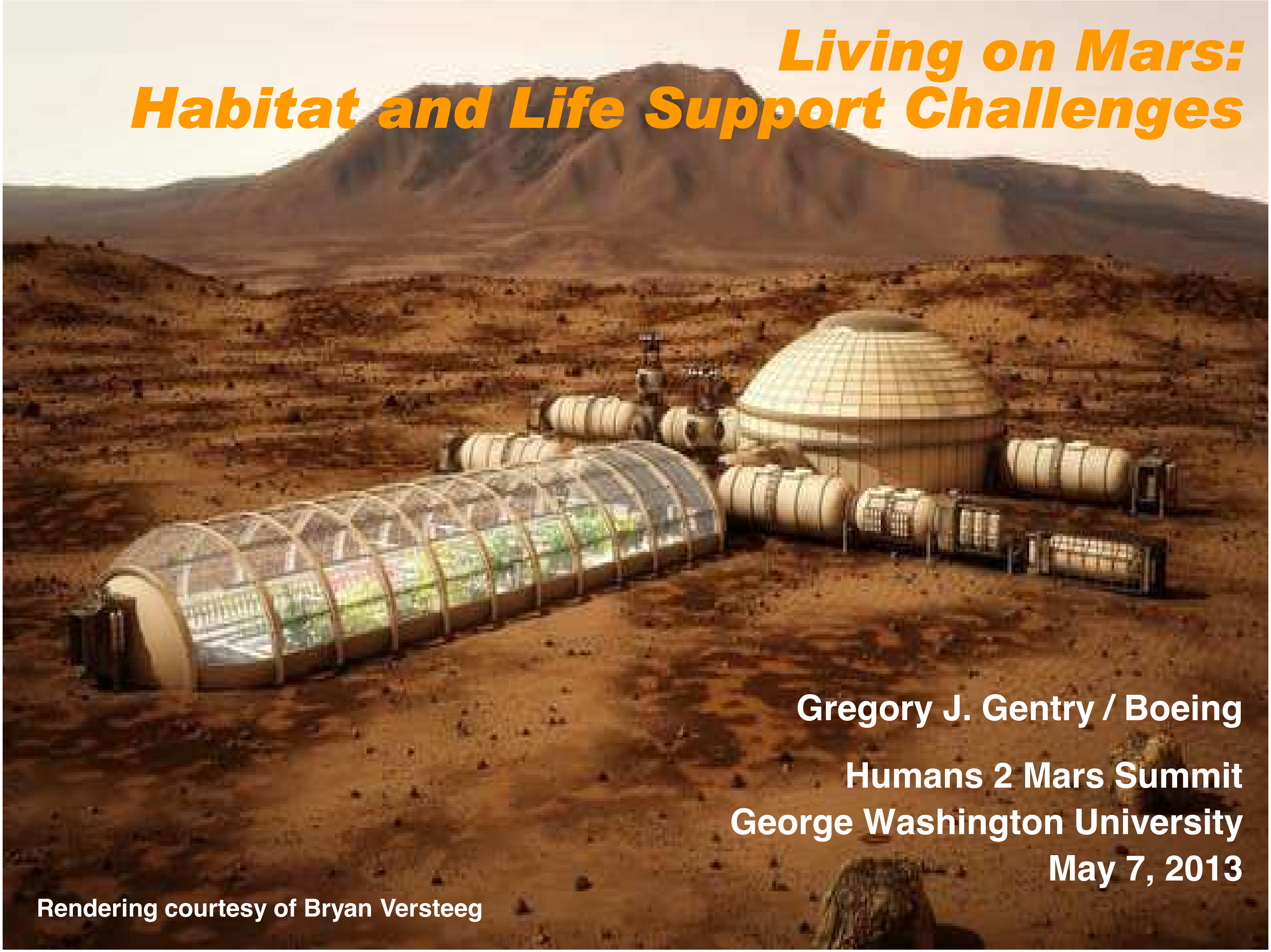
Living on Mars:
Habitat and Life Support Challenges



