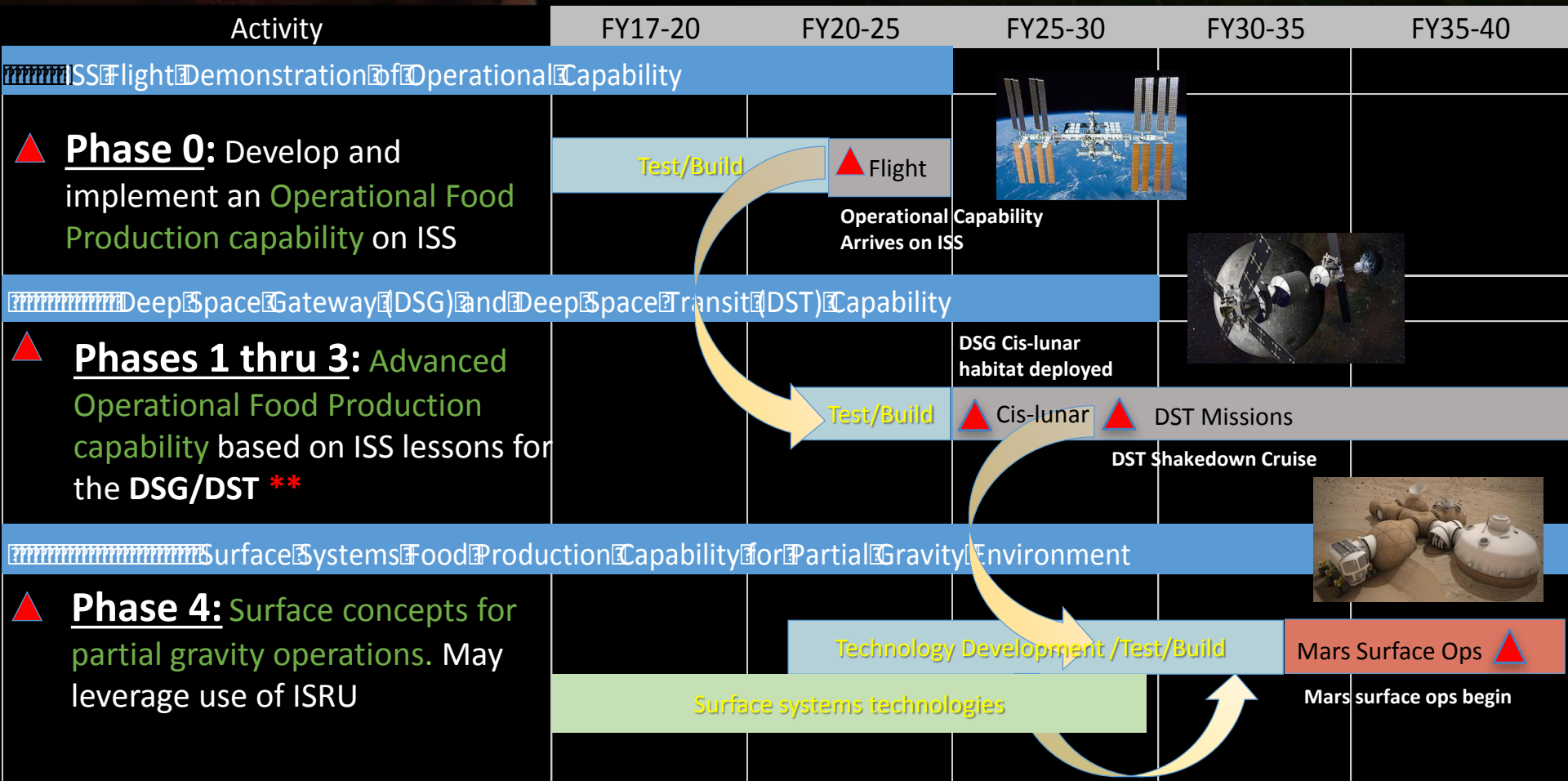




Future Food Production System Development Pulling From Space Biology Crop Growth Testing in Veggie

