Moon/Mars Life Support Systems – How far along are we?

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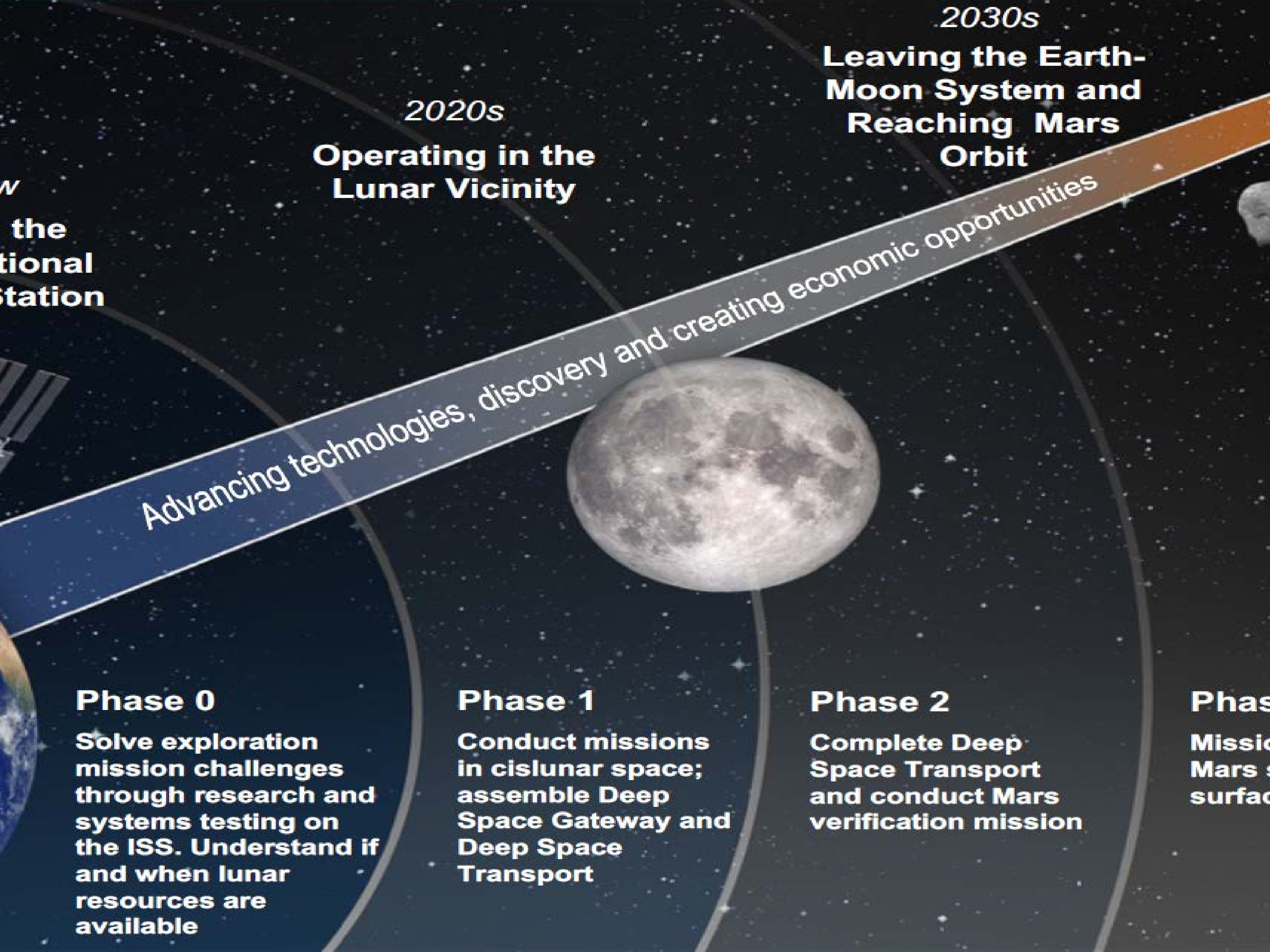
National Aeronautics and Space Administration

24 Mai 2017



2030s
Leaving the Earth-Moon System and Reaching Mars Orbit
2020s
Operating in the Lunar Vicinity
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Station
Advancing technologies, discovery and creating economic opportunities
Phase 0
Solve exploration mission challenges through research and systems testing on the ISS. Understand if and when lunar resources are available
Phase 1
Conduct missions in cislunar space; assemble Deep Space Gateway and Deep Space Transport
Phase 2
Complete Deep Space Transport and conduct Mars verification mission
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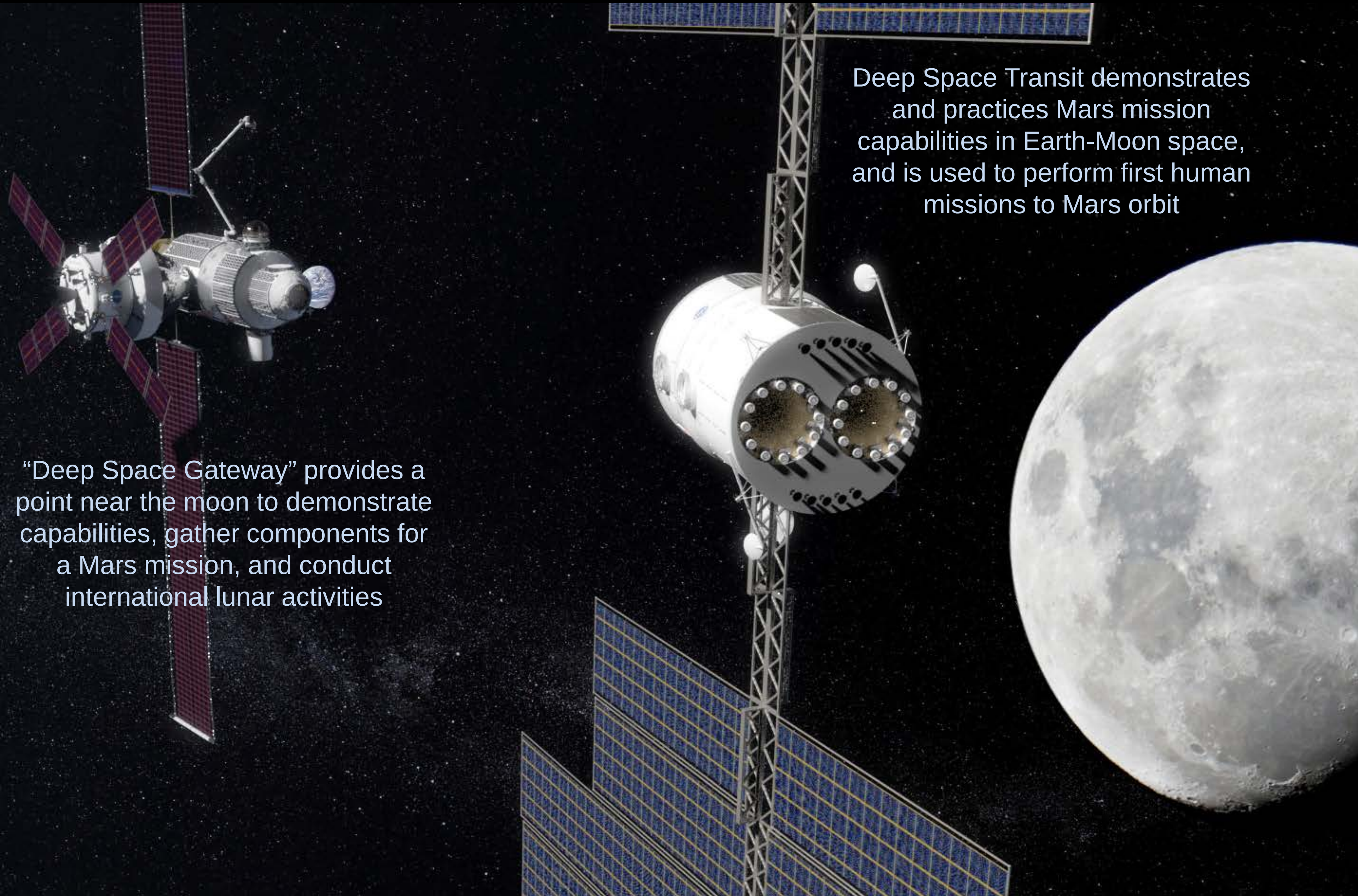
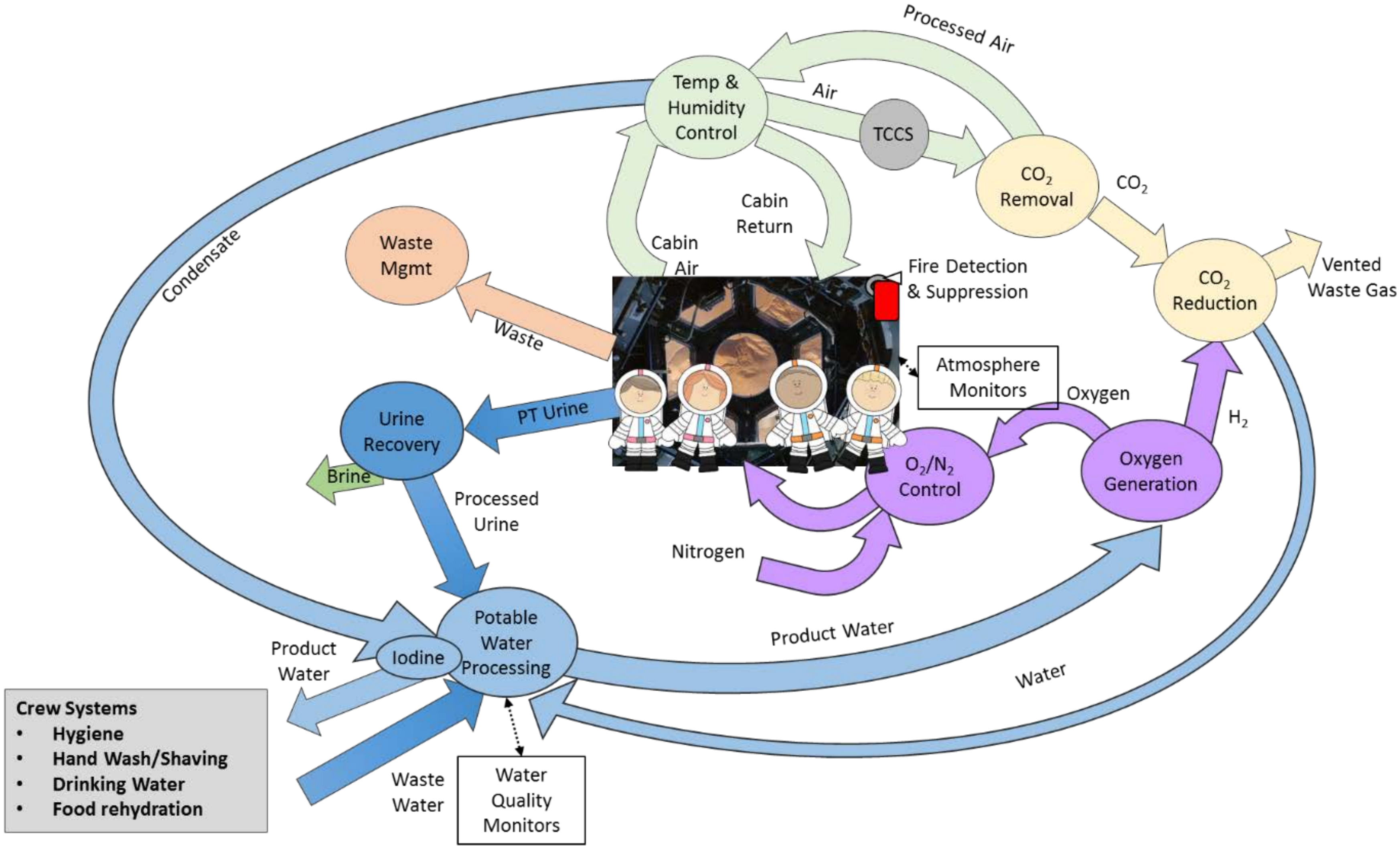
Concepts for New Vehicles Require New Systems



