

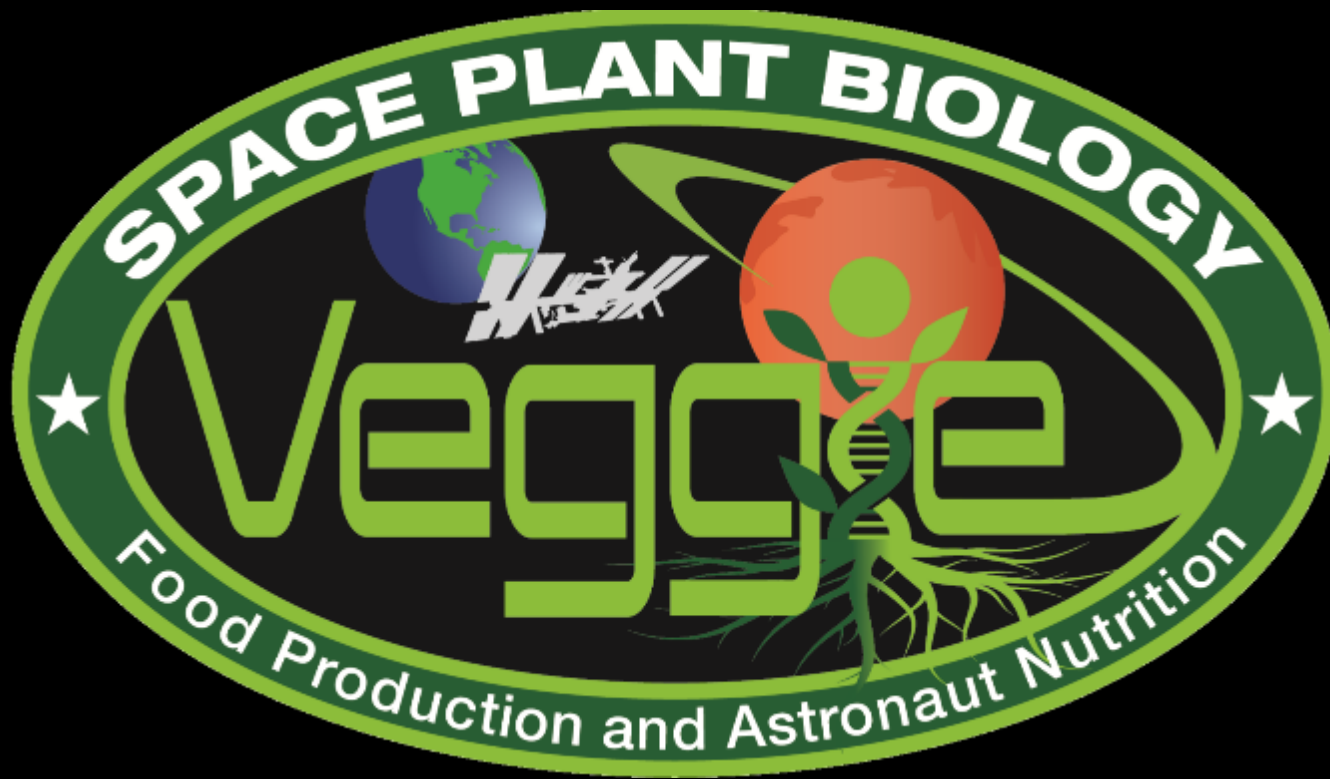


Growth Chambers on the International Space Station for Large Plants

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8th International Symposium on Light in Horticulture
May 22-26, 2016 East Lansing, MI

A vertical decorative strip on the right side of the image. It features a close-up of a green leaf at the bottom, a view of the Milky Way galaxy in the middle, and a bright light source (possibly a sun or moon) at the top creating a lens flare effect.

VEGGIE
Vegetable Production System

Veggie on the ISS



An easily stowable, simple, low resource plant growth system capable of supporting plant growth for improving crew habitability.

