UCF
Senior Design I

A Plant Habitation System for Life Sciences Research

University of Central Florida, Orlando FL
National Aeronautics and Space Administration, Cape Canaveral FL

College of Engineering and Computer Science
Department of Electrical and Computer Engineering
Department of Computer Science
Dr. Lei Wei & Dr. Samuel Richie

Project Document and Group Identification
Divide and Conquer II
Group 30

Nicolas El Tenn	Computer Engineer	nicktenn@knights.ucf.edu
Raquel Guzman	Computer Engineer	rg11145@knights.ucf.edu
Matthew Philpott	Electrical Engineer	matt.philpott13@knights.ucf.edu
Shivani Kumar	Computer Science	shivanik19@knights.ucf.edu
Noah Heikes	Computer Science	noah.heikes@knights.ucf.edu

Project Narrative

University of Central Florida Senior Design Group 30 is working to develop a plant habitation system with a human-machine interface for Life Sciences research to produce high-yield plants and reduce crew time operation (1). By using interchangeable research modules that work in Low Earth Orbit, a Lunar Outpost, Lunar Orbit, on Earth, and on the Moon, the advancements and discoveries made through this development can then be implemented in all locations (1). As a result, benefiting mankind entirely. The data gathered will be from sensors that monitor the internal conditions of the plant habitation system as well as sensors that monitor the plant's soil conditions. This sensor data includes humidity, temperature, pH, CO2 levels, pressure, water levels, and light levels. The group will also need to be mindful that none of the component parts exceed the budget and timeframe thresholds allotted. As a result, reporting back data on plant status, providing insight on growth and yield (2). The ability to grow supplemental food through plant crops would allow humans to explore deep space with long-term missions (2). Additionally, growing food in space is crucial since it provides a solution to rid the constant costly supply of packaged food from Earth that is currently the standard for a permanent presence in space (2).

The plant habitation system will be composed of off-the-shelf components as well as components that will be designed and tested in-house. The reason behind this design selection is to abide by the constraints set forth by both UCF and NASA which are quite similar in nature. The constraints are discussed extensively in this document in the Constraints section. From the hardware perspective, the frame is highly likely to be constructed in-house so it abides by the volume and weight constraints. The team is aiming for a 6U CubeSat volume to house the plant(s) as well as the array of sensors, power supply, Micro Controller Unit (MCU), wiring, display system, water irrigation system, air filtration system, lightning system, temperature system, etc. The power supply module will be within the limitation of the spacecraft allowed wattage and tested to that threshold. The weight requirement will also be heavily considered when designing this system as it limits the selection of components based on their weight. Moreover, the components will also be selected based on their thermal limitations and heat emissions which would affect not only the system, but the plant(s) on board.

Project Requirements

Software:

- Software will be written in Python
- The user interface will display sensor data, light settings, and images.
- The UI will be checked at least twice a day (once in the morning and once at night).
- The camera will take 3 pictures daily and upload them to the UI
- Pictures will be compared every 2 weeks.
- Data will be transmitted within 2 hours of being gathered.
- Optimal plant settings will be adjusted every 2 weeks based on gathered data (mainly light settings, and water level)
- Settings are also manually adjustable within UI
- The UI will notify the user if plant is ready for harvest, or if other components in the system need assistance
- Display technical habitation system environment information when requested
    - Temperature sensor data
    - Humidity sensor data
    - CO2 sensor data
    - Pressure sensor data
    - pH sensor data
    - Water level
    - LED light level
- Display plant-specific information when requested
    - Real-time plant health monitoring
    - Expected yield data
    - Expected size growth
    - Plant classification
- Display planning tools
    - Task procedures
    - Daily planning
    - Irrigation procedures
    - Plant harvesting procedures
- Document processing functions
    - View documents
    - Edit documents
    - Take notes

Hardware:

