



# Adapting Plants to the Space Environment for Improved Crop Productivity and Safety

Gioia Massa, Trent Smith, Elison Blancaflor, Raymond Wheeler

Exploration Research & Technology Programs

NASA, Kennedy Space Center

*Committee on Biological and Physical Sciences in Space*

*Adapting to Space*



# Why grow plants in space?

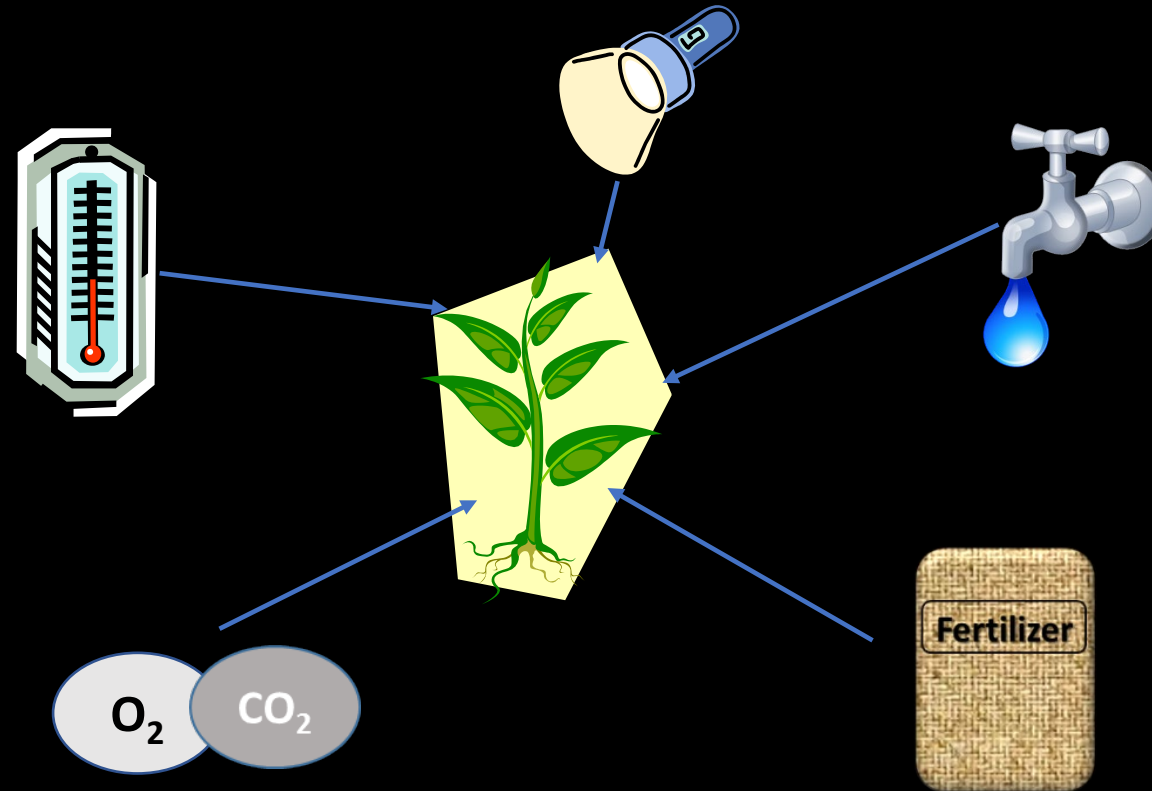
- Food
- Psychological well being
- Atmosphere
- Water



