National Aeronautics and Space Administration

Environmental Control and Life Support Systems – Crew Health and Performance (ECLSS-CHP) – Future Research Needs and Alignment

Biological and Physical Sciences Research Fall Committee Meeting – 10/20/2022

James Broyan
ECLSS-CHP System Capability Leadership Team (ECLSS-CHP SCLT) Lead

What are ECLSS-CHP Systems?

- The systems and technologies that keep our astronauts healthy and productive while living and working in space
- 9 Capability Areas are further decomposed to capabilities and sub-capabilities to define gaps

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS (ECLSS)

Life Support

Environmental Monitoring

Fire Safety

Logistics

CREW HEALTH AND PERFORMANCE SYSTEMS (CHP)

(Strongly coordinated with HRP risks)

Spacesuit Physiology

Crew Health Countermeasures

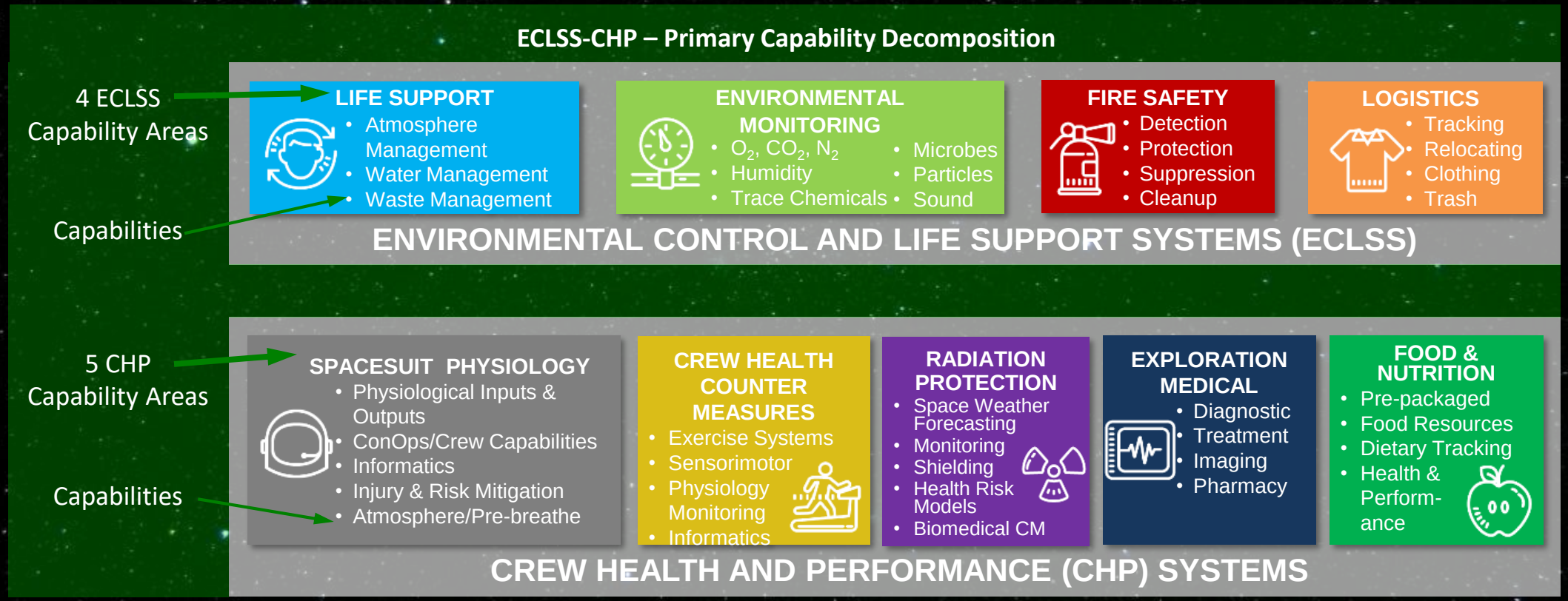
Radiation Protection

Exploration Medical

Food and Nutrition

ECLSS-CHP SCLT Capability Areas and Capabilities

- Capability areas are divided into 25 technology development roadmaps
  - Roadmaps capture development, tech demos, validation, reliably testing and mission infusion targets
  - Roadmaps are directorate (e.g. ESDMD, SOMD, STMD) and program (EC, ISS, HRP, GCD) agnostic
- ECLSS-CHP has 87 ESDMD Capability Integration Team (CIT) recognized gaps plus numerous related gaps



