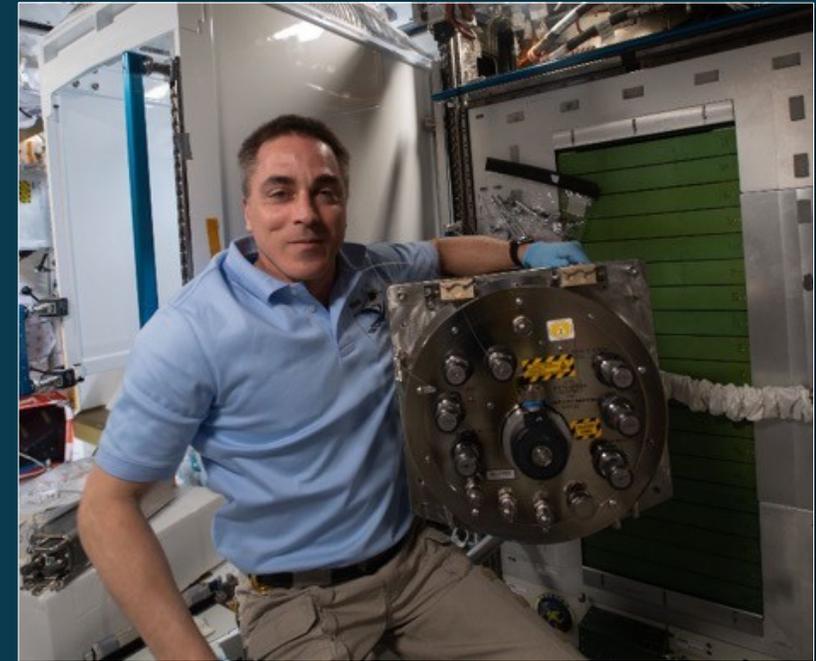
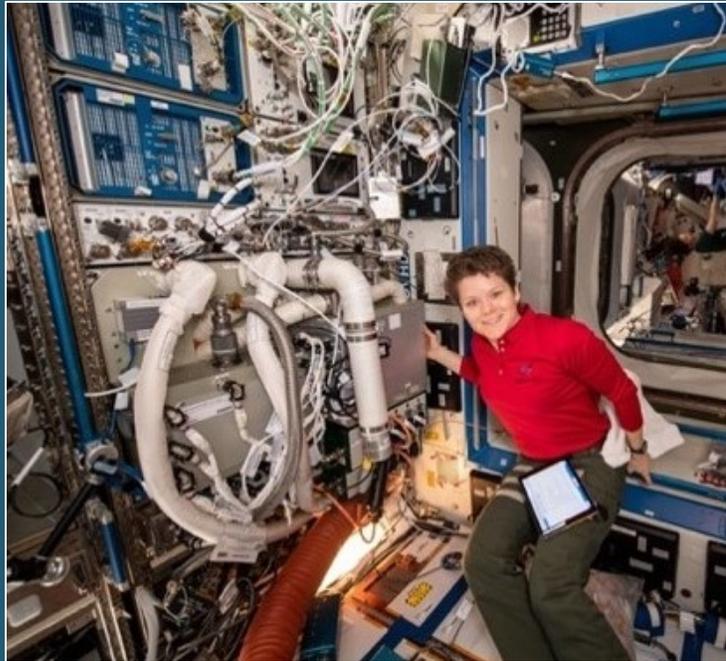




Lunar Life Support Overview

James Broyan – NASA ECLSS-CHP SCLT Deputy



Outline

- **ECLSS-CHP overview**
 - Capabilities
 - Interaction of surface elements
- **Potential science interactions**
- **Summary comments**
- **Nomenclature**
 - ECLSS – Environmental Control and Life Support Systems
 - CHP – Crew Health and Performance
 - SCLT – System Capability Leadership Team

ECLSS-CHP Capabilities Overview

- **Capability needs depend on key mission characteristics**
 - Strength of gravity (μg , lunar, Martian)
 - Total length of the mission or combined missions of an element
 - Uncrewed periods (dormancy) between missions