Rendering courtesy of Bryan Versteeg

Gregory J. Gentry / Boeing

Humans 2 Mars Summit
George Washington University
May 7, 2013

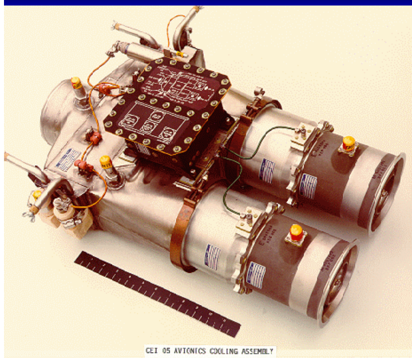
Mission/Platform Comparison - Shuttle

System	Flight modes	Duration	Crew	Volume (ft^3)	ECLS Capabilities/Challenges
Shuttle	Launch Orbit Rendezvous Reentry Landing	1-2 weeks (10 years (3X ext))	Up to 8	~ 3,000 Crew Module & Airlock	• Simple fluid-mechanical systems, single volume • Common redundancy • Tank storage, overboard venting • No planned in-flight maintenance • Fire & leak response – Emergency return to earth



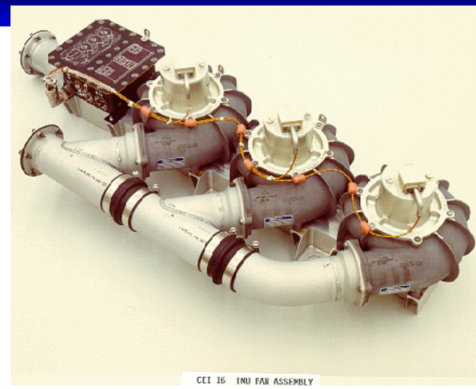



Shuttle ECLSS Hardware Review

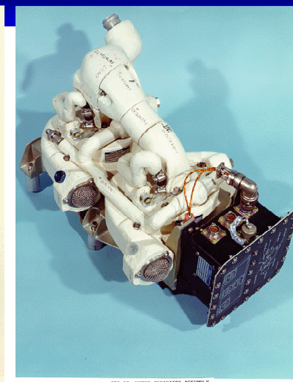


Cabin fans

LiOH can

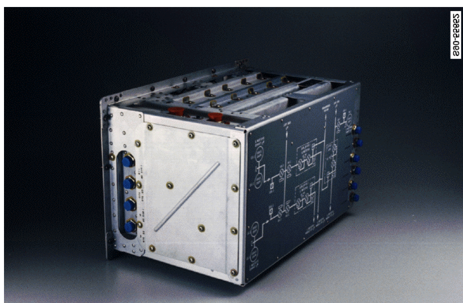


IMU fans

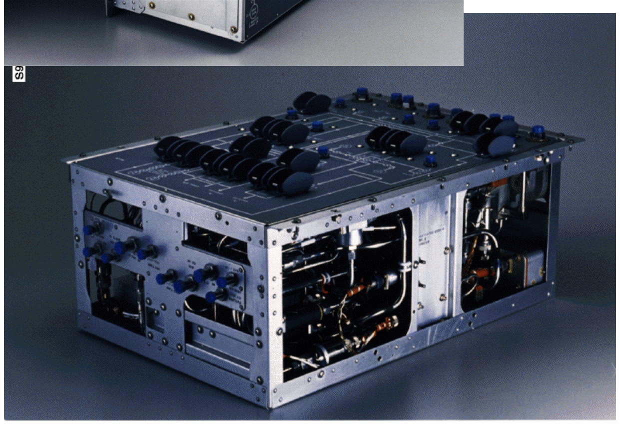


Hum Seps

Commode



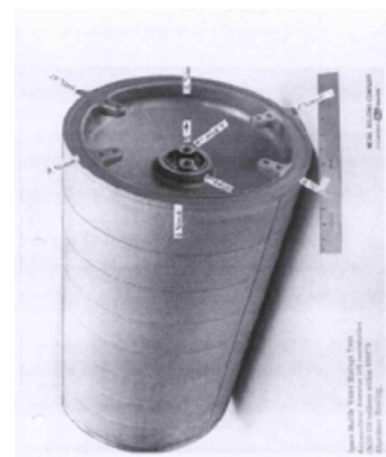
N2/O2 Supply Panel



N2/O2 Control Panel

N2 tank

O2 Fuel Cell cryo tank



Potable & Waste tanks

Mission/Platform Comparison - ISS

System	Flight modes	Duration	Crew	Volume (ft^3)	ECLS Capabilities/Challenges
ISS	Orbit	6 mo INC 15 year design life with expected life extension efforts	6 + handovers + Shuttle Max to-date: 13	~30,000 SM, FGB, DC1 MRM1, Soyuz Progress, ATV, HTV, SpaceX PMA 1,2,3 Node 1, 2, 3 Airlock, US Lab ESA Lab, JEM Lab JEM ELM-PS PMM, Cupola	