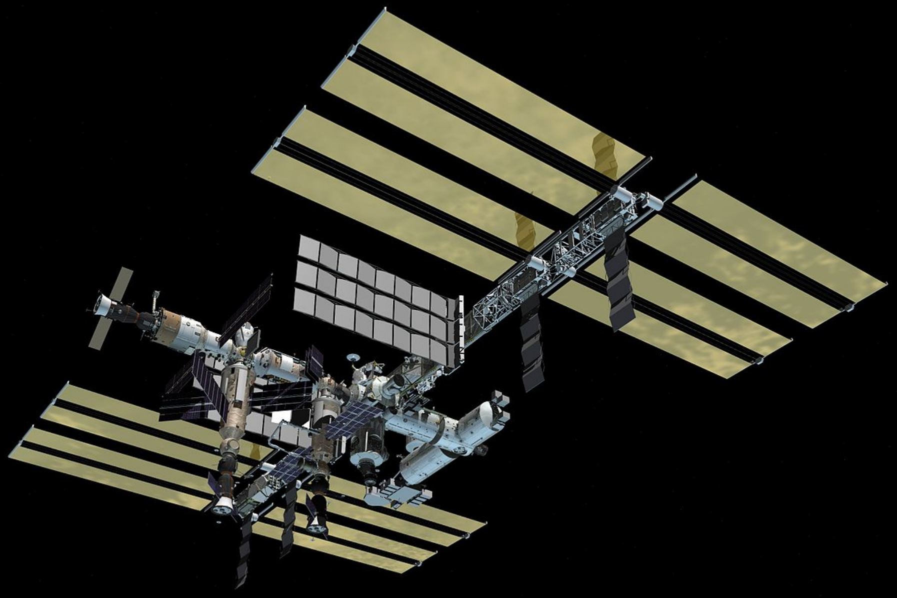


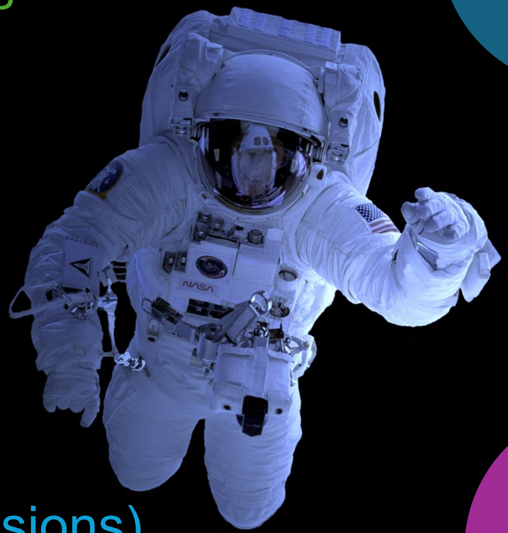
An Integrated System for Water and Nutrient Recovery to Enable Sustainable Space Habitation

Alaa Kullab, Abhilash Vakkada Ramachandran*, Isra Omer, Frederico Marques Penha, Prithvi Simha, Anastasija Vasiljev, Arjun Monga

Importance of Environmental Control Life Support System (ECLSS)

Environmental Control and Life Support Systems (ECLSS) are essential for sustaining human life in space.

They provide breathable air, clean and sufficient water, waste treatment, and maintain thermal conditions.



Open-loop (supply-dependent, short missions)

Closed-loop (regenerative, long missions).

The future of deep space missions depends on efficient, closed-loop ECLSS.

Water Reuse is Critical in Space

Life Support Requirements (Per Person-Day)

Daily inputs - Nominal

Oxygen	0.84
Food Solids	0.62
Water in Food	1.15
Food Prep Water	0.76
Drink	1.62
Hand/Face Wash	4.09
Shower Water	2.73
Clothes Wash Water	12.50
Dish Wash Water	5.45
Metabolized Water	0.35
TOTAL	30.60

