Challenges with Operating a Water Recovery System (WRS) in the Microgravity Environment of the International Space Station (ISS)

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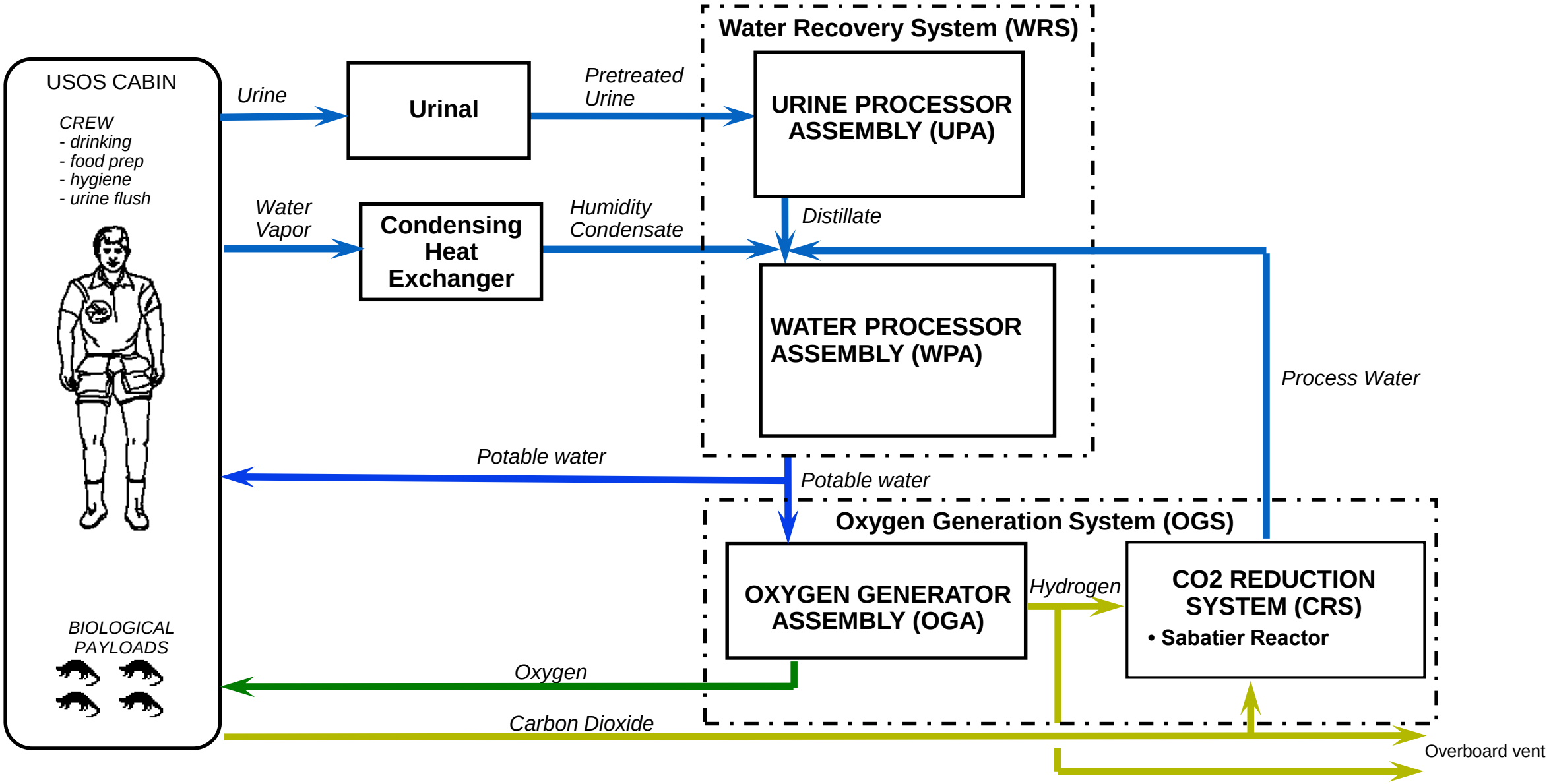
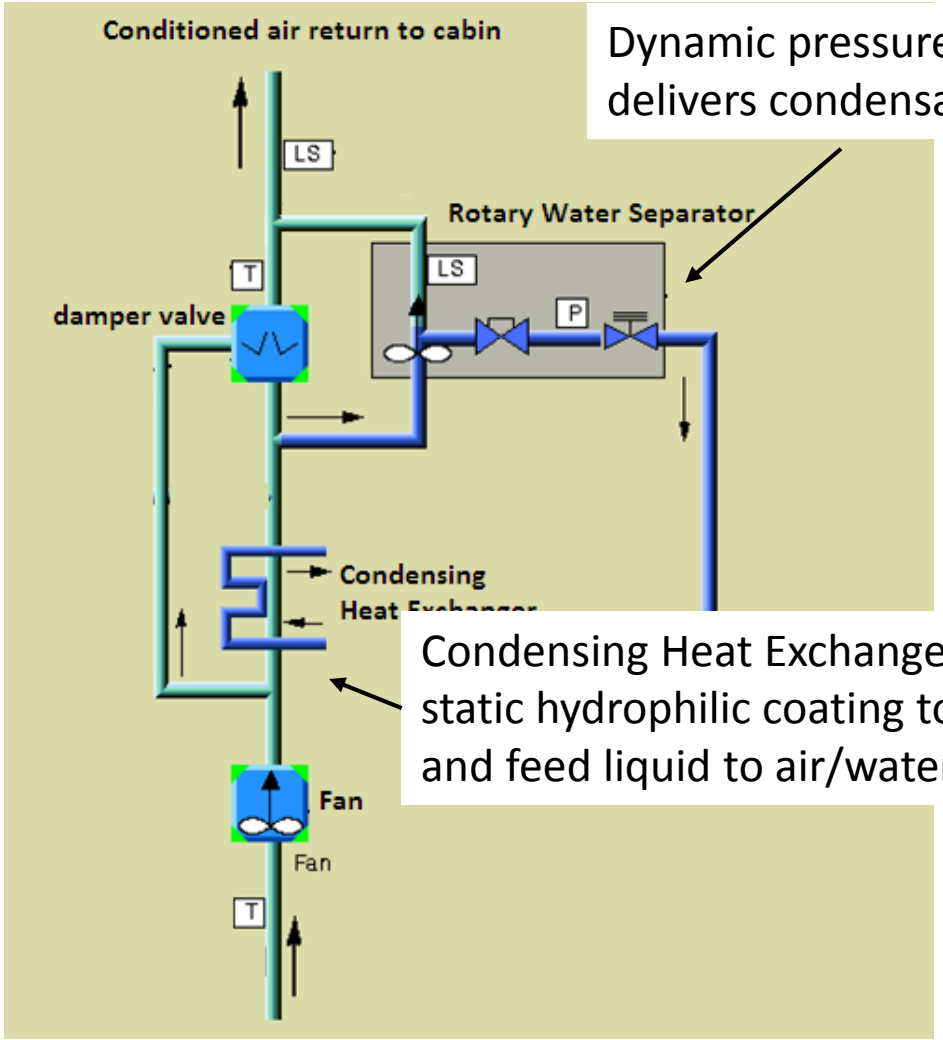
Introduction