Veggie Components

LED Light
Cap

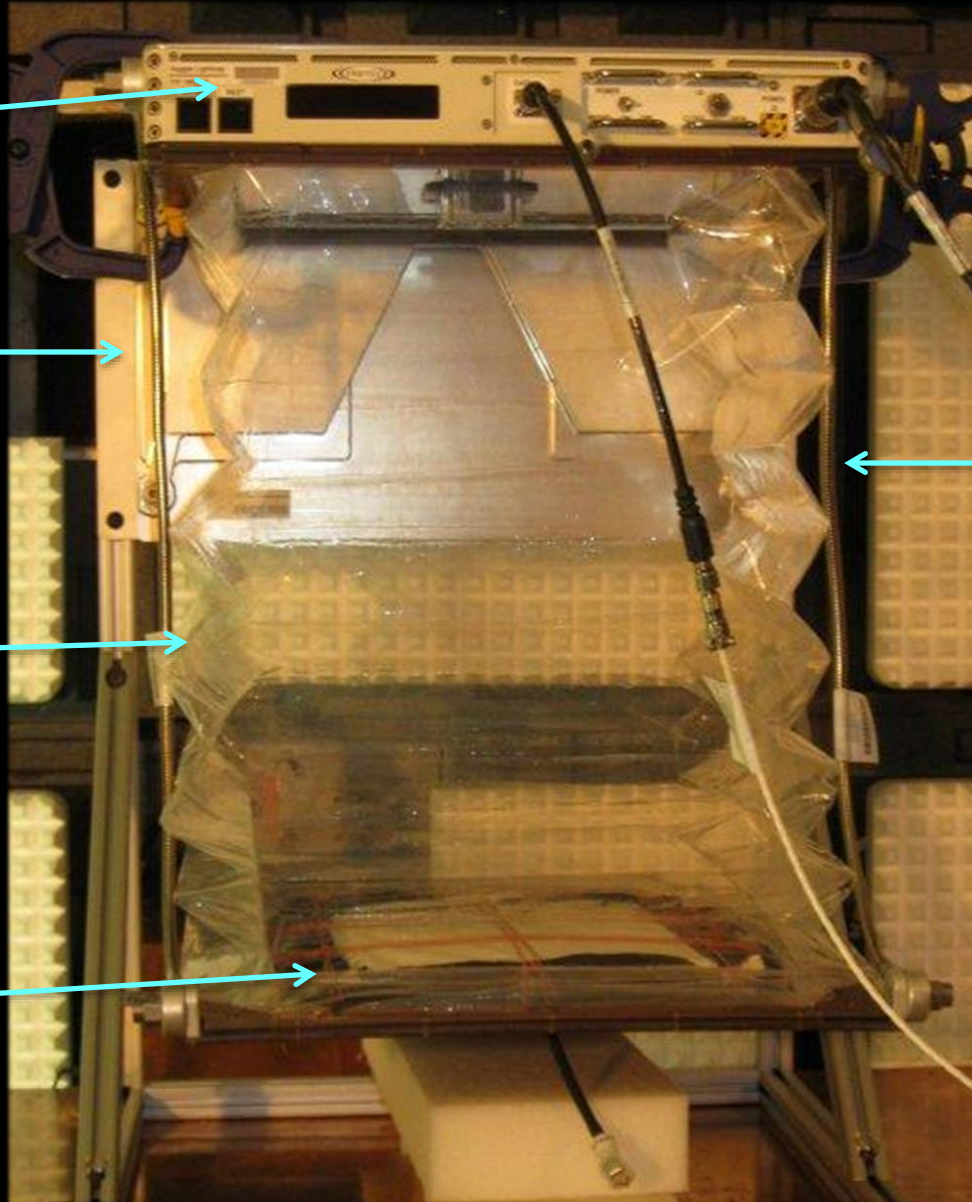
EXPRESS
Rack
Mounting
Plate

Transparent
Bellows

Root Mat
Reservoir

Flexible
Support
Arms

Image courtesy
of Felix Joe, NASA



Plant Pillow Concept

- Different sizes for variety of plant types
 - 1, 2, 3 or 6 per Veggie
- Media and fertilizer containment
- Plant/glue seeds dry
- Hydrate on orbit
- Passive wicking from reservoir
- Minimal maintenance
- Single use, disposable

