https://ntrs.nasa.gov/search.jsp?R=20180008564 2020-02-11T23:50:19+00:00Z

Wheat Crop in the Advanced Plant Habitat of the International Space Station

- Oscar Monje, Jeffrey T. Richards
  - AECOM – LASSO KSC
- Dinah I. Dimapilis
  - Jacobs – TOSC KSC
- Gillermo M. Tellez-Giron, Matthew De Mars
  - Sierra Nevada (formerly Orbitec)
- Nicole F. Dufour, Howard G. Levine, and Bryan G. Onate
  - NASA / KSC

Astronaut "Ricky" Arnold

2018 ASA and CSSA Meeting, Baltimore, MD
Nov 4-7 2018

AECOM

Advanced Plant Habitat

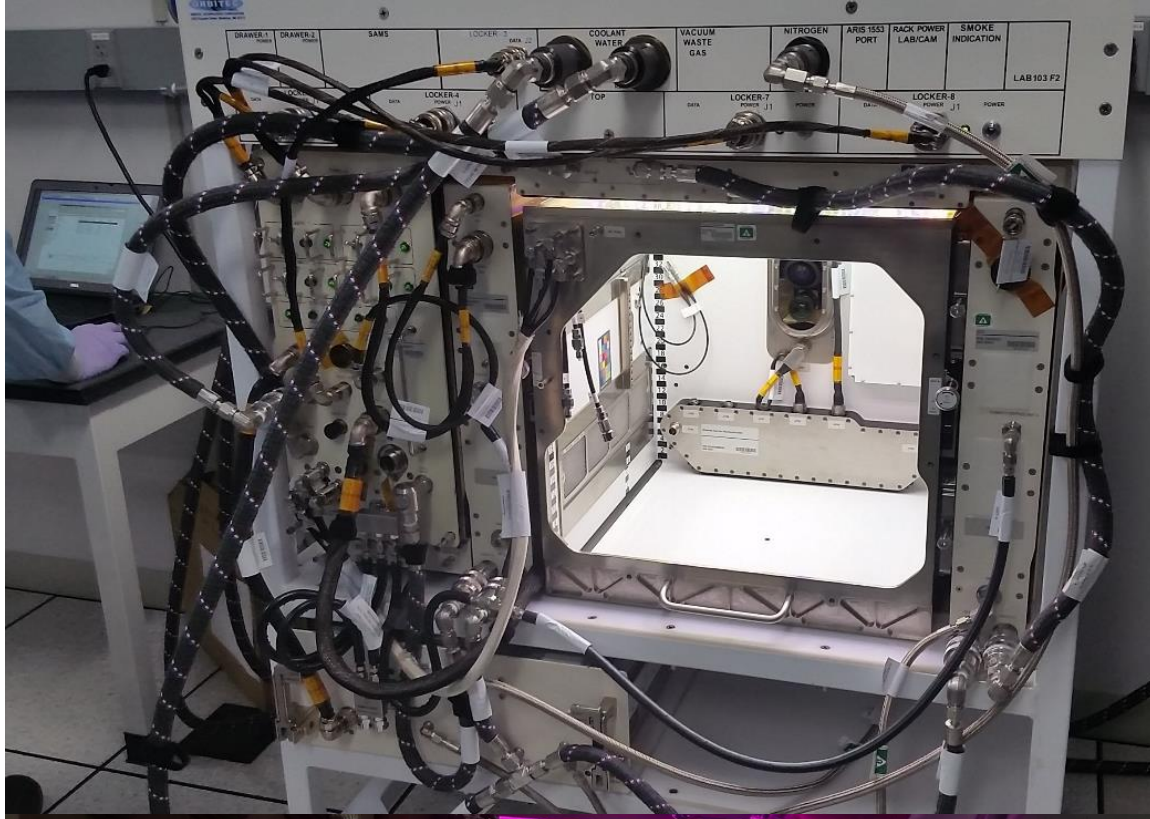
An automated plant growth facility for conducting plant research supporting space biology and food production projects on the International Space Station (ISS).

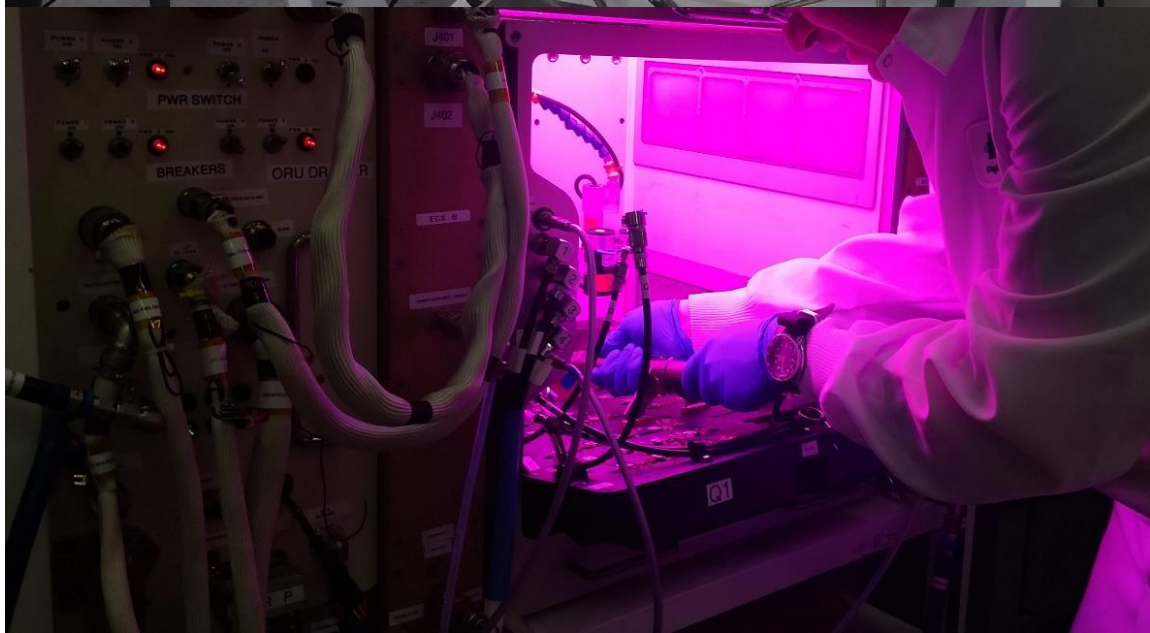
Plants are grown in the Science Carrier (SC) of the APH, (0.2 m^2 instrumented) root module.

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.

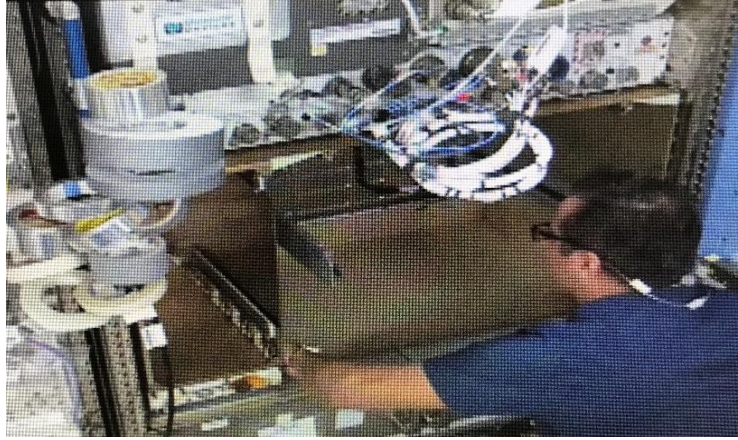
The planting and germination protocols for growing wheat (cv Apogee) and Arabidopsis (cv Colombia) were developed and tested at KSC in the APH Engineering Development Unit (EDU). Protocols were tested on orbit during the post-installation growth checkout of APH on ISS.