LIFE SUPPORT



- Atmosphere Management
- Water Management
- Waste Management

ENVIRONMENTAL MONITORING



- Pressure
- Microbes
- Moisture
- Chemicals
- Particles
- Sound

FIRE SAFETY



- Detection
- Protection
- Suppression
- Cleanup

LOGISTICS



- Tracking
- Relocating
- Clothing
- Trash

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS (ECLSS)

EVA PHYSIOLOGY



- Physiological Inputs & Outputs
- ConOps/Crew Capabilities
- Informatics
- Injury & Risk Mitigation
- Atmosphere/Pre-breathe

COUNTER MEASURES



- Exercise Systems
- Sensorimotor
- Physiology Monitoring
- Informatics

RADIATION PROTECTION



- Space Weather Forecasting
- Monitoring
- Shielding
- Health Risk Models
- Biomedical CM

EXPLORATION MEDICAL



- Diagnostic
- Treatment
- Imaging
- Pharmacy

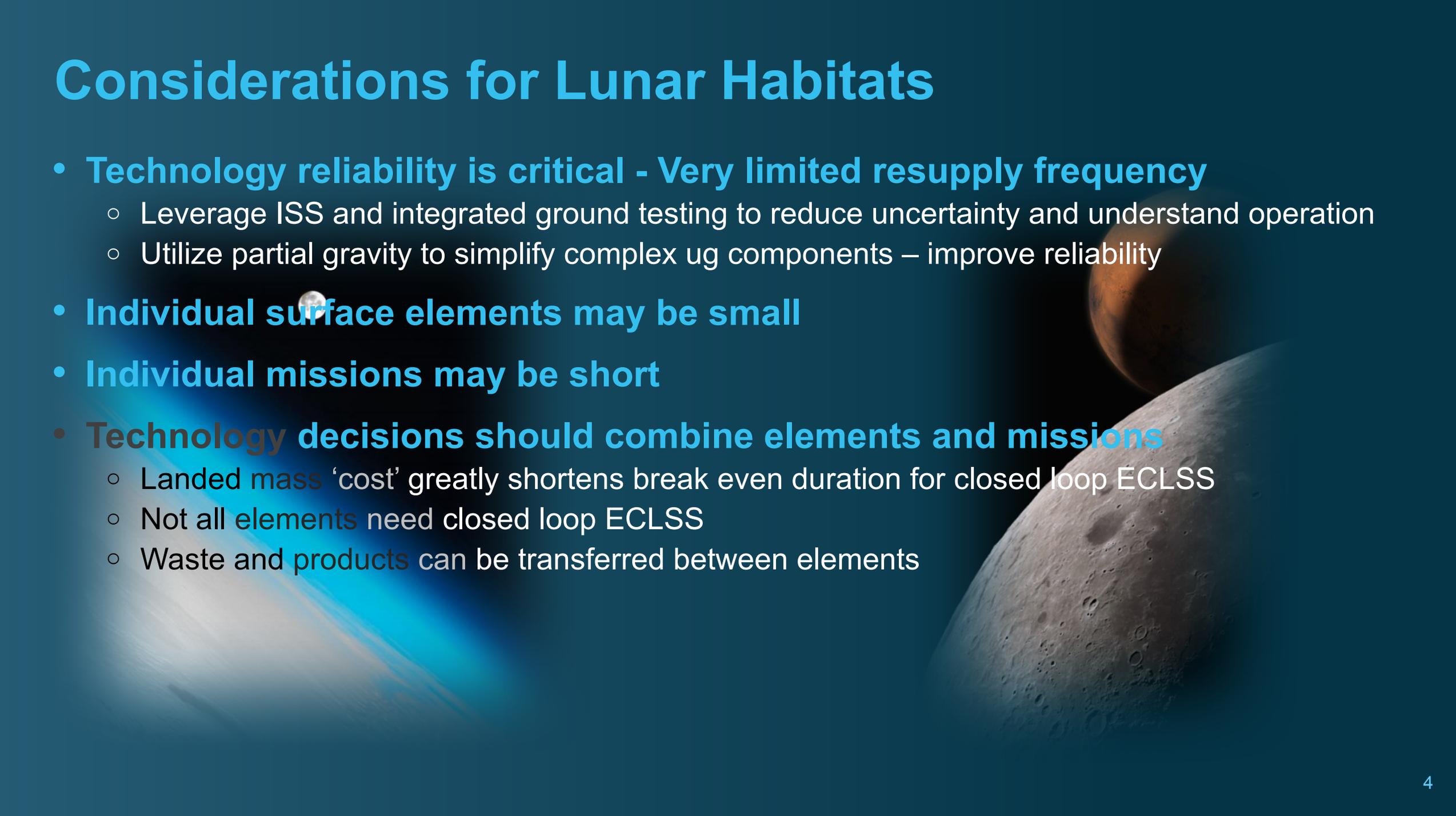
FOOD & NUTRITION



- Pre-packaged
- Food Resources
- Dietary Tracking
- Health & Performance

CREW HEALTH AND PERFORMANCE (CHP) SYSTEMS

Considerations for Lunar Habitats

The background of the slide features a deep blue space scene. In the upper right, a reddish-orange planet (Mars) is partially visible. In the lower right, a large, cratered grey sphere (the Moon) dominates the foreground. In the upper left, a small white sphere (the Earth) is visible. A bright blue light source, likely the Sun, is positioned in the lower left, creating a lens flare effect across the scene.