ECLSS-CHP Envisioned Future Decomposition by Capability Area

(Mission need)
- L = Lunar surface
- T = Transit to Mars
- M = Mars surface

LIFE SUPPORT

- Reliable long-duration life support with Earth independent diagnostics and repair (L,T,M)
- >20% reduction in spares and installed mass (T)
- Enable single missions >800 days w/o resupply (T)
- Repeated missions with >9 months dormancy (L,T,M)
- >75% oxygen recovery at 2 mm-Hg CO_2 (T)
- High pressure oxygen recharge for EVA (L,M)
- >98% water recovery (L,T,M)
- Remove respirable lunar and Mars dust (L,M)
- Planetary protection compatible ECLSS venting (M)

ENVIRONMENTAL MONITORING

- Identify and quantify chemical (>12 water, >33 air) and microbial species in-flight with out sample return (L,T,M)
- Ability to detect unknown constituents (T,M)
- Distinguish between fire, habitat dust, and surface dust particles (L,M)
- Support forward and backward planetary protection detection (both microbial and non-culture techniques) (M)

FIRE SAFETY

- Test-verified partial gravity flammability characteristics and countermeasures (L,M)
- ECLSS compatible fire suppression (L,T,M)
- Reduce post fire clean-up time (L,T,M)
- Common fire safety strategy across element architectures (L,T,M)

LOGISTICS

- Jettison >90% of trash mass during Mars transit (T)
- Mars trash disposal compatible with planetary protection (T,M)
- In-flight autonomous logistics (L,T,M)
- Reducing clothing and wipes mass by >50% (L,T,M)
- Clothing flammability (and other non-metallics) >36% O2 (L,M)

EVA PHYSIOLOGY

- 100% of tasks within human performance (L,T,M)
- Predict and mitigate decompression sickness (L,M)
- Predict and mitigate of suit or EVA injury (L,M)
- 6 Major physiological informatics parameters provided in-suit to enable real time self assessment or loss of communication areas (L,M)

COUNTER-MEASURES

- Reduce mass and volume (L,T,M)
- Maintain/monitor fitness in-flight to enable unassisted landing egress & EVA (L,T,M)
- Validated lunar and Mars fitness standards (L,M)

RADIATION PROTECTION

- 24-hr prediction of solar storm duration and intensity to >90% (L,T,M)
- High energy neutron detectors (L,T,M)
- Earth independent monitoring/forecasting (T,M)
- GCR shielding (T,M)

EXPLORATION MEDICAL

- In-flight diagnostics and treatment for 100 of 120 medical risk conditions (L,T,M)
- Autonomous medical skill and & decision support systems (T, M)

FOOD & NUTRITION

- 100% of nutrient stability >5-year shelf life (T,M)
- Food acceptability >90% (L,T,M)
- <30% launched water content (T,M)
- Exploration counter-measure in-flight nutrition intake monitoring (L,T,M)

BPS Research and development needs for SCLT envisioned futures

Requests for BPS	Synergism	ECLSS-CHP SCLT needs
Study how physical characteristics and human/crop interact in the ug and partial gravity environments; and lower pressure/higher oxygen habitats	Coordinate research, solicitations, and projects to close knowledge gaps, identify novel phenomena for technology development	Identify, characterize and mitigate the risks to life support systems human health and performance in space

