

NASA HUMAN LANDER CHALLENGE 2026, HUNTSVILLE, AL

P.H.A.T.

Peltier-based Hydration Accumulation Terminal

Adding cold water functionality to existing flight-proven technology

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Faculty



Faculty Advisor
John Chen



Senior Project Coach
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Team Members



Team Co-Lead
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Treasurer
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Manufacturing
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Team Co-Lead
Ethan Pace



Project Manager
Renee Rebolledo



Secretary
Sabrina Luo

The Challenge

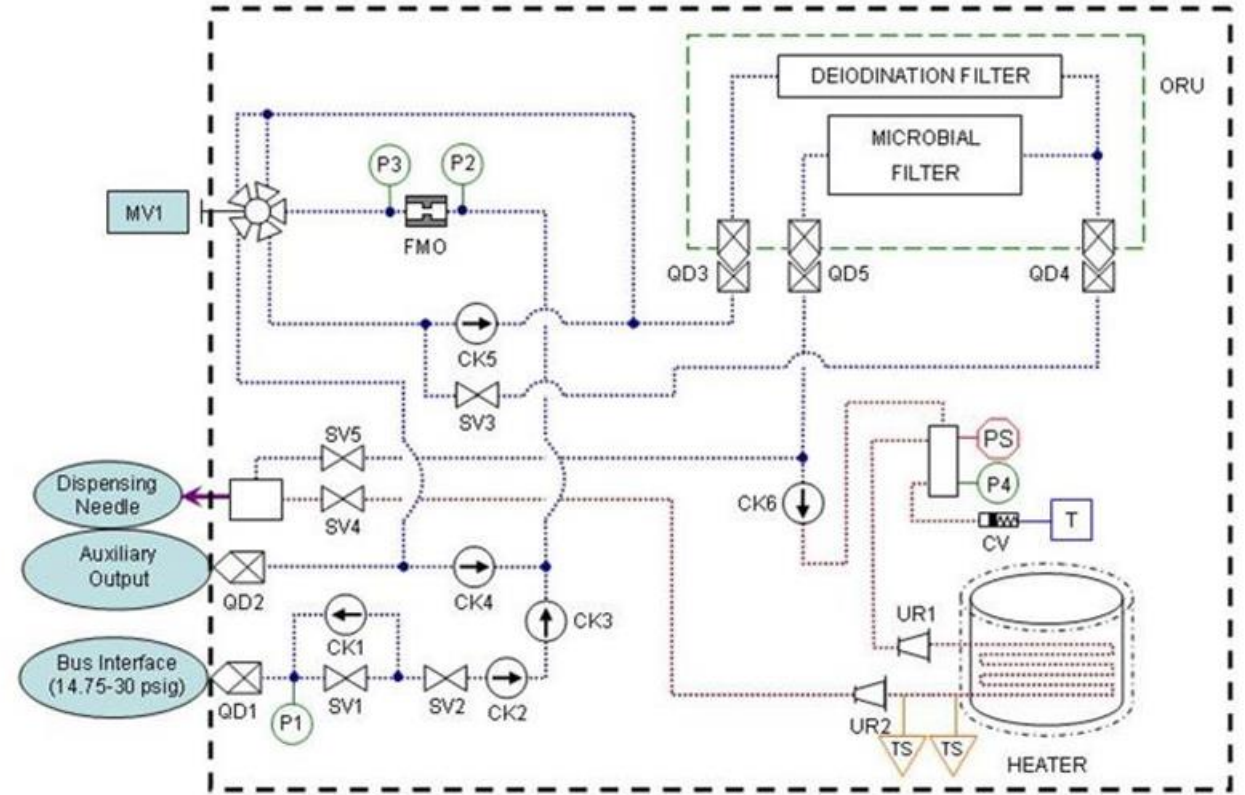
Current NASA Potable Water Dispensers

68 - 79°C

Stated by NASA-STD-3001

18 - 27°C

Stated by NASA-STD-3001



Objectives & Constraints

≤ 16°C outlet

Meet NASA-STD-3001 standard under worst case water temperature (27°C)

Preserve heritage

Keep flight-proven hot & ambient dispensing intact

No refrigerants

Solid-state cooling — gravity-independent, no compressor

Rack-scale fit

Package within the spacecraft / Express Rack interface

30 & 1,200-day life

Lunar and Mars-forward mission durations

Maintainable & modular

Crew-replaceable hardware, minimal added risk

The PHAT Impact

Mission impact	First cold potable water in a flight dispenser lineage
Technology readiness	Heritage TRL 9; new risk contained at the subsystem
Affordability	Adapts a proven design instead of a clean-sheet rebuild
Programmatic fit	Two Express Rack lockers, no new spacecraft interfaces
Risk	Solid-state, no refrigerants; cold failure never affects hot/ambient

