PHAT Peltier-based Hydration Accumulation Terminal

HuLC HUMAN LANDER CHALLENGE

Mechanical Engineering CAL POLY

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THE PROBLEM

Current spaceflight water dispensers have no cold potable water capability. This year's challenge asked students to create a solution that can safely deliver cold water to astronauts.

OUR SOLUTION

PHAT integrates a thermoelectric cold-water subsystem into the existing ISS PWD architecture without replacing the flight-proven core.

- Add cold water capability (≤16°C)
- Preserves hot & ambient dispensing
- Pressure-fed, pump free operation (microgravity compatible)
- No refrigerants or compressors
- Fits in Express Rack and maintainable
- Supports both lunar (30-day) and Martian (1,200-day) missions

OPERATING MODES

HOT COLD AMBIENT FLUSH

KEY HARDWARE & ARCHITECTURE

- **10 × 180 W-class TEC modules** — solid-state, no refrigerant or moving fluid
- **3/4 in. Sch. 10 316L SS serpentine pipe** — keeps copper away from iodinated water path
- **External copper saddle blocks** — improve thermal contact at TEC cold face
- **Liquid heat-exchanger hot side** — rejects worst-case heat to spacecraft coolant loop
- **60 mm aerogel cold-side enclosure** — limits condensation
- **UV-C Filtration at outlet** — redundant microbial protection

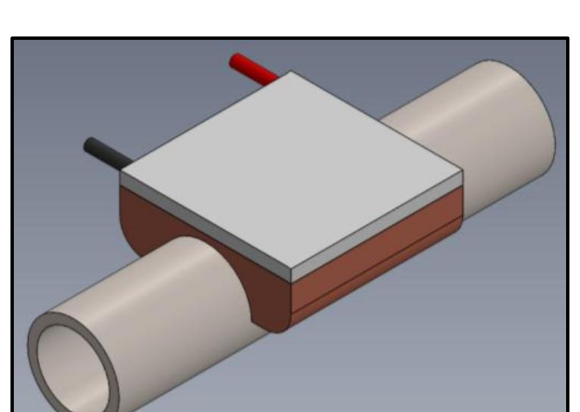

Figure 1: PHAT cold-loop hardware concept.

The flow-through design avoids dead legs, reducing microbial-growth risk.

THEORY

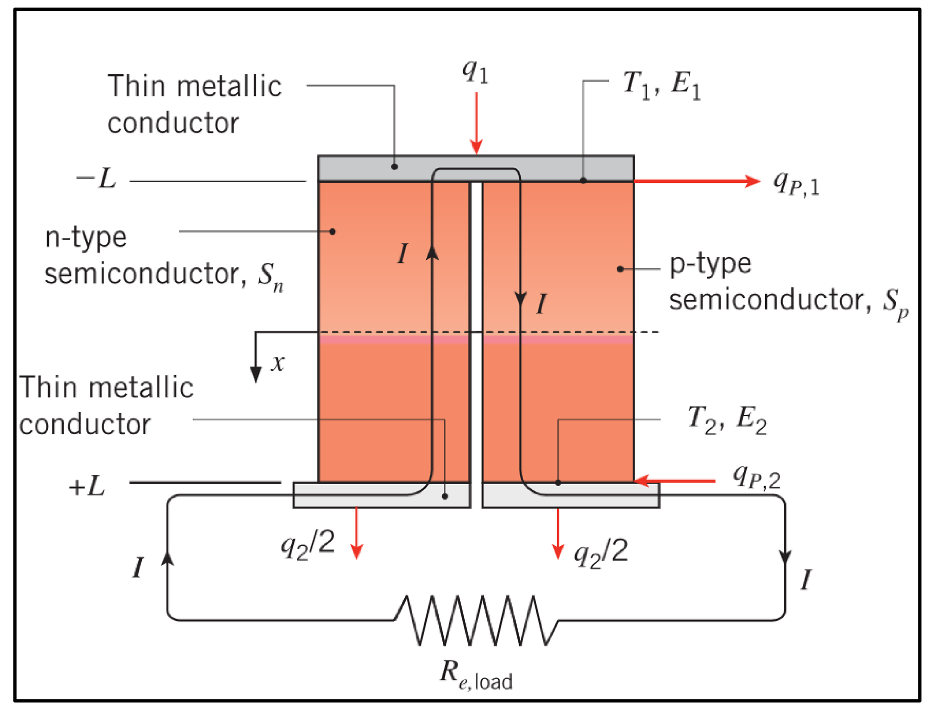

Figure 3: A thermoelectric module uses the Peltier effect to transfer heat across semiconductor junctions.