Hardware Validation – 1st plant growth test





APH Facility – Assembly / Functional Test

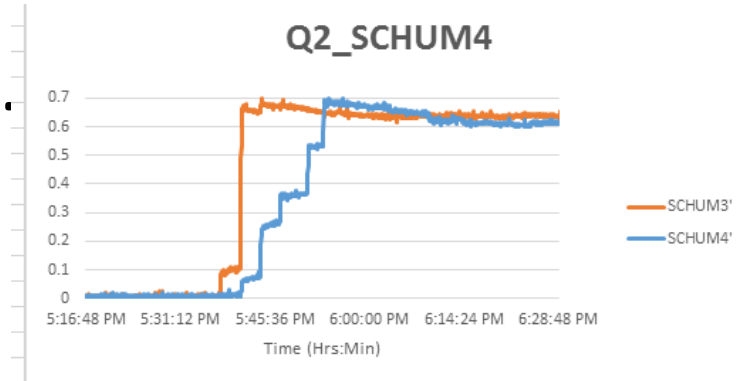


Astronaut Joe Acaba

- APH - transported to ISS on SpaceX 11 and OA-7.
- APH - assembled on the Kibo Module in 27Oct17.
- First power-up and 5-day functional test - 27Nov to 1Dec 2017 tested:
  - commanding, telemetry, and data retrieval from PHARMER.
  - 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.
  - Light levels
  - CO_2 scrubbing, CO_2 injection, Ethylene Scrubbing functions
  - Experiment Profile scripts (T, RH, CO_2, Pictures).
- An acoustic test was completed on 8Dec17.

APH Facility – Validation Schedule

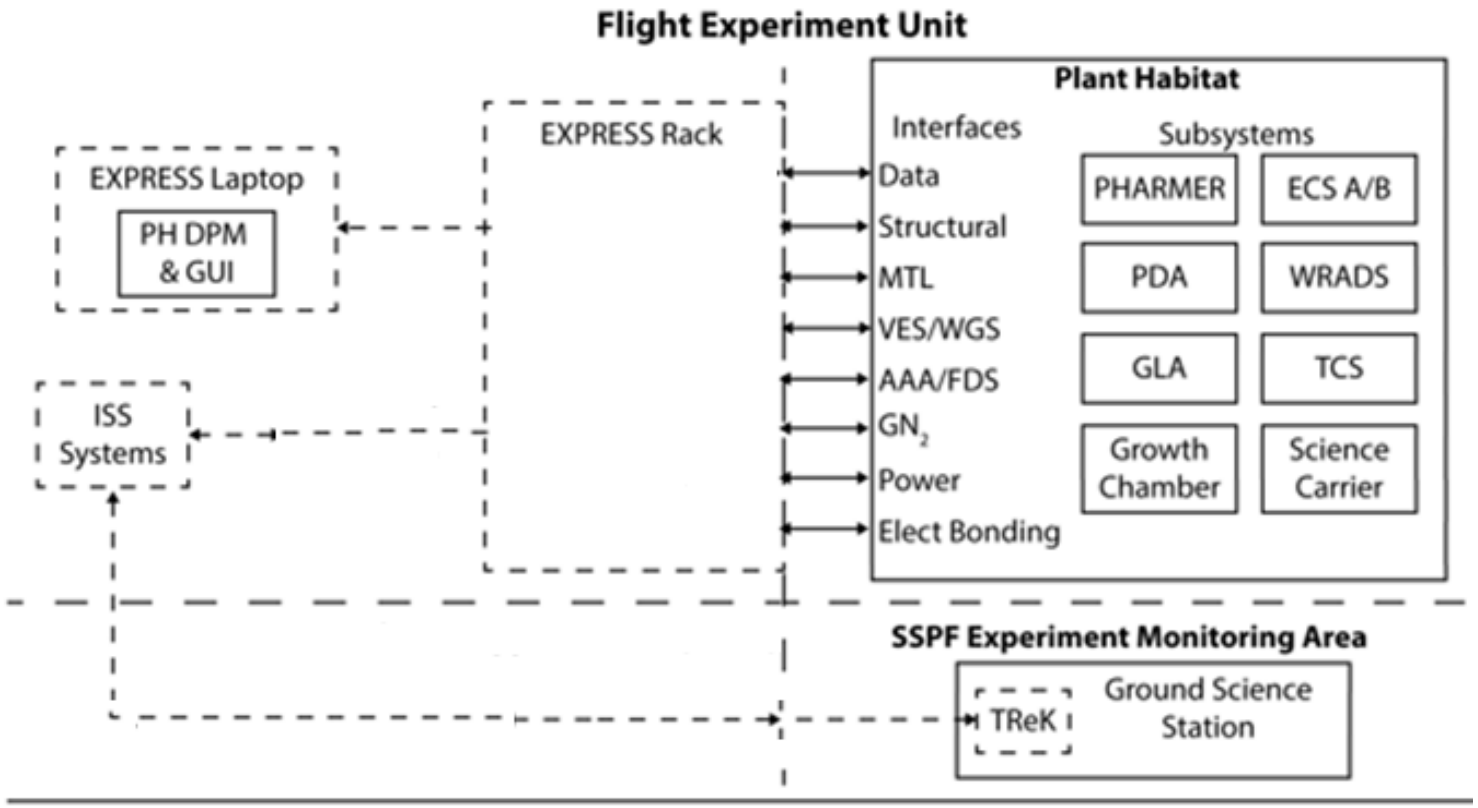
- Activated APH 19Jan18
- Initiated First Plant Test on 22Jan18 - verify that science is supported on APH hardware.
  - Install pre-planted SC: WT Arabidopsis and Apogee semi-dwarf wheat
  - Two week growth of WT Arabidopsis and 33 days of wheat conducted to demonstrate adequate plant growth for future 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 watering protocol.
- Demonstrate on-orbit germination / harvest protocols.
- Demonstrate experiment profile scripts



APH - Subsystems

The APH communicates with crew via a laptop

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

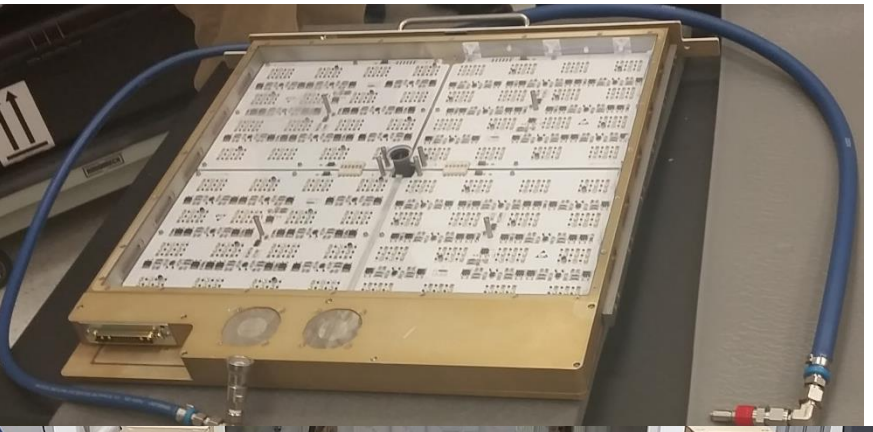
Plant Habitat Subsystems

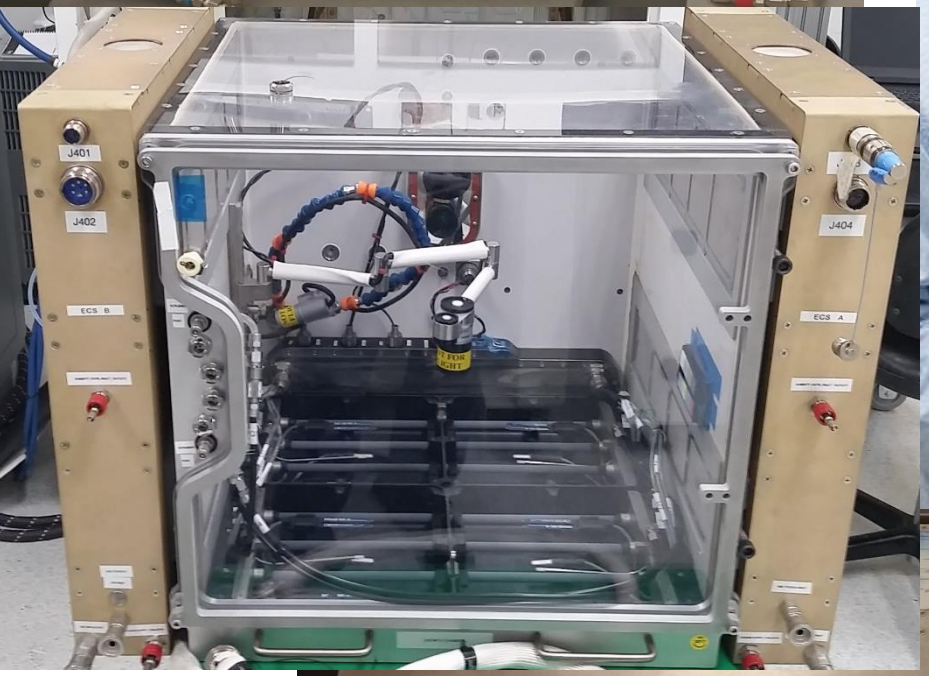
DPM	Data Processing Module
ECS	Environmental Control Subassembly
GLA	Growth Light Assembly
GUI	Graphical User Interface
PDA	Power Distribution Assembly
PHARMER	Plant Habitat Avionics Realtime Manager in EXPRESS Rack
SMA	Structrual Mounting Assembly
TCS	Thermal Control Subsystem
WRADS	Water Recovery and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