- **Technology reliability is critical - Very limited resupply frequency**
 - Leverage ISS and integrated ground testing to reduce uncertainty and understand operation
 - Utilize partial gravity to simplify complex ug components – improve reliability
- **Individual surface elements may be small**
- **Individual missions may be short**
- **Technology decisions should combine elements and missions**
 - Landed mass ‘cost’ greatly shortens break even duration for closed loop ECLSS
 - Not all elements need closed loop ECLSS
 - Waste and products can be transferred between elements

Evolving Habitation Systems for SUSTAINABLE HUMAN EXPLORATION

Use ISS as Testbed for Evolution of ECLSS and CHPS



Continue Testbeds on Commercial Platforms in LEO



Notional Commercial Platform in LEO

Infuse Technologies into Gateway



Orion and Gateway

- Toilet
- CO₂ removal
- Environmental monitoring
- Exercise technology
- Radiation protection and monitoring
- Medical system
- Fire suppression and cleanup

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

International Space Station (ISS)

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

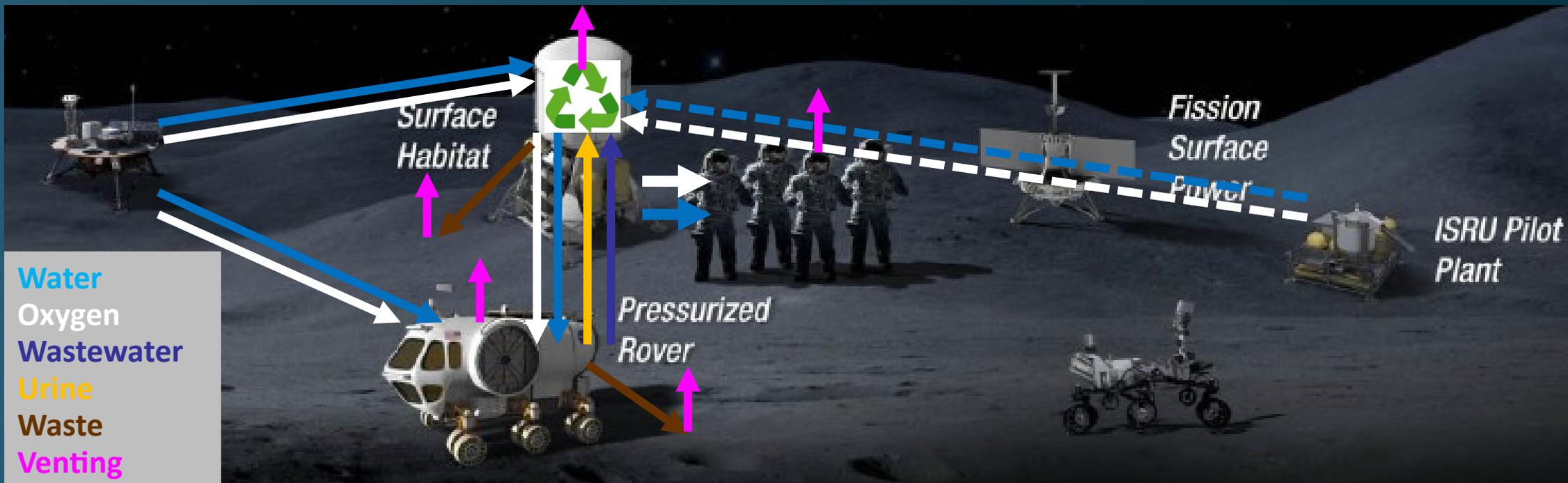
- Robust microbial and chemical monitoring
- Planetary protection compatible waste strategy