- The ISS water system produces potable water by the reclamation of crew latent and urine
- The technologies are common to those employed on earth for water purification
  - Distillation
  - Filtration
  - Adsorption and ion exchange
  - Catalytic oxidation
- The design challenge was making these technologies work in the absence of gravity
- Primary issue is dealing with multi-phase fluid scenarios
  - Waste water collection
  - Phase separation
  - Distillation technology
  - Anomalies that create multi-phase fluids

ISS Water Recovery System

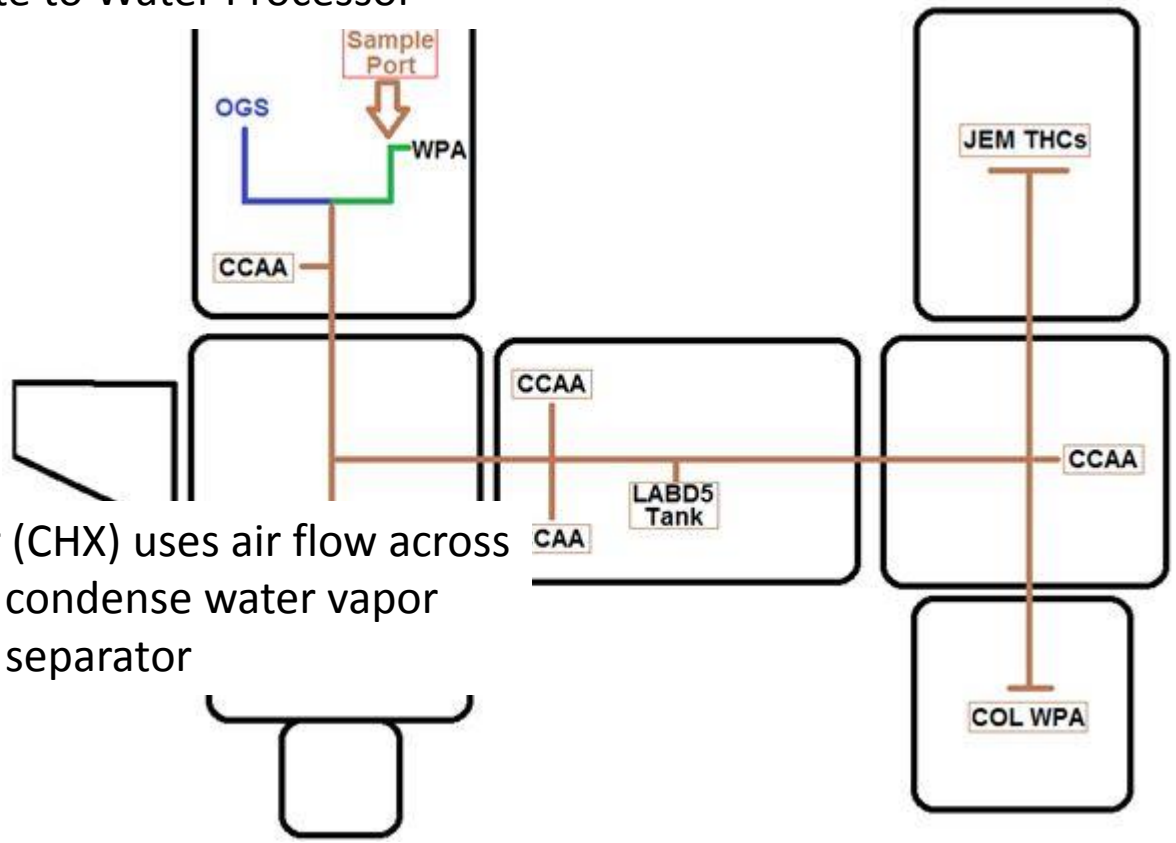


Common Cabin Air Assembly (CCAA)