Its solid-state architecture eliminates moving parts and refrigerants.

(diagram via Bergman's Fundamentals of Heat Transfer)

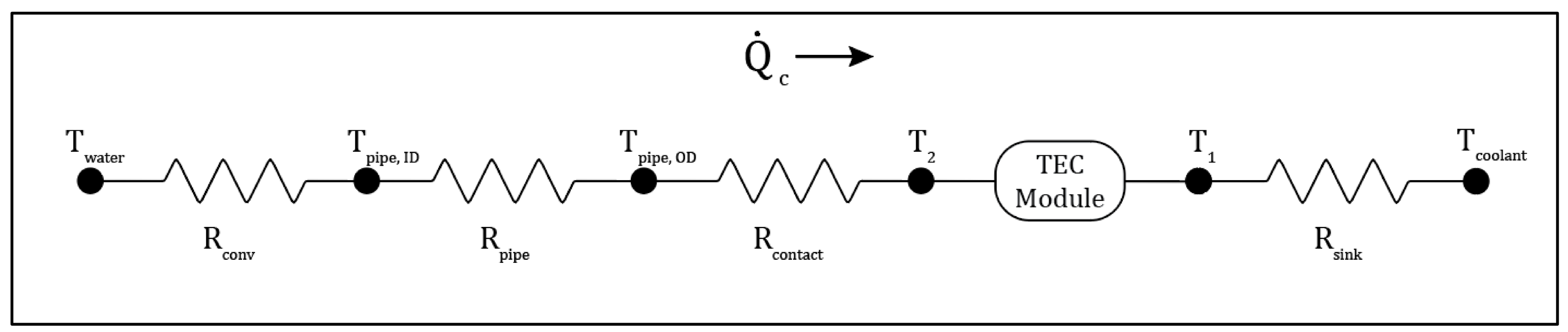

Figure 3: Equivalent thermal circuit used to model heat transfer from process water through the TEC module to the spacecraft thermal-control system.