Deep Space Transit demonstrates and practices Mars mission capabilities in Earth-Moon space, and is used to perform first human missions to Mars orbit

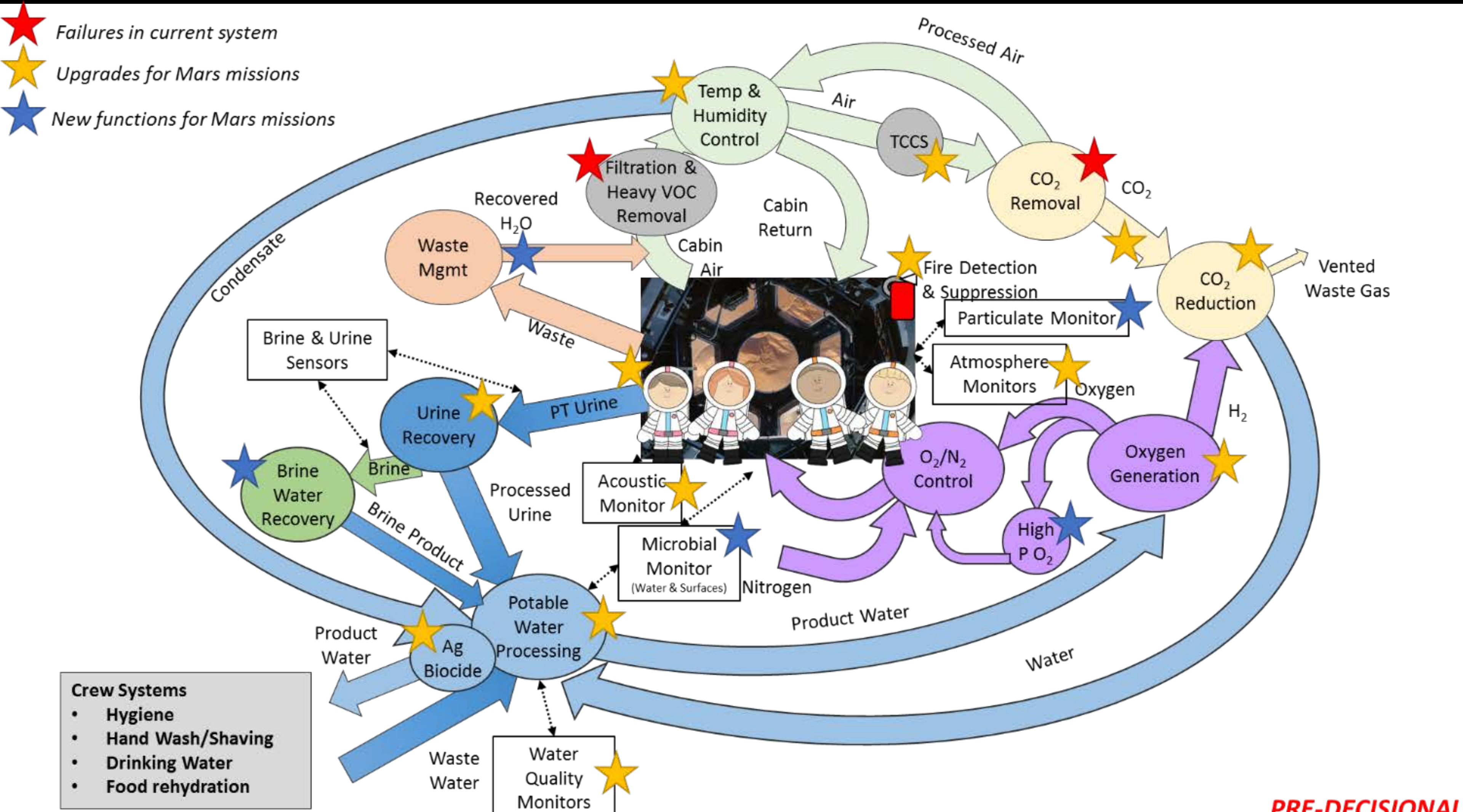
“Deep Space Gateway” provides a point near the moon to demonstrate capabilities, gather components for a Mars mission, and conduct international lunar activities

Experience in Closed-Loop Life Support



- **Humans need the same things to keep them healthy no matter where they are.**
- **Design technologies and systems to find the most efficient, cost effective, and reliable way to meet those needs.**
- **The right answer varies depending on the mission and vehicle.**
- **Life support systems for long duration missions are very interconnected**

Evolution of Life Support Systems

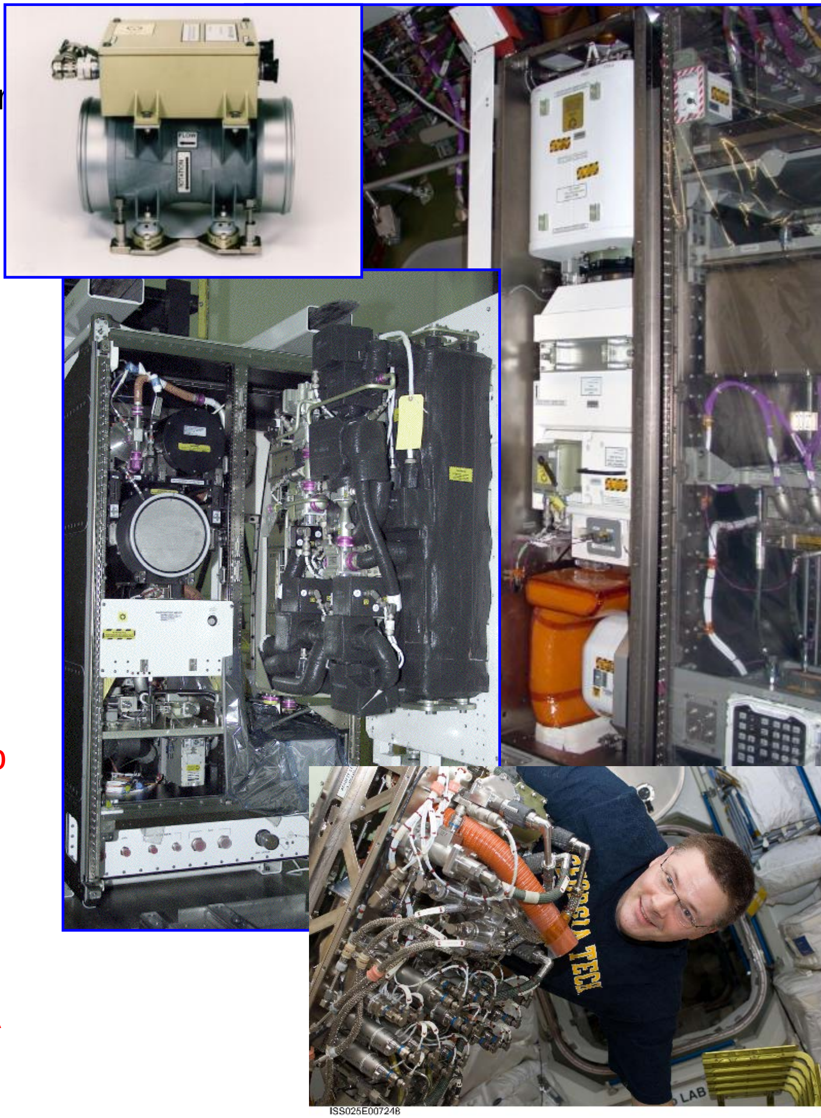


PRE-DECISIONAL

- **Nearly every function in the system will be updated because of lessons learned in previous spaceflight missions and new technology developments**
- **These will make the crew more self-sufficient for future missions, by recycling more waste materials, and having more information on their own systems**

