Exploration Life Support System Demonstration on the International Space Station

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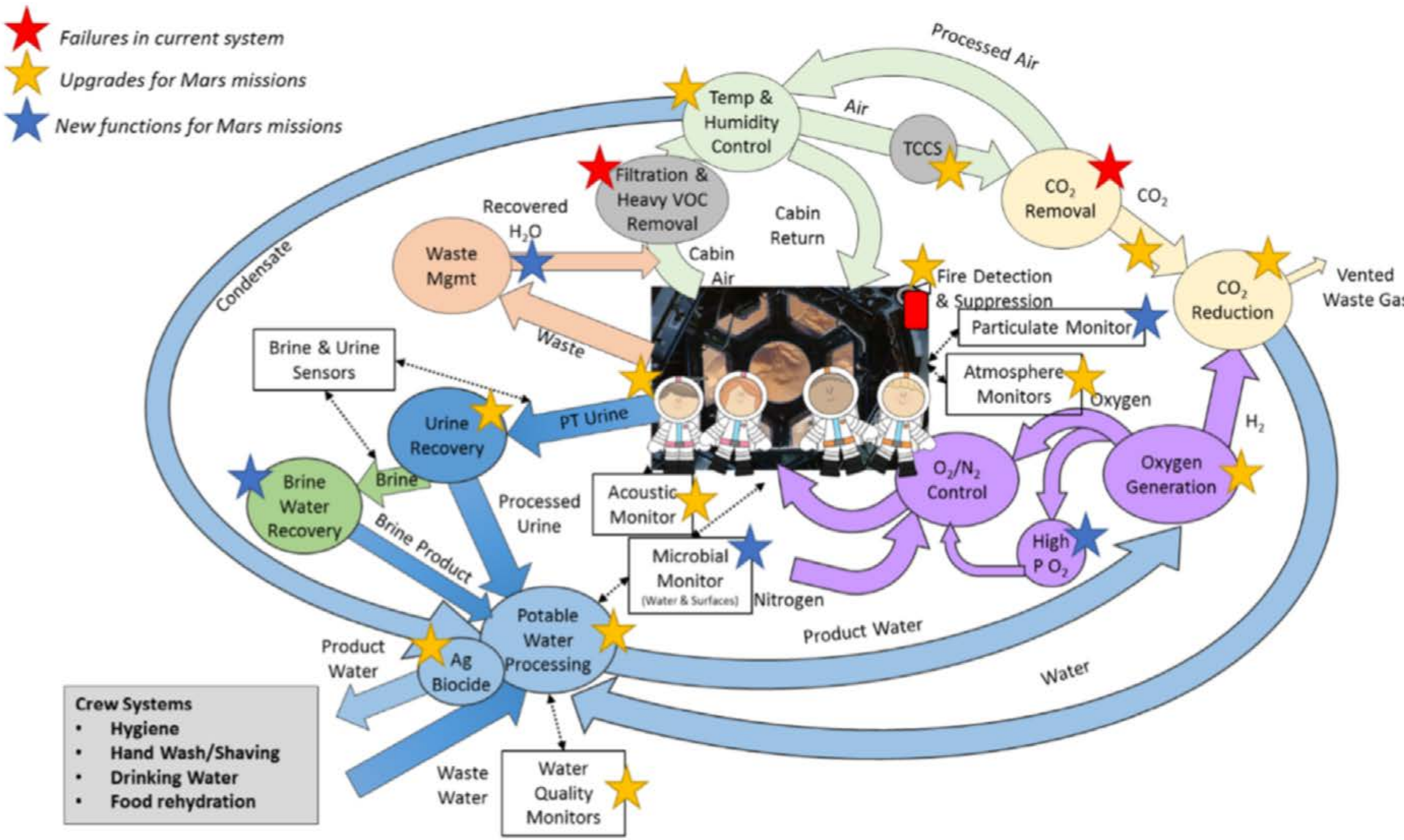
Introduction

