National Aeronautics and
Space Administration

Regenerative Exploration ECLSS Technology Development

Humans to Mars Summit
Technical Session 3, Closed Loop ECLSS Panel

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What is the ECLSS-CHP Scope?

- The ECLSS-CHP SCLT is a community-of-practice team comprised of subject matter experts from across the Agency in support of NASA's human exploration and aeronautics research missions
- Includes 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

- Spacesuit Physiology
- Crew Health Countermeasures
- Radiation Protection
- Exploration Medical
- Food and Nutrition

ECLSS Envisioned Futures

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

LIFE SUPPORT

- Reliable long-duration life support, >800 days w/o resupply (L,T,M)
- >20% reduction in spares and installed mass (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)

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)

ENVIRONMENTAL MONITORING

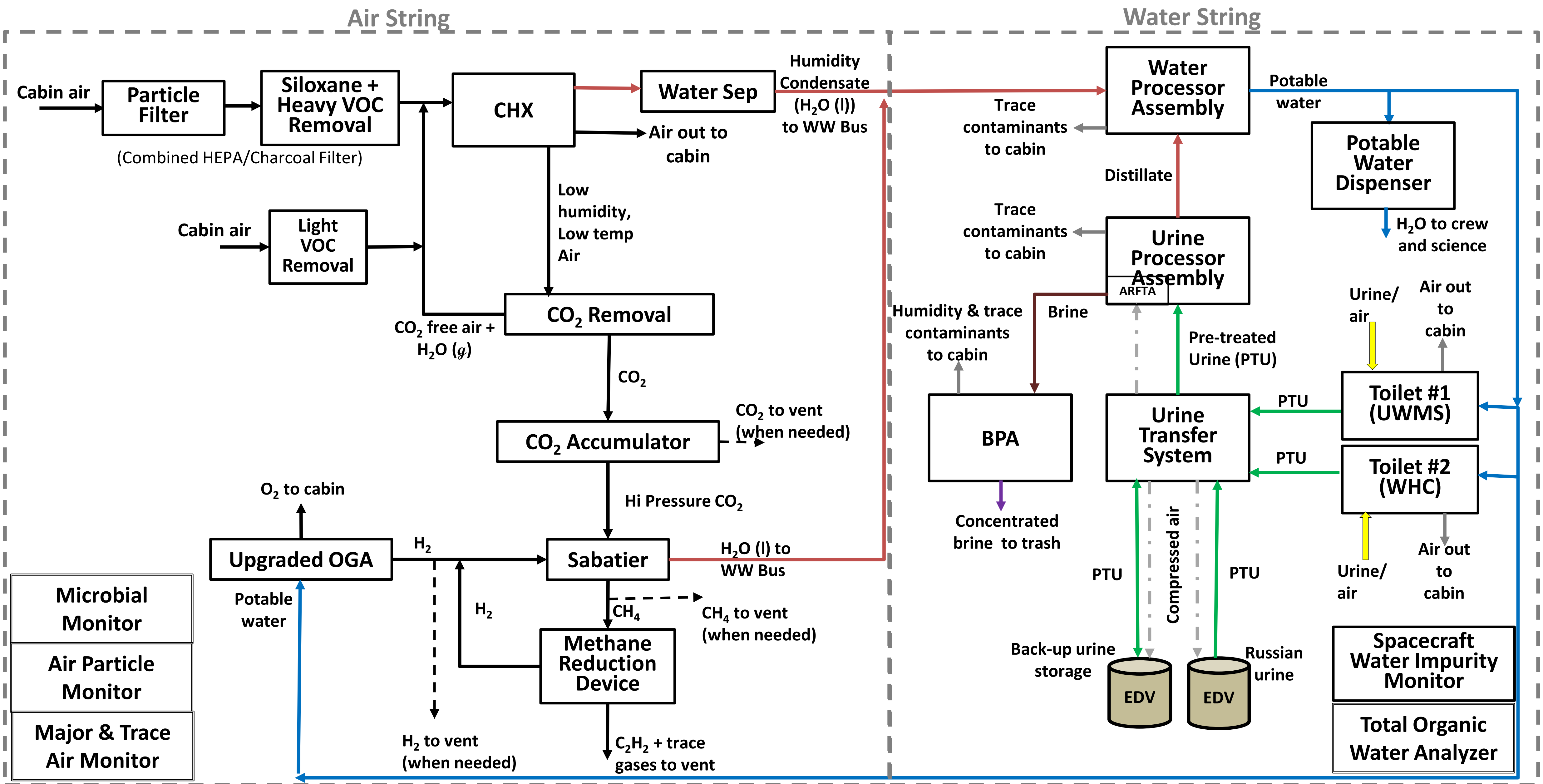
- Identify and quantify chemical (>12 water, >33 air) and microbial species in-flight with out sample return (L,T,M)
- Ability to detect unknown constituents (T,M)
- Distinguish between fire, habitat dust, and surface dust particles (L,M)
- Support forward and backward planetary protection detection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