- Multiple sensors to measure CO_2 levels at least 3 times an hour.
  - 3.25V - 5.5V power
  - ±3% accuracy
- Multiple sensors to measure soil moisture and humidity 2-3 times every hour.
  - 3.3V - 5V power
- Individual component to measure remaining water levels. Sends signal to microcontroller if water levels are low.
- Camera and ruler to determine plant height
  - 720p - 1080p resolution
  - 30fps - 60fps frame rate
  - 3.3V - 5V power
- Water-resistant components and waterproofed electrical connections
- Individual sensor to measure the system's temperature. Measured every hour.
  - 2.4V - 5.5V power
- Sensor to measure pH level of plant once every hour.
  - 2.4V - 5.5V power
- System-wide reliable connection
  - Raspberry Pi will connect sensors to software
  - Raspberry Pi will regulate power to the system

Constraints

The plant habitation system must be in the range of a standard CubeSat. Accordingly, there are restraints to the project's volume and weight. Additionally, the constraints set forth by the College of Engineering and Computer Science as well as NASA and FSGC.

Constraints	**Description**
Volume	The dimensions of a standard CubeSat are 10 cm x 10 cm x 10 cm per unit with units ranging between 1U, 2U, 3U, or 6U.
Weight	Within the CubeSat range, the system must weigh less than 1.33 kg or 3 lbs per U.
Time	The system will be in space for a few months. Sensor data, water levels, and photos will need to be measured and recorded frequently to accommodate the plant's limited time in orbit.
Budget	This project has received funding from the Florida Space Grant Consortium, however the team would like to minimize costs when possible. As of right now, the team has estimated costs are about $904 but this will increase as the team continues to search for parts.
Testing	The testing environment that will be used to test the hardware will be the Senior Design labs located at Harris Engineering Center, University of Central Florida, Orlando FL. The equipment that will be used is provided by University of Central Florida. The equipment includes, but not limited to, a function generator, an oscilloscope, a multimeter, a logic analyzer, etc.

Table 1

Block Diagrams

The diagram shown in Figure 1 describes how the user will login and be introduced by a homescreen that includes at least four main functions. The user can then select one of the functions. The functions include, but not limited to, viewing the sensor data, viewing the timeline of plant growth, viewing plant details, and viewing daily tasks. The first function, viewing sensor data, introduces a screen that includes graphs of sensory data over time, from pH levels, CO_2 levels, etc. The second function, viewing the timeline of plant growth, portrays the plant growth over time in terms of size to date, yield to date, expected size in the near future, expected yield in the near future, etc. The third function, viewing plant details, includes real-time data on plant health, plant type, plant division, class, order, family, genus, species, etc. The fourth function, viewing daily tasks, will display watering procedures, lighting requirements, and plant harvesting details for the day.