SYSTEM CONCEPT

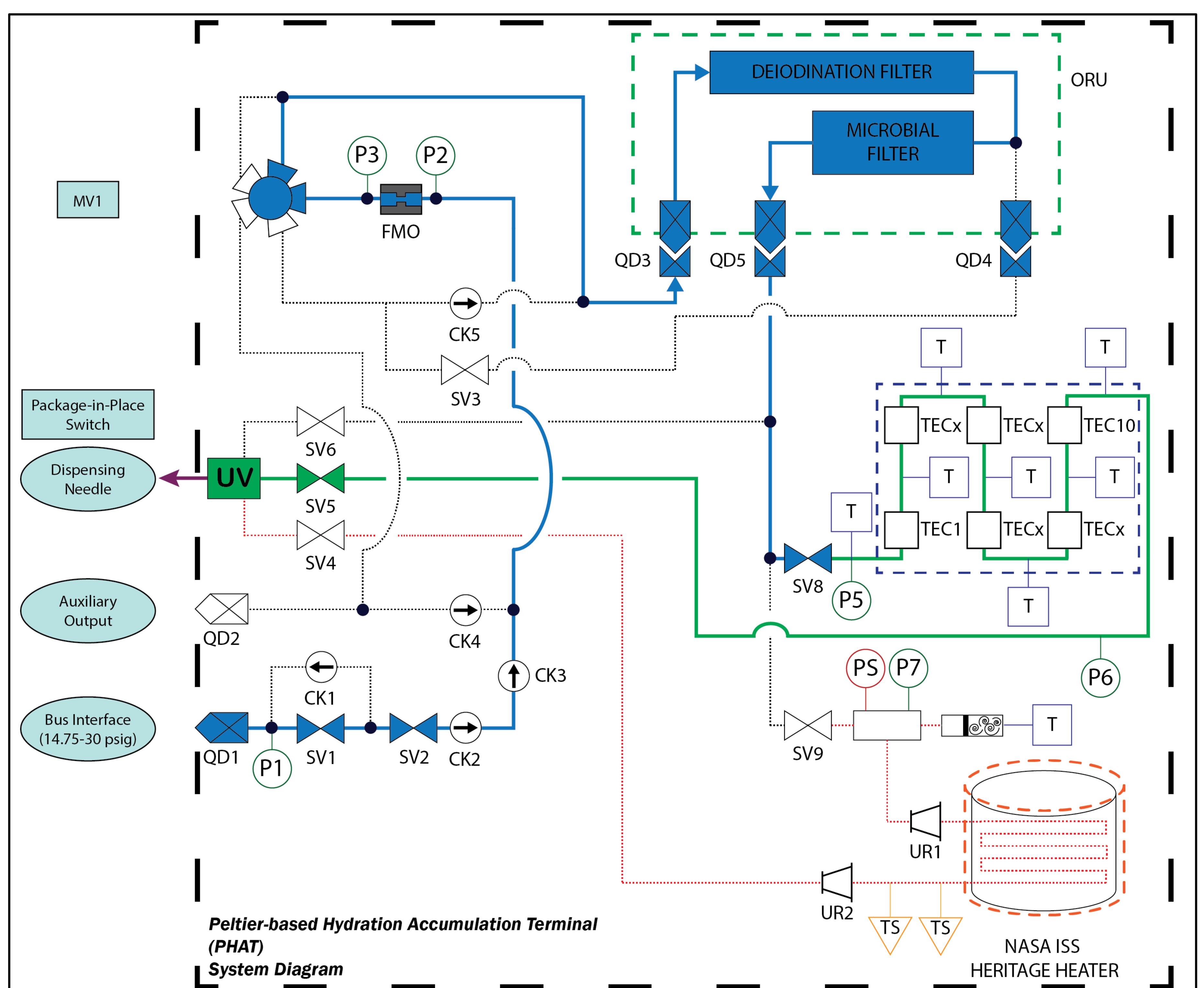

Figure 4: PHAT integrates a modular thermoelectric cold-water subsystem into the heritage ISS PWD while preserving hot and ambient dispensing modes.

Cold Loop Highlighted

PERFORMANCE AT A GLANCE

16°C
Outlet Temp (worst case inlet temp)

421 W
Cold Mode Power Draw (2000W max)

0.91
System COP (worst case inlet temp)

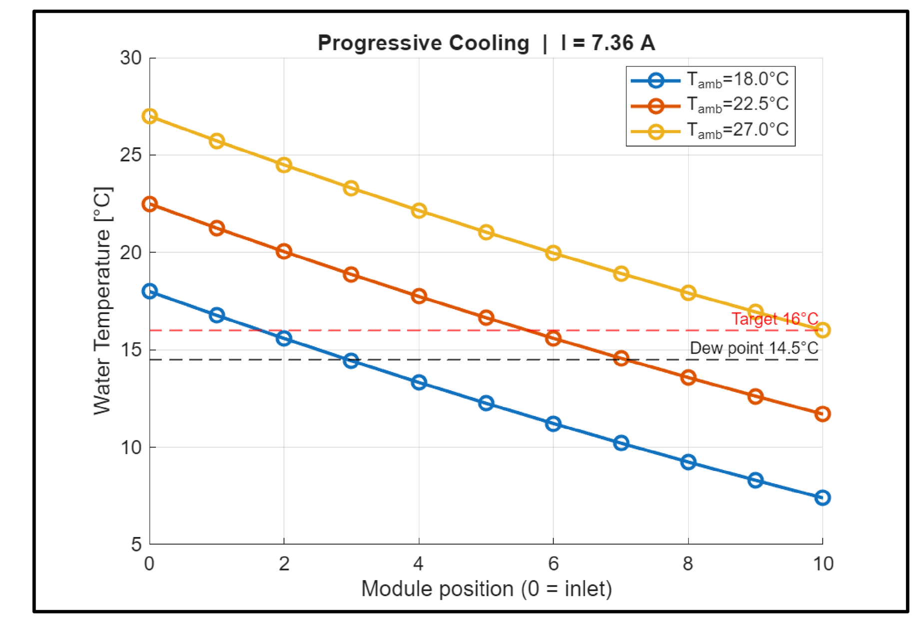

Figure 5: Progressive cooling across the ten-stage thermoelectric pipeline.

The design meets the 16°C cold-water requirement across the expected water temperature range.

PATH TO FLIGHT

- **2026-27** *Component testing* → TRL 5
- **2028-29** *Subsystem integration* → TRL 6
- **2030-32** *ISS demo* → TRL 7
- **2033** *HLS certification* → TRL 8
- **2033+** *Lunar flight ops* → TRL 9

Preliminary Projected Cost: $9.21M

LESSONS LEARNED, MARS SCALABILITY, FUTURE WORK

LESSONS LEARNED

- Increased residence time required
- Liquid hot-side cooling required
- Aerogel insulation required

MARS SCALABILITY

- Additional TEC stages
- Parallel cold loops
- Variable flow rates
- Modular replacement

FUTURE WORK

- CFD thermal analysis
- FEA structural validation
- Integrated prototype testing
- Lifecycle & reliability testing