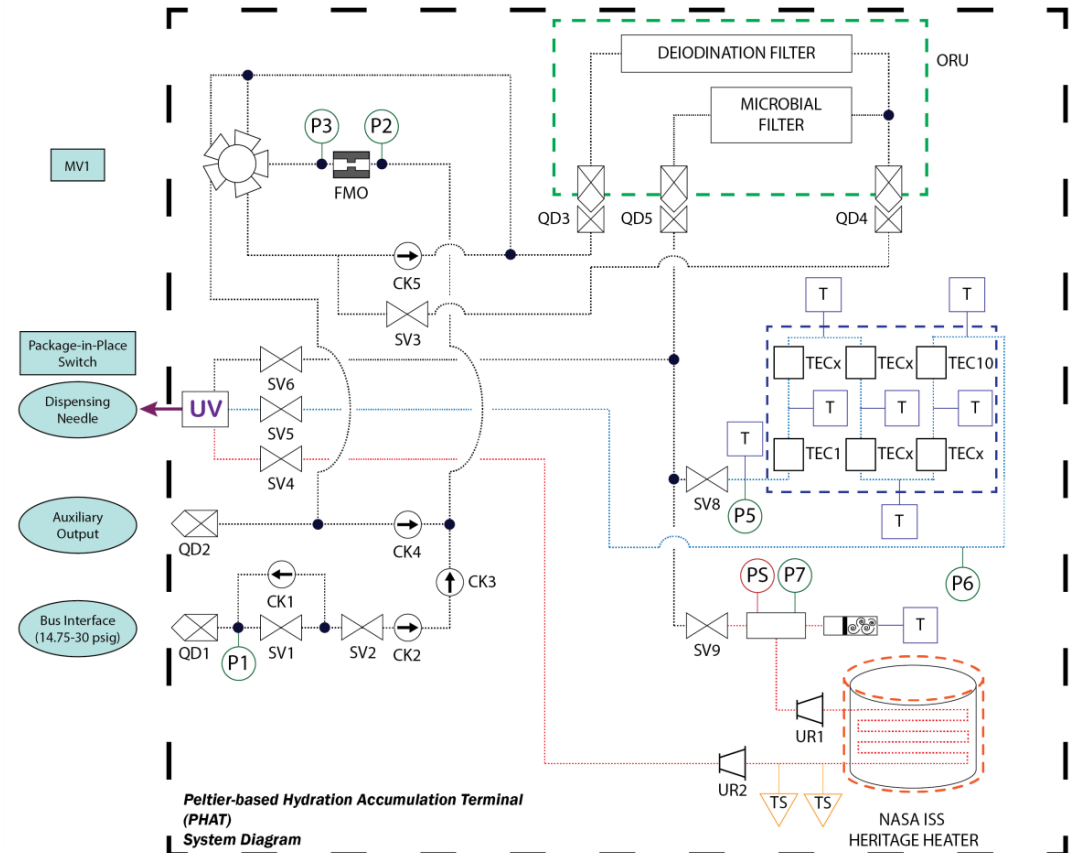
Overall Design

THE PHAT PREMISE

Provide crewmembers with cold water by integrating thermoelectric cooling into proven systems.

