Validation of the Advanced Plant Habitat Facility on ISS

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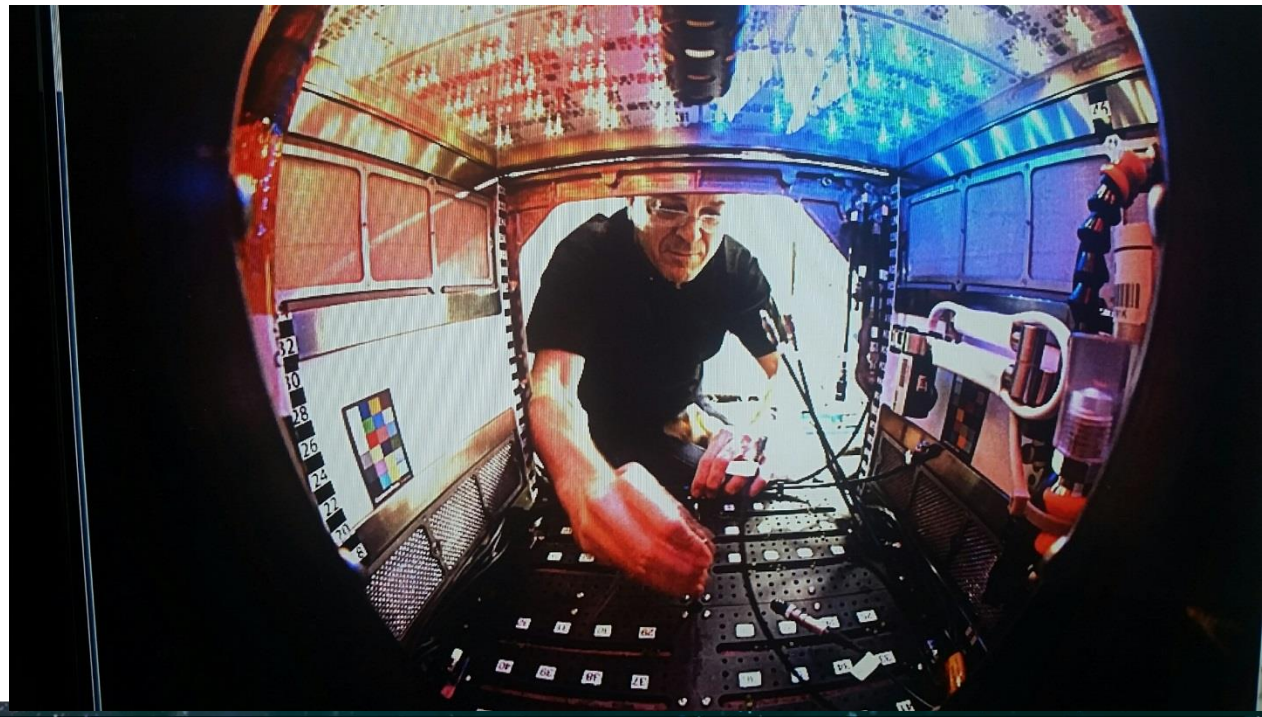


Advanced Plant Habitat

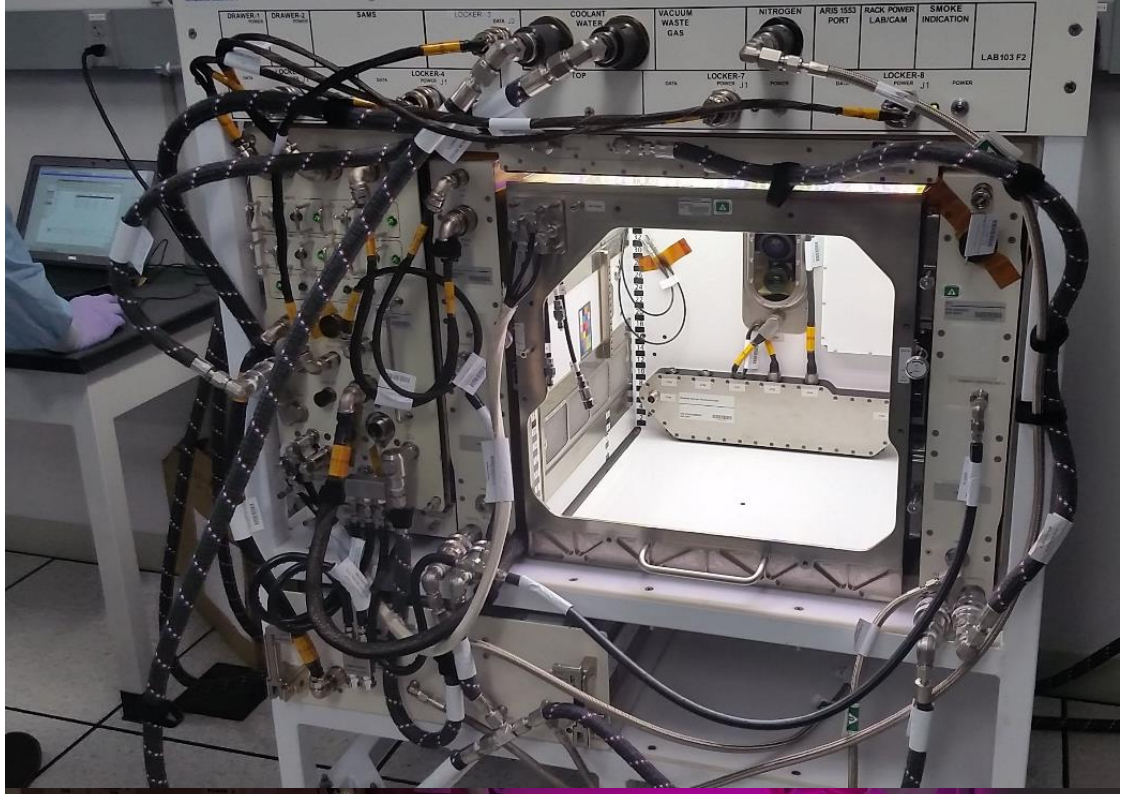
A fully automated plant growth facility for conducting plant research supporting space biology and food production projects on the International Space Station (ISS).

Plants are grown in the Science Carrier (SC) of the APH, (0.2 m^2 instrumented) root module.

