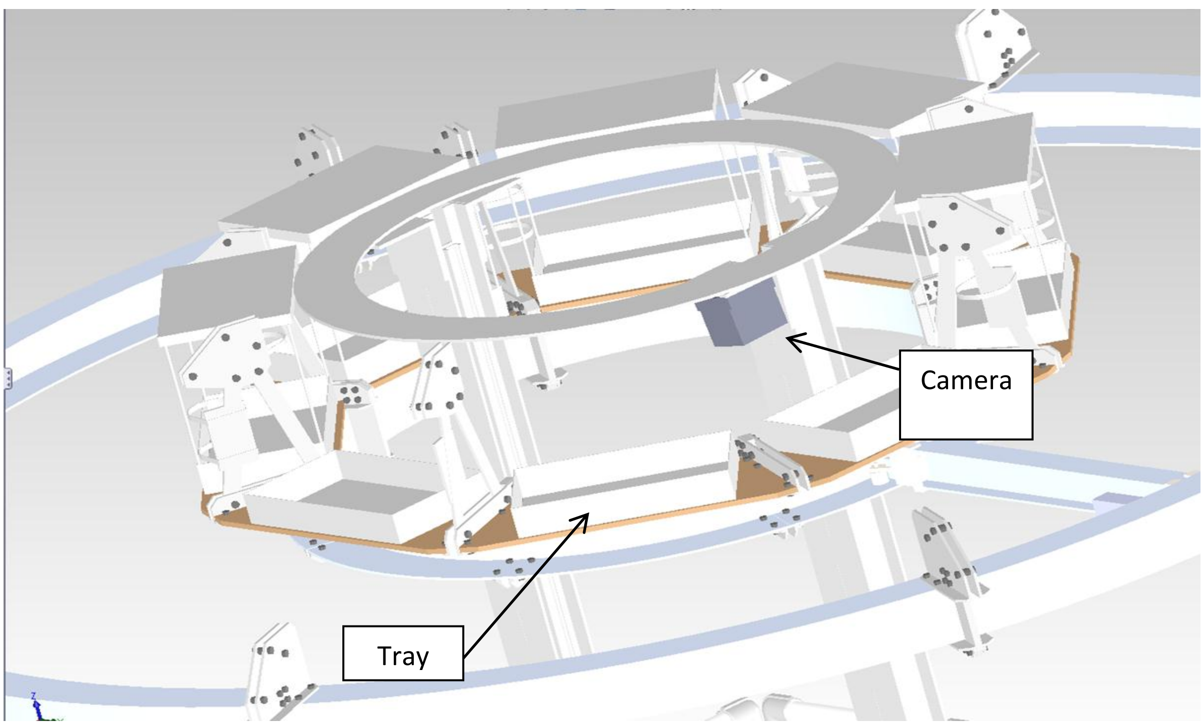


Figure 4: Camera position from a different angle with the trays being the same from Figure 3.



Methods and Activities

The project team first met in early May 2011 to meet with team members and begin writing a proposal for NASA. At the first meetings many preliminary topics were discussed. Each member was given a part of the project to manage and oversee and literature review began. Dr. Ling was in charge of submitting a proposal in order to become part of the X-HAB challenge. In late May 2011, our project had been approved and meeting times were set for the remainder of the quarter.

Throughout the spring quarter and summer a lot of reading took place for each of the members in order to become more fluent with their respective portions. Baseline references were obtained from NASA and read by all members in order to better understand the habitation unit and task at hand. Several power points were sent to us through NASA and the summer consisted of research and learning.

Beginning in September 2011 the team began weekly meetings with NASA in order to obtain more specifics on the unit. Major topics during this timeframe included lighting and irrigation. NASA got back to us in December and informed us that they had created teams specifically in charge of sensing, integration, and lighting. This eliminated the need for our team to choose certain lighting and the lighting became more focused on minimizing light pollution.

By the start of winter quarter, January 2012, NASA had a check-up meeting with the team in order to find a focus point for the project and narrow the project goal. Winter quarter consisted mostly of choosing multiple design alternatives and selecting sensors for the unit. The quarter ended with an update meeting with NASA in which possible testing of software, blinds and trays were discussed and action items for the next meeting were created.

In April 2012 the LabView programs were our main point of concern. The tray and plant unit was utilized and a plate for the load cells was created. Hardware was selected, purchased and obtained. The blinds, camera, sensors, and irrigation system underwent testing and options finalized. The final hardware and software are to be delivered to NASA in Houston, Texas in May, 2012.