Gioia Massa, Matt Romeyn, Ralph Fritsche
Exploration Research and Technology Programs
NASA, Kennedy Space Center

Food Production as an Element of NASA's Deep Space Habitation Strategy



- ▲ Capability online
- Microgravity technology development and implementation
- Partial gravity technology development and implementation

** DSG - Deep Space Gateway
DST – Deep Space Transport

Technology and Knowledge Gap Focus

- **Identify and demonstrate effective options to provide both water and oxygen to the root zone in microgravity**
 - Investigate benefits of both passive and active systems
- **Understand the deep space radiation impacts on seeds and plants**
- **Investigate the relationship between microbiomes and food safety:**
 - Effectively sanitize produce with few consumables and low inputs
 - Control biotic stresses and pathogens
 - Use the microbiome to protect crops or enhance growth.
- **Identify potential crops:**
 - Yield, nutrition, organoleptic attributes, psychosocial benefits
 - Light recipes, elevated CO₂ impacts, fertilizer requirements
 - Custom space crops
- **Automation and human factors:**
 - Identify operations and capabilities that require automation
 - Understand which crew activities are desirable and at what scale
- **Storage and handling of seeds to ensure they are viable, free of contaminants and long-lived.**
- **Scalability for different concepts and architectures**

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Veggie on ISS



Shane Kimbrough
Expedition 49/50

Veggie Technology Validation Tests

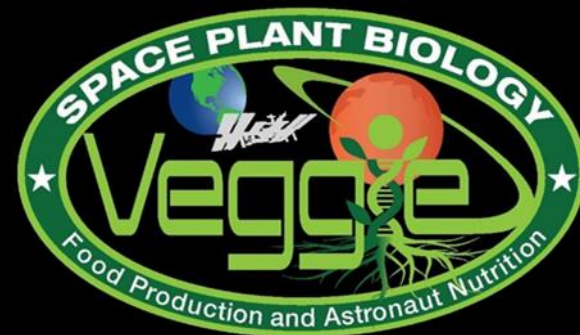
VEG-01

- 2014-2016
- 'Outredgeous' lettuce and 'Profusion' Zinnia
- Crew consumption approval
- Watering challenges
- Fungus