ECLSS = Environmental Control and Life Support Systems | CHPS = Crew Health and Performance Systems | LEO = Low-Earth Orbit

Lunar Regen ECLSS and Fluid/Gas Transfers

- **Consolidate regenerative ECLSS in the surface habitat**
 - Transfer waste from rover crew to surface habitat for processing
 - Recycle urine, condensate water, and carbon dioxide
 - Transfer water and oxygen to rovers and EVA
 - ECLSS processes, EVA, waste disposal, and leakages contribute to releases to the lunar surface



Potential Science Interactions (1/2)

- **Potable water biocides**

- May need biocide removal prior to science use
- Early elements with only stored water may use silver or iodine
- Regen ECLSS will use iodine

- **Disinfection solution generation**

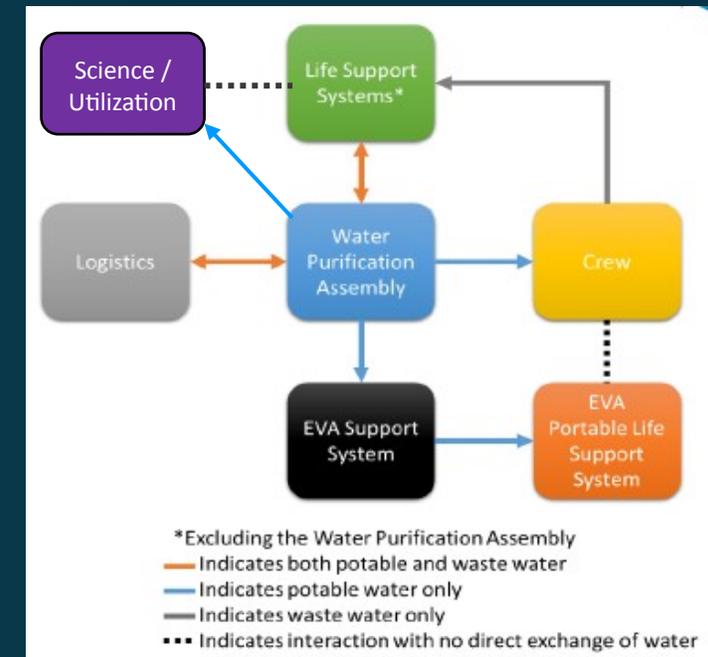
- Could be available for science surface and equipment cleaning
- Developing in-flight hydrogen peroxide generation

- **Lower atmospheric pressure**

- Lower pressures may impact diffusion processes thermal cooling
- 10.2 or 8.2 psia likely used to facilitate frequent EVA

- **Reduced ECLSS during uncrewed (dormant) periods**

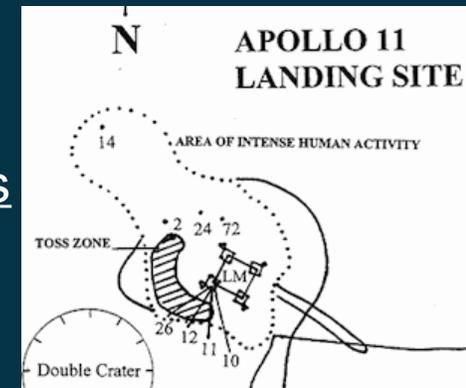
- What science atmosphere conditions are required with no crew?
- Reduced humidity, temperature, pressure being considered
- Possibly lower air recycling and no or infrequent CO2 removal



