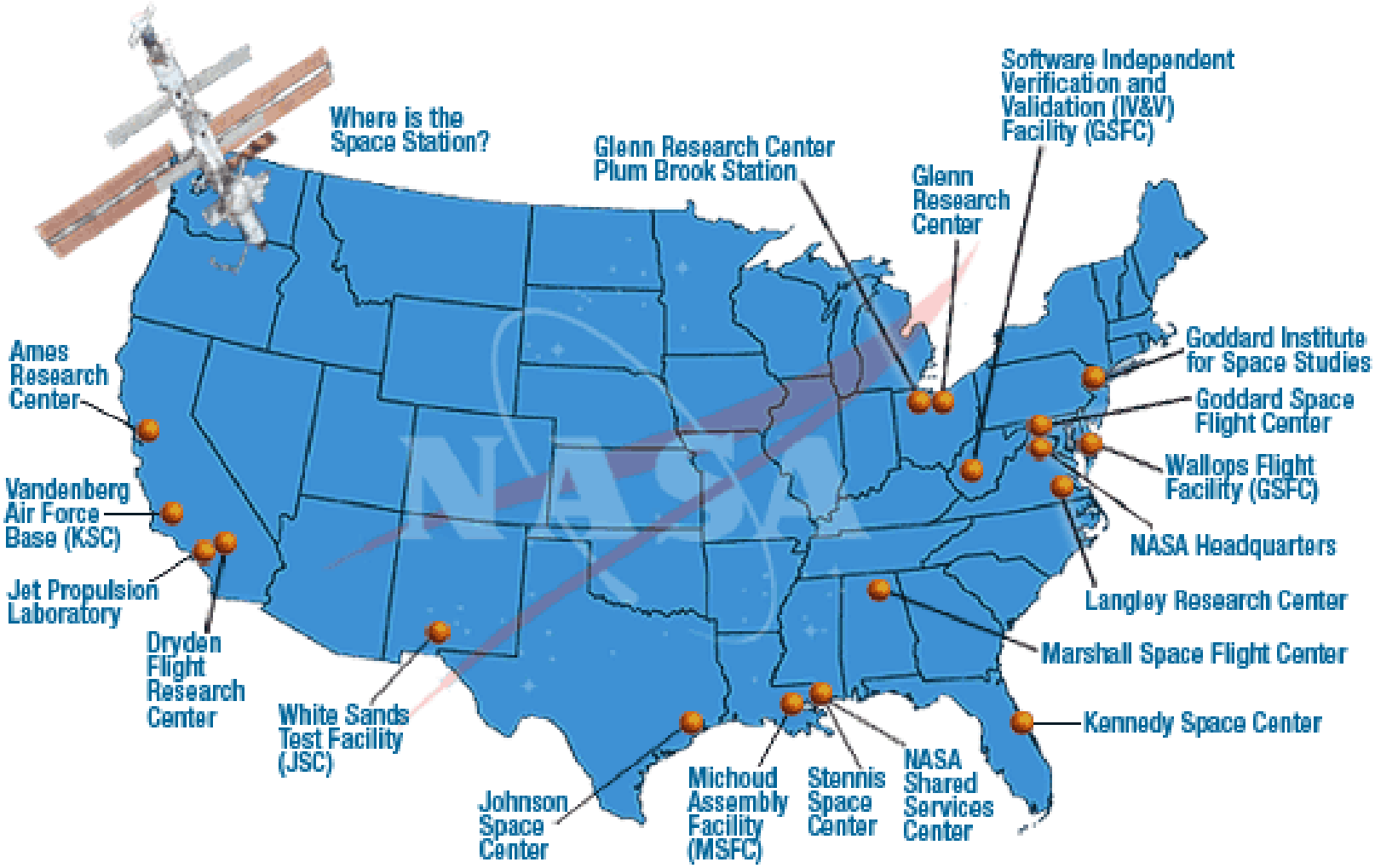
Overview of NASA's Environmental Control and Life Support Systems (ECLSS)

NASA/ Monsi Roman
Project Manager
Marshall Space Flight Center

NASA Centers

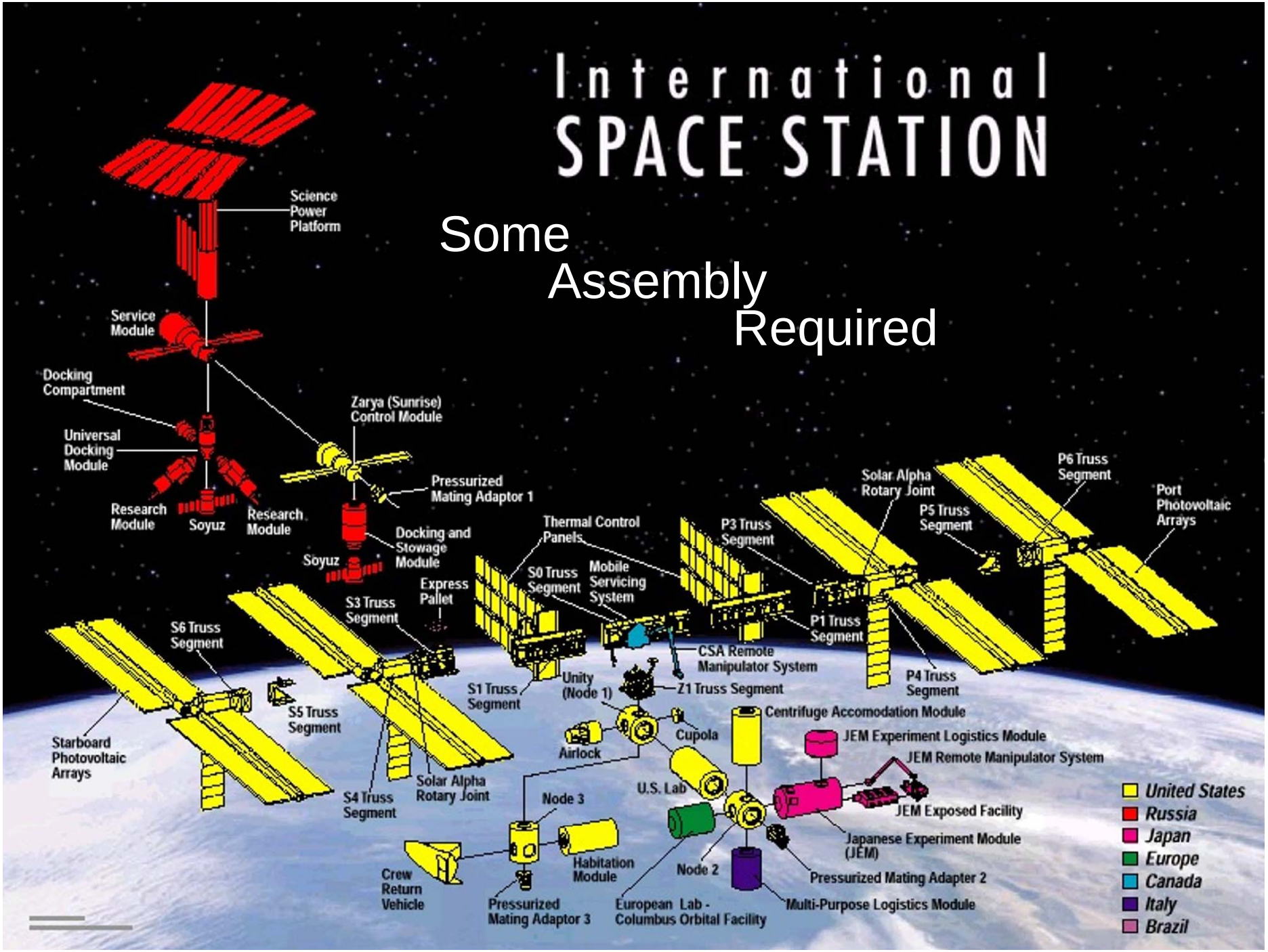


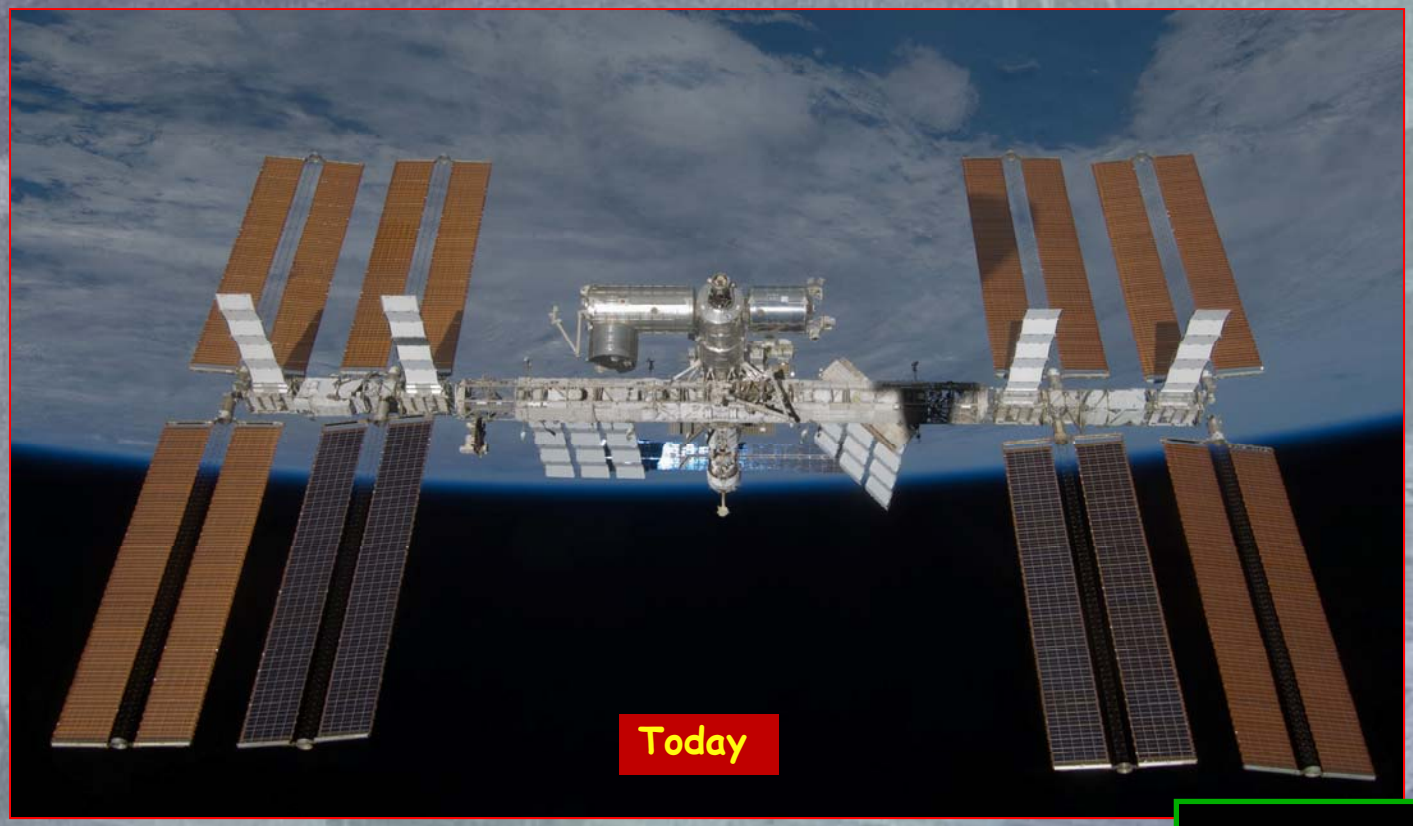
Marshall Space Flight Center

My Education

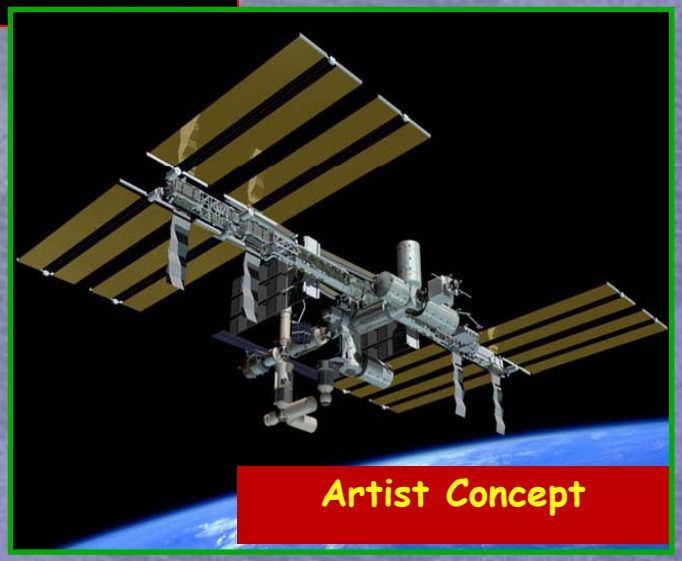
UAH
The University of Alabama in Huntsville

College of Science


International
SPACE STATION
Some
Assembly
Required
Science Power Platform
Service Module
Docking Compartment
Universal Docking Module
Research Module
Soyuz
Research Module
Zarya (Sunrise) Control Module
Pressurized Mating Adaptor 1
Soyuz
Docking and Stowage Module
Express Pallet
S3 Truss Segment
S6 Truss Segment
S5 Truss Segment
Starboard Photovoltaic Arrays
S4 Truss Segment
Solar Alpha Rotary Joint
Thermal Control Panels
S0 Truss Segment
Mobile Servicing System
P3 Truss Segment
Solar Alpha Rotary Joint
P5 Truss Segment
P6 Truss Segment
Port Photovoltaic Arrays
P1 Truss Segment
P4 Truss Segment
CSA Remote Manipulator System
Z1 Truss Segment
S1 Truss Segment
Unity (Node 1)
Centrifuge Accomodation Module
Cupola
JEM Experiment Logistics Module
JEM Remote Manipulator System
Airlock
U.S. Lab
JEM Exposed Facility
Node 3
Japanese Experiment Module (JEM)
Habitation Module
Node 2
Pressurized Mating Adapter 2
Crew Return Vehicle
Pressurized Mating Adaptor 3
European Lab - Columbus Orbital Facility
Multi-Purpose Logistics Module
United States
Russia
Japan
Europe
Canada
Italy
Brazil

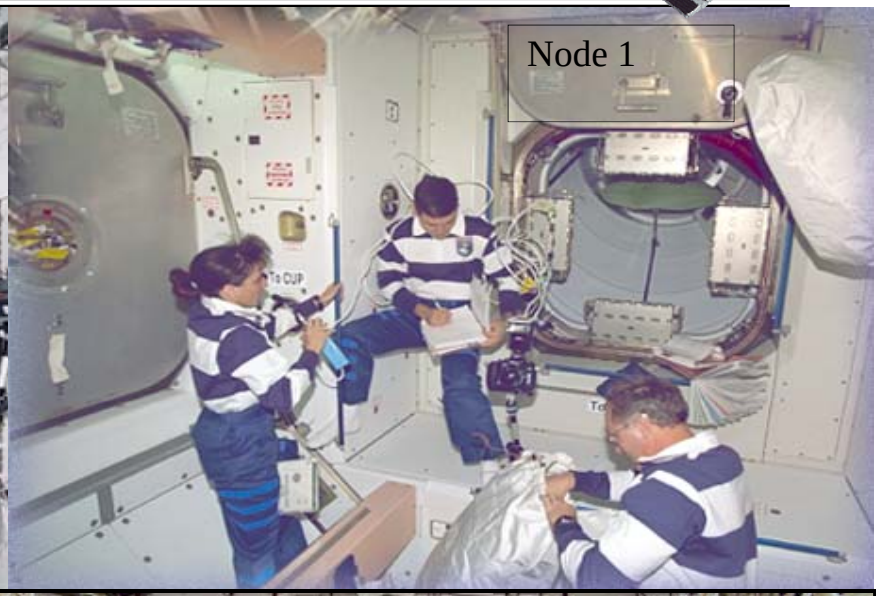


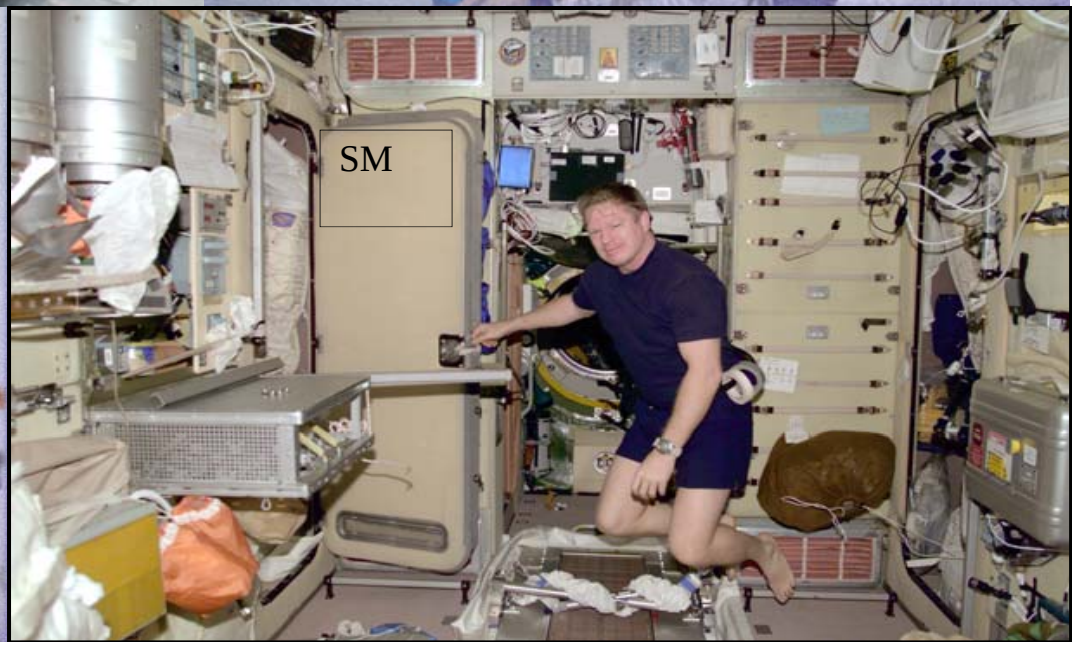
Today



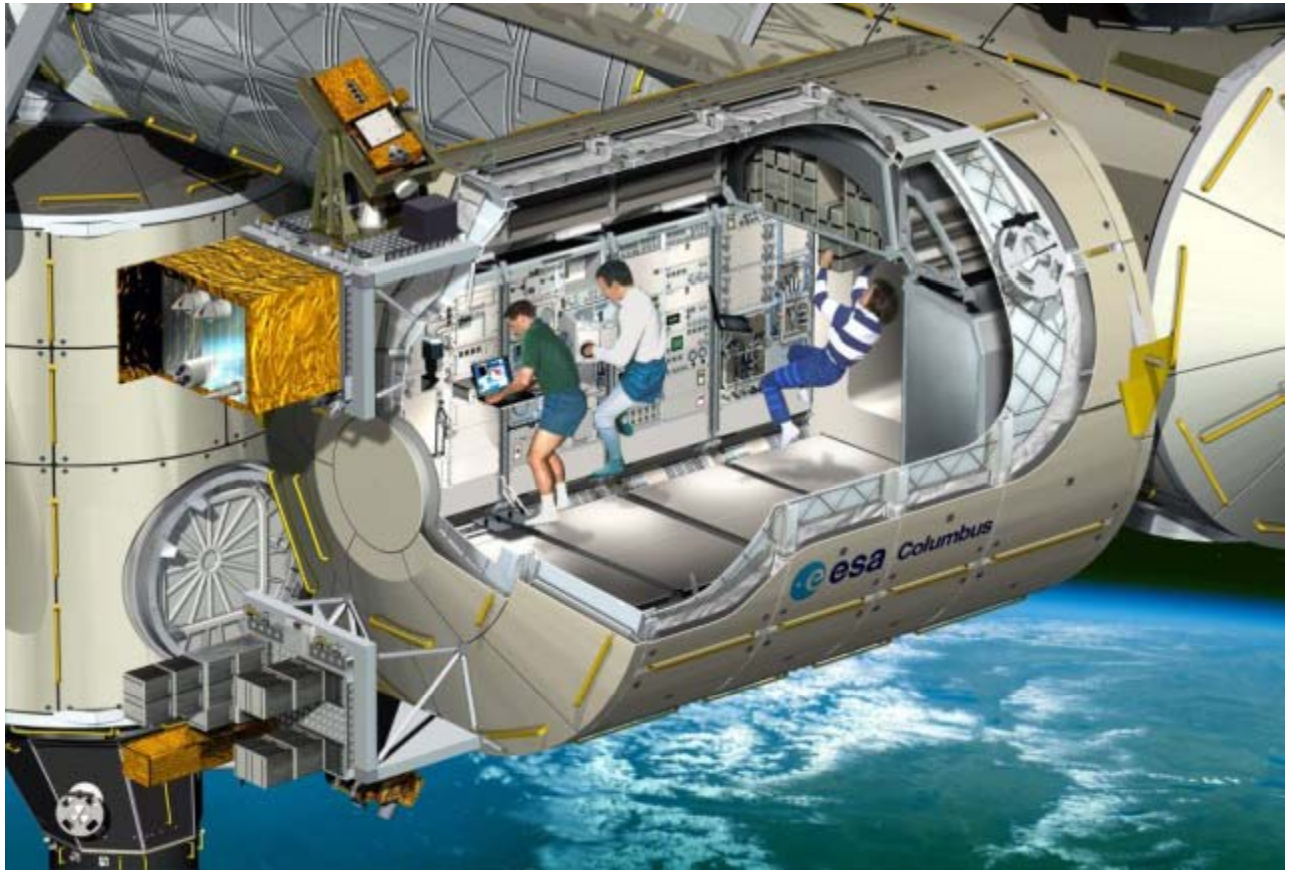
Artist Concept

A Look Inside ISS

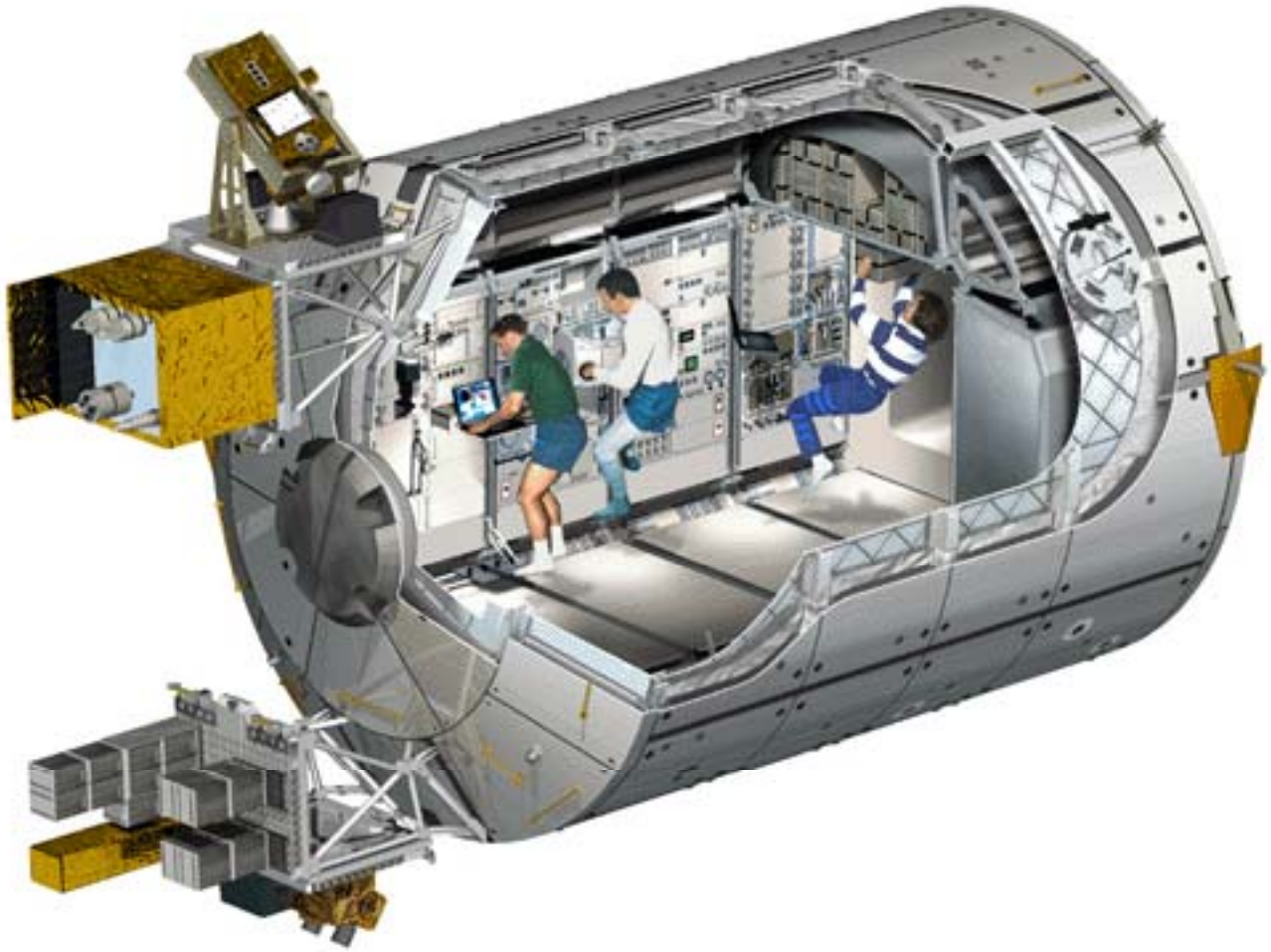




Columbus Module



Kibo Module



Environmental Control and Life Support Systems

Control Atmosphere Pressure

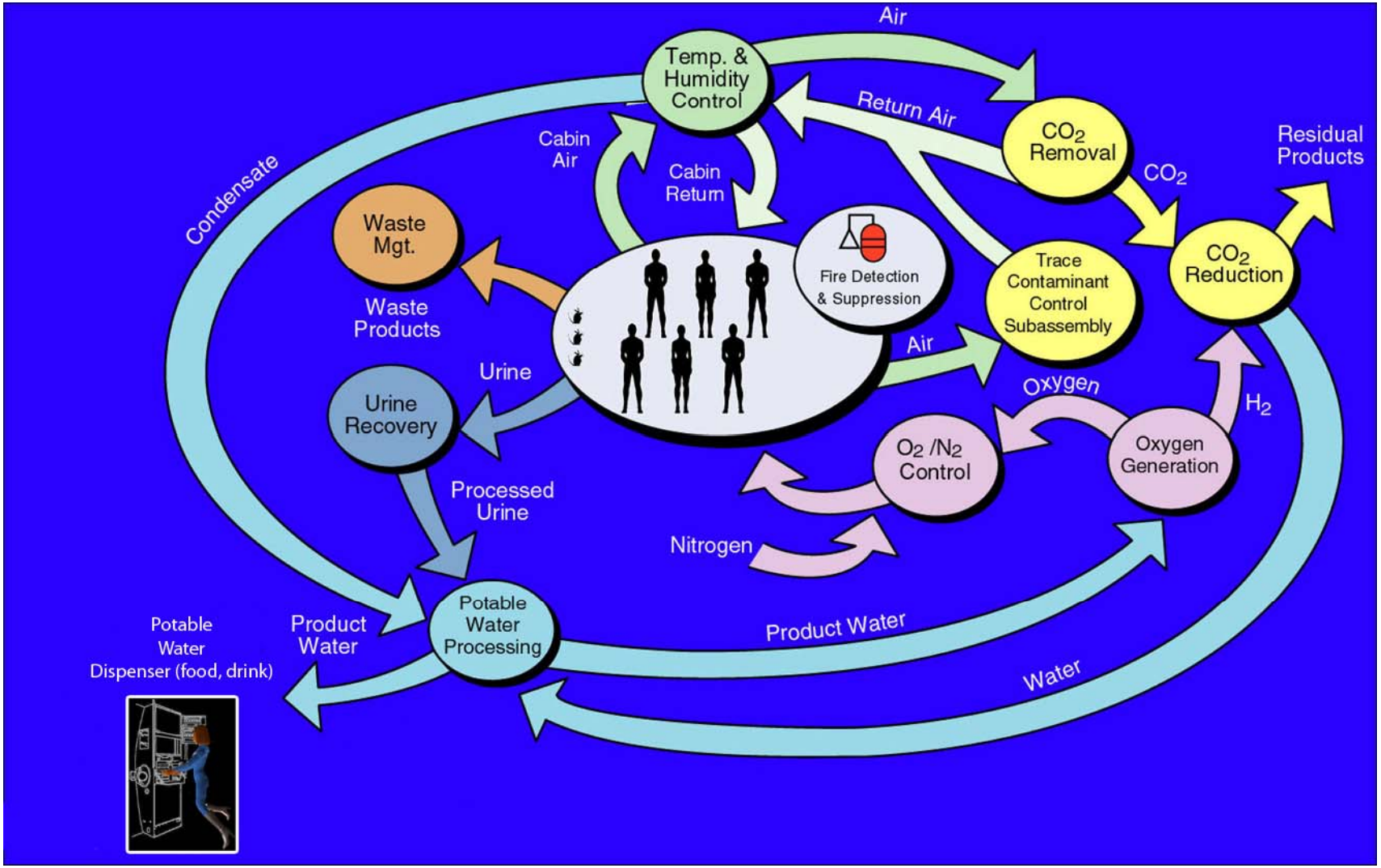
Condition Atmosphere

Respond to Emergency Conditions

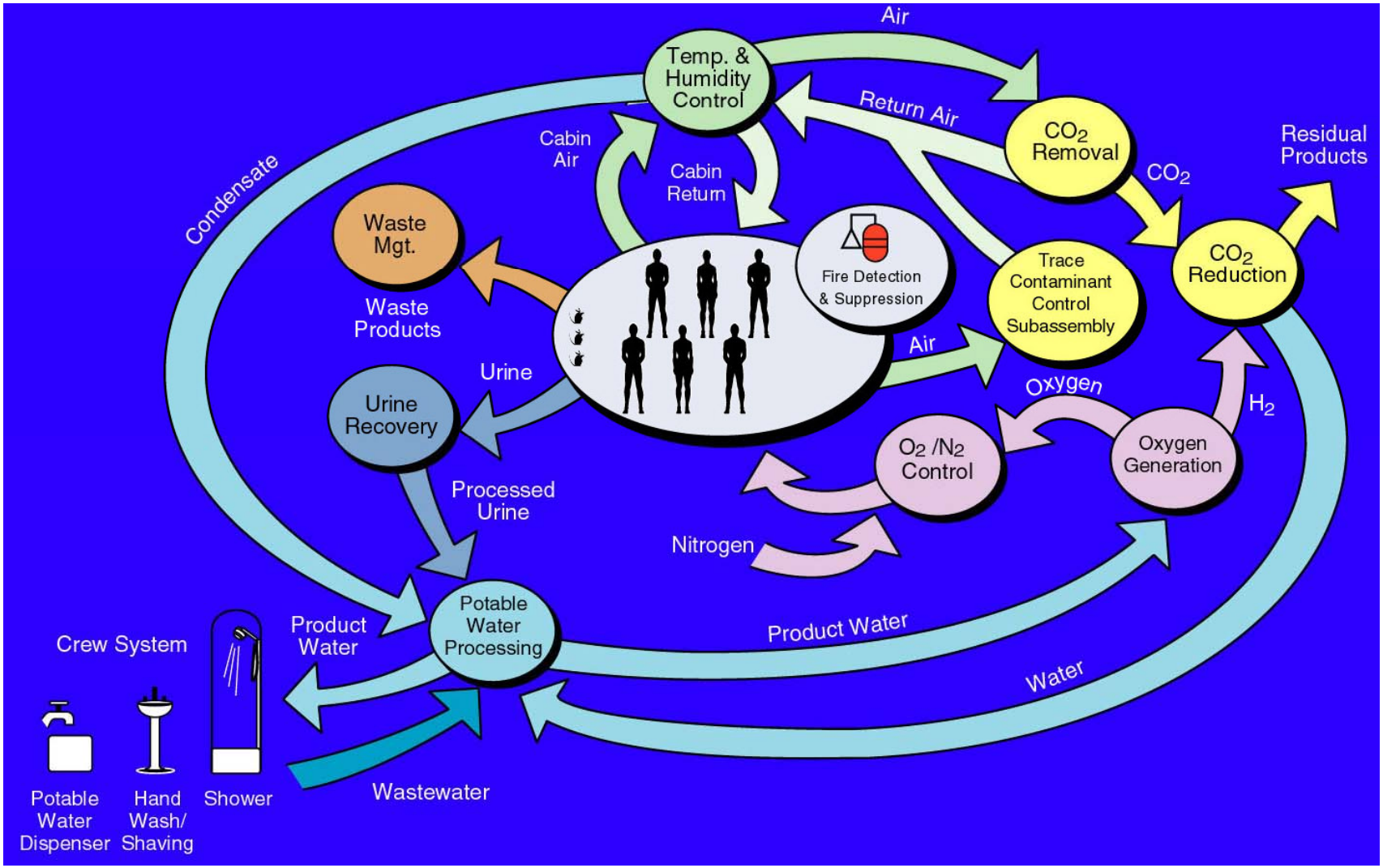
Control Internal CO2 & Contaminants

Provide Water

Where We Will be in a Few Months



Where We Want to Be



THE ECLS CHALLENGE

Needs

Oxygen = 0.84 kg (1.84lb)

Food Solids = 0.62 kg (1.36lb)

Water in Food = 1.15 kg (2.54lb)

Food Prep Water = 0.76 kg (1.67lb)

Drink = 1.62 kg (3.56lb)

Metabolized Water = 0.35 kg (0.76lb)

Hand/Face Wash Water = 4.09 kg (9.00lb)

Shower Water = 2.73 kg (6.00lb)

Urinal Flush = 0.49 kg (1.09lb)

Clothes Wash Water = 12.50 kg (27.50lb)

Dish Wash Water = 5.45 kg (12.00lb)

Total = 30.60 kg (67.32lb)

Effluents

Carbon Dioxide = 1.00 kg (2.20lb)

Respiration & Perspiration Water = 2.28 kg (5.02lb)

Food Preparation, Latent Water = 0.036 kg (0.08lb)

Urine = 1.50 kg (3.31lb)

Urine Flush Water = 0.50 kg (1.09lb)

Feces Water = 0.091 kg (0.20lb)

Sweat Solids = 0.018 kg (0.04lb)

Urine Solids = 0.059 kg (0.13lb)

Feces Solids = 0.032 kg (0.07lb)

Hygiene Water = 12.58 kg (27.68lb)

Clothes Wash Water
Liquid = 11.90 kg (26.17lb)
Latent = 0.60 kg (1.33lb)
Total = 30.60 kg (67.32lb)

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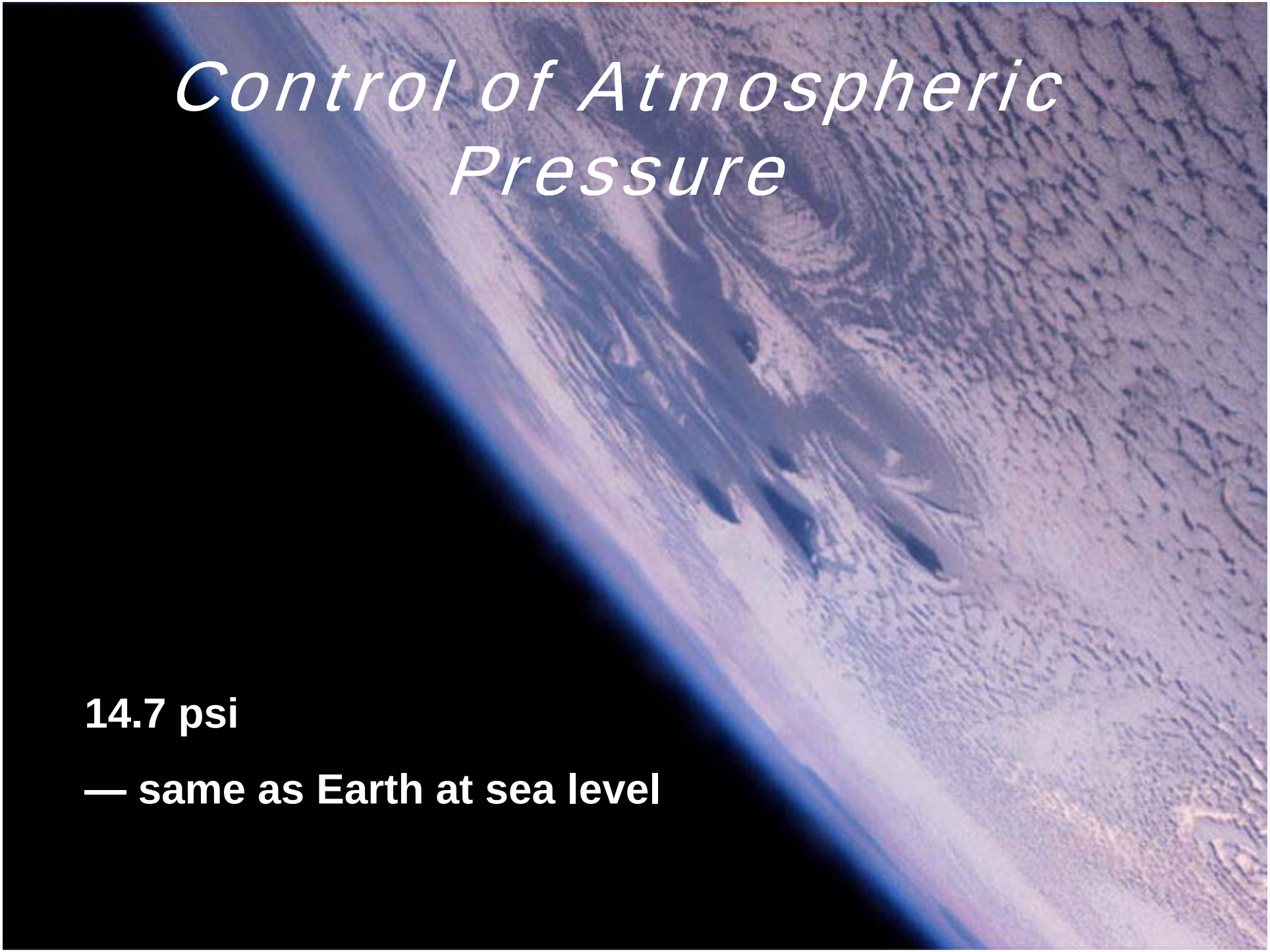


Control of Atmospheric Pressure

14.7 psi

— same as Earth at sea level

Control of Atmospheric Pressure

8 psi- almost half of Earth's

Temperature and Humidity Control

Average Temp: 69.8 to 73.4º F

Dew Point: 48ºF

Environmental Control and Life Support Systems

Control Atmosphere Pressure

Condition Atmosphere

Respond to Emergency Conditions

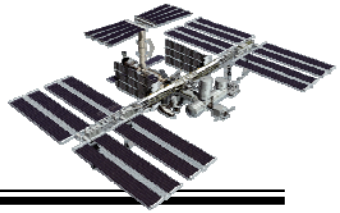
Control Internal CO_2 & Contaminants

Provide Water

Removal of Particulates

Why?

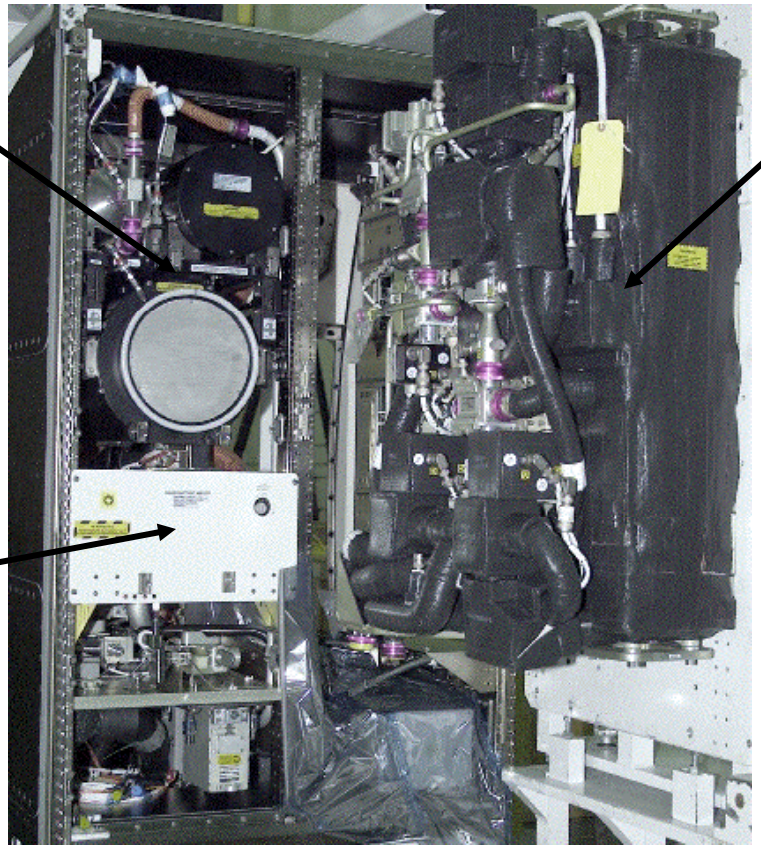
Removal of CO_2 and Trace Contaminants



TRACE CONTAMINANT CONTROL SUBASSEMBLY

CO_2 REMOVAL ASSEMBLY

MAJOR CONSTITUENT ANALYZER



Environmental Control and Life Support Systems

Control Atmosphere Pressure

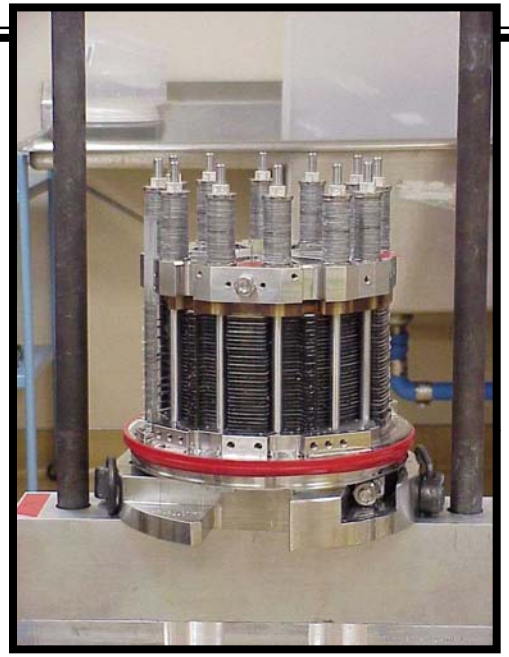
Condition Atmosphere

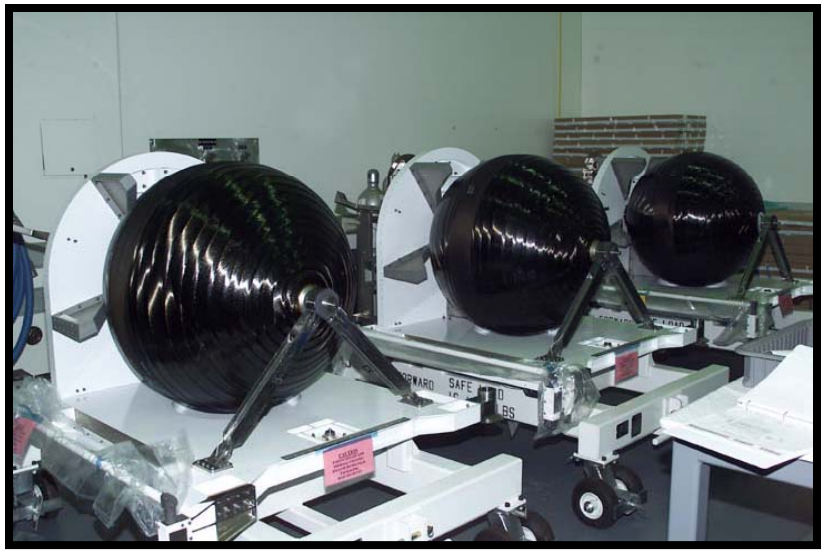
Respond to Emergency Conditions

Control Internal CO_2 & Contaminants

Provide Water

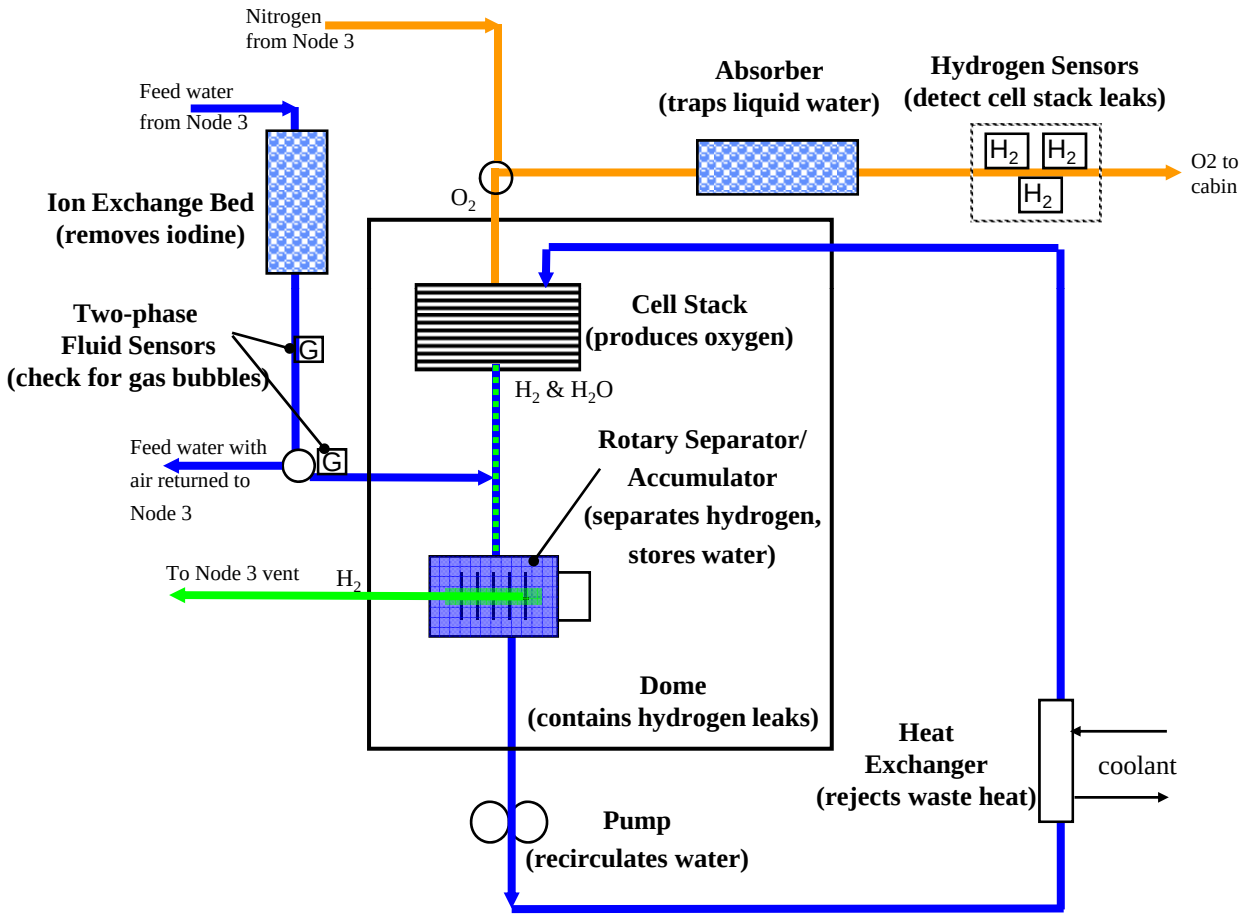
Oxygen





Oxygen Generator Description

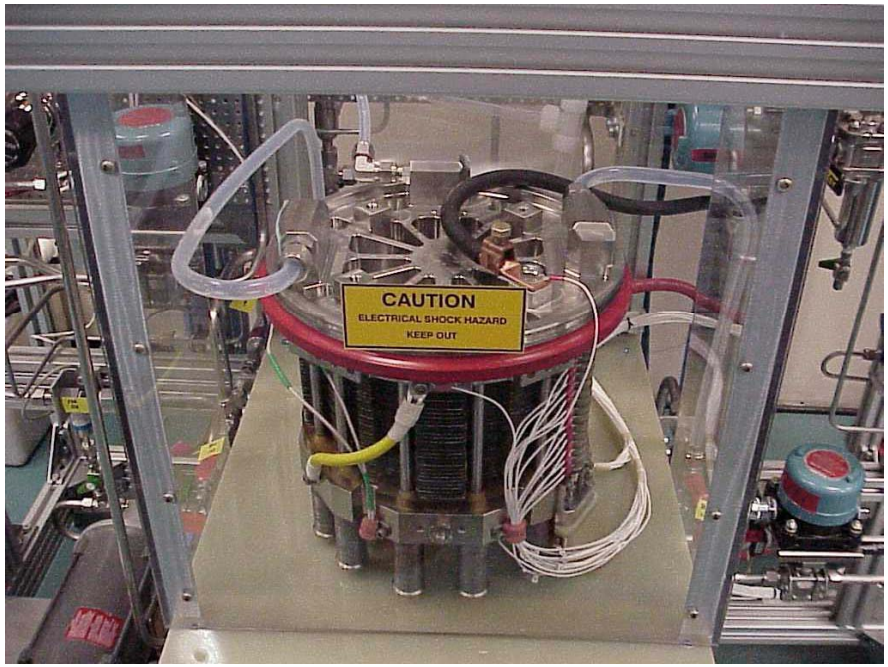
- **Integrated Process**
  - » Oxygen & hydrogen produced in 28-cell stack
  - » O_2 delivered to cabin
  - » H_2 mixed with excess re-circulated water, separated dynamically, and vented overboard (ISS baseline)
  - » Makeup water periodically added and stored within rotary separator
  - » Oxygen lines purged with nitrogen for safety after shutdowns



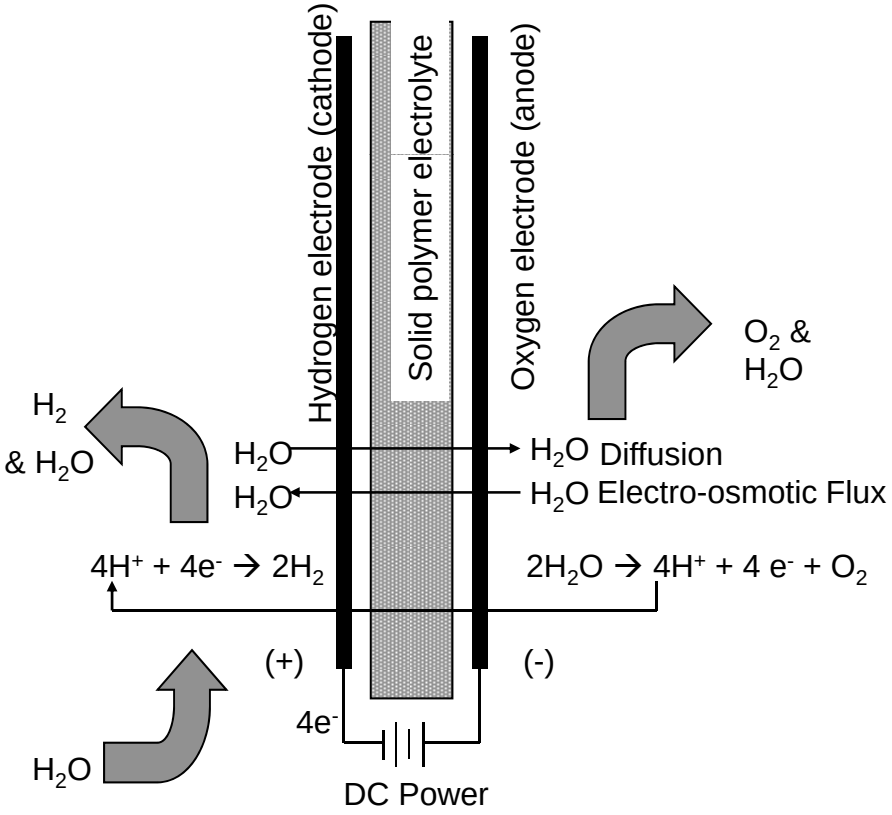
Space Station Oxygen Generator

- **Core Technology: Solid Polymer Electrolysis (cathode feed)**

Cell Stack



Electrolysis Cell Reactions



Environmental Control and Life Support Systems

Control Atmosphere Pressure

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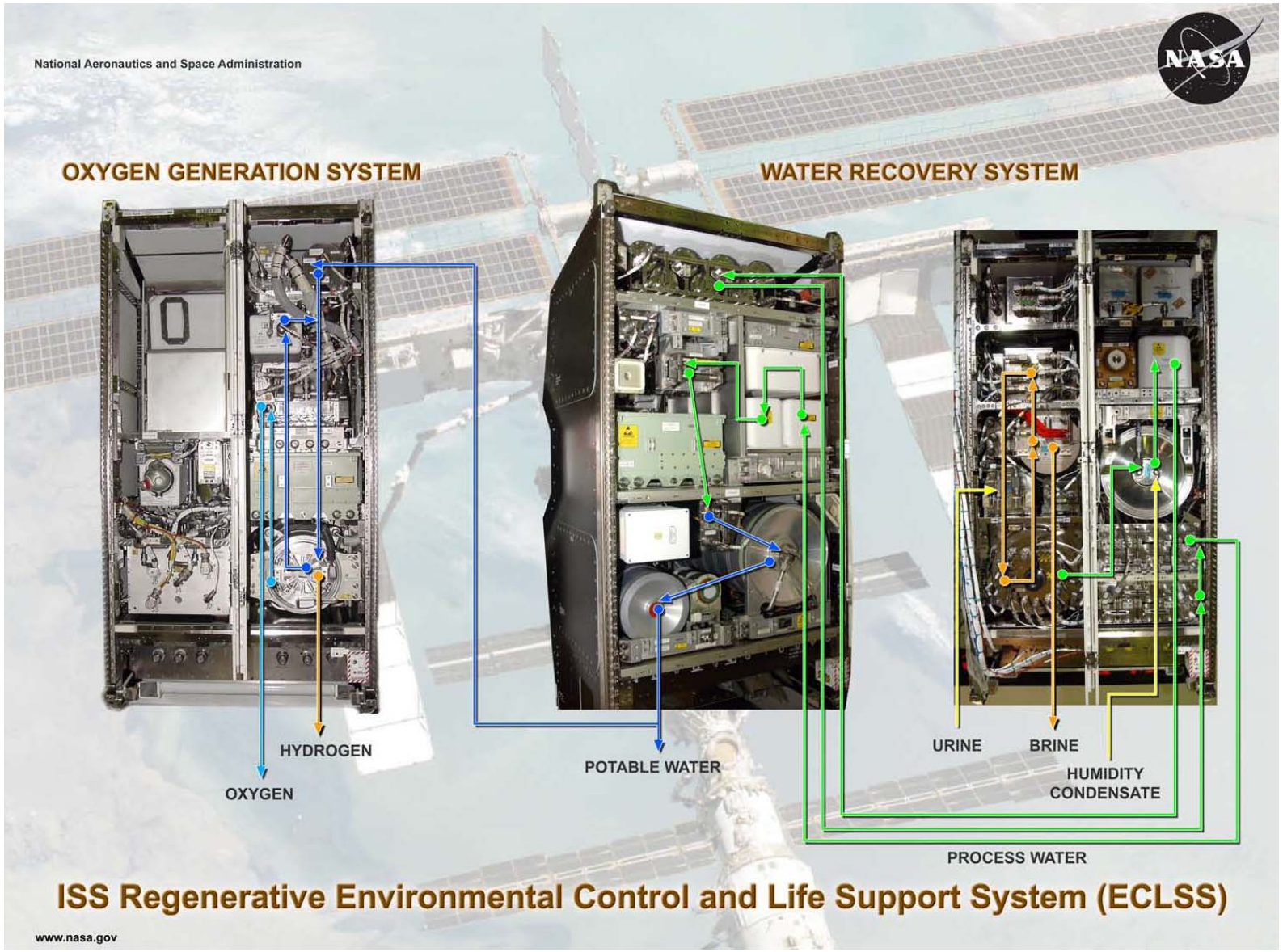
Respond to Emergency Conditions

Control Internal CO_2 & Contaminants

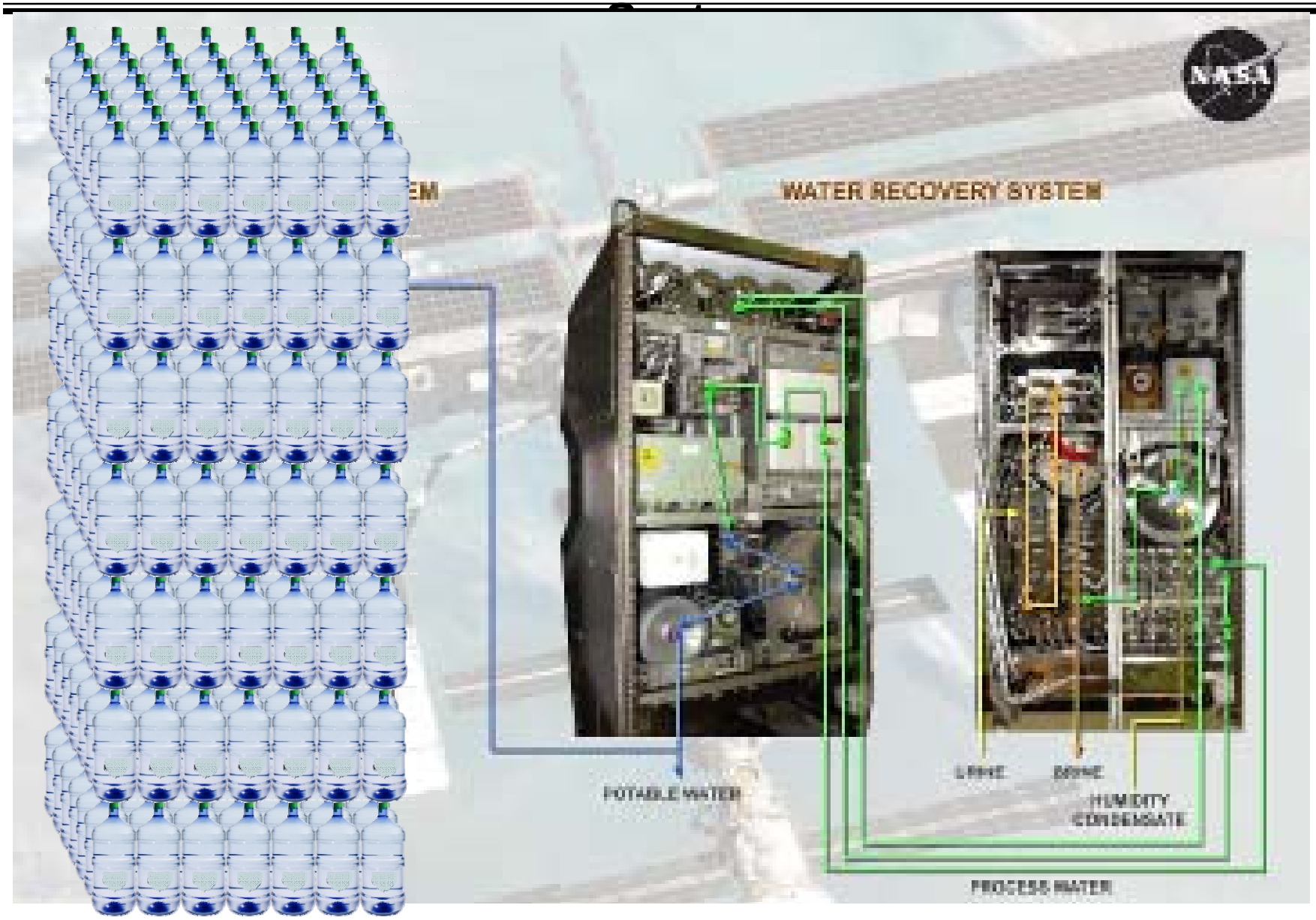
Provide Water

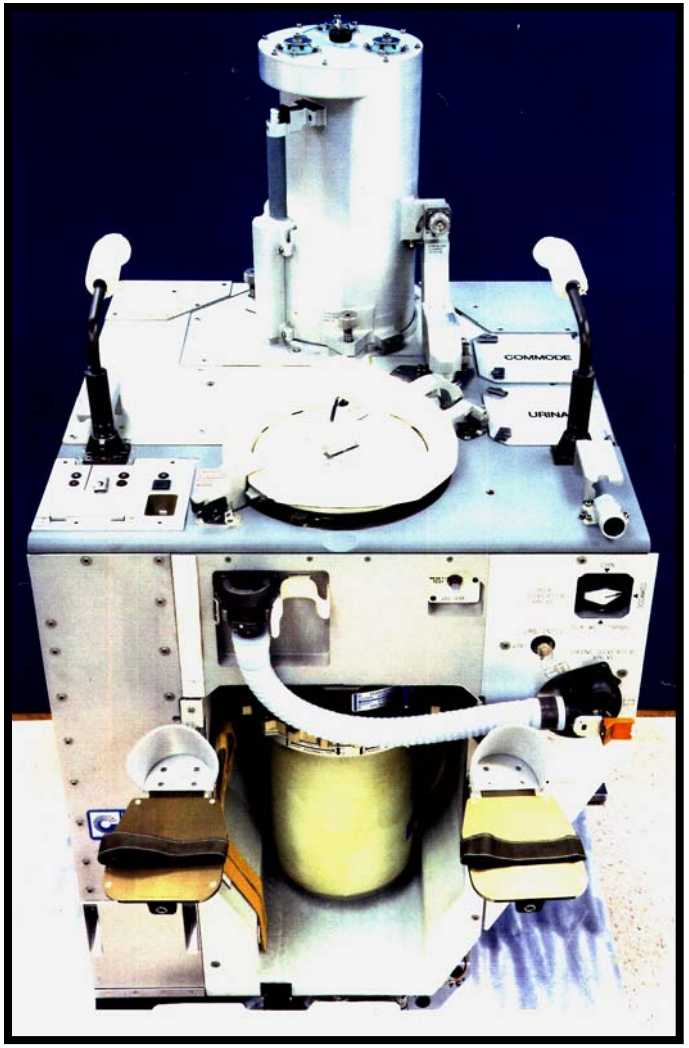

MAGGOT
ON
BOARD

Space Station Regenerative ECLSS



Annual Water Produced by ISS Water Recovery



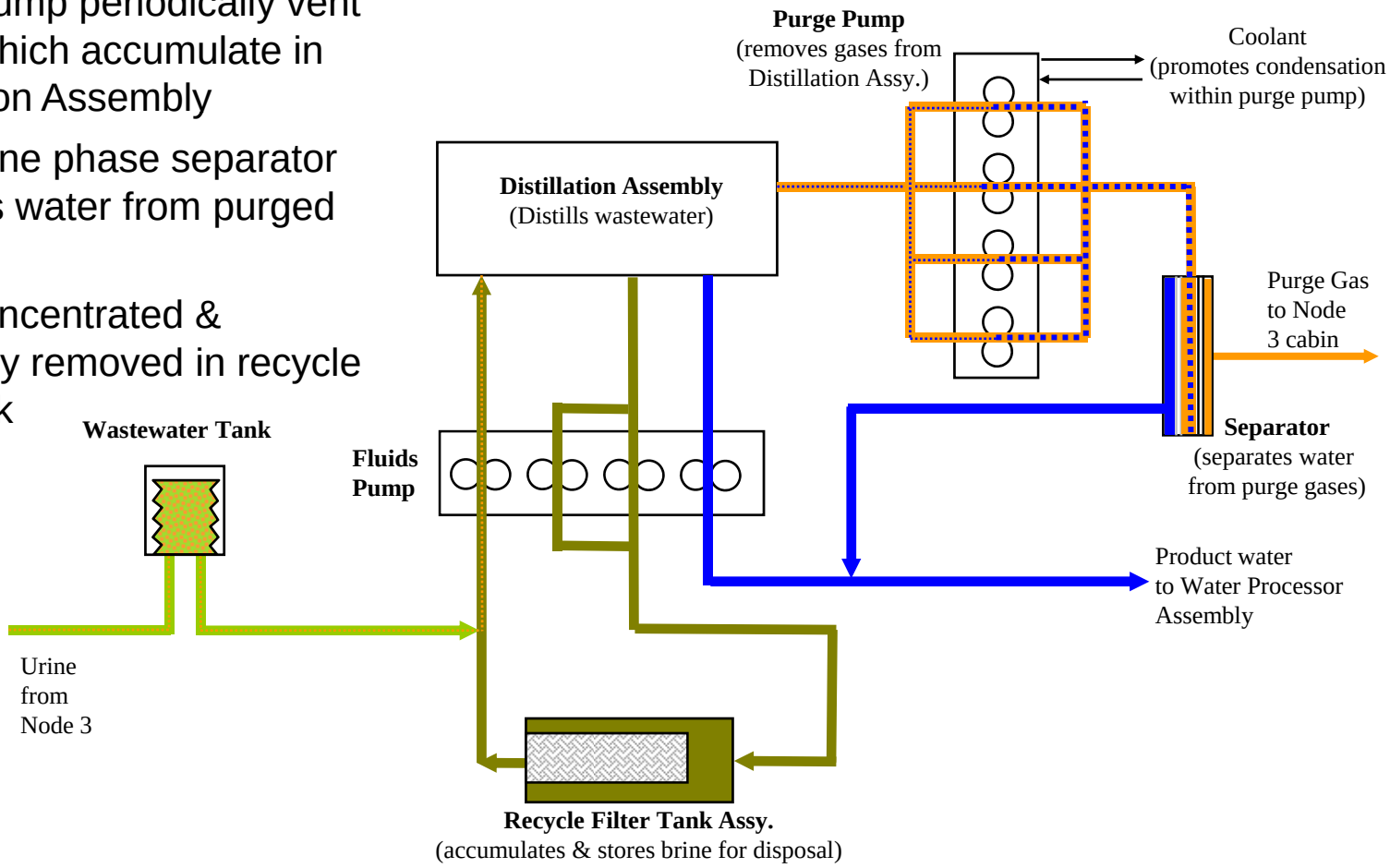

COMMODE
URINA

Urine Processing Challenges

- **Microgravity – separating steam from liquid**
- **Keeping the hardware from gunking up or corroding**
  - » It has to last for 10 years
- **Making sure urine doesn't escape**
  - » Health/safety hazard
  - » Triple seals
- **What to do with the leftovers**

Urine Processor Description

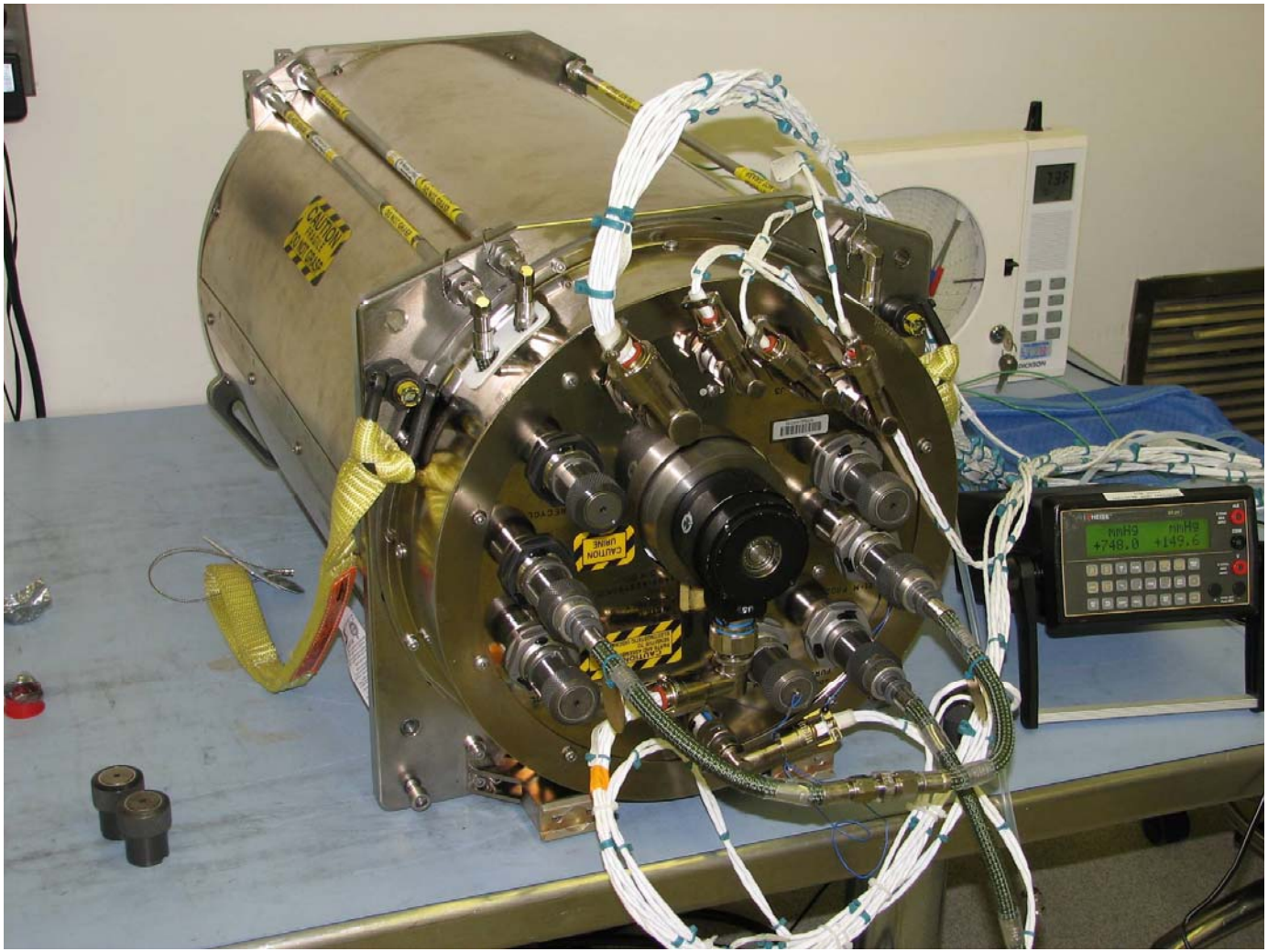
- **Integrated Process**
  - » Pretreated urine temporarily stored prior to processing
  - » Fluids pump circulates urine brine and removes product water through DA
  - » Purge pump periodically vent gases which accumulate in Distillation Assembly
  - » Membrane phase separator recovers water from purged gases
  - » Brine concentrated & ultimately removed in recycle filter tank



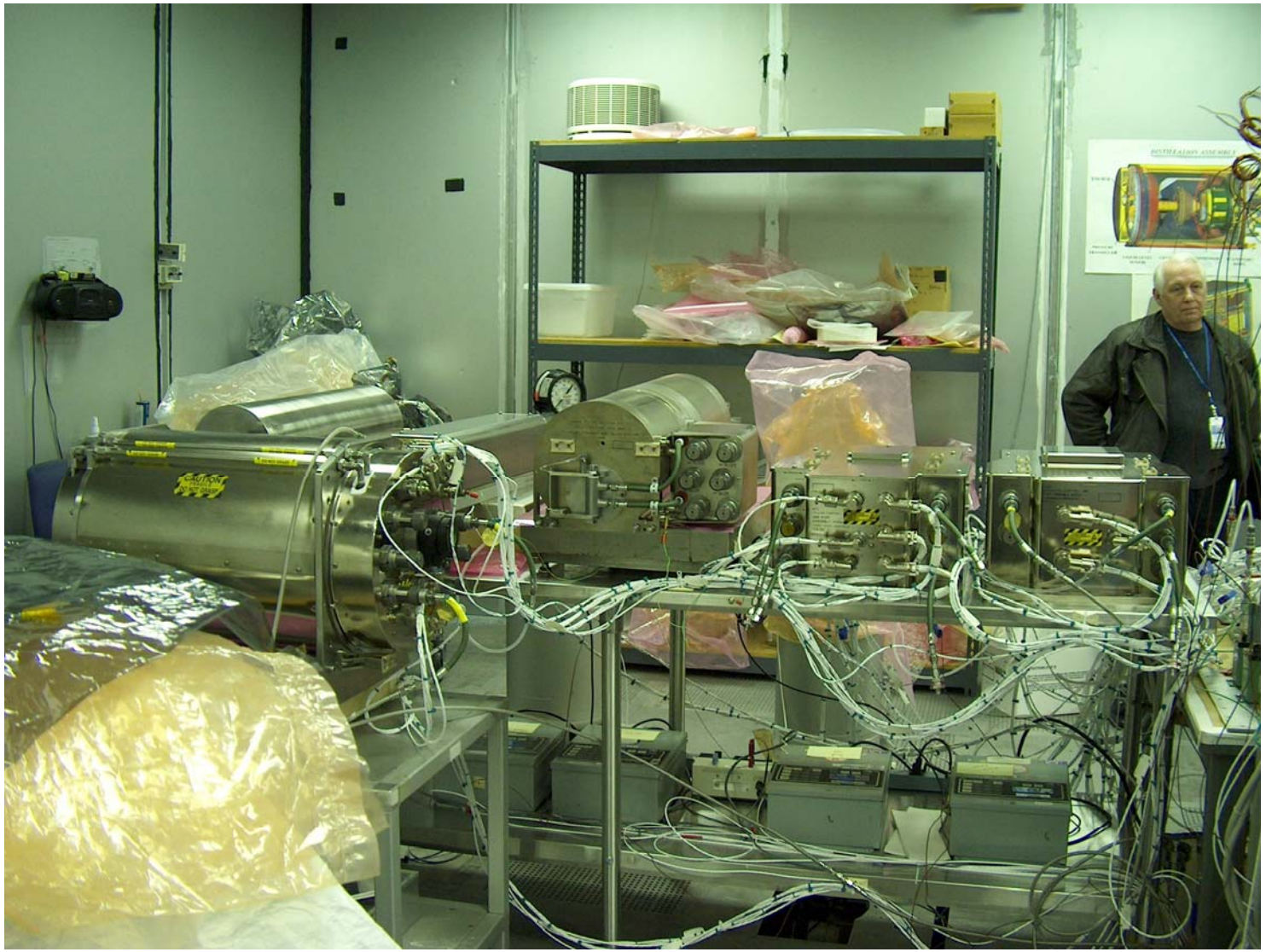
ISS Urine Processor Description

- **Core Technology: Vapor Compression Distillation**
  - » Ambient temperature, low pressure distillation
  - » Evaporator, compressor, and condenser integrated into centrifuge assembly for dynamic phase separation

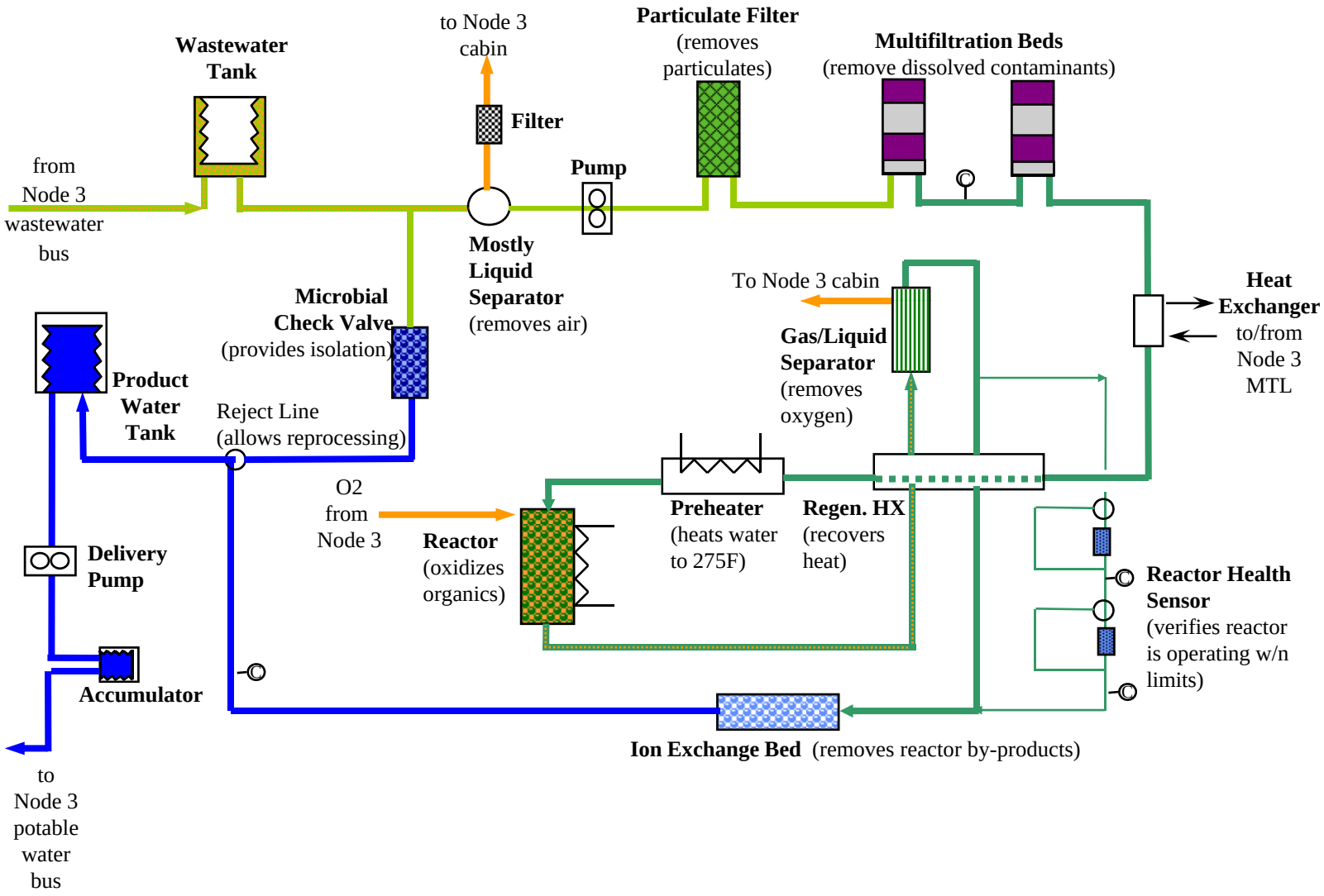
Or you can do this!



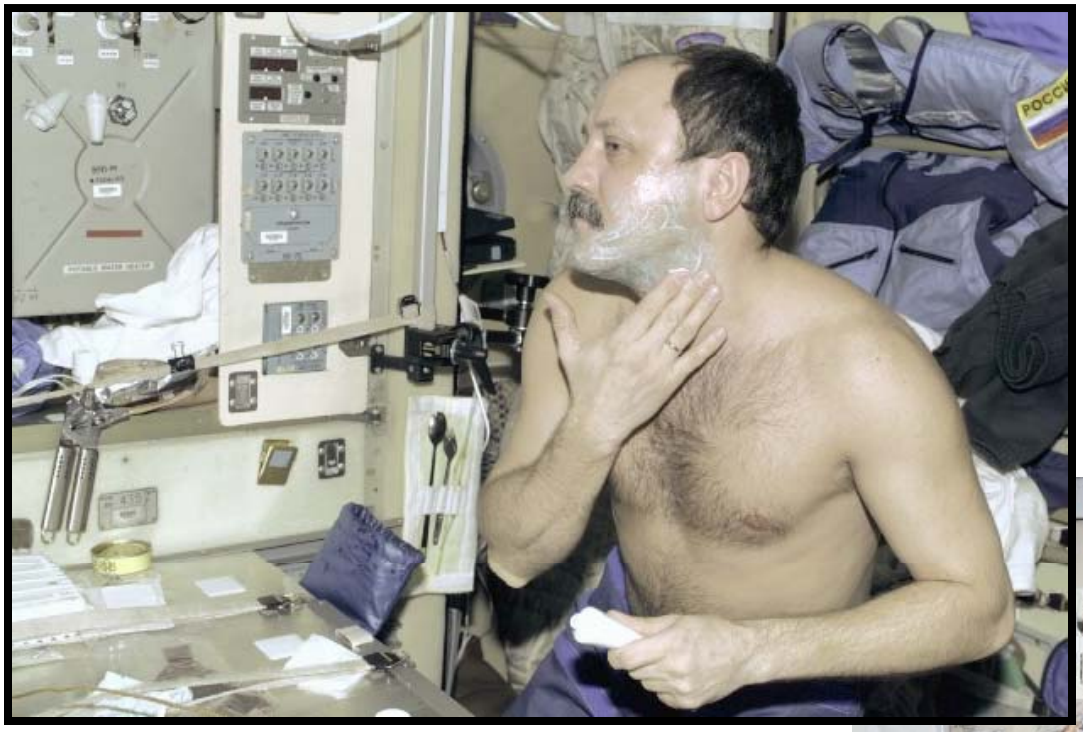
The Whole Urine Processor being tested



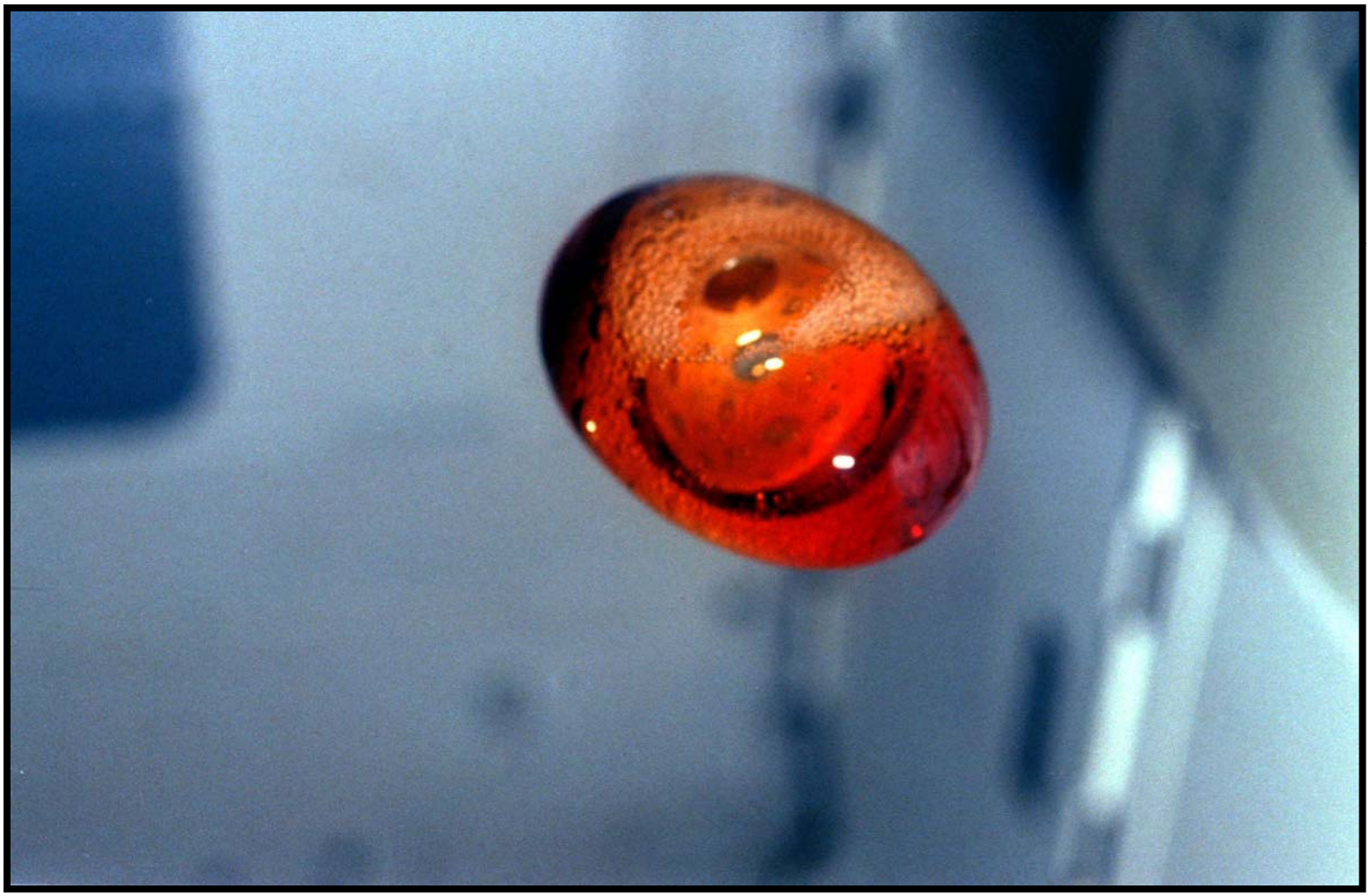
ISS Water Processor Description




Crest




PORT



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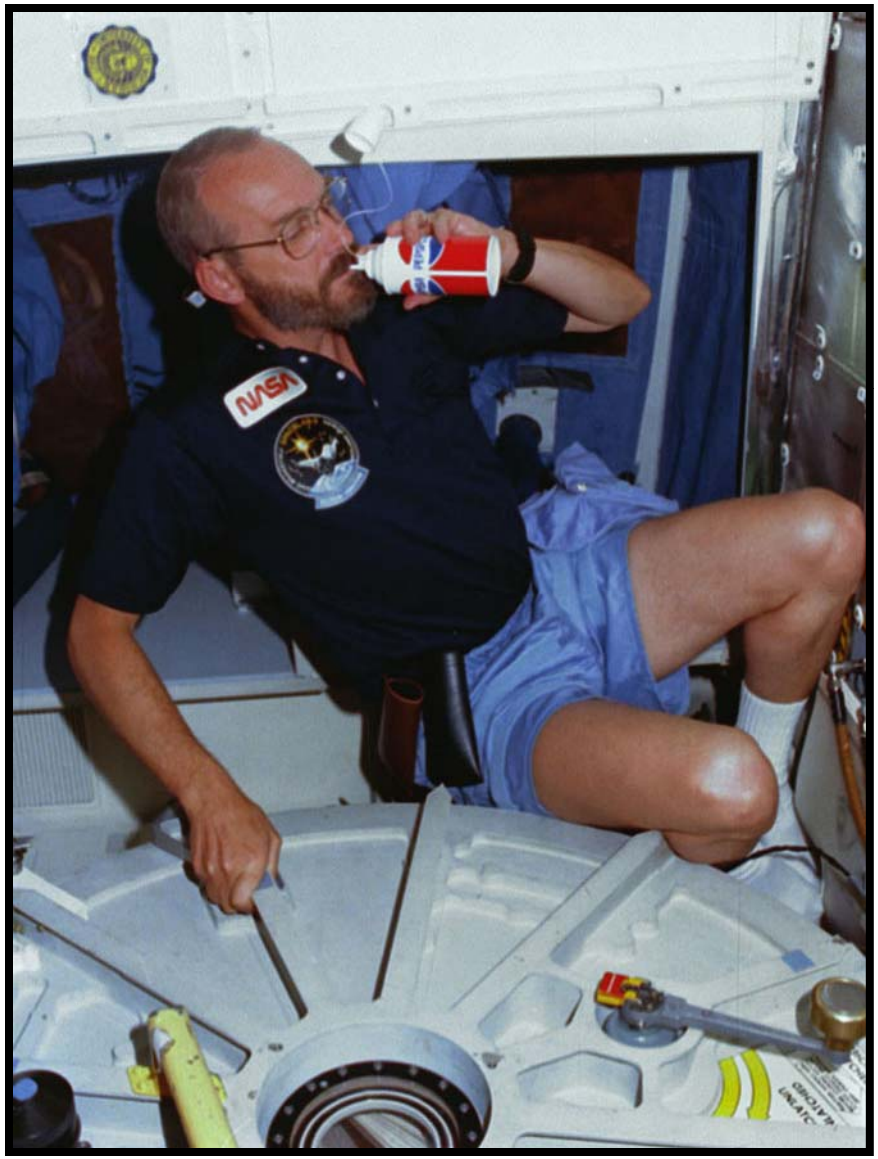

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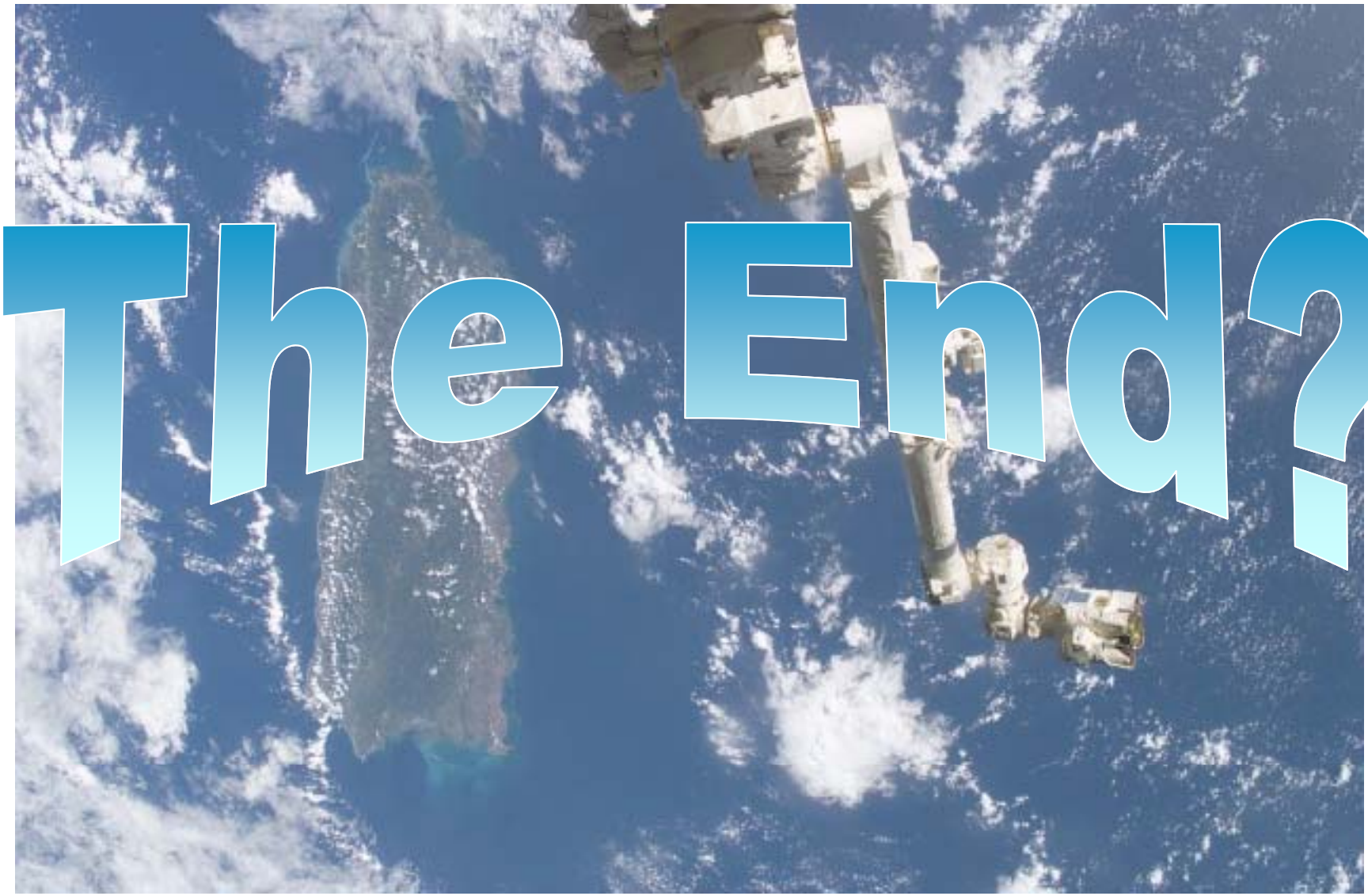
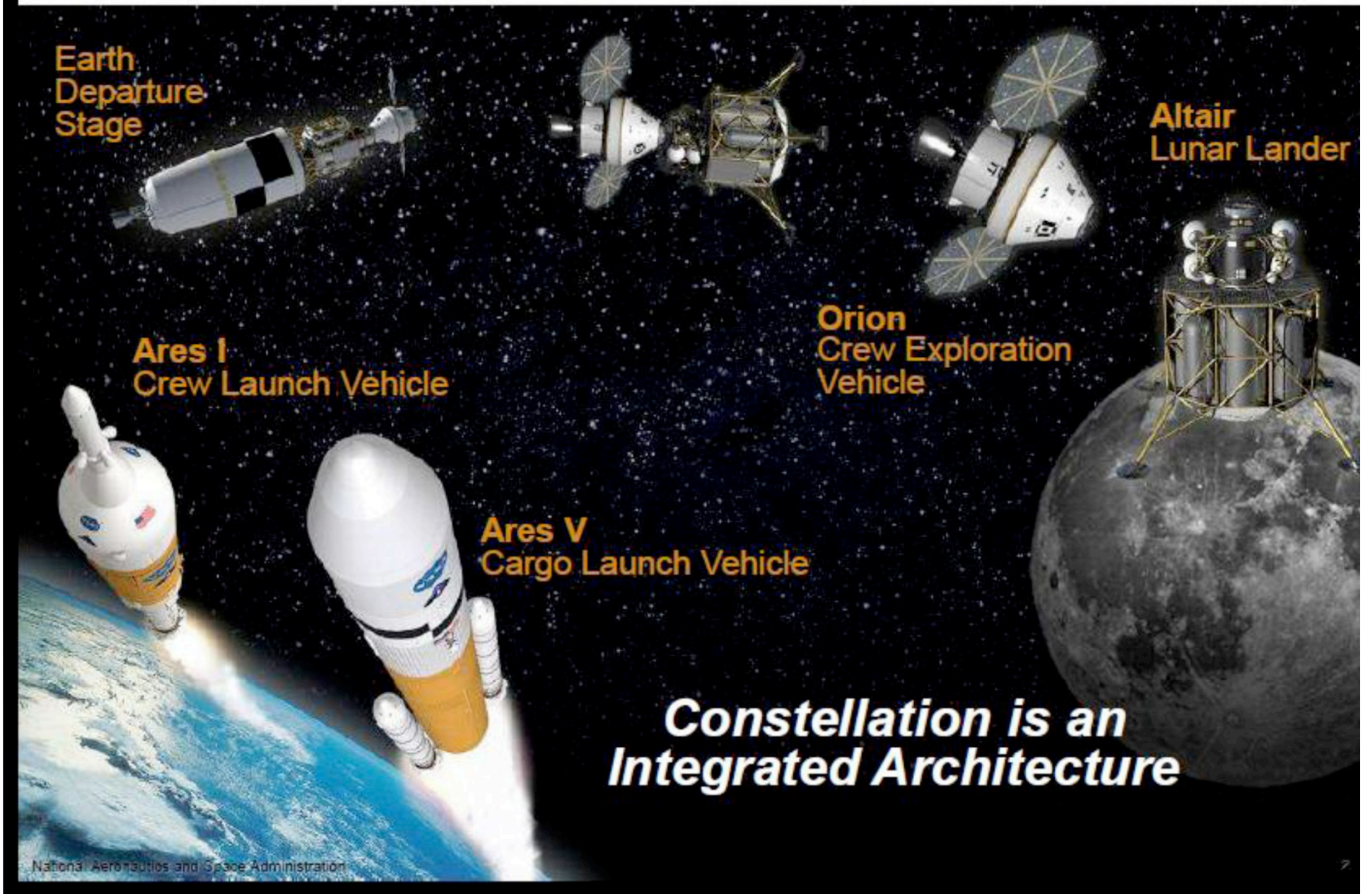
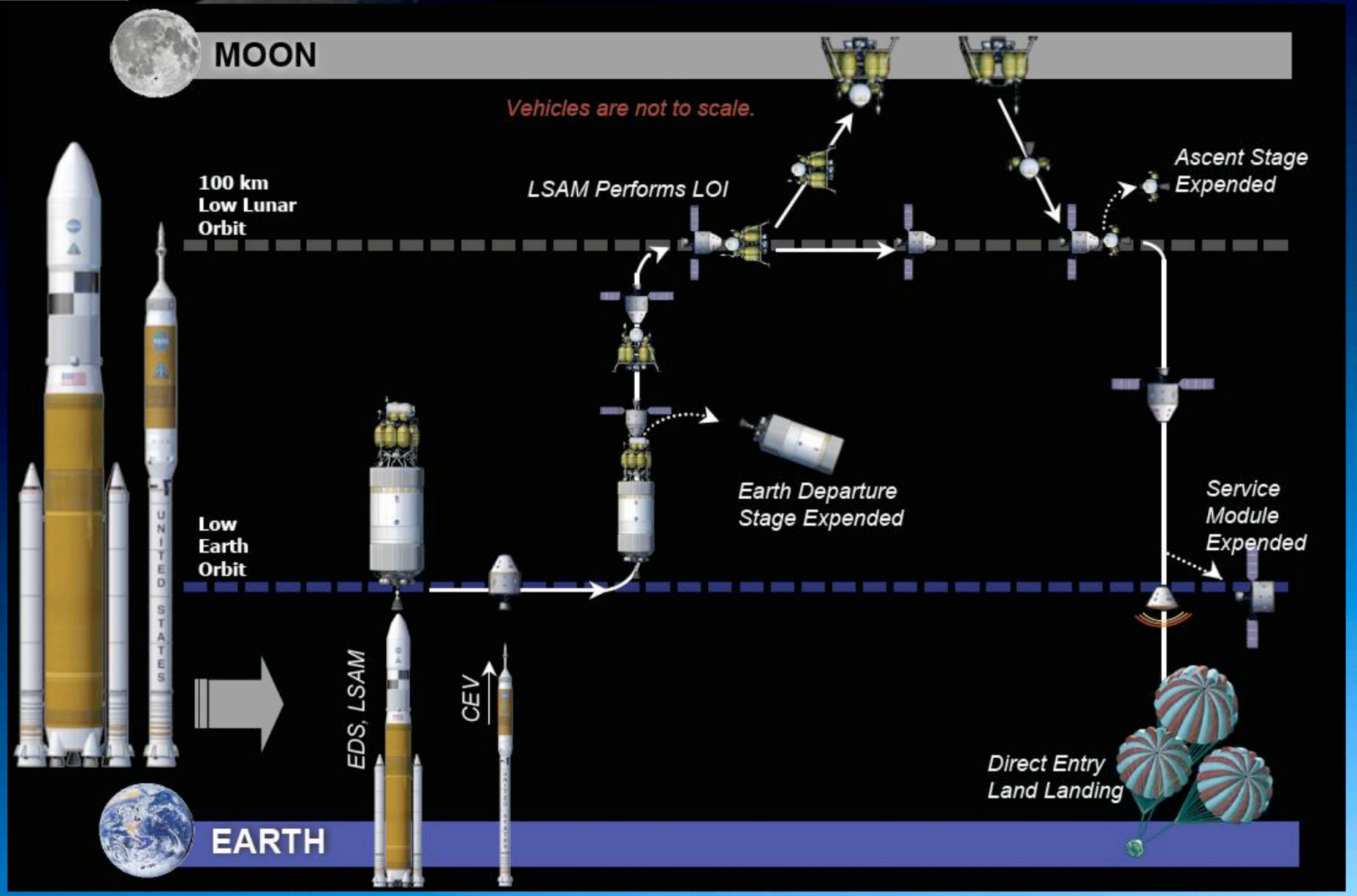
Apollo 8 Earth Rise


The End?

Constellation Architecture



Lunar Mission



Orion ISS and Lunar Missions

- **ISS Mission:**
  - Transport 4 crew to ISS and back
  - 210-day stay time; emergency return capability
- **Lunar Mission:**
  - Transport 4 crew to LLO and back
  - 180-day LLO loiter (unmanned)
- **H2O loop**
  - stored potable supply; urine collected & discarded
- **O2 loop**
  - stored O2 supply
  - CO2 scrubbed with Rapid Cycling Amine & vented overboard

Altair Lunar Lander

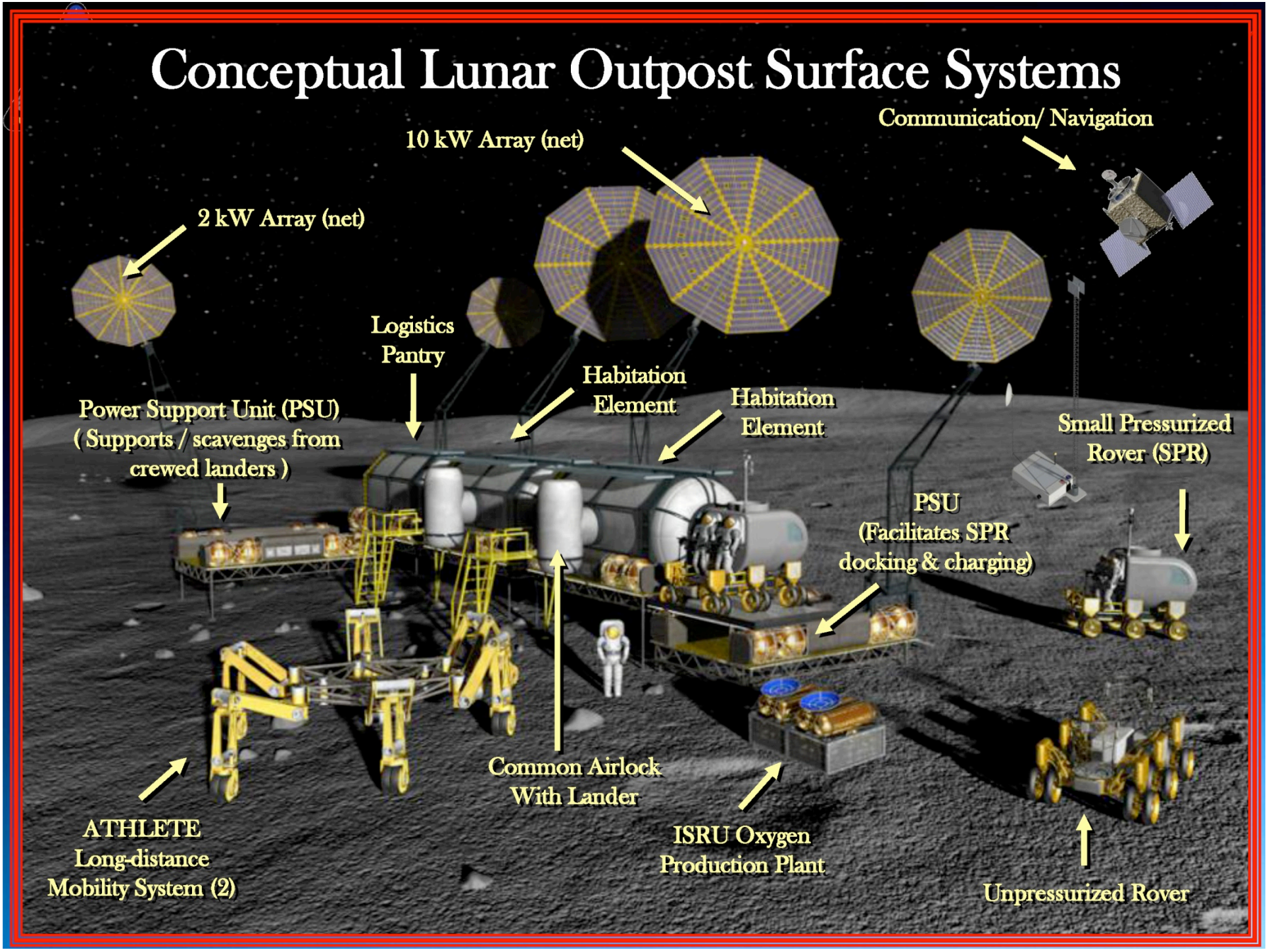
- Crewed version transports 4 crew from LLO to surface & back
  - Support 7-day surface stays during initial outpost buildup
- H2O loop
  - stored potable supply; urine collected & discarded
- O2 loop
  - stored O2 supply
  - CO2 scrubbed & vented overboard

Characteristics of Lunar Architectures

- **Sortie, Extended Stay, and Outpost** capabilities
- **Pervasive Mobility**; ability to explore an extended range (25–100 km) around landing sites
- Solar power with sufficient energy storage to keep assets alive **between human visits**
- **Habitation functions distributed** among multiple elements
- Emphasis on understanding the lunar environment and its applicability to human exploration objectives
  - Developing & testing science protocols
  - **Testing planetary protection approaches**
  - **Improving reliability and functionality** of EVA & life support systems
  - **Testing** systematic approaches for resolving complex problems such as **dust mitigation & radiation protection**
- NASA's Point of Departure Surface Architecture will be informed by NASA's Lunar Exploration Objectives as well as International Partner interests and budget

Lunar Outpost

- Continuous habitation for 4 crew
- Extent of H2O and O2 loop closure subject to ongoing architecture trades; Trade options include:
  - Wastewater recovery, brine recovery, solid waste drying
  - O2 generation from H2O & lunar regolith, CO2 reduction (to CH4 or C)
- Commonality is a key goal. Example opportunities include:
  - Electrolysis (ECLSS, ISRU, & energy storage RFCs)
  - CO2 Removal (Habs, Pressurized Rovers, EVA PLSS, CEV) & compatibility w/ CO2 Reduction
  - Fluid system components (pumps, valves, sensors, etc)


Conceptual Lunar Outpost Surface Systems
Communication/ Navigation
10 kW Array (net)
2 kW Array (net)
Logistics Pantry
Habitation Element
Habitation Element
Power Support Unit (PSU) (Supports / scavenges from crewed landers)
Small Pressurized Rover (SPR)
PSU (Facilitates SPR docking & charging)
Common Airlock With Lander
ATHLETE Long-distance Mobility System (2)
ISRU Oxygen Production Plant
Unpressurized Rover

Typical ECLSS Functions Distributed Throughout and Integrated Lunar Outpost

Pressure Control Subsystem
- **O2 Storage & Supply**
- **N2 Storage & Supply**
- **Positive Pressure Relief**
- **Intermodule Pressure Equalization**
- **Cabin Pressure Monitoring**

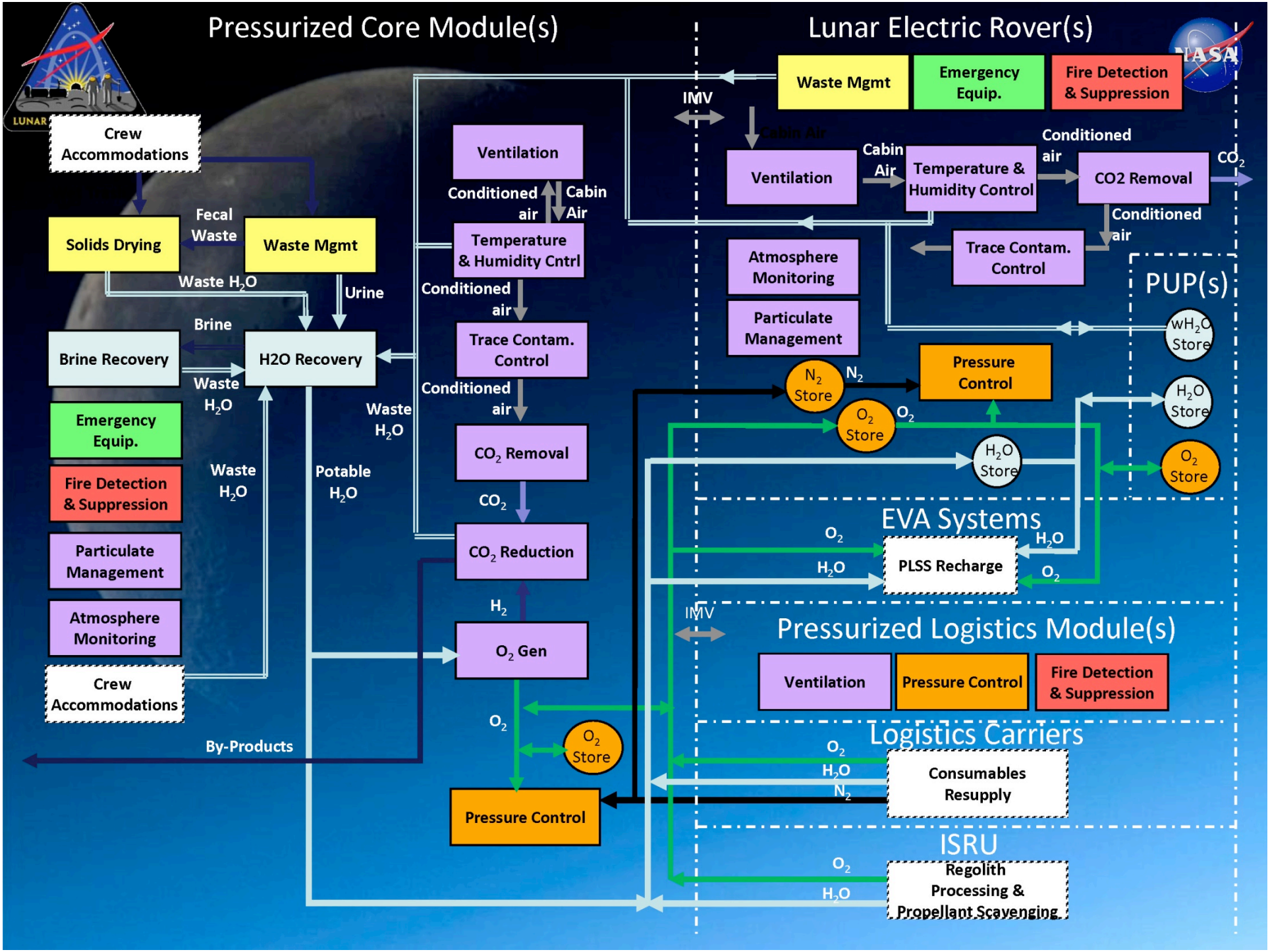
Fire Detection & Suppression Subsystem
- Fire Detection
- Fire Suppression

Emergency Equipment
- O2 Masks
- Toxic Masks

Air Revitalization Subsystem
- CO2 Removal
- CO2 Reduction
- O2 Generation
- Temperature & Humidity Control
- Trace Contaminant Control
- Ventilation
  - intra-module
  - inter-module
- Airborne Particulate Control and Monitoring
- Atmosphere Composition Monitoring
  - ppO2
  - ppCO2
  - ppH2O (v)
  - Trace Contaminants

Water Recovery & Mgmt Subsystem
- H2O Recovery
  - Humidity Condensate
  - Waste Hygiene
  - Urine
- Brine Recovery
- Water Storage & Distribution
- Water Quality Monitoring

Waste Mgmt Subsystem
- Urine Collection & Pretreat
- Fecal Collection & Drying
- Trash Collection, Compaction, & Drying
- Laundry


Pressurized Core Module(s)
Lunar Electric Rover(s)
Crew Accommodations
Solids Drying
Fecal Waste
Waste Mgmt
Waste H_2O
Urine
Brine
Brine Recovery
H2O Recovery
Waste H_2O
Emergency Equip.
Fire Detection & Suppression
Particulate Management
Atmosphere Monitoring
Crew Accommodations
Waste H_2O
Potable H_2O
By-Products
Ventilation
Conditioned air
Cabin Air
Temperature & Humidity Cntrl
Conditioned air
Trace Contam. Control
Conditioned air
CO_2 Removal
CO_2
CO_2 Reduction
H_2
O_2 Gen
O_2
O_2 Store
Pressure Control
IMV
Waste Mgmt
Emergency Equip.
Fire Detection & Suppression
Cabin Air
Ventilation
Cabin Air
Temperature & Humidity Control
Conditioned air
CO2 Removal
CO_2
Conditioned air
Trace Contam. Control
Atmosphere Monitoring
Particulate Management
PUP(s)
wH_2O Store
N_2 Store
N_2
Pressure Control
O_2 Store
O_2
H_2O Store
H_2O Store
O_2 Store
EVA Systems
O_2
H_2O
PLSS Recharge
H_2O
O_2
IMV
Pressurized Logistics Module(s)
Ventilation
Pressure Control
Fire Detection & Suppression
Logistics Carriers
O_2
H_2O
N_2
Consumables Resupply
ISRU
O_2
H_2O
Regolith Processing & Propellant Scavenging

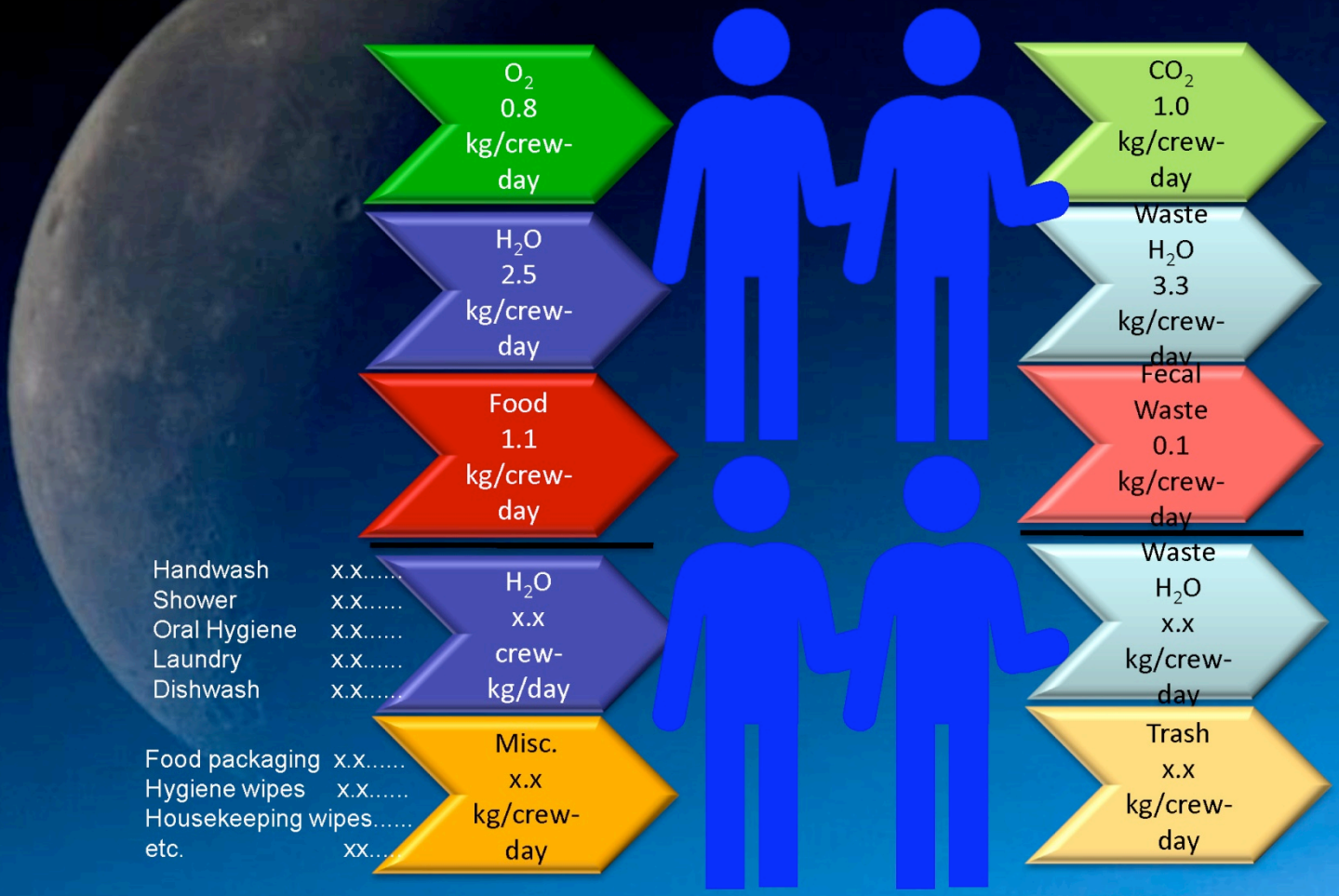
CxP ECLSS Technology Needs

- **Closed loop air revitalization (oxygen loop closure)**
  - CO_2 Removal w/ ability to recover CO2
  - CO2 Reduction
  - O2 Generation via electrolysis (high pressure capability)
  - Trace contaminant control (improved sorbents and catalysts)
  - Atmosphere particulate control & monitoring
- **Closed loop H2O Recovery**
  - Water recovery from wastewaters and brines
  - Pretreatments, biocides, low expendable rates, robustness, etc.
- **Lunar Airborne Dust Removal**
  - characterization, detection, and control techniques
- **Post-fire Cleanup Monitor**
  - ensure safety after fire event

CxP ECLSS Technology Needs

- **Long duration waste stabilization**
  - water recovery from solid wastes
- **Fire detection with low false alarm rates**
- **Low-g Fire Suppressants in elevated ppO2 atmospheres**
  - characterization for lunar application
- **Long-life Atmosphere monitors**
  - major atmosphere constituents
  - trace contaminants

Typical Life Support Mass Balance



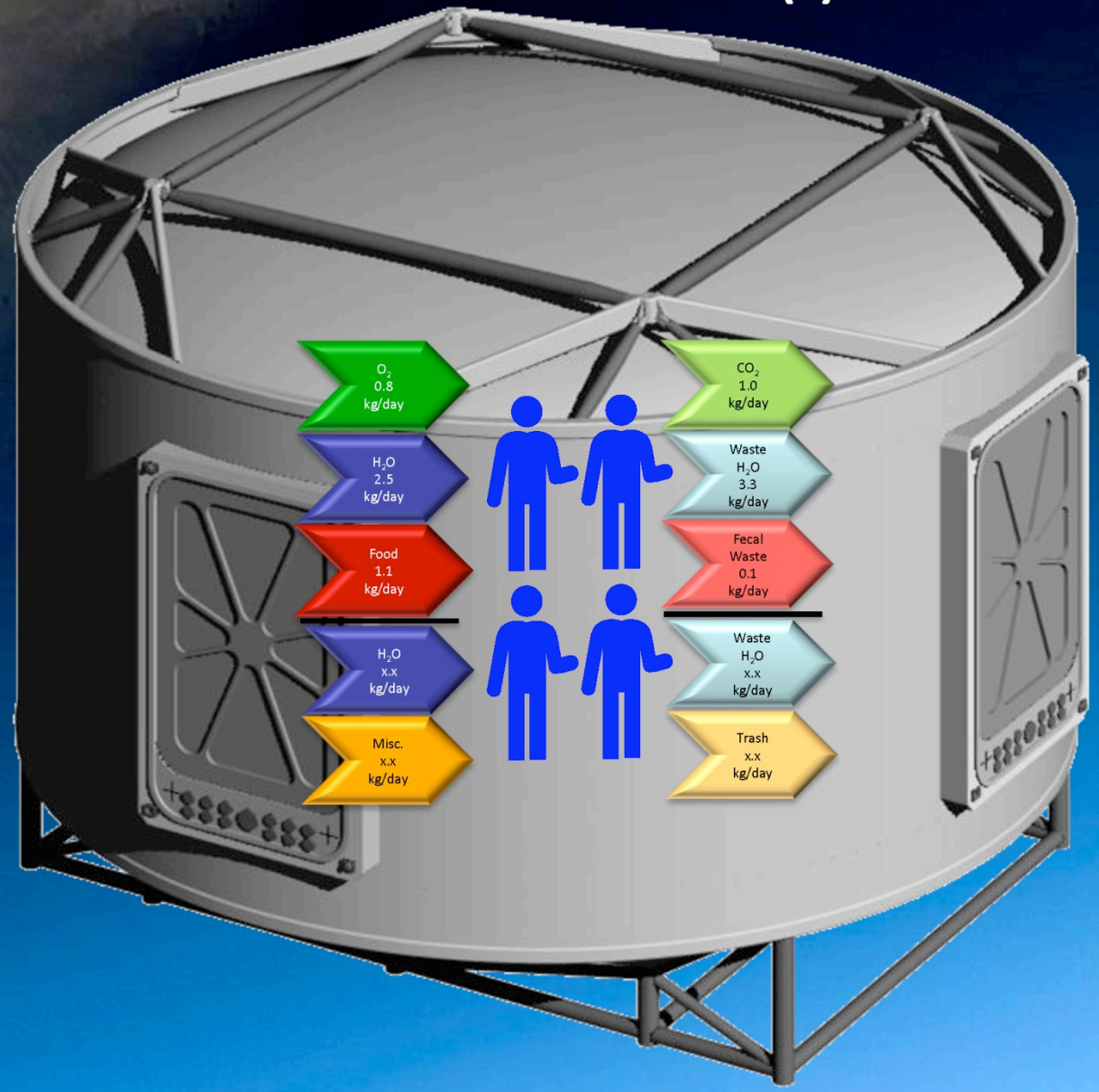
Handwash x.x.....
Shower x.x.....
Oral Hygiene x.x.....
Laundry x.x.....
Dishwash x.x.....

Food packaging x.x.....
Hygiene wipes x.x.....
Housekeeping wipes.....
etc. xx....

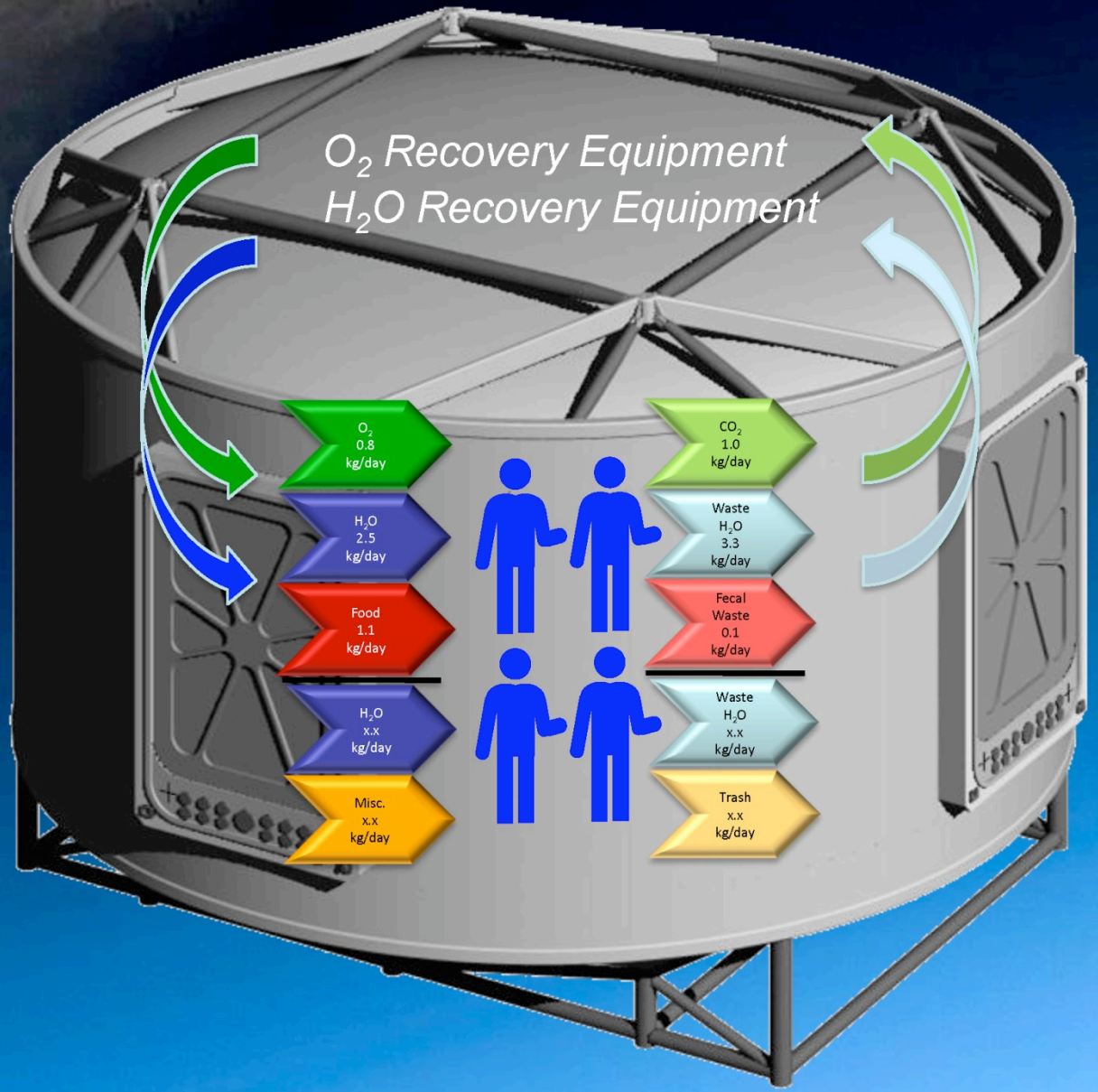
Daily Usage = x.x kg/day

Daily Output = x.x kg/day

Typical Vision: Crew Members Live Within a Fixed Habitat(s)



Typical Vision: Crew Member Wastes are Available in Fixed Habitat(s) for Recycling



More Likely Scenario: Crew Member Wastes May be Unavailable in Fixed Habitat(s) for Recycling