

Development of Advanced Plant Habitat Flight Unit

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With NASA's current goals and resources moving forward to bring the idea of Manned Deep-Space missions from a long-thought concept to a reality, innovative research methods and expertise are being utilized for studies that integrate human needs with that of technology to make for the most efficient operations possible. Through the capability to supply food, provide oxygen from what was once carbon dioxide, and various others which help to make plant research one of the prime factors of future long-duration mission, the Advanced Plant Habitat will be the largest microgravity plant growth chamber on the International Space Station when it is launched in the near future (2014 – 2015). Soon, the Advanced Plant Habitat unit will continue on and enrich the discoveries and studies on the long-term effects of microgravity on plants.

Abbreviations and Acronyms

Units of measure and some terms commonly understood within the subject disciplines have been abbreviated in the body of this document without callout but are included among the following.

<i>APH</i>	=	<i>Advance Plant Habitat</i>
<i>KSC</i>	=	<i>Kennedy Space Center</i>
<i>AAA</i>	=	<i>Avionics Air Assembly</i>
<i>ECS</i>	=	<i>Environmental Control Subsystem</i>
<i>WRADS</i>	=	<i>Water Recovery and Distribution System</i>
<i>TCS</i>	=	<i>Thermal Control Subsystem</i>
<i>NE</i>	=	<i>Engineering and Technology Directorate</i>
<i>ECLSS</i>	=	<i>Environmental Control and Life Support Systems</i>
<i>LED</i>	=	<i>Light Emitting Diode</i>

1. Background Information

Over the course of the summer, the opportunity to assist the testing of the Advanced Plant Habitat (APH) system that will go on to provide a wide array of plant experiments on board for the International Space Station. As a part of the Fluids and Propulsion Division (NE-F) and overall, the Engineering and Technology Directorate (NE) at the Kennedy Space Center had presented itself. Within NE-F, Environmental Control and Life Support Systems engineers help develop the Water Recovery and Distribution Subsystem, the Environmental Control Subsystem, and the Thermal Control Subsystem components of the APH system. Overall, the APH will improve on grounds set by other former and similar systems such as the Plant Research Unit (Fig.1) & Biomass Production System and share likenesses with the current Vegetable Production System (VEGGIE) system (Fig.2), a changeable and deployable gardening unit that will supply flight crews with fresh food and with minimal space occupied and resources.



Figure 1: The Plant Research Unit (PRU)

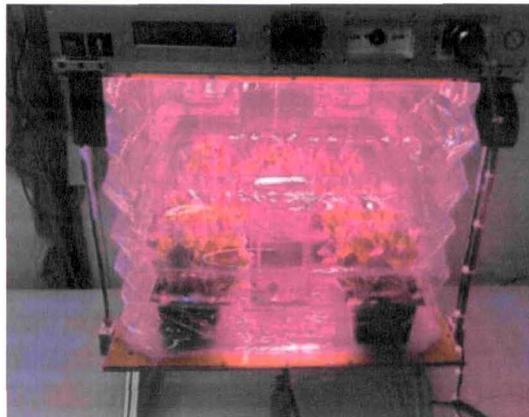


Figure 2: The "VEGGIE" system

2. Product Design

The Kennedy Space Center's ISS Ground Processing and Research Project Office requires the APH will operate as an outsized, enclosed, environmentally controlled chamber designed to support commercial and central plant research onboard the International Space Station. The design must be constructed on an open architecture concept that permits vital subsystems to be removed and replaced onboard the ISS. The APH will also be constructed as a quad-locker plus ISIS (International Sub-rack Interface Standard) drawer payload to be mounted in a standard EXPRESS (Expedite the Processing of Experiments to Space Station) Rack. This

multipurpose payload rack system stores and aids research and science experiments across many fields by providing structural interfaces, power, data, cooling, water and other necessities to activate science payloads in orbit in the U.S. Laboratory.

The science carrier component of the APH consists of a structural element, a water delivery mechanism, and a standard interface plate that will provide instrumentation support as part of the basic plant habitat capabilities. The carrier also will provide additional instrumentation interfaces for other experiment-specific measurement data required to allow investigators to extend the habitat's basic capabilities.