VEG-03

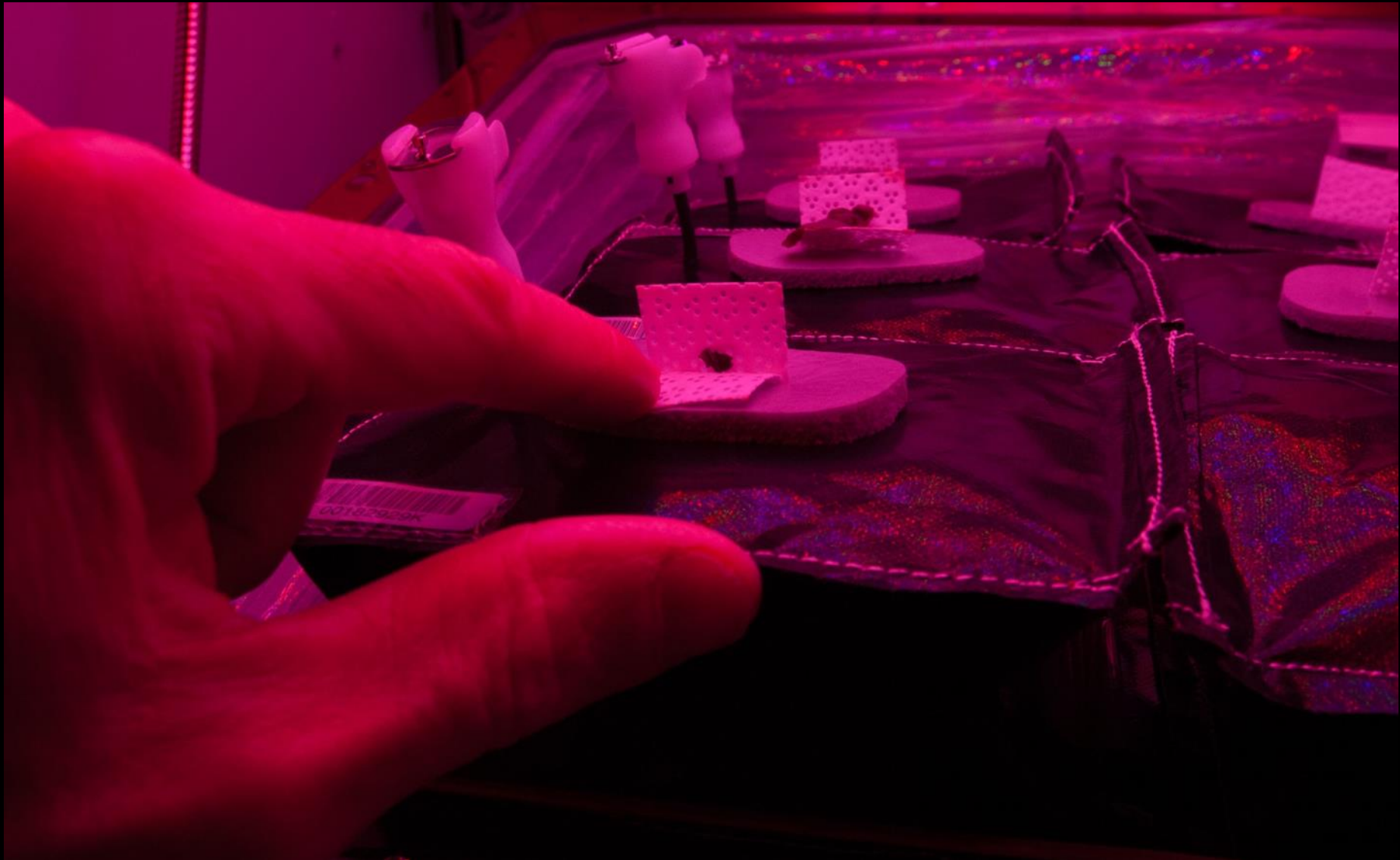
- 2016-Present
- 'Outredgeous' lettuce, 'Tokyo Bekana' Chinese cabbage, Mizuna, 'Waldmann's Green' lettuce
- Cut-and-come-again harvesting
- Mixed cropping



Food Production Challenge

- Identify and demonstrate effective options to provide both water and oxygen to the root zone in microgravity.

Root Zone Water – Insufficient



Root Zone Water – Excess



Condensation on Bellows



Stunting and Chlorosis

Root Zone Water – Excess



Guttation and Leaf Curling



Abnormal Growth

What's Next

- Developing a ground-based Food Production Demonstration Unit test bed to evaluate and compare candidate solutions.
- Will test active and passive concepts
- Collaborative work between plant scientists, microgravity fluid physicists, and engineers with student design teams also participating.