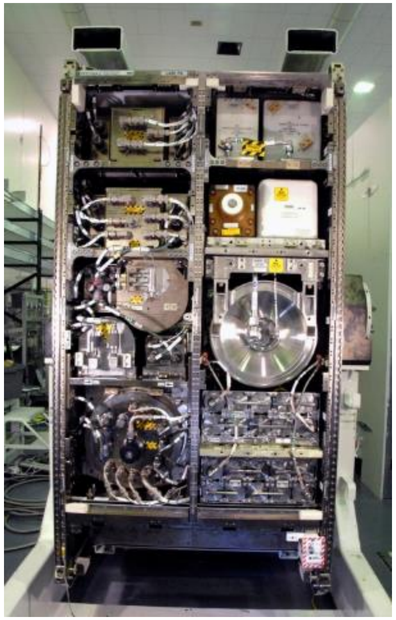
Current ISS Capabilities and Challenges: Atmosphere Management

- **Circulation**
  - ISS: Fans (cabin & intermodule), valves, ducting, muffler expendable HEPA filter elements
  - Challenges: Quiet fans, filters for surface dust
- **Remove CO_2 and contaminants**
  - ISS: Regenerative zeolite CDRA, supports ~2.3 mmHg ppCO2 for 4 crew. MTBF <6 months. Obsolete contaminant sorbents.
  - Challenges: Reliability, $ppCO_2$ <2 mmHg, commercial sorbents
- **Remove humidity**
  - ISS: Condensing heat exchangers with anti-microbial hydrophilic coatings requiring periodic dryout, catalyze siloxane compounds.
  - Challenge: Durable, inert, anti-microbial coatings that do not require dry-out
- **Supply O_2**
  - ISS: Oxygen Generation Assembly (H_2O electrolysis, ambient pressure); high pressure stored O_2 for EVA
  - Challenge: Provide high pressure/high purity O_2 for EVA replenishment & medical use
- **Recovery of O_2 from CO_2**
  - ISS: Sabatier process reactor, recovers 42% O_2 from CO_2
  - Challenge: >75% recovery of O_2 from CO_2



Current ISS Capabilities and Challenges: Water Management

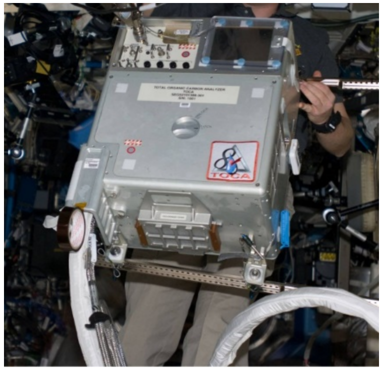
- **Water Storage & biocide**
  - ISS: Bellows tanks, collapsible bags, iodine for microbial control
  - Challenges: Common biocide (silver) that does not need to be removed prior to crew consumption; dormancy
- **Urine Processing**
  - ISS: Urine Processing Assembly (vapor compression distillation), currently recovers 80% (brine is stored for disposal)
  - Challenges: 85-90% recovery (expected with alt pretreat formulation just implemented); reliability; recovery of urine brine water
- **Water Processing**
  - ISS: Water Processor Assembly (filtration, adsorption, ion exchange, catalytic oxidation, gas/liquid membrane separators),100% recovery, 0.11 lbs consumables + limited life hw/lb water processed.
  - Challenges: Reduced expendables; reliability



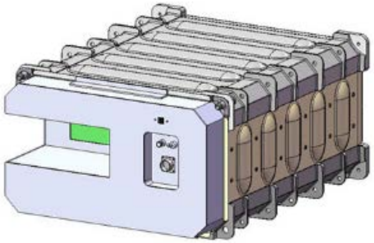
Current ISS Capabilities and Challenges: Waste Management

- **Logistical Waste (packaging, containers, etc.)**
  - ISS: Gather & store; dispose (in re-entry craft)
  - Challenge: Reduce &/or repurpose
- **Trash**
  - ISS: Gather & store; dispose (in re-entry craft)
  - Challenge: Compaction, stabilization, resource recovery
- **Metabolic Waste**
  - ISS: Russian Commode, sealed canister, disposal in re-entry craft
  - Challenge: Long-duration stabilization, potential resource recovery, volume and expendable reduction

Current ISS Capabilities and Challenges: Environmental Monitoring



- **Water Monitoring**
  - ISS: On-line conductivity; Off-line total organic carbon, iodine; Samples returned to earth for full analysis
  - Challenge: On-orbit identification and quantification of specific organic, inorganic compounds.
- **Microbial**
  - ISS: Culture-based plate count, no identification, 1.7 hrs crew time/sample, 48 hr response time; samples returned to earth.
  - Challenge: On-orbit, non culture-based monitor with identification & quantification, faster response time and minimal crew time



- **Atmosphere**
  - ISS: Major Constituent Analyzer (mass spectrometry – 6 constituents); COTS Atmosphere Quality Monitors (GC/DMS) measure ammonia and some additional trace gases; remainder of trace gases via grab sample return; Combustion Product Analyzer (CSA-CP, parts now obsolete)
  - Challenges: On-board trace gas capability that does not rely on sample return, optical targeted gas analyzer

- **Particulate**
  - ISS: N/A
  - Challenge: On-orbit monitor for respiratory particulate hazards
- **Acoustic**
  - SOA: Hand held sound level meter, manual crew assays
  - Challenge: Continuous acoustic monitoring with alerting

Brine Water Processing to Recover More Water

Brine

IWP Brine Processing Bag

Water

Safe Disposal

Air Revitalization to Recover More Oxygen

Electrolysis Reaction

$2\ H_2O \rightarrow 2\ H_2 + O_2$

Sabatier Reaction

$CO_2 + 4\ H_2 \rightarrow 2\ H_2O + CH_4$

Conclusion:

- **It takes 4 H_2 to make 2 H_2O, but you only get 2 H_2 back when you split H_2O to make O_2.**
- **You can't repeat the cycle 100% because you lost H_2, so you have to vent unreacted CO_2 which wastes oxygen.**

How can we recycle more? What challenges does that create?