Flight Experiment Unit Technical Boundaries

Subsystems

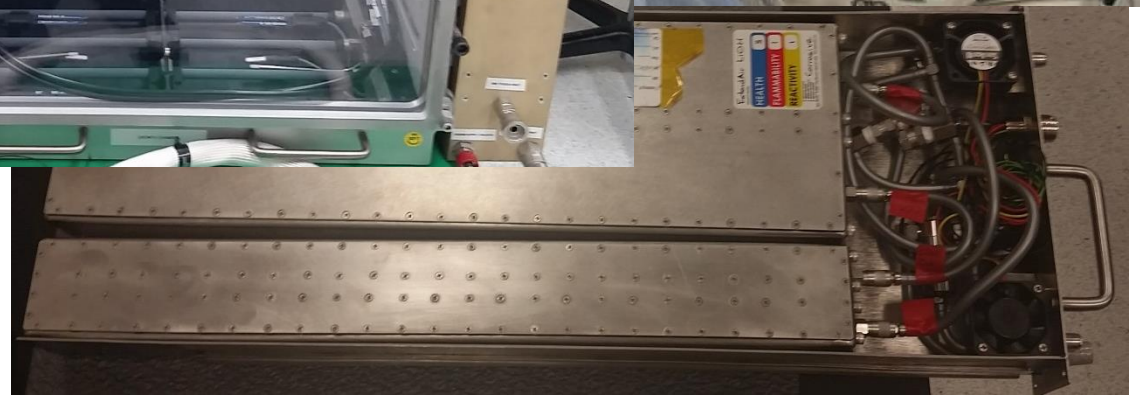
Growth Light Assembly





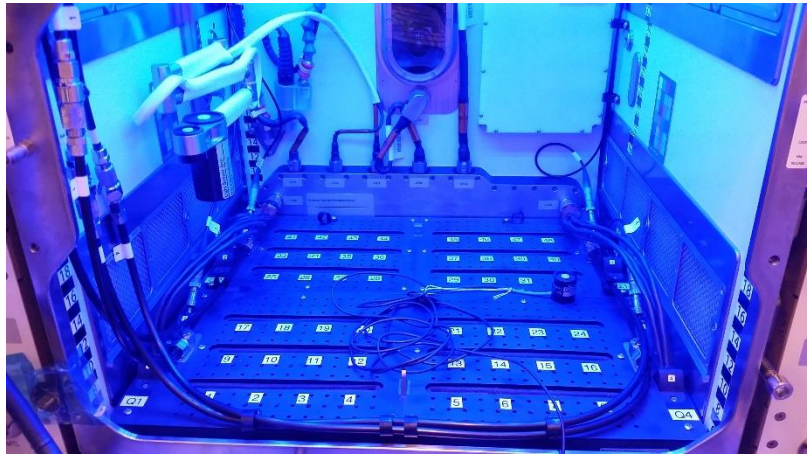
Growth Chamber

ISIS Drawers



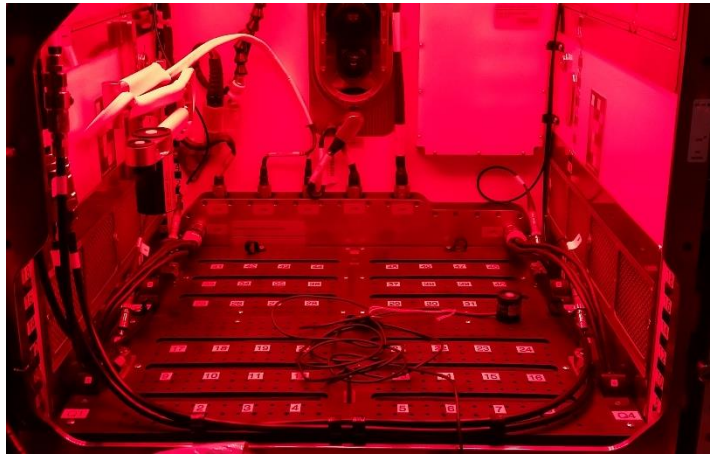
Power Distribution Assembly

GLA - Spectral Quality & Intensity

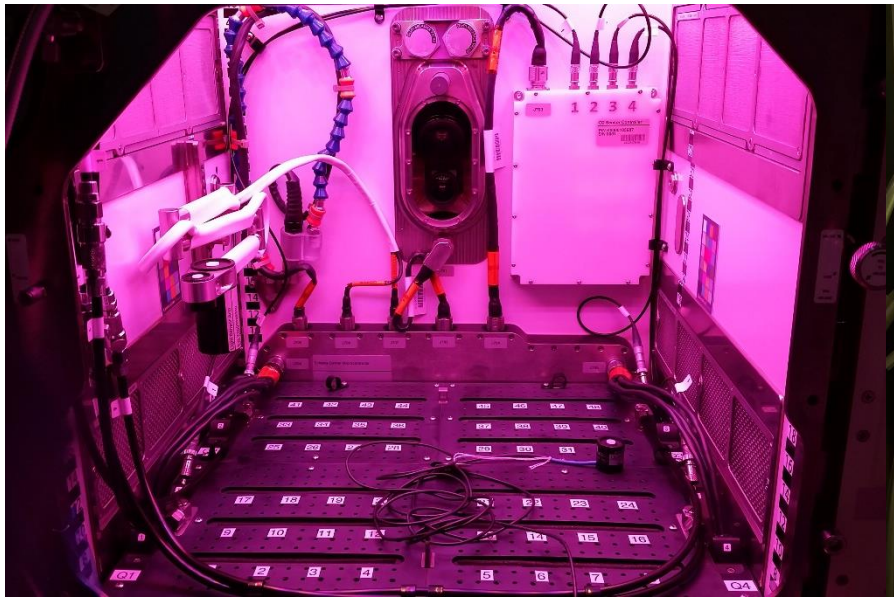


0-400 µmol m^{-2} s^{-1} at 450 nm ±10 nm

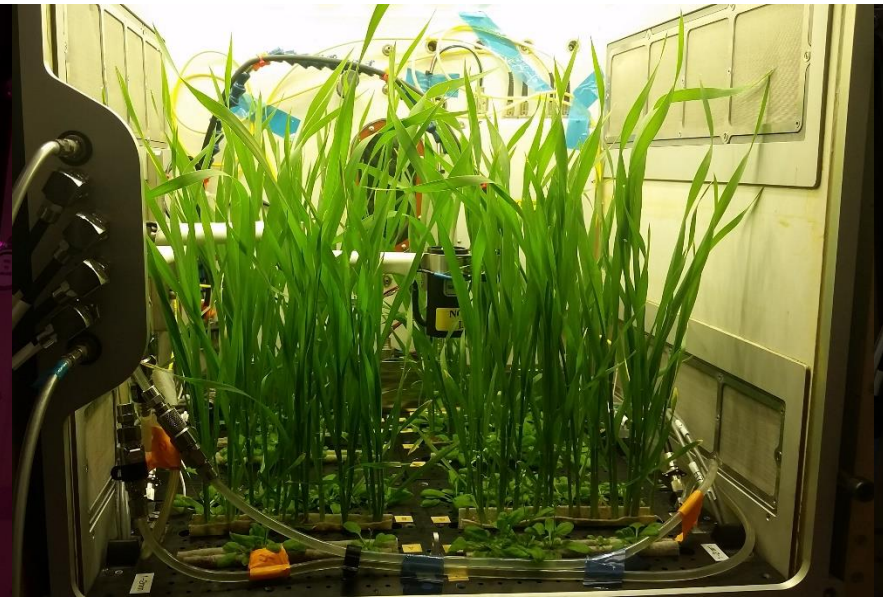
0-100 µmol m^{-2} s^{-1} at 525 nm ±10 nm