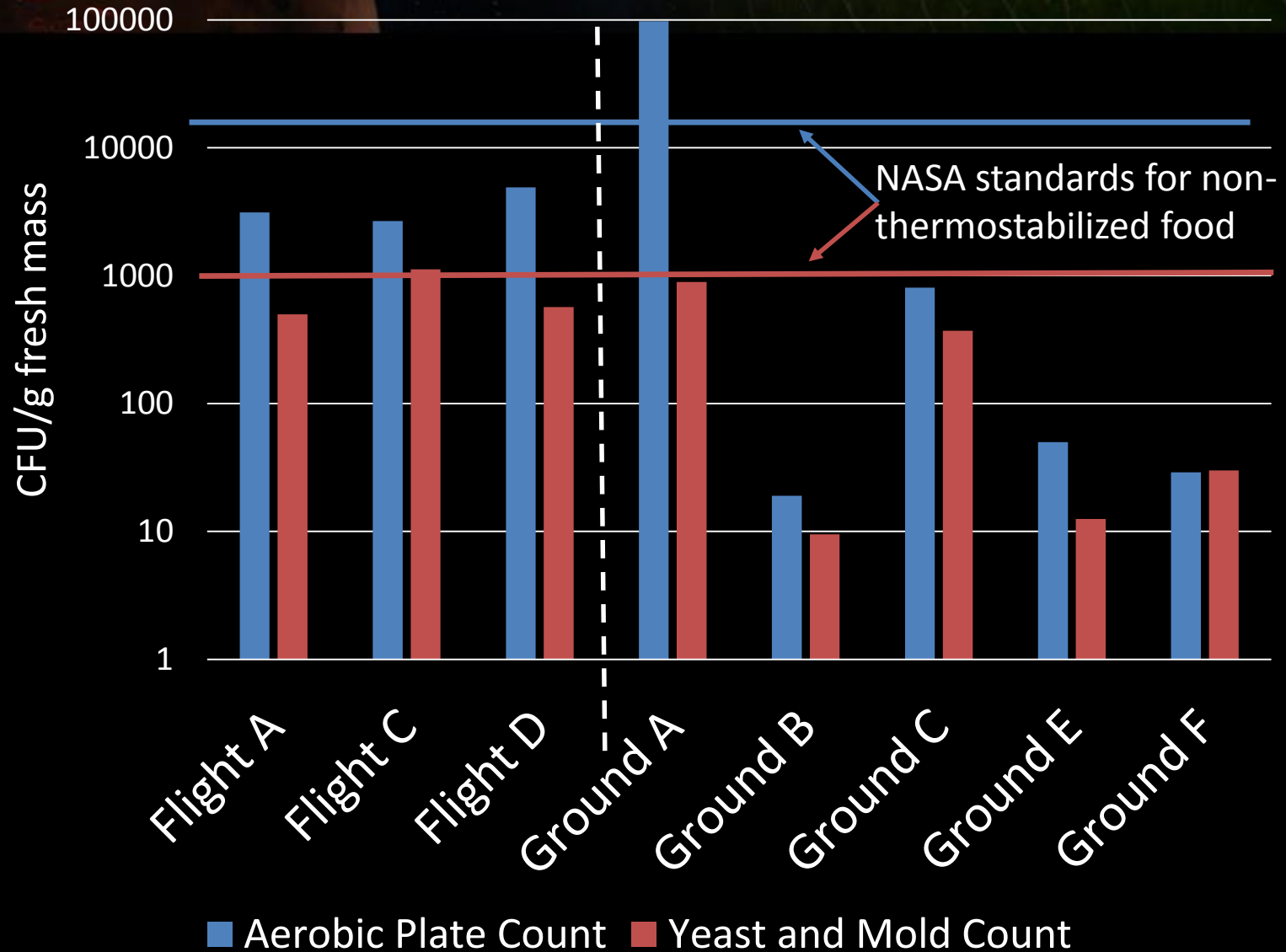
Image courtesy of Techshot and Tupperware Brands

Food Production Challenge

- Investigate the relationship between microbiomes and food safety:
 - Effectively sanitize produce with few consumables and low inputs
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 - Use the microbiome to protect crops or enhance growth.