Daily outputs - Nominal

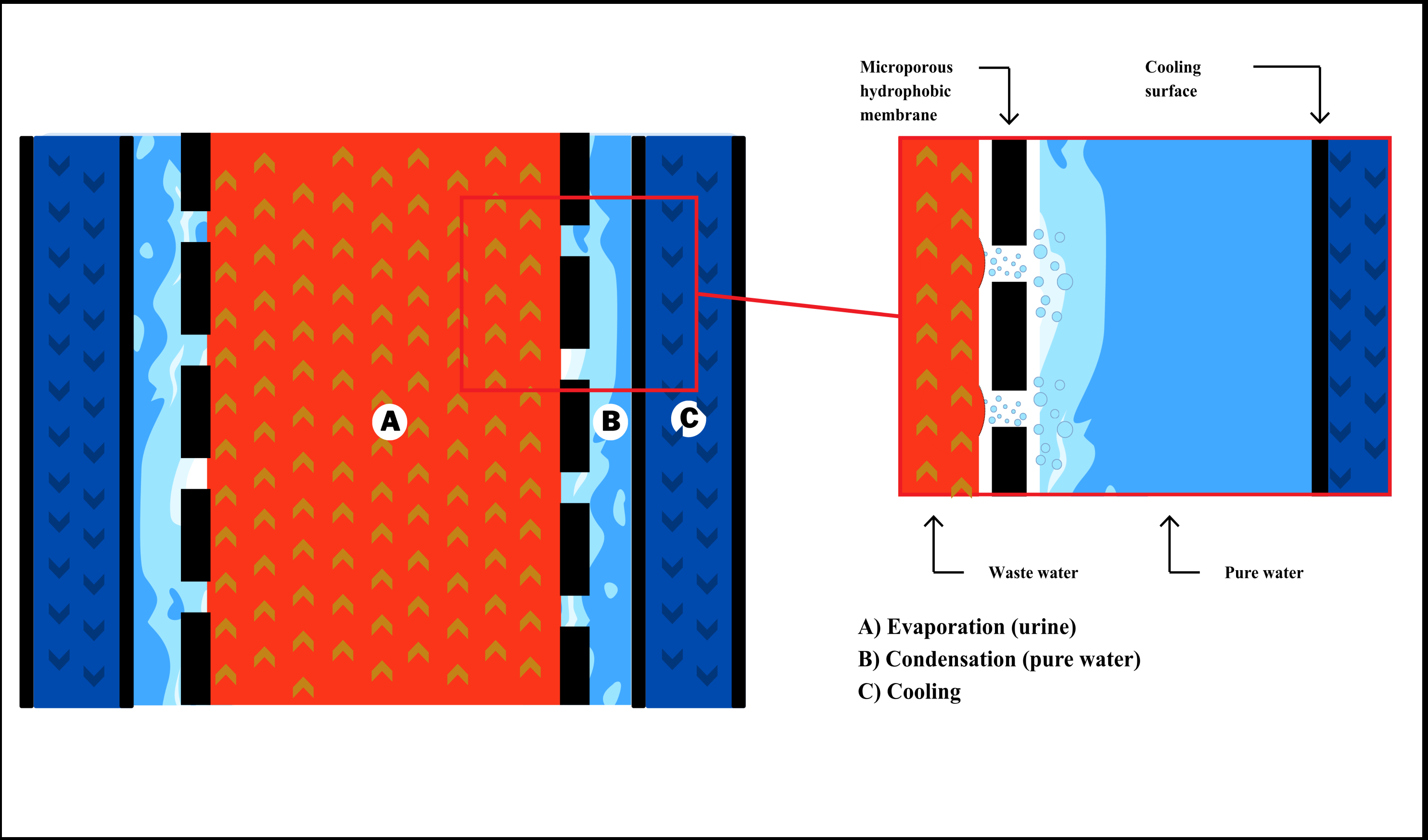
Carbon Dioxide	1.00
Respiration and Perspiration Water	2.28
Urine	1.50
Feces Water	0.09
Sweat Solids	0.02
Urine Solids	0.06
Feces Solids	0.03
Hygiene Water	12.58
Clothes Wash Water	11.90
Clothes Wash Latent Water	0.60
Other Latent Water	0.60
Food prep. Latent Water	0.04
Flush Water	0.50
TOTAL	30.60

Credit: NASA BVAD

hydromars™

USP: Zero-waste water management for Space & Earth

Solution:
harnessing the principle of membrane distillation under controlled conditions



Core principle

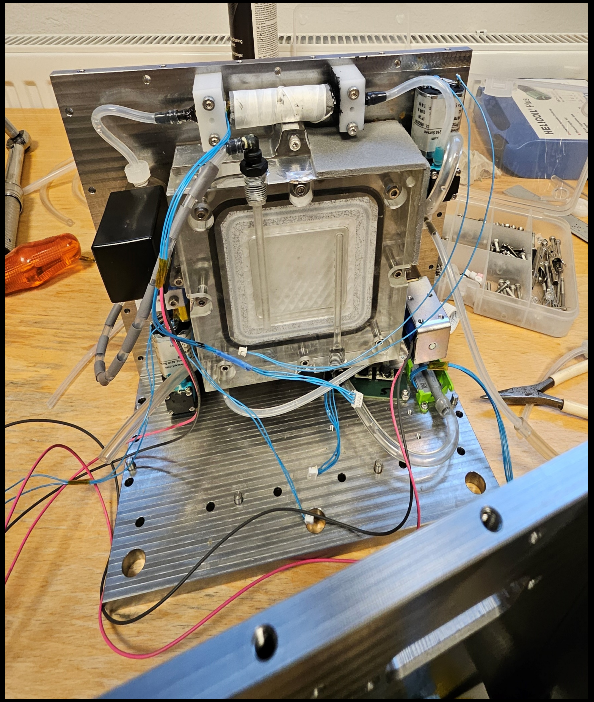
- sub-boiling evaporation-condensation with a hydrophobic membrane and a novel permeate gap that reduces heat loss, maximises thermal efficiency, achieving high water recovery.
- patented plate-membrane bonding forms sealed condensation chambers with integrated cooling.

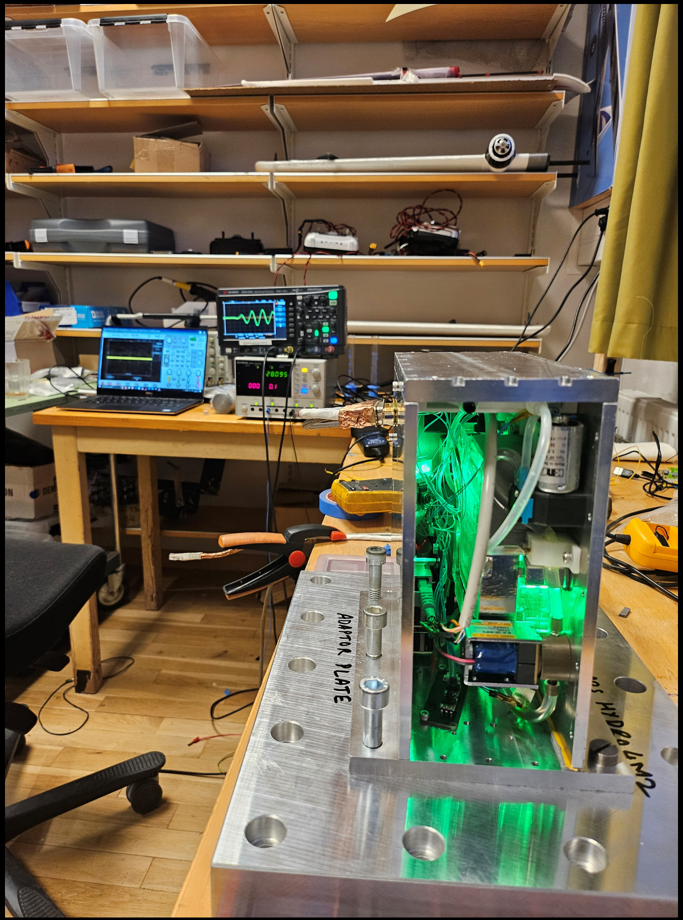
Hydro4M2 - selected by ESA for space validation 1(2)