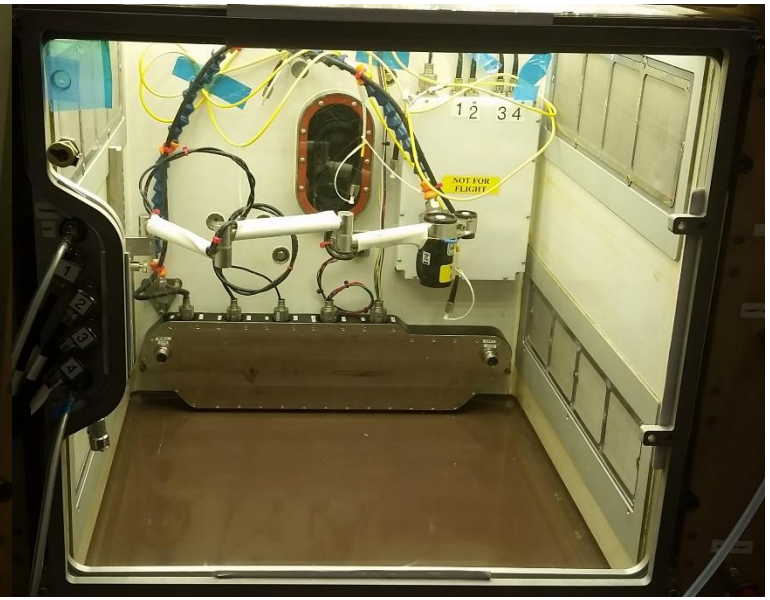
0-600 µmol m^{-2} s^{-1} at 630 nm ±10 nm



PI Mixture



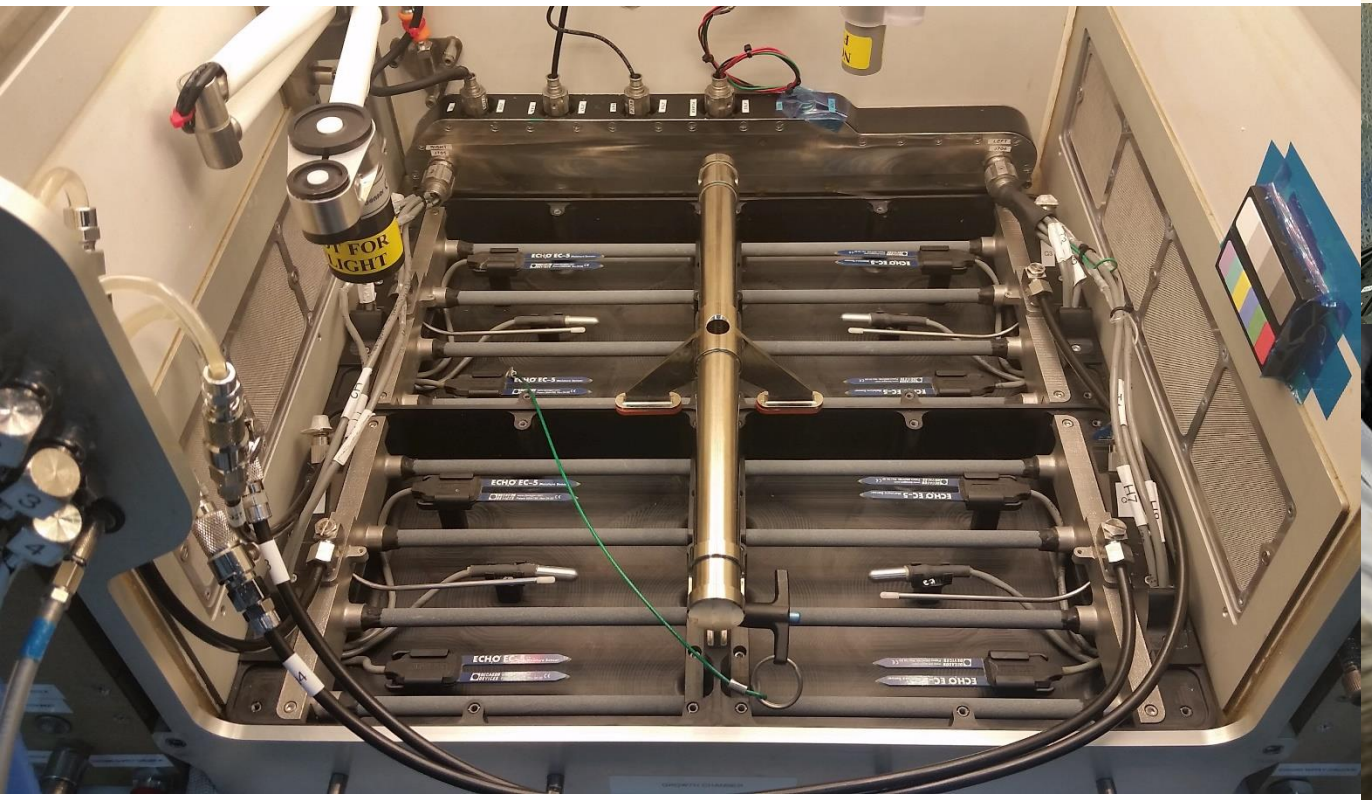
IR 0-50 µmol m^{-2} s^{-1} at 735 nm ±10 nm

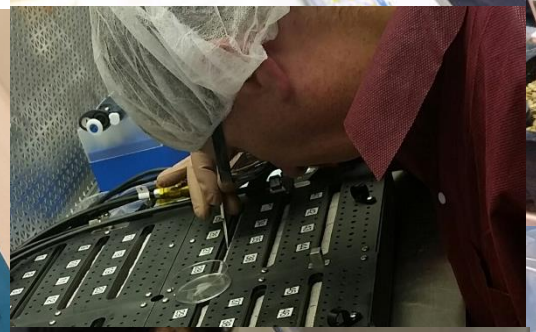


W 0-600 µmol m^{-2} s^{-1} at 400-700 nm

APH Science Carrier

- Four quadrants – independent moisture control
- Baseline – TRL-9 porous substrate / slow release fertilizer
- Pre-planted / Contains water and substrate