0 - 16°C

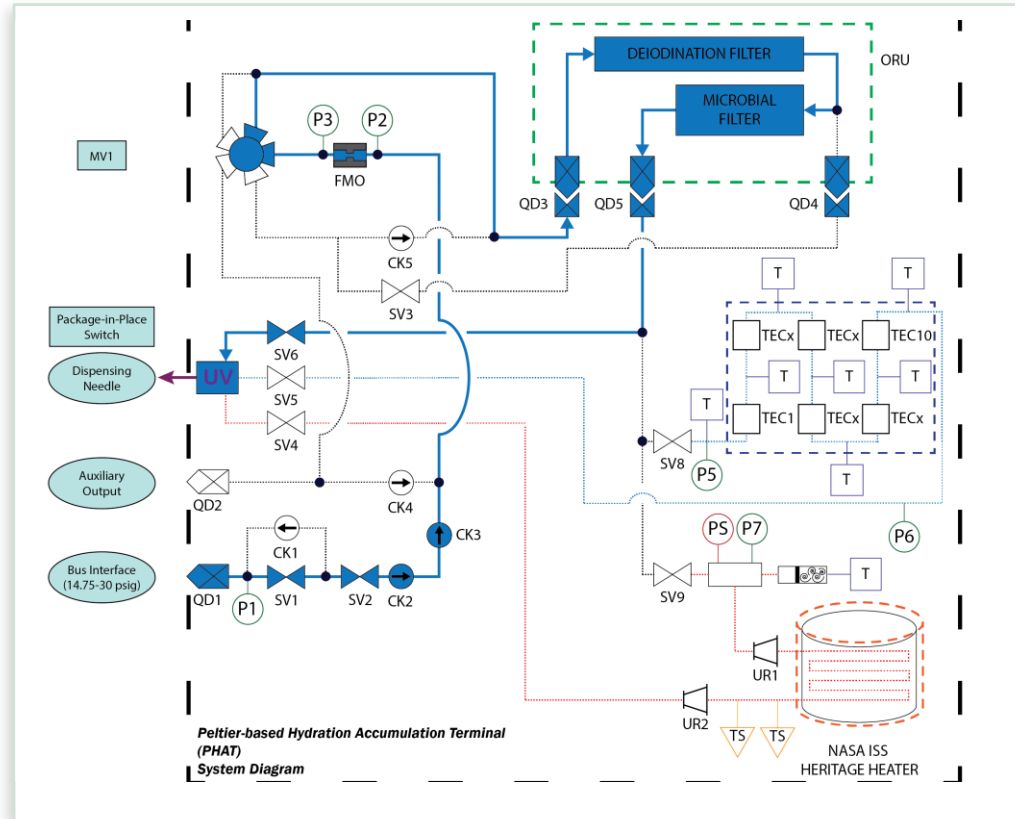
Stated by NASA-STD-3001



PHAT extends the ISS PWD architecture — heritage core preserved

Concept of Operations

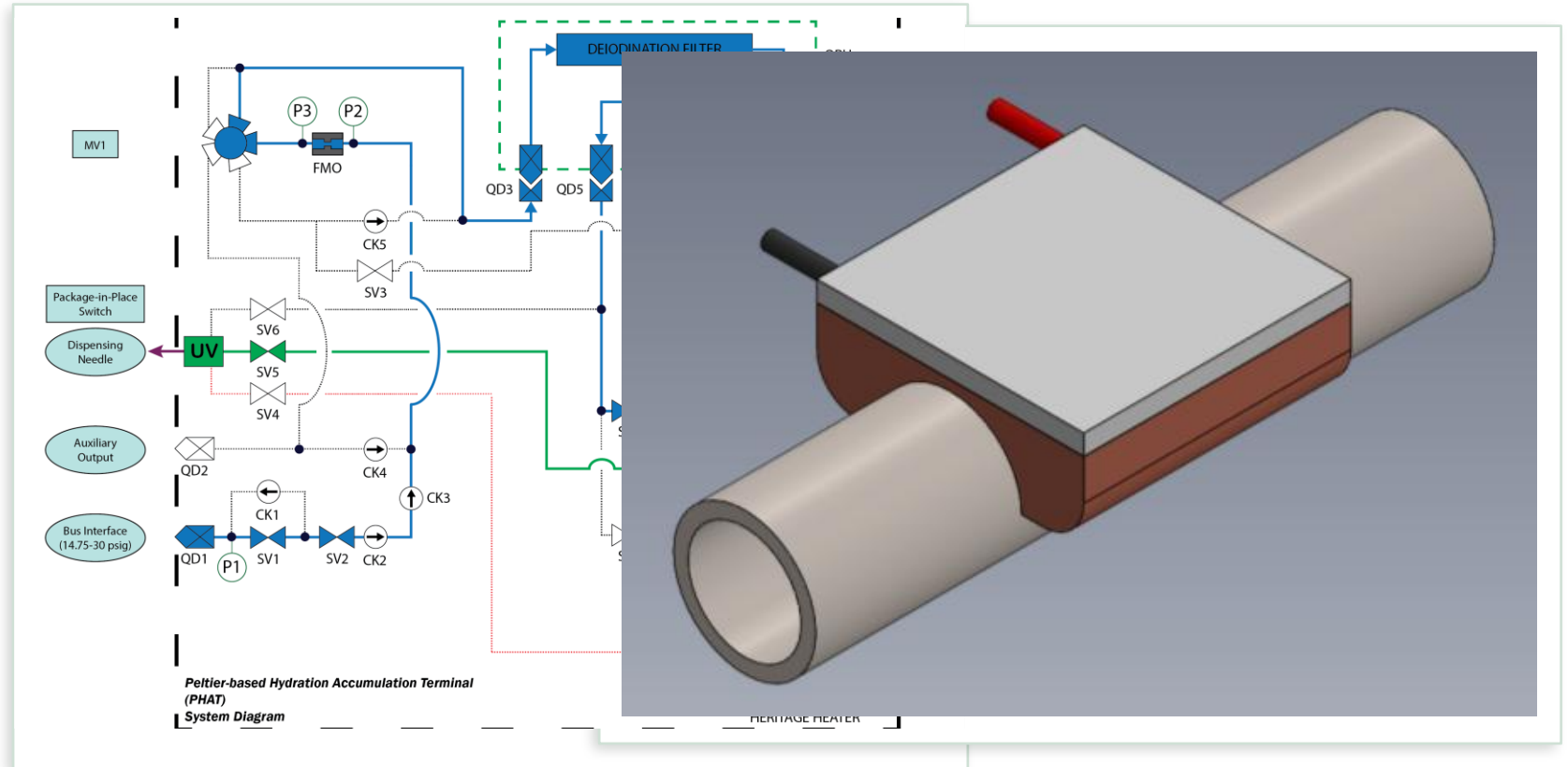
AMBIENT



— Ambient water

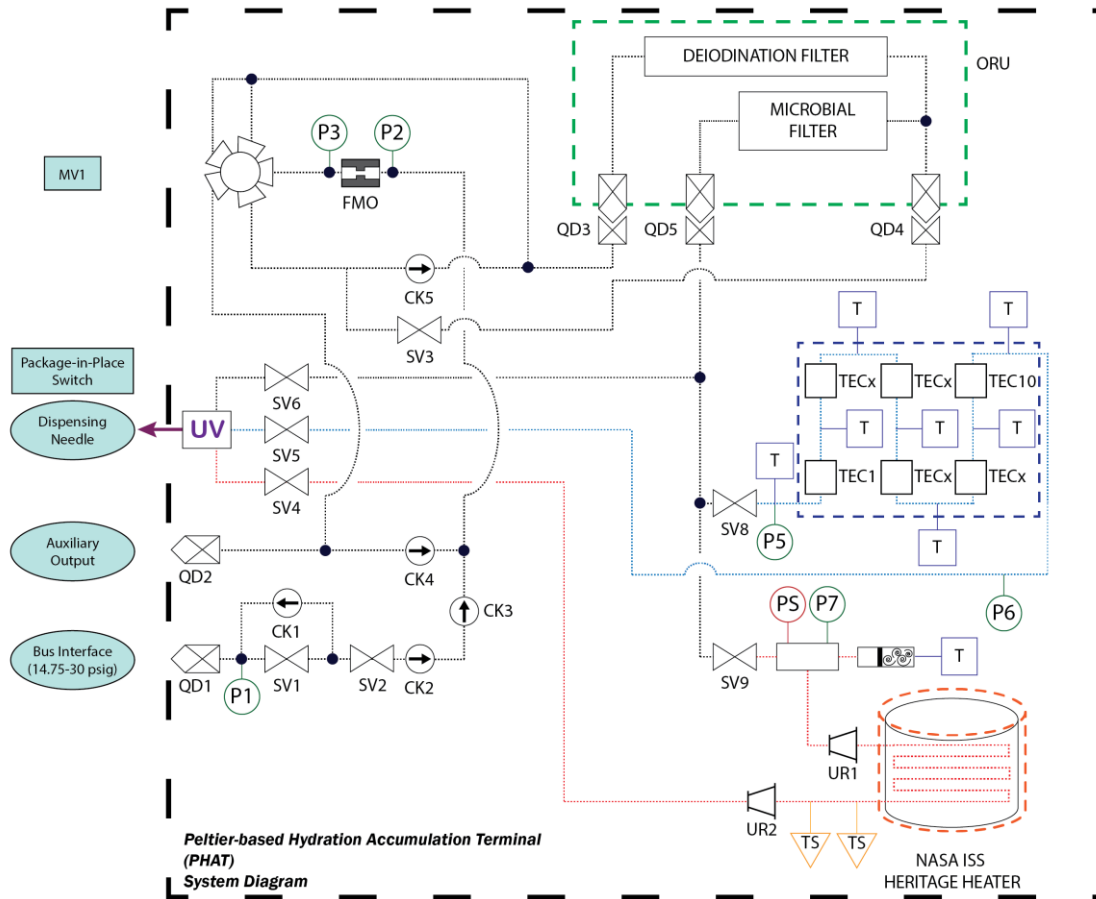
Concept of Operations

COLD



— Cold water

Architecture



- **Hot / ambient path = unchanged ISS PWD**
- Cold branch is a discrete, testable, replaceable subsystem
- ACTEX deionization retained for iodine removal
- In-line UV-C adds microbial-control redundancy
- **Develops & fails independently of the heritage core**