Water transfers between capability areas

Potential Science Interactions (2/2)

- **Habitat/ECLSS venting and leaking**
 - Venting/leaking can deposit on cold lunar surfaces
 - Are witness plates, additional monitoring and sample curation required?
 - ECLSS process bi-products
 - Air lock residual releases
 - EVA suit leakage and water evaporation for thermal rejection
- **Habitat/Rover trash surface disposal**
 - Trash will release water and gases which can deposit on cold lunar surfaces
 - Trash bags/containers may not be pressure sealed
- **ECLSS-CHP Monitoring capabilities**
 - Maybe possible to use ECLSS monitors for science
 - Examples: Radiation sensors, trace gas analysis, water constituents, microbial, and CHP ultrasound
- **Habitat interior dust filtration**
 - Filters will keep it within CHP respiration limits
 - Are lower particulate levels required for some science?

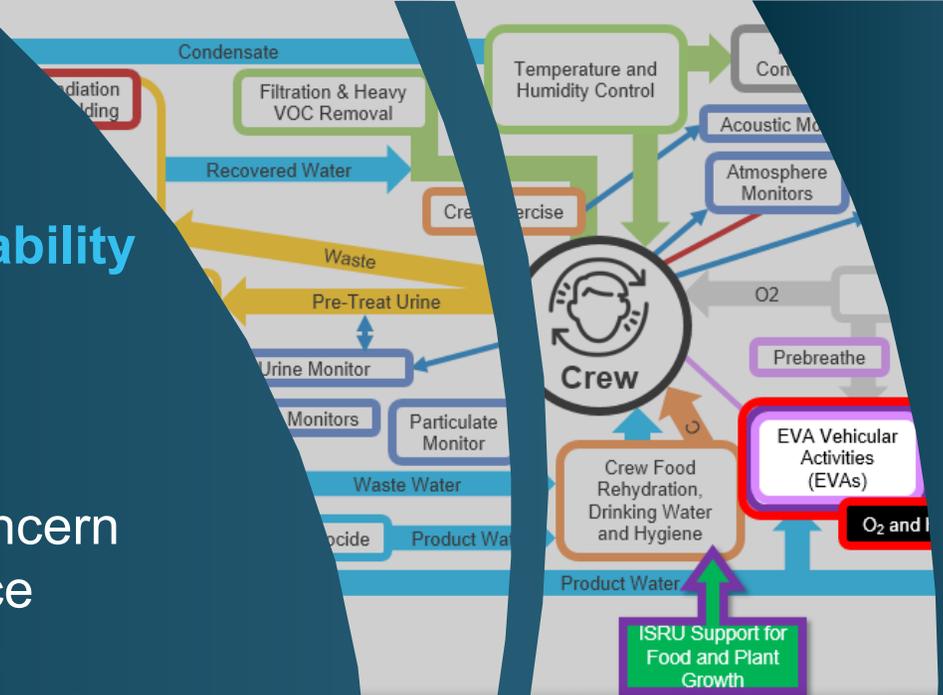


Apollo trash
disposal region



Summary Comments

- **ECLSS will leverage ISS μ g technology to ensure reliability**
 - Includes ECLSS restart after long uncrewed periods
- **ECLSS venting and surface trash disposal will locally contribute chemical/biological signatures to science**
 - Need to identify if there are compounds of science concern
 - Need to understand if gas/fluid transfer or trash surface disposal concept of operations are of science concern
 - Need to understand how habitat influences or impacts science sample curation outside and inside the habitat
- **Maybe possible for science to utilize ECLSS-CHP monitors**
 - Need to identify science utilization use cases
 - Need to identify sample type, frequency, mission phase
- **Need to identify what ECLSS products and environments are needed for science**
 - Both for crewed and uncrewed periods





Questions?