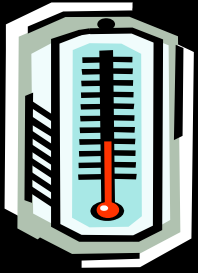


# Cardinal Factors to Consider for Plants to Thrive in Space

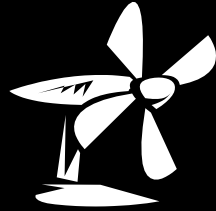
---



# How these work in the Space Environment

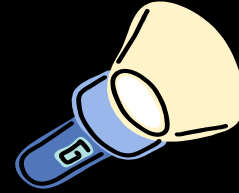


No natural convection without gravity so need to mix the air



O<sub>2</sub>

CO<sub>2</sub>



Key plant characteristics may be modified with novel light recipes



Water forms a ball, and water and air don't mix well, and roots need both



Fertilizer is heavy to launch so we need to learn how to recycle plant (and other) wastes



# Space Crop Production Challenges

## LEO/Deep Space

- Microgravity
- Fluid movement
- No convection

## Water Recycling

- Radiation
- Pressure
- Micrometeorites

## Surface

- Dust
- Regolith
- Partial gravity

- Plant Size
- High CO<sub>2</sub>
- Food Safety & Microbiome
- Nutrient output
- Sustainability
- Abiotic stresses
- Vehicle resources
- Crew time
- Waste

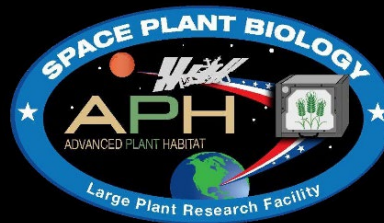
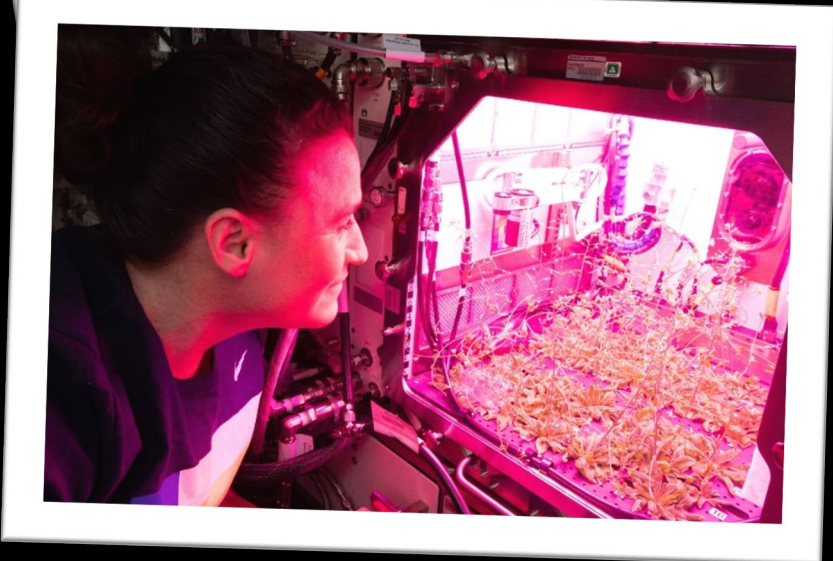
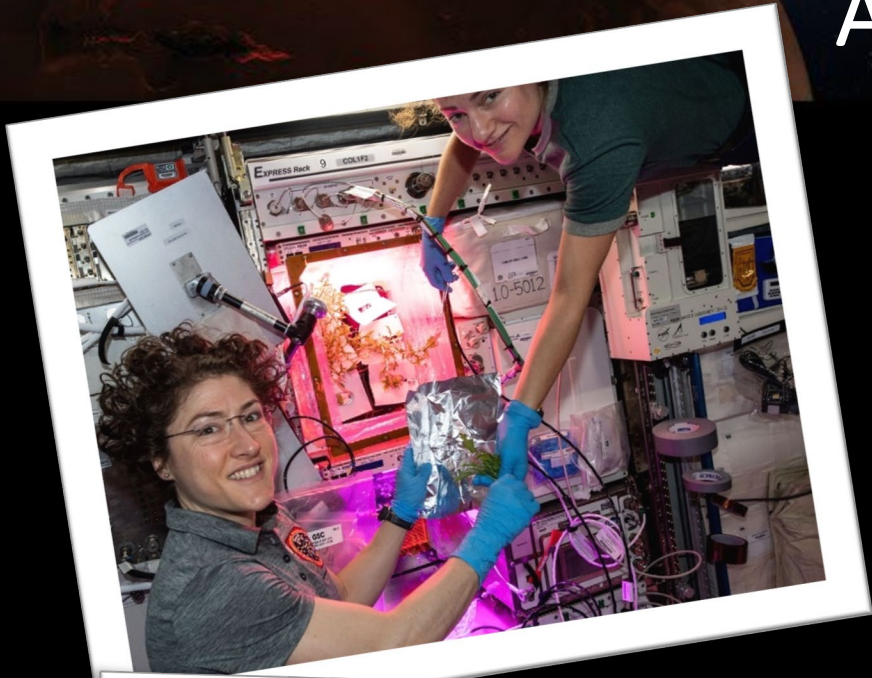
- Productivity
- Stress tolerance
- Environmental optimization
- Crop scheduling