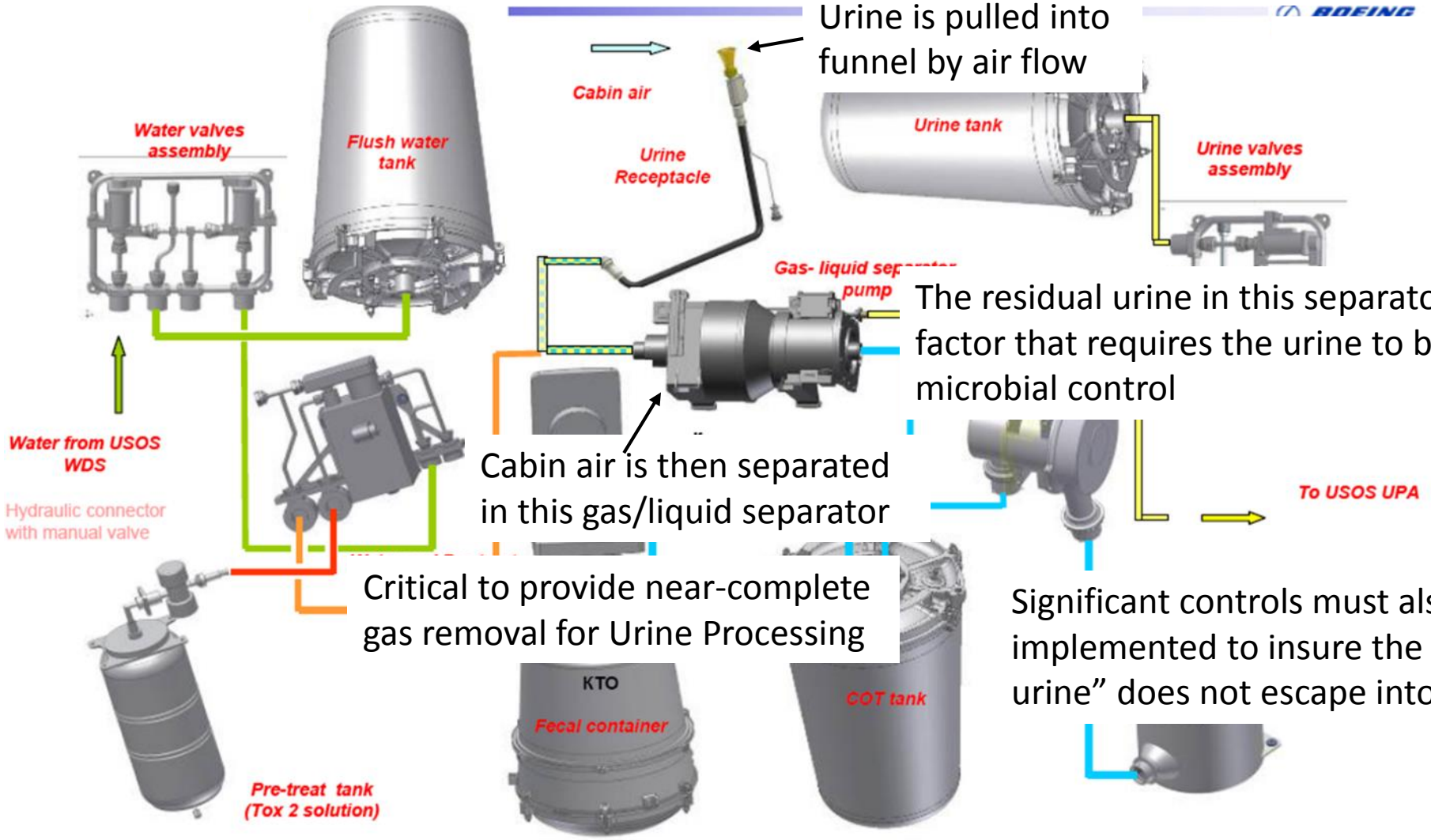


Dynamic pressure from rotary separator delivers condensate to Water Processor

Condensing Heat Exchanger (CHX) uses air flow across static hydrophilic coating to condense water vapor and feed liquid to air/water separator



Waste and Hygiene Compartment (Urinal)