Backup Charts



Estimates of Contaminant Release to Mars Surface from 200 kg Gas Loss*

Approximate Cabin Atmosphere Contaminant Levels Based on ISS Experience		
<i>Contaminant</i>	<i>Value</i>	<i>Units</i>
Airborne Bacteria	50	CFU/m ³
Airborne Fungi	10	CFU/m ³
Methane	6	mg/m ³
Alcohols + Acetone	6	mg/m ³
Octafluoropropane	9	mg/m ³
Formaldehyde	0.03	mg/m ³
Other VOCs	4	mg/m ³

Estimate Released (540 d)		
<i>Cabin Pressure</i>		<i>Units</i>
<i>8 psi</i>	<i>10.2 psi</i>	
15,486	12,159	CFU
3,097	2,432	CFU
1,858	1,459	mg
1,858	1,459	mg
2,787	2,189	mg
9	7	mg
1,239	973	mg

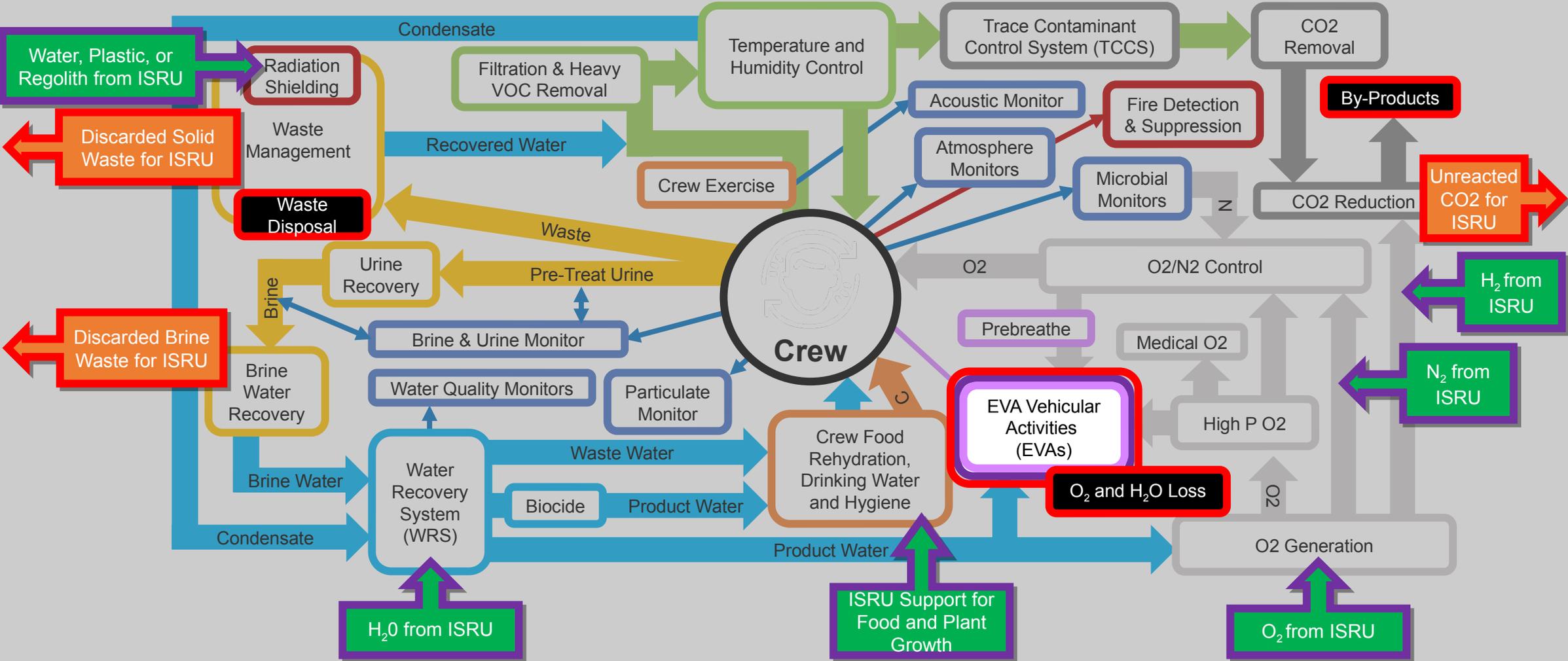
- ◆ Potential releases from habitat leakage represent about ¼ of the total and would be hard to mitigate. We are assuming primary leakage is from seals and bulkheads (unfiltered) rather than wall of hull.
- ◆ Potential releases due to airlock use could be mitigated by suit port
- ◆ Unplanned or contingency depresses (in the case of fire or toxic chemical release) could result in the entire cabin volume vented.