Carbon Formation from Methane

$CH_4 \rightarrow C + 2\ H_2$

Bosch Reactions

$CO_2 + 2\ H_2 \rightarrow 2\ H_2O + C$

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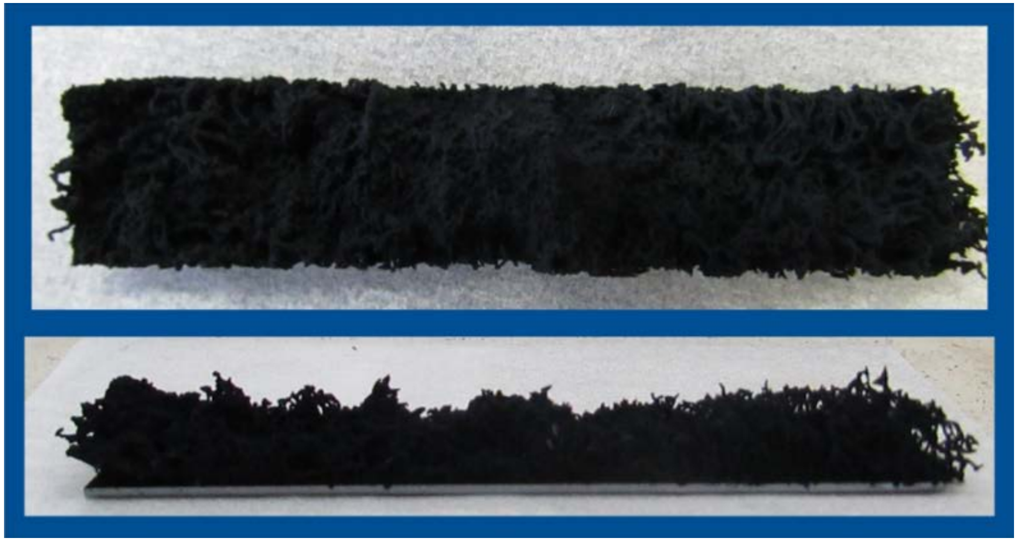
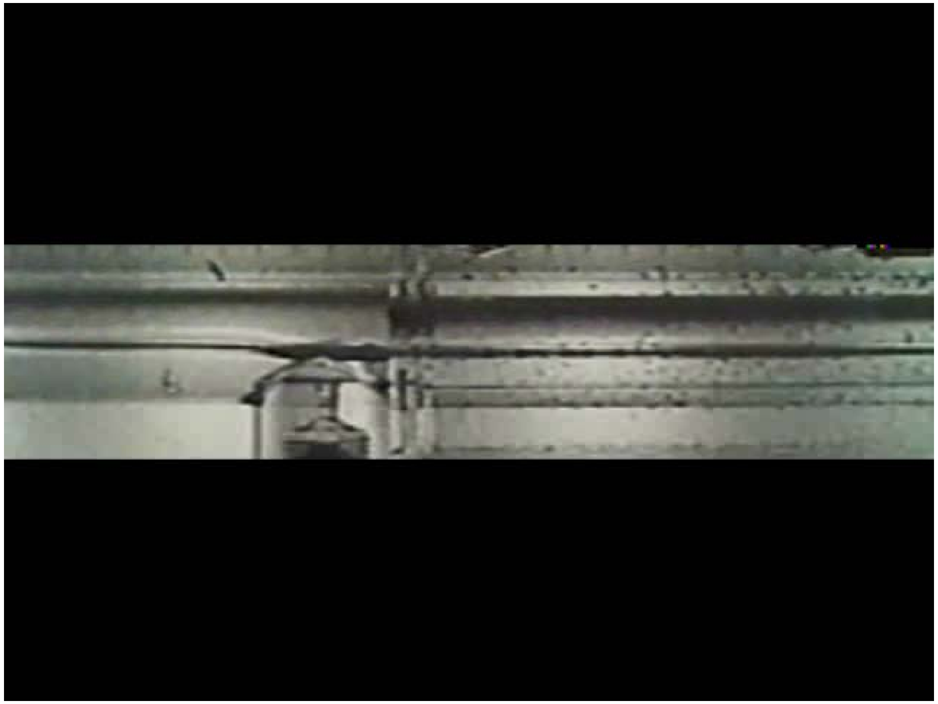
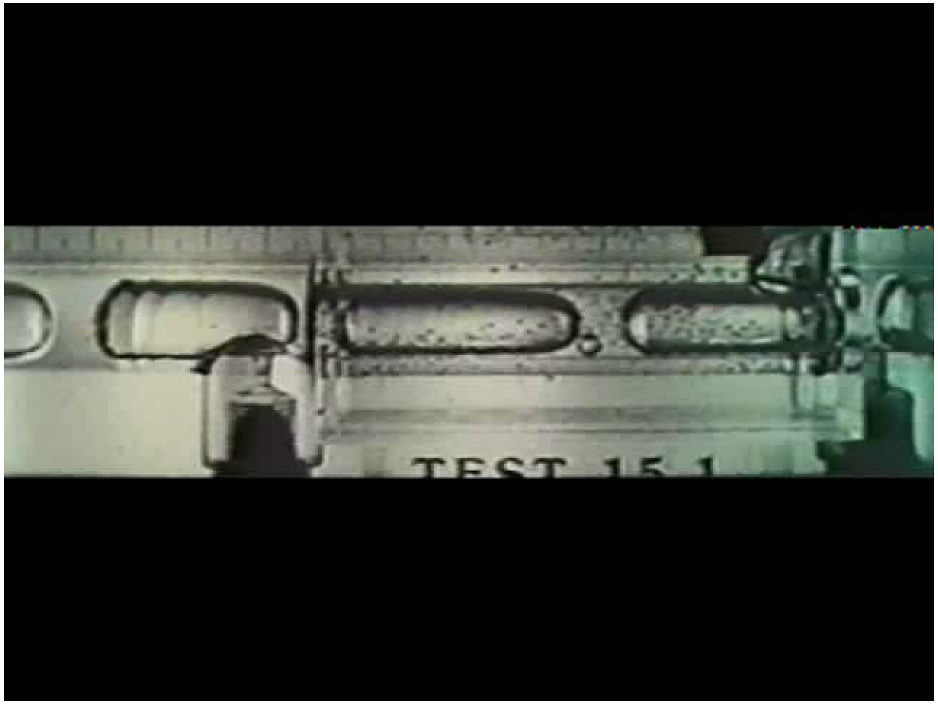


Microgravity Science Can Lead to Innovation





Each movie has the same inlet flow: Alternating pulses of water and air

Surface tension vs gravity!

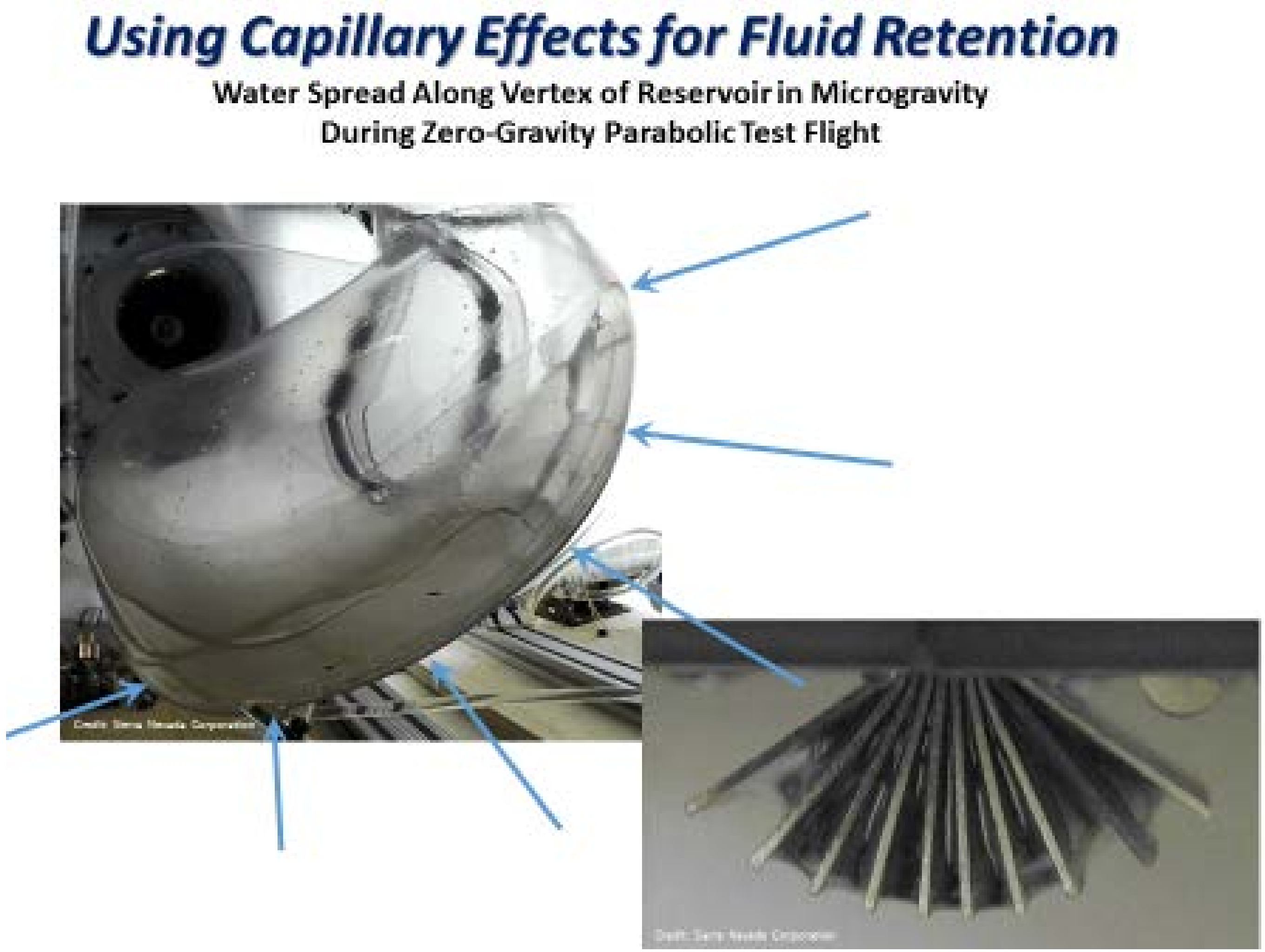
Steps from Science to Design

Steps from Science to Design

Condensing Heat Exchanger

Spaceflight condensing heat exchangers:

- Use hydrophilic coating to keep water attached to surface by surface tension, but coating wears out over time
- Suck the water through holes in the heat exchanger
- Do not let water droplets get carried into the air revitalization system!



What if you didn't have to worry about where the droplets of water went?