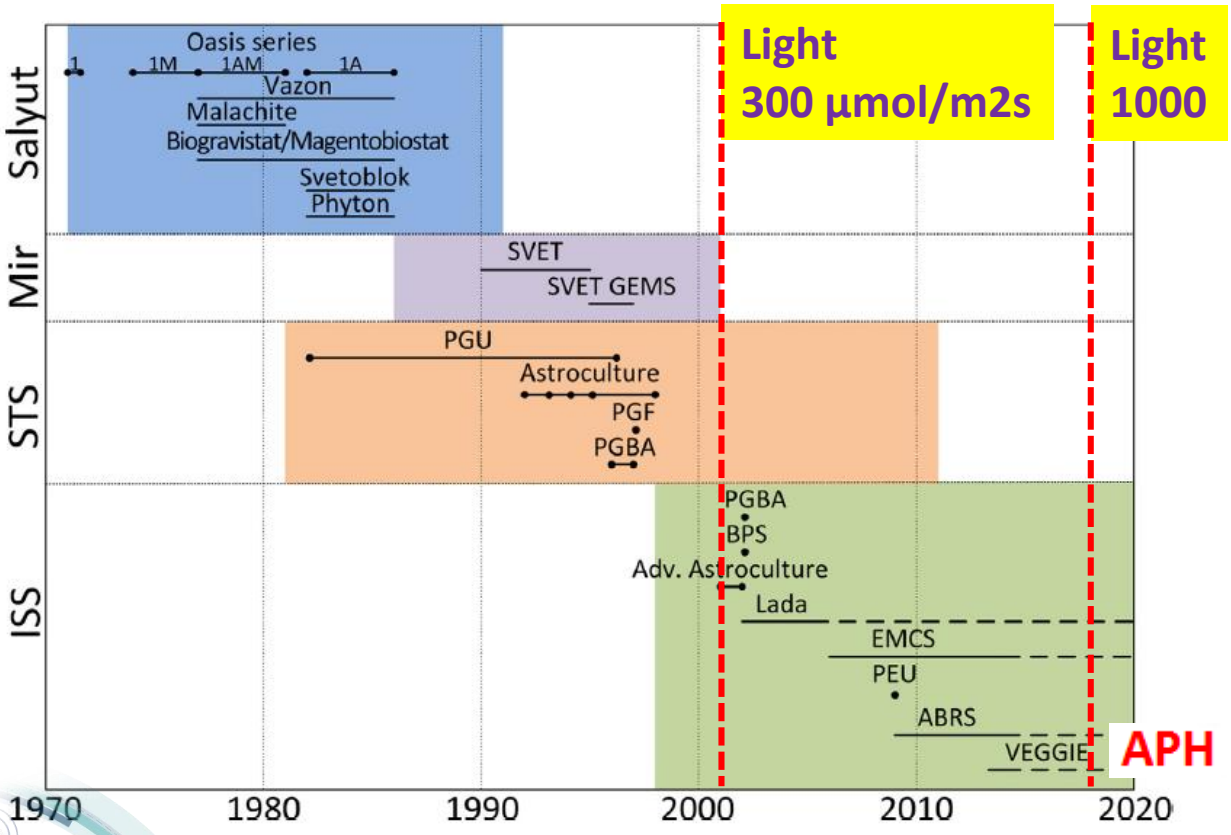
The SC is packed with media, seeded on Earth, and transferred dry to the APH facility on ISS. The plant experiments are initiated when the SC is installed in the APH growth chamber and it is fully wetted.

The planting and germination protocols for growing wheat (cv Apogee) and Arabidopsis (cv Colombia) were developed and tested at KSC in the APH Engineering Development Unit (EDU). These protocols were tested on orbit during the post-installation growth checkout of APH on ISS.

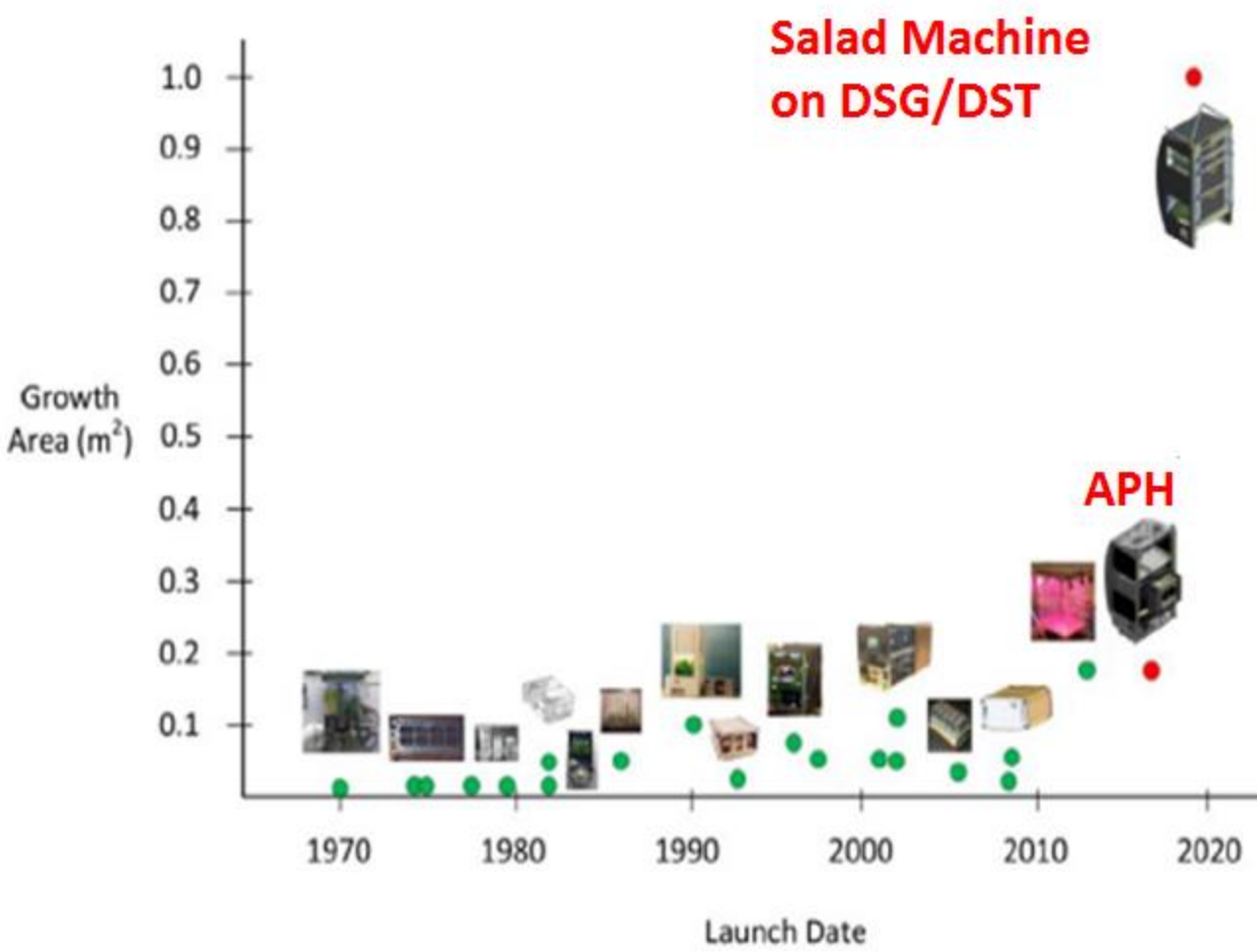
Hardware Validation – 1st plant growth test