• Simple and complex fluid-mechanical systems working across ~ 24 isolatable habitable volumes • Software & firmware controlled H/W & processes • Common and non-common redundancy • Tank storage, regenerative & non-regen systems • All maintenance, troubleshooting and repair done in-situ by astronauts • Weeks to months between logistic resupplies • Potential to have to “throw away” a failed component w/o understanding failure • Fire & leak response – Stay & fight ***or*** abandon station (return to earth)

ISS Key Info

12.5 Years to build

31 US & Russian assy flights

155 EVAs total
- 127 EVAs from ISS A/Ls
- 787 ISS based EVA hours

Habitable volume:
~ 30,000 ft^3 (850 M^3)
~ 2,290 lbs. of air (~1,041 kg)

35 ISS Increments so far
~ 52 crew person years to date
(not including STS crews)

Inhabited and utilized during assembly

S119E008580 View of ISS as Shuttle Orbiter Discovery departs during STS-119/15A March 17, 2009

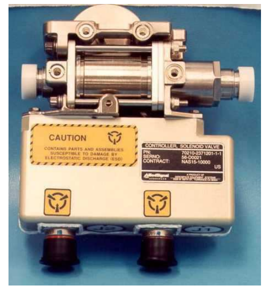
~ 19,000 lbs. of USOS ECLS Hardware (not including spares)
Over 100 different component (Orbital Replaceable Unit (ORU)) types

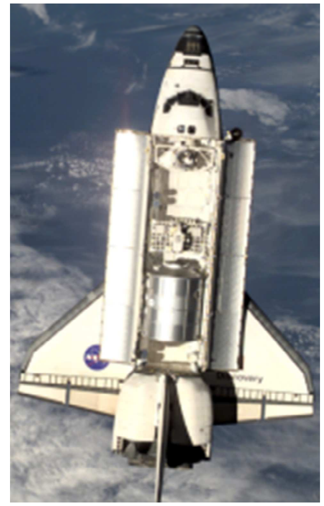
Last 2 year average atmosphere:
Total pressure: 14.5 +/- .4 psia (Std Dev 0.16 psi)
Temperature: 71.8 +/- 5 F (Std Dev 0.987 F)
ppO2: 165 +/- 15 mm Hg (Std Dev 5.7 mm)
ppCO2: 2.4 +/- 2.2 mm Hg (Std Dev 0.7 mm)