• Flowing gas/liquid/porous media and surface interactions
• Flammability, combustion physics testing and modeling in partial-g
• Exterior to habitat microbial transport modeling in ug and partial-g surfaces
• Biofilm prevention mechanisms
• Cryogenic gas separation
• Plant topics
  • Hyperspectral imaging
  • Moisture/multiple-growth-cycle impacts on microbiome
  • Water/nutrient management
  • Leafy/fruiting cultivator evals
• Radiation interactions with stored crew consumables/crops/crew
• Dust and regolith water/oxygen interactions
	• Multiphase flow research
	• Lunar surface flammability/ combustion research facilities
	• External ISS and lunar lander microbial characterization
	• Multiyear biofilm research
	• Use of permanently shadowed regions
	• Novel crop development
	• Crop health monitoring research
	• Leafy/fruiting/microgreen cultivator evals
	• Plant growth research facilities (media, aeroponics/hydroponics)
	• Radiation/microgravity interactions
	• Non-earth centric radiation monitoring/modeling/warning capabilities
	• Chemical and physics modeling and ersatz development
		• Gas/liquid separator, pressure drop in 2-phase flow heat exchangers, filter performance, interior dust transport
		• Improved flammability materials selection and reduced vehicle risk
		• Emergency response upgrades
		• Life support accommodations for planetary protection
		• Improved life support dormancy
		• Novel cabin gas separation/trace gas removal
		• Crop/food production facilities
		• Space radiation countermeasures
		• Crew health countermeasure systems
		• Exploration medical diagnostic and treatment systems
		• Improved water and gas processing to remove new contaminant sources