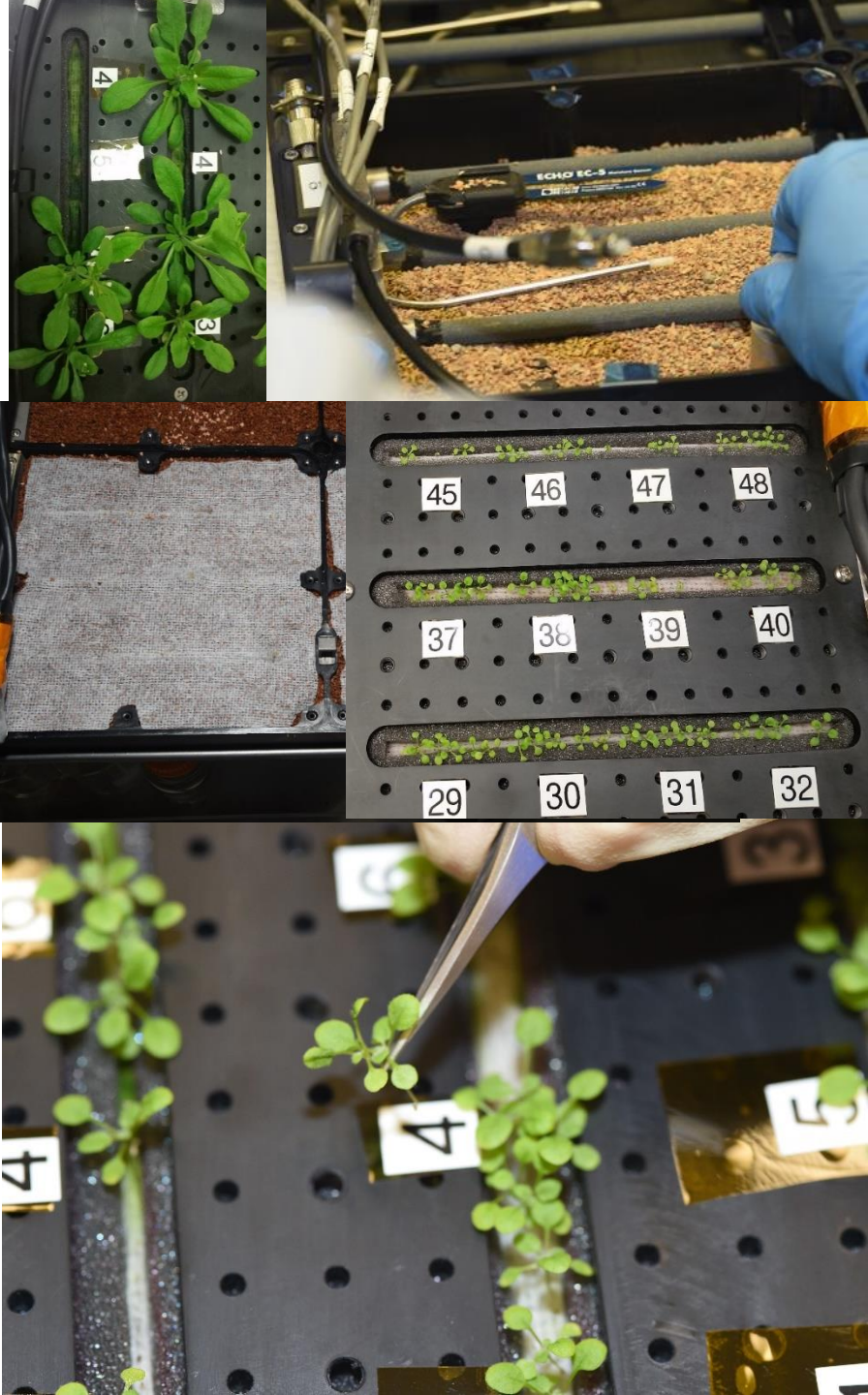
Planting and Germination

planting protocols (launch vibration):

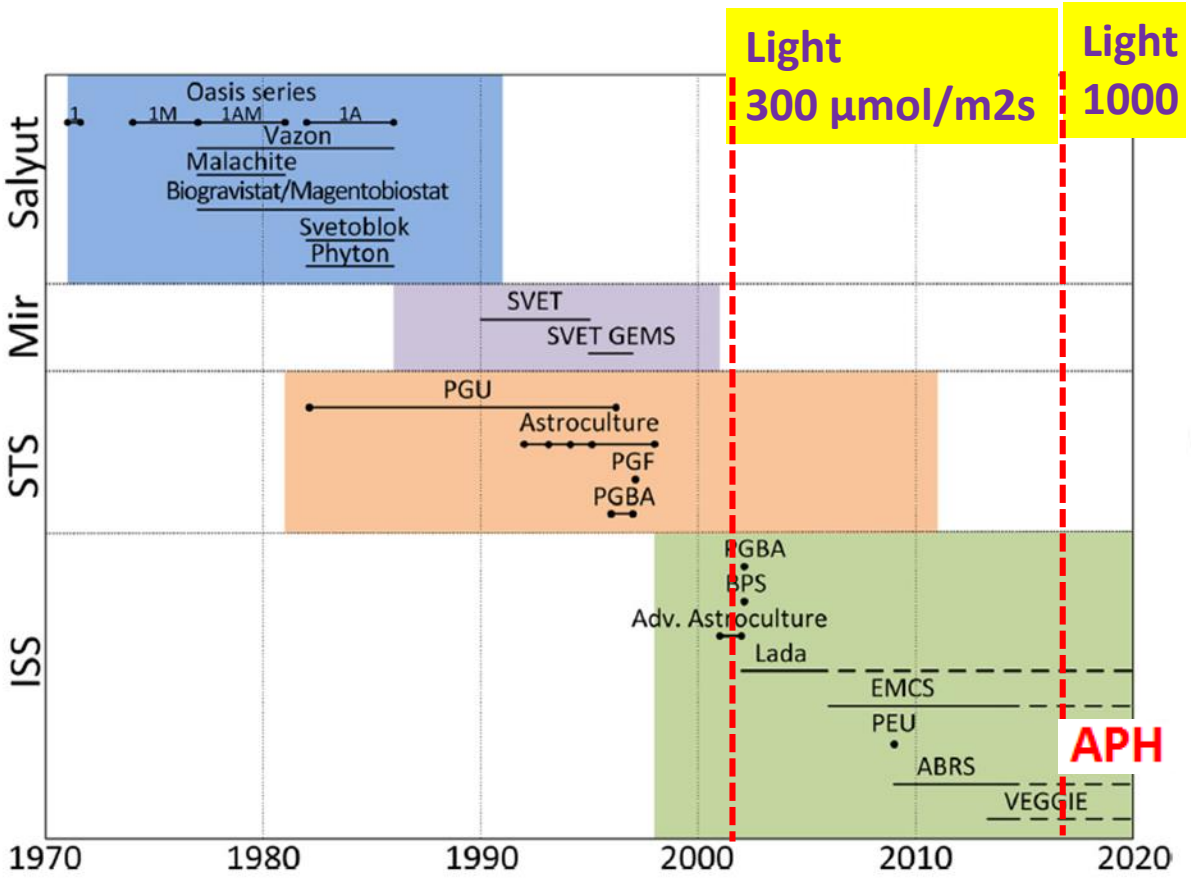
- Preparing the planting media, foam – sift, autoclave
- Packing (legacy to Mir, BPS)
- Seeding the SC (immobilize seeds).

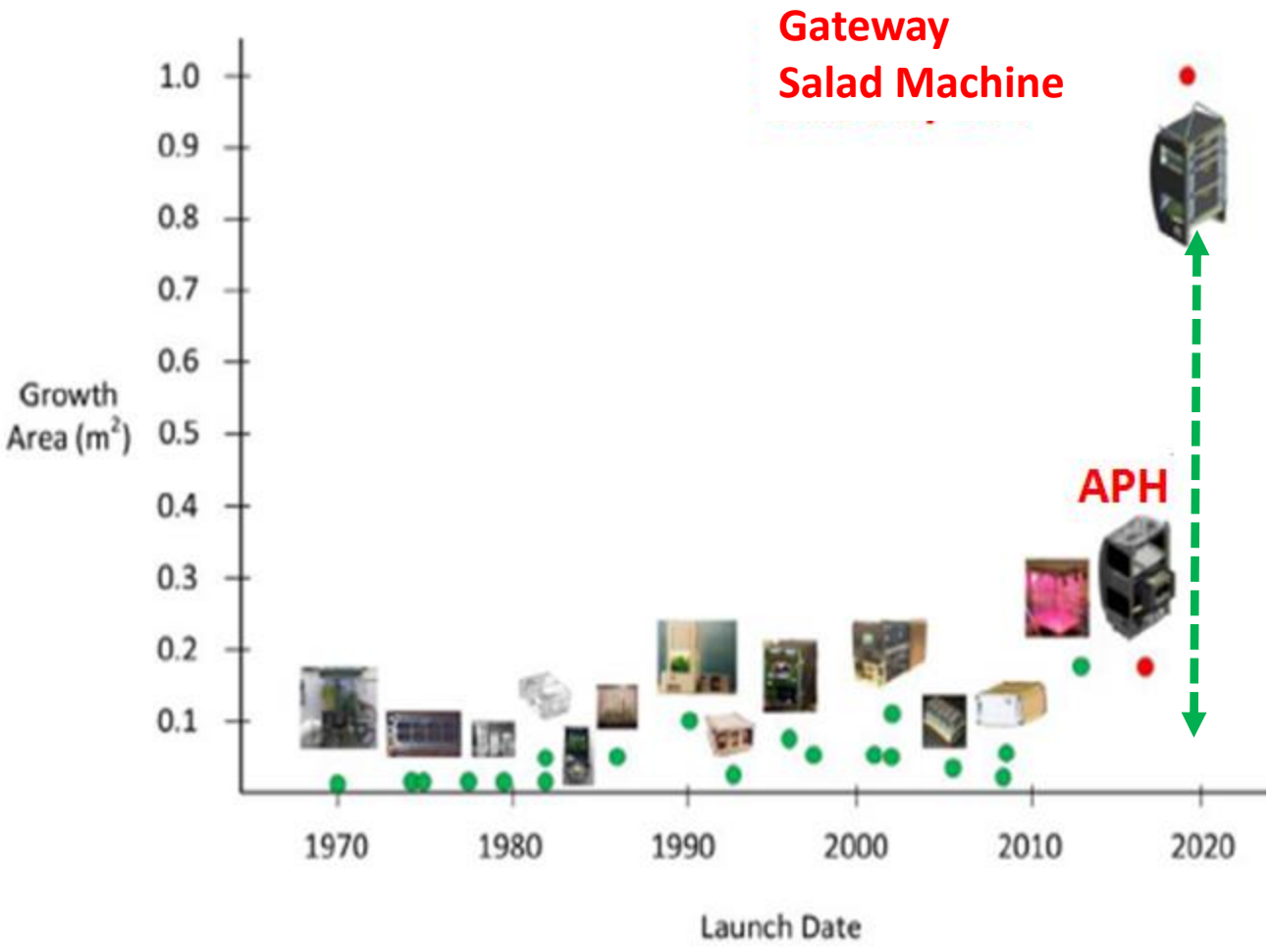
germination protocols:

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



Context: Spaceflight Plant Growth Systems



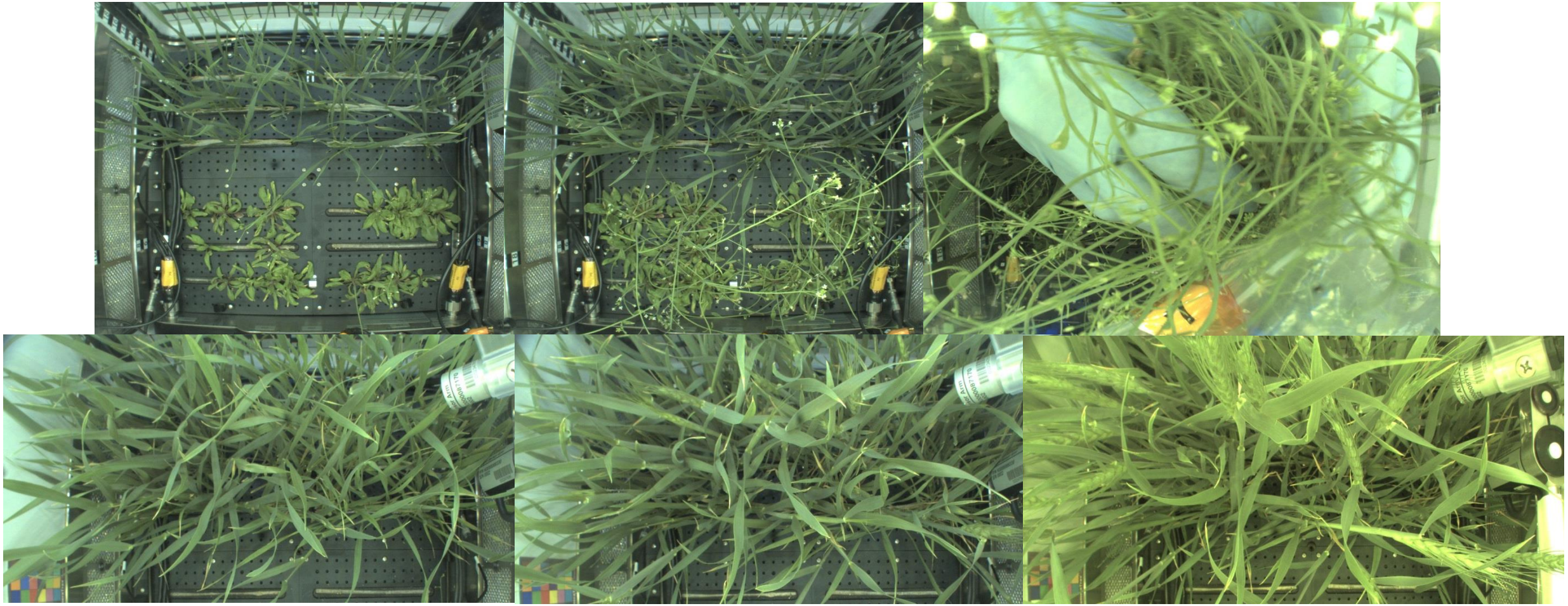


Zabel et al. Life Sci. Space Res. (2016)

APH – current capabilities

- Automated substrate-based watering system – 0.2 m^2 - Active
- Cultural Conditions
  - LED lighting: 0 to 1000 umol/m^2s, photoperiod
  - Spectral bands: white, blue, green, red, far red
  - Environmental control: CO_2, Tair, RH, soil moisture, ventilation
  - Teleoperation via commanding: manual mode, scripts
  - Crew tended functions: planting, harvest, sensors, maintenance
  - Imagery: aerial growth rates, health, watering

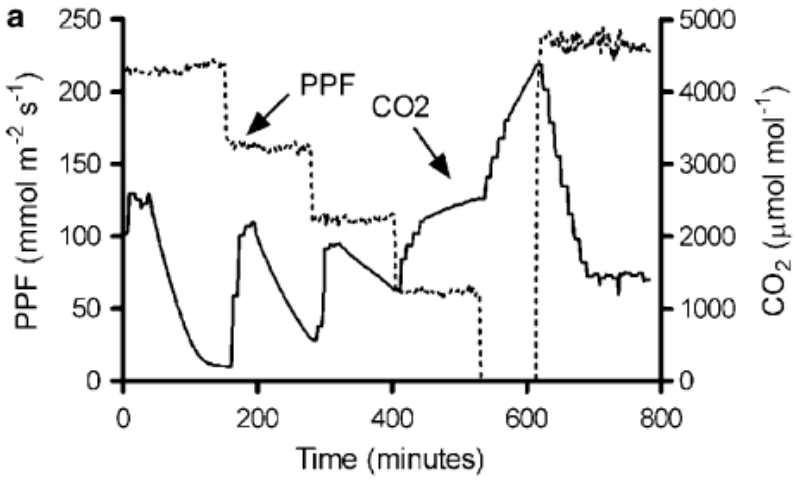
APH Facility – First Plant Test

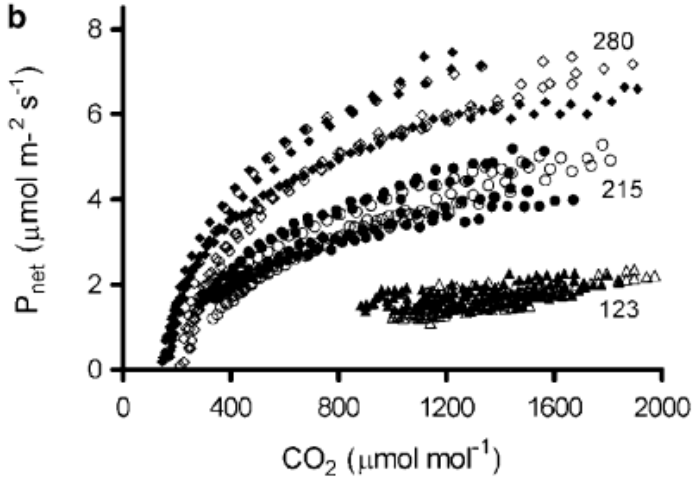


Arabidopsis (Quadrants 2 & 3) initiated on 1/22/18.
Apogee wheat (Quadrants 1 & 4) Initiated on 2/7-8/18.
Feb 22, 26, harvest Mar 6, 9, 12 2018 - Arabidopsis harvested on Mar 6 – observed debris containment. Apogee wheat (Quadrants 1 & 4) was 32 days old on Mar12.