LOGISTICS

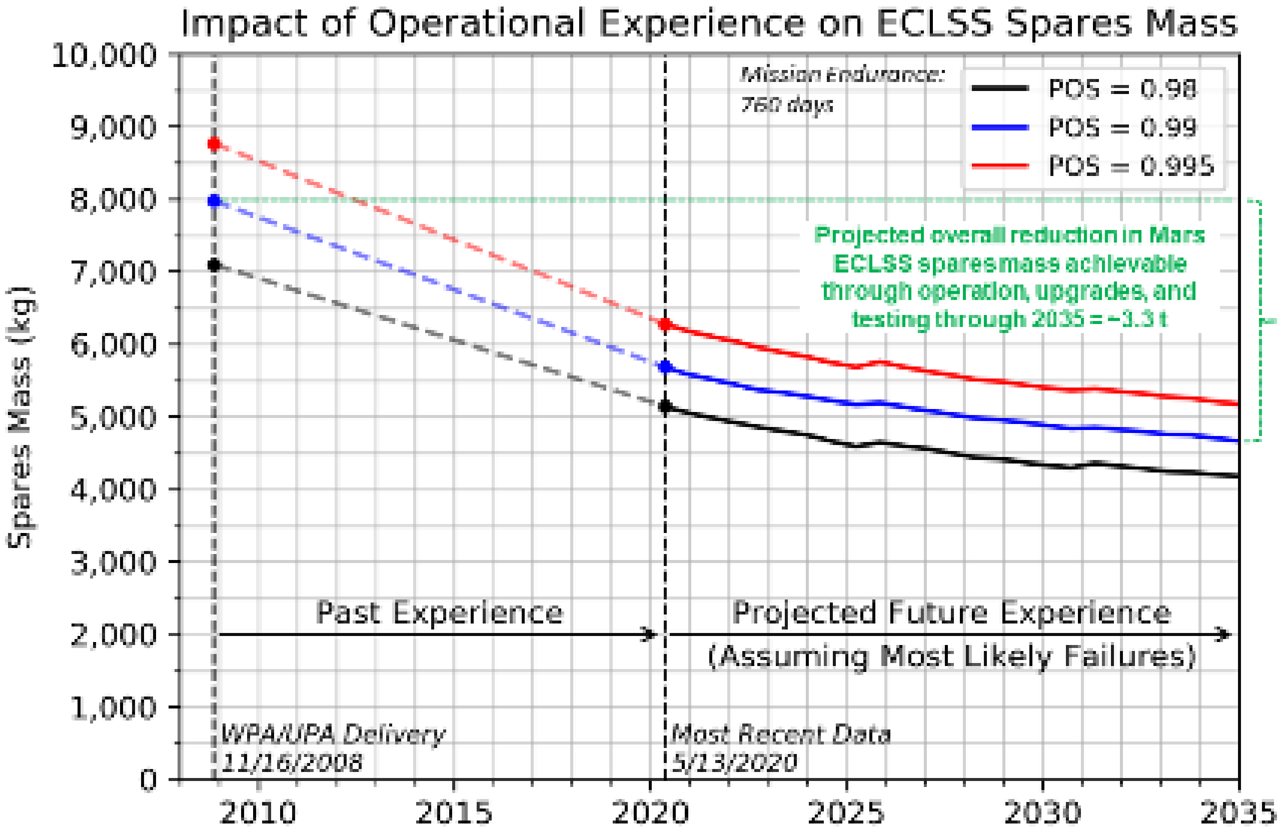
- Jettison >90% of trash mass during Mars transit (T)
- Mars trash disposal compatible with planetary protection (M)
- In-flight autonomous logistics (L,T,M)
- Reducing clothing and wipes mass by >50% (L,T,M)
- Clothing flammability (and other non-metallics) >36% O2 (L,M)

Exploration ECLSS on ISS

Getting to 98% water & >75% oxygen recovery requires integration and verification of many systems



Long-term Test Verified ECLSS is Critical for Mars Reduces Mass and Improves Crew Safety