Veggie Microbiology

Food Safety



Veggie Microbiology

Plant pathogenesis



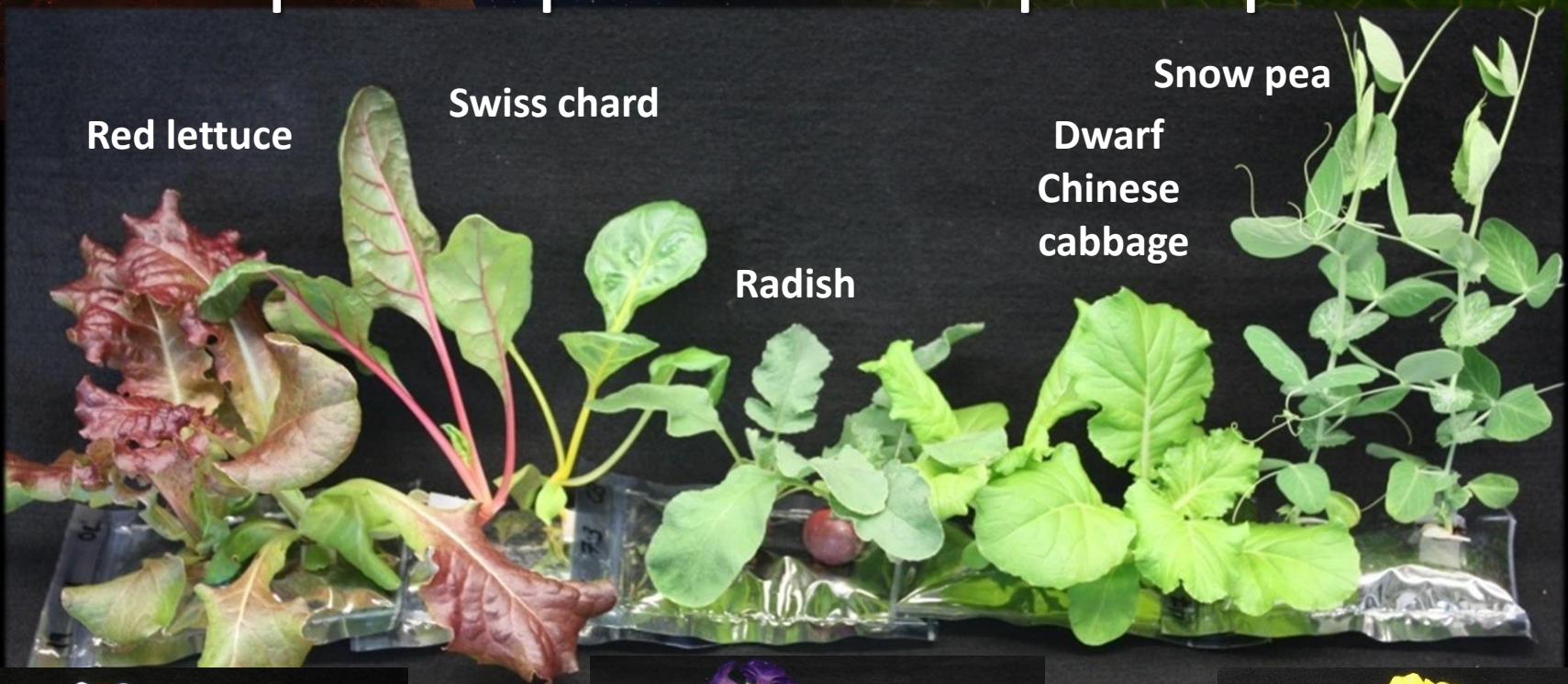
What's Next

- Conduct ground-based microbial food safety and microbiome testing of candidate crops.
- Develop fresh produce food safety standards for space.
- Use on orbit resources when applicable.
 - Developing process flow for on-orbit sampling of fresh produce microbiome, nucleic acid isolation, library generation, sequencing, and data analysis.