Logistics & Waste Processing

ISS stores trash it burns in Earth's atmosphere when cargo vehicles leave

Logistics & Waste Processing

ISS stores trash it burns in Earth's atmosphere when cargo vehicles leave

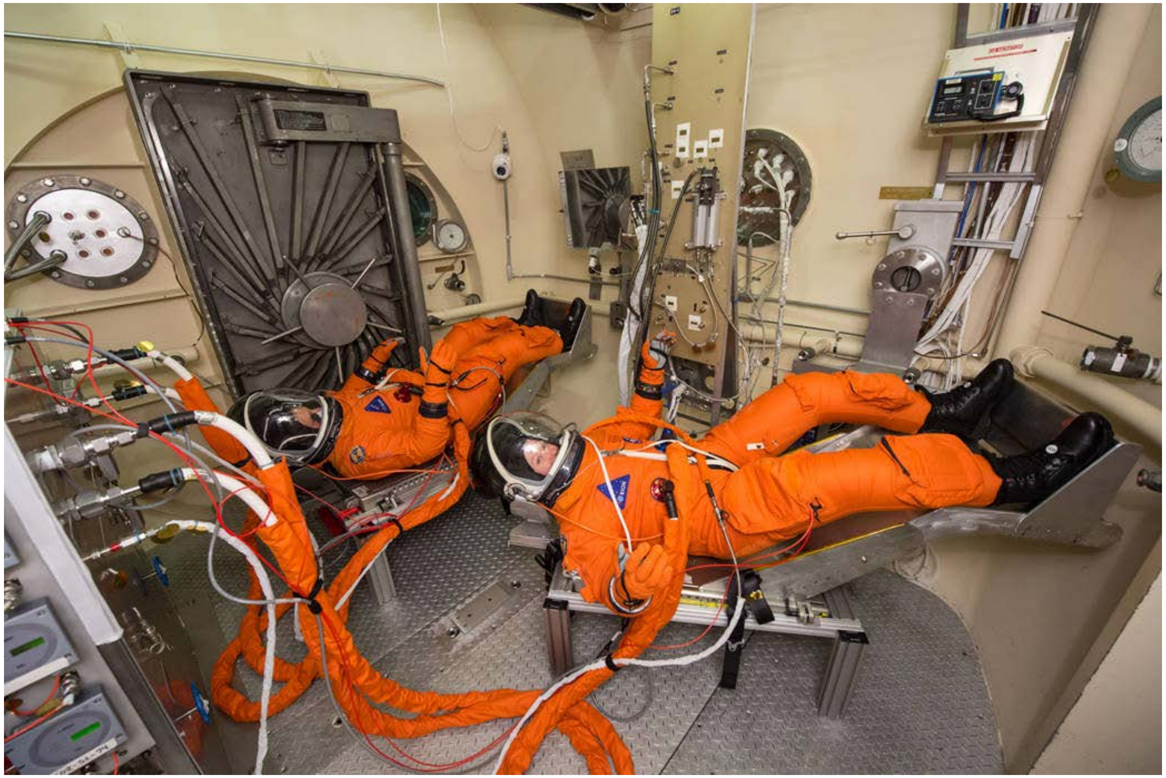
What should we do for the future?

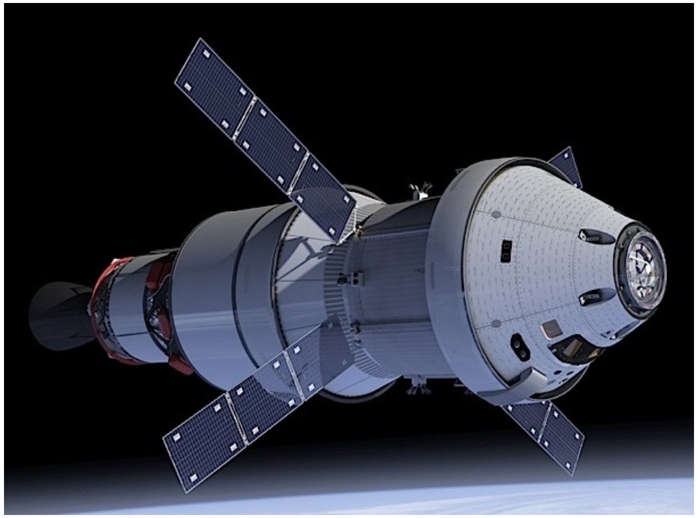
- **Drying?**
- **Compaction?**
- **Destruction?**

Figure 6. Top: Photograph of a sample of undried (50 %, moisture) fecal simulant (left) and a torrefied sample (right), heated to a maximum temperature of ~ 250 °C. Bottom: Photograph of a sample of fresh canine feces (left) and a torrefied sample (right). The torrefied sample was heated to a maximum temperature of ~250 °C and gently crushed.

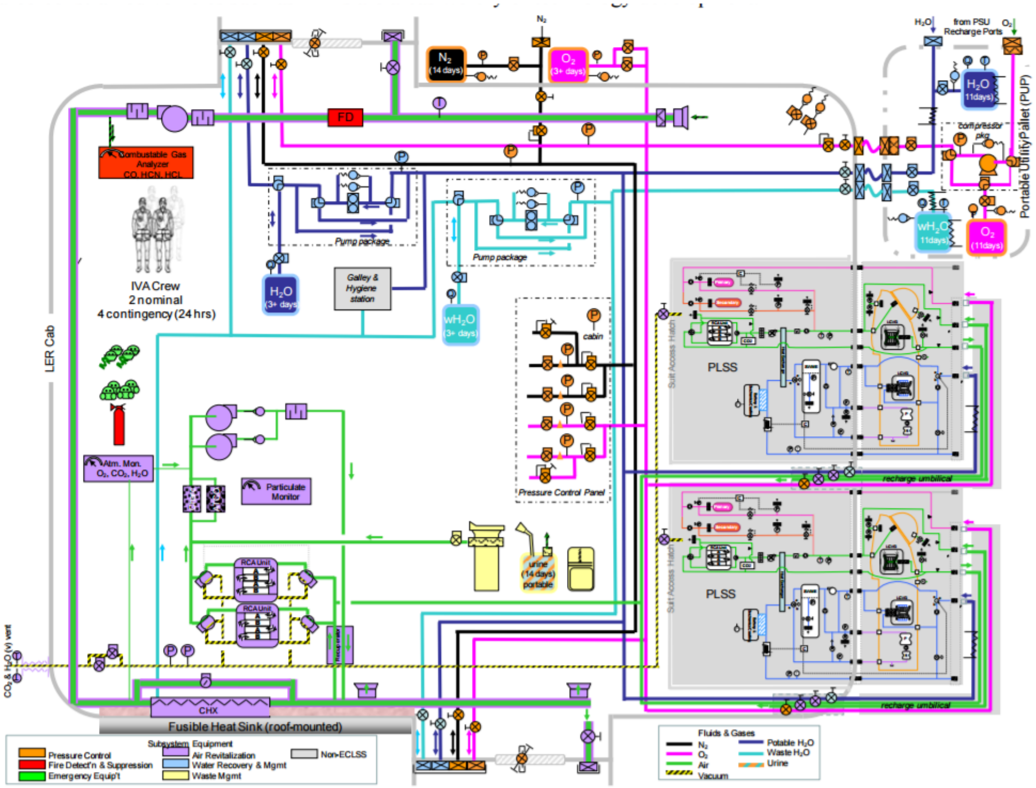
Life Support in Short Duration Vehicles

Orion Suit Loop: Shared life support in cabin air, or spacesuits to survive 6-day emergency return home if the vehicle cabin loses pressure