## Crop

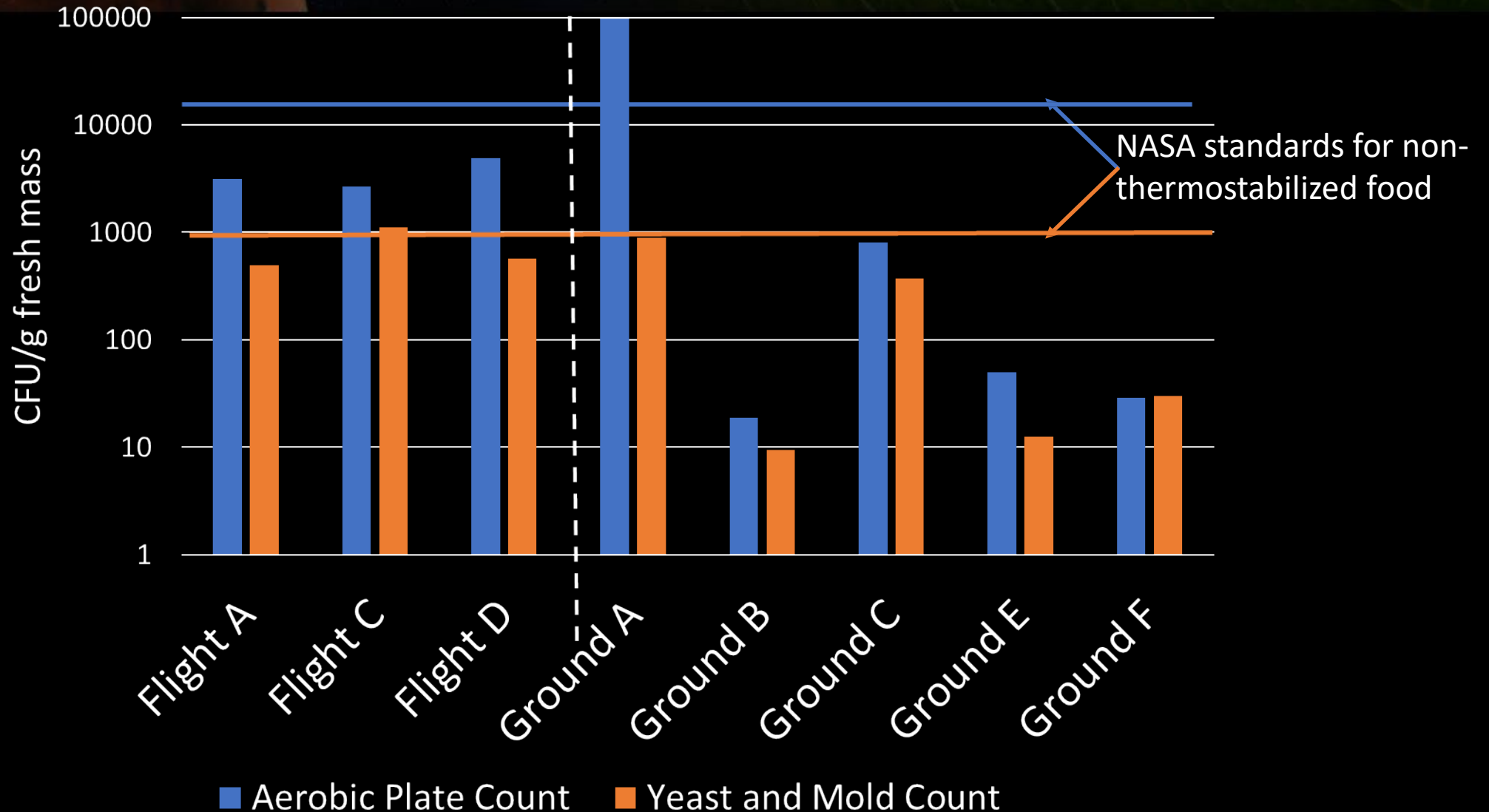
*Solving space crop production challenges requires a basic understanding of BIOLOGICAL and PHYSICAL processes*