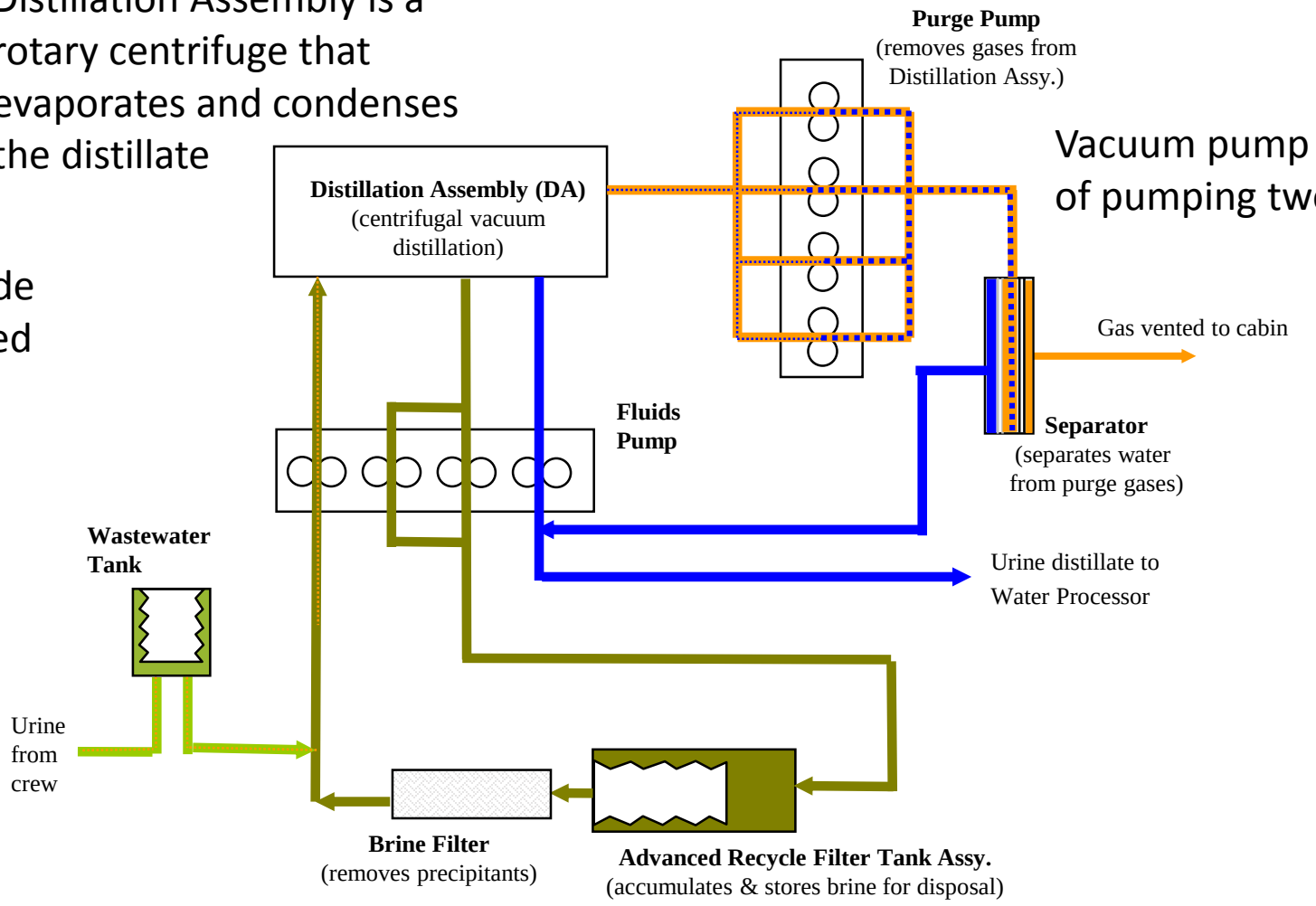
Urine Processor Simplified Schematic

Distillation Assembly is a rotary centrifuge that evaporates and condenses the distillate

Vacuum pump must be capable of pumping two-phase flow

Tank bellows must provide a positive pressure to feed the rest of the system

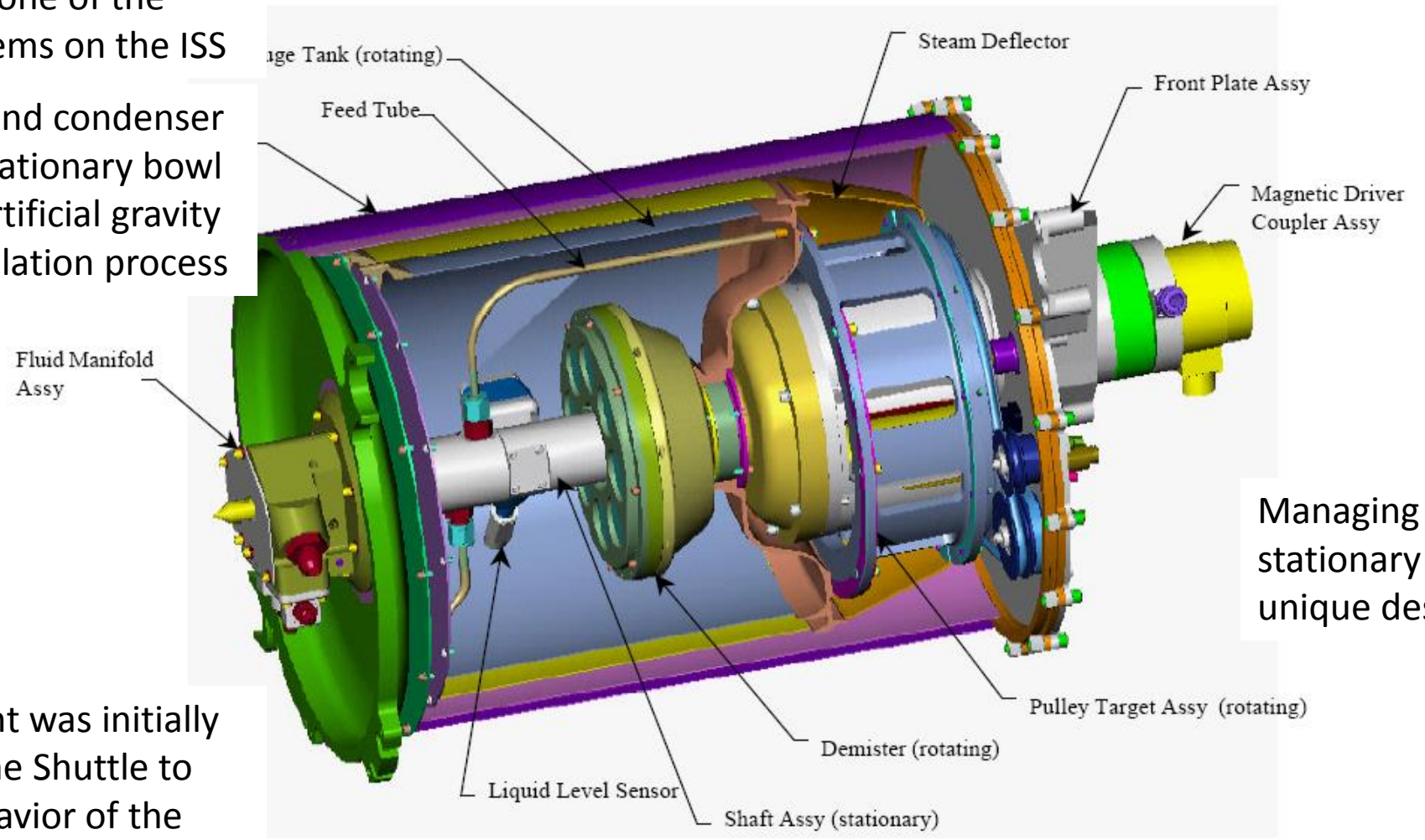
Gas in tank is difficult to remove, and provides starting point for microbial growth