Schedule

Figure 5 is a breakdown of the schedule with an end date of May 31st, 2012. It is separated by the sections of irrigation, blinds, sensing, camera, software, and outreach and also shows who is responsible for each. Some items such as the selection of materials or sensors and the location of these sensors have been completed since the interim design report. The majority of our time for the remaining weeks will focus on debugging and refining the programming in LabView for calibration and reading of the sensors.

	Task Name	Start	Finish	Member Responsible
1	**NASA X-HAB**	**Fri 12/9/11**	**Thu 5/31/12**	**All**
2	**Irrigation**	**Fri 12/9/11**	**Thu 5/31/12**	**Henry**
3	Water Source	Fri 12/9/11	Fri 1/20/12	Henry
4	Flowmeter Selection	Fri 12/9/11	Fri 2/10/12	Henry
5	Solenoid Selection	Fri 12/9/11	Fri 2/10/12	Henry
6	Check Valve Selection	Fri 12/9/11	Fri 2/10/12	Henry
7	Testing	Fri 2/10/12	Tue 5/29/12	Henry
8	Installation	Wed 5/30/12	Thu 5/31/12	Henry
9	**Binds**	**Fri 12/9/11**	**Thu 5/31/12**	**Deborah**
10	Material Selection	Fri 12/9/11	Fri 2/10/12	Deborah
11	Location Selection	Fri 12/9/11	Fri 2/10/12	Deborah
12	Testing	Fri 2/10/12	Tue 5/29/12	Deborah
13	Installation	Wed 5/30/12	Thu 5/31/12	Deborah
14	**Sensing**	**Fri 12/9/11**	**Thu 5/31/12**	**Anupriya**
15	Load Cell Selection	Fri 12/9/11	Fri 2/10/12	Anupriya
16	RH/Temp Selection	Fri 12/9/11	Fri 2/10/12	Anupriya
17	Soil Moisture Selection	Fri 12/9/11	Fri 2/10/12	Anupriya
18	Canopy Temp Selection	Fri 12/9/11	Fri 2/10/12	Anupriya
19	PAR Selection	Fri 12/9/11	Fri 2/10/12	Anupriya
20	Testing	Fri 2/10/12	Tue 5/29/12	Anupriya
21	Installation	Wed 5/30/12	Thu 5/31/12	Anupriya
22	**Camera**	**Fri 12/9/11**	**Thu 5/31/12**	**Mason**
23	Camera Selection	Fri 12/9/11	Fri 2/10/12	Mason
24	Location Selection	Fri 12/9/11	Fri 2/10/12	Mason
25	Testing	Fri 2/10/12	Tue 5/29/12	Mason
26	Installation	Wed 5/30/12	Thu 5/31/12	Mason
27	**Software**	**Fri 2/10/12**	**Thu 5/31/12**	**All**
28	LabVIEW Programming	Fri 2/10/12	Tue 5/29/12	All
29	LabVIEW Installation	Wed 5/30/12	Thu 5/31/12	All
30	Educational Outreach	Thu 2/23/12	Tue 5/29/12	All