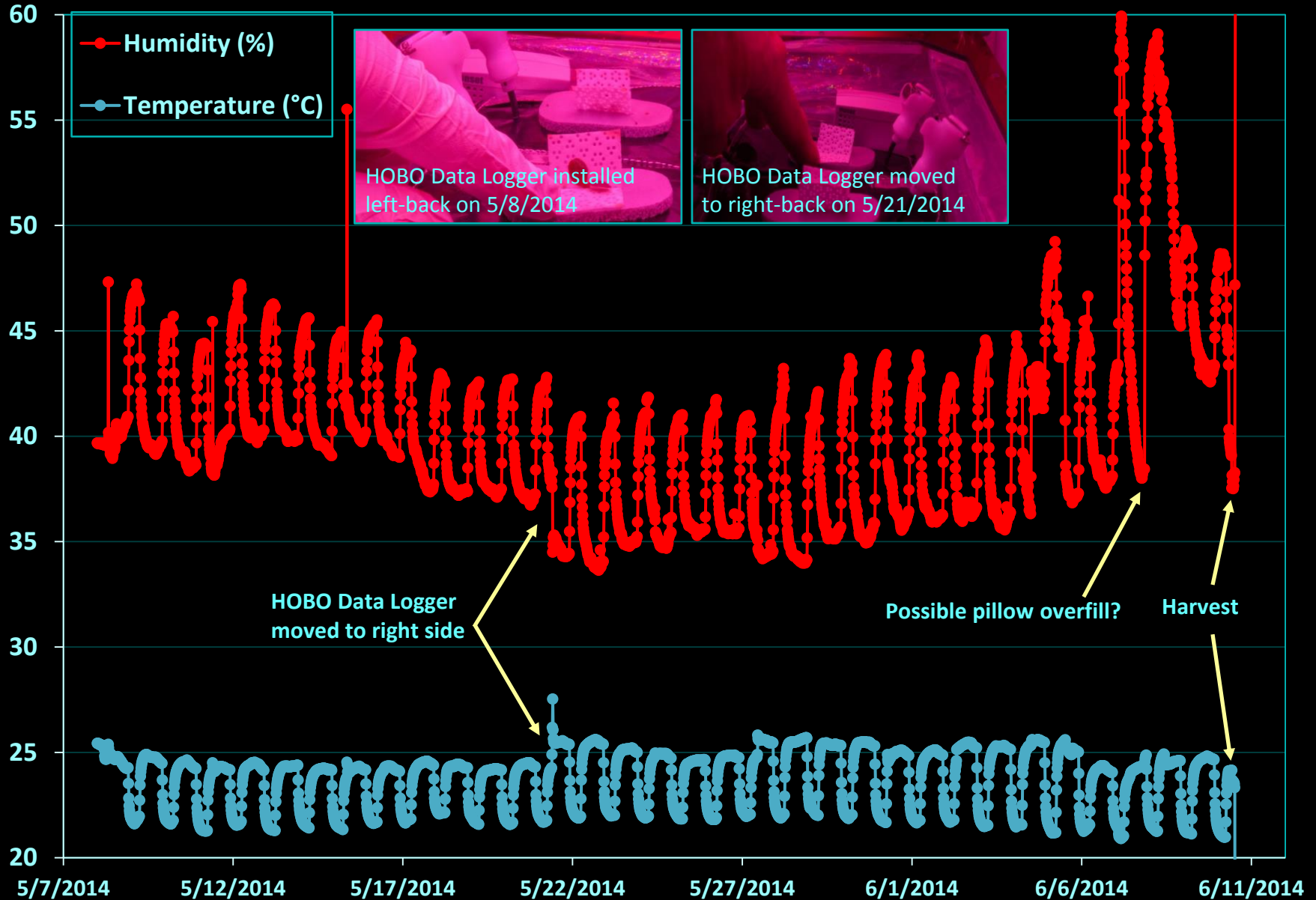


Watering concept being revisited based on microgravity performance

Veggie Specifications

- LED Light Cap: Red (630 nm): low, med, high
 Blue (455 nm): low, med, high
 Green (530 nm): on/off
- Cabin Air Fan: Low / High / Off
- Temperature/RH: monitored by data logger
- Footprint: Baseplate: 29.2 cm x 36.8 cm
 Root mat: 21.6 cm x 35.6 cm
- Max. Height: 47 cm empty; 41.9 cm w/ root mat

Environment Inside Veggie during VEG-01



Veggie Lightcap



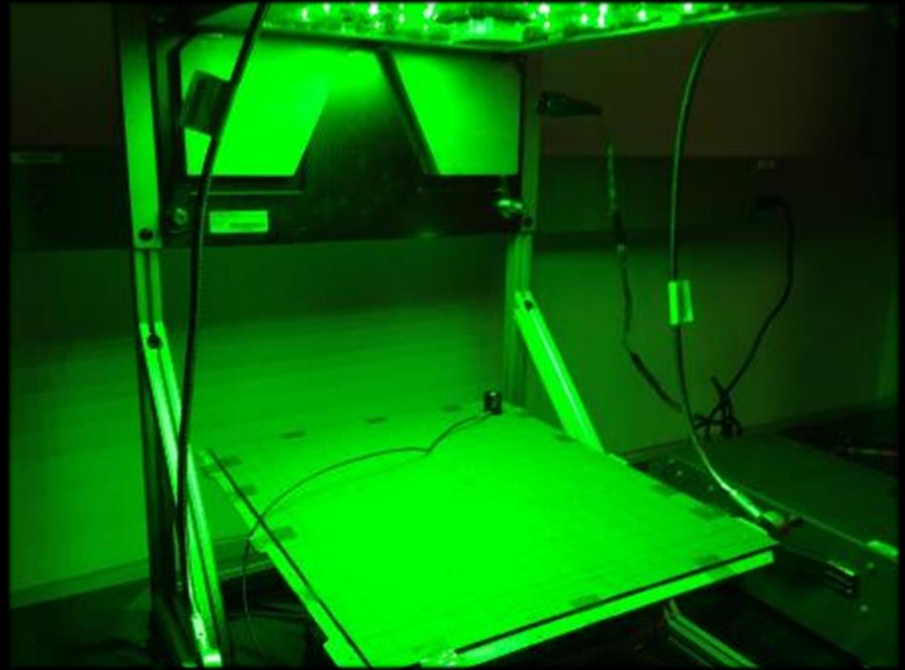
Veggie LED Capabilities

Light Setting	630 nm red	455 nm blue	530 nm green
Low	120 ± 10%	30 ± 10%	-
Medium	240 ± 10%	60 ± 10%	-
High	360 ± 10%	90 ± 10%	-
On	-	-	30 ± 5%
Custom (max levels)	550	150	100

Levels in $\mu\text{mol m}^{-2} \text{s}^{-1} \pm \%$ at 10 cm beneath light cap.