Spaceflight Plant Growth Systems

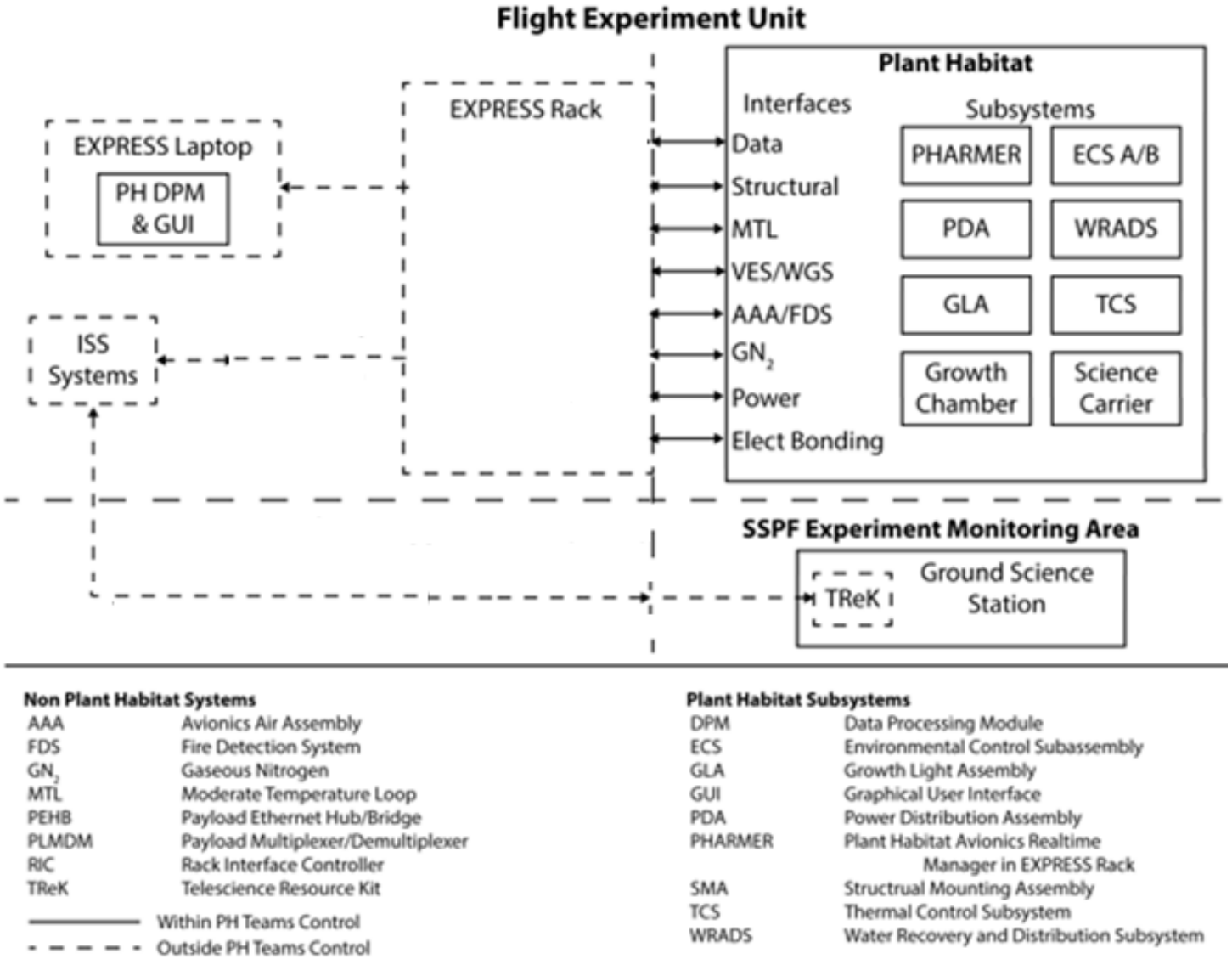


Zabel et al. Life Sci. Space Res. (2016)



APH - Subsystems

The APH communicates with crew via a laptop and receives ground commands from the KSC Experiment Monitoring Area



Non Plant Habitat Systems

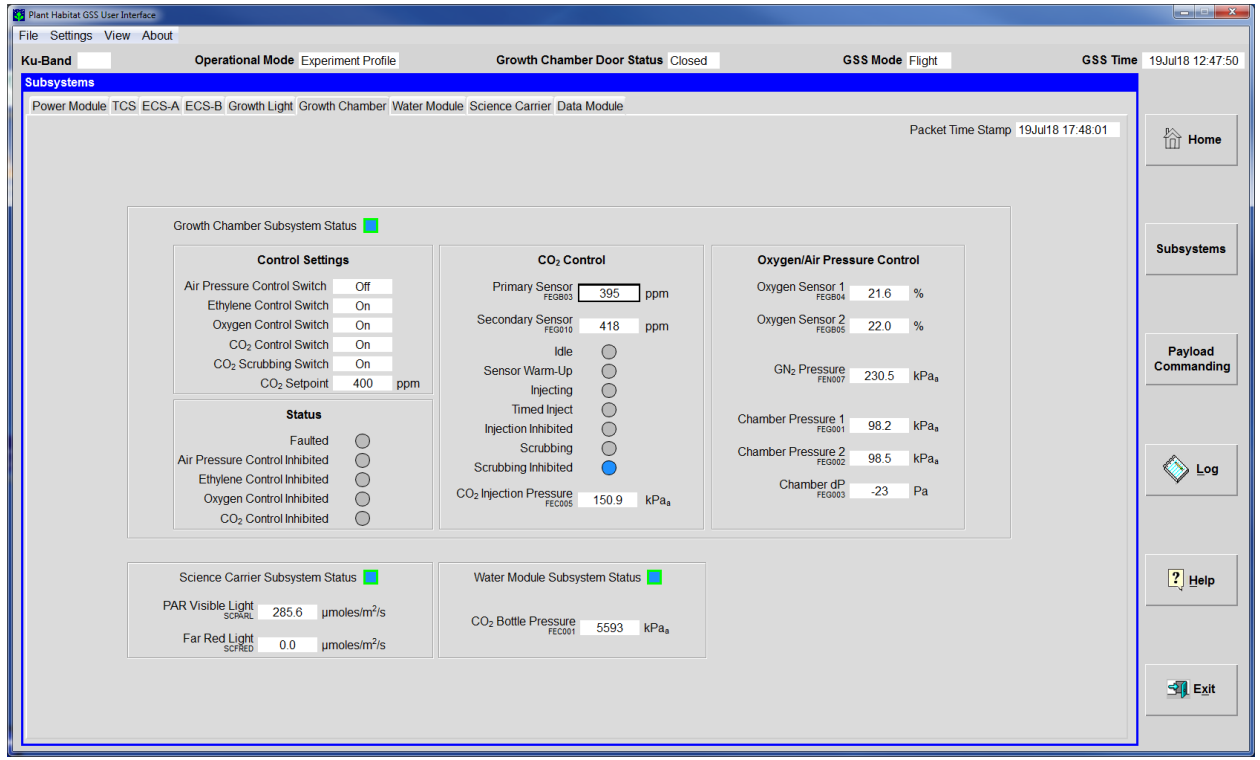
AAA	Avionics Air Assembly
FDS	Fire Detection System
GN_2	Gaseous Nitrogen
MTL	Moderate Temperature Loop
PEHB	Payload Ethernet Hub/Bridge
PLMDM	Payload Multiplexer/Demultiplexer
RIC	Rack Interface Controller
TReK	Telescience Resource Kit
———	Within PH Teams Control
- - -	Outside PH Teams Control