Cold-Loop Design & Material Compatibility

Design Driver

- Iodinated water is incompatible with copper
- Therefore, 316L stainless steel is the only wetted material

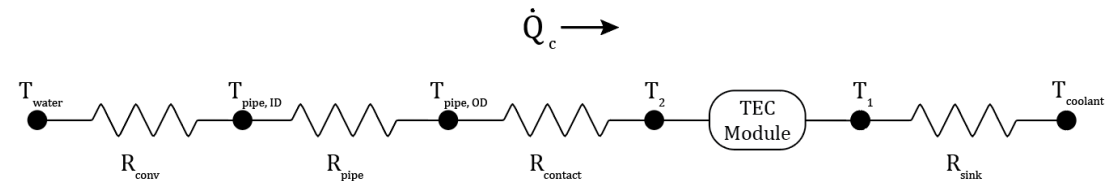
Solution

- External copper saddle block for thermal coupling
- Liquid-cooled hot side and aerogel-insulated cold side

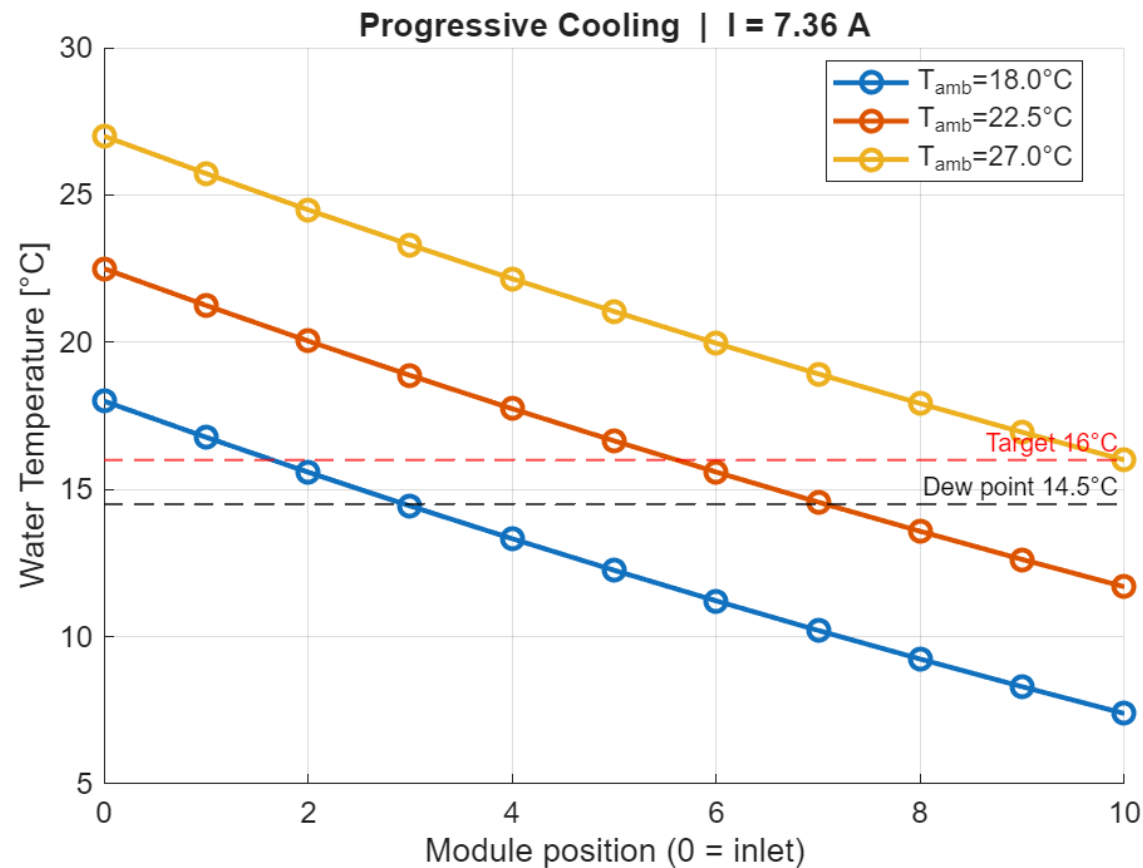
Trade

- Higher cold-side resistance accepted
- Preserves water-system compatibility

Cold-side thermal path (heat flow →)
Water → 316L Pipe → Copper Saddle → TEC → HX Coolant Loop



Stage-by-Stage Cooling Performance



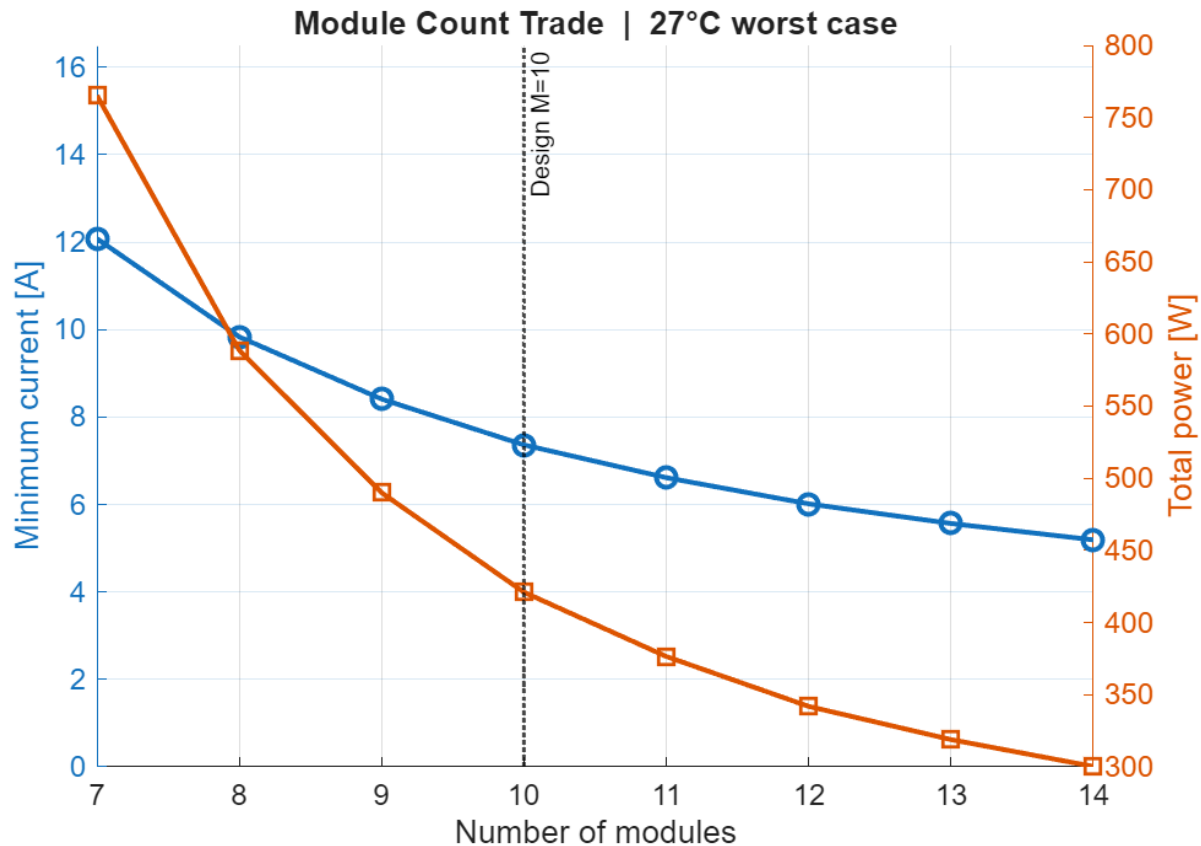
Why Sequential?