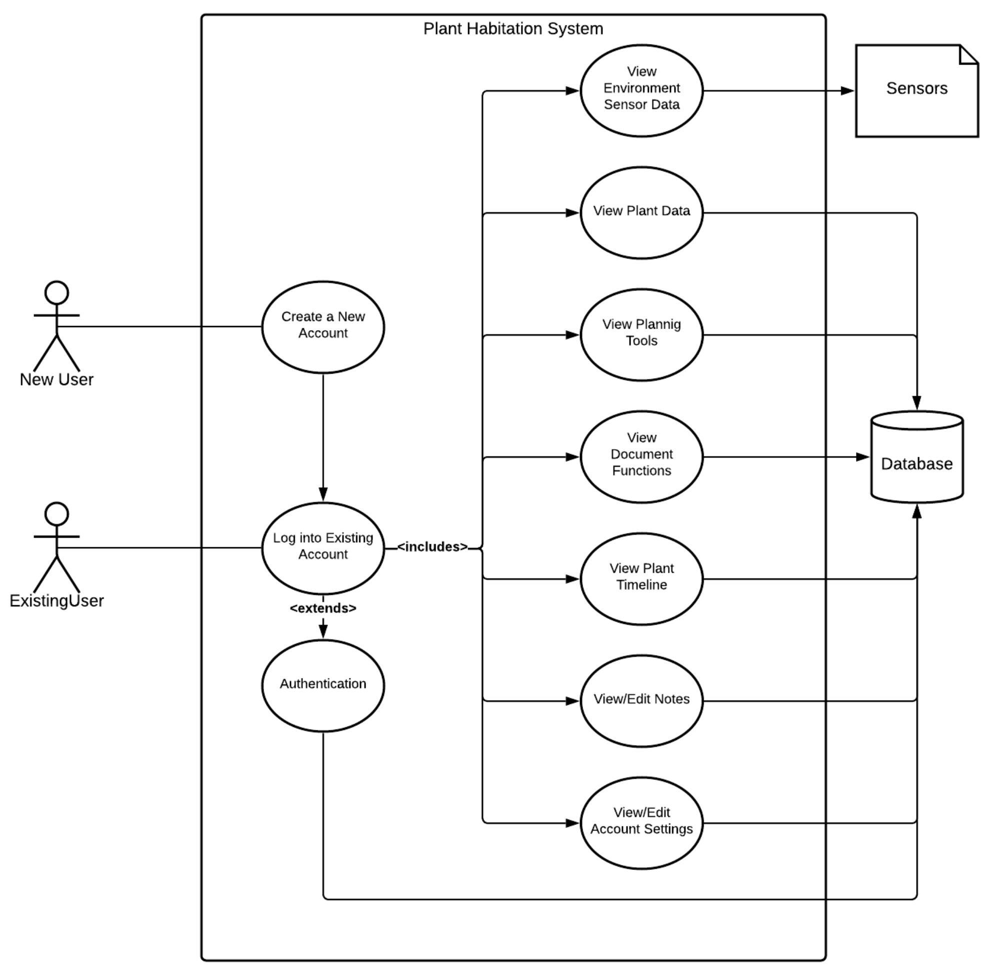


Figure 1

The diagram in figure 2 displays the connections between the GUI and hardware components. It also gives a general layout of the system. On the left, user input will be entered on the display module and sent as a command through the GUI. Data is then transmitted between the plant habitat and the GUI. Note that a majority of components lie in the plant habitat which are each controlled and regulated by the microcontroller. Some sensors will measure environmental factors such as temperature and CO2 levels, others will be used to monitor plant health such as soil moisture and pH. The water supply module will include a water reservoir and an irrigation system to distribute water. The lighting module will consist of LEDs to maintain appropriate light levels. The air filtration and temperature modules will regulate the CO2 levels and temperature of the habitat. On the far right is the power module which distributes power to the entire system and is also regulated by the microcontroller.

