Life Support Systems Microbial Challenges

August 24, 2009

Monsi C. Roman
NASA/ Marshall Space Flight Center
ECLSS Chief Microbiologist
(256)544-4071

Agenda

- Environmental Control and Life Support Systems (ECLSS) What is it?
- A Look Inside the International Space Station (ISS)
- The Complexity of a Water Recycling System
- ISS Microbiology Acceptability Limits
- Overview of Current Microbial Challenges
- In a Perfect World What we Would Like to Have
- The Future

Environmental Control and Life Support Systems (ECLSS)

Control Atmosphere Pressure

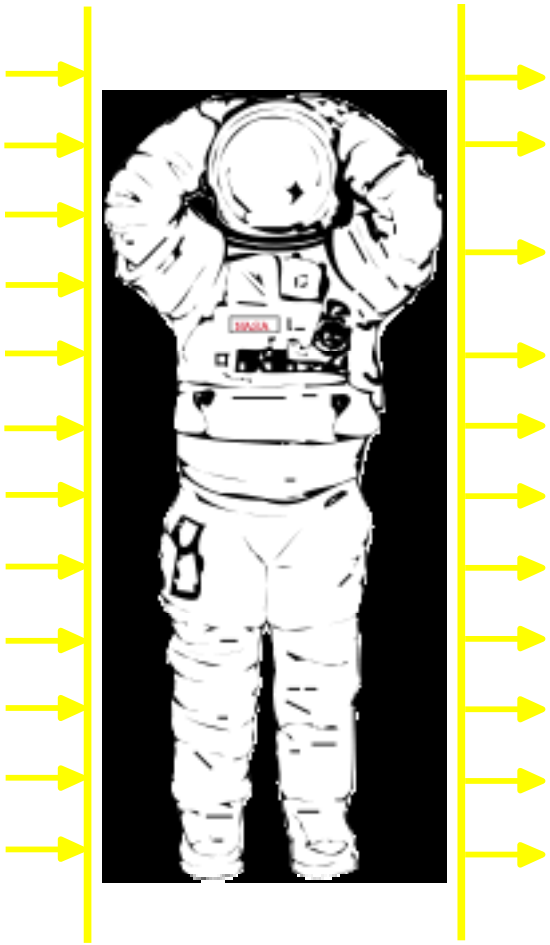
Condition Atmosphere

Respond to Emergency Conditions