Nondestructive data – Gas exchange

- APH measures nondestructive growth data – C fluxes.
- Example: CO_2 Response Curves from 20 day old wheat





CO_2 Drawdown Technique:

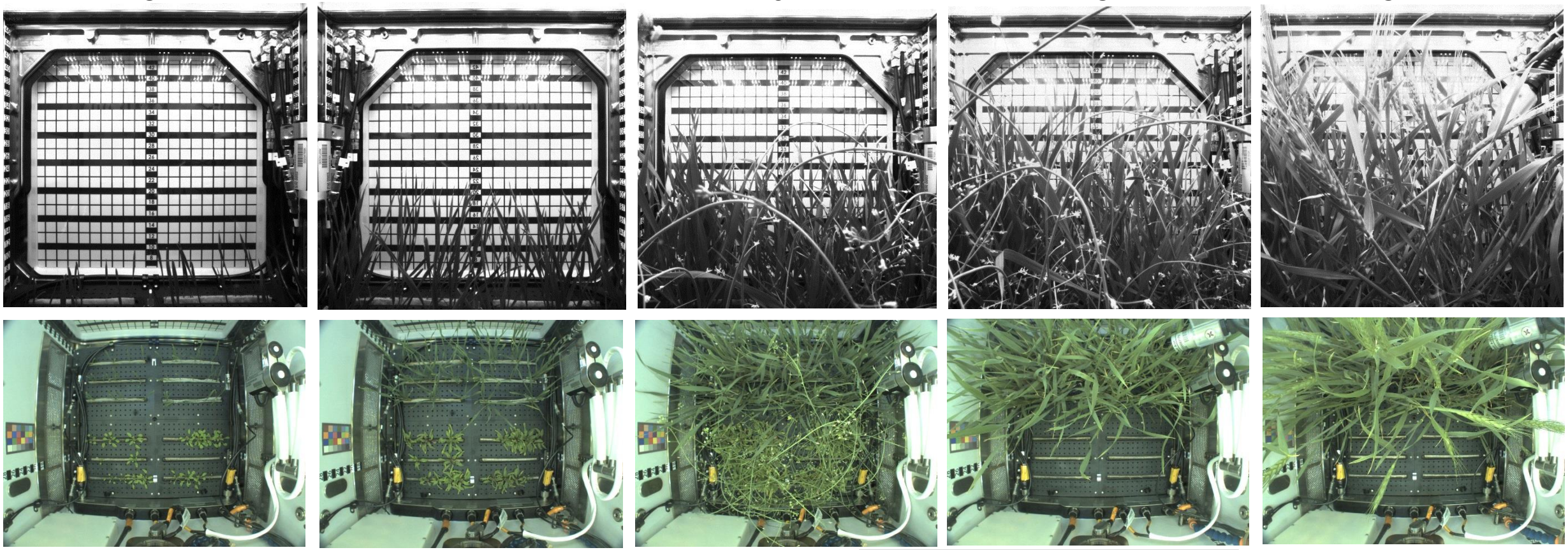
- Change the light level, disable CO_2 control, and photosynthesis consumes chamber CO_2 - drawdown.
- Allows Light response curves to be measured as well.
- Daily Growth – Lights come on.

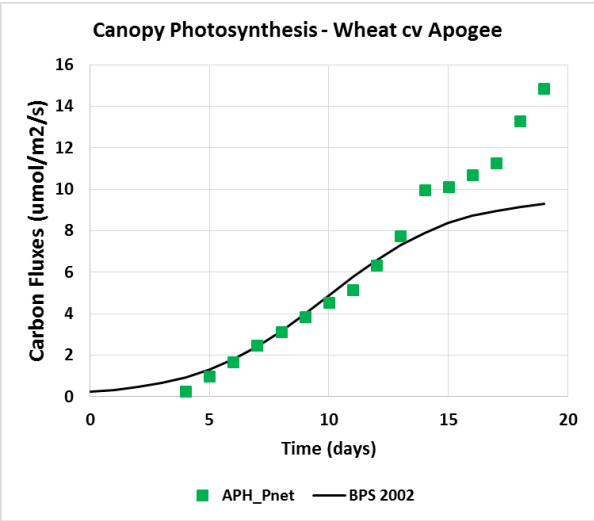
ISS 2002 - BPS – Biomass Production System

PESTO - Photosynthesis Experiment Subsystem Testing and Operations - PI_G. Stutte

Stutte et al. Planta (2005)