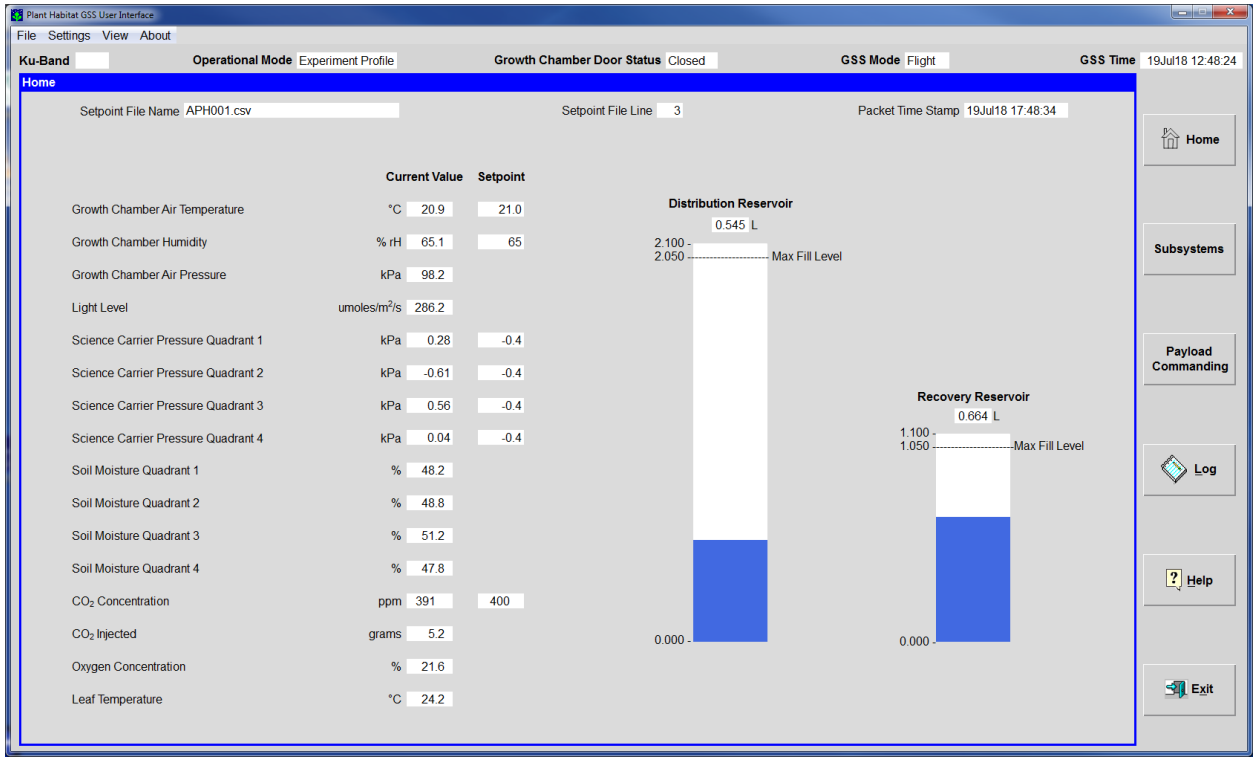
Plant Habitat Subsystems

DPM	Data Processing Module
ECS	Environmental Control Subassembly
GLA	Growth Light Assembly
GUI	Graphical User Interface
PDA	Power Distribution Assembly
PHARMER	Plant Habitat Avionics Realtime Manager in EXPRESS Rack
SMA	Structrual Mounting Assembly
TCS	Thermal Control Subsystem
WRADS	Water Recovery and Distribution Subsystem