The design project is a NASA-led effort with the Orbital Technologies Corporation (ORBITEC) arranging the design and fabrication the solid state lighting system in three proposed phases, with a total period of performance projected to be three years. Phase I of the effort will encompass providing design support to the NASA-led design team in the form of design review, concept analysis, applications of previous lessons learned to the design effort, and supporting design review meetings. Phase II is to advance flight and ground hardware production efforts to apply the design prerequisites established in Phase I. Phase II will close with the finished assembly of two Advanced Plant Habitats—a ground support unit and a flight unit ready for certification assessment for operation on the station. The final phase, Phase III, will execute the certification assessment and analysis required for flight to and use on the space station; this phase will conclude with the APH flight unit being certified for flight.

In **Figure 3** is the physical schematic of the structural enclosure, location of subsystems, science carrier, growth chamber center light- emitting diode (LED) bank and other components. The front panel, shown open for display of internal view, sleeve ports allows for access to operate contents of the PH, offers a viewport to monitor plants, and unlocks for removal of plant experiment. The growth chamber slides out of the structural mounting assembly to deliver ideal viewing access for subject manipulation through the top clear panel that separates the growth chamber from the center LED bank.

PH Conceptual Picture (Skin has been hidden)

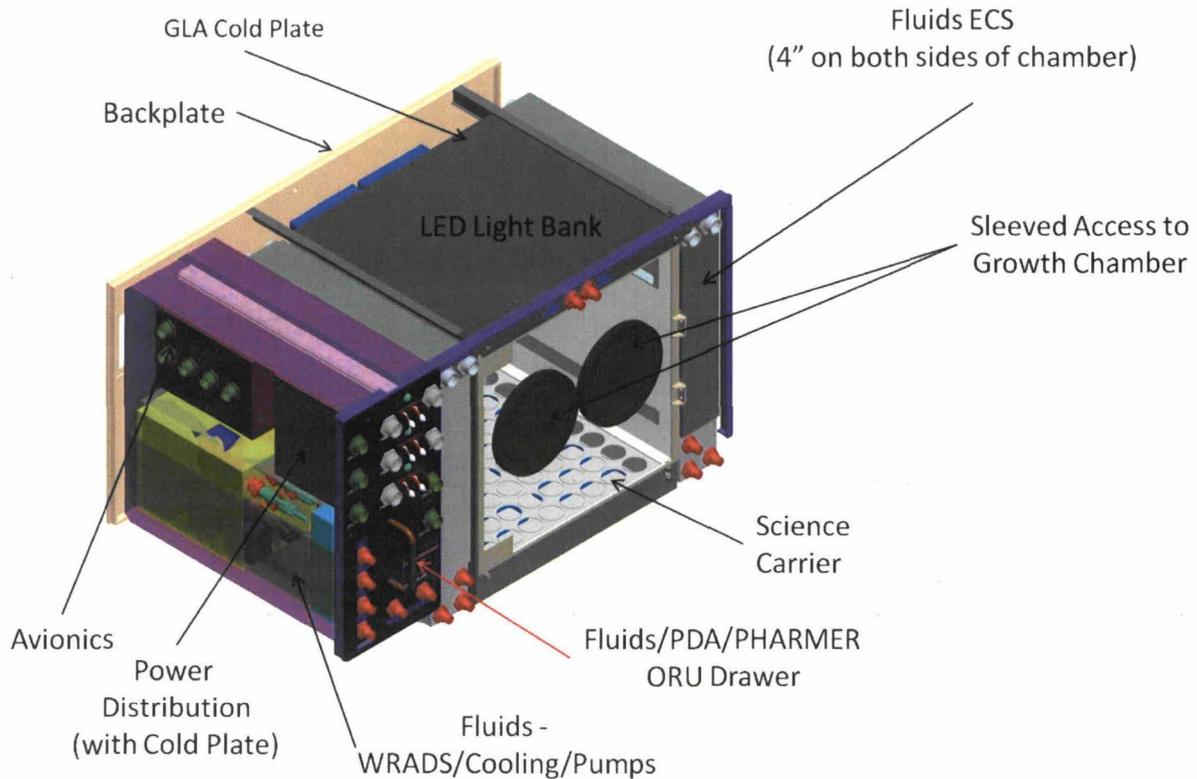


Figure 3: Depictions of the Advanced Plant Habitat Flight Unit

3. Summary

The finished PH will contain both integrated proven microgravity plant growth technologies with newly established fault tolerances and recovery technology to raise overall proficiency, dependability, and robustness and will make for at least one year of continuous operation without malfunction. The three main subsystems (Water Recovery and Distribution Subsystem, the Environmental Control Subsystem, and the Thermal Control Subsystem) of the Fluids division of the major system components will work efficiently together and utilize the resources of the EXPRESS rack

As for the TCS, The PH will use a of the EXPRESS Rack-provided avionics air circulation and a temperature loop to provide heat rejection for the subsystems of the PH as well as reducing

noise and minimizing the use of ISS Cabin Air. The WRADS runs in combination with the PH's ECS (primarily with the Humidity Control Unit (HCU)) to provide the essential fluid system for the plant growth chamber to the Science Carrier root tray.