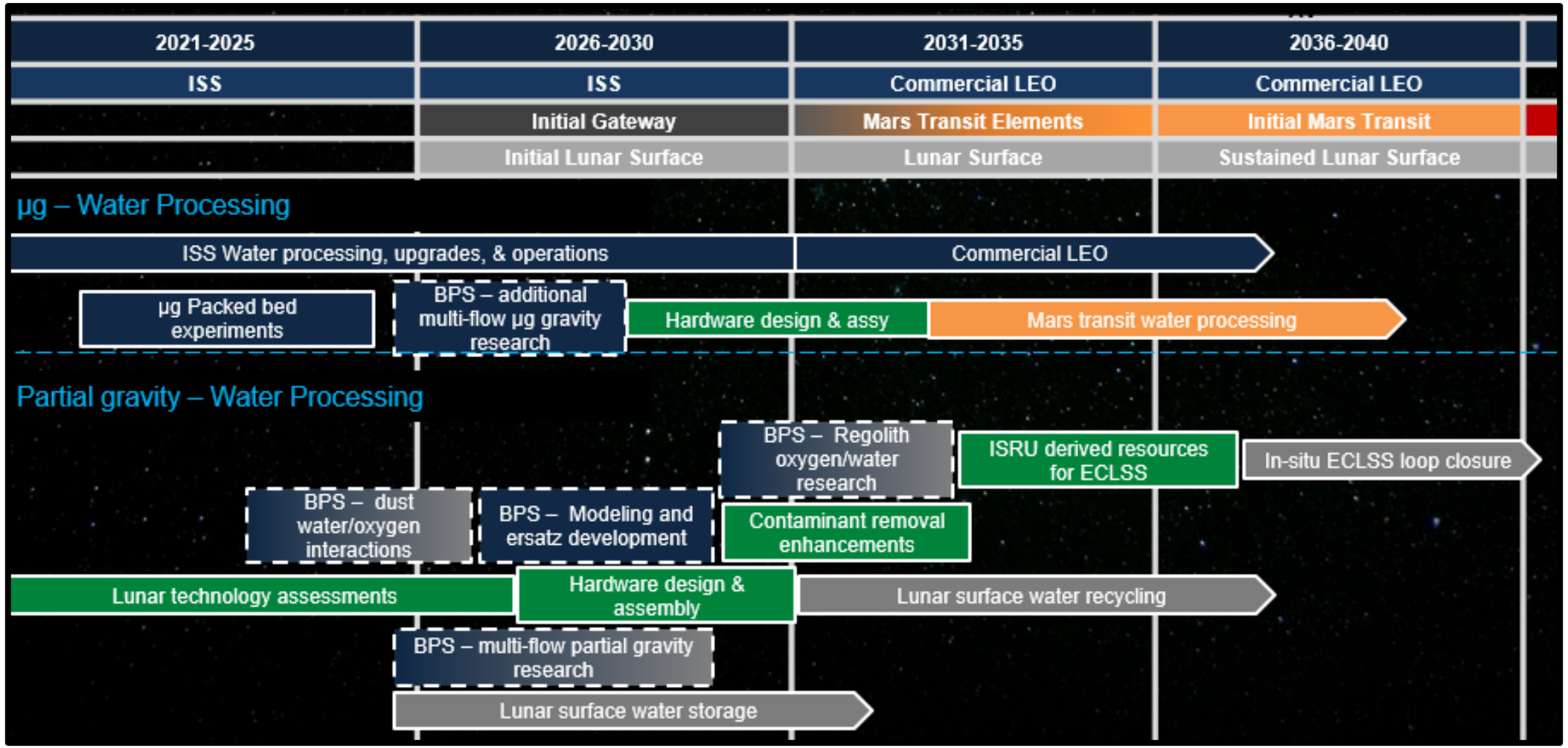
Focus area: Multi-phase Flow Phenomena

- **Research needs: Flowing gas/liquid/porous media and surface interactions**
- **Technology development supported:**
  - Gas/liquid separators, 2/3-phase flow pressure drop and flow distribution in packed beds, free flowing surface media beds, plant root zones, plumbing pipes, condensing heat exchangers, and filters
  - Liquid distribution greatly influences air/water interface where microbial/fungal mitigation is challenging during operation and uncrewed periods
- **Supports NASA Moon to Mars Objectives**
  - AS-1LM: Characterize and monitor the contemporary environments of the lunar and Martian surfaces and orbits, including investigations of micrometeorite flux, atmospheric weather, space weather, space weathering, and dust, to plan, support, and monitor safety of crewed operations in these locations.
  - AS-3LM: Characterize accessible lunar and Martian resources, gather scientific research data, and analyze potential reserves to satisfy science and technology objectives and enable In-Situ Resource Utilization (ISRU) on successive missions.
- **Key aspects**
  - Complex media, surfaces changed by biological activity over time, and partial gravity transitions
  - Vehicle and crew acceleration perturbations

Focus area: Lunar Dust and Regolith

- **Research needs: Unweathered dust and regolith water/oxygen interactions inside habitats**
- **Technology development supported:**
  - Ensuring robustness to air and water recycling technology to understand potential for new contaminant and interactions with processing catalysts and surfaces
  - Inform novel approaches to using ISRU derived oxygen, water, and other consumables for ECLSS
- **Supports NASA Moon to Mars Objectives**
  - HBS-2LM: Evaluate and validate progressively Earth-independent crew health & performance systems and operations with mission durations representative of Mars-class missions.
  - AS-3LM: Characterize accessible lunar and Martian resources, gather scientific research data, and analyze potential reserves to satisfy science and technology objectives and enable In-Situ Resource Utilization (ISRU) on successive missions.
- **Key aspects**
  - Establishing ground truth with actual range of lunar materials
  - Development of chemically representative dust, regolith, ice simulates/ersatz
  - Identifying new compounds or chemicals that may require detection, monitoring, and mitigation for crew health or maintaining vehicle performance
  - Extensibility of basic research to crop growth media (covered under crops focus area)