ISS ECLS Hardware Review - ACS

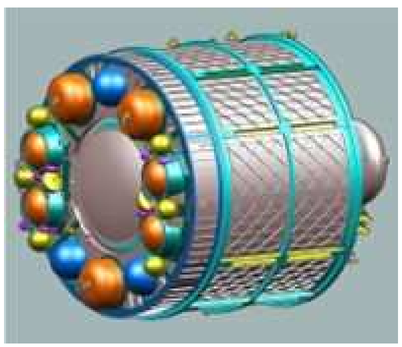

Airlock HPGTs


TGK

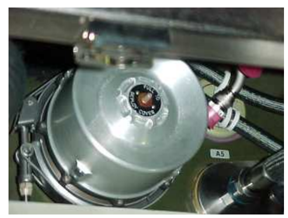

NIV/OIV


O2/N2 Delivery


OGA


Progress/ATV Tanks


Elektron


NPRV

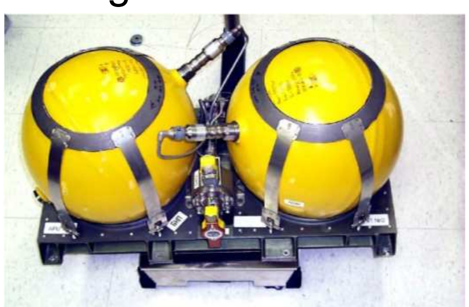

Manometer

PPRV

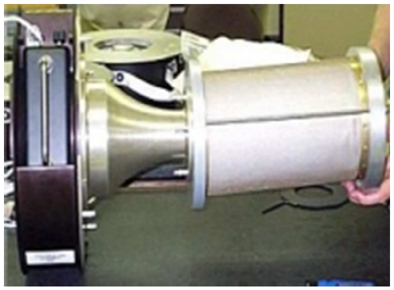


PCA

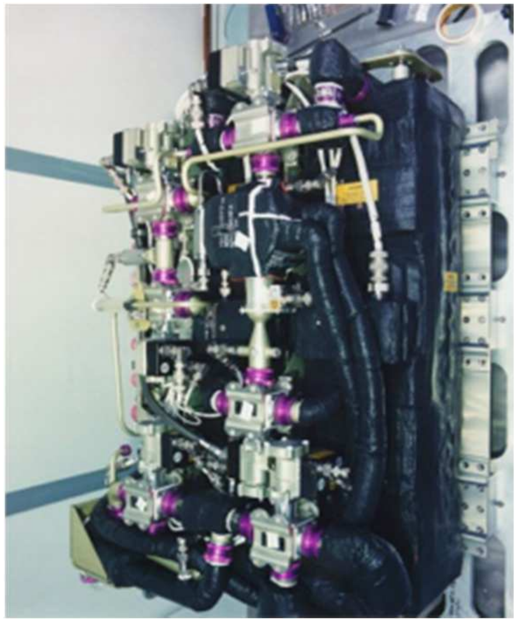

VRV


BNP

ISS ECLS Hardware Review - AR



US CO2 Removal Kit



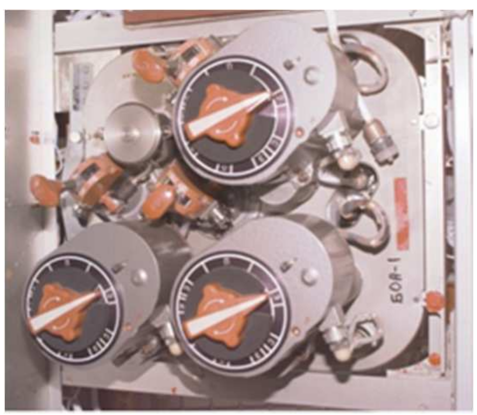
CDRA

MCA

ATCO

BMP

RS CO2 Absorber



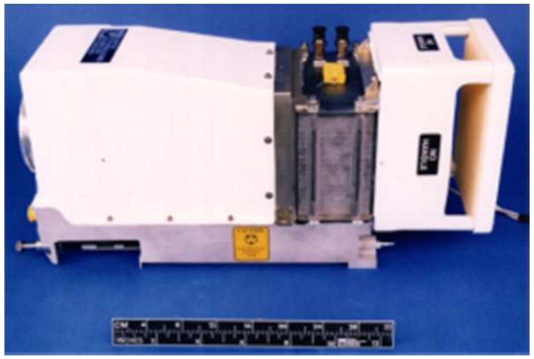
Vozdukh

METOX Regenerator

TCCS

ISS ECLS Hardware Review – THC, FDS

CCAA



AAA

US IMV Fan

RS Fan

HEPA Filter & box

US IMV Valve

RS SDs

RS PFE

US PFE

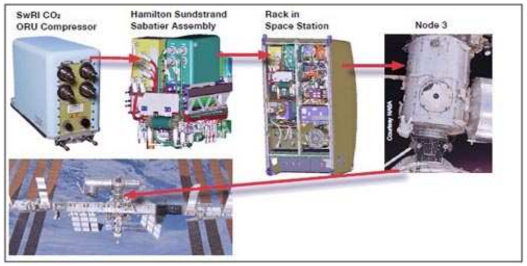
US SD

ISS ECLS Hardware Review – WRM / WM

WRS #1 (WPA)

