NCERA-101 STATION REPORT FROM KENNEDY SPACE CENTER, FL, USA (Mar. 2013)

Impact Nugget:

A small plant growth chamber called "VEGGIE", for growing vegetables on the International Space Station (ISS) was built by ORBITEC, Madison, WI and delivered to NASA's Kennedy Space Center. The VEGGIE is scheduled for installation on the ISS beginning in Oct 2013. KSC and ORBITEC will team up to conduct a technology verification test growing lettuce on the International Space Station.

Facility Description:

The Space Life Sciences Lab (SLSL) Controlled Environment Lab (CEL) has been operational for 9 ½ years (commissioned Sept. 2003) and provides 622+ ft^2 (58 m^2) of controlled environment chamber space. The CEL provides support to both basic and applied research with emphasis on ground-based and space applications. Redundant to local chamber environmental control, the laboratory has developed and maintained a centralized command, monitoring, and data system (CMDS) with an associated database and alarming capabilities. The CEL is used to support the needs of a variety of scientific research areas including NASA, private industry, and academia. NASA has returned operations of the SLSL to Space Florida, the agents representing the State of Florida. The NASA-related research at the SLSL is being managed under the Engineering Services Contract (ESC), with QinetiQ-North America as the prime contractor.

Kennedy Space Center (KSC) management is still looking at moving the biological research group from the Space Life Sciences Lab (SLSL) to some other facility on the main part of KSC. Whether we would continue to use the growth chambers in the SLSL building, or move some chambers to another facility is still to be determined. Stay tuned for further developments from Florida.

New Equipment / Sensors / Control Systems:

- We continued to test "UFO" red/blue LED lighting fixtures (50 W each) as part of growing plants in a human habitation testbed, called the Habitation Demonstration Unit or HDU. The crops were grown in an "atrium" surrounding a lift that went between the lower and upper modules of the HDU. The fixtures were purchased from AIBC Intl., Ithaca, NY Office, USA. Measurements using an integrating sphere showed the fixtures were approximately 25% efficient (i.e., 25 W of PAR from 100 W of electric power).
- We also tested 10 custom-built, white (warm white) LED flat panel lighting fixtures from AIBC. The thin panels are dimmable and can provide approximately 300 µmol m^{-2} s^{-1} at 6 inches (15 cm) below the panel. The panels were tested in 2012 in the same human habitation module as the red/blue UFO fixtures in 2011.
- We received 16 red/blue/green smart LED High Efficiency Lighting with Integrated Adaptive Control or HELIAC "Lightsicles" from ORBITEC, Madison, WI, USA. These linear LED arrays were built on a Small Business Innovative Research grant from NASA and tested at Purdue University for intra-canopy lighting applications with plant detection capabilities. The Lightsicles have been mounted on the inside of a rotating plant growing drum (Volksgarden, Omega Garden) to provide lighting for the plants grown on the periphery of the drum, and in a non-rotating control system in the same chamber.
- We tested seven small LED units from ORBITEC to conduct light transmission studies. Lights wavelengths are: 400, 450, 530, 595, 630, 655 and 735 nm. Crops tested included lettuce, soybean, pepper, canola, radish, and cucumber.

Unique Plant Responses:

- Transmission data of different spectra LEDs showed the expected high attenuation of blue and red wavelengths (2-8% transmittance), with greater transmittance in the green to amber (10-13%), and the greatest transmittance (~51%) in the far-red. These were averaged for several species and from leaves grown at different PPF levels.

Accomplishments:

- Completed the third operational field testing of the food production system called the plant atrium in the Deep Space Habitat (DSH) at NASA's Johnson Space Center in Aug.- Sept. 2012. Lettuce (two cvs), mizuna, radish (two cvs), were grown under white LED lighting for the 2-week duration of the test. The crew also went through surface sanitizing procedures before consuming any of the harvested plants. One of the trays was outfitted with sensors and an

automatic irrigation system by Ohio State University students as part of the eXploration HABitation (X-HAB) challenge program. Peter Ling was the faculty advisor for the student team.

- We have been working with Orbitec and engineering teams at KSC to provide inputs for a design of a "large" plant research chamber that would be installed in the International Space Station. The "Advanced Plant Habitat" would be the largest plant chamber every flown in space (approximately 0.2 m^2 growing area). Building the chamber and ultimately launching it to the ISS would be subject to program directives and of course funding. Stay tuned for future updates.

- Continued testing passive water and nutrient delivery system for microgravity to support salad crop production in space using ORBITEC's VEGGIE plant growth unit. The rooting packets or "pillows" contain an arcillite media and time-release fertilizer and then draw water passively through capillary connections to a Nomex fabric connected to a water reservoir. The concept seems to work well but we've had some challenges maintaining complete seals on the reservoirs. The testing led to a formal "Science Verification Test" (SVT) conducted at KSC, which will be followed by a second SVT and then a payload verification test (PVT), which is the final dress rehearsal before launch. In addition to lettuce, flowers are also being tested for growth while the crew awaits microbial tests on lettuce.

Impact Statements:

- For a third year, NASA KSC has demonstrated salad crop production using realistic environmental constraints in a simulated outpost as part of NASA's Deep Space Habitat project. The crew responded positively to having plants in the environment and consumed half of the plants for fresh salads. The crew also gave positive comments about the white LED light within the habitat.

Recent Publications/Presentations:

Hummerick, M.P., J. Gates, B-T. Nguyen, G.D. Massa and R.M. Wheeler. 2012. The effect of plant cultivar, growth media, harvest method and post-harvest treatment on the microbiology of edible crops. Amer. Inst. Aeronautics Astronautics, AIAA 2012-3506, 42nd ICES, San Diego, CA.

Levine, LH, J.L. Coutts, J.T. Richards, P.E. Hintze, and C.A. Clausen. 2012. Review on transforming TiO_2 into a visible-light- responsive catalyst for water and air purification. Amer. Inst. Aeronautics Astronautics, AIAA 2012-3629, 42nd ICES, San Diego, CA.

Downey, P.J., L.H. Levine, M.E. Musgrave, M. McKeon-Bennett, and S. Moane. 2012. Effect of hypergravity and phytohormone on isoflavonoid accumulation in soybean (*Glycine max* L.) callus. Microgravity Sci. Technol. DOI 10.1007/s12217-012-9322-9

Kaplan, F., W. Zhao, J.T. Richards, R.M. Wheeler, C.L. Guy and L.H. Levine. 2012. Transcriptional and metabolic insights into the differential physiological responses of Arabidopsis to optimal and supraoptimal atmospheric CO_2. PLOS ONE 7(8):e43583.

Paul, A.L., R.M. Wheeler, H.G. Levine, and R.F. Ferl. 2013. Fundamental plant biology enabled by the Space Shuttle. Amer. J. Bot. 100(1): 226–234.

Scientific Outreach:

Committees / Panels:

ASHS CE Working Group (Stutte, Wheeler, Massa)
Intl. Advanced Life Support Working Group (Wheeler)
Com. on Space Research (COSPAR) F4 (Wheeler)
ACMAP Board of Directors (Stutte)
ASGSR Governing Board (Massa)

Sabbatical Leave

Gary Stutte, Marie Curie Fellowship from EU
(working at Limerick Institute of Technology, IE)