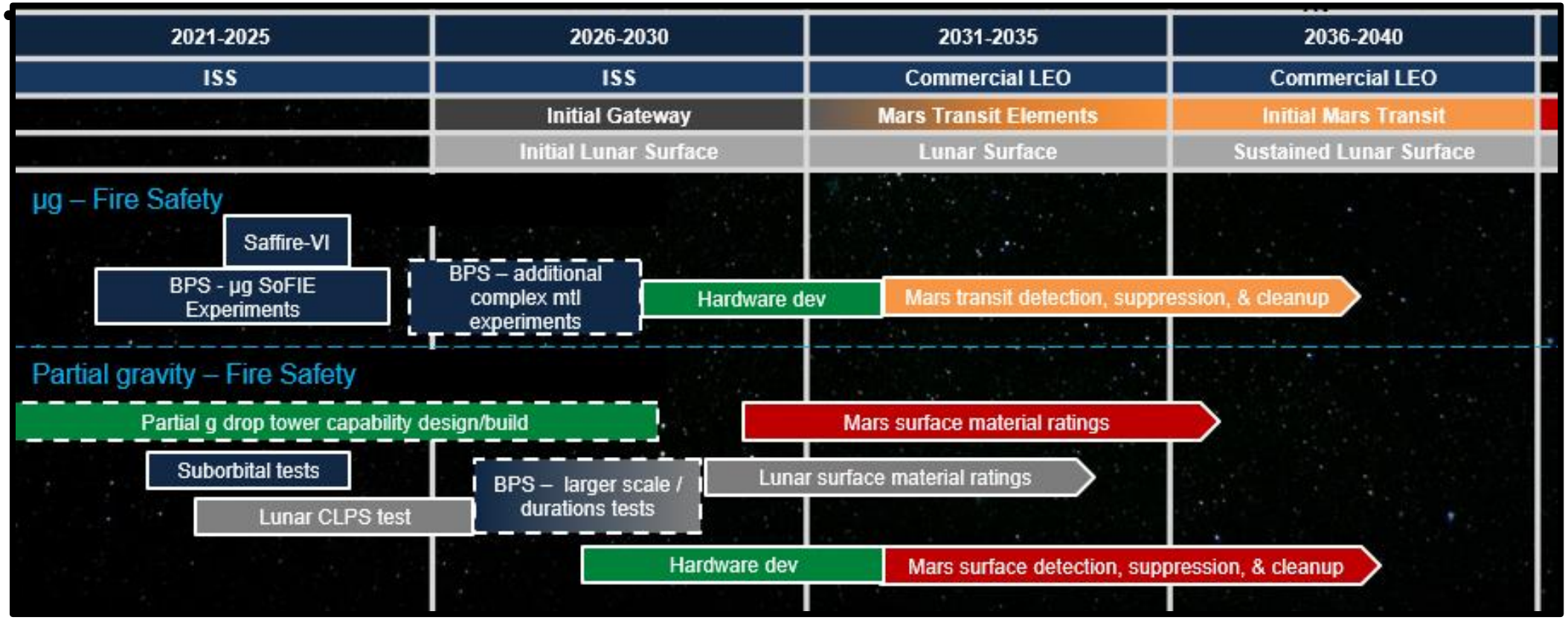
Notional Roadmap of Multiphase Flow, Dust, and ISRU Resources Research Support for Exploration Water Processing



Focus area: Flammability and Fire Safety

- **Research needs: Partial gravity testing methods, material characterization, and models**
- **Technology development supported:**
  - Materials selection and vehicle construction layout standards
  - Improved fire detection, suppression, and post-fire cleanup technologies
- **Supports NASA Moon to Mars Objectives**
  - PPS-2LM: Advance understanding of physical systems and fundamental physics by utilizing the unique environments of the Moon, Mars, and deep space.
  - AS-6LM: Advance understanding of how physical systems and fundamental physical phenomena are affected by partial gravity, microgravity, and general environment of the Moon, Mars, and deep space transit.
- **Key aspects**
  - Complex multimedia material, charring material characterizations in range of partial gravity environments.
  - Establishment of ground truth in lunar gravity and correlation of sub-orbital and ground testing analogs
  - Validation of large-scale fire modeling
  - Characterization of pre-combustion and post-combustion chemical and physical environments in lunar fire environments (partial-g, high oxygen concentration, low total pressure)

Notional Roadmap of Combustion & Fire Research Support for Exploration Fire Safety