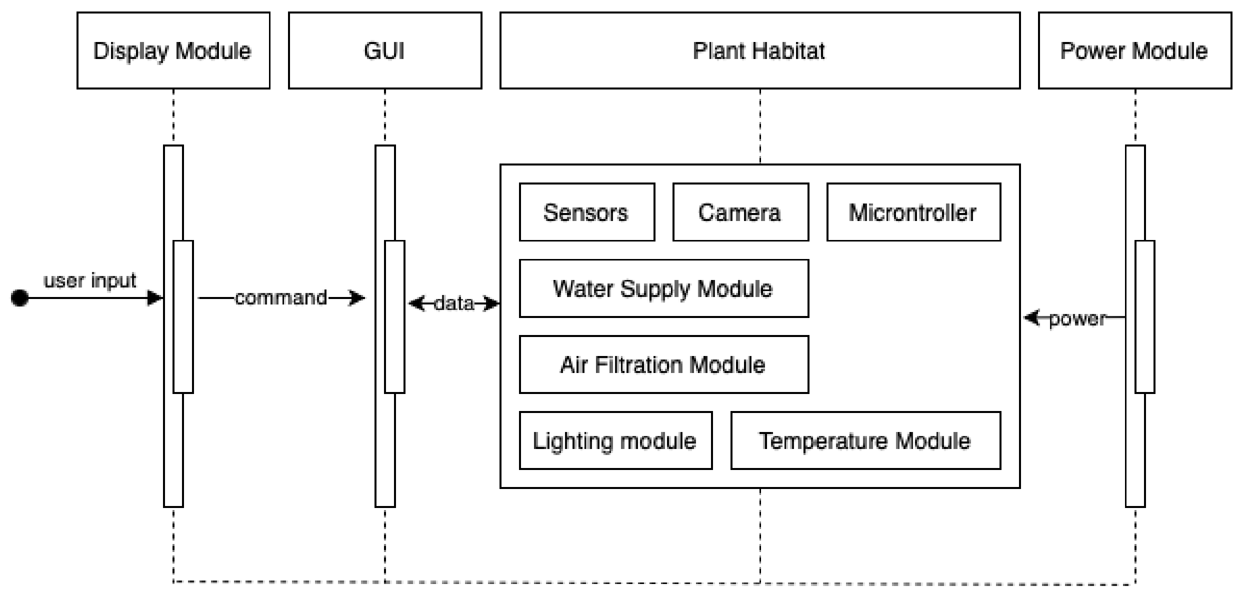


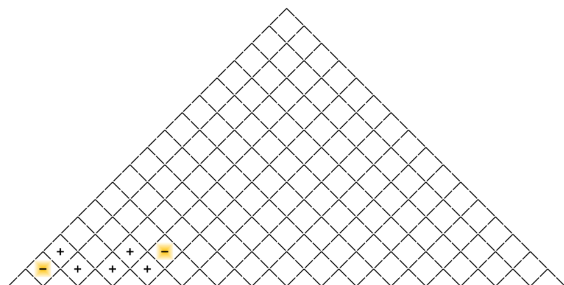
Figure 2

House of Quality

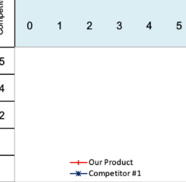
Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



Category	Weight	Customer Requirements (Explicit and Implicit) / Engineering Requirements	Frame Dimensions	Sensor Accuracy	Sensor Operating Voltage	Data Upload Time	Cost												Our Product	Competitor #1: *Product Name*	Competitor #2: *Product Name*	Competitor #3: *Product Name*	Competitor #4: *Product Name*	Row #
		Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Customer Competitive Assesment					
		Direction of Improvement	▼	▲	◇	▲	▼																	
	8	Volume	▽	▽			○												3	3	4	1	5	1
	8	Weight		○	●	▽													5	4	1	2	4	2
	4	Time	▽		○	●													1	2	4	0	2	3
	6	Budget		○	○	○	●																	4
	7	Testing	▽	●	●	●	○																	5



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Target	10cm x 10cm x 10cm per U, 6U max	±4%	2.4V-6V	≤ 2 hours	≤ $1600											
Max Relationship	1	9	9	9	9											
Technical Importance Rating	#REF!	#REF!	#REF!													
Relative Weight	#REF!	#REF!	#REF!													
Weight Chart	#REF!	#REF!	#REF!													
Our Product	1	3	4	2												
Competitor #1: *Product Name*	2	3	5	1												
Competitor #2: *Product Name*	3	0	4	5												
Competitor #3: *Product Name*	4	1	5	4												
Competitor #4: *Product Name*	5	5	2	1												

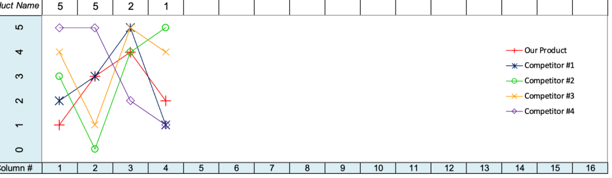


Figure 3

Budget & Finance

Item	Amount	Cost	Total
Raspberry Pi	1	$100	$100
MCU	2	$45	$90
Battery	2	$10	$20
CO2 Sensor Module	4	$52	$108
Soil Moisture Sensor	1	$30	$30
Pressure/Temperature Sensor	4	$8	$32
Camera	2	$40	$80
pH Sensor	1	$32	$32
Frame (testing)	3	$50	$150
Frame (prototype)	1	$250	$250
MUX	1	$27	$27
Power PCB/Components	1	$30	$30
LEDs	20	$1	$20
LED Boards	4	$10	$40
Monitor w/ Touch Screen	1	$90	$90
Irrigation System	1	$90	$90
Testing Equipment	3	$77	$231
Safety	3	$60	$180
Total Costs			$1600

Table 2

The team is still investigating the best parts for the water irrigation system and looking into different materials for our system's frame. Our group has been awarded $1600 from the FSGC which will cover all current costs. Any additional costs will be covered by the group if the total were to exceed the allotted budget.

References

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