Flight Experiment Unit Technical Boundaries

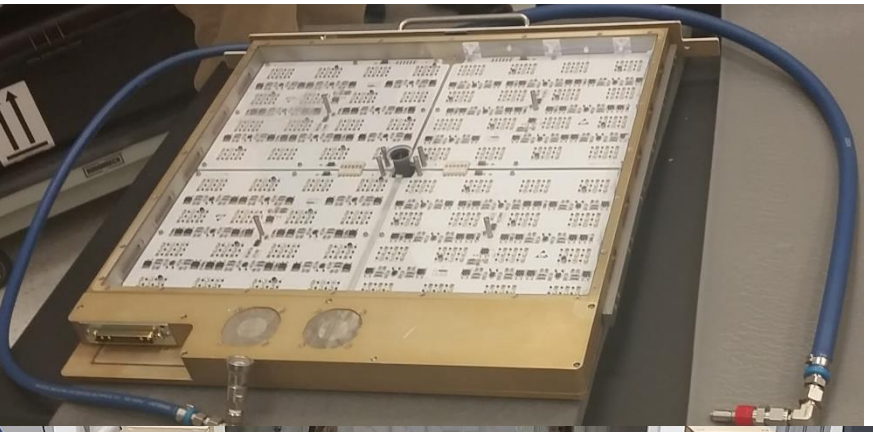
APH – User Interface

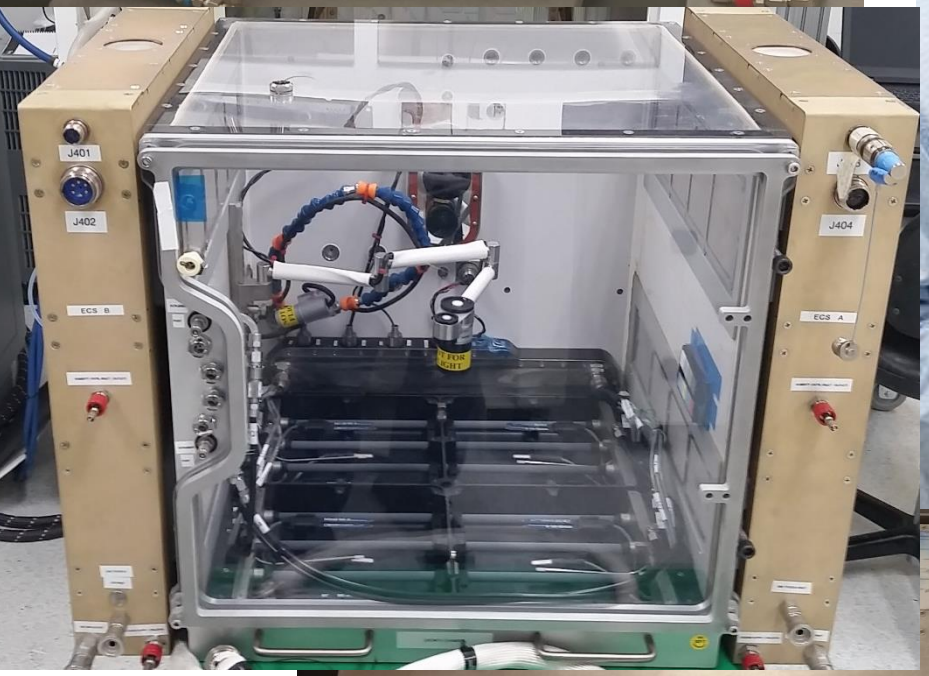




Subsystems

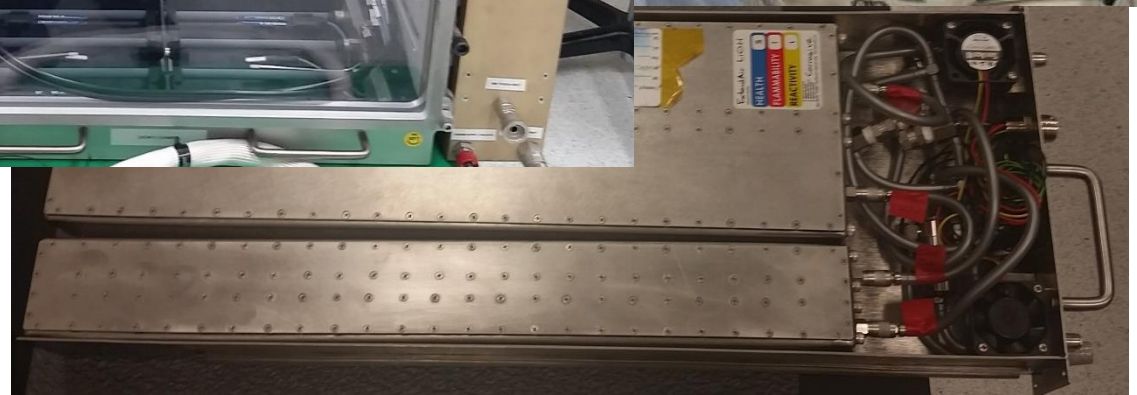
Growth Light Assembly





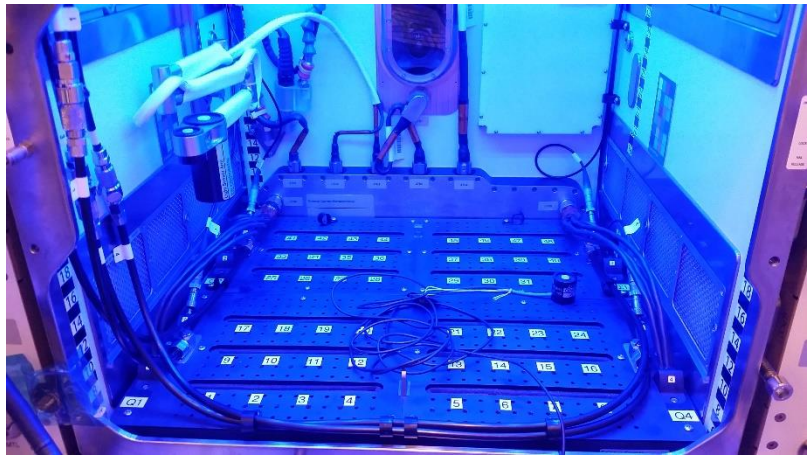
Growth Chamber

ISIS Drawers

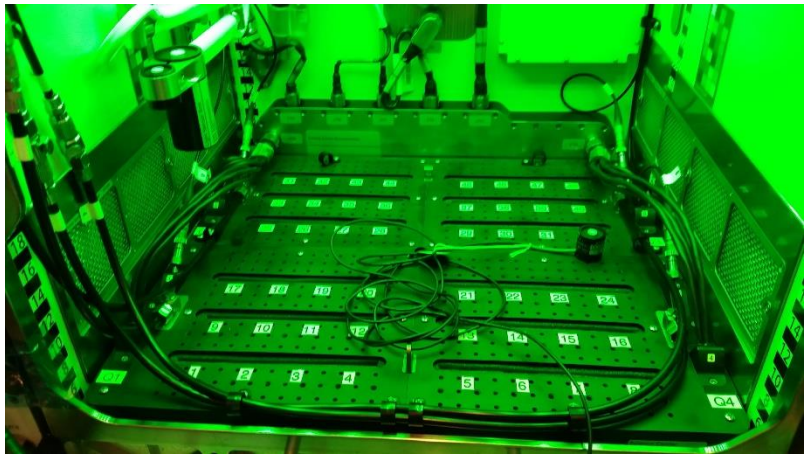


Power Distribution Assembly

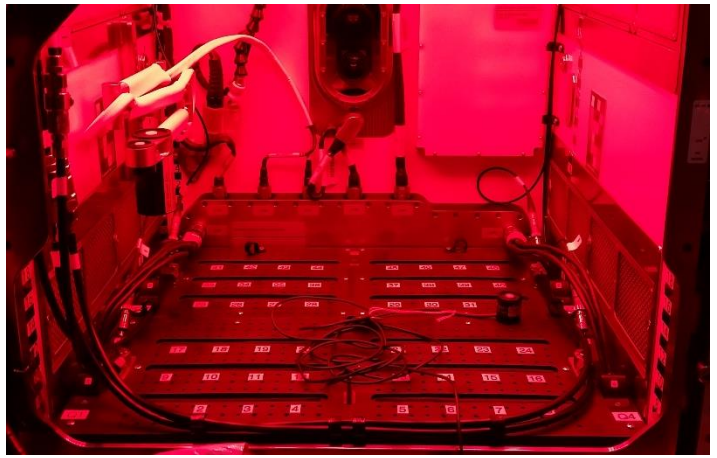
GLA - Spectral Quality & Intensity



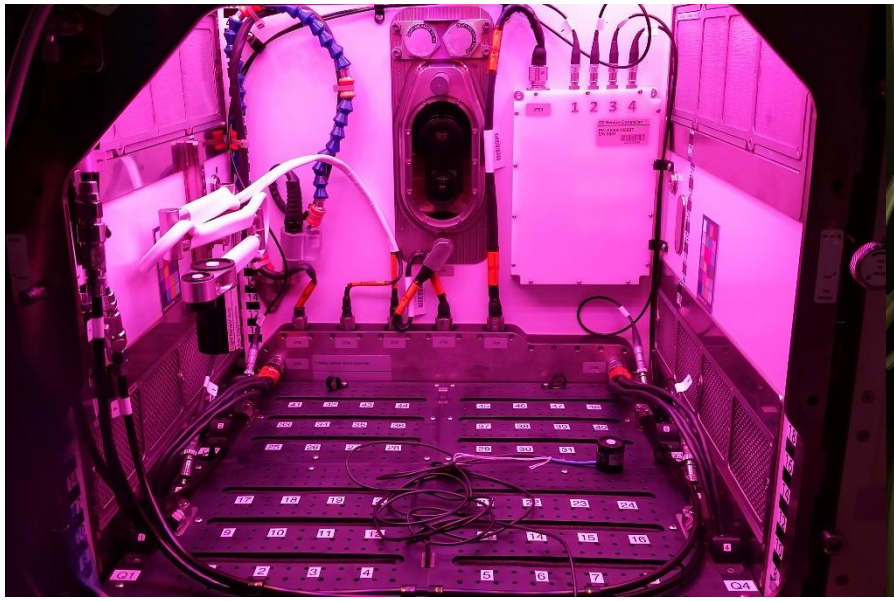
0-400 µmol m^{-2} s^{-1} at 400-500 nm ±10 nm



0-100 µmol m^{-2} s^{-1} at 525 nm ±10 nm



0-600 µmol m^{-2} s^{-1} at 630-660 nm ±10 nm



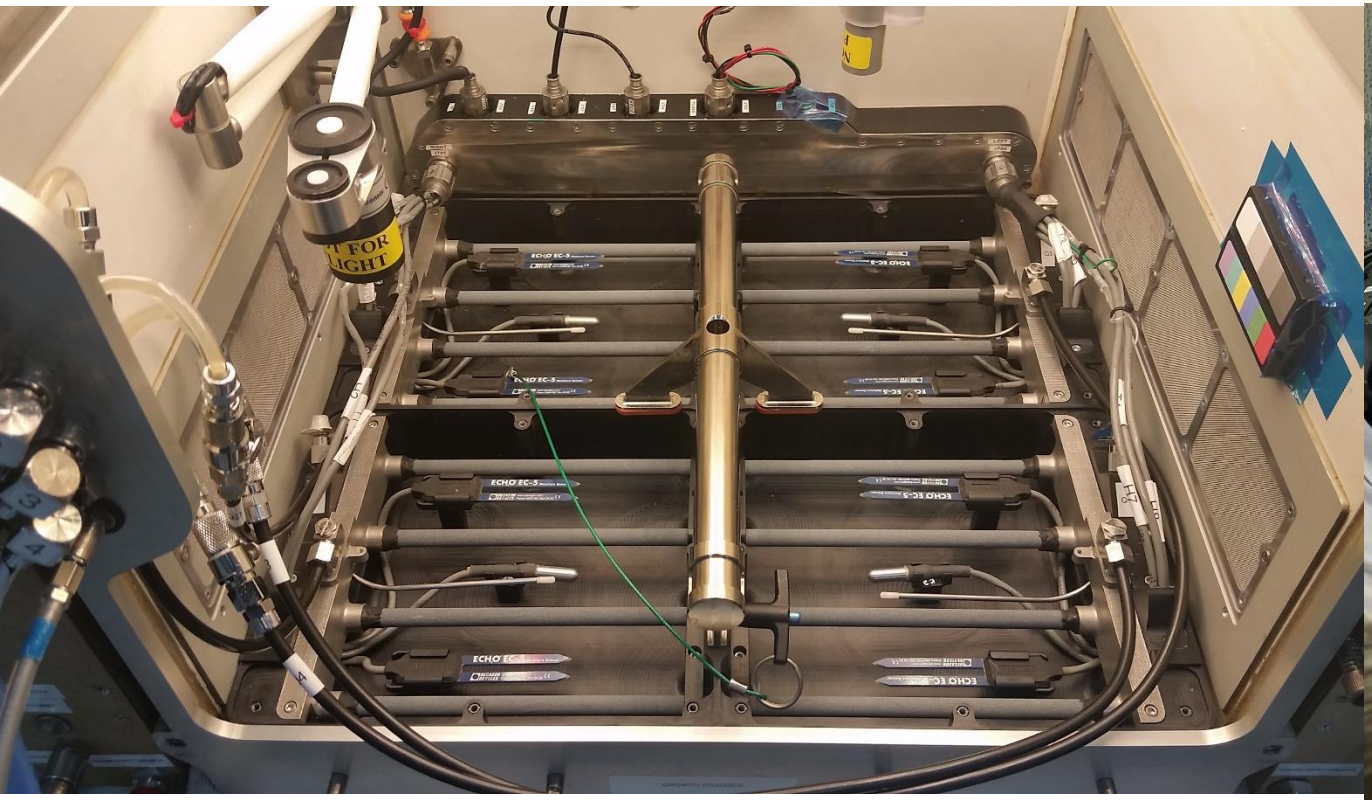
PI Mixture

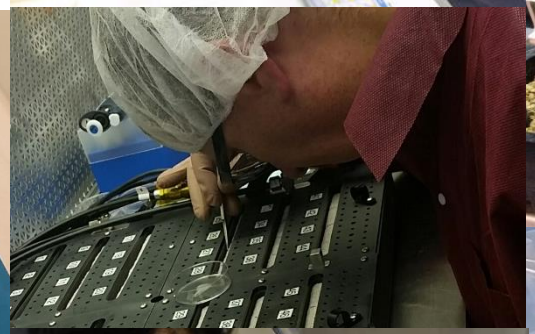
IR 0-50 µmol m^{-2} s^{-1} at 730-750 nm ±10 nm