*D. Barta, M. Anderson, K. Lange, W. Vonau COSPAR, July 17, 2018

Spacecraft Habitation Functions + ISRU interfaces with potential **forward** and **backward** contamination sources

KEY

- Crew Safety
- Crew Systems
- EVA
- Waste Management
- Temperature and Humidity Control
- O2 Generation Assembly (OGA)
- ← Habitation Systems Outputs to ISRU
- ISRU Inputs to Habitation Systems
- Water Recovery System (WRS)
- Environmental Monitoring
- CO2 Removal and Reduction



Gas Venting ^(1/2)

- **Air lock venting**

- Air save pumps recover air prior to hatch opening
- Pumping down to low pressures increases pump size and time
- SOA: ISS Quest airlock pumps to ~ 5 psia before venting
- No microbial countermeasures prior to venting

- **Seals and vehicle joint leaking***

- Combination of elastomeric and metallic seals
- Monitoring: atmospheric pressure, major gas constituents, and resupply quantities

- **Airlock and leak quantity estimates**

- Based on NASA-SP-2009-566-ADD2 (2014) with three 6.5 hr EVAs/week would result in 0.18-0.53 kg/day loss
- Habitat leakage estimated at 0.1 kg/day

- **Possible mitigations**

- Suit-locks could reduce gas loss but not flight proven yet



*ISS Quest Joint Airlock installation
on STS-107*

* D. Barta, M. Anderson, K. Lange,
W. Vonau COSPAR, July 17, 2018 ¹⁴

Gas Venting (2/2)



• Atmospheric Revitalization

- SOA: ISS Oxygen Generation Assembly, CDRA, Sabatier ~47% recovery. Quantities*:

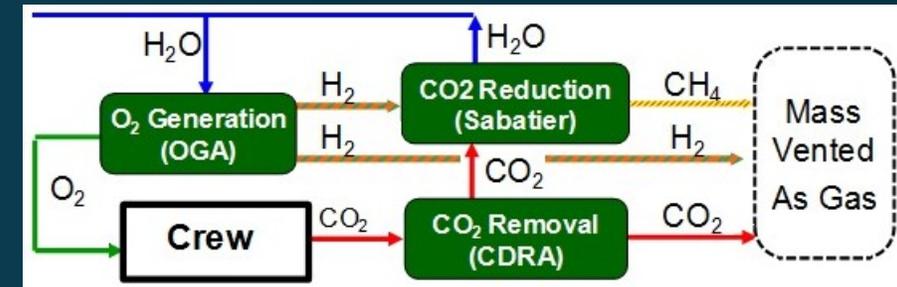
- Methane: 0.21 – 0 kg/CM/day
- Carbon dioxide: 0.48-1.04 kg/CM/day
- Hydrogen: 0 – 0.10 kg/CM/day
- Trace organics ~0.04 ppm
- Micro-organisms – not known but possible

- Future CO₂ reduction technology in development >75% recovery (Bosch or methane pyrolysis)

- Possible quantities depend on technology*
 - ‘Solid’ carbon ~0.27 kg/CM/day
 - Acetylene ~0.3 kg/CM/day

• Possible mitigations

- Preventing specific gases requires additional equipment and mass
- Sterilizing vented gases
- Witness plates and/or monitoring