Most of my work over the course of the summer was focused on the ECS, a vital subsystem that monitors and regulates the temperature, pressure, humidity, CO₂, and O₂, and removes Ethylene inside the growth chamber where there are two ECS orbital replaceable unit (ORU) components attached on each side. Although each ECS ORU module has the capability of full growth chamber environmental control each module will operate at half capacity for ideal air mixing inside the chamber. The KSC Operations and Checkout Building (O&C) contains our prototype lab with a nearly full-scale model of one ECS unit and the Growth Chamber where NE engineers have utilized power boards, transducers, sensors, thermocouples, and other means of instrumentation to display and generate data from the current set-up and will play a major role in providing the final settings and conditions for the APH (Fig.4).

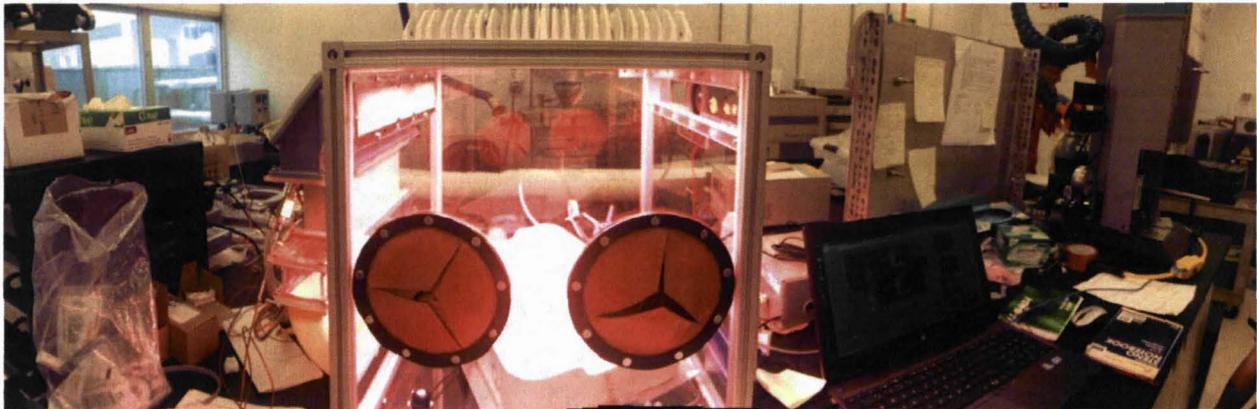


Figure 4: The full-scale model of the Growth Chamber with one ECS unit on the left side.

My main task was to create a stable environment where readings from the sensors would reach a state approximately at equilibrium. This was achieved by keeping the LED lighting at a setting that met the needs of the plants, positioning the sensors where the difference in air temperature is minimal, and applying a certain amount of volts (10-12 V) and current (0.5 – 6 A) to our fans and other controllers (in particular, the controllers of the thermoelectric coolers). By using LabView (National Instruments) software, a custom dashboard was made to keep track of almost every aspect from mass of the plant subjects to the dew point of the chamber and from there we could test new ideas and concepts (such as changing the processes in the mechanics such as the flow of an fluid or implementing new parts) to see what could improve the settings

further with a flight-ready chamber. Now with near-constant readings (in key readings such as relative humidity, air temperature, and inlet & outlet temperature), we began to test our own ideas for equipment such as a single porous ceramic tube that we would compare to the current humidity control unit with many smaller-sized tubes and from there we learned that current set-up actually worked better due to the multiple tubes allowing for more control. Also trying out different system set-ups with our thermocouples to the temperature & humidity monitoring and control unit within the ranges for conditions for the APH.