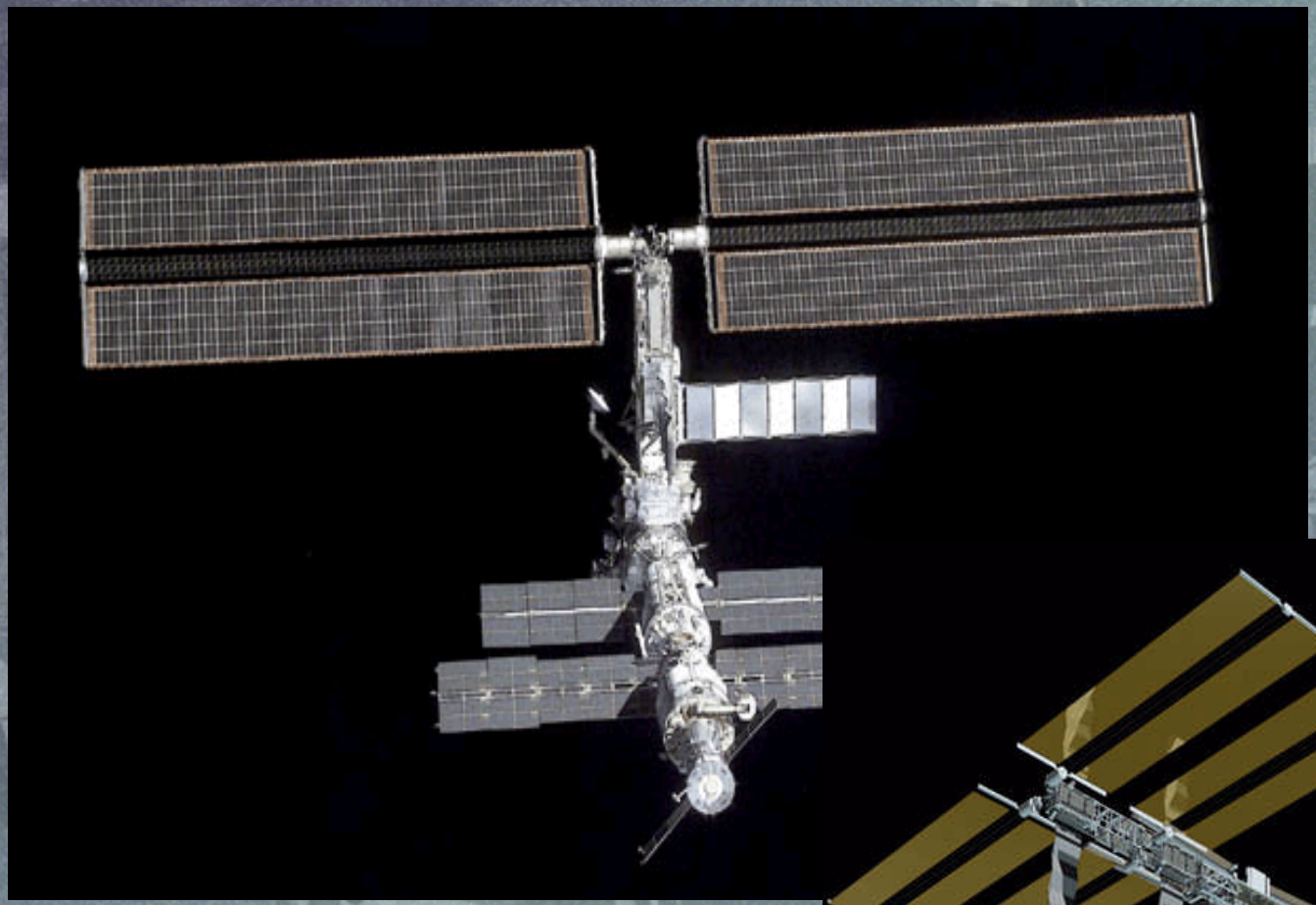
Control Internal CO_2 & Contaminants

Provide Wate

Needs

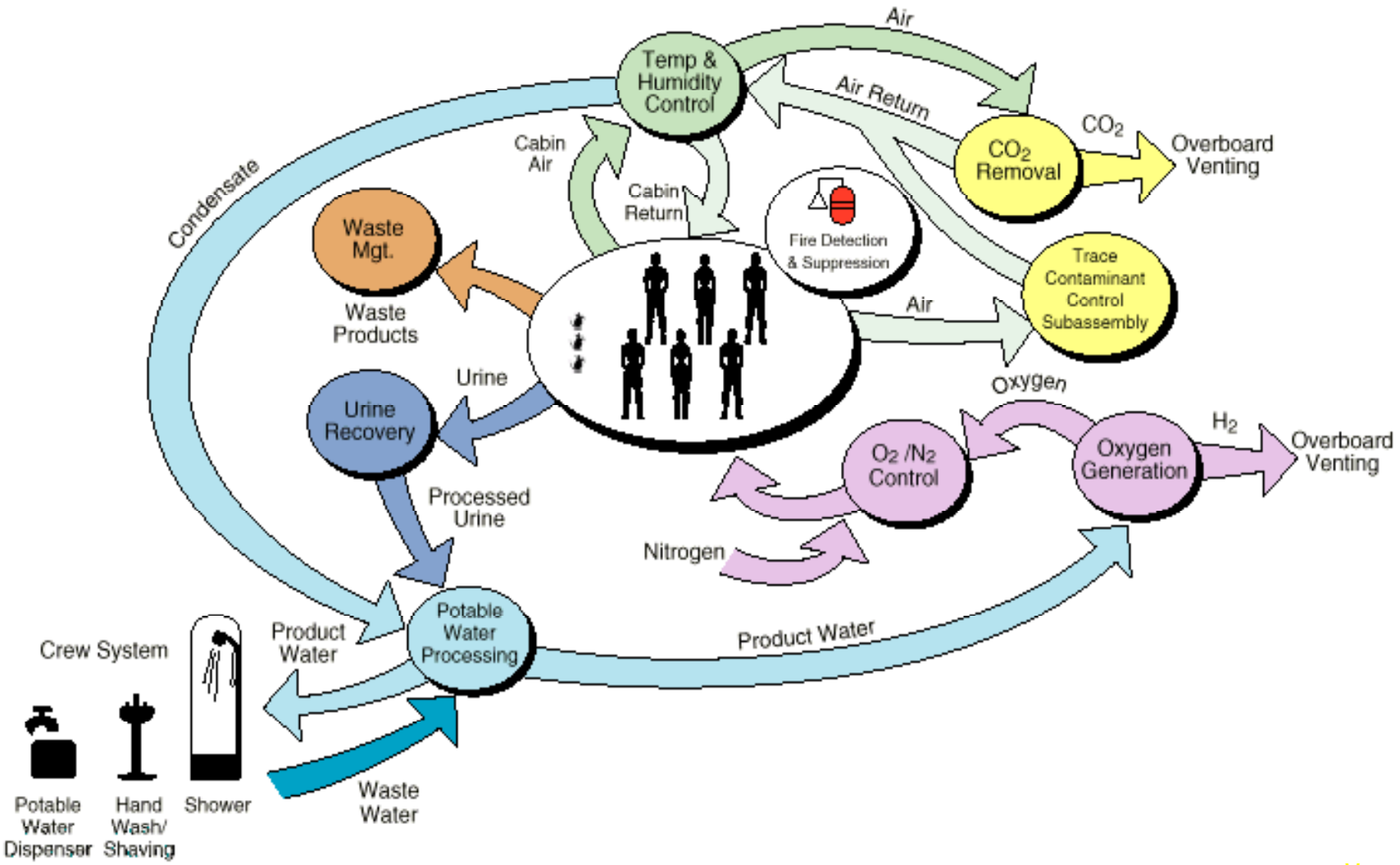


Effluents

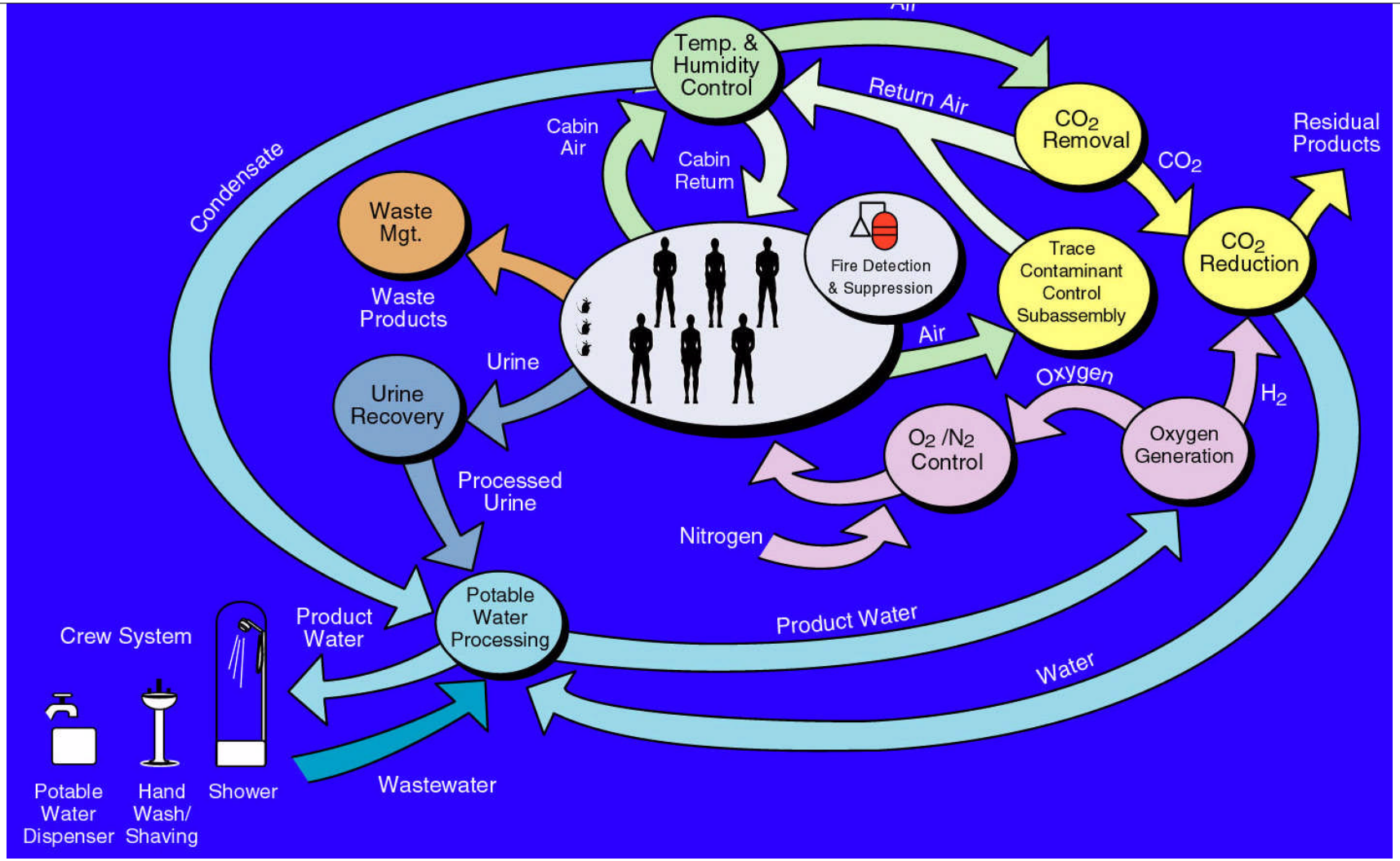


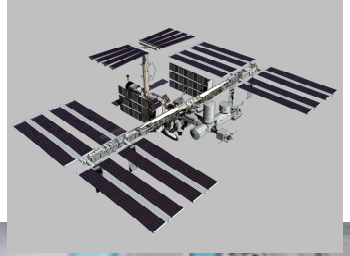

Development Complete

Space Station Regenerative ECLSS Flow Diagram (Current Baseline)