- Each module receives colder water
- Cooling capacity decreases downstream
- COP decreases downstream

Results

- 10 modules required
- 16°C outlet achieved at 27°C cabin ambient
- 421 W worst-case power draw

Module Count Design Trade



- **Fewer than 8 modules:** Insufficient to cool water to target temperature and requires higher current.
- **10 modules gives comfortable temperature margin at worst case**
- 10-module configuration draws **421 W** within the 2 kW allocation

Power and Temperature Results

Cabin ambient	Outlet	TEC power	Cooling	System COP
18.0 °C	15.9 °C	11 W	73 W	6.87
22.5 °C	15.9 °C	122 W	228 W	1.88
27.0 °C (worst case)	16.0 °C	421 W	383 W	0.91

Worst case still leaves margin: 7.36 A/module vs 15 A limit · 421 W vs 2000 W payload budget · ~804 W rejected to coolant loop

421 W

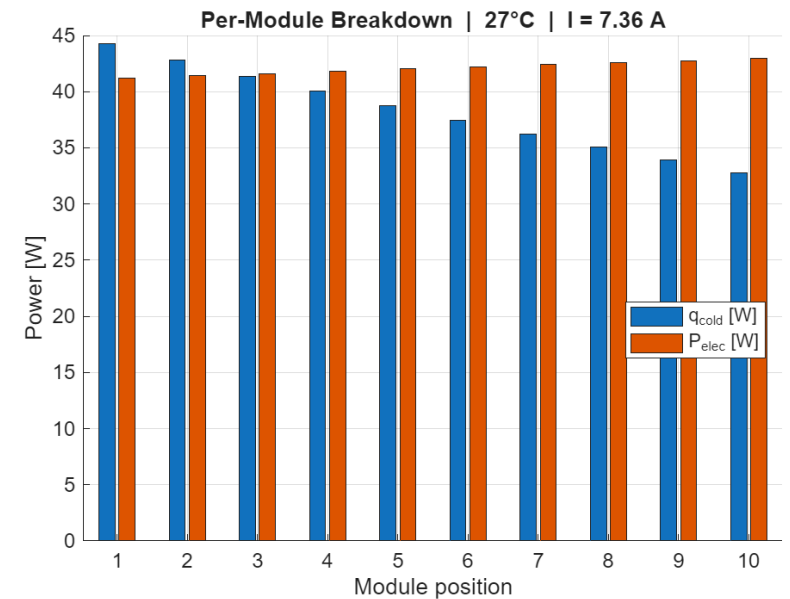
Worst-case TEC power

0.91

Worst-case COP

16 °C

Outlet, all cases



Mass & Size

Envelope

- 906 × 1274 × 500 mm
- Double EXPRESS Rack locker

Mass Estimate

- Cold-loop addition: ~14 kg
- Total system: ~30 kg

Mass Reduction Opportunities

- Heat-exchanger blocks
- Structural components

~30 kg

Total system (est.)