Food Production Challenge

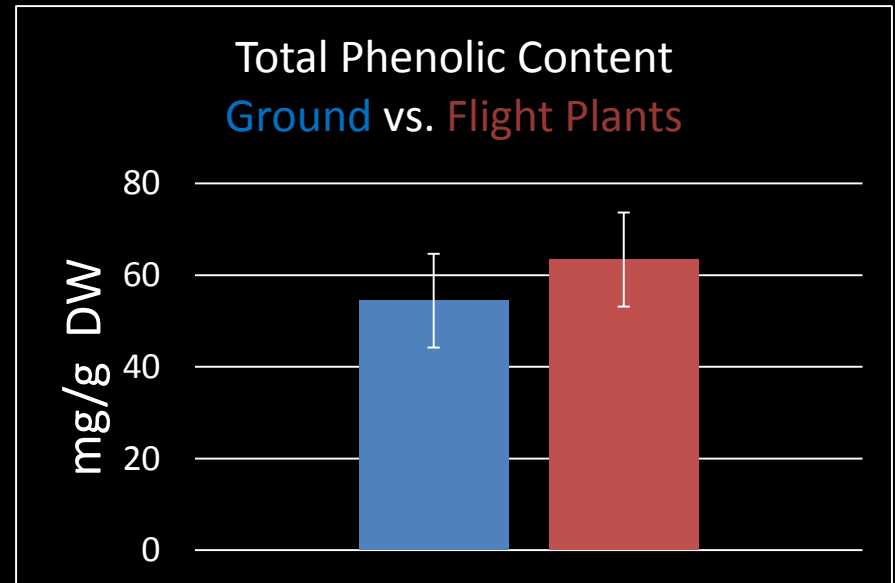
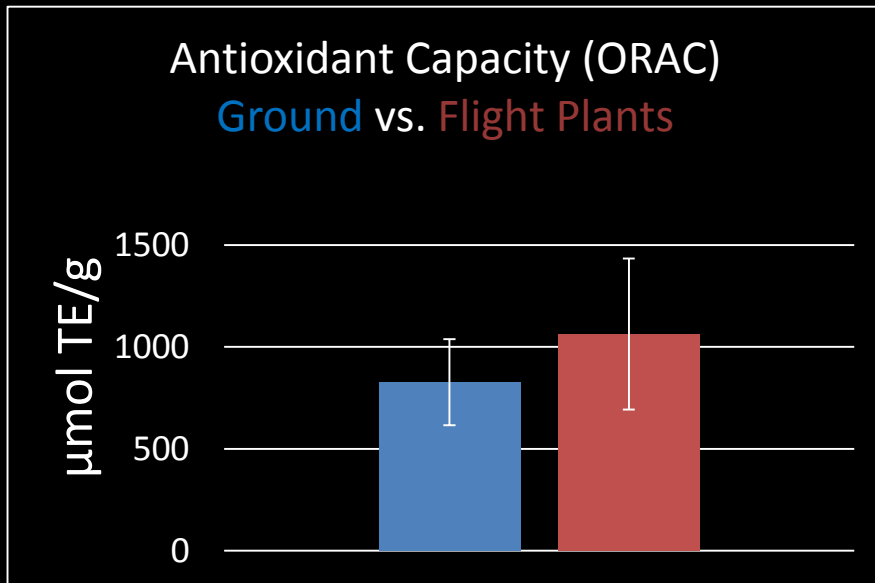
- Identify potential crops:
 - Yield, nutrition, organoleptic attributes, psychosocial benefits
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Example crops tested in plant pillows



Nutrient Levels – Veg-01 lettuce

- Fe, Ca, Mo & P and Anthocynains = between flight and ground.
- B, Cu, Mg, Mn, Na & S were slightly > in flight plants.
- K slightly > in ground plants.
- Ni & Zn considerably > in flight plants.



Happy Crew



Thomas Pesquet
@Thom_astro

#TGIF! On Fri
best food item
lettuce with lol
-chef @AstroF



RETWEETS 199
LIKES 725

11:18 AM - 16 Dec 2016

Thomas Pesquet

#TGIF! Comme tou:
vendredi soirs on s
retrouve tous pour
nos meilleurs plats.
menu ici: salade sp
par @AstroPeggy



ISS Research
@ISS_Research

"Better than any
on the ground."
space farming is



Peggy Whitson
@AstroPeggy

I am growing cabbage on
station. I love gardening on
Earth, and it is just as fun in
space... I just need more room
to plant more!



LED and Elevated CO₂ Impacts on Chinese Cabbage





What's Next

- Assessing new crop candidates:
 - Preliminary screening at >130 middle and high schools in Fairchild Garden's Growing Beyond Earth Challenge.
 - Down-selected varieties will be tested in high-fidelity environments at KSC.
- Upcoming experiments (VEG-04, VEG-05) include psychosocial and organoleptic evaluations to measure produce impacts on microgravity life.