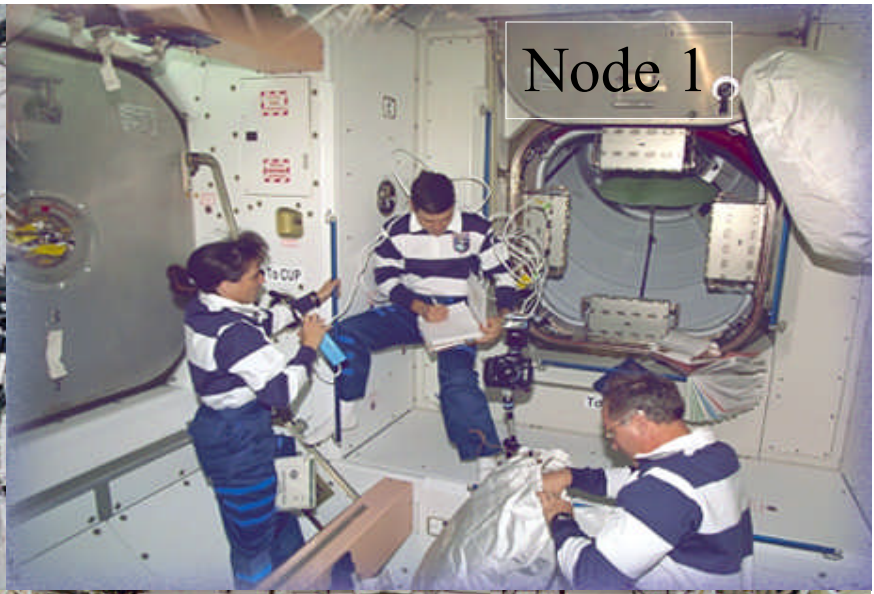


International Space Station ECLSS





A Look Inside ISS



ISS008E22249

NASA/ M. Roman

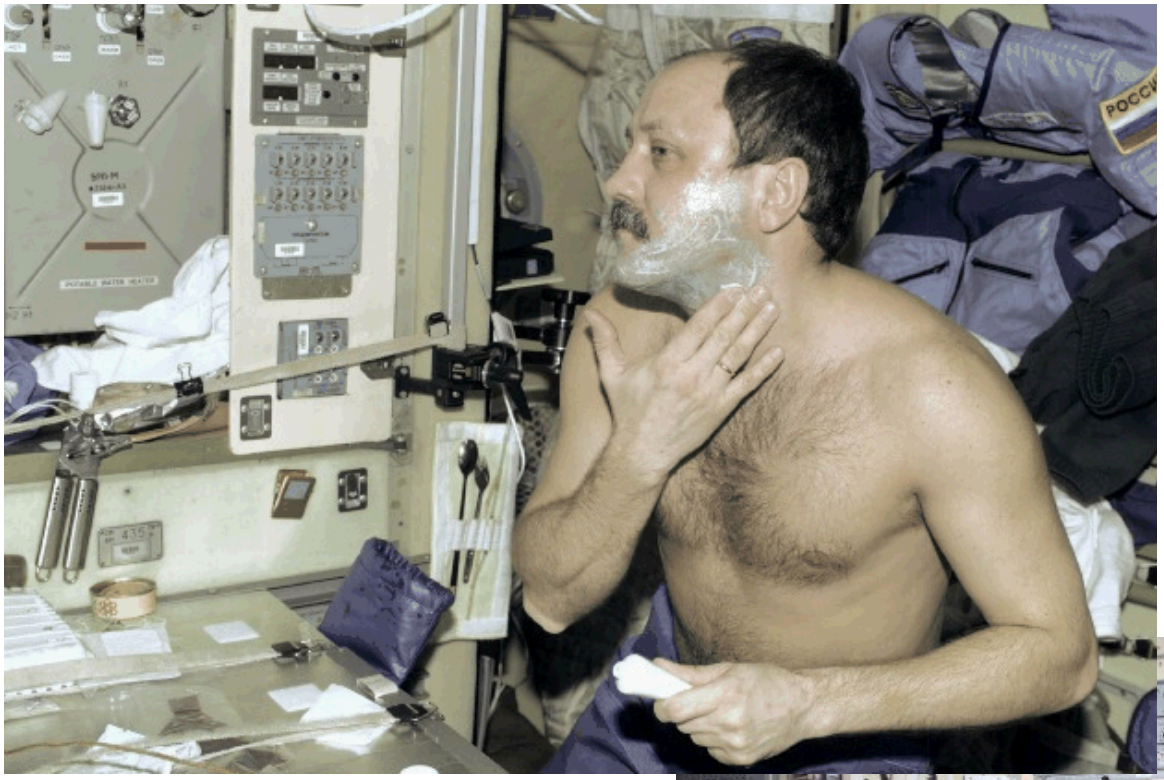
ISS003E8389 2001/12/15 02:02:09

NASA/ M. Roman

Living in Space

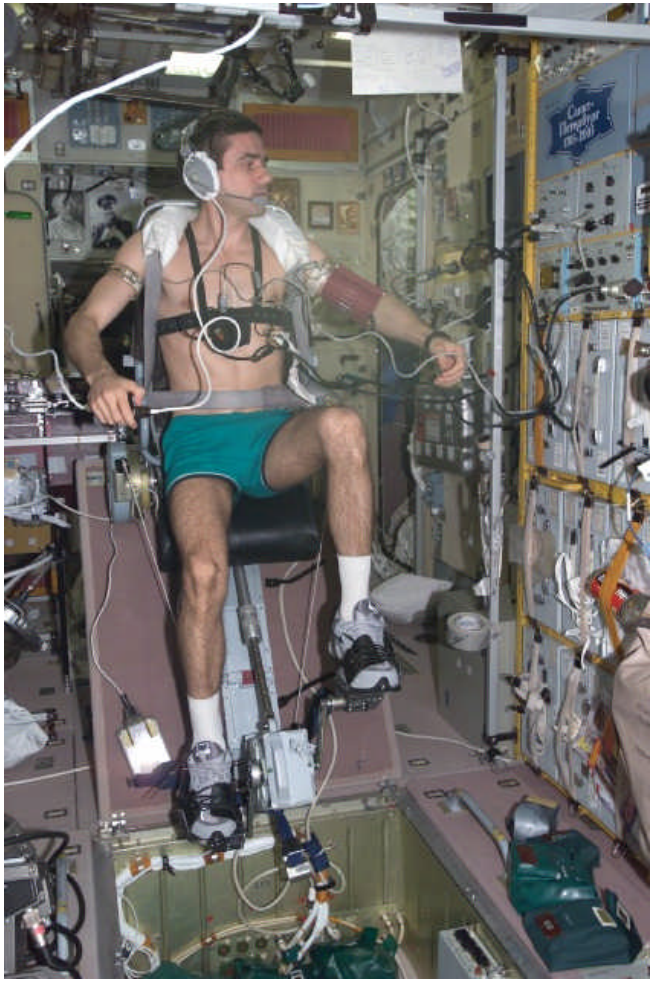
ISS007E06455


Crest



ISS002E5775 2001/03/28 06:43:01

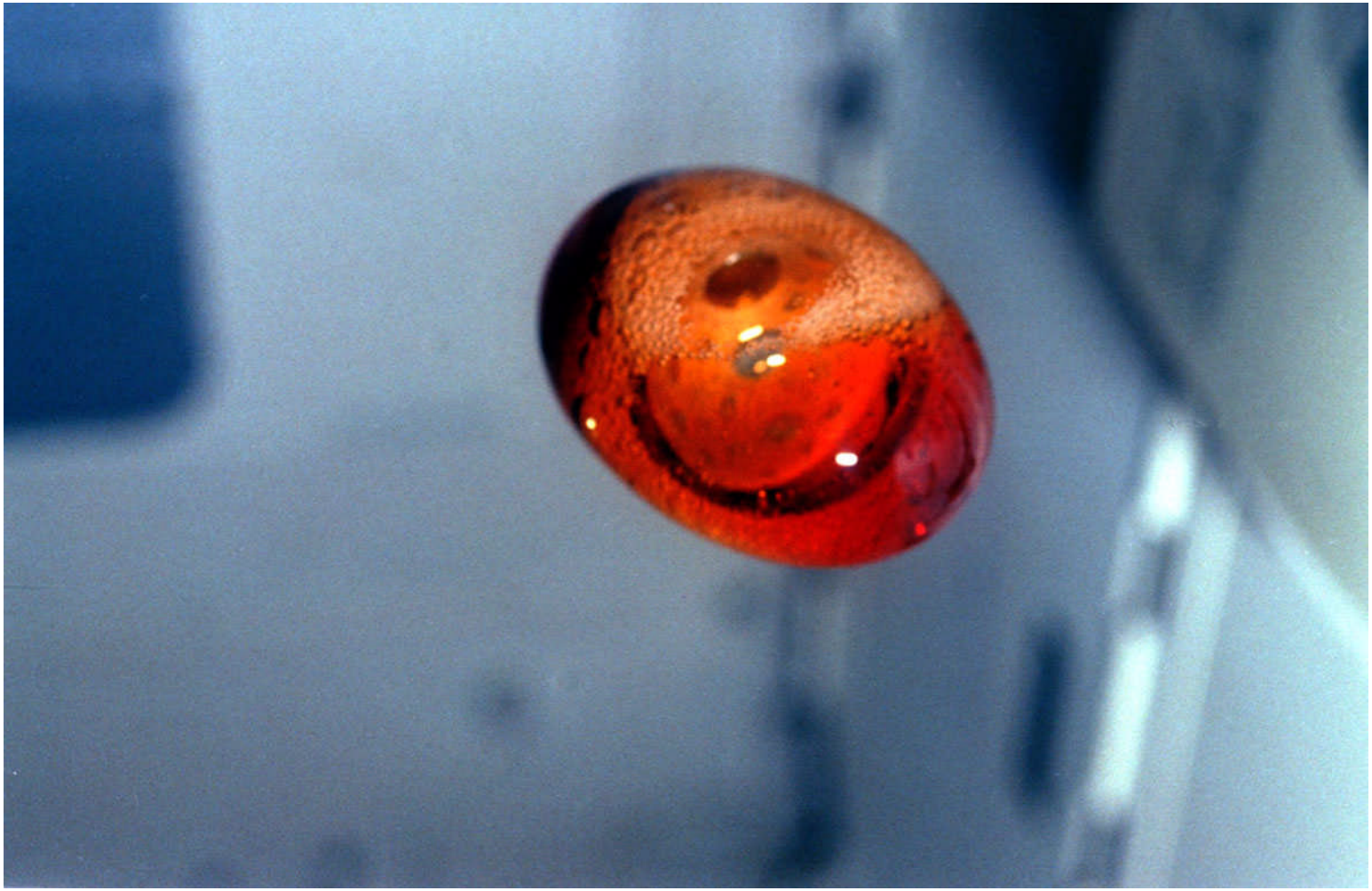

MAGGOT
ON
BOARD




MF57G
SAREX

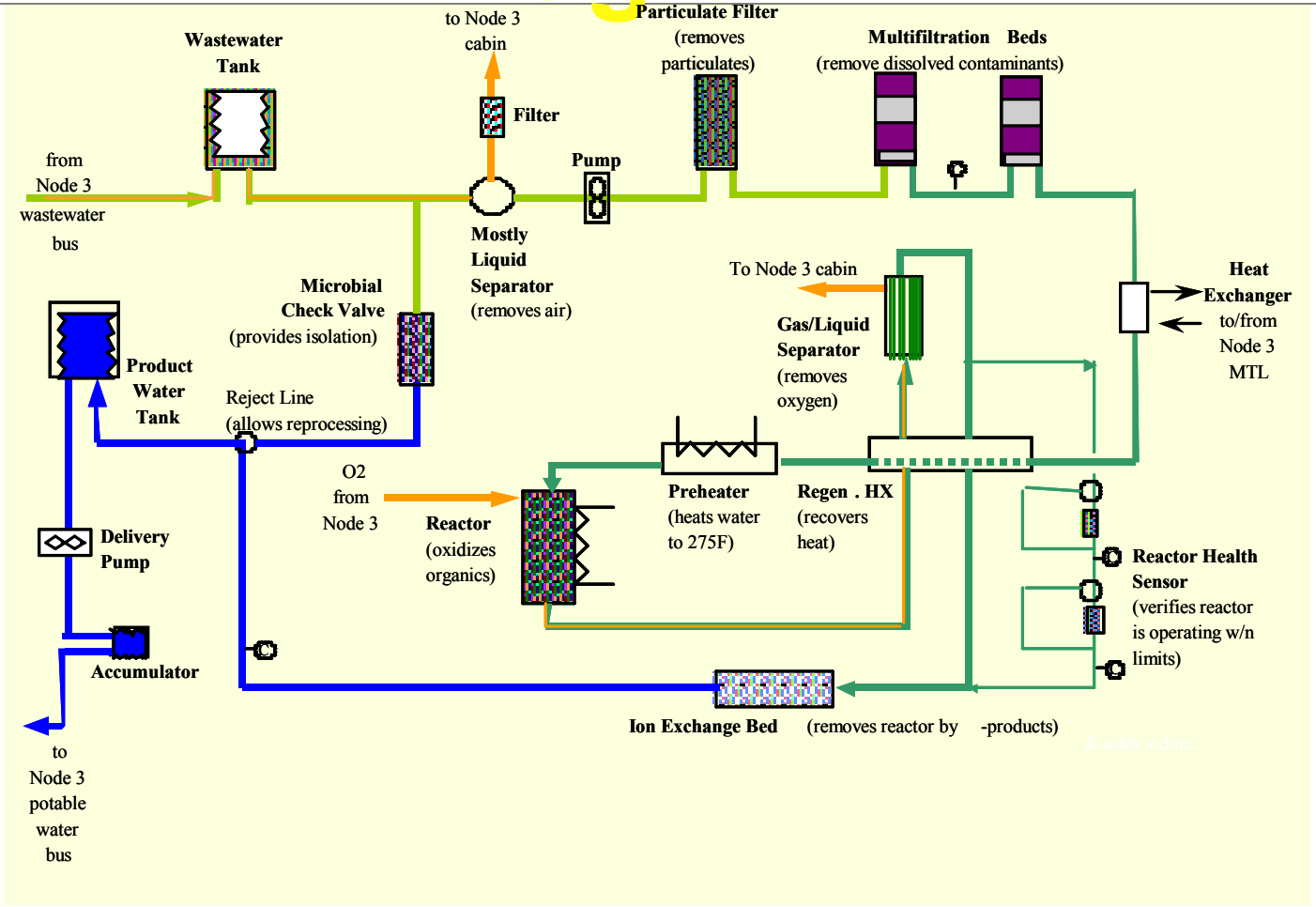
Filling up a bag of water in the Zvezda, SM

NASA/ M. Roman

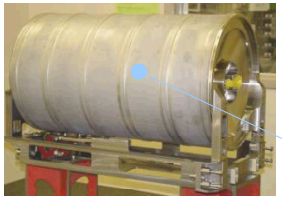


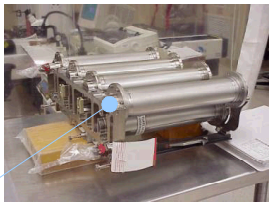
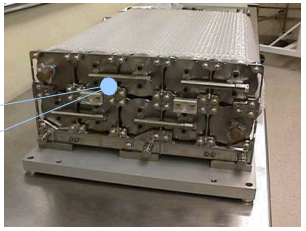
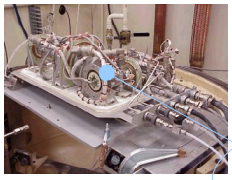
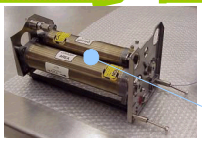
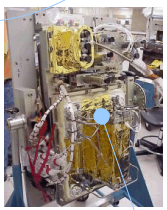
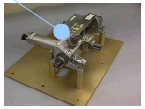
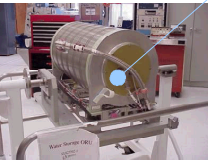