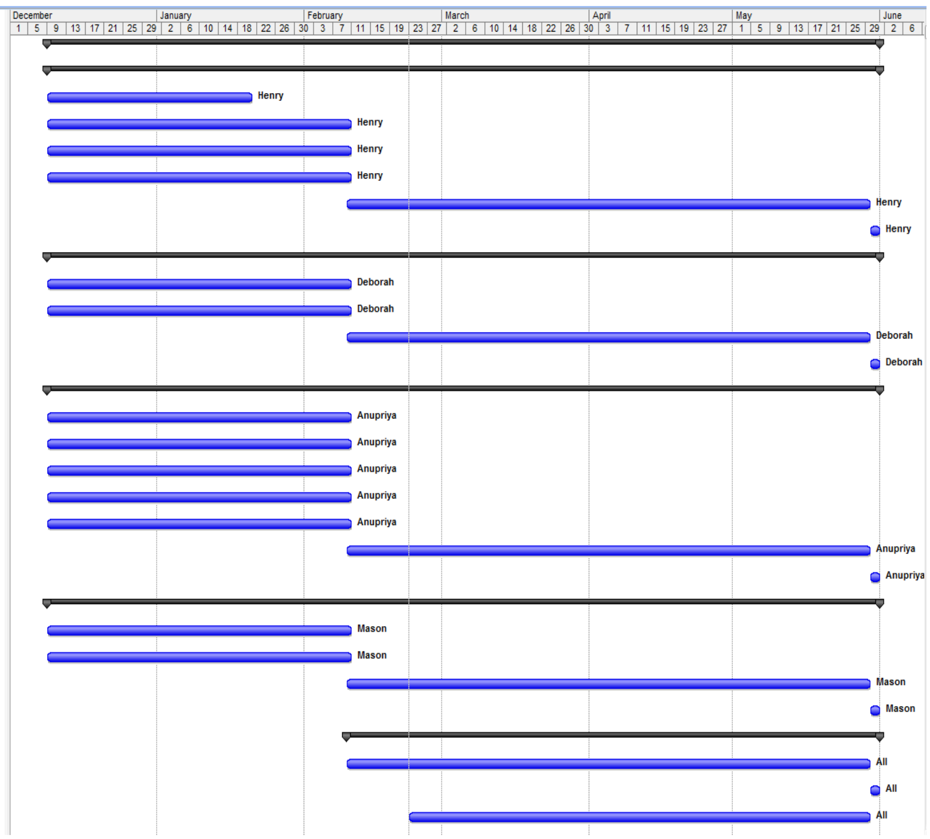


Figure 5: Schedule Breakdown.

Budget

Table 7 includes the budget for the project. This budget is broken down into sections of sensors and hardware. The budget below is shown for only one tray of the X-HAB plant production unit, which is what the team was in charge of developing. Since weight is an intricate part of the project the weight cost is also included. Table 8 is a continuation of the budget which includes the travel expenses for the team to go down to the Johnson Space Center in Houston, Texas and implement the production unit.

Table 7: Sensor and hardware budget including the weight and weight cost for one plant production unit.

Sensors	Cost	Amount	Total	Weight (lbs)	Weight Cost
Flow		1		1.10	
Load		2		0.22	
RH/ Temp		1		0.05	
Soil Moisture		1		0.12	
Canopy Temp		1		0.42	
Camera		1		0.90	
PAR		1		0.22	
Hardware	**Cost**	**Amount**	**Total**	**Weight (lbs)**	**Weight Cost**
Blinds		1		3.32	
Tubing		50 ft		1.10	
Fittings		10		0.22	
Solenoid		2		3.67	
Relays		2		0.02	
Magnets		2		0.11	
DAQ		1		0.35	
CPC		2		0.01	
Weight Plate		1		4.70	
Board		1		0.23	
Box		1		1.60	
Total				18.36 lbs	

Table 8: Travel budget.

Travel	Cost	Amount	Total
Plane Ticket		5	
Rental Car		1	
Hotel		2	

Figure 6 below shows an estimation of the amount of money saved after implementing our system to all of the current trays. The money saved was first calculated in crew time by estimating the crew spends 1.17 hours/week manually watering the trays. 60 kg/hr/week was then used as an equivalent system conversion factor that NASA created in an effort to convert all units including time to kilograms. This conversion factor is used regardless of mission time. The $/kg is how much it costs to send a kilogram into space. This results in a $ savings. The cost of the system was calculated from the weight and the cost of applying the sensors and hardware to all eight trays. The total cost of the system was $. This yields a savings of $ per mission.

Figure 6: Estimated savings after implementing the system.