Food Production Challenge

- Automation and human factors:
 - Understand which crew activities are desirable and at what scale
-

- Estimate crew time and compare activities with estimates
 - Gather data in crew debriefs
-

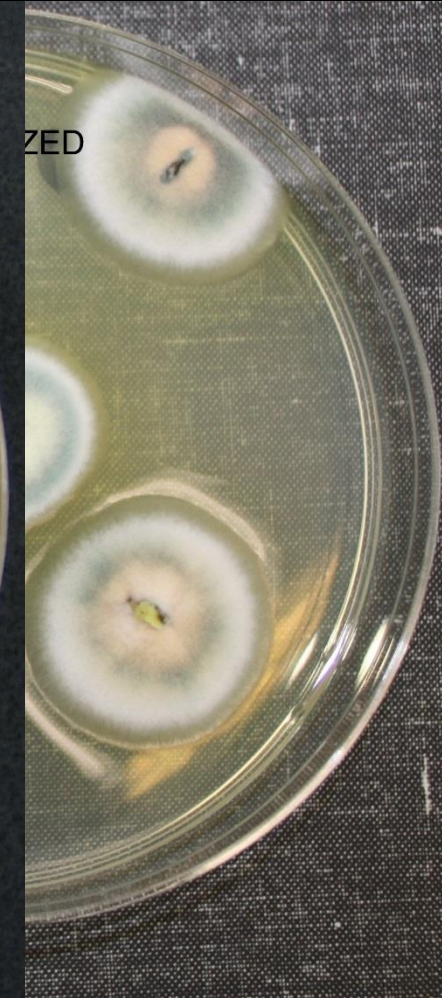
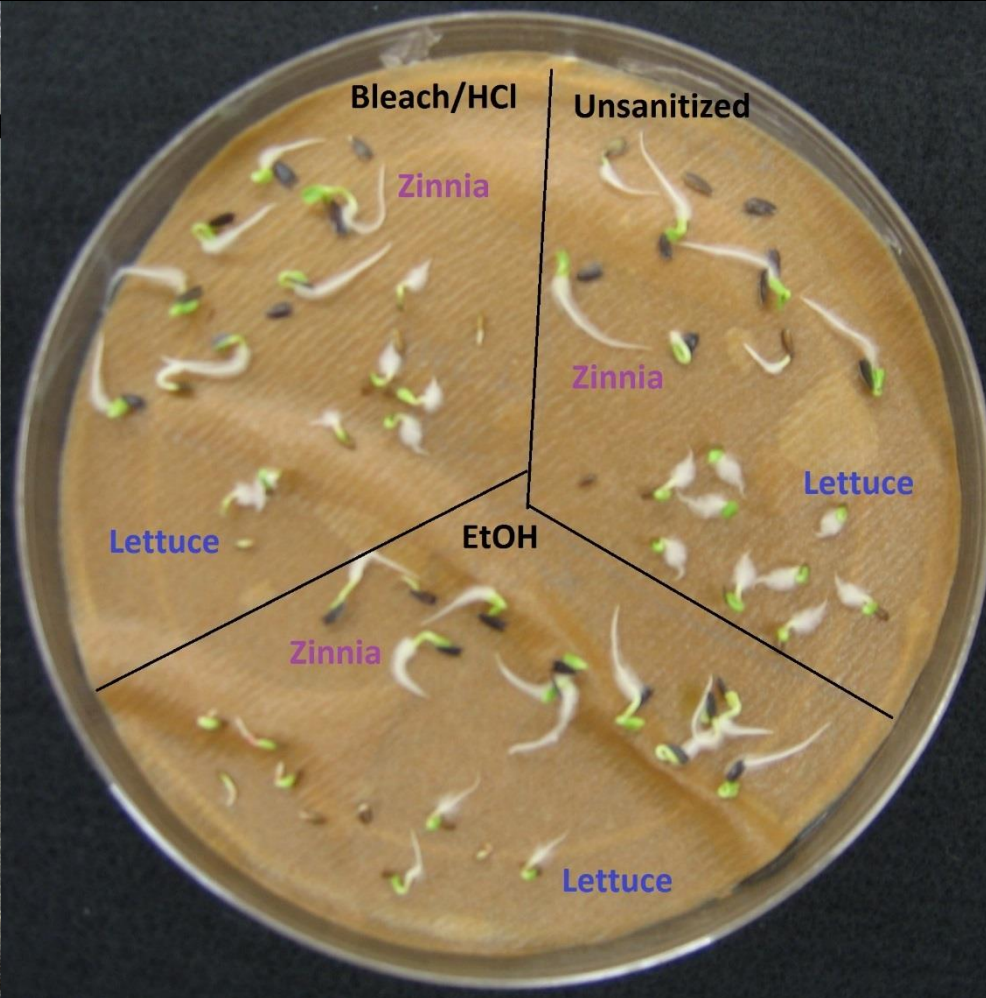
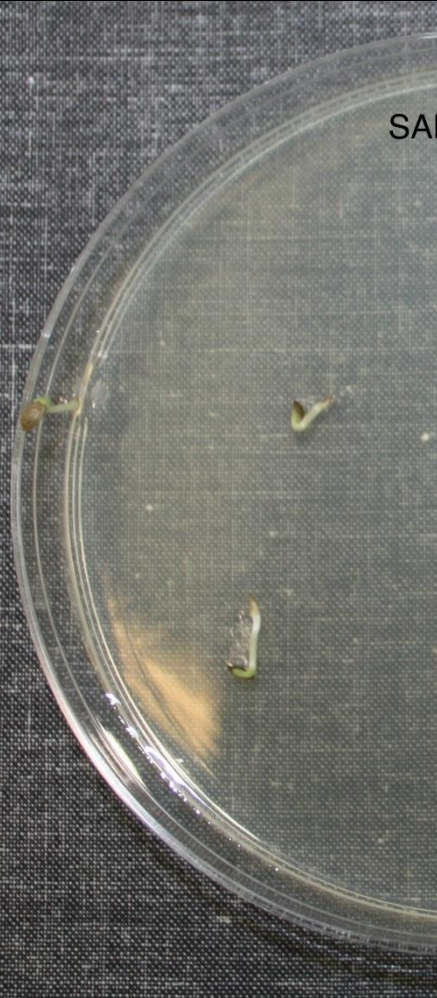
What's Next: Create capability for 100% automation and crew independence.