WRS #2 (UPA & WPA)

Sabatier Reactor



W&HC

Example ISS Lessons Learned

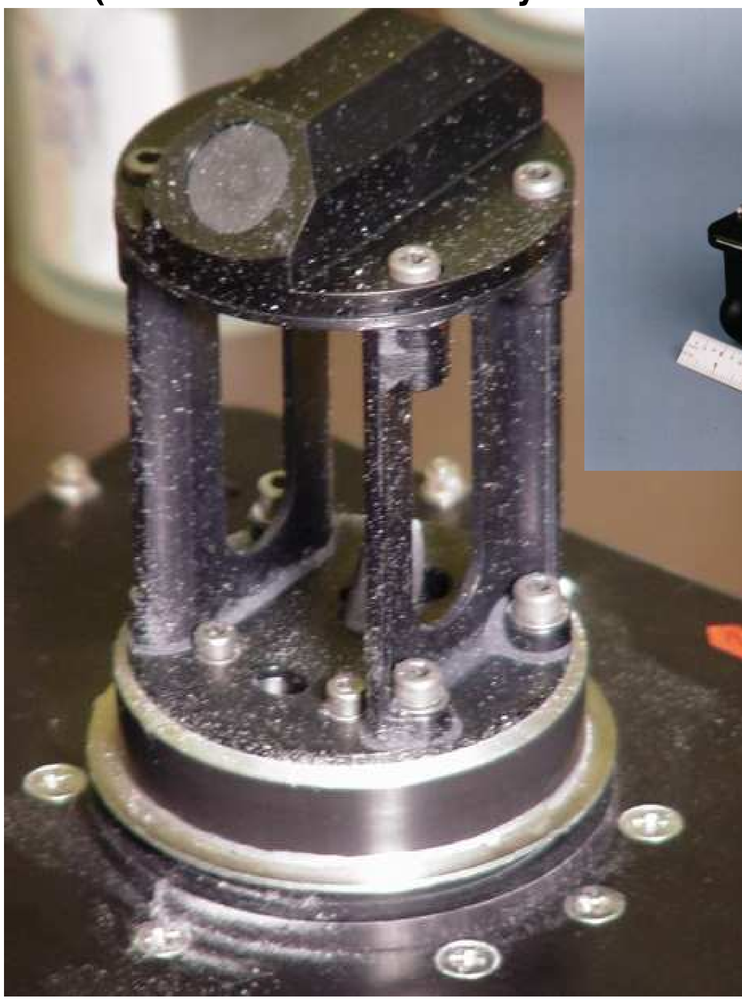
1. As-used vs. as-designed (and envisioned) equipment expectations

U.S. Lab Module at Launch (as envisioned during design of ventilation system, emergency response, etc.)

U.S. Lab Module in actual use (impacts ventilation concept and access to emergency fire ports)

Example ISS Lessons Learned

2. Variations in local environment - Unexpectedly high air velocities over one Smoke Detector caused it to get very dirty (unusable & out of family with all other USOS SDs)



3. Extending equipment performance life can result in finding new/unexpected life limiting effect -TCCS LiOH bed deliquescence created high ΔP

Example ISS Lessons Learned

4. Unexpected system response -
IMV circuits intended as "pass-thru" between Elements: Collect dust/lint to the point of stall, requiring periodic invasive crew maintenance

5. Bugs will grow - Microbial & fungal growth in wastewater system tanks, plumbing & valves:
Biofilm clogs WPA flow passages: Low flow & high ΔP

