National Aeronautics and Space Administration

# Environmental Control and Life Support Systems – Crew Health and Performance Future Research Needs

## STMD Decadal Survey on Biological and Physical Sciences Research in Space 2023-2032 Committee Meeting – 9/14/2022

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# 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)

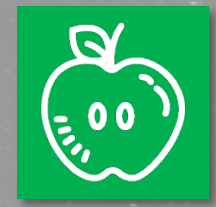
(Strongly coordinated with HRP risks)

Spacesuit Physiology

Crew Health Countermeasures

Radiation Protection

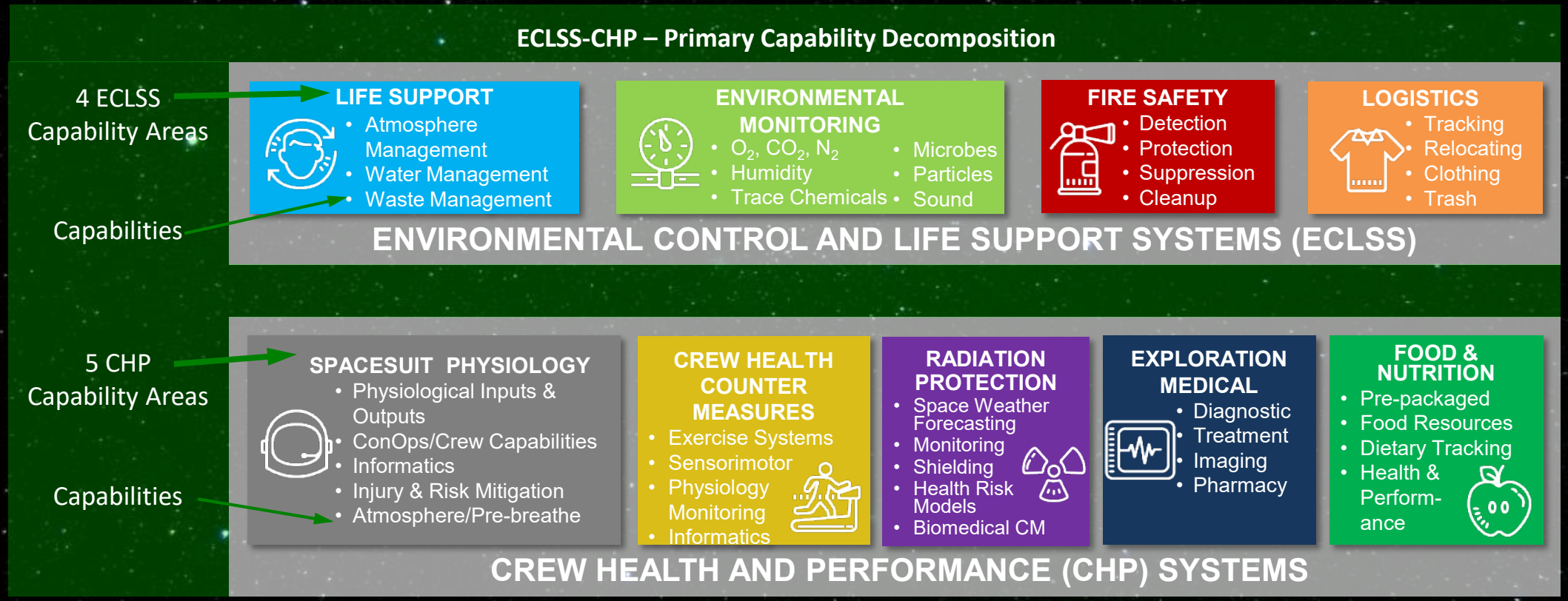
Exploration Medical



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 life interacts 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<br>• Flammability, combustion physics testing and modeling in partial-g<br>• Exterior to habitat microbial transport modeling in ug and partial-g surfaces<br>• Biofilm prevention mechanisms<br>• Cryogenic gas separation<br>• Plant topics<br>  • Hyperspectral imaging<br>  • Moisture/multiple-growth-cycle impacts on microbiome<br>  • Water/nutrient management<br>  • Leafy/fruiting cultivator evals<br>• Radiation interactions with stored crew consumables/crops/crew | • Multiphase flow research<br>• Lunar surface flammability/ combustion research facilities<br>• External ISS and lunar lander microbial characterization<br>• Multiyear biofilm research<br>• Use of permanently shadowed regions<br>• Novel crop development<br>• Crop health monitoring research<br>• Leafy/fruiting/microgreen cultivator evals<br>• Plant growth research facilities (media, aeroponics/hydroponics)<br>• Radiation/microgravity interactions<br>• Non-earth centric radiation monitoring/modeling/warning capabilities | • Gas/liquid separator, pressure drop in 2-phase flow heat exchangers, filter performance<br>• Improved flammability materials selection and reduced vehicle risk<br>• Emergency response upgrades<br>• Life support accommodations for planetary protection<br>• Improved life support dormancy<br>• Novel cabin gas separation/trace gas removal<br>• Crop/food production facilities<br>• Space radiation countermeasures<br>• Crew health countermeasure systems<br>• Exploration medical diagnostic and treatment systems |
| Science identifying possible issues, enhancing, or enabling phenomena | More basic ← → More applied | Technology maturation to close known gaps |

# White papers  submitted to BPS decadal the support ECLSS-CHP needs

- **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)