~14 kg

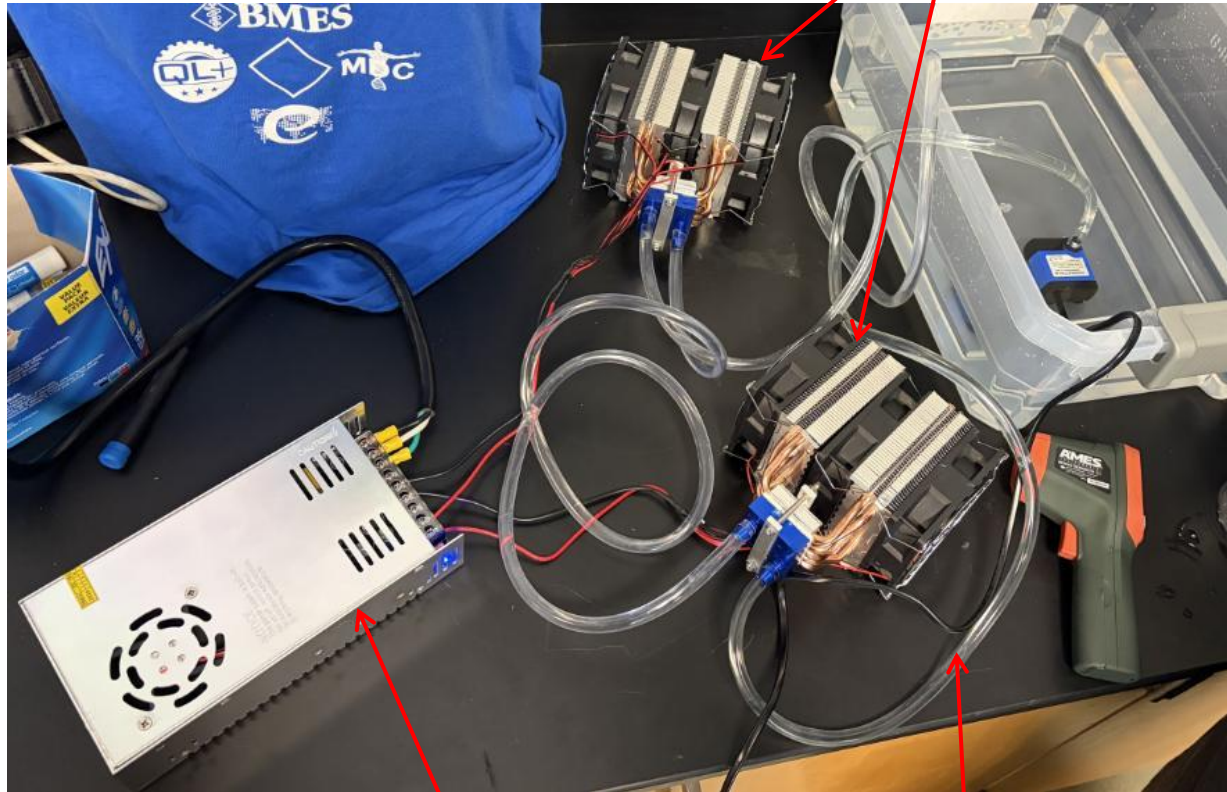
Cold-loop addition

INTEGRATION

Fits within two EXPRESS Rack lockers
No new spacecraft interfaces required

Bench Test Verification

2X 180 W Peltier Modules



Power Supply

Silicone Tube

Purpose

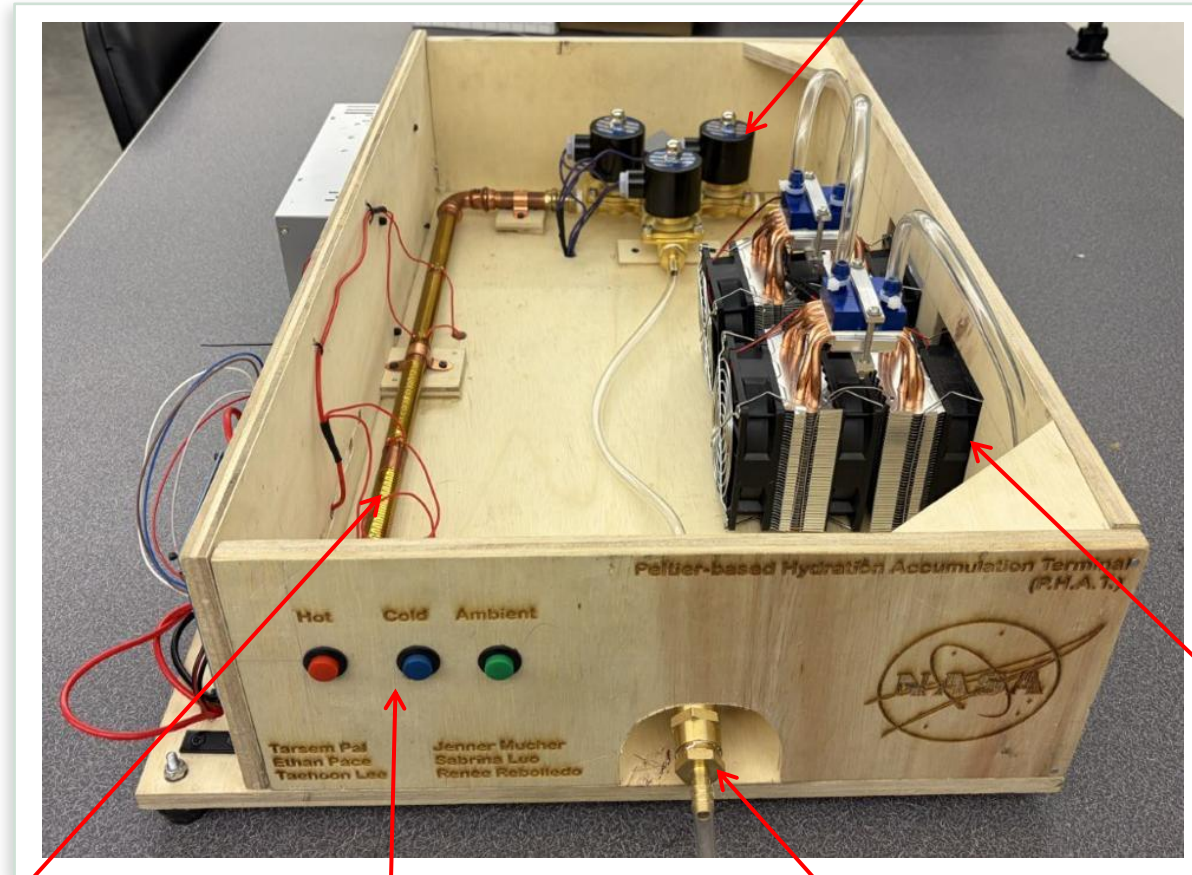
- Measure ΔT
- Flowrate (velocity)
- Power Input

Findings

- Long resistance time
- Inefficient Hot-side heat rejection
- Heat loss through uninsulated tubes

Verification Prototype

Solenoid Valves
(under PLC + Arduino control)



- Cal Poly ME senior-project builds

- Three-dispensing modes (Hot, Cold, Ambient)