NASA/ M. Roman

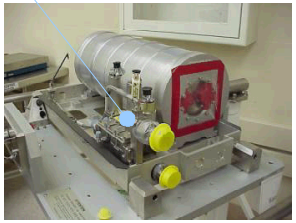
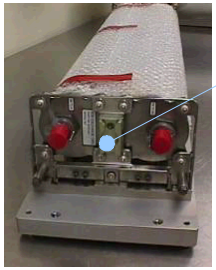
ISS Water Processor Diagram



Water Processor Assembly




ECLSS Microbial Challenges

- Wetted Materials in space life support systems include:
  - Titanium
  - 316L Stainless Steel
  - Teflon
  - Viton O-rings
  - Nickel-Brazed Stainless Steel

ECLSS Microbial Challenges

ISS Microbial Acceptability Limits (U.S.)

	Bacteria	Fungi
Surfaces	10,000 CFU/100 cm^2	100 CFU/100 cm^2
Water	100 CFU/ 100 ml (no detectable coliforms)	N/A
Air	$\leq$ 1,000 CFU/m^3	100 CFU/ m^3

CFU/cm^2= colony forming units per square centimeter; CFU/ m^3= colony forming units per cubic meter; CFU/ ml= colony forming units per milliliter

ECLS Microbial Challenges

- **Urine/Pretreated Urine**
  - Hardware Performance Issues
    - Control of biofilm on wetted surfaces
    - Control of fungal growth in pretreated urine
- **Water (potable/wastewater)**
  - Health and Hardware Performance/Life Issues
    - Control of biofilm on wetted surfaces
      - Conditions of flight equipment unknown
    - Control of microorganisms in potable water
      - Re-growth potential/resistance to antimicrobials/MIC
    - Control microorganisms in humidity condensate

ECLS Microbial Challenges

- **Coolant**
  - Health and Hardware Performance/Life Issues
    - Control of microorganisms in the fluid
    - Control of biofilm on wetted surfaces
    - Microbiologically Influenced Corrosion (MIC)
- **Surfaces**
  - Health and Hardware Performance/Life Issues
    - Fungi, bacteria
- **Air**
  - Health and Hardware Performance/Life Issues
    - Fungi, bacteria