W 0-600 µmol m^{-2} s^{-1} at 400-700 nm

APH Science Carrier

- Four quadrants – independent moisture control
- Baseline – porous substrate / slow release fertilizer
- Pre-planted / Contain water and substrate





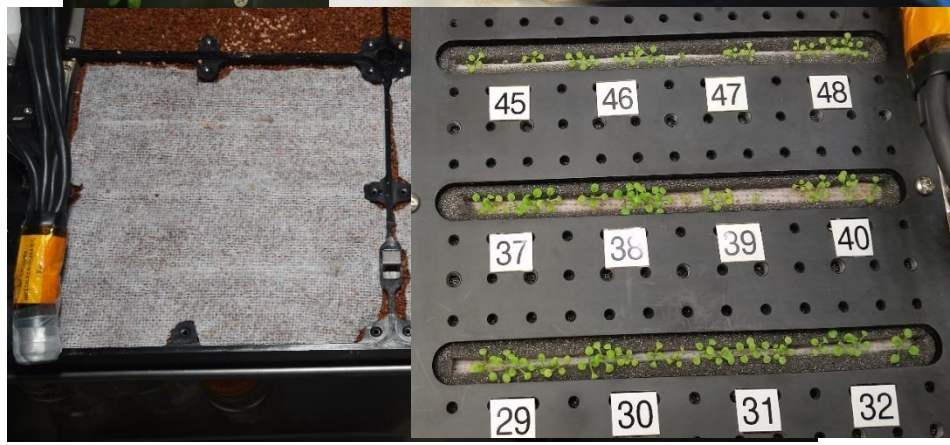
Planting and Germination

The planting protocols (launch vibration):

- Preparing the planting media, foam – sift, autoclave
- Packing (legacy to Mir, BPS)
- Seeding the SC (immobilize seeds).

The germination protocols:

- Seed sterilization
- Determining the wicking system used to germinate the seeds in the SC.
- Determine environmental conditions to ensure germination
- Thinning as needed

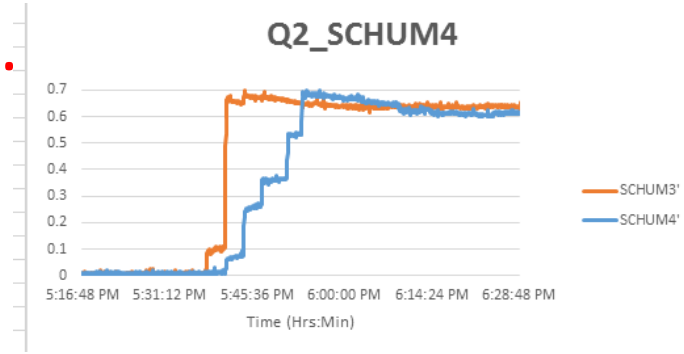


APH Facility – Assembly / Functional Test

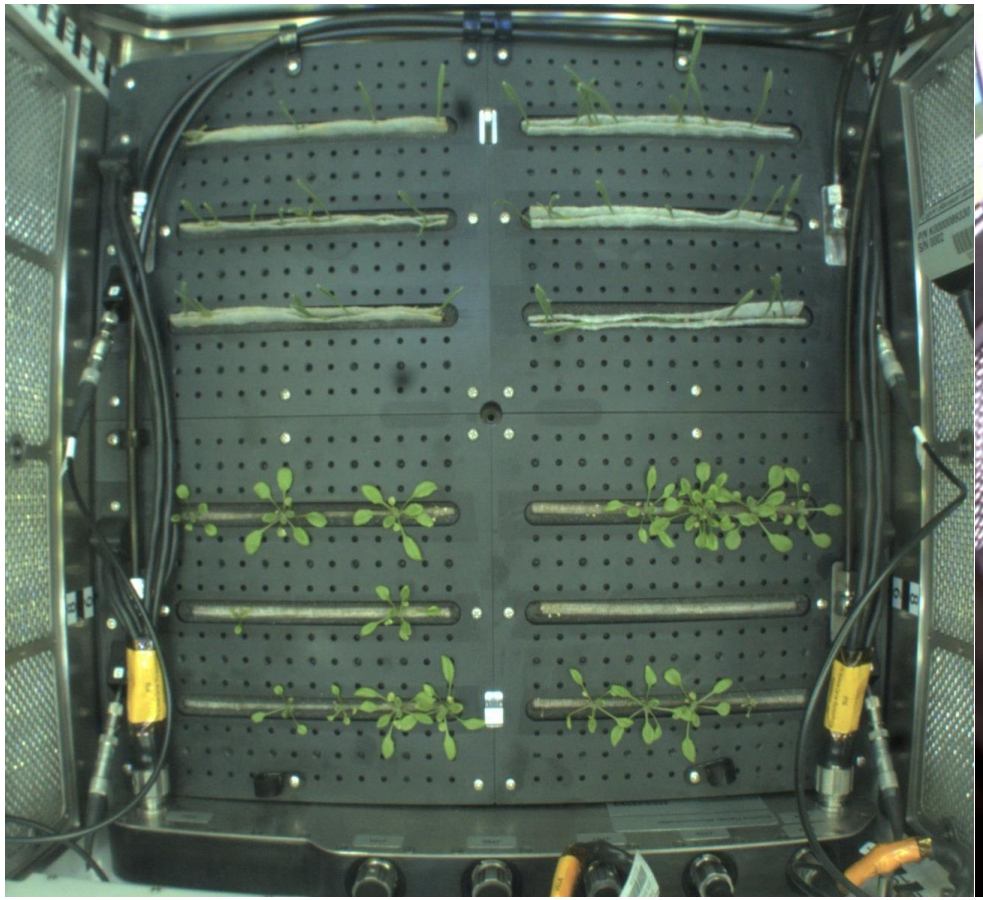
- APH was transported to ISS on SpaceX11 and OA-7.
- APH was assembled on the Kibo Module in Oct 27 2017.
- First power-up and a 5-day functional test was conducted by Astronaut Joe Acaba and the APH team from Nov 27 to Dec 1 2017.
  - Tested commanding, telemetry, and data retrieval from PHARMER.
  - Tested T/RH control modules at 23 C/70% RH, 18 C/50% RH, 18 C/90% RH, 30 C/90% RH, and 30 C/50% RH. Tested light Levels.
  - Tested CO_2 scrubbing, CO_2 injection, Ethylene Scrubbing functions
  - Tested Experiment Profile scripts (T, RH, CO2, Pictures).
- An acoustic test was completed on Dec 8 2017.