Cross Section of Distillation Assembly

This assembly is one of the most complex items on the ISS

The evaporator and condenser spin inside the stationary bowl to maintain an artificial gravity field for the distillation process



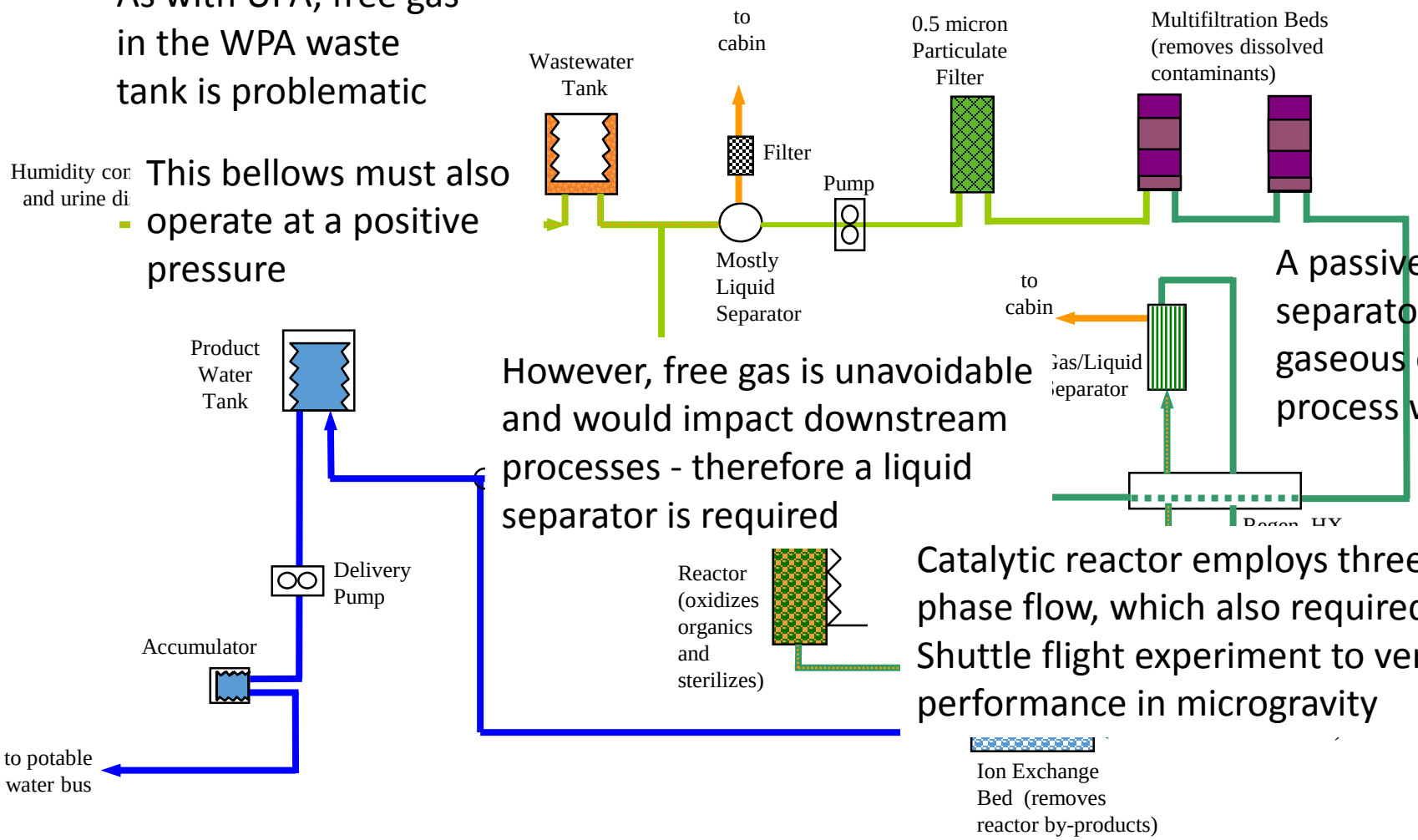
Managing condensate in the stationary bowl presented a unique design challenge

Flight experiment was initially performed on the Shuttle to confirm the behavior of the liquid in microgravity