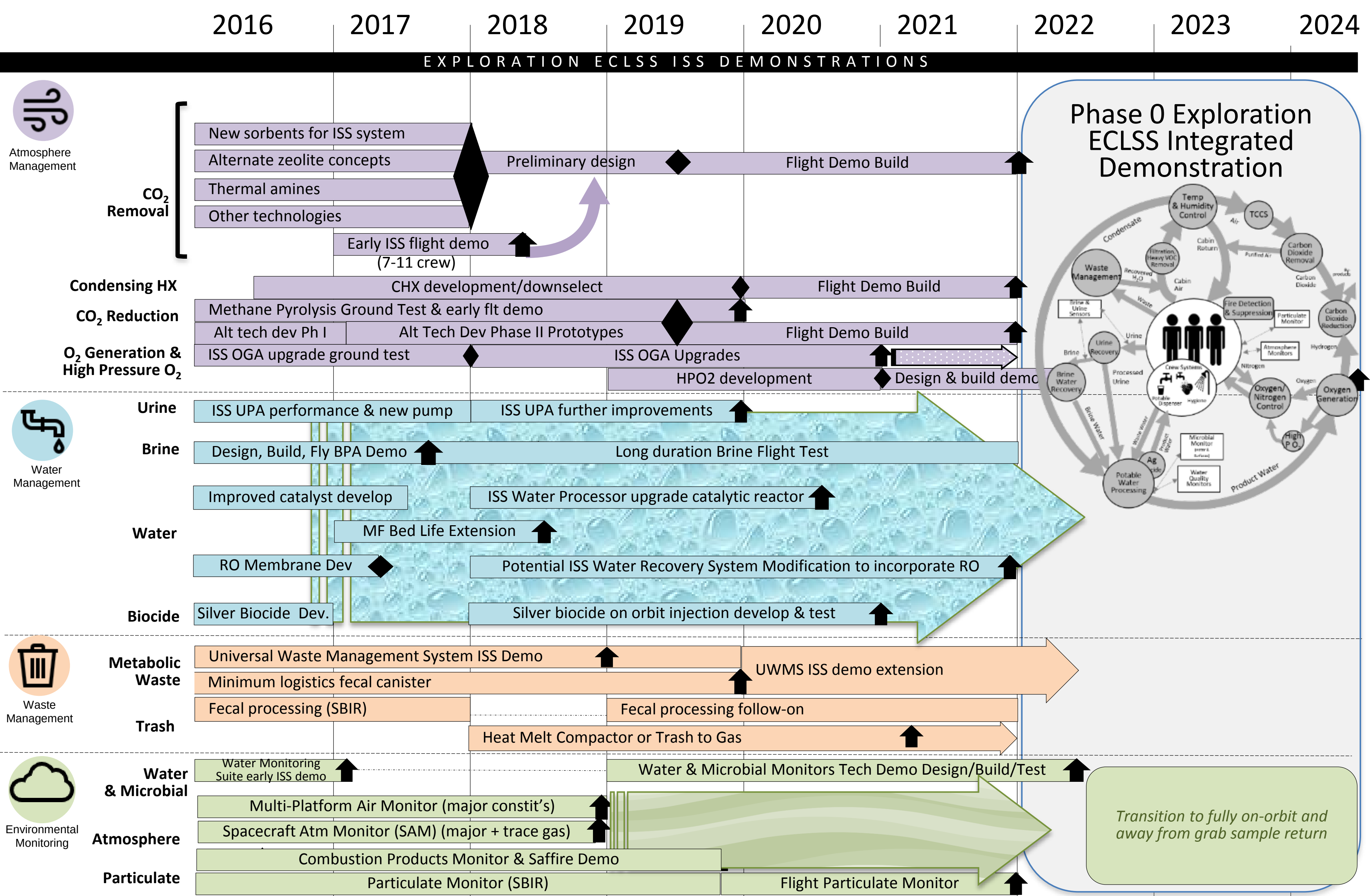


Pressurized Rovers

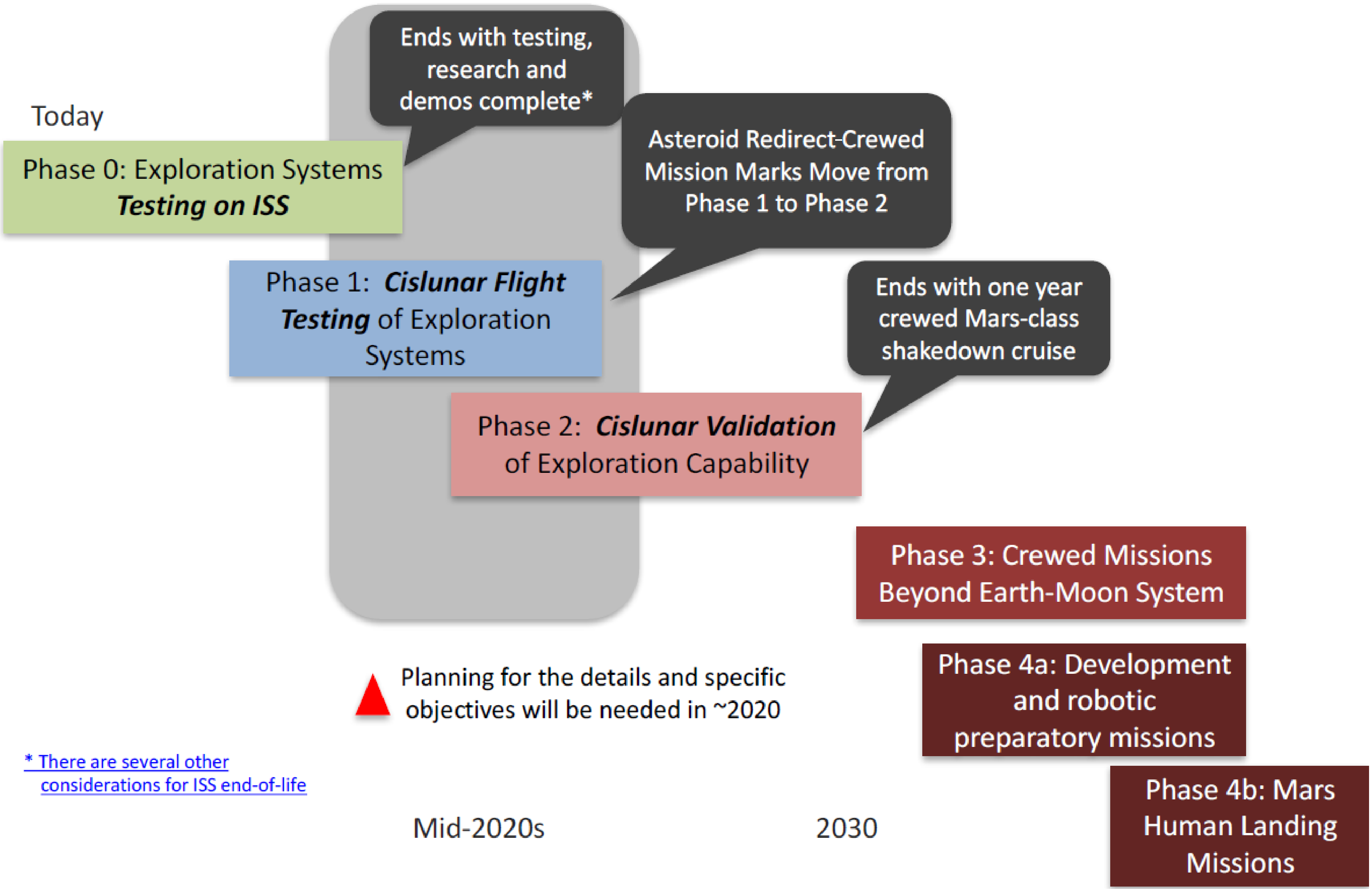


- **Even small,**

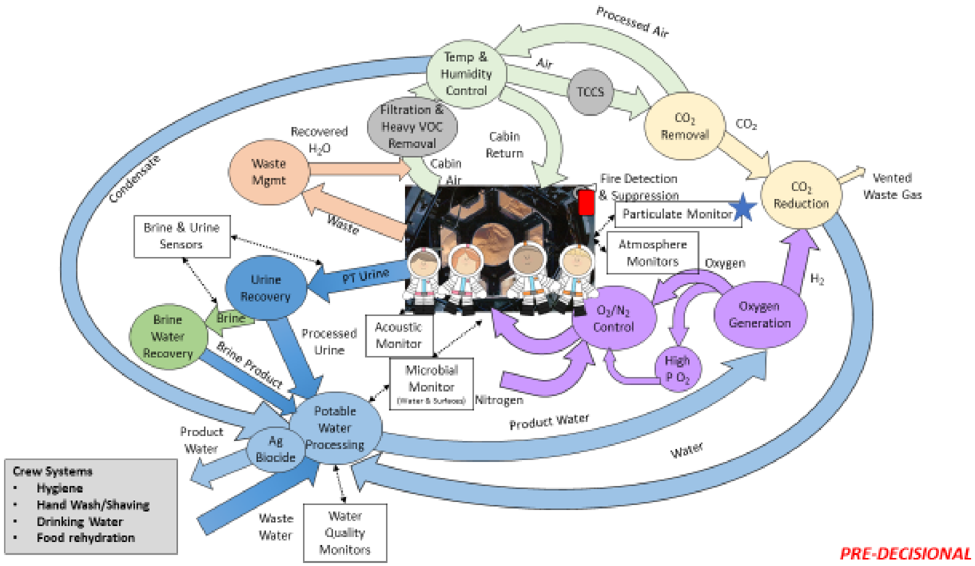
When Will We Be Ready?



Human Space Exploration Phases From ISS to the Surface of Mars
as of November 2016