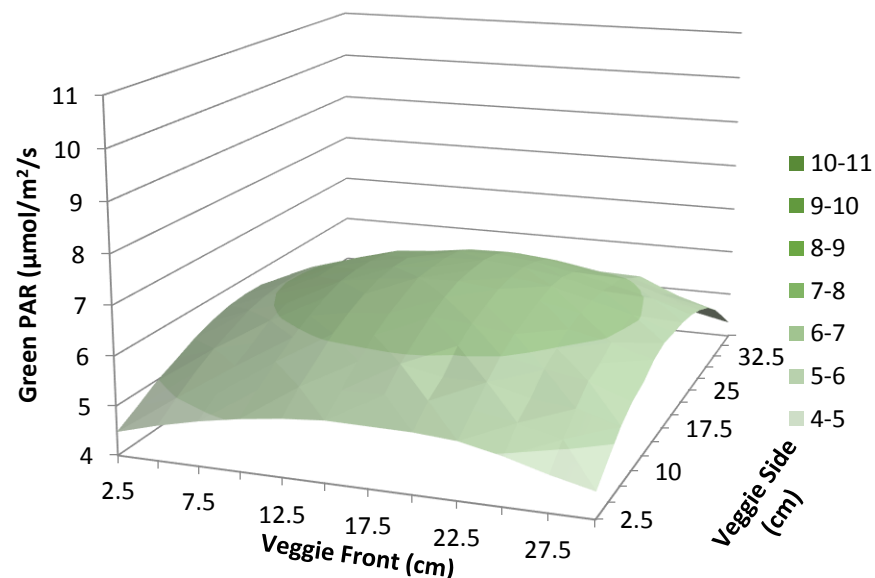
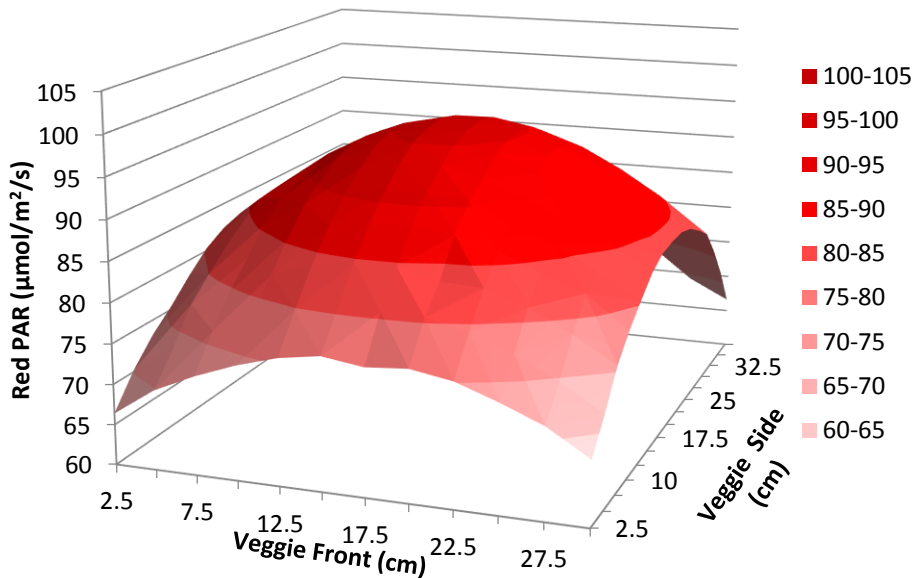
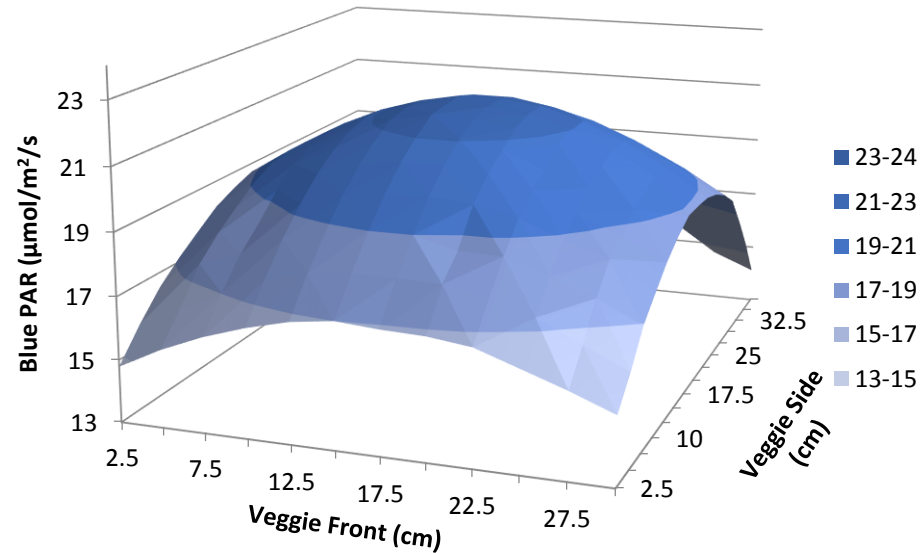
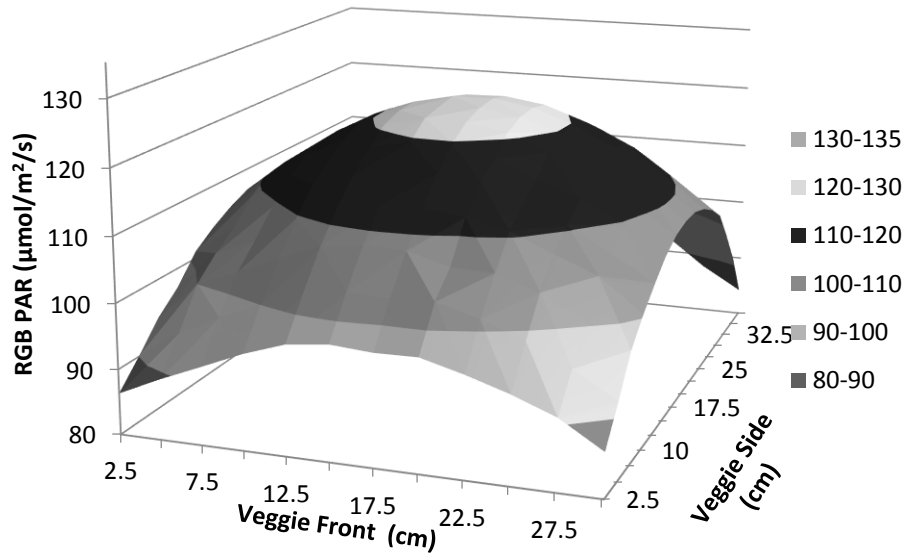
Wavelength requirements are $\pm 10 \text{ nm}$