Water Processor Simplified Schematic

As with UPA, free gas in the WPA waste tank is problematic

- This bellows must also operate at a positive pressure



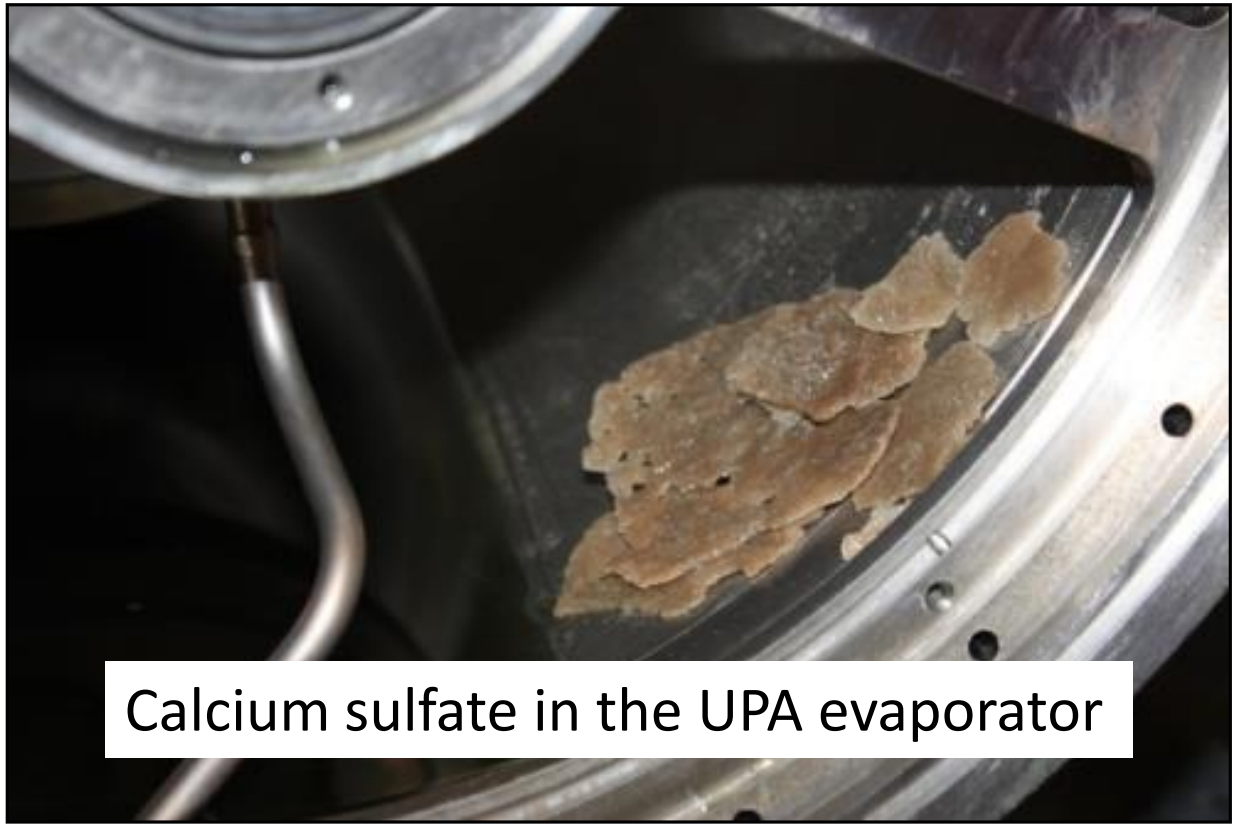
However, free gas is unavoidable and would impact downstream processes - therefore a liquid separator is required

A passive hydrophilic membrane separator is used to separate gaseous oxygen and CO2 from process water

Catalytic reactor employs three-phase flow, which also required a Shuttle flight experiment to verify performance in microgravity

WRS Anomalies on ISS due to Microgravity

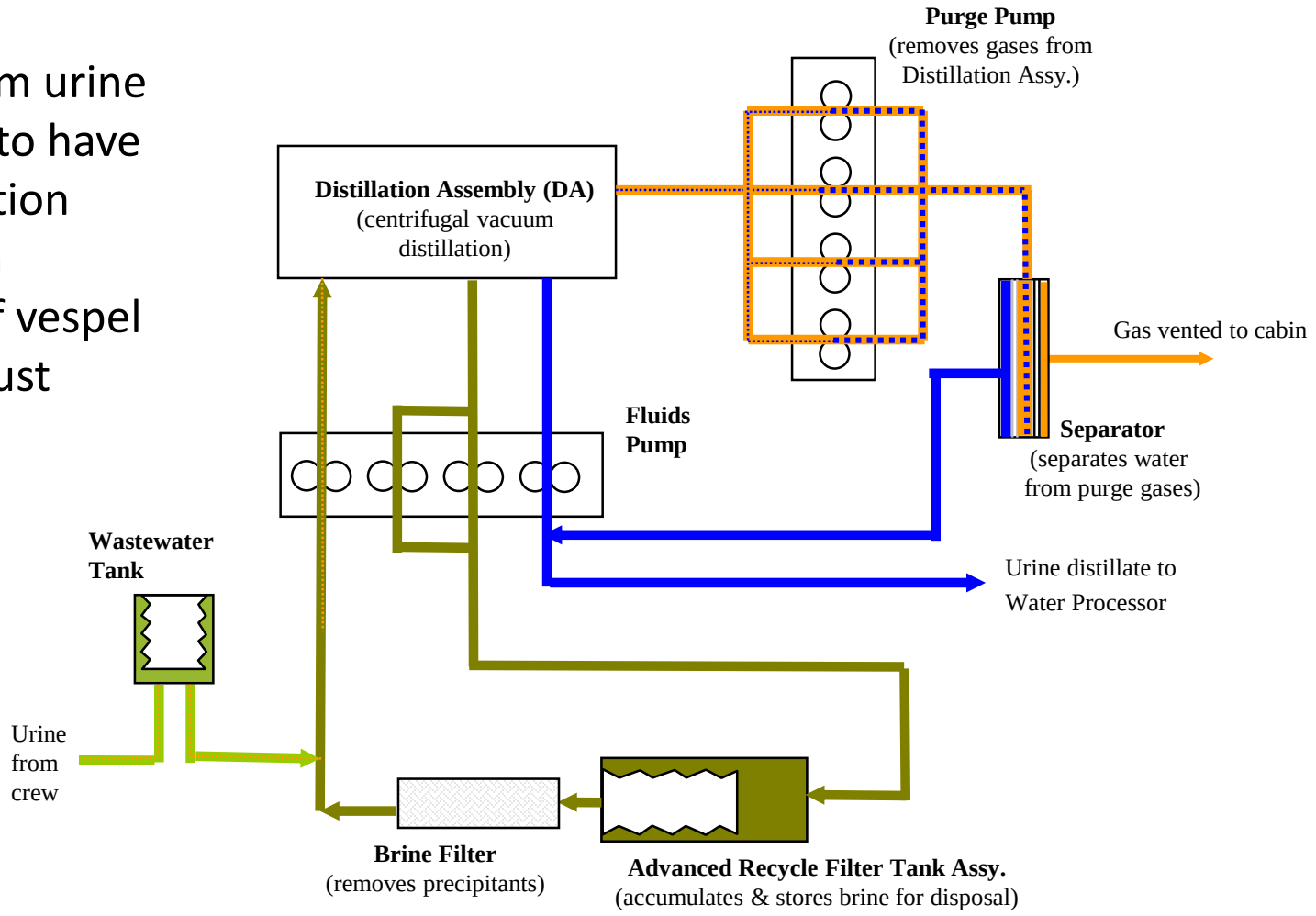
- Precipitation of calcium sulfate due to bone loss in microgravity