Food Production Challenge

- Storage and handling of seeds to ensure they are viable, free of contaminants and long-lived.

Veggie Microbiology

Seed Sanitizing



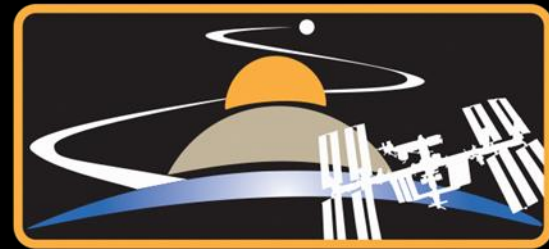
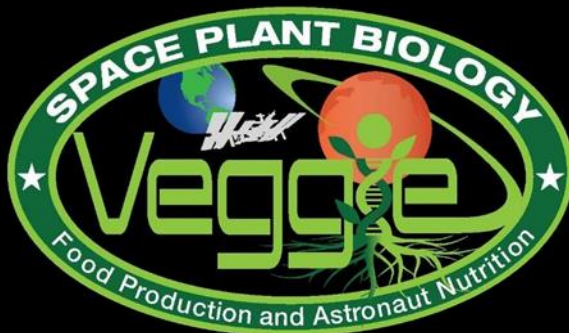
What's Next

- Testing each new seed type
- Learning from commercial growers and seed producers
- Testing methods to handle and store seeds



Thank you!

- The Veg-01 and Veggie teams
 - Data from Mary Hummerick, Christina Khodadad, LaShelle Spencer, Trent Smith
- The astronauts!
- KSC's Food Production Team
- Funding from NASA Space Life and Physical Sciences Space Biology Program



**Exploration Research and
Technology Programs**