Life Support & Biological Systems



Earth has Buffers

Earth = 510 km^2 surface area, 2m tall

1 x 1015 m^3 shared by 7.5 Billion People

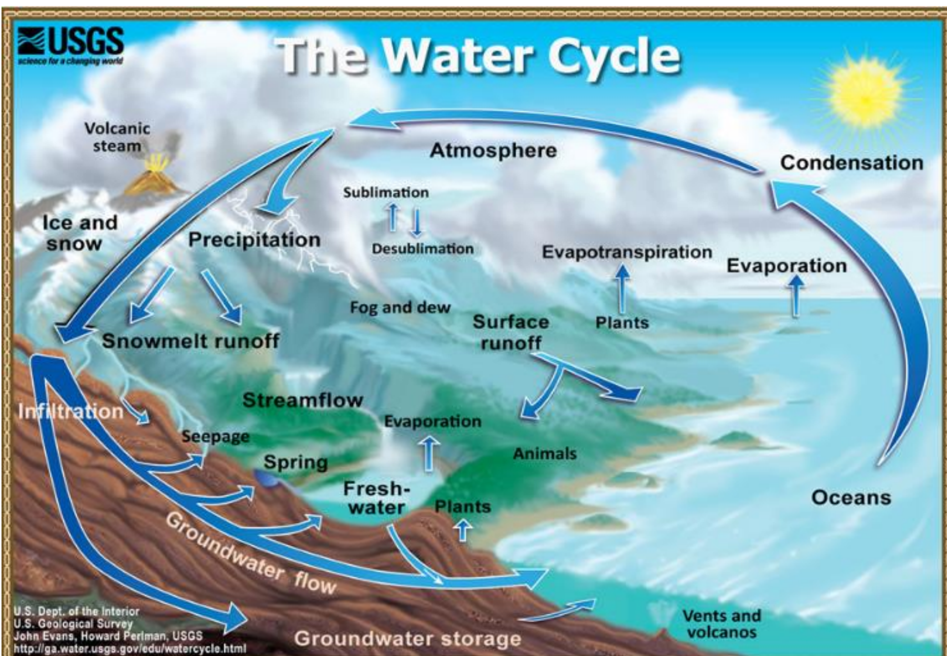
→ 136,000 m^3 per person on Earth

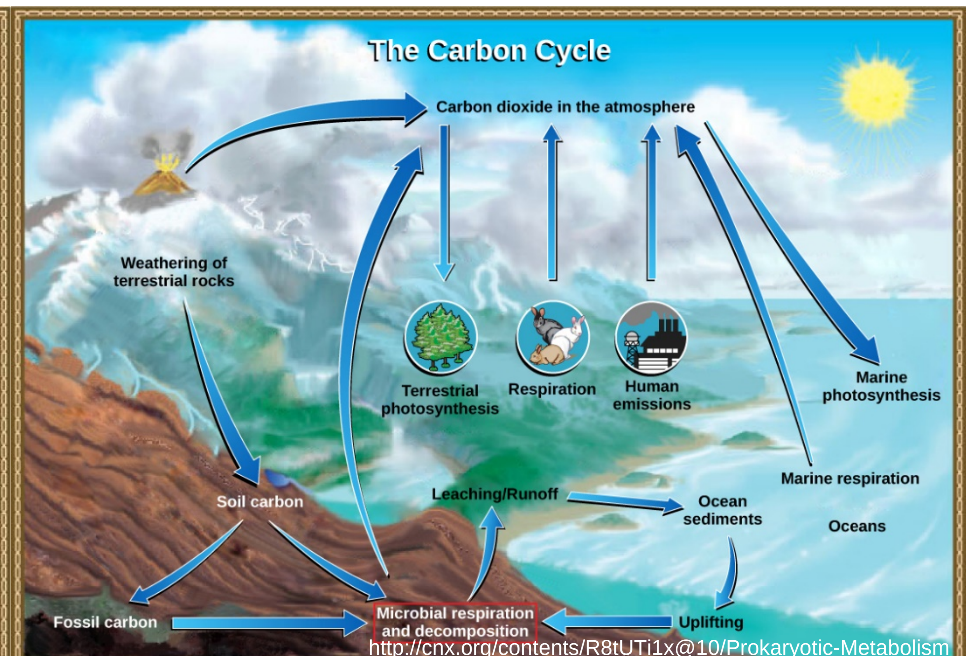
(Not including ocean depths or atmosphere thickness)

Future spacecraft volume ~25 m^3/person

Changes are felt very fast!

Processing equipment must be small!





Biological Water Processor

How do we take advantage of biological processes in microgravity?

Biological Water Processor

How do we take advantage of biological processes in microgravity?

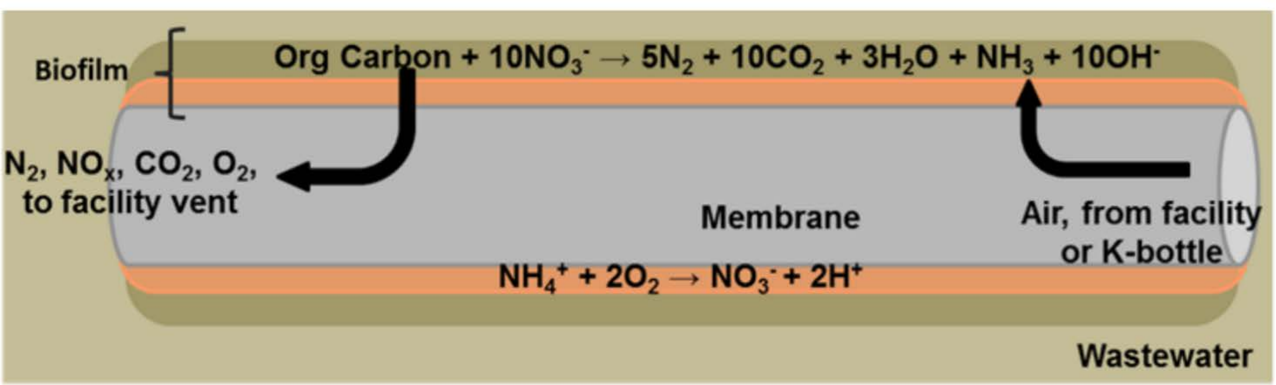
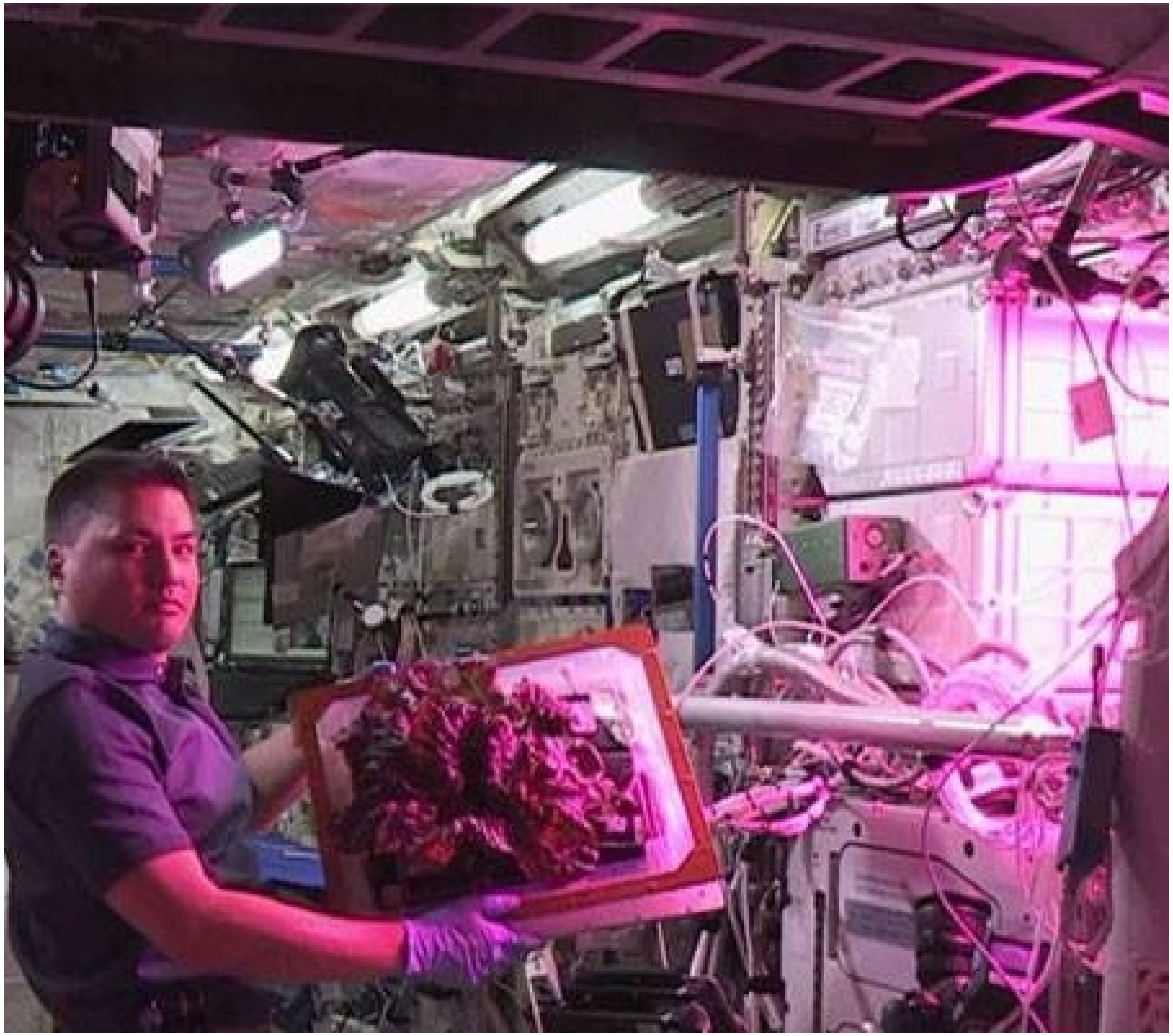
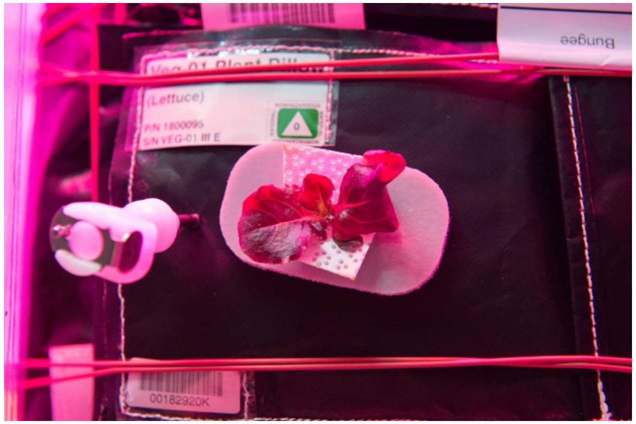
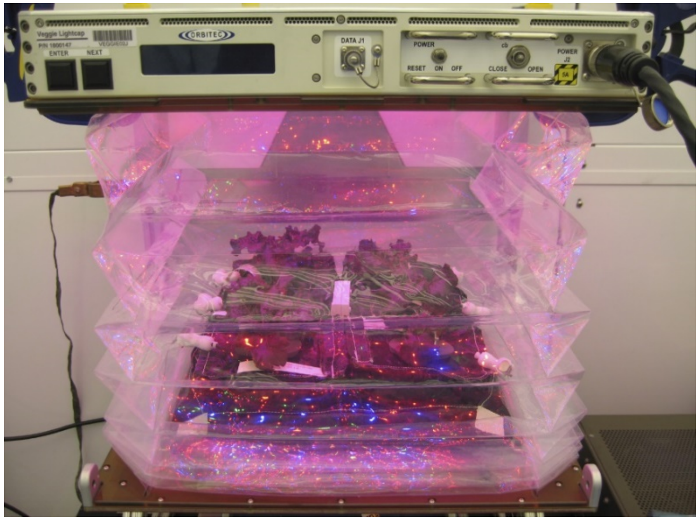