Final Results

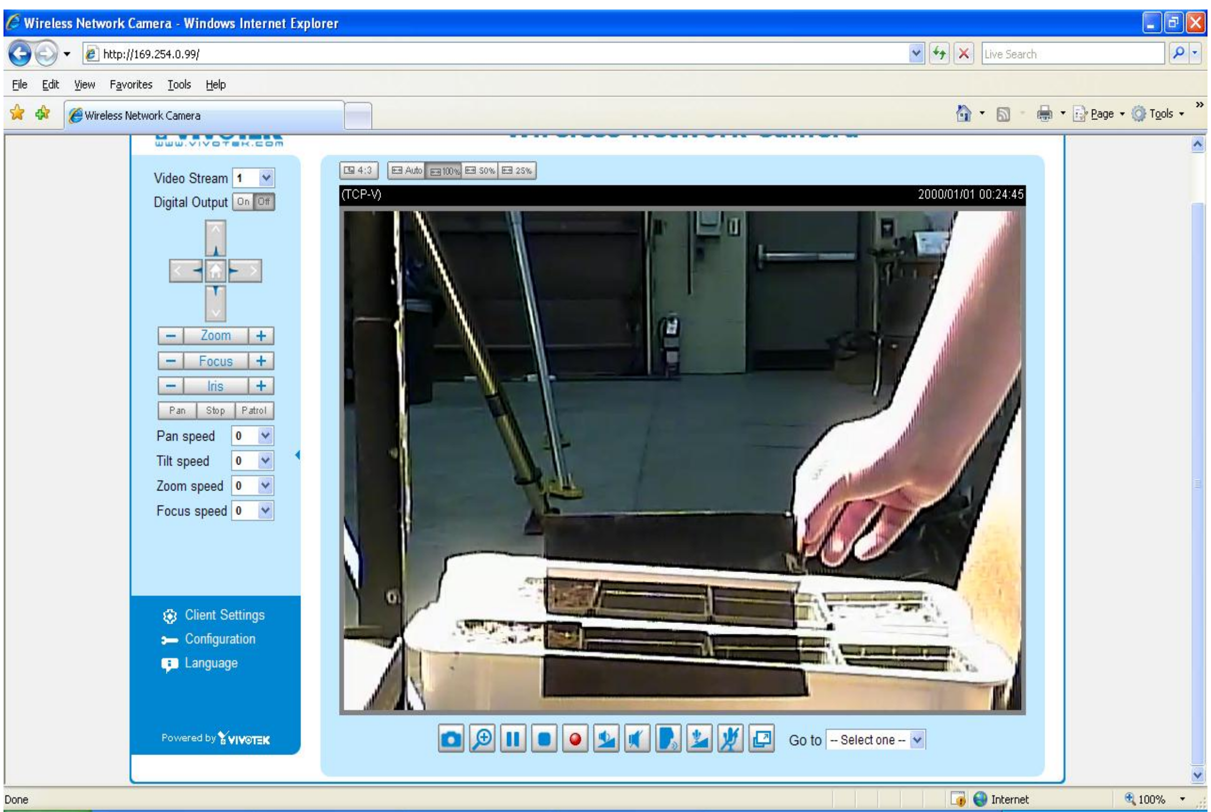
Testing has been conducted on each of the sensors and several of the LabView programs to ensure they are compatible with the sensors and DAQ. Preliminary testing showed that the original 1608 DAQ was not sufficient for the task at hand, so a 2408 DAQ was obtained. After determining how to operate the 2408 data acquisition board the LabView programs were altered for this DAQ. The programs were able to allow each sensor to operate in an effective manner. The team's task at hand was then to eliminate noise and make sense of the data received from the DAQ.

Testing of the blinds and camera consisted of ensuring compatibility of the camera and computer, visibility through blinds, accessibility through web browser and capability of camera to pan, tilt and zoom through the aforementioned browser. The camera views, with and without the blind, are shown below in *Figure 6* and *Figure 7*. After accessing the web browser it was determined that the web browser was capable of all functions necessary including: pan, tilt, zoom. The web browser is shown below in *Figure 8*. *Figure 8* also shows the difference of how the shade controls the light and actually enables more visibility of the tray.

Figure 6: Camera view with Halcyon Blinds present showing that the visibility is maintained through the blinds.

Figure 7: Camera view without Halcyon Blinds present which allows for more color, but compared to Figure 6 shows little difference.

Figure 8: Camera view with blinds and controls via web browser. This shows that the light pollution makes a difference from the total point of view and the effect of blinds on visibility. The pan, tilt, and zoom functions for the camera, which can be accessed through the web browser, are also shown.



Conclusion

In the final quarter for this project, the main goal was to build and test the design we formed throughout the year. A Labview program was built for the sensor network, which also includes automated irrigation system and alerts for sensor failure and water leakage. The sensor locations were also selected depending on the space available in the tray. The blinds were finalized along with the mounting bracket that could be easily fitted on arrival at the location. A preassembled board of all the parts required for irrigation was made to reduce installation time. All the final designs for each subsystem were selected and built after several testing, and were approved by NASA.

The building of the design was done keeping in mind the straightforward integration into the system due to limited time on location. The final system will be delivered at Johnson Space Center in Houston, Texas on May 31st, 2012.

Qualifications of Personnel

The research team consists of four undergraduate students, one graduate student, and two faculty members. We have met weekly for the past 4 weeks preparing this student driven proposal. The members' roles are listed below.

Young, Mason: Ecological Engineering. Mason addressed the camera aspect of the design as well as be the student team leader.

Bleasdale, Deborah: Biological Engineering. Deborah led the blinds design and evaluation effort as well as outreach through OSU campus open house activities.

Boucherle, Henry: Biological Engineering, Economics minor. Henry led the effort of irrigation system design.

Chetal, Anupriya: Biological Engineering. Anupriya focused her effort on the plant monitoring aspect of the project.

Martin, Jay: Ecological Engineering, Associate Professor. Jay teaches the Capstone Design Course and will provide generic engineering design training.

Ling, Peter: Horticultural Engineering, Associate Professor. Peter is developing horticultural engineering teaching modules and provided XHAB project specific training as well as managed the project.

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