APH Facility – Validation Schedule

- Activated APH Jan 19 2018 and initiated First Plant Test on Jan 22 2018 to verify that science is supported on APH hardware.
  - A SC pre-planted with WT Arabidopsis and Apogee semi-dwarf wheat was installed.
  - Two week growth of WT Arabidopsis and 33 days of wheat conducted to demonstrate adequate plant growth for future science experiments.
  - Demonstrate and evaluate performance of on-orbit watering protocols.
- WT Arabidopsis – verify planting protocols of PH-01 Experiment.
- Wheat Plants – provide a biological 'load' on the system.
- Demonstrate on-orbit harvest protocols.

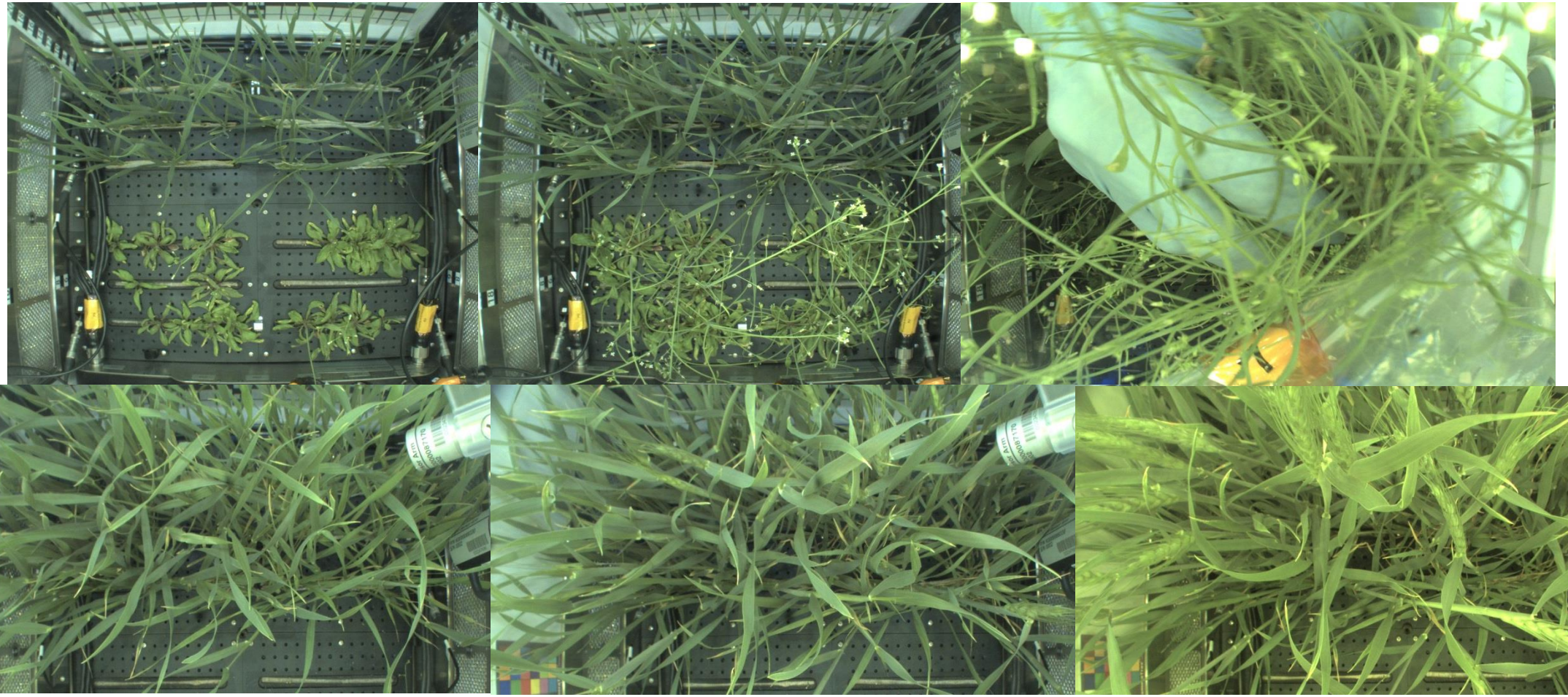


APH Facility – First Plant Test



Feb 13 2018 - Arabidopsis (Quadrants 2 & 3) initiated on 1/22/18 - 3 weeks of growth.
Apogee wheat (Quadrants 1 & 4) Initiated on 2/7-8/18. – 6 day old.

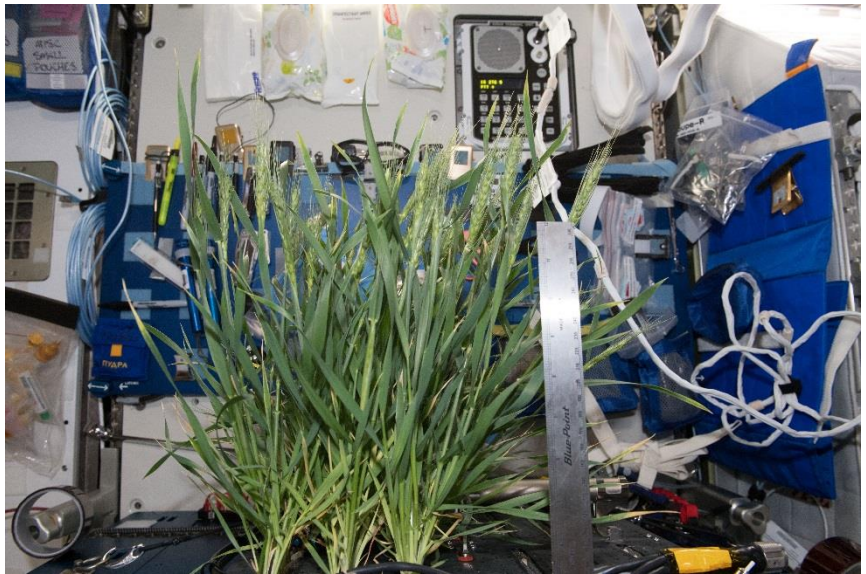
APH Facility – First Plant Test



Feb 22, 26, Mar 6, 9, 12 2018 - Arabidopsis harvested on Mar 6 – observed debris containemnt. Apogee wheat (Quadrants 1 & 4) was 32 days old on Mar12.