- Missions beyond Low Earth Orbit present significant challenges for areas such as life support - Environmental Control and Life Support System (ECLSS)
- ISS operational experience has dramatically improved our understanding of life support systems and challenges, but more improvements are needed
- NASA has initiated an effort to develop and demonstrate exploration-class ECLSS on the ISS to develop a capability portfolio that supports all potential exploration mission scenarios
  - New capabilities in-development, existing system upgrades
- Objective is to characterize system performance and reliability over long duration in a fully integrated and fully relevant environment
  - Most applicable to micro-gravity / interplanetary transit missions
  - Ground testing can prove systems appropriate for partial gravity / planetary surface missions
- ISS is unique and essential as a testbed for life support-type systems
  - Multi-phase flow in microgravity
  - Relevant constituents in crew waste products during exposure to microgravity
  - Closed environment spacecraft
  - Fully integrated ECLS system supporting actual crewmembers
- Therefore, ISS is the location for NASA’s exploration-class ECLSS testbed

The ECLSS Loop



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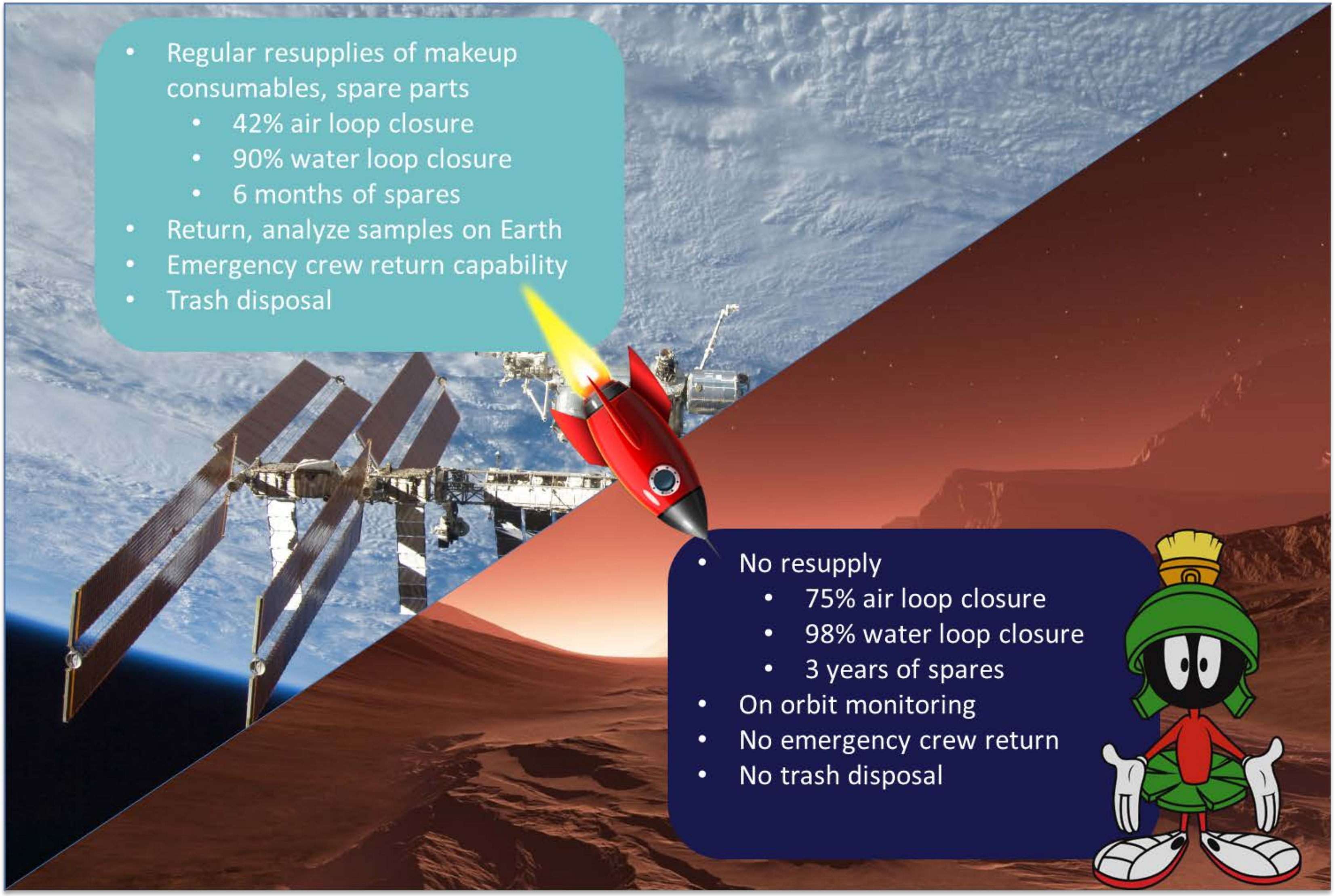
Why Focus on ECLSS Improvements?