# Hardware on ISS that Enables a Basic Understanding of Crop Adaptation to Space

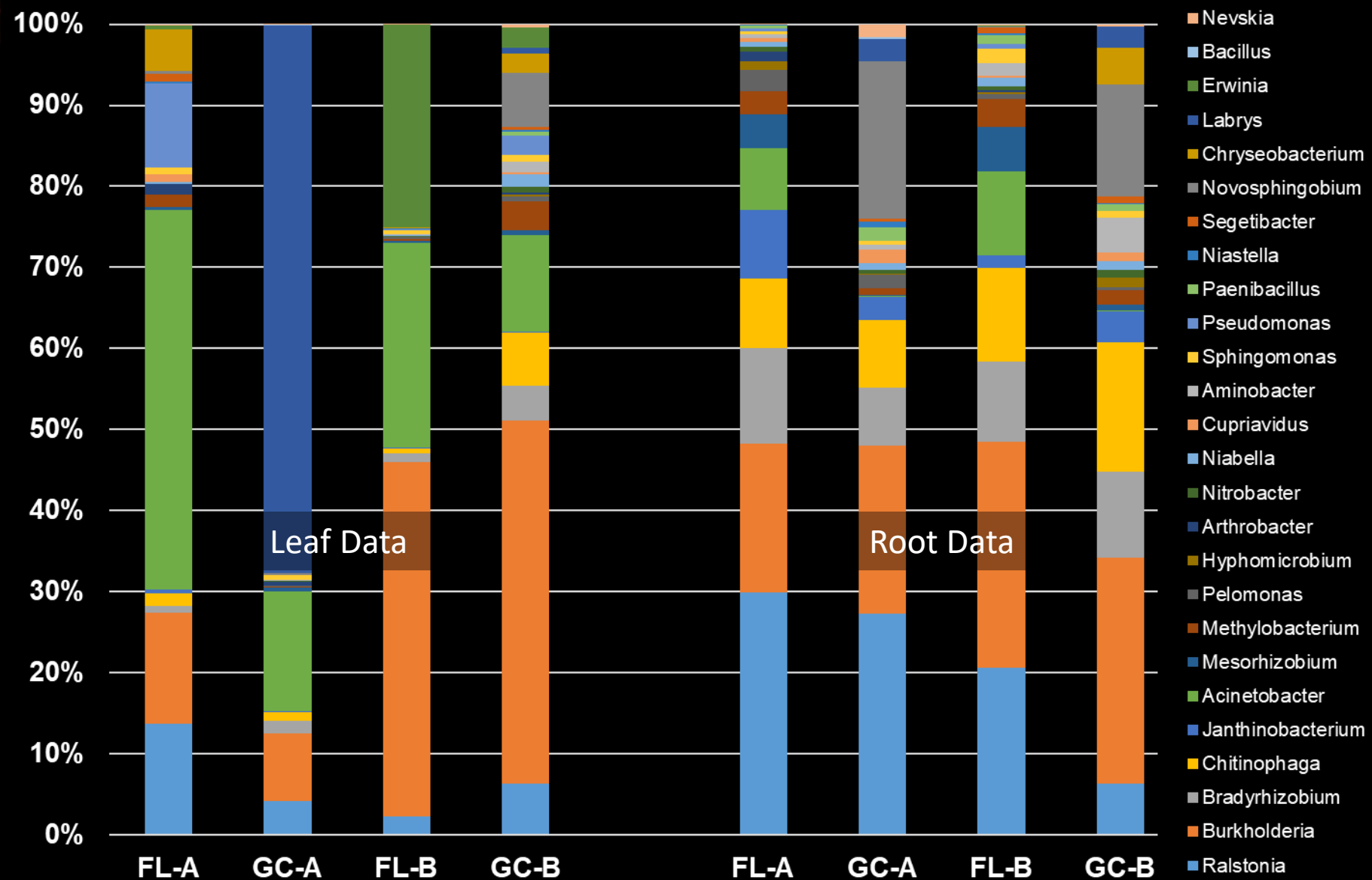


# Assessing Crop Microbial Food Safety for Humans





# Space and Ground Crop Microbiomes Differ with Time, Tissue Type, and Stress





# Ventilation and Water Issues & Consequences in Zinnia



Guttation and Leaf Curling



Fungal Development & Abnormal Growth



# Key Crop Plant Takeaways

---

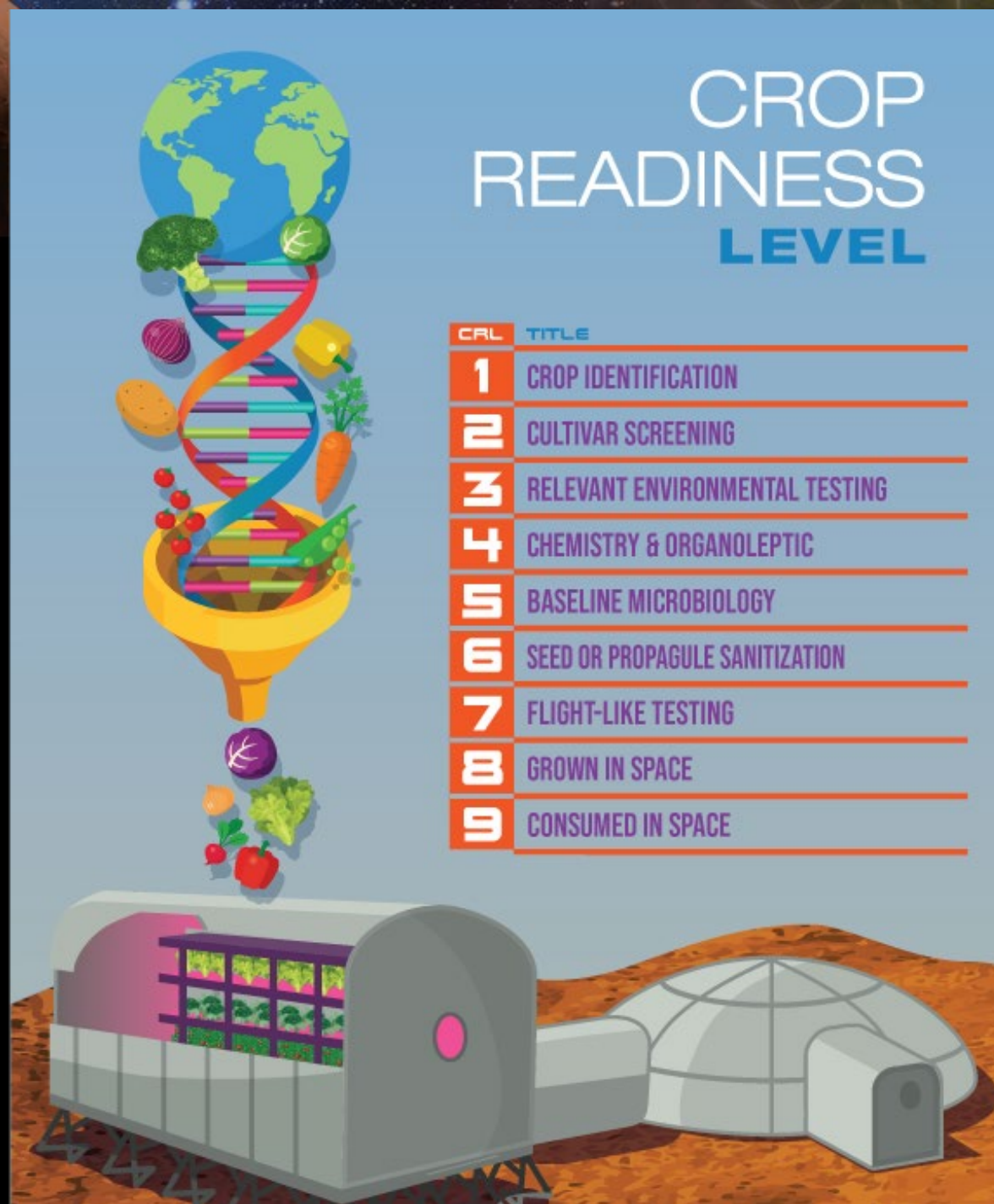
- Data indicate astronauts enjoy growing and eating plants in spaceflight
- Crop yield is similar between ground and flight when plants are not stressed<sup>1</sup>
- Some differences between ground and flight plant nutrient content, but these are not consistent between species or experiments <sup>1, 2</sup>
  - Influenced by crop type, harvest scenario, other environmental conditions (e.g., light, stress)
- Microbial counts and compositions vary between flight and ground-grown plants<sup>1, 2</sup>