Veggie Light Mapping

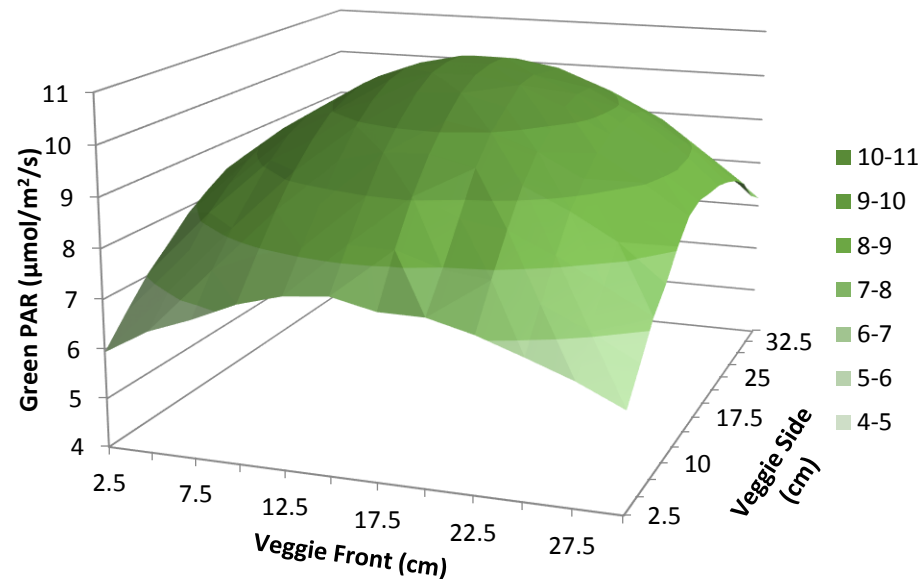
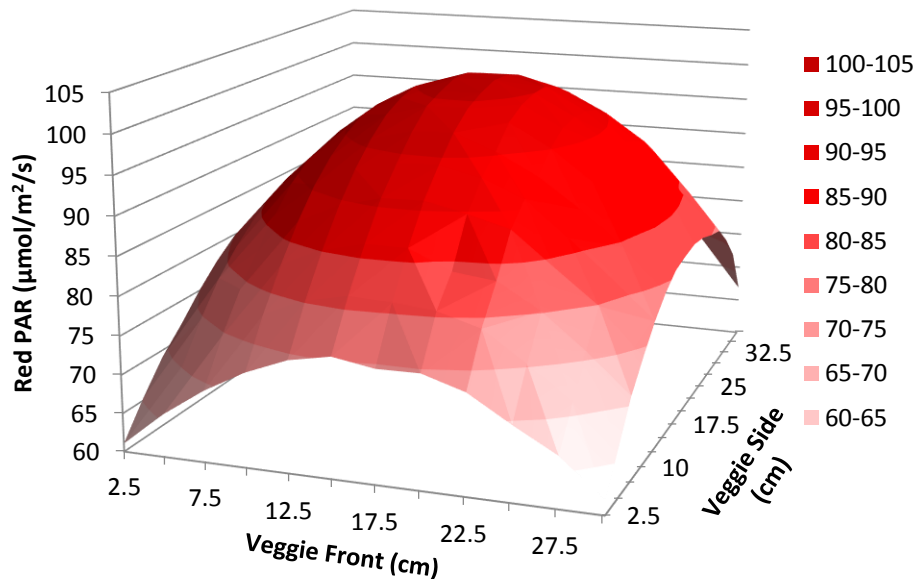
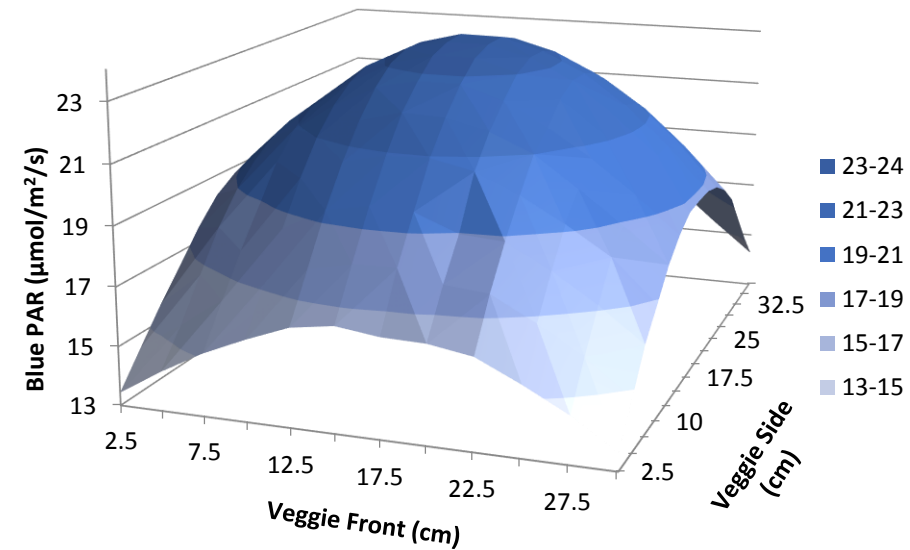
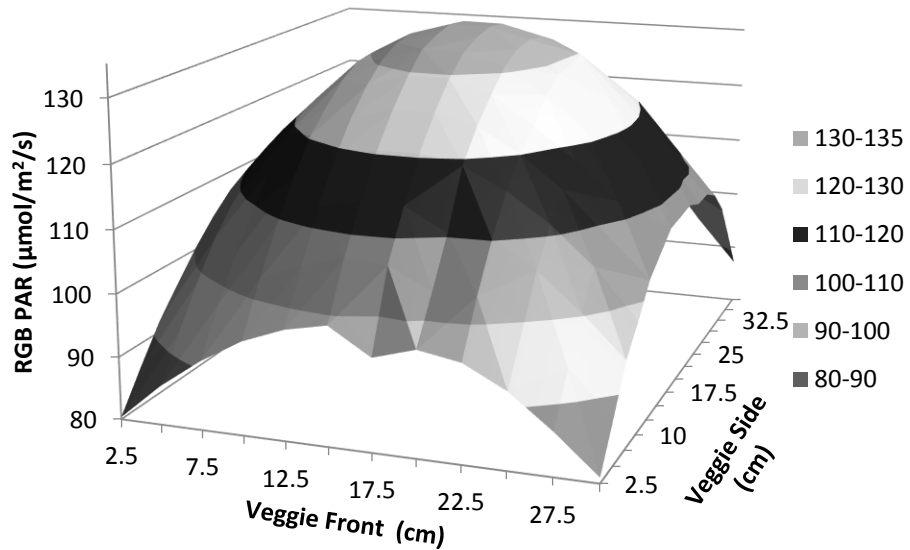