Example ISS Lessons Learned

6. Non-common redundancy is handy, but integration/maintenance/logistics complexities can result from multiple H/W providers

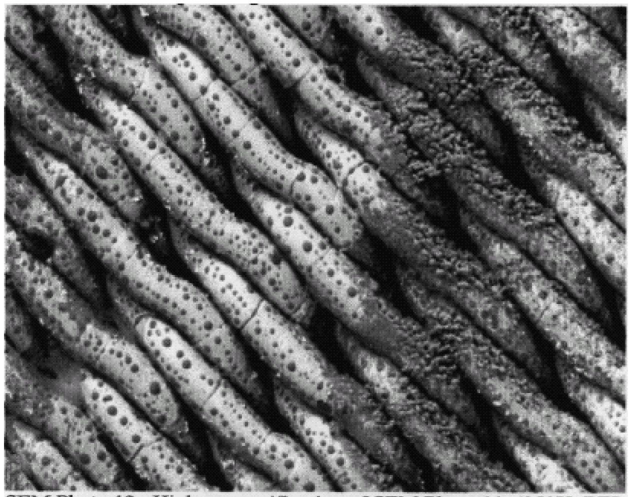
Russian Vozdukh CO2 removal device requires periodic maintenance/component replacement – usually done by Russian Crew members

U.S. CDRA CO2 removal device requires periodic maintenance/component replacement - usually done by American Crew members

Two sets of maintenance procedures, spares stockpiles and emergency response protocols req'd.

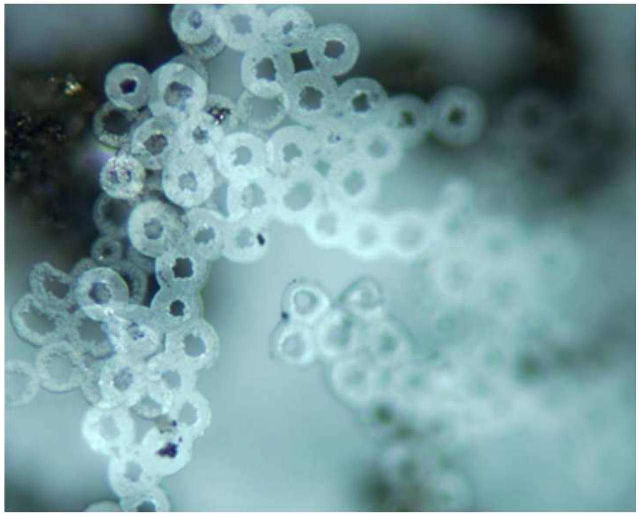
Example ISS Lessons Learned

7. Unexpected duty cycle as compared to design vision - Infrequent use of Airlock CCAA caused scale generation, build up & subsequent water separator failure



SEM Photo 12: Higher magnification of SEM Photo 11. (250X, BEI)

8. Use different than design - Due to higher urine calcium levels on-orbit as compared to ground test donors calcium precipitation clogged UPA DA flow path and failed DA



9. Unexpected things happen - Formation of washer-shaped discs of Zinc Oxide (unknown reason) in U.S. Lab condensate plugged & failed the U.S. Lab condensate vent line screen during 5A.1 vent first use

Mission/Platform Comparison - Mars

System	Flight modes	Duration	Crew	Volume (ft^3)	ECLS Capabilities/Challenges
Mars	Launch Transit Landing Surface Rover Launch Return	1 day 270 days 1 day 525 days 7 days 1 day 200 days 1005 days	4	TBD Isolatable habitable volumes: TBD	• All maintenance, troubleshooting and repair to be done in-situ by astronauts • Fire & leak response: Stay/fight, or ***Escape to orbit*** • Significant dormant periods before and after use • Multiple platforms • Partial gravity environment • Dust invasion • Common vs. non-common redundancy??