*ISS Air Recovery Schematic**

* D. Barta, M. Anderson, K. Lange, W. Vonau COSPAR, July 17, 2018¹⁵

Trash Jettison



• Trash collection

- Wide array of dry and wet materials**
- Temporary storage and disposal in bags (non-pressure seal)
- SOA: Unprocessed trash jettisoned in ISS visiting vehicle every ~30-120 days
- Estimated quantity*: 0.91 kg/CM/day, ~20-25% water by mass
- Wet trash is microbially active and outgas is managed by atmospheric trace contaminant control system (TCCS)

• Possible mitigations

- Improved trash bags (partial microbial control)
- Trash Compactor Processing System (TCPS) ~160C
- Trash-to-gas (TtG) >600C
- Challenges
 - Thermal processing releases >80 volatiles**
 - Maintaining sterility after processing



ATV departing ISS (top left), Shuttle Trash 'foot ball' (top right),

Apollo jettison bag (middle), Prototype TCPS tile (bottom)

* D. Barta, M. Anderson, K. Lange, W. Vonau COSPAR, July 17, 2018

** Young, J. et.al. ICES-2020-374; Delzeit, L., et. al., AIAA 2013-3395

Toilet Waste



- **Urine – collect and chemically pretreated**

- SOA:

- Short missions: vent (Apollo, Shuttle, Orion), jettison (Apollo)
 - Long missions: >94% recovery with urine and brine processing

- Quantity:

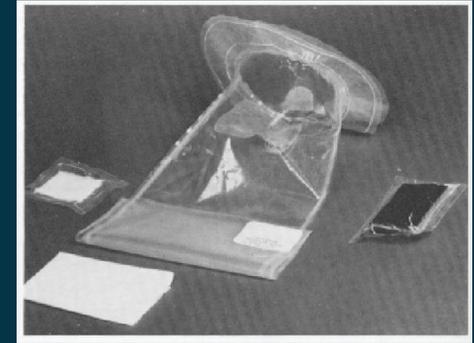
- 1.5 urine l/CM/day without processing, ~1-4% solids (salts and organics)
 - ~0.1 l/CM/day with urine and brine processing

- **Fecal – collect, store, and jettison**

- SOA: Storage, no treatment, no water recovery
 - Quantity: 0.3 kg/CM/day + wipes
 - ~75% water, ~25% organics*, microbially active

- **Possible mitigations**

- Improved storage containers
 - Fecal drying



*Apollo Fecal Bag** (top),
Apollo Urine Collection Device** (middle),
Orion Toilet System*** (bottom)*

* D. Barta, M. Anderson, K. Lange, W. Vonau COSPAR, July 17, 2018

** J. Broyan, ICES-2007-273

*** D. Autrey, et. al., ICES-2020-278

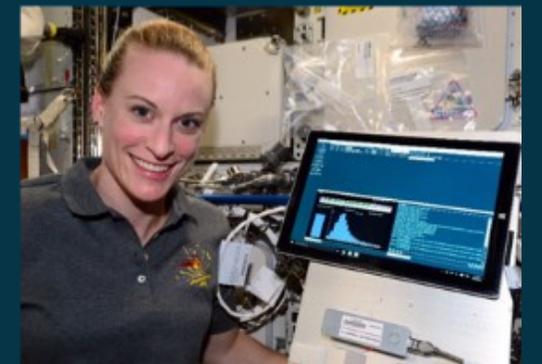
Environmental Monitoring



- **Current Technology/SOA**
 - Distinct technologies for : air, water, microbial, particulate, and acoustic monitoring
 - Reliance on returned samples and ground analysis
- **Future Exploration Goals**
 - In-mission analysis of samples, significantly reduced ground support
 - Improved efficiency and reliability with lower mass and volume
- **Technology Development and Demonstration**
 - Spacecraft Atmosphere Monitor (SAM) – upgrade for trace gases
 - MinION Biomolecular Sequencer
 - Airborne Particulate Monitor (APM)
 - Advanced Total Organic Carbon Analyzer (TOCA)
 - Organic water monitor
- **Possible Forward Contamination**
 - Improved chemical and microbial species identification, witness plates?
- **Possible Reverse Contamination**
 - Ability to detect unknown contaminants
 - Non-DNA detection, tracer compounds, witness plates?



SAM installed on the space station



ISS MinION DNA Sequencer