- 180-point light mapping conducted without bellows at different heights
- Bellows provides avg. increase of $5.7 \mu\text{mol m}^{-2} \text{s}^{-1}$ (± 1.4)

Veggie Light Map-High @ 43.5 cm



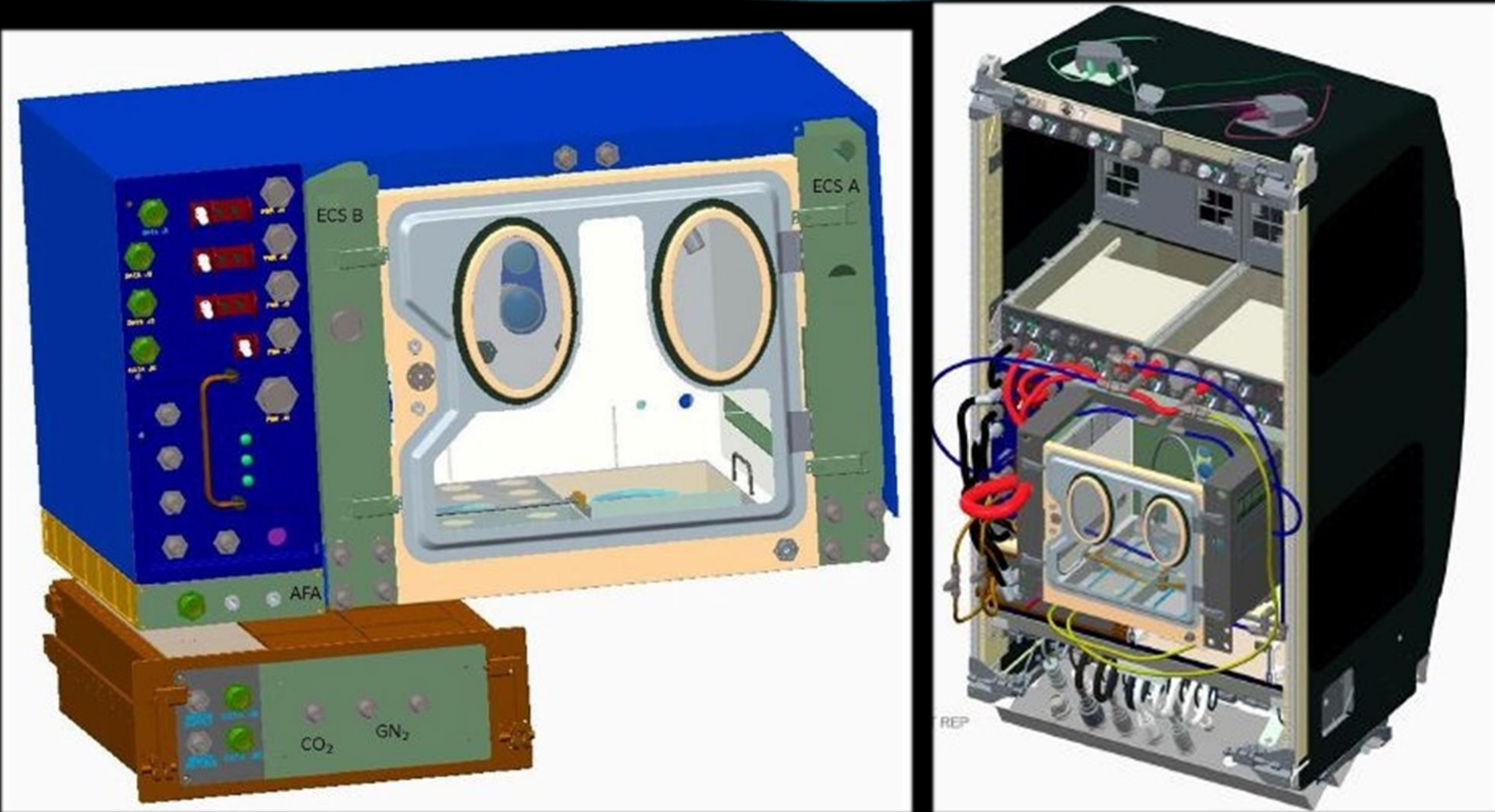
Veggie Light Map-Med @ 32.5 cm



Advanced Plant Habitat



APH Hardware Overview

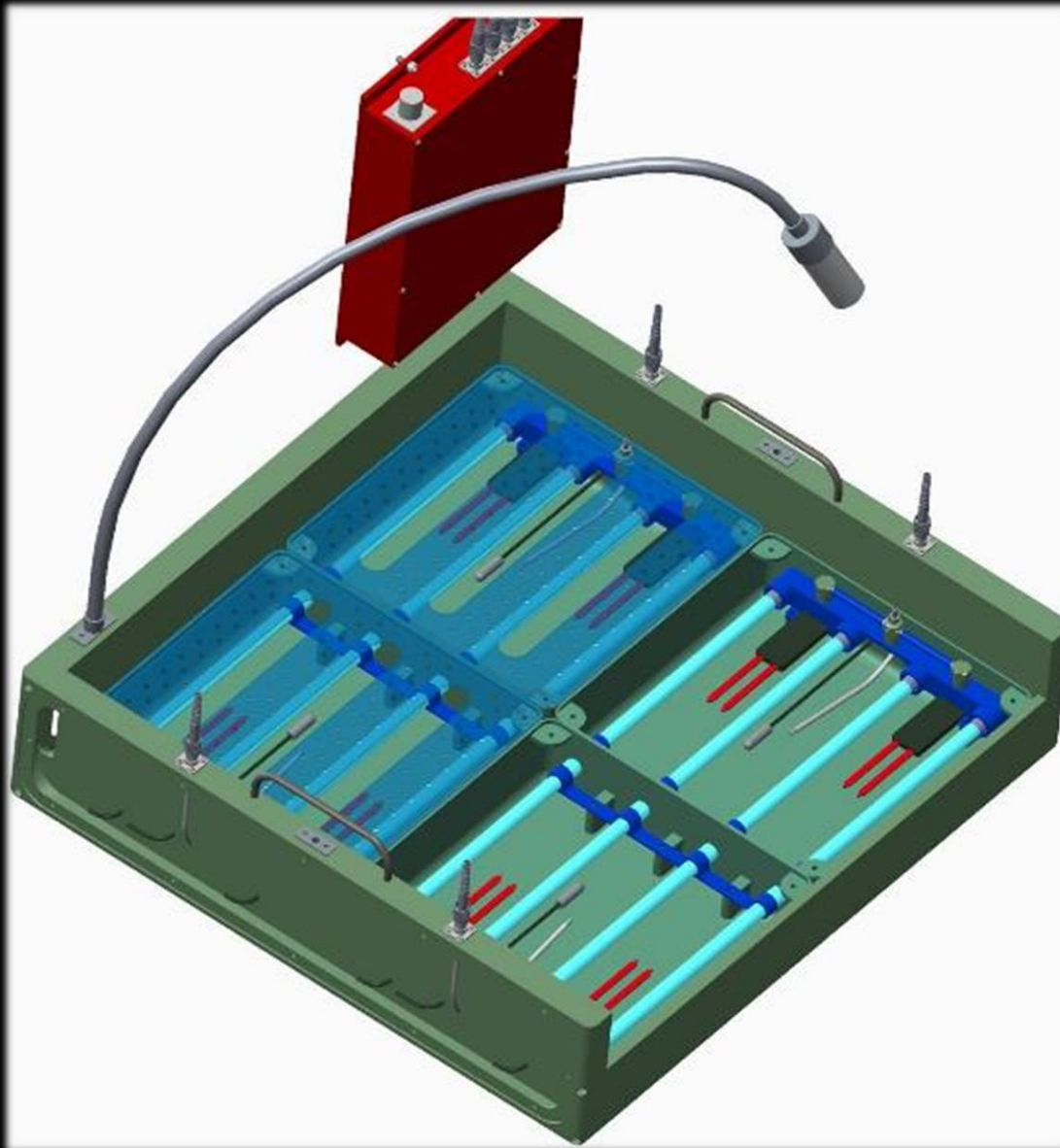


Chamber slides out 10" from main unit for viewing through the top window.

APH Growth Chamber



Base Science Carrier



Dwarf Wheat in Science Carrier in APH EDU



APH Specifications

- Growth Light Assembly: 0-1000 $\mu\text{mol m}^{-2} \text{s}^{-1}$ PPF set in increments of 50
- Colors: Red, Blue, Green, White, Far Red
- Uniformity: $\pm 15\%$ (15 cm below GLA, 5 cm in from wall)
- Temperature: 18°C-30°C ($\pm 1^\circ\text{C}$)
- RH: Controlled / monitored: 50-90% ($\pm 5\%$)
- CO₂: Controlled / monitored: 400 ppm-5000 ppm (± 50 ppm or 3%)