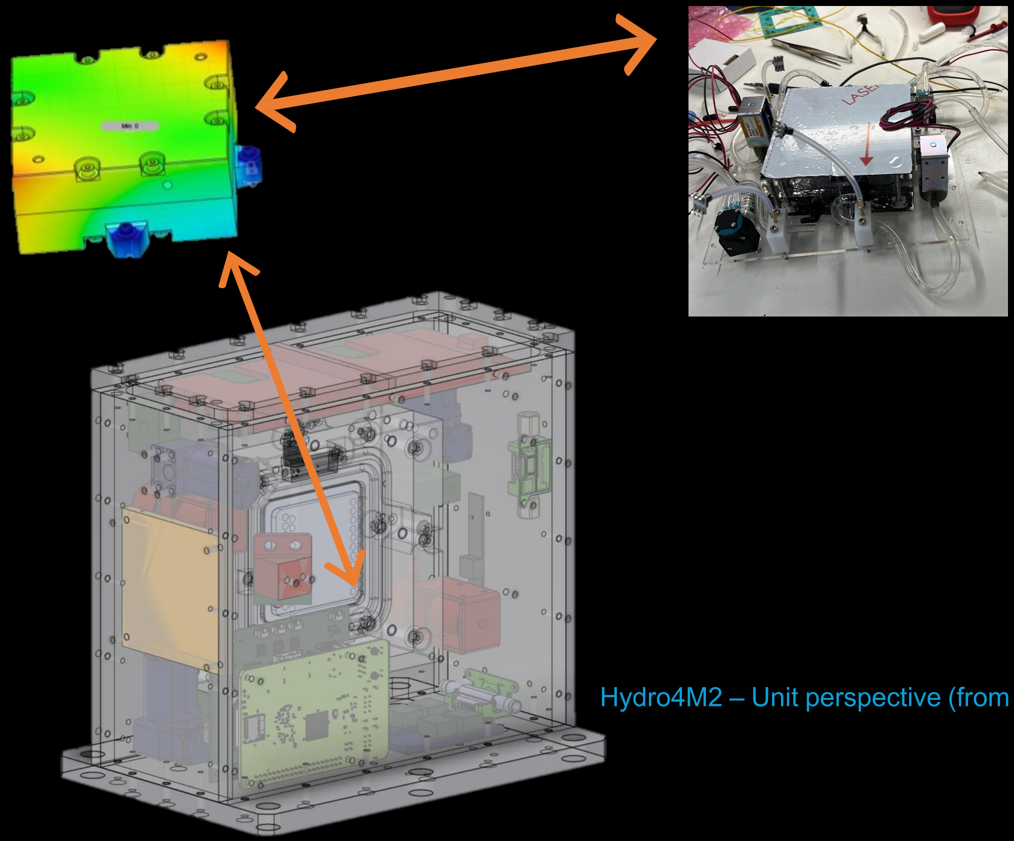
- → A drastically scaled-down version to **test technology performance when in microgravity**
- → **World's first** orbital class VMD demonstrator
- → **World's smallest** space-grade water treatment unit

Sketch
May 2023

Flight ready
August 2024







Hydro4M2 – Unit perspective (from inside)

Hydro4M2 – product delivery and launch 2(2)

→ Delivered to TEC: December 13, 2024
→ Integrated Into Nyx capsule: March 2025
→ Launch from Falcon 9: June 2025

Project SUSTAIN

Rymdstyrelsen
Swedish National Space Agency

Project SUSTAIN

Tests on human urine on Hydromars proprietary proof-of-concept unit, Novum labs, 2025

hydromars™

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SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES
SLU