ECLSS Microbial Challenges (Design and Test)

- Flow rates: low, intermittent or no flow
- Dead-legs
- Potential long term storage of water in Teflon bags
- Limitations with the use of antimicrobials
- Gravity/microgravity effects
- Wastewater in narrow tubes

ECLSS Microbial Challenges (Design and Test)

- Holding time (between sample and analysis)
- Limited monitoring technology available
- Data interpretation
- Acceptable levels of microorganisms/biofilm
- Need for long term ground testing
- Replicate applicable flight conditions to ground tests

	Fleet Leader (Ground Test)	ISS LTL (Flight Sample)	ISS MTL (Flight Sample)
Acidovorax avenae		X	
Acidovorax delafieldii	X	X	X
Acidovorax facilis	X		X
Acidovorax konjaci	X		X
Acidovorax temperans		X	
Acinetobacter lwoffii/genospecies 9			X
Brevibacterium casei			X
Brevundimonas vesicularis			X
Burkholderia glumae	X		
Comamonas acidovorans	X	X	
Flavobacterium resinovorum			X
Janthinobacterium lividum	X		
Oligella species			X
Ralstonia eutropha (very similar genetically to R. paucula)			X
Ralstonia paucula		X	X
Ralstonia pickettii	X		X
Sphingobacterium spiritovorum		X	
Sphingomonas paucimobilis			X
Stenotrophomonas maltophilia	X		
Unidentified non-fermenting Gram Negative Rod (GNR)	X	X	X
Variovorax paradoxus	X		X

ECLSS Microbial Challenges

Challenges with monitoring ECLS systems in-flight include:

- Microbial count (quantification)
  - Viable vs non-viable
  - How will it compare with culture methods?
- Real-time identification
  - Bacteria, Fungi, Viruses
- Flexible
  - Integrated to systems (in-line)
  - Hand-held (for clinical applications)
- Robustness
  - Will the hardware survive qual/acceptance testing?

ECLSS Microbial Challenges

- If gene-base technology will be used what challenges, like damage to genetic material due to radiation, will need to be addressed?
- Expendables (how much waste will be generated)
- Consumables (reusable is preferred)
- Low power consumption
- Equipment size
- Non-hazardous reagents
- Non-generation of hazardous waste