  - Microbes typical of the space station environment are often associated with ISS-grown plants
  - Human pathogens are rarely identified on space-grown plants and only below levels of concern to human health
- Microbial communities vary between shoot and root tissues and but not as much between flight and ground <sup>2</sup>
- Plants adapt well to the space environment, and to date, space-grown crops are safe to eat, nutritious, and highly acceptable to astronauts <sup>1,2</sup>

1. Bunchek et al., 2024, Pick-and-eat space crop production flight testing on the International Space Station, J. Plant Interact.

2. Khodadad et al., 2020, Microbiological and Nutritional Analysis of Lettuce Crops Grown on the International Space Station, Front. Plant Sci.



*Key Science  
Questions  
under the  
“Adapting to  
Space” Theme  
help guide  
Crop Readiness  
Levels*



*Modified from Romeyn et al., 2019,  
Crop Readiness Level (CRL): A Scale to  
Track Progression of Crop Testing for  
Space*

# Examples of Knowledge Gaps for Space Crop Production

- The library of crops tested is limited – we need to test a wider diversity of different crops and crop types for exploration
  - One plant family should not make up  $>1/3$  of the entire crop library
- Plant Microbiome - Food Safety/Plant Health
  - Crops will be grown hydroponically in space habitats near to mid-term. There are many unknowns on hydroponic water and nutrient delivery, and few data on the hydroponic microbiome.
  - Plant performance in exploration atmospheres (reduced pressure) is largely unstudied, including plant-microbial interactions, responses to pathogens, etc.
- Deep-space radiation impacts on seeds and plants remain unknown





# Thank you!

---

- Veggie, APH, and Space Crop Production teams
- NASA's astronauts
- NASA's Biological and Physical Sciences Division, ISS Program, Human Research Program, Mars Campaign Office