Towards the end of the term, we began to make modifications to an indoor hydroponics plant growth-wheel (**Fig.5**) to replicate a model for possible applications in space for future missions and started testing on a Temperature Control Unit (TCU); this test would simulate how the PH controls growth chamber temperature and humidity by mixing air through metal fins over porous ceramic materials so that water may pass in either direction. From there, thermoelectric modules are used to condition the air to the required temperature set point and to condition the water in the porous metallic materials to attain air humidification or dehumidification; the condensed water is recovered by the WRADS and air will pass through a 300 micron screen and High Efficiency Particulate Air (HEPA) filter to help guard the components of the ECS. The instrumentation will be provided and regulated via LabView and controllers to observe and control temperature and humidity for the inlet and outlet. The setup involved a duct vent attached to a duct assembly with a coldplate and ORU HCU house (**Fig.6 and 7**). Overall, this test would produce data for power consumption of the fan and thermoelectric coolers versus the amount of heat rejected; another essential decision on the settings/conditions that will make for a more capable and longer-lasting APH system.



Figure 5: The depiction of a modified Hydroponics Plant Growth-Wheel with an LED tube for lighting (center) and an internal water-feeding system



Figure 6: A duct vent attached to a duct assembly with a coldplate and ORU HCU house

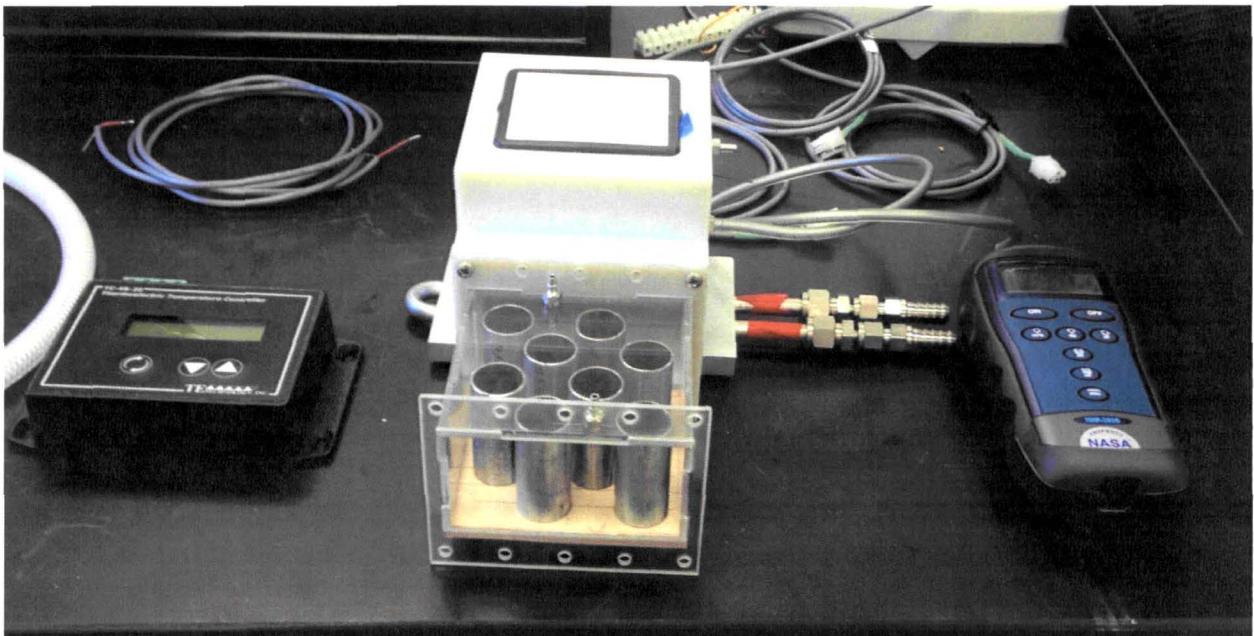


Figure 7: Duct Assembly with Coldplate and ORU HCU House (center) along with a TEC Controller (left) and Manometer (right)

4. Conclusion and Personal Statement

In all, although there is so much more to learn about the APH system, this summer term (my second overall internship with KSC) has been very beneficial; The projects of the OSB-II varies very much from that of the Bioreactor Lab of the Space Life Science Lab (my location for the 2012 summer term and where I received an offer to return for the 2013 term) in terms of the technology utilized, software for data analysis, and many others. However, these are variables I always saw as a challenge and ways to further improve my knowledge and skills as an engineer and continue to link, back and forth, the role of a student with that of a professional engineer. Despite not getting a chance to finish the Temperature Control Unit testing in the later end of the summer term due to scheduling conflicts, wait-time for parts and machining, other assignments, and the overall short length of my internship (10 weeks), the testing will surely continue on in my absence and same for the vast and impressive progress on the Advanced Plant Habitat Unit.