Calcium sulfate in the UPA evaporator

Urine Processor Operational Anomaly

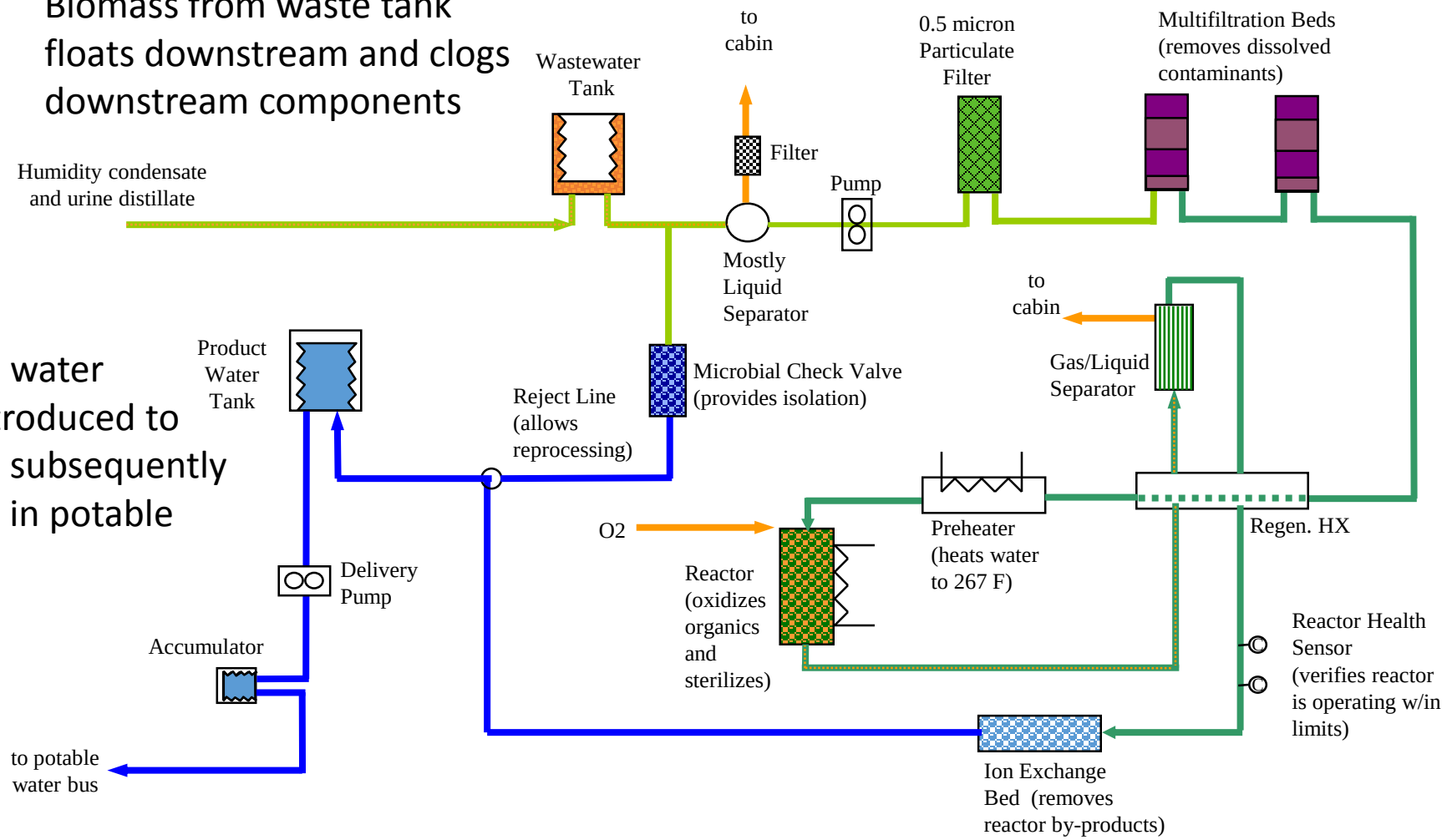
Excessive free gas from urine container is believed to have overwhelmed Distillation Assembly, resulting in significant quantity of vespel (compressor lobes) dust loading on Separator