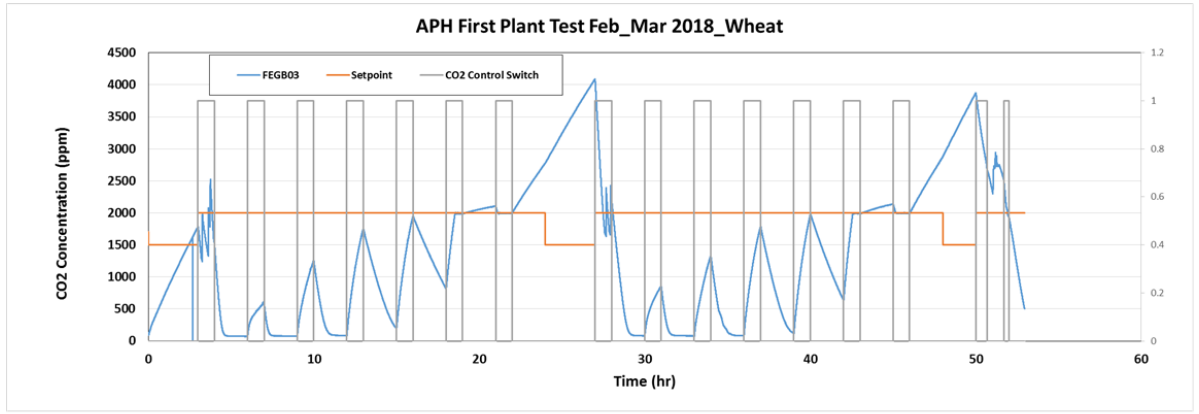


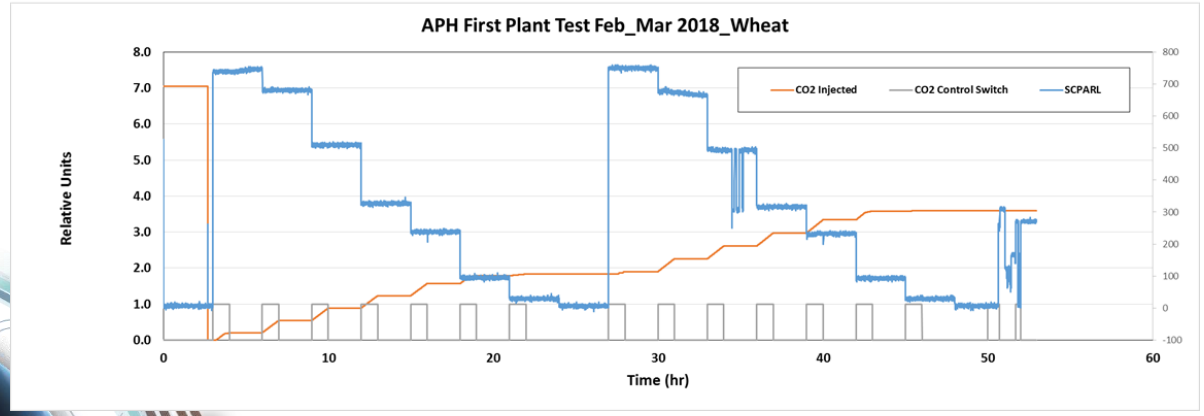
- Wheat harvest was conducted by removing the SC - Astronaut Norishige “Nemo” Kanai




Nondestructive data – Gas exchange

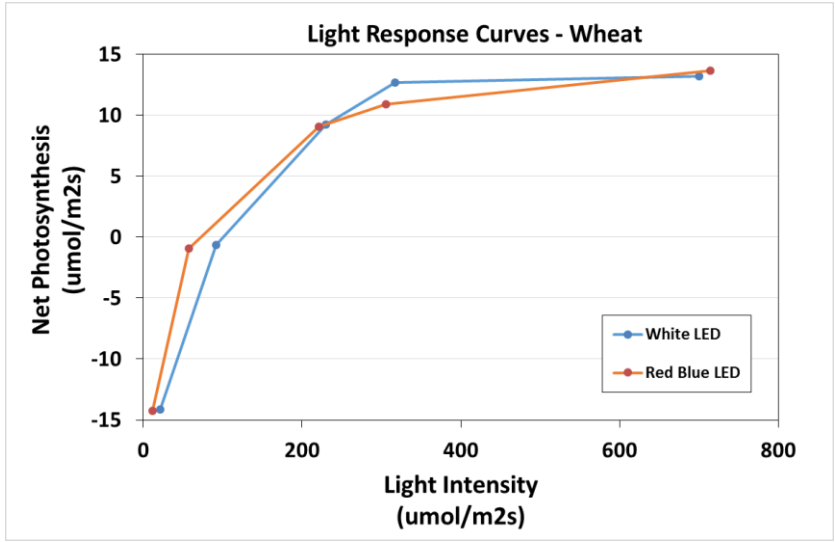
- APH collects nondestructive growth data throughout each growout.
- Example: Light Response Curves from 20 day old wheat





Technique: Change the light level, disable CO_2 control, and measure changes in chamber CO_2 drawdown.

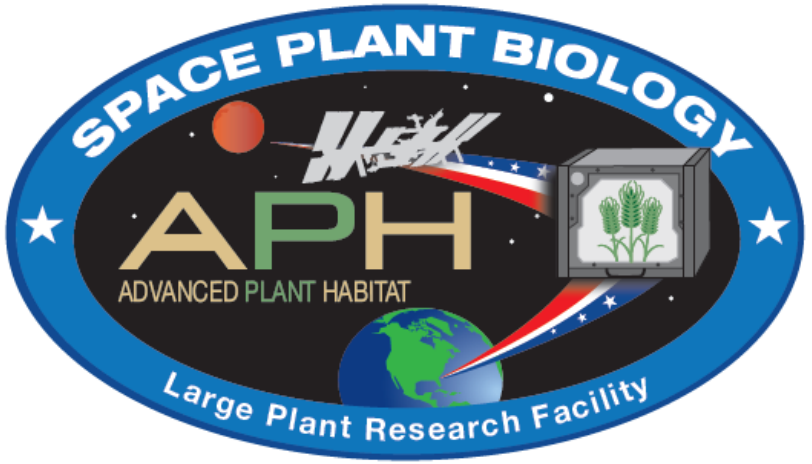
Demonstrated APH as a research tool

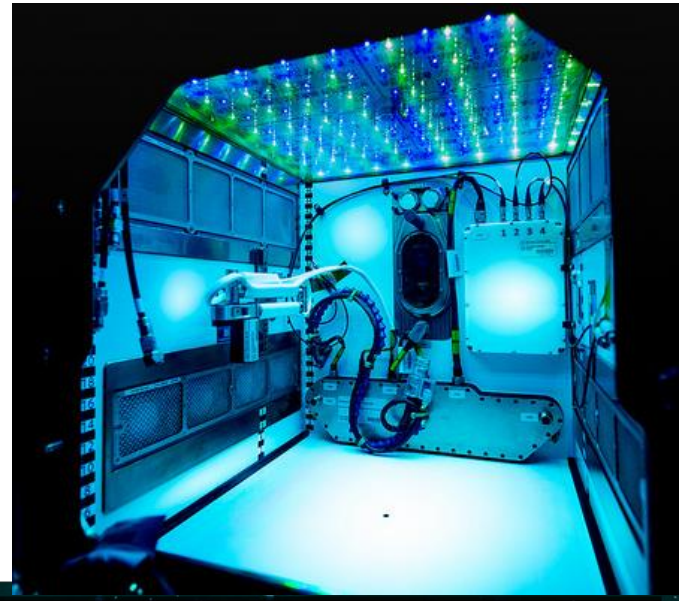


Conclusions

- APH Facility was installed, assembled and validated for conducting plant research on ISS.
- Two species – Wheat and Arabidopsis plants were successfully grown from seed and harvested after 30 days of growth on ISS.
- Environmental data and nondestructive plant growth data was collected during each growout.
- Hardware supports science.

Go APH!





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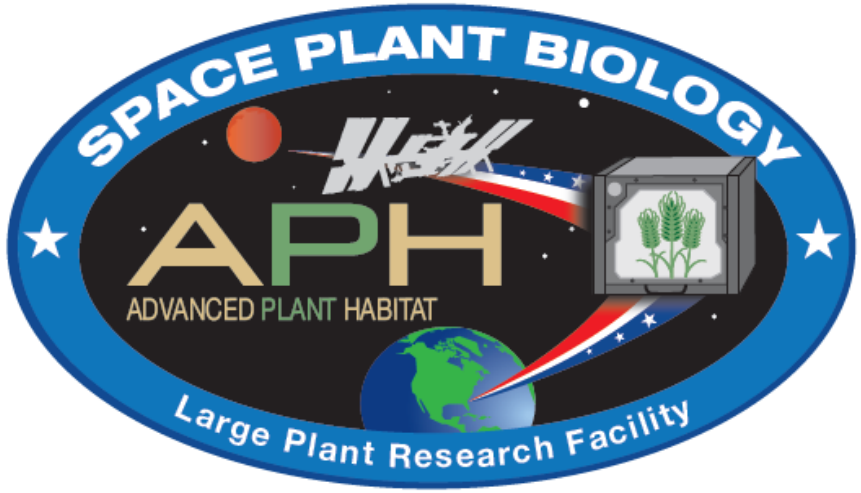

Questions?