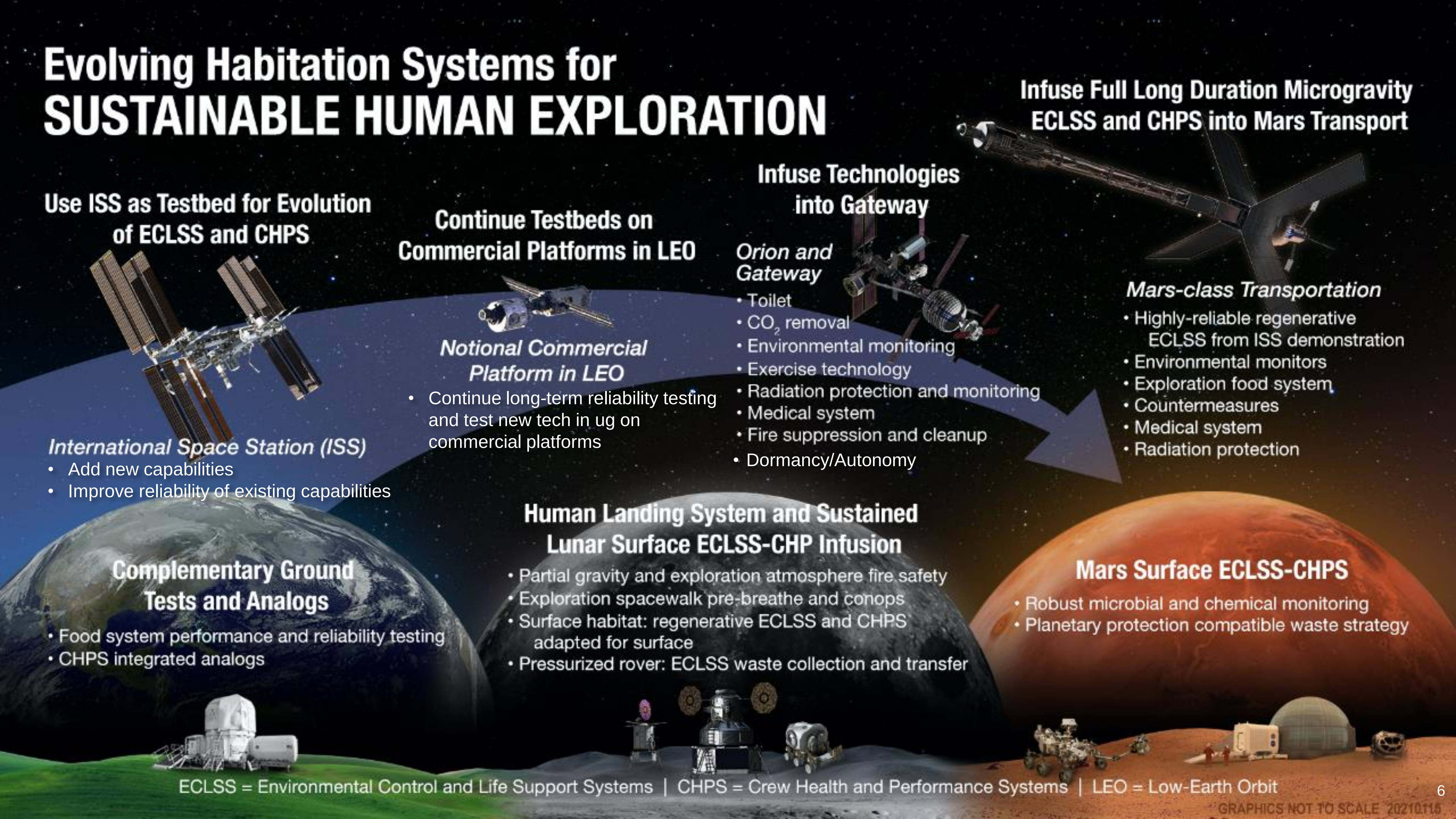


*ECLSS spares allocated to achieve a **reasonable range** of Probability of Sufficient (POS) spares for a **760-day Mars-class mission** using initial, current, and projected future failure rate estimates.*

- **Failure rates cannot be measured directly**
- **Must be statistically estimated from test & operational data**
  - **ISS experience shows that initial failure rate estimates are often incorrect, sometimes by >4x**
  - **ISS flight experience has been extremely valuable, providing data to refine failure rate estimates**
    - 30% reduction in spares mass
    - Improved crew safety via identification and mitigation of hidden risk from underestimated failure rates (too low a spares mass allocation or taking the wrong complement of spares)

Open loop ECLSS for 4 Crew on round trip Mars mission (860 days) requires:

- **~16,500 kg water**
- **~3,300 kg oxygen**
- **~ 6,000 kg food (@25% hydration)**
- **Does not include tankage, packaging and structure**


