COSPAR – Planetary Protection | December 1, 2020

Waste and Venting Current Performance Measures

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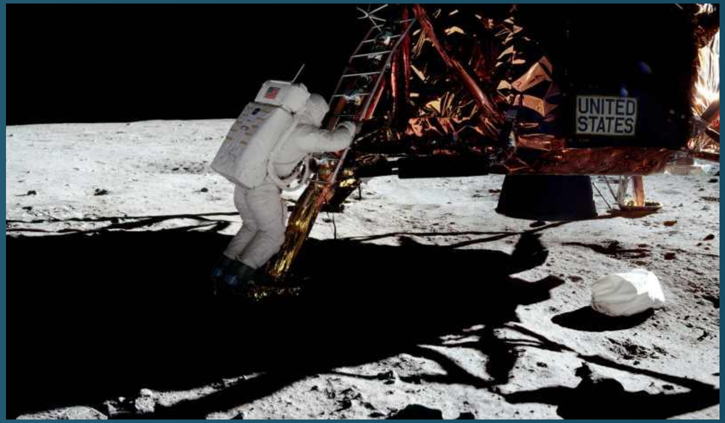


Outline

- ECLSS-CHP contamination overview
- Venting sources and characteristics
- Trash Waste sources and characteristics
- Monitoring capabilities
- Summary comments

- Nomenclature
  - ECLSS-CHP – Environmental Control and Life Support Systems – Crew Health and Performance
  - SCLT – System Capability Leadership Team

Habitation System – Planetary Protection Interfaces

Potential forward and backward contamination sources or mitigation tools

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS (ECLSS)

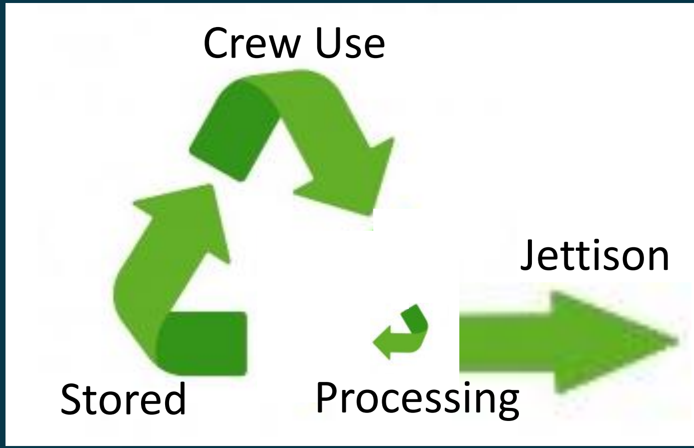
- Life Support
- Environmental Monitoring
- Fire Safety
- Logistics

CREW HEALTH AND PERFORMANCE (CHP) SYSTEMS

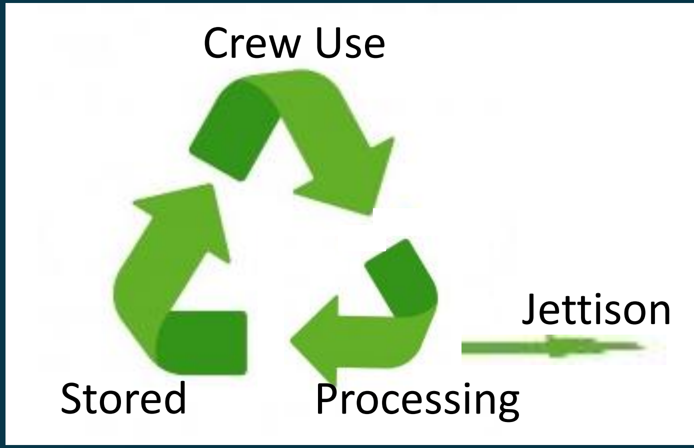
- EVA Physiology
- Radiation
- Countermeasures
- Food and Nutrition
- Exploration Medical

Considerations for Mars Habitats

- **Life support technologies will vary depending on mission length**
- Short surface duration missions <30 days (single mission)
  - Largely open loop except for CO_2
  - Trash stabilization not required
  - Toilet waste typically jettisoned from vehicle (Apollo)
- Long surface duration missions >180 days
  - Largely closed loop for oxygen and water
  - Trash processing may not be required for water recovery
    - Water vapor and volatiles may be vented overboard
  - Toilet waste typically jettisoned from vehicle (ISS logistics module disposal)
- Possible to utilize in-situ resources for oxygen and water but increases interfaces and planetary protection complexity