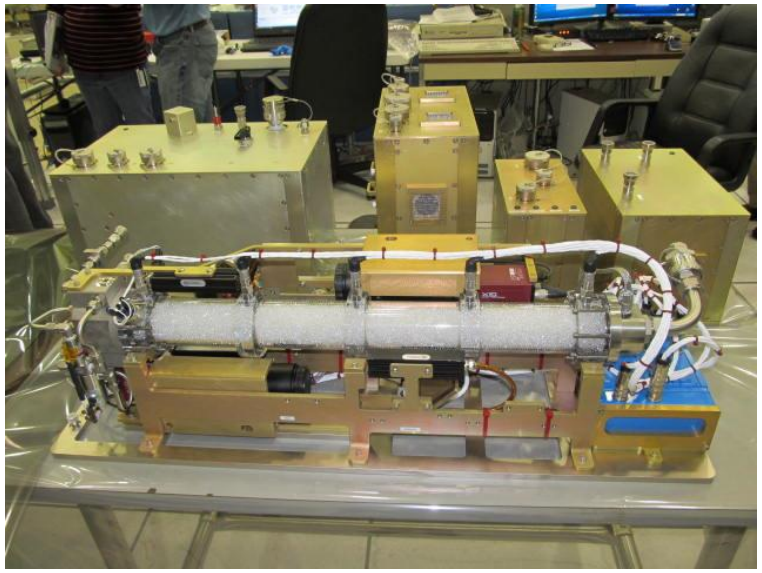
Water Processor Simplified Schematic

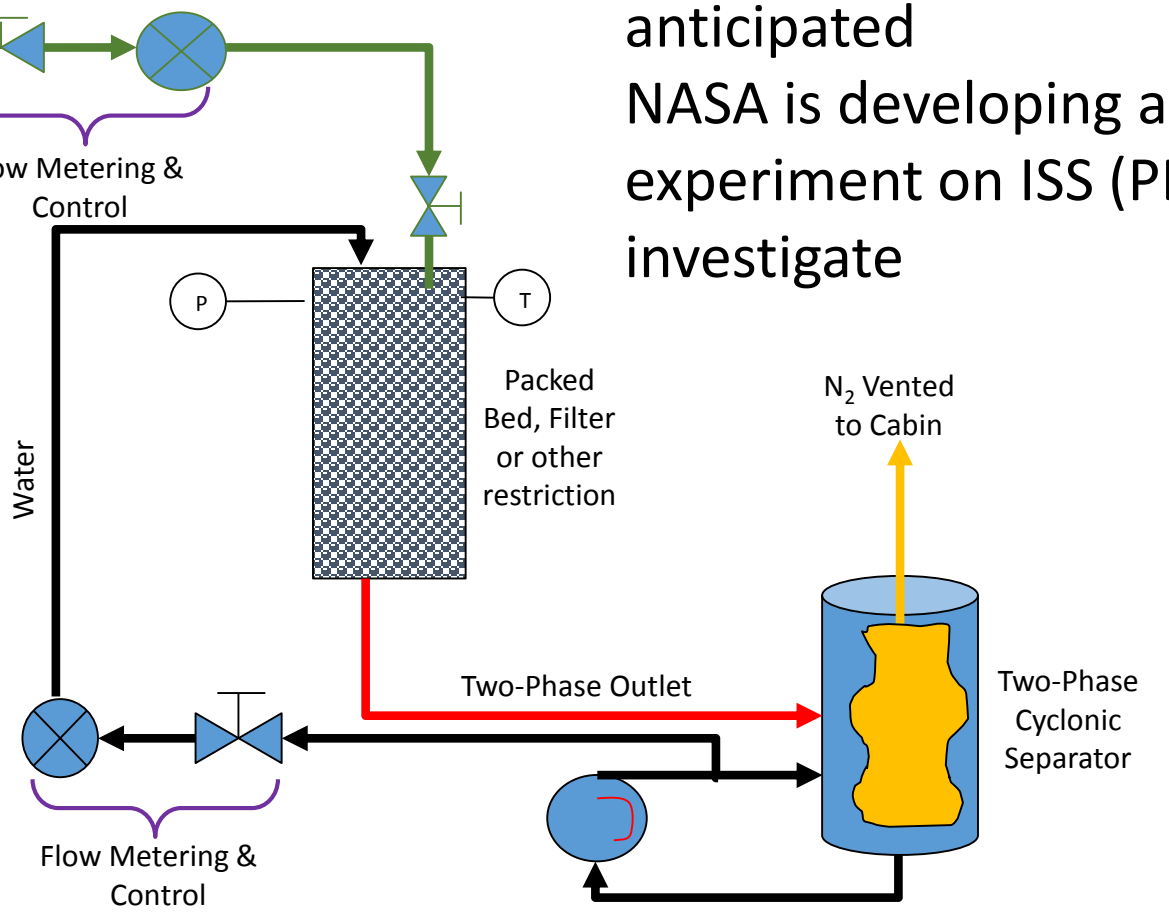
Biomass from waste tank floats downstream and clogs downstream components

Free gas from water containers introduced to Product Tank, subsequently clogging filter in potable dispenser



PBRE Simplified Flow Schematic





In multiple instances on ISS, pressure drop associated with two-phase flow was higher than anticipated

NASA is developing a flight experiment on ISS (PBRE) to investigate

Lessons Learned

- Design robust solutions for multi-phase flow
- Be prepared for free gas in liquid systems
- Anticipate worst-case scenario for destination of solids