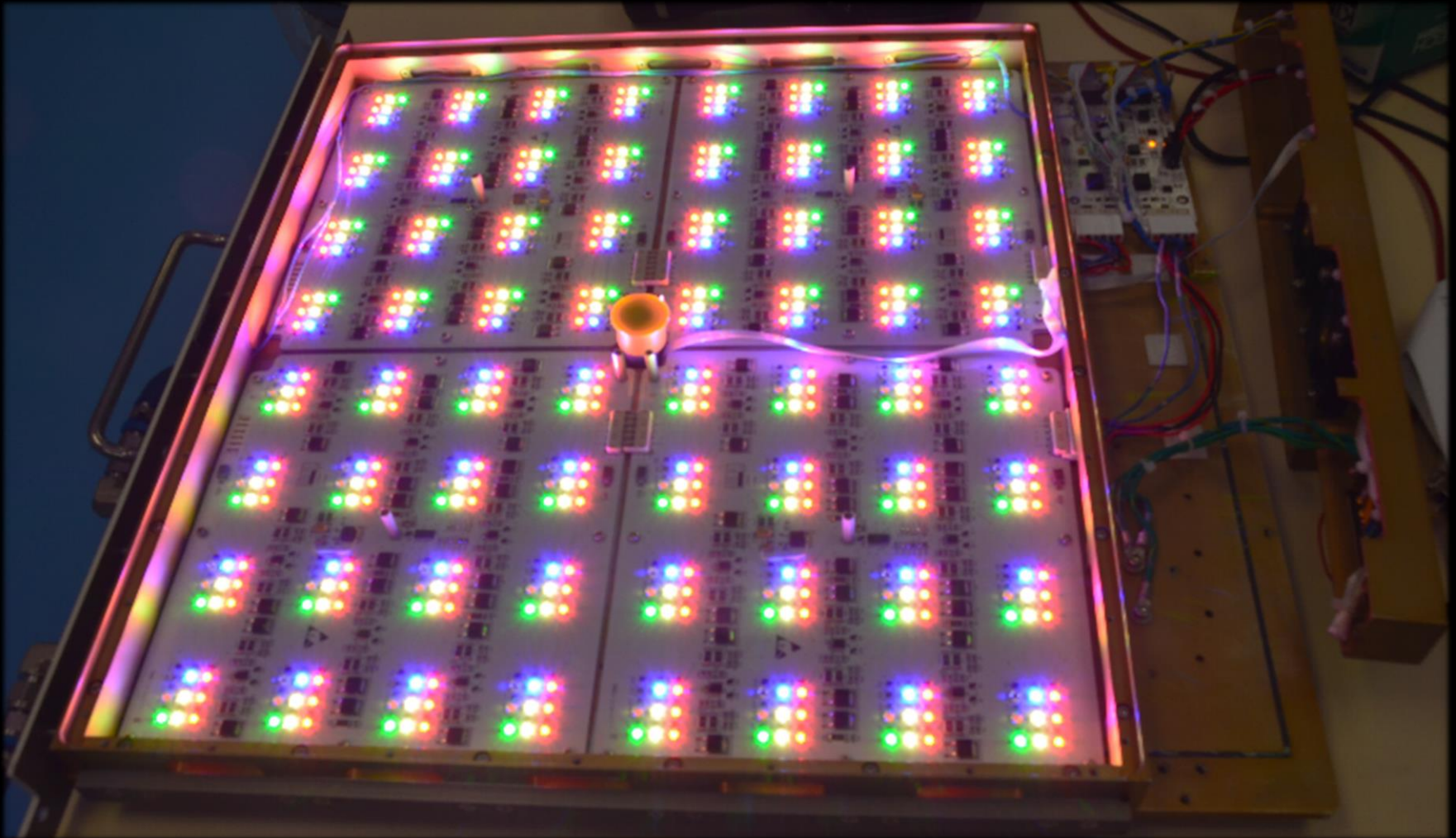
APH Specifications (Cont.)

- Ethylene: Scrubbed to <25 ppb
- Air Flow: Controlled between 0.3-1.5 m/s
- Leak Rate: $\leq 10\%$ by volume a day
- Root Zone Moisture: Monitored 25%-100% ($\pm 10\%$) and controlled by flow rate

Growth Chamber

- Shoot zone: 0.19 m²
- Height: 50 cm total
max. shoot height 45 cm

APH Lightcap



APH LED Capabilities

Wavelength	PPF ($\mu\text{mol m}^{-2} \text{s}^{-1}$)
Red (630 nm)	0-600
Blue (450 ± 10 nm)	0-400
Green (525 ± 10 nm)	0-100
Broad Spectrum White (4100 K)	0-600
Far Red (730 nm)	0-50
No light	≤ 0.02

Max allowable light level is $1000 \mu\text{mol m}^{-2} \text{s}^{-1}$

Imaging

- Top Down and Side Viewing
- Light and Dark Cycle (IR)

Side view, near IR, narrow angle



Top Down view, color



Side view, color, wide angle



APH Additional Features

- Plant experiments up to 135 days
- Removable Science Carrier Tray – base design – 5 cm
- Door plus sleeve ports
- Window
- PAR sensor
- O₂ Sensor-Root & shoot
- CO₂ Sensor
- CO₂ draw-down capability
- Leaf Temperature Sensor
- Air pressure monitored and maintained
- RH condensate recycling
- Condensate measuring
- Air filtration
- Ionizing radiation measurements
- Water and nutrient delivery
 - Porous tubes, solid media
 - Liquid NDS or solid fertilizer
- Sample ports- air, water

Opportunities to Experiment

- For US investigators:
 - NASA Research Announcements
(<https://nspires.nasaprs.com/external/>)
 - Center for the Advancement of Science in Space
(<http://www.iss-casis.org/>)
- For International Investigators:
 - International Life Science Research Announcements
 - Local Space Agencies (ESA, CSA, JAXA, Roscosmos, etc.)

Thank you!

- Veggie and APH teams at Kennedy Space Center and ORBITEC
- Science advisory teams and engineering design review boards
- NASA's Space Life and Physical Sciences and International Space Station Programs