Short Duration Mission ECLSS



Long Duration Mission ECLSS

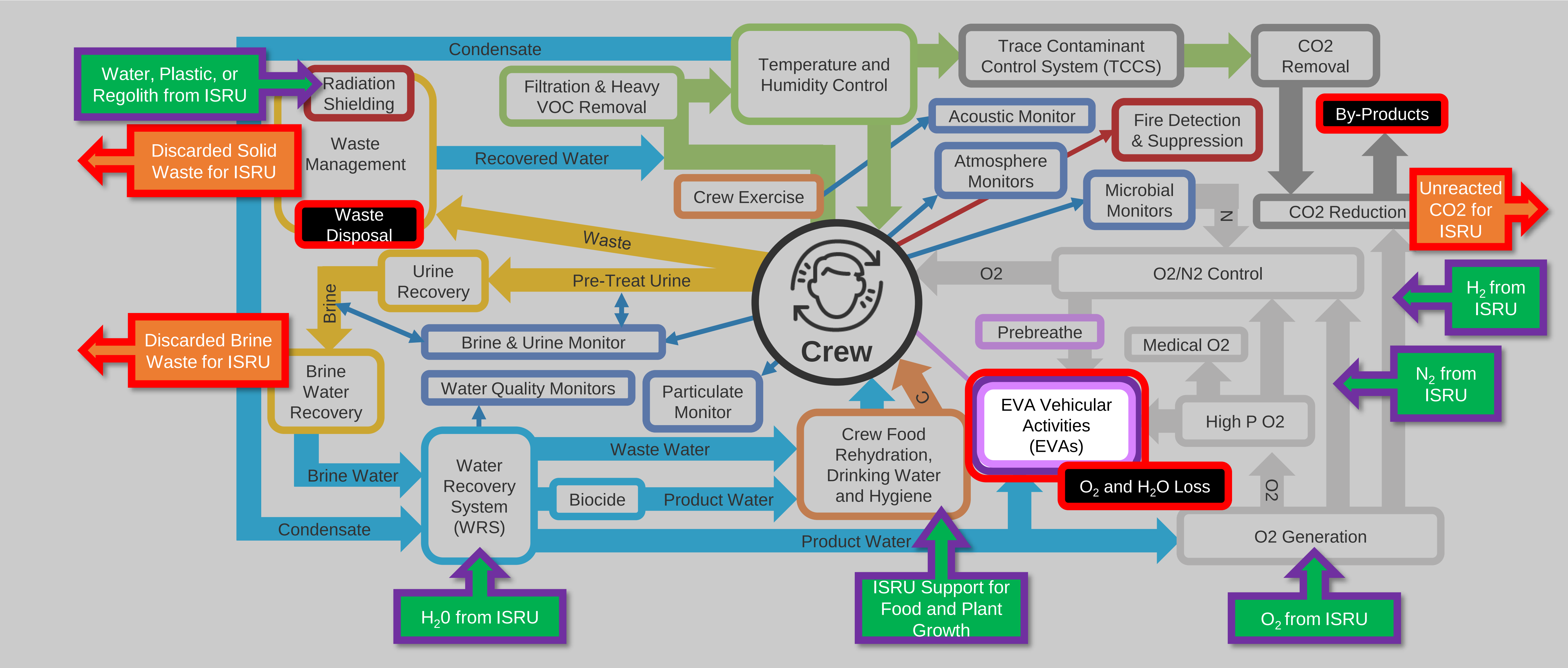
Spacecraft Habitation Functions + ISRU interfaces with potential forward and backward contamination sources

KEY

Habitation Systems Outputs to ISRU

ISRU Inputs to Habitation Systems

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



Gas Venting (1/2)

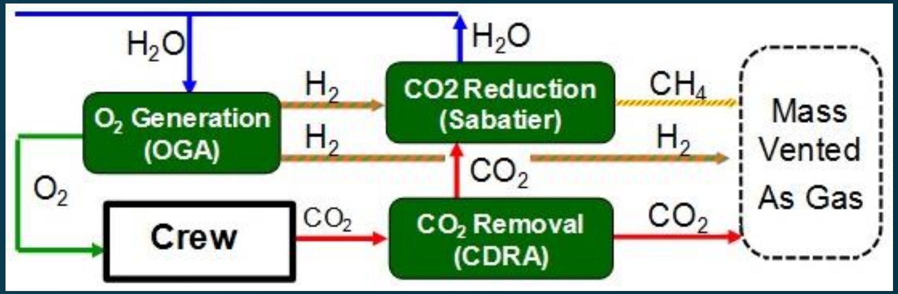
- **Air lock venting**
  - Air save pumps recover air prior to hatch opening
  - Pumping down to low pressures increases pump size and time
  - SOA: ISS Quest airlock pumps to ~ 5 psia before venting
  - No microbial countermeasures prior to venting
- **Seals and vehicle joint leaking***
  - Combination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