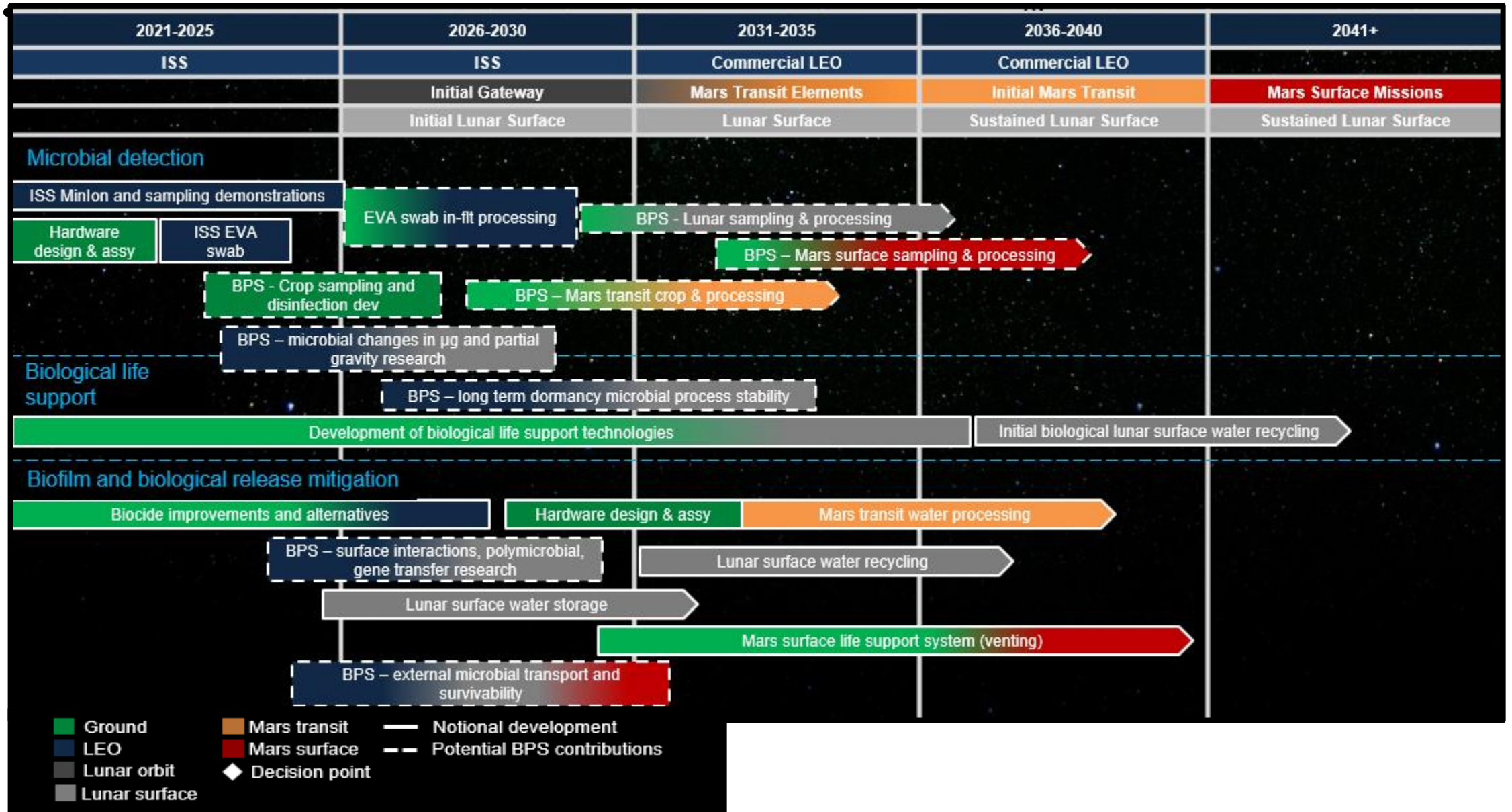


Ground
LEO
Lunar orbit
Lunar surface
Mars transit
Mars surface
Decision point
Notional development
Potential BPS contributions

Focus area: Microbial Transport, Mitigation, and Monitoring

- **Research needs: extravehicular microbial transport and survivable, adaption of biofilm in space environments and disrupting proliferation, stable biological life support processes**
- **Technology development supported:**
  - CO2 removal, airlock, vehicle pressure relief, bacterial air filters, and spacesuit venting mitigations for planetary protection
  - Life support disinfection and dormancy technologies
  - Biological life support processes for partial gravity
- **Supports NASA Moon to Mars Objectives**
  - HBS-1LM: Understand the effects of short- and long-duration exposure to the environments of the Moon, Mars, and deep space on biological systems and health, using humans, model organisms, systems of human physiology, and plants.
  - AS-4LM: Conduct applied scientific investigations essential for the development of bioregenerative-based, ecological life support systems
  - LPS-4M: Advance understanding of the origin of life in the solar system by identifying where and when potentially habitable environments exist(ed), what processes led to their formation, how planetary environments and habitable conditions have co-evolved over time, & whether there is evidence of past or present life in the solar system beyond Earth
- **Key aspects**
  - Polymicrobial biofilms on 3D surfaces during crewed and uncrewed periods (wet/dry/nutrient variations)
  - Radiation modifications and mitigation resistance modifications
  - Detection of modifications and their significance on long duration missions