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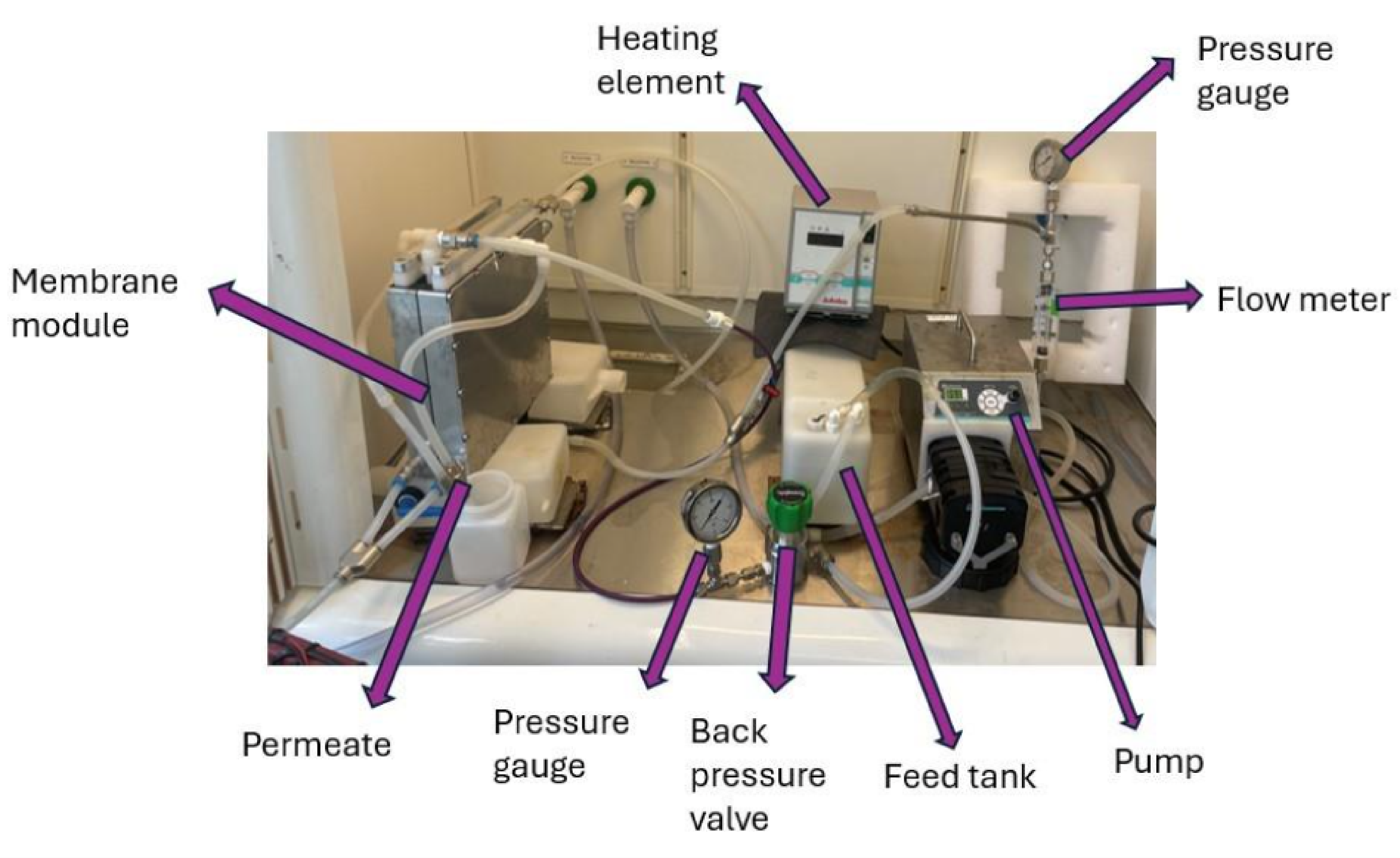
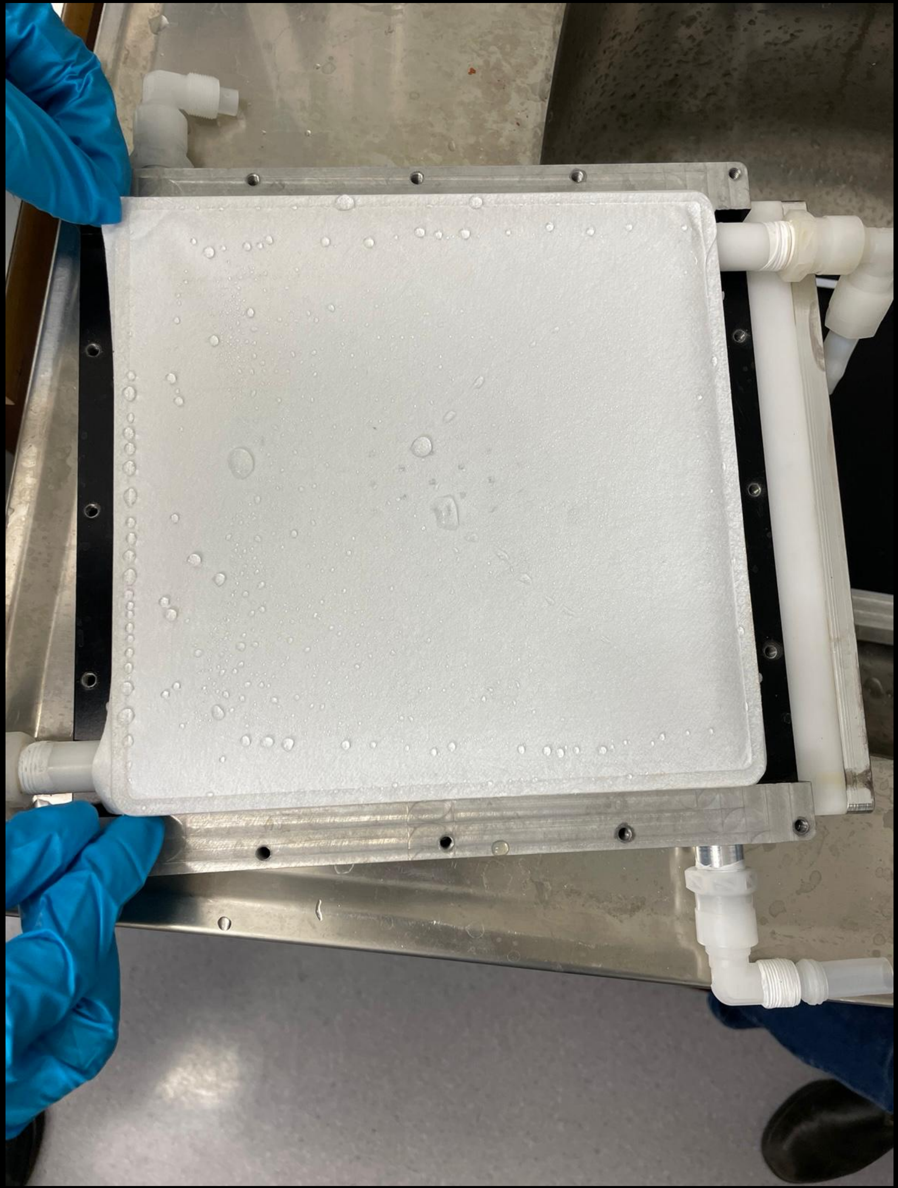
Experimental setup

