ISS REGENERATIVE LIFE SUPPORT: CHALLENGES AND SUCCESS IN THE QUEST FOR LONG-TERM HABITABILITY IN SPACE

Abstract

This presentation will discuss the International Space Station's (ISS) Regenerative Environmental Control and Life Support System (ECLSS) operations with discussion of the on-orbit lessons learned, specifically regarding the challenges that have been faced as the system has expanded with a growing ISS crew.

Over the 10 year history of the ISS, there have been numerous challenges, failures, and triumphs in the quest to keep the crew alive and comfortable. Successful operation of the ECLSS not only requires maintenance of the hardware, but also management of the station resources in case of hardware failure or missed re-supply. This involves effective communication between the primary International Partners (NASA and Roskosmos) and the secondary partners (JAXA and ESA) in order to keep a reserve of the contingency consumables and allow for re-supply of failed hardware.

The ISS ECLSS utilizes consumables storage for contingency usage as well as longer-term regenerative systems, which allow for conservation of the expensive resources brought up by re-supply vehicles. This long-term hardware, and the interactions with software, was a challenge for Systems Engineers when they were designed and require multiple operational workarounds in order to function continuously.

On a day-to-day basis, the ECLSS provides big challenges to the on console controllers. Main challenges involve the utilization of the resources that have been brought up by the visiting vehicles prior to undocking, balance of contributions between the International Partners for both systems and resources, and maintaining balance between the many interdependent systems, which includes providing the resources they need when they need it.

The current biggest challenge for ECLSS is the Regenerative ECLSS system, which continuously recycles urine and condensate water into drinking water and oxygen. These systems were brought to full functionality on STS-126 (ULF-2) mission. Through system failures and recovery, the ECLSS console has learned how to balance the water within the systems, store and use water for contingencies, and continue to work with the International Partners for short-term failures.

Through these challenges and the system failures, the most important lesson learned has been the importance of redundancy and operational workarounds. It is only because of the flexibility of the hardware and the software that flight controllers have the opportunity to continue operating the system as a whole for mission success.

Mission Operations Directorate
Expedition Vehicle Division
Life Support Systems Group

ISS Regenerative Life Support: Challenges and Success in the Quest for Long-Term Habitability in Space