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 CO_2 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



*ISS Air Recovery Schematic**

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

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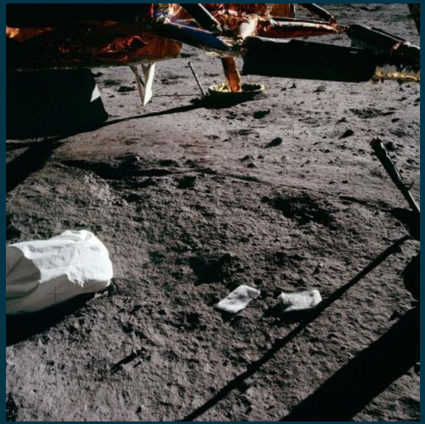
Trash Jettison

- **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



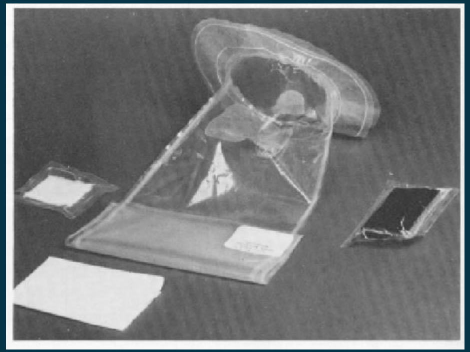



ATV departing ISS (top left), Shuttle Trash 'foot ball (top right), Apollo jettison bag (middle), Prototype TCPS tile (bottom)

* 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

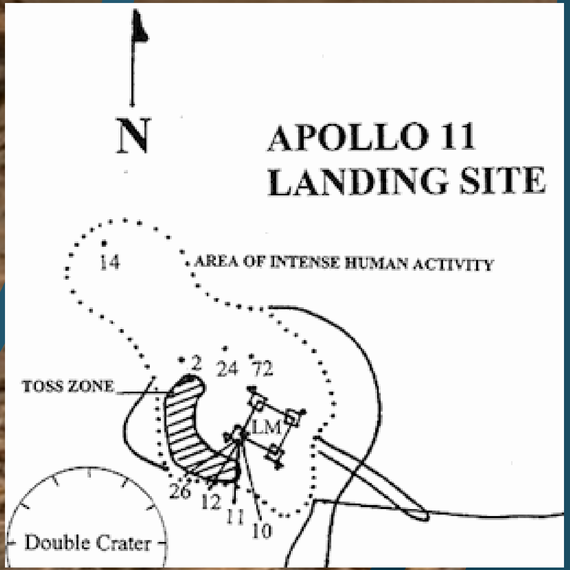
- **Current Technology/SOA**
  - Distinct technologies for : air, water, microbial, particulate, and acoustic monitoring
  - Reliance on returned samples and ground analysis
- **Future Exploration Goals**
  - In-mission analysis of samples, significantly reduced ground support
  - Improved efficiency 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

Summary Comments

- **ECLSS-CHP is the second largest mass allocation after propellant**
  - Strong program pressure to reduce mass
  - Very difficult to justify additional mass without requirements
- **Forward planetary protection represents an additional set of requirements**
  - Will impact technology selection by limiting or prohibiting certain kinds of operations or processes (e.g. venting, disposal)
  - Necessitate additional operations (e.g. sterilization)
  - Prohibit what can be brought on a mission (e.g. extremophiles)
  - Create need for new capabilities/technologies (e.g. containment)
- **Backward planetary protection represents an additional set of requirements**
  - Hardware tolerance, cleaning, and shorten equipment life
  - Extra processing for use of ISRU consumables
- **Need to align ECLSS-CHP and planetary protection needs to define requirements and technology/system gaps**
  - Identify roadmap closure timelines and interdependencies