- Hands-on insight into TEC behavior & flow-path routing

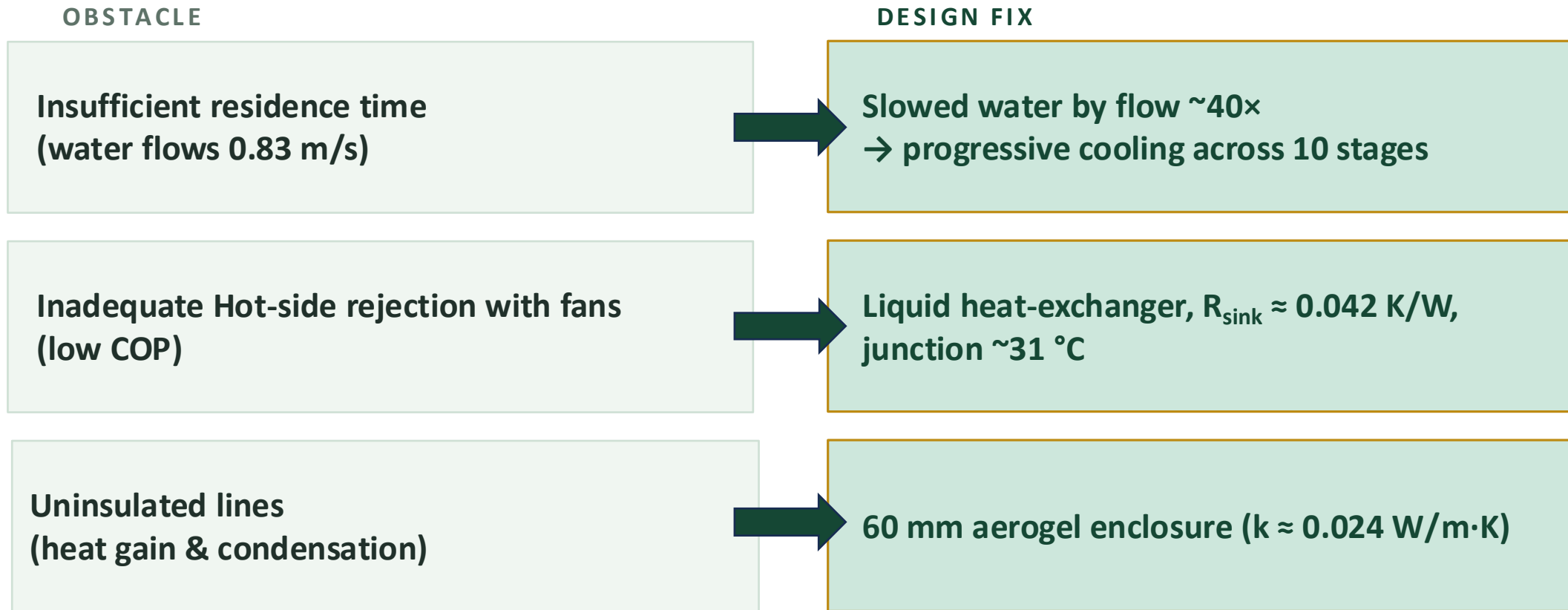
2X 180 W Peltier Modules
(Cooling System)

Heating System

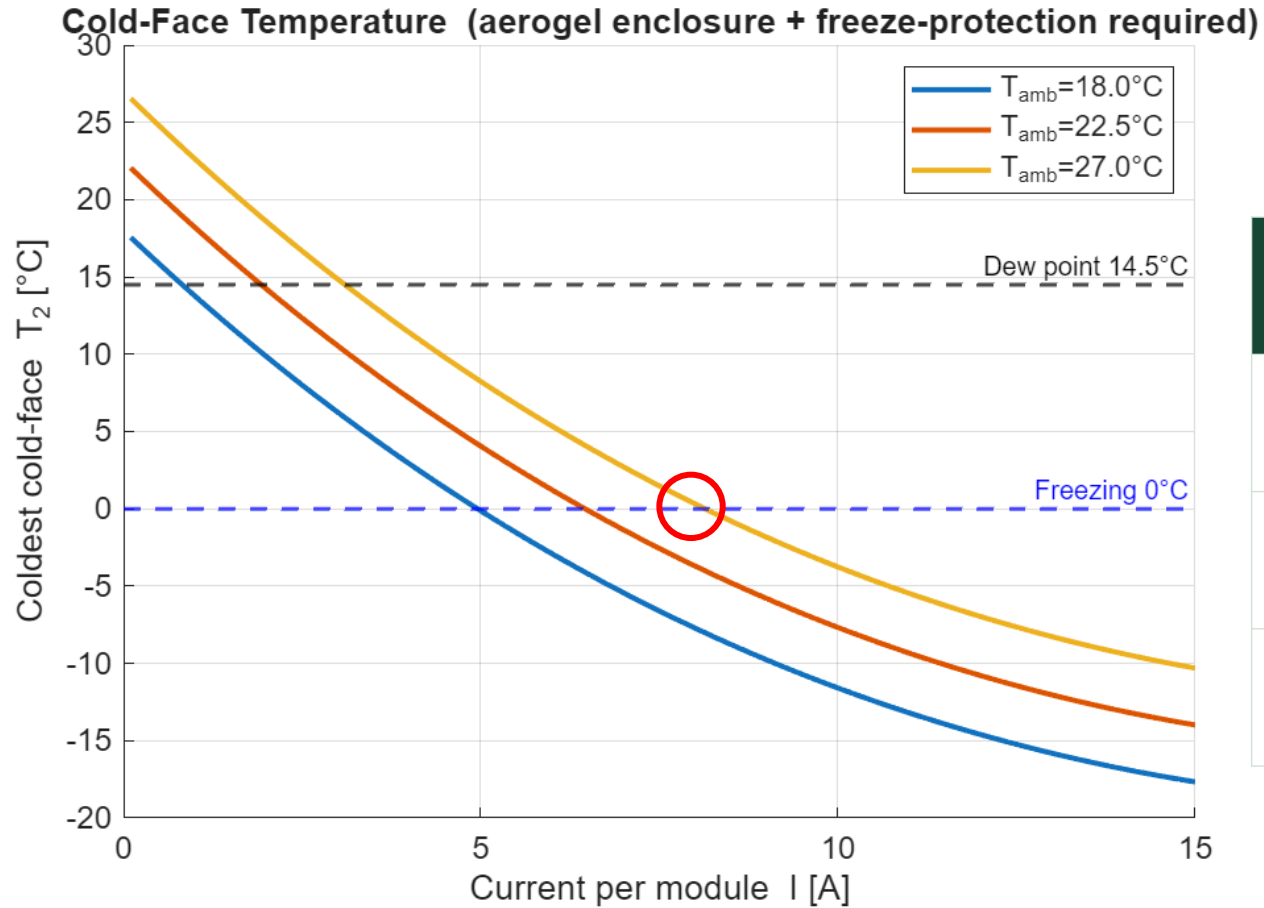
Control Buttons

Dispensing Unit

Obstacles & Mitigations



Freeze & Condensation Protection



Worst-Case Operating Point
 $T_2 = 1.8^{\circ}\text{C} @ 7.36 \text{ A}$

Hazard	Protection
Freezing	Cold-face current limiter
Condensation	60 mm aerogel enclosure
Temperature Drift	PID Control