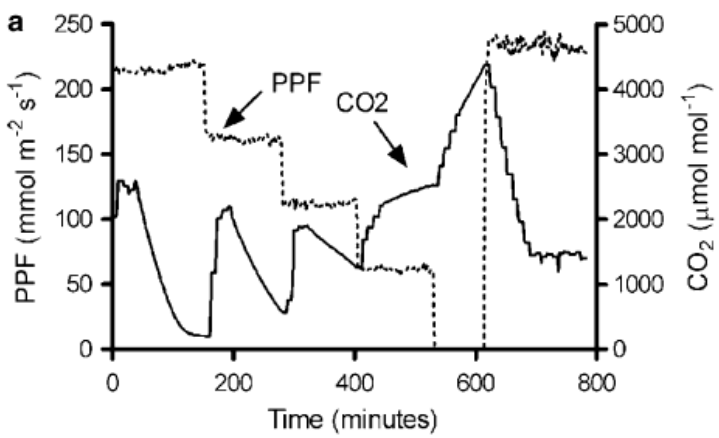
5 11 20 25 31

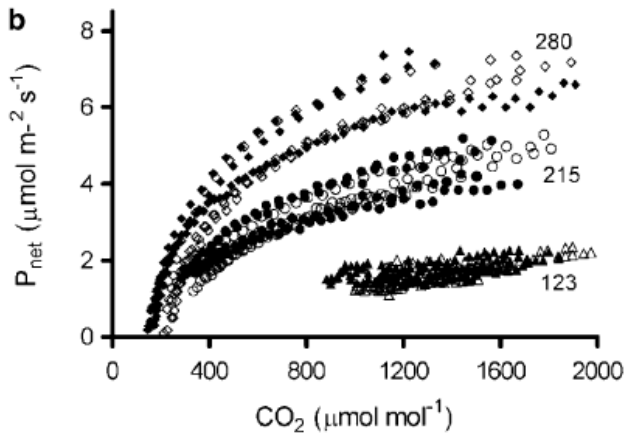


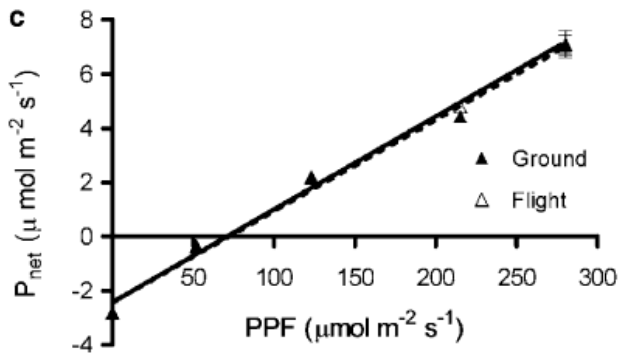


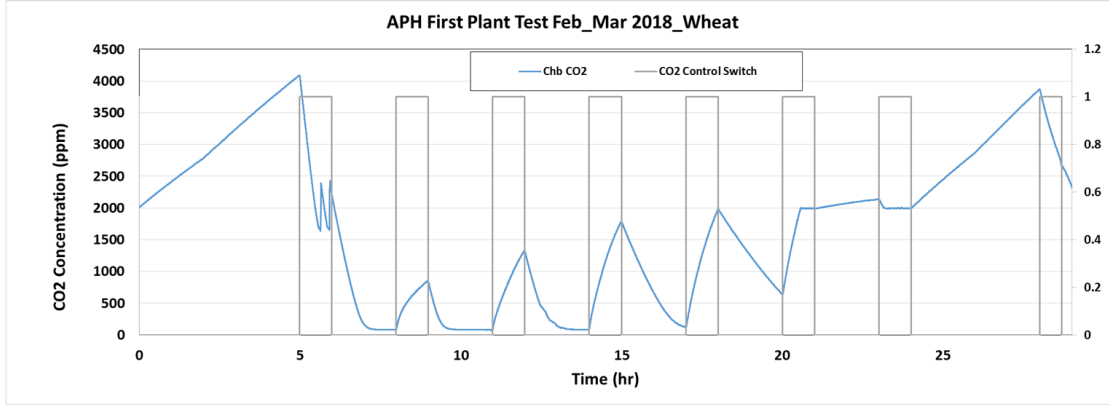
Daily CO_2 DrawDown Data

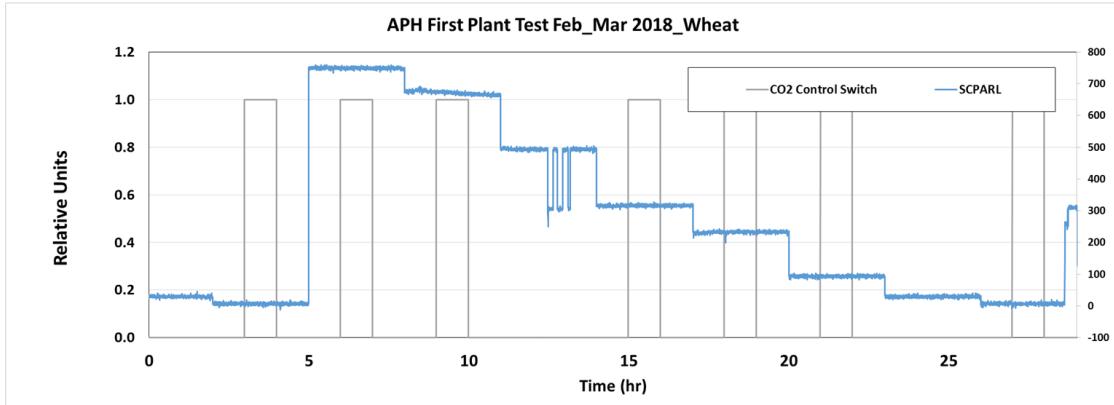
Monje et al. Planta (2005)



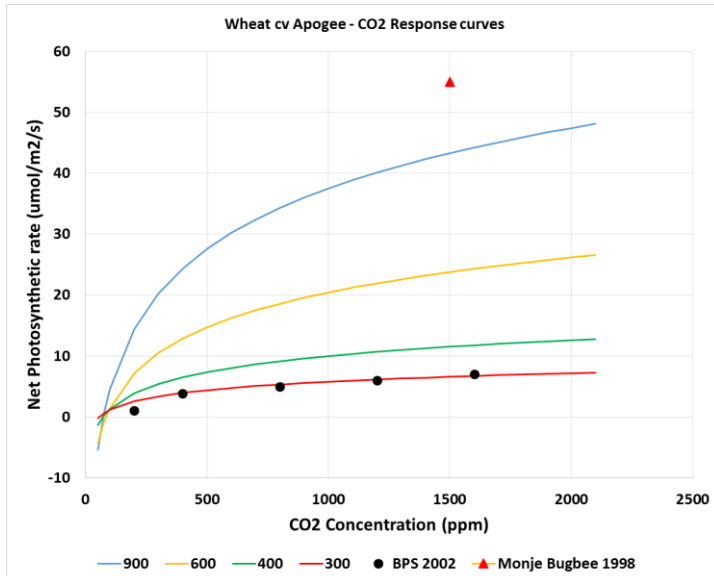


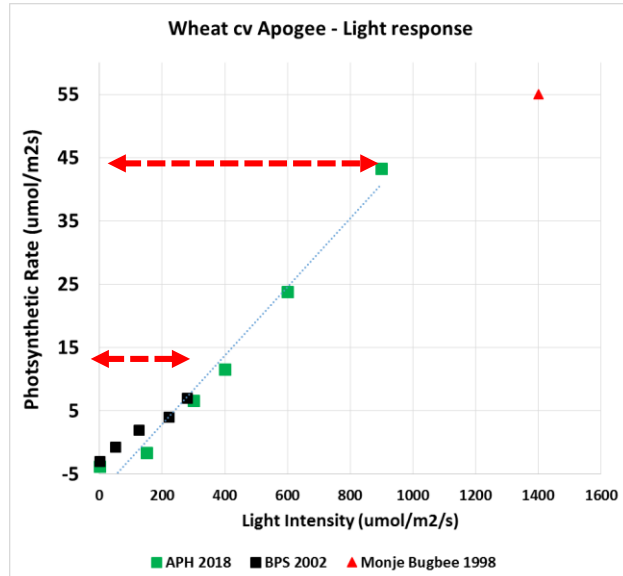




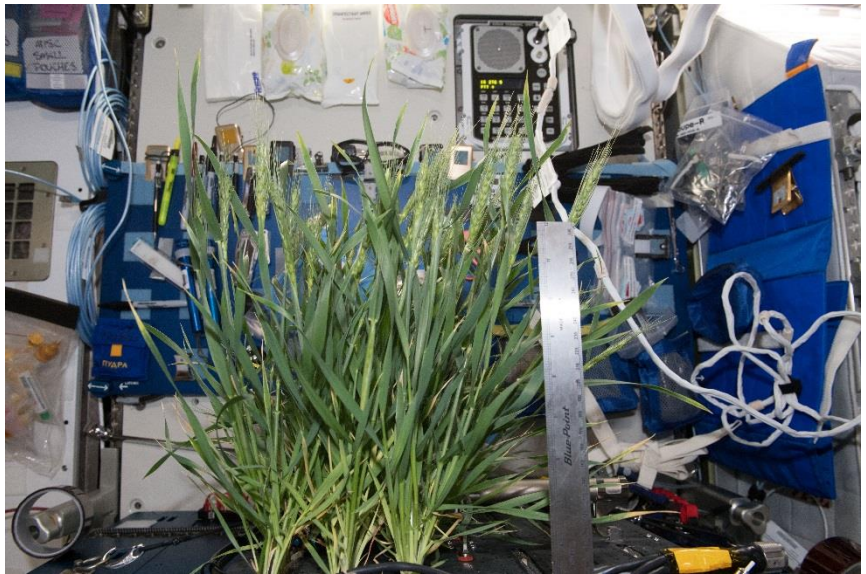


Measuring CO_2 and light response curves of wheat plants in microgravity





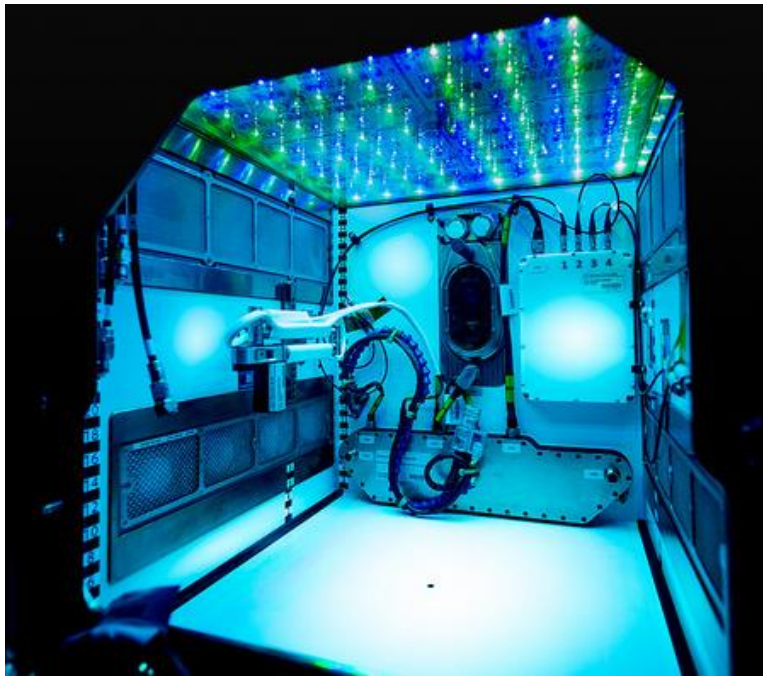
- Wheat harvest was conducted by removing the SC - Astronaut Norishige “Nemo” Kanai



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.
- Validated planting, germination and watering protocols.
- Collected nondestructive plant growth data – space crop model.
- Hardware supports science.

Go APH!



Acknowledgements

APH was sponsored by NASA's ISS Program and Space Life and Physical Sciences Research and Applications Division (SLPSRA) and co-developed by NASA and Sierra Nevada Corp. (formerly ORBITEC) of Madison, Wisconsin.

APH is available to support SLPSRA selected fundamental biology plus U.S. National Laboratory investigations sponsored by the Center for the Advancement of Science in Space.

Questions?

SPACE PLANT BIOLOGY

APH

ADVANCED PLANT HABITAT

Large Plant Research Facility