Figure 2. Biological reactions occurring at the surface of the membrane and in the biofilm

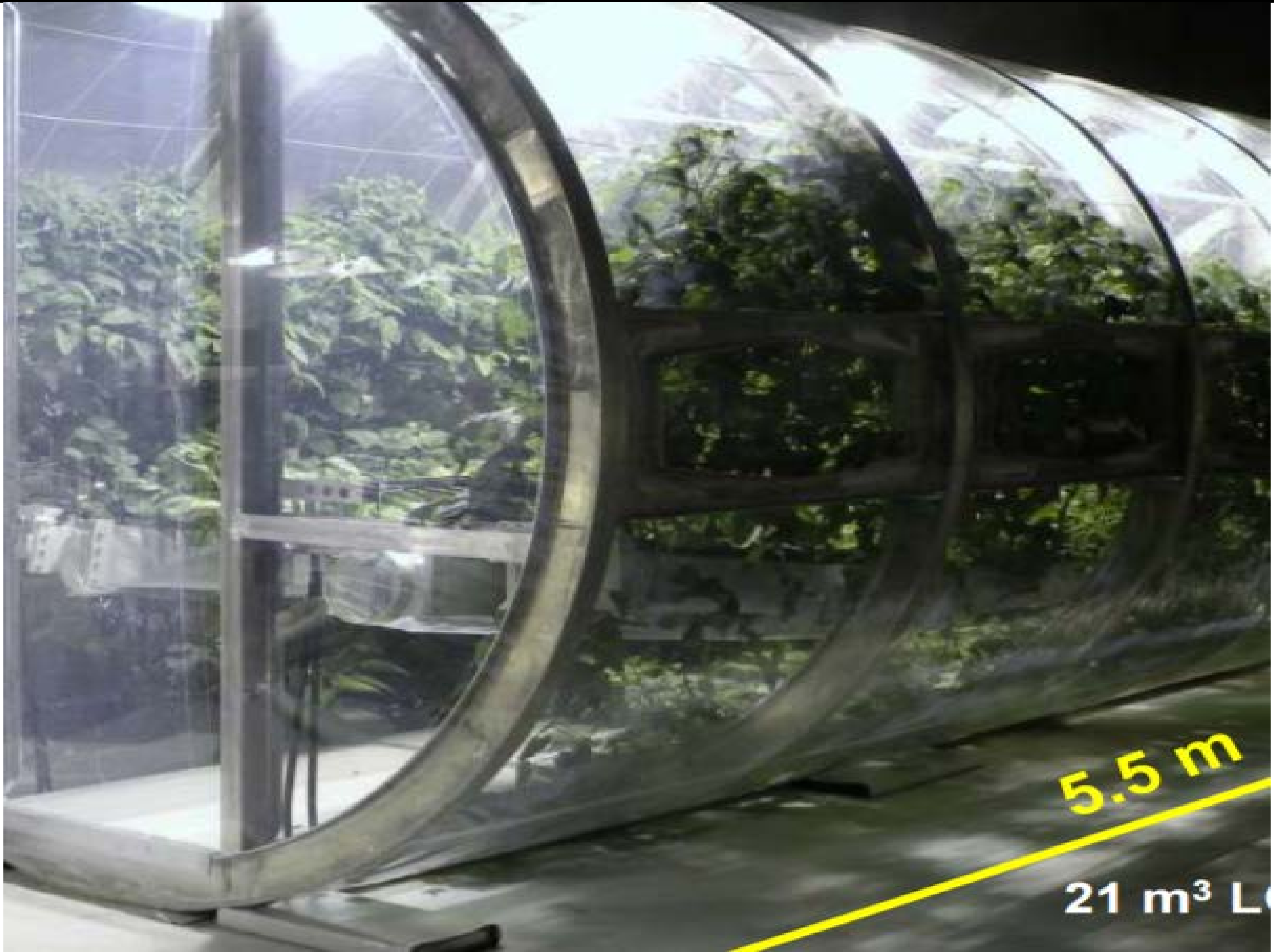
VEGGIE







University of Arizona Lunar Greenhouse



University of Arizona Lunar Greenhouse

International Experiments

DLR LUFTFAHRT RAUMFAHRT VERKEHR ENERGIE SICHERHEIT RAUMFAHRTM

Start Nachrichten Multimedia Kommunikation & Presse

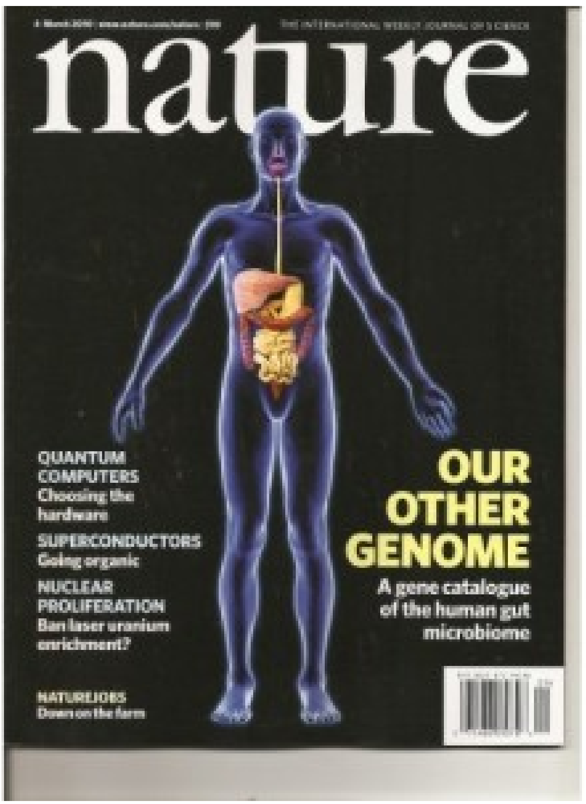
Home › DLR › Standorte › **Bremen**

Eu:CROPIS: Tomatenzucht im Weltall

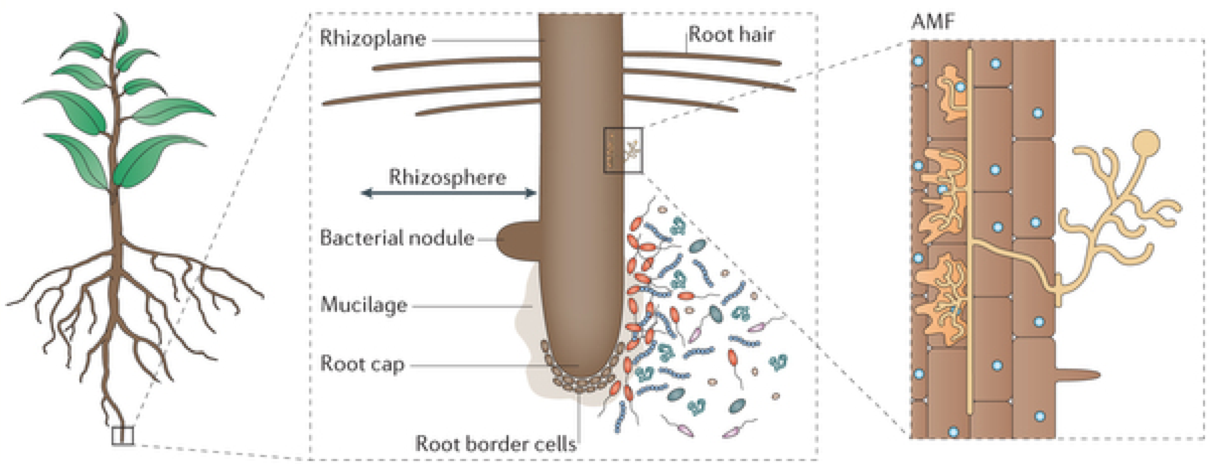
Donnerstag, 24. April 2014

New Technology, New Information, New Questions

THE NATIONAL MICROBIOME INITIATIVE



Oxford Nanopore MinION Sequencer



Nature Reviews | Microbiology

One Step at a Time!

Questions?