Budget Assessment

Cost allocation	PHAT (\$M)	Est. ISS PWD (\$M)
Design & development	4.89	2.38
System test hardware	1.70	0.72
Total production	2.62	1.11
Total cost	9.21	4.20

Estimated with NASA's PCEC v2.4

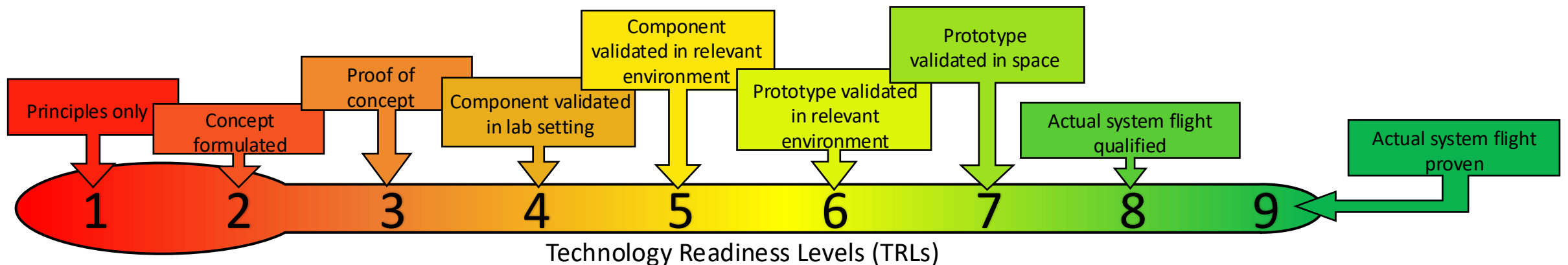
Crew-system multi-variable and CER, ISS Water Recovery System analogs, two missions over a 10-year horizon.

≈ 2.2×

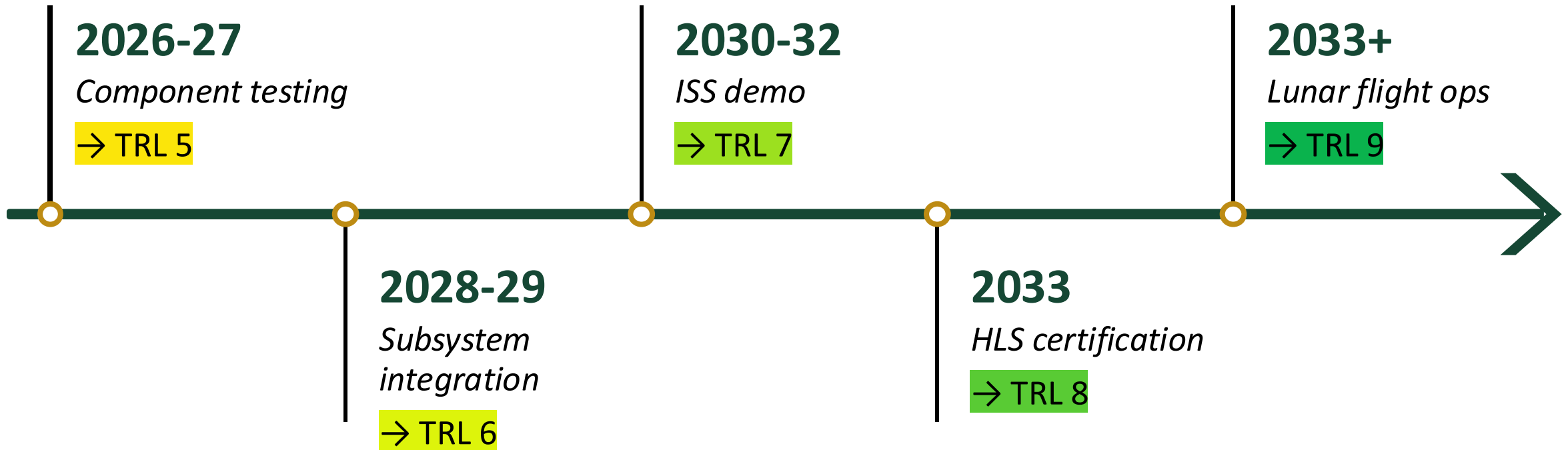
Cost of adding cold vs. heritage-only PWD

Technology Readiness

Subsystem	TRL	Basis
ISS PWD heritage core (heater, valves, filters)	9	Flight-proven through ISS operations
TEC modules	6-7	Spacecraft instrument-cooling heritage
SS pipe / Cu saddle / liquid heat-exchanger	3	Analytical model, validated vs datasheets
Aerogel condensation enclosure	3	Analytical proof of concept
Integrated PHAT system	3	Design & analysis complete; no integrated hardware



Path to Flight



Mission Architecture

LUNAR · 30 DAYS

- Drop-in HLS crew-cabin water upgrade
- ~240 TEC thermal cycles — well within qualified module life
- No cold-loop consumables limit the mission
- Hot + ambient + cold dispensing in one unit

MARS · 1,200 DAYS

- ~9,600 TEC cycles — modular replacement keeps it serviceable
- Scales by module count, flow rate, or parallel cold loops
- ACTEX swaps, UV-C lifetime tracking, spare TEC logistics
- ~6 min/day crew maintenance over the mission

THANK YOU

Questions & Discussion

PHAT — Peltier-based Hydration Accumulation Terminal

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