Backup Charts

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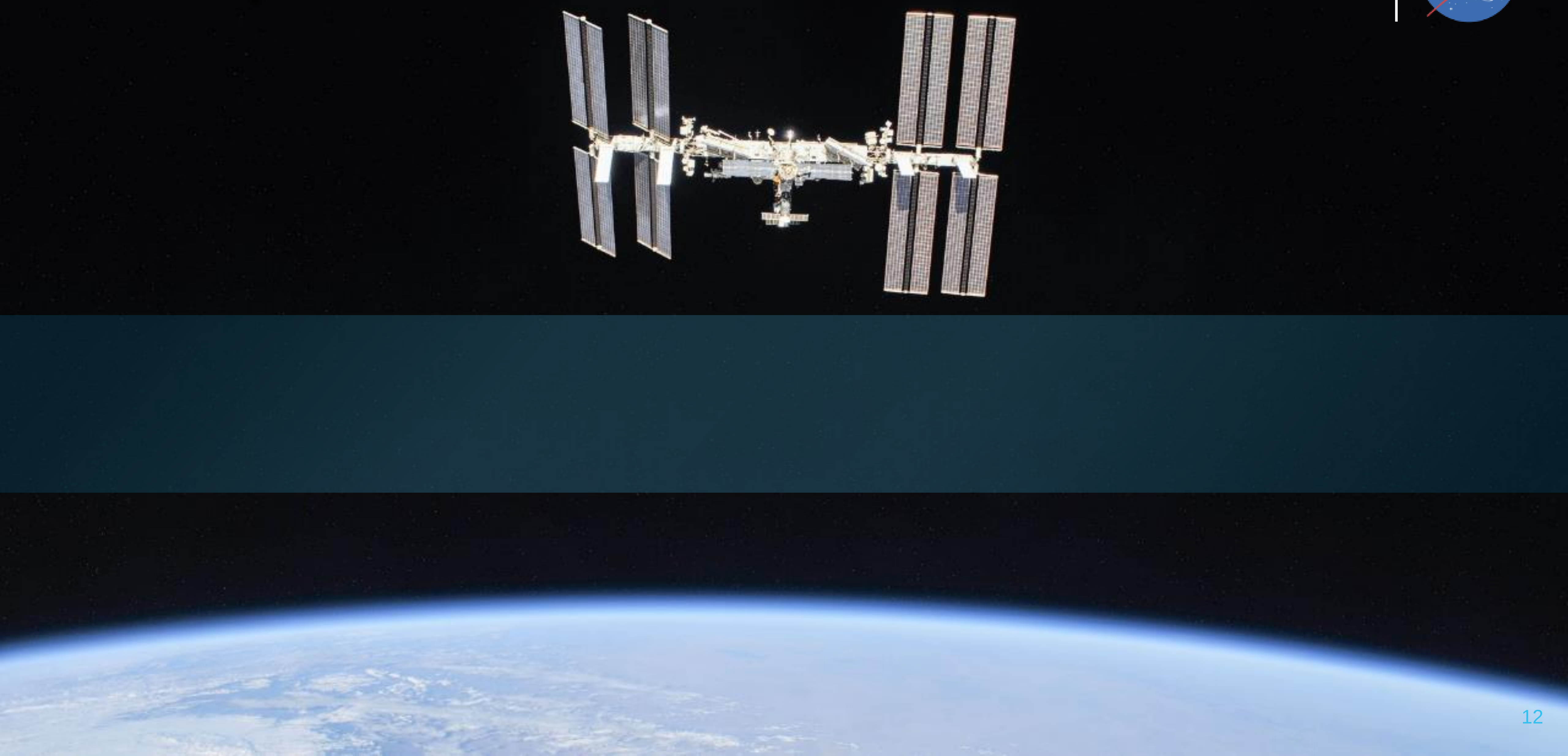

Estimates of Contaminant Release to Mars Surface from 200 kg Gas Loss*

Approximate Cabin Atmosphere Contaminant Levels Based on ISS Experience			Estimate Released (540 d)		
			Cabin Pressure		
Contaminant	*Value*	*Units*	*8 psi*	*10.2 psi*	*Units*
Airborne Bacteria	50	CFU/m³	15,486	12,159	CFU
Airborne Fungi	10	CFU/m³	3,097	2,432	CFU
Methane	6	mg/m³	1,858	1,459	mg
Alcohols + Acetone	6	mg/m³	1,858	1,459	mg
Octafluoropropane	9	mg/m³	2,787	2,189	mg
Formaldehyde	0.03	mg/m³	9	7	mg
Other VOCs	4	mg/m³	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