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Jesse Bazley

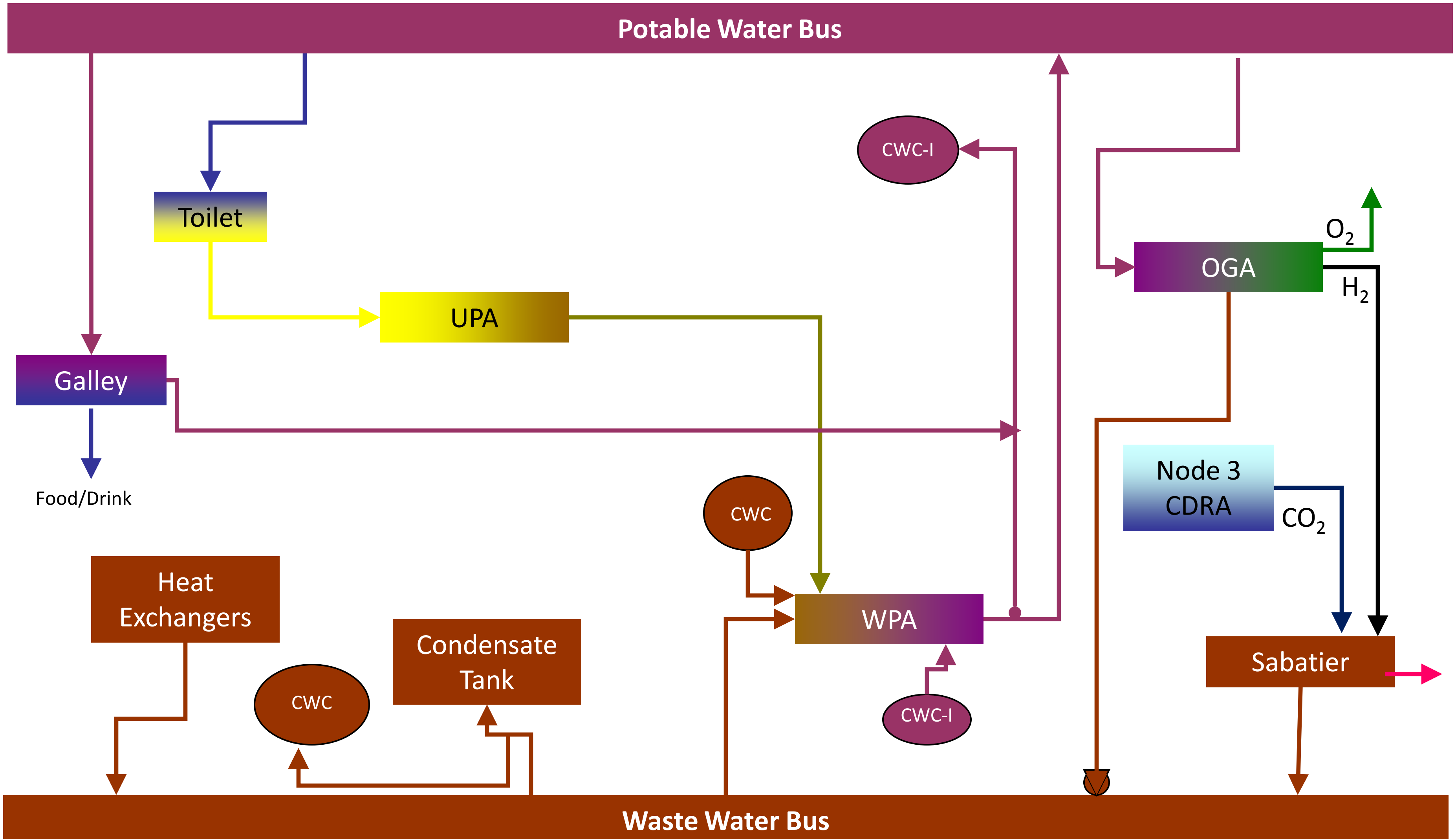
United Space Alliance

ECLSS Flight Controller

Outline

- Regen ECLSS Intro
- Water Balance Challenges
- Common System Failure Modes
- Important Lessons Learned

Regenerative ECLSS Overview



Primary Systems

- Urine Processing Assembly (UPA)
  - Receives pre-treated Urine from toilet and produces distillate for WPA
- Water Processing Assembly (WPA)
  - Receives UPA distillate and Condensate (Waste Water) and produces Iodinated Potable Water for crew and OGA consumption
- Oxygen Generating Assembly (OGA)
  - Takes Potable Water and produces Oxygen (to cabin) and Hydrogen (vented overboard or sent to Sabatier)

Primary Systems

- Carbon Dioxide Removal Assembly (CDRA)
  - Regenerative means to remove Carbon Dioxide to vent overboard or send to Sabatier
- Sabatier Reactor Assembly (SRA)
  - Combines Hydrogen and Carbon Dioxide to produce water for Waste Water bus and Methane (vented overboard)

Manual Water Storage Capabilities

- Contingency Water Container (CWC)
  - Stores Technical (silver-biocide) or Potable (silver-biocide + minerals) water
  - Can be processed by Russian equipment or processed in WPA
- Contingency Water Container – Iodine (CWC-I)
  - Stores Iodinated water for re-introduction to WPA or Potable Bus

Water Balance Basics

- Ideally:

Input = Output

- Reality:
  - Input = function (# of crew onboard, crew metabolic rates, Sabatier production)
  - Output = function (# of crew drinking, crew drinking rates, OGA production, payloads usage)
  - Can vary largely from day-to-day or week-to-week (operations domain), but usually more stable in long-term (logistics domain)

Water Balance Challenges

- Regenerative ECLSS fluid tanks are under-sized compared to input/output volume
  - Need to manage all tanks, which have individual quantity constraints, to prevent over-filling or running out of water
- Crew specified metabolic rates does not always equal actual values
  - Creates challenges at beginning of new crew time period to understand how to manage system
- With OGA running, have a long-term water deficit due to added consumption of water
  - Requires periodic adding of water into the WPA from stored water

System Clogging

- Systems tend to clog due to biofilm or precipitants in loops
  - Biofilm grows in tanks containing Condensate
  - Precipitants form when removing water (i.e. UPA)
- Affects flow through valves, pumps, lines, etc
- Control growth through tank cycling and limited reclamation
  - Bellows in tank “scrape” walls of tank clean
  - Limited reclamation prevents reaching precipitation concentration of elements (i.e. Calcium)

Water Leaks

- Multiple failures caused water to enter cabin
  - Toxicity varies from low (de-iodinated water) to moderate (urine)
- Common leak paths are through seals, Quick Disconnects (QDs), etc
  - QD leaks can be mitigated by keeping QDs connected
  - Seal leaks usually terminal to ORU and requires replacement with proper seals
- Water bags tend to leak around fittings when mis-handled

Important Lessons Learned

- Storage of excess water is invaluable
  - Available for use either in system failure or to supplement for water imbalance
- Redundancy of critical systems important
  - US water processing, oxygen production and carbon dioxide removal systems have Russian equivalent systems and contingency capabilities
- System interfaces critical
  - Regen ECLSS comprises several individual systems, each with own constraints, which all must work together to operate as one

Important Lessons Learned

- Water system design need to be universal
  - Regen ECLSS has countless different QD sizes and keying which require adapters and hoses for contingency interfaces
- Spreadsheets help predict and manage water systems
  - Console utilizes spreadsheets to predict tank quantities and manage the system, within constraints, for next several days
  - Shown to be unpredictable more than ~5 days out, though
- ISS important test-bed for the future
  - Regenerative ECLSS never performed in space until ISS
  - Systems need to be perfected to go to Mars and Beyond

Questions?

Acronyms

- Environmental Control and Life Support System (ECLSS)
- Urine Processing Assembly (UPA)
- Water Processing Assembly (WPA)
- Oxygen Generating Assembly (OGA)
- Carbon Dioxide Removal Assembly (CDRA)
- Sabatier Reactor Assembly (SRA)
- Contingency Water Container (CWC)
- Contingency Water Container – Iodine (CWC-I)