Evolving Habitation Systems for
SUSTAINABLE HUMAN EXPLORATION
Use ISS as Testbed for Evolution of ECLSS and CHPS
International Space Station (ISS)
• Add new capabilities
• Improve reliability of existing capabilities
Continue Testbeds on Commercial Platforms in LEO
Notional Commercial Platform in LEO
• Continue long-term reliability testing and test new tech in ug on commercial platforms
Infuse Technologies into Gateway
Orion and Gateway
• Toilet
• CO_2 removal
• Environmental monitoring
• Exercise technology
• Radiation protection and monitoring
• Medical system
• Fire suppression and cleanup
• Dormancy/Autonomy
Infuse Full Long Duration Microgravity ECLSS and CHPS into Mars Transport
Mars-class Transportation
• Highly-reliable regenerative ECLSS from ISS demonstration
• Environmental monitors
• Exploration food system
• Countermeasures
• Medical system
• Radiation protection
Complementary Ground Tests and Analogs
• Food system performance and reliability testing
• CHPS integrated analogs
Human Landing System and Sustained Lunar Surface ECLSS-CHP Infusion
• Partial gravity and exploration atmosphere fire safety
• Exploration spacewalk pre-breathe and conops
• Surface habitat: regenerative ECLSS and CHPS adapted for surface
• Pressurized rover: ECLSS waste collection and transfer
Mars Surface ECLSS-CHPS
• Robust microbial and chemical monitoring
• Planetary protection compatible waste strategy
ECLSS = Environmental Control and Life Support Systems | CHPS = Crew Health and Performance Systems | LEO = Low-Earth Orbit
GRAPHICS NOT TO SCALE 20210115

Takeaways

- The interactions of air, water, crew consumables, and crew in a closed loop habitat are chemically and physically complex and understanding issues evolves over time
- Reducing spares mass with reliability testing and CO_2 reduction/reduced launched food water content are the largest knobs to turn to reduce Mars Transit departure mass
- Test verified ECLSS-CHP systems requires many years of ground and LEO operation
  - Systems fail and interact in unexpected ways
  - New failure modes still being identified after 10+ years of operational time
- Long term NASA ECLSS-CHP investments have dramatically improved loop closure, resolved unexpected performance issues, and is prepared for long term reliability testing
- It is possible to on-ramp new ECLSS technologies, but it requires significant test verified performance and understanding of interactions across the habitat

References

- **ICES 2022 Conference: 10-14 July 2022, Minneapolis, MN**
  - **Annual ECLSS overview** (numerous references to specific tech papers, ~same title last 5+ years)
    - Broyan, J. L., Shaw, L., McKinley, Meyer C., Ewert, M.K., Schneider, W. F., Meyer, M., Ruff, G.A., Owens, A. C., Gatens, R. L., “NASA Environmental Control and Life Support Technology Development and Maturation for Exploration: 2020 to 2021 Overview,” 50th International Conference on Environmental Systems, virtual, ICES-2021-384, July 12-15, 2021.
    - 2022 paper is #ICES-2022-281 (will be released in July).
  - **Annual CHP Technology overview**
    - Abercromby A., F.,J., Douglas, G., Kalogera, K.L., Somers, J.T., Suresh, R., Thompson, M. S., Wood, S., J., “NASA Crew Health and Performance Capability Development or Exploration: 2021 to 2022 Overview,” 51st International Conference on Environmental Systems, St. Paul, Minnesota, ICES-2022-299, July 10-14, 2022. (will be released in July).
  - **Reliability and spares**
    - Owens, A. C., Cirillo, W. M., Piontek, N., Stromgren, C., and Cho, J. “More Data Needed for Failure Rate Estimation, Validation, and Uncertainty Reduction.” 50th International Conference on Environmental Systems, Virtual Event, 2021. ICES-2021-370.
    - Owens, A., Cirillo, W. M., Piontek, N., Stromgren, C., and Cho, J. “Analysis and Optimization of Test Plans for Advanced Exploration Systems Reliability and Supportability.” 50th International Conference on Environmental Systems, 2021. ICES-2021-199.
  - **ECLSS Evolution Testing on ISS**
    - Shaw, L., J. Garr, L. Gavin, D. Hornyak, C. Matty, A. Ridley, M. Salopek, K. Toon, “International Space Station as a Testbed for Exploration Environmental Control and Life Support Systems – 2021 Status,” ICES-2021-20, 50th (virtual) International Conference on Environmental Systems, July 10-15, 2021.
- **Human Research Program Investigator’s Workshop TBD February 2023** (usually in Galveston TX)