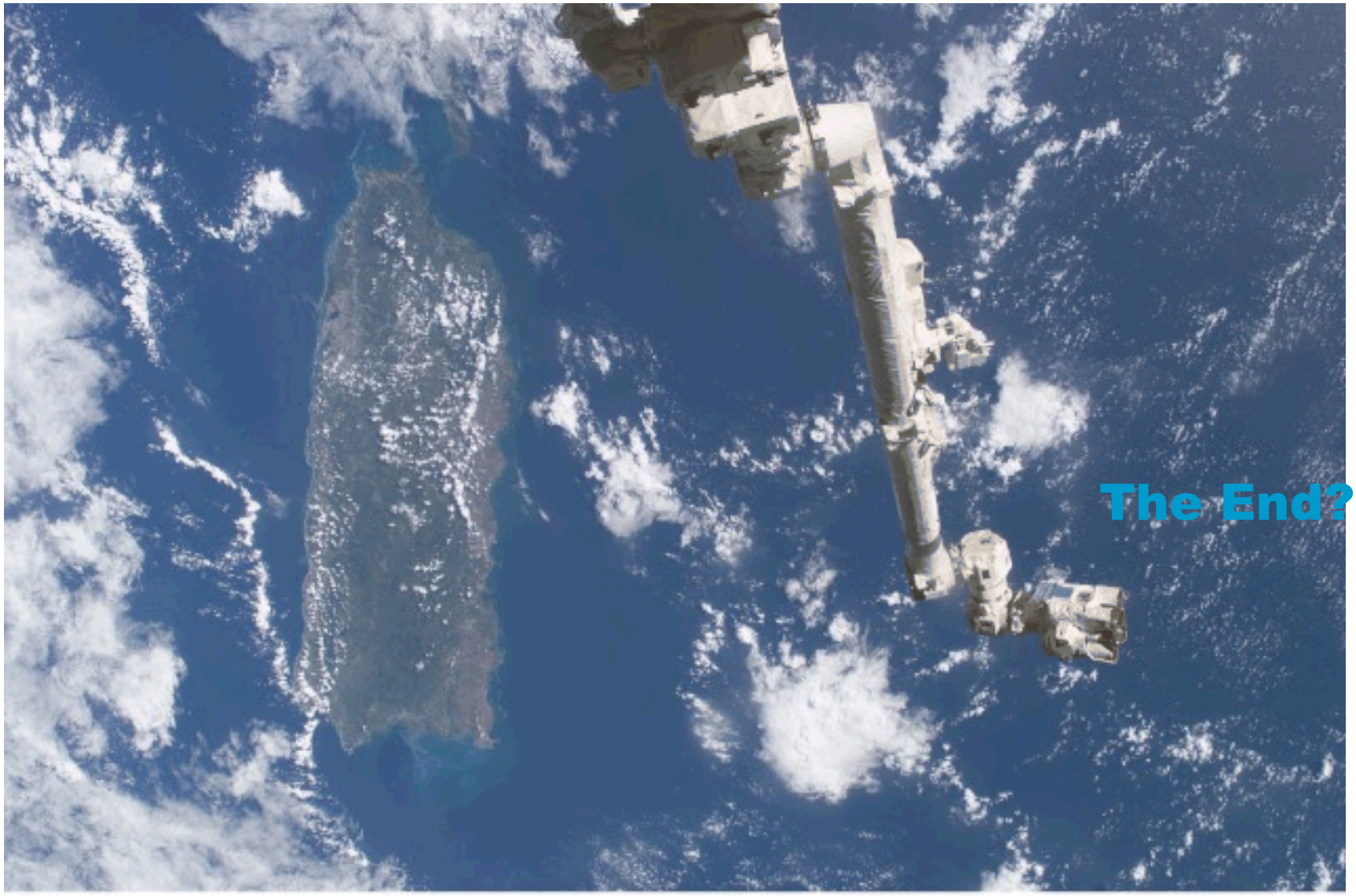
ECLSS Microbial Challenges

- Calibration (positive/negative controls?)
- Cleaning/disinfection of the sample collection areas
  - How to avoid cross contamination?
- What chemicals/conditions(temp, humidity, etc) could cause a problem (void the reaction)?
- Maintenance/repair (ORU's?)
- Construction materials
  - Are the materials acceptable in a close environment?

ECLSS Microbial Challenges

- Sample size
- Detection limit (currently <300 CFU/100 mL)
- Microgravity sensitivity
- Sensitivity to particles/precipitates in the fluid
- A system that can be upgraded as needed is preferable (as “target” organisms are identified)
- Will the crew be able to “read” the results on-orbit; can the results be sent to the ground?
- Sample archival for later analyses

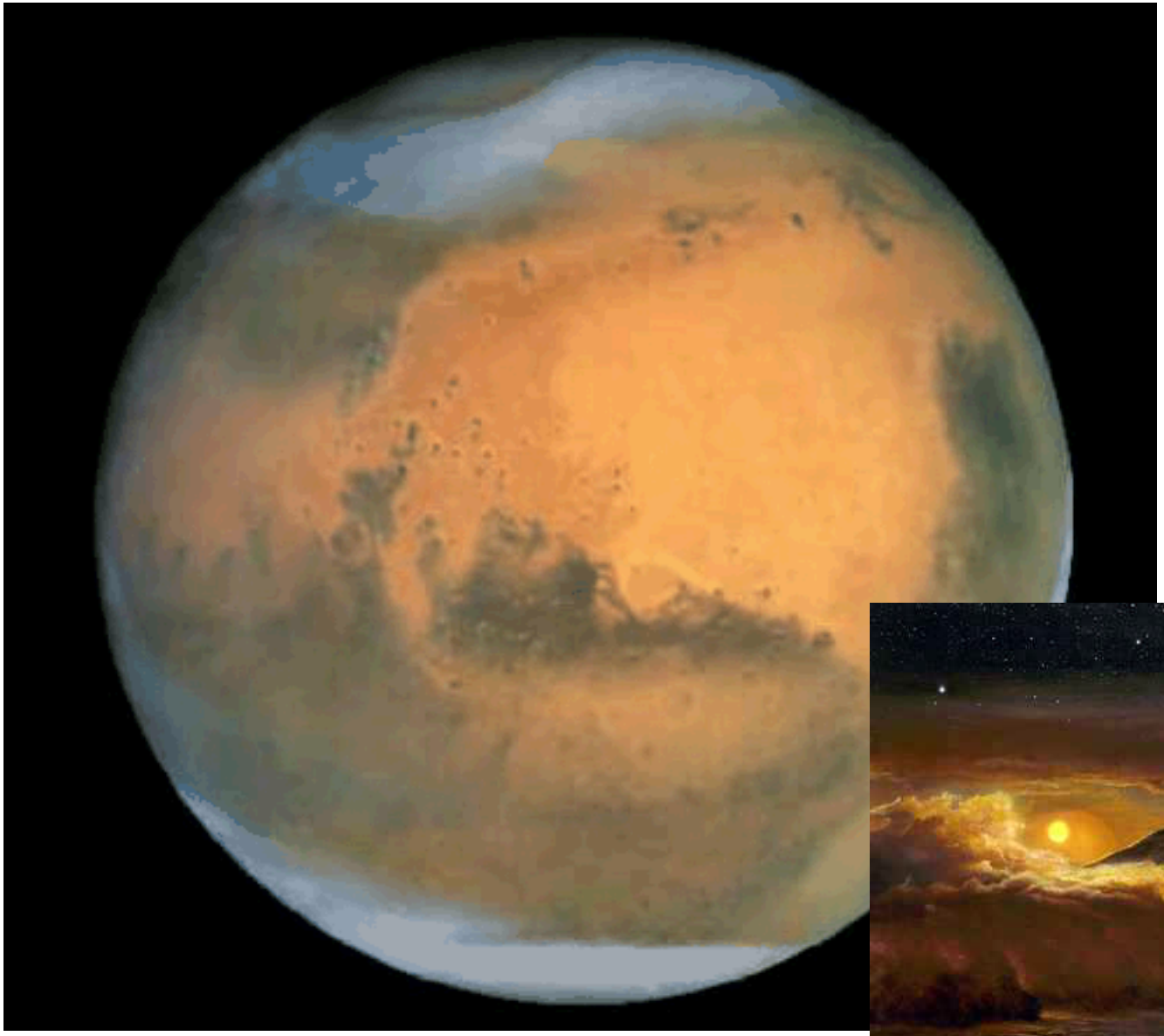
NASA/ M. Roman



ISS006E16953

NASA/ M. Roman

NASA/ M. Roman



NASA/ M. Roman