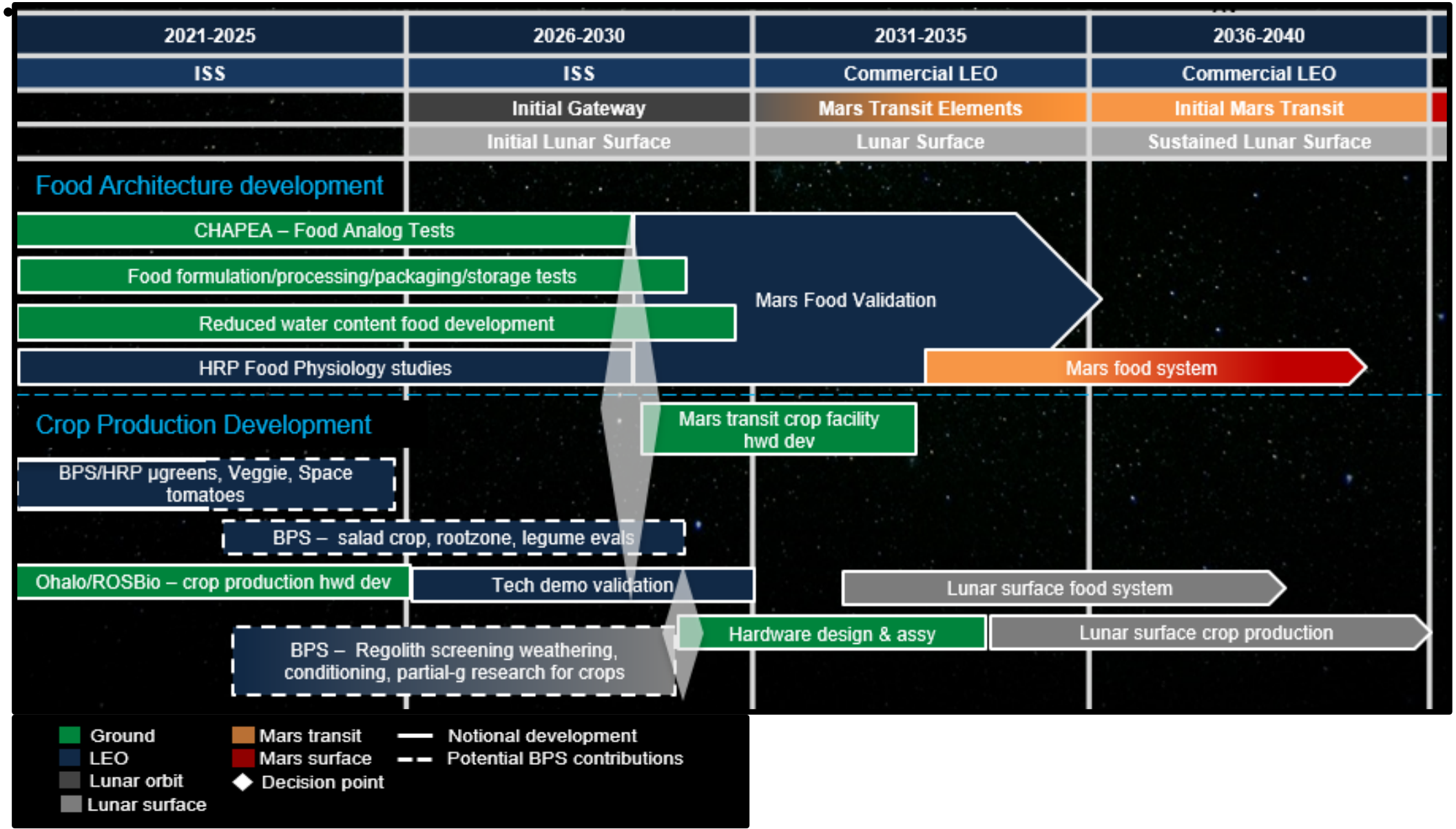
Notional Roadmap of Microbial Transport, Mitigating, and Monitoring Research Support for Environmental Monitoring, Life Support Processes, and Planetary Protection