ISS ECLS Hardware Map to Mars Platforms (Interchangeability)

Fcn	H/W	Transit	Ascent/D	Habitat	Rover	Suit
ACS	PCA	X		X	X	N/A
	OGA	X	N/A	X		N/A
THC	Cabin Fan	X		X		N/A
	CHX	X		X		N/A
FDS	Smoke D	X		X		N/A
	PFE	X		X		N/A
AR	MCA (MPAM)	X	X	X	X	N/A
	TCCS	X	N/A	X		N/A
	CDRA	X		X		N/A
	TCM	X	N/A	X	N/A	N/A
WRM	UPA	X	N/A	X	N/A	N/A
	WPA	X	N/A	X	N/A	N/A
	W&HC	X		X		N/A

Mars Transit Vehicle & Habitat Requirements Achievable with ISS H/W

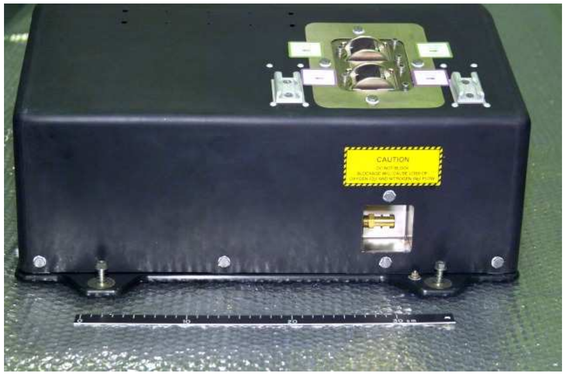
- **ACS:**
  - **Total pressure and pressure control**
  - **Oxygen partial pressure**
- **THC**
  - **Ventilation**
  - **Temperature control**
  - **Humidity control**
- **FDS**
  - **Smoke detection**
  - **Fire suppression**

Tuolumne Meadows, Yosemite National Park, CA

- **Loop closure**
  - **Current ISS level of loop closure is probably sufficient for a 4-crew/1000 day Mars mission**

Types of USOS H/W that could be use-as-is

- **ACS:**
  - PCA (PCP & VRV)
  - O2/N2 system regulators, valves and sensors



~ 30 years of cumulative run time

- **THC:**
  - Cabin fans
  - IMV fans
  - AAA fans
  - HEPA filters

~ 50 years of cumulative run time

~ 120 years of cumulative run time

- **FDS:**
  - Smoke detectors
  - CO2 PFEs

These components have demonstrated 10+ years of solid service on ISS in multiple locations. Supporting a 3+ year mission should not be an issue.

Mars Requirements/Conditions that Pose ISS ECLSS Equipment Challenges

- CO2 partial pressure average daily exposure limit
  - If requirement lowered by NASA Flt Docs as expected
- Trace contaminant monitoring
  - No more Summa canisters returning to earth for analysis every 3 months
- Supporting frequent (daily/weekly) EVAs
- Trash & solid waste accumulation/treatment/disposal
- Gas and waste water overboard venting

  Concern with Planetary Protection limitations
- Dormancy periods before and after use
- Desire for Interchangeability Between Platforms (IBP)
- Radiation environment for ISS designed ECLS system electronics
- Surface dust sensitivity/tolerance/management
- Partial (earth) gravity ops
- ISRU

  Not testable on ISS
- Emergency support
  - Ascent/Transit vehicle safe havens (*escape to orbit*: ops, spares & food storage)

Candidate ISS Test Bed ECLSS Hardware

ACS:
- NORS Tanks
- Ceramic oxygen separator & compressor *or* HPOGA
- Ceramic CO_2 reduction/O_2 generator

THC:
- New formula CHX coating

FDS:
- Water mist PFEs
- Next-gen smoke detectors

AR:
- Trace contaminant monitor (FTIR)
- Regenerative TCCS
- MPAM (MCA replacement)
- CO_2 removal:
  - -5 CDRA bed(s)
  - Solid Amine (Development unit on ISS today)

Regen:
- UPA, WPA, OGA – All systems need size/weight reduction and reliability increase
- Brine water recovery technologies
- Microbial & fungal control technologies

WM:
- W&HC needs size/weight reduction and reliability increase
- Trash volume reduction/stabilization technologies