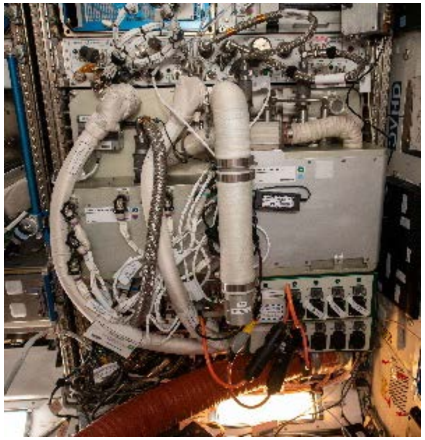
- Regular resupplies of makeup consumables, spare parts
  - 42% air loop closure
  - 90% water loop closure
  - 6 months of spares
- Return, analyze samples on Earth
- Emergency crew return capability
- Trash disposal

- No resupply
  - 75% air loop closure
  - 98% water loop closure
  - 3 years of spares
- On orbit monitoring
- No emergency crew return
- No trash disposal

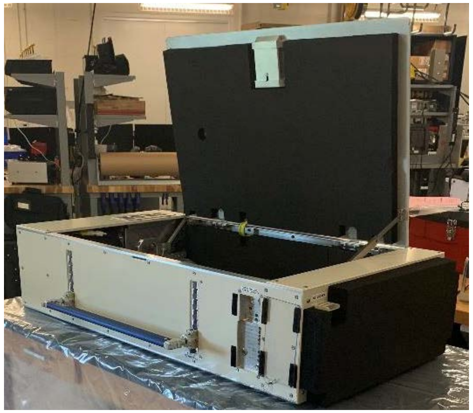
Keys Areas of Emphasis for Improvements

- Lower cabin carbon dioxide (CO_2) levels
  - ISS crew feedback has led to a drive to reduce cabin CO_2 levels from 3mmHg on ISS to ≤2mmHg for exploration
    - For reference: Original ISS Carbon Dioxide Removal Assembly (CDRA) design point was 5.6mmHg average and 7.3mmHg peak
  - Three distinct systems will be demonstrated on ISS to prove their efficacy and reliability, leading to down select for long-term integrated testing on ISS
    - One technology is based on ISS CDRA, one is based on Orion's CO_2 removal system, and the third is a novel microfluidic technology
    - First demonstration unit – Thermal Amine Scrubber – is on ISS and recovering from a fan failure, will be back in operation in December
    - Next CO_2 removal demonstration unit delivered in late 2020
- New capabilities
  - Adding urine brine dewatering technology to recover additional water that has been disposed of on ISS – increases overall water recovery
    - Delivery to ISS in late 2020 for long-term integrated testing on ISS
  - Supplemental CO_2 reduction to improve oxygen recovery rate

Thermal Amine Scrubber Installed on ISS



Brine Processor Assembly



Keys Areas of Emphasis for Improvements

- Increased subassembly/piece part replaceability to reduce overall spares mass burden
  - Example: Oxygen Generation Assembly electrolyzing cell stack removed from blast dome to enable replacement of subassembly instead of large Orbital Replacement Unit (ORU)
  - Example: Sabatier (CO_2 reduction) reactor relocated to accessible location within system to enable replacement in-flight
- Lessons learned from ISS operations that improve reliability
  - Removing silicon-based long chain organics (siloxanes) from atmosphere and reducing sources, i.e. certain hygiene products
    - ISS ops revealed siloxanes impact the life of the Water Processor packed beds, efficacy of CO_2 removal desiccant beds, and will poison Sabatier catalyst
  - Improvements to Urine Processor Assembly (UPA) distiller to reduce urine carryover, improve centrifuge drive belt system robustness
  - Improvements to Water Processor Assembly (WPA) catalytic oxidation reactor to more effectively remove siloxanes as well as reduce potential for water leakage over time

Siloxane Filters Installed on ISS

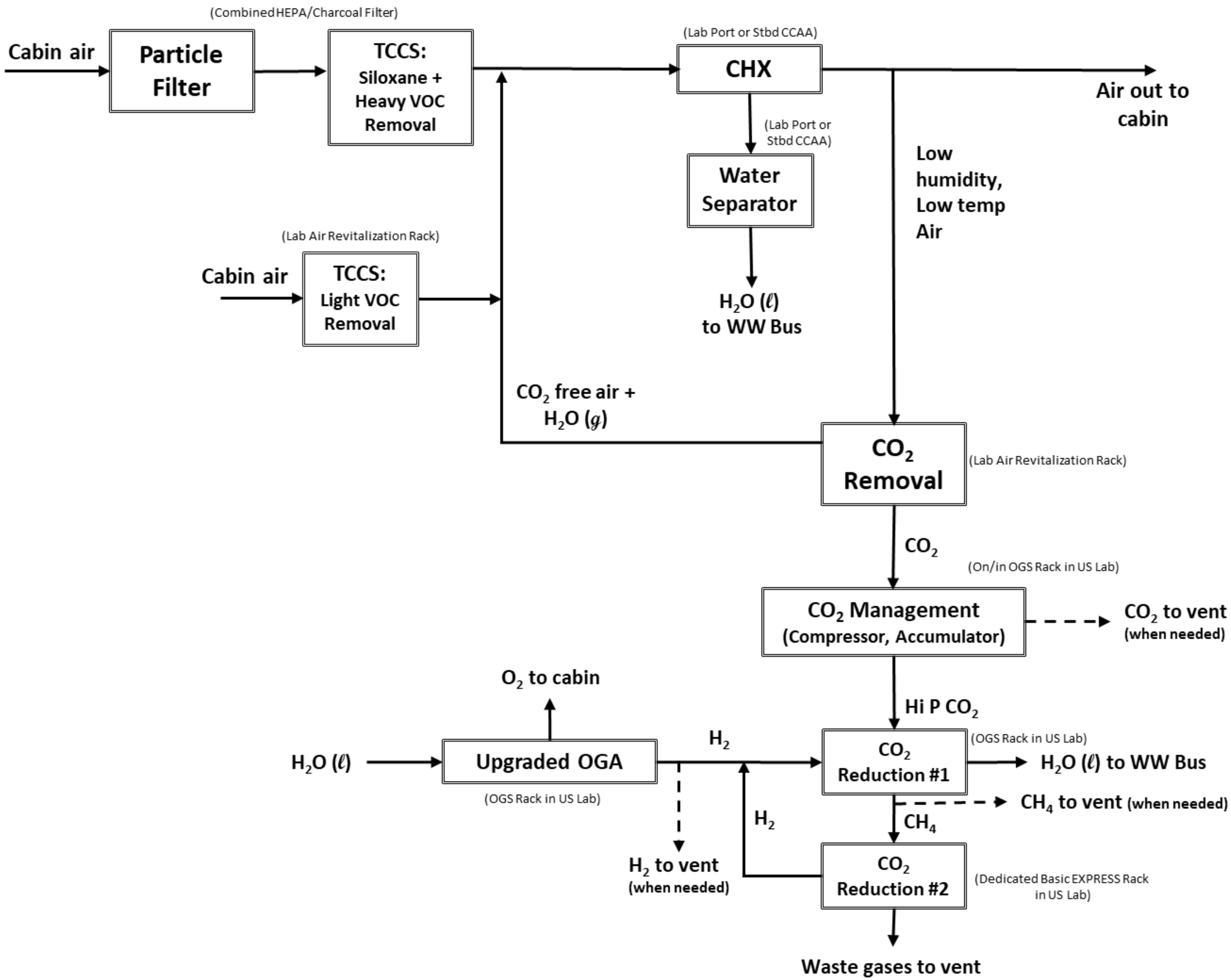
Technology Demonstration Approach

- Develop a testbed that mimics exploration spacecraft life support system as much as possible
  - ISS architecture presents limitations such as rack architecture, 120VDC power, MIL-STD-1553 command and data handling systems, varying crew size
  - New capabilities have been developed to increase the usefulness of ISS as a testbed, such as an Ethernet-based command and data handling system
  - ISS utilities (power, active cooling, and available installation locations) have been assessed and can handle the currently planned suite of hardware and upgrades
    - But additional hardware such as supplemental CO_2 Reduction may only be accommodated in sub-scale depending on their power and cooling needs
  - Objective is to mature performance and reliability predictions of the core system components (e.g. Urine Processor Assembly Distillation Assembly) and enable repackaging/layout of the systems when actual mission profiles and spacecraft designs are established
- For ease of integration into ISS, overall system is divided into two strings:
  - Air String
  - Water String
- Environmental Monitors are installed as their functions dictate, such as water monitoring devices placed near the Water Processor Assembly

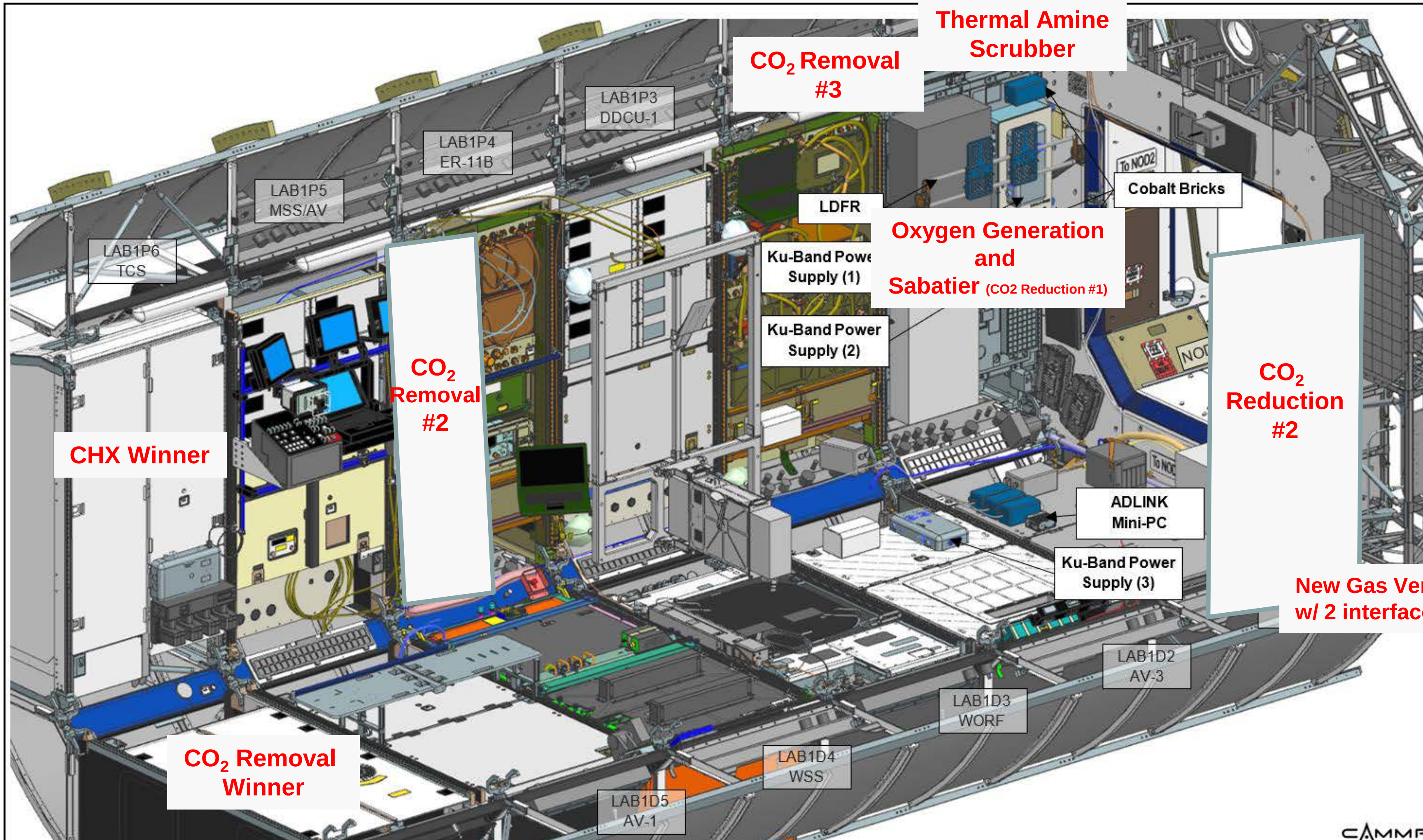
Air and Water String Overviews

- Air String will be located in the US Laboratory Module and comprise the following functions:
    - Condensing heat exchanger (CHX) to remove crew latent heat and humidity
    - Post-CHX water separation to enable downstream condensate processing
    - Trace contaminant control system (TCCS)
    - Carbon dioxide (CO_2) removal from cabin
    - CO_2 reduction to close air loop and utilize all available resources
    - Oxygen generation (OGA) for crew metabolic needs
- Water String will be located in the Node 3 Module and comprise the following functions:
    - Human waste collection - toilet
    - Urine processing (UPA) to close water loop and utilize all available resources
    - Water processing (WPA) to polish water from urine processor and revitalize condensate
    - Brine processing (BPA) to close water loop by dewatering Urine Processor generated brine
    - Water dispensing (PWD) to provide drinking water and food rehydration for crew
        - Located in Node 1
- The Water String is integrated with the Air String via the common ISS atmosphere and the potable and waste water buses that run throughout the ISS USOS

Air String Schematic



Air String Layout in US Lab



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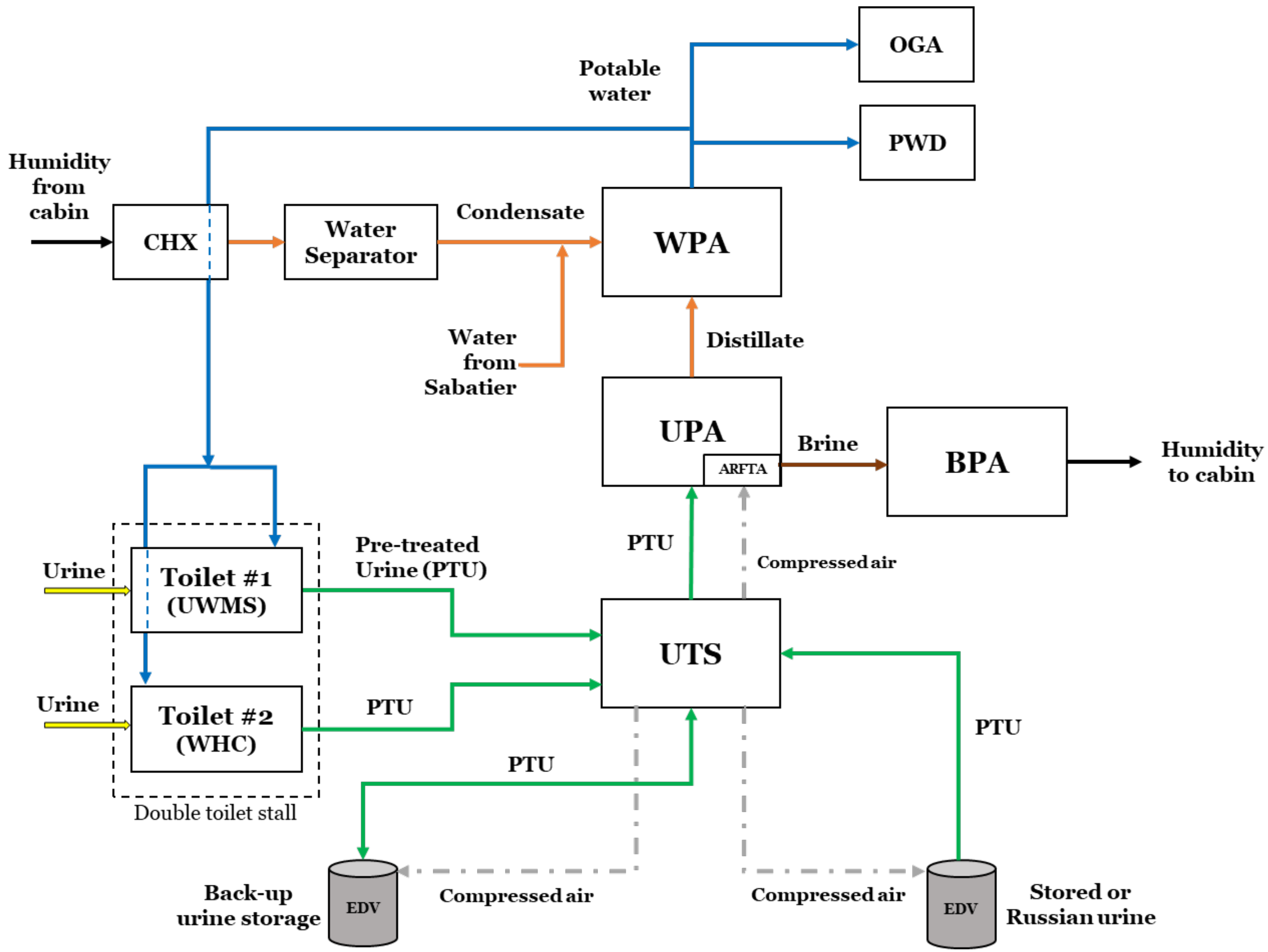
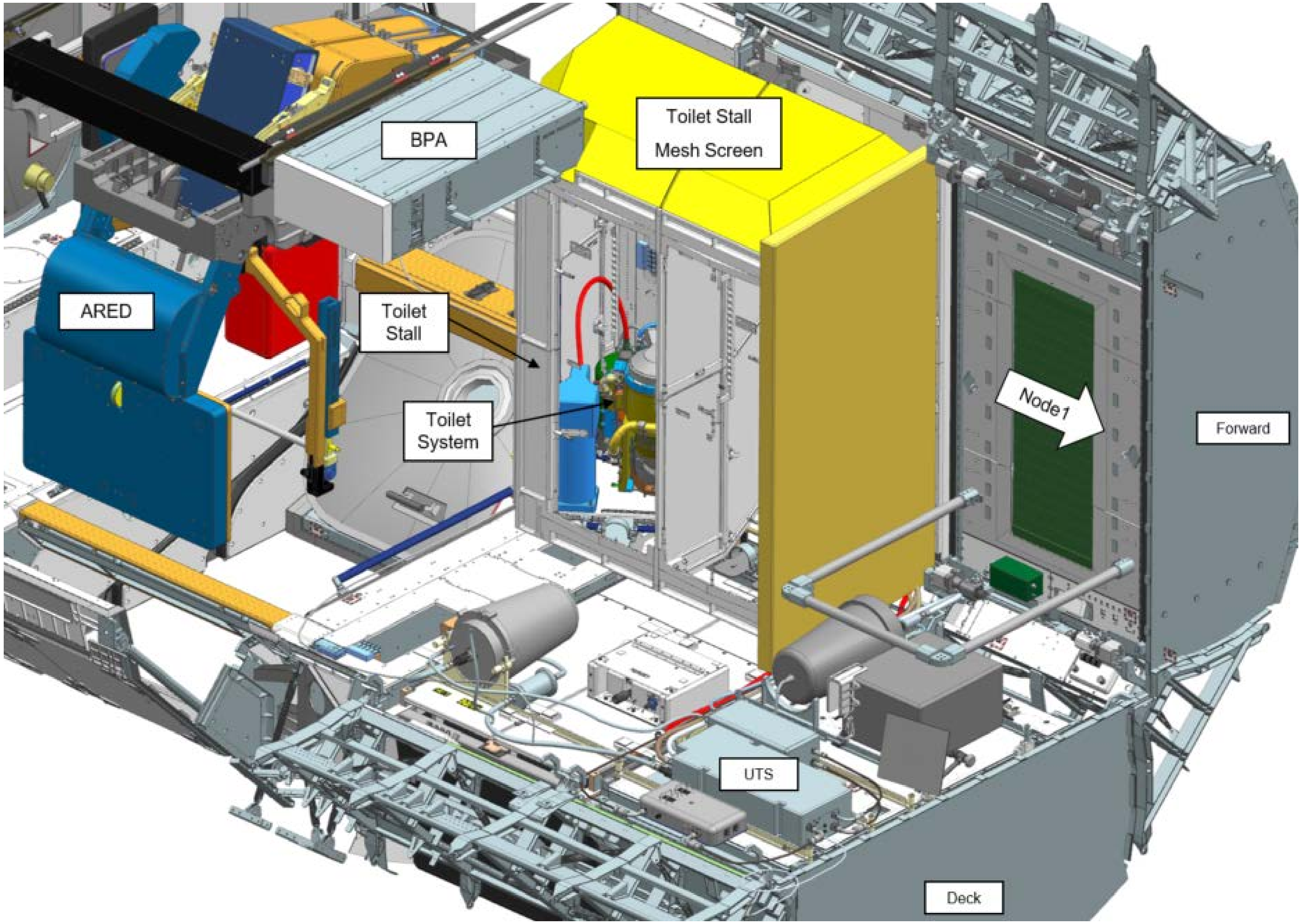
Water String Schematic



Water String Layout in Node 3



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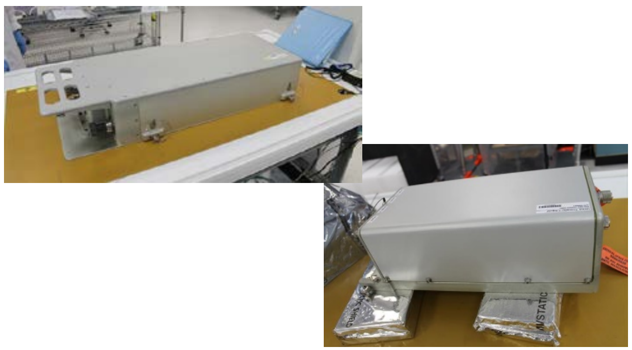
Water String Hardware Pictures

Urine Transfer System Ready for Flight Packing



Toilet Training Unit

Double Toilet Stall Deployed on ISS

Schedule

- Majority of Air String is expected to be installed and operating on ISS by approximately 2023
  - Supplemental CO_2 Reduction is likely to be later
- The first major components of Water String are expected to be installed and operating on ISS by approximately late 2020
  - Includes Toilet, Urine Transfer System, Brine Processor, portion of WPA Upgrades, UPA Upgrades
- Additional Water String upgrades and the Exploration PWD are expected in 2021 and beyond

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Questions?