Focus area: Crops, Food, and Nutrition

- **Research needs: adapted varieties, water & nutrient delivery, & microbiome management**
- **Technology development supported:**
  - Crop production for supplement nutrition and variety on long duration lunar surface & Mars transit missions
- **Supports NASA Moon to Mars Objectives**
  - HBS-1LM: Understand the effects of short- and long-duration exposure to the environments of the Moon, Mars, and deep space on biological systems and health, using humans, model organisms, systems of human physiology, and plants.
  - HBS-2LM: Evaluate and validate progressively Earth-independent crew health & performance systems and operations with mission durations representative of Mars-class missions.
  - AS-5LM: Define crop plant species, including methods for their productive growth, capable of providing sustainable and nutritious food sources for lunar, Deep Space transit, and Mars habitation.
- **Key aspects**
  - Selection of most productive range of crops based on relevant ug and partial-g environments
  - Long term microbial/fungal control and moisture management over many crop cycles
  - Radiation affects on stored crop supplies and crop growth
  - Closing knowledge gaps on regolith screening, conditioning, and augmentation of lunar environment

Notional Roadmap of Crop, Food, & Nutrition Research Support for Food, Nutrition, and Crew Health Countermeasures



Backup Charts

- **Sampling of relevant BPS Decadal Committee white papers**
- **Moon to Mars Objectives most relevant to ECLSS-CHP**

Select white papers submitted to BPS Decadal that support ECLSS-CHP

- **Direct support of ECLSS-CHP needs**
  1. Challenges and Research Needs for Micro- and Partial-Gravity Fires (Lead: Ya-Ting Liao)
  2. Recommendations for Fire Extinguisher Research for Crewed Missions (Lead: John Easton)
  3. Spacecraft Materials Fire Safety (Lead: Fletcher Miller)
  4. Research Questions and Challenges for Improved Spacecraft Fire Detection (Lead: Claire Fortenberry)
  5. Solid Fuel Combustion in Partial and Micro-Gravity (Lead: Michael Gollner)
  6. Recommendations for Spaceflight Research to Enable Crop Plant Growth Systems for Exploration (Lead: Alexandra Whitmire)
  7. Spaceflight Food System: Impacts to Nutritional Adequacy, Health, Performance, and Resources in Space Exploration (Lead: Grace Douglas)
  8. Microbial Food Safety in Space Production Systems (Lead: Jessica Lee)
  9. Elevating the Use of Genetic Engineering to Support Sustainable Plant Agriculture for Human Space Exploration (Lead: Natasha Haveman)
  10. What to Take? When to Make? How to Break Even? Avoid Mistakes in Microbial Bio-manufacturing in Support of Human Near-to-Deep Space Exploration (Lead: Nils Averesch)
  11. Planetary Protection Knowledge Gaps and Enabling Science for Crewed Mars Missions (Lead: J Andy Spry)

- **HRP related submissions that support ECLSS-CHP needs**
  - Greater understanding at the fundamental science levels can lead to more targeted and efficient applied biomedical solutions
    - Provides input for SCLT technology development to close exploration gaps
  1. Vision for the Next Generation of Spaceflight Microbiology: Human Health and Habitat Sustainability (Lead: Mark Ott)
  2. The Need for Biological Countermeasures to Mitigate the Risk of Space Radiation-Induced Carcinogenesis (Lead: by Broc Sishc)
  3. Development of Medical Capabilities & Tech for Health Monitoring, Diagnostics, & Treatment during Human Exploration Spaceflight (Lead: Shean Phelps)
  4. Enabling a Precision Health System for Deep Space Exploration (Lead: Corey Theriot)

Alignment to NASA Moon to Mars Objectives (Sept 2022 release)

- **NASA Moon to Mars Objectives source for the most relevant objectives listed in presentation**
- **https://www.nasa.gov/sites/default/files/atoms/files/m2m-objectives-exec-summary.pdf**