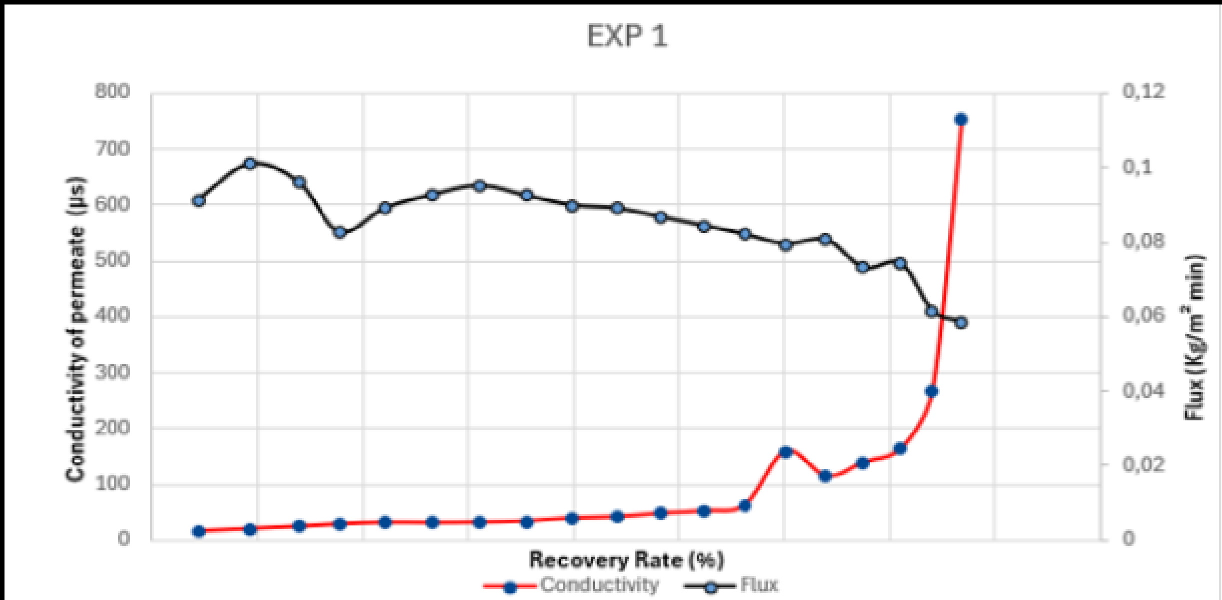


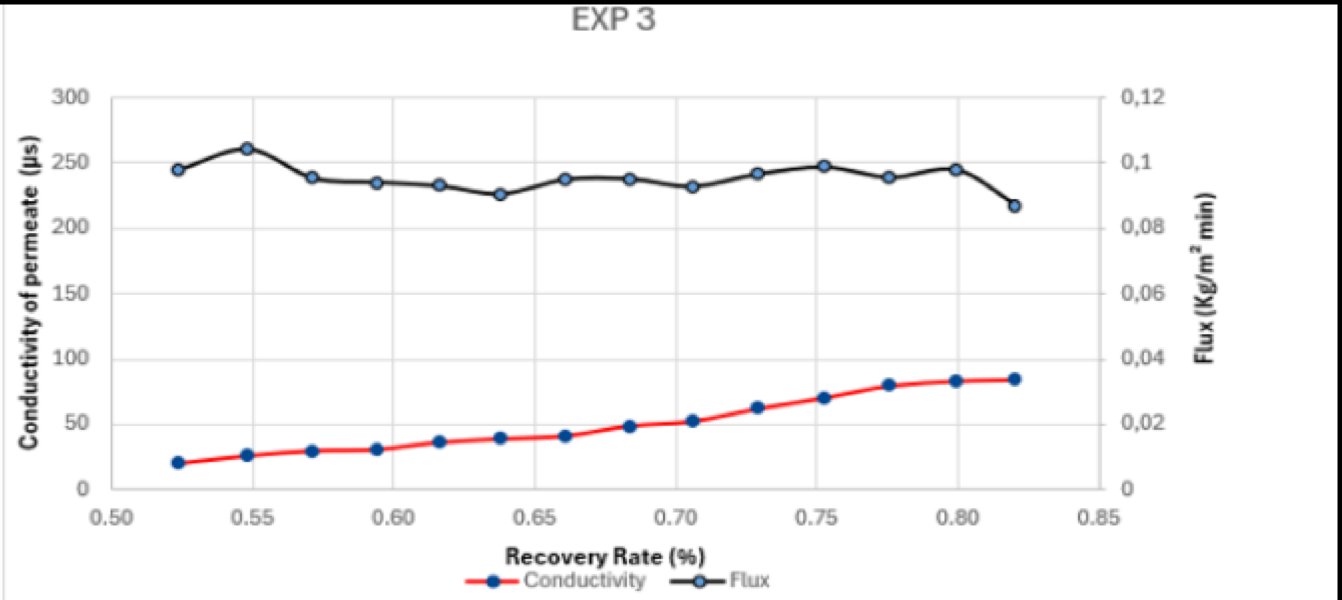
Membrane module

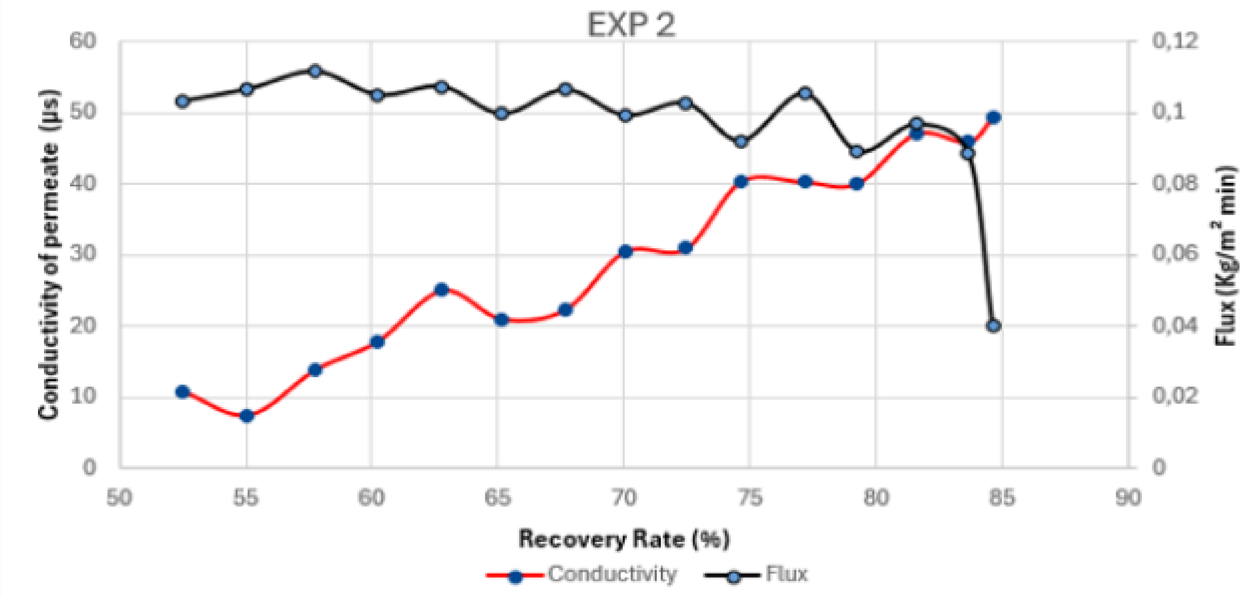


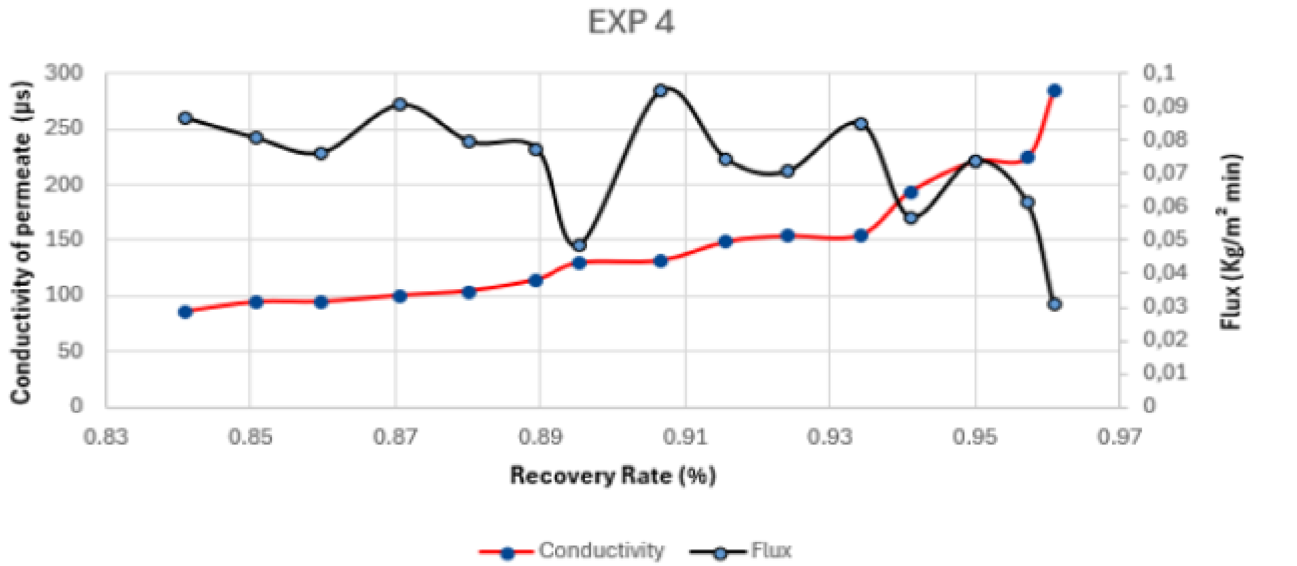
- Permeate flux of 500 ml/hour
- PTFE hydrophobic membrane
- 0.1 micron
- Thickness 0.2 mm
- area(20*20 cm) =0.08 m2
- Feed (65-70 C)
- 1.4 l/min
- Cooling (20-25 C)

Recovery rate

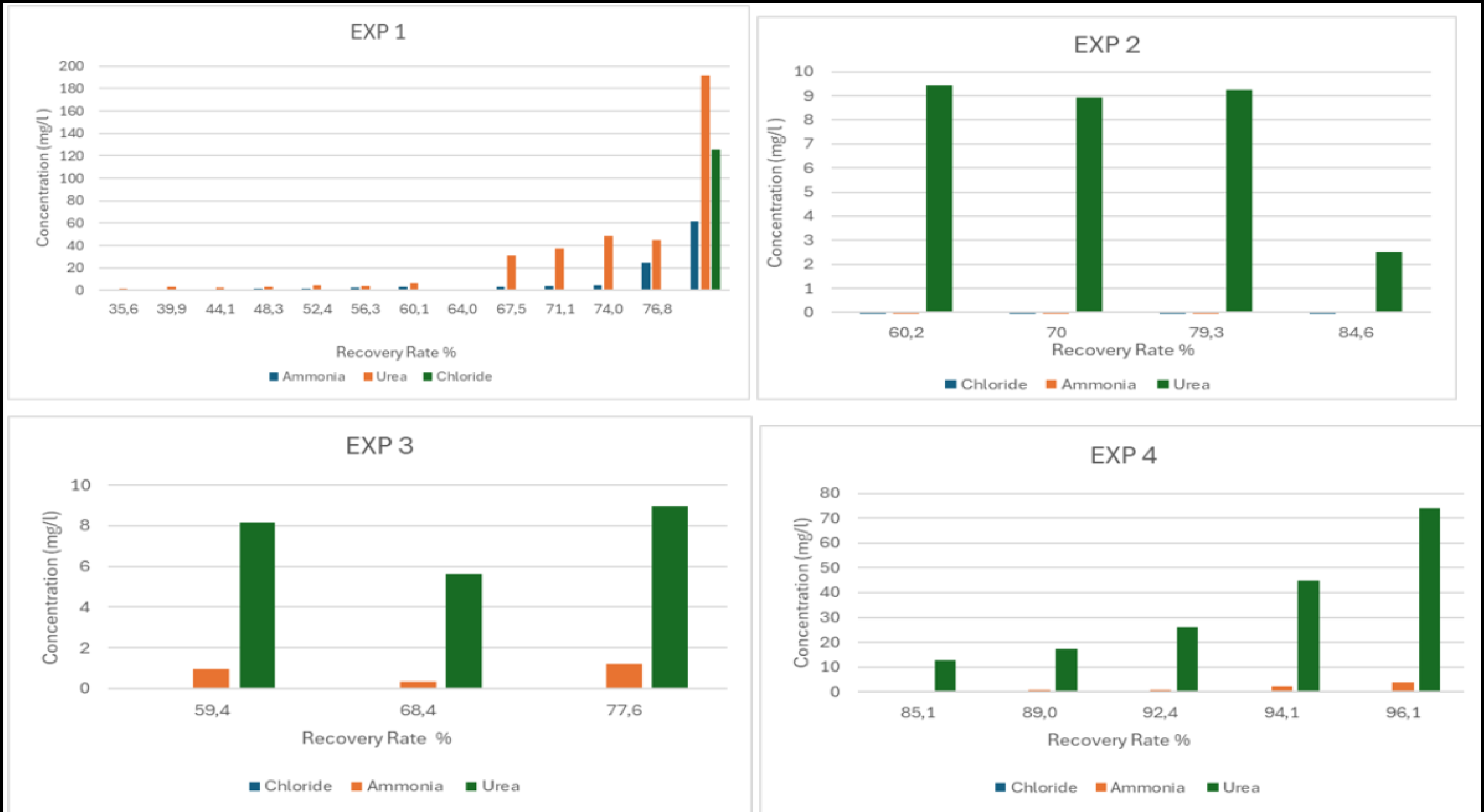








Concentration analysis of the permeate



Results

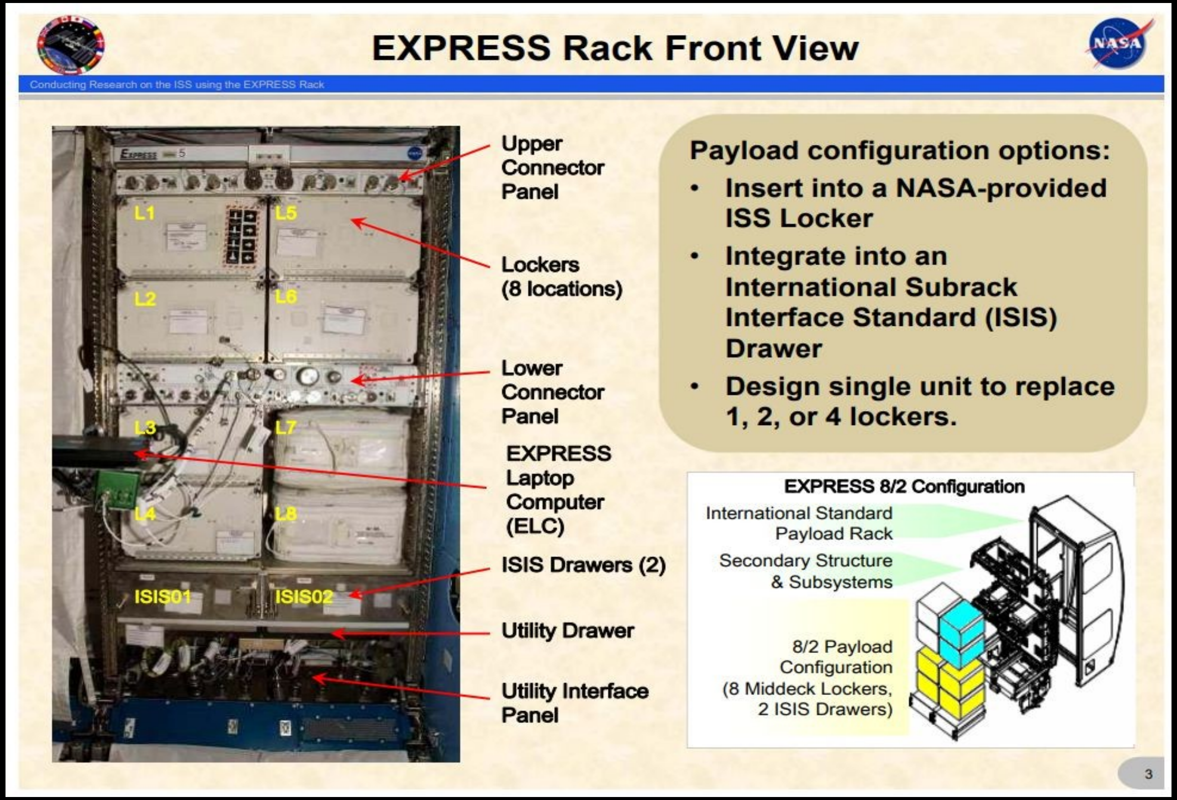
- **Conductivity Trends:**
  Conductivity of the permeate increased with recovery rate in all experiments.
  – Sharp rise after 60% recovery in Experiment 1 (after overnight pause).
  – Gradual increase in Experiments 2 and 4.
- **Flux Decline:**
  Flux decreased as recovery increased.
  – Stable initially in Experiment 1, then dropped sharply.
  – Steady decline in Experiments 2 and 4, indicating earlier fouling or concentration polarization.
- **Solute Transport:**
  Urea detected in permeate in all experiments, increasing over time.
  Ammonia transport more pronounced in Experiments 1, 3, and 4.
- **Ion Rejection:**
  Chloride fully rejected in Experiments 2-4; breakthrough only in late stage of Experiment 1.
  → Confirms strong rejection of non-volatiles and partial passage of volatiles (urea, ammonia).

Hydromars within CRS mission to ISS (2025-2027)

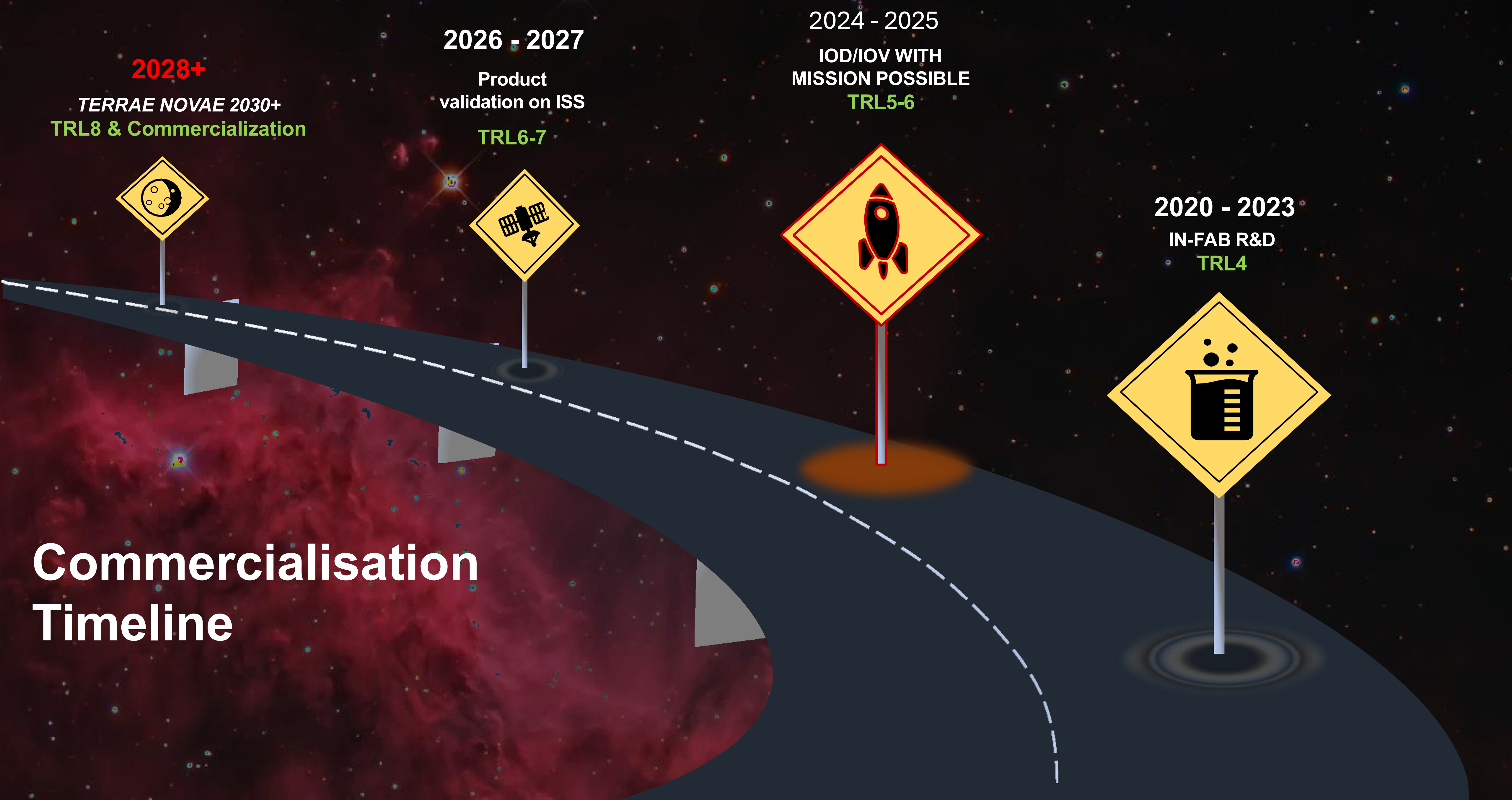
→ Target: Test sub-scale system within ISS Middeck Locker

→ Feed: astronauts' urine

→ Duration: 20 days of testing and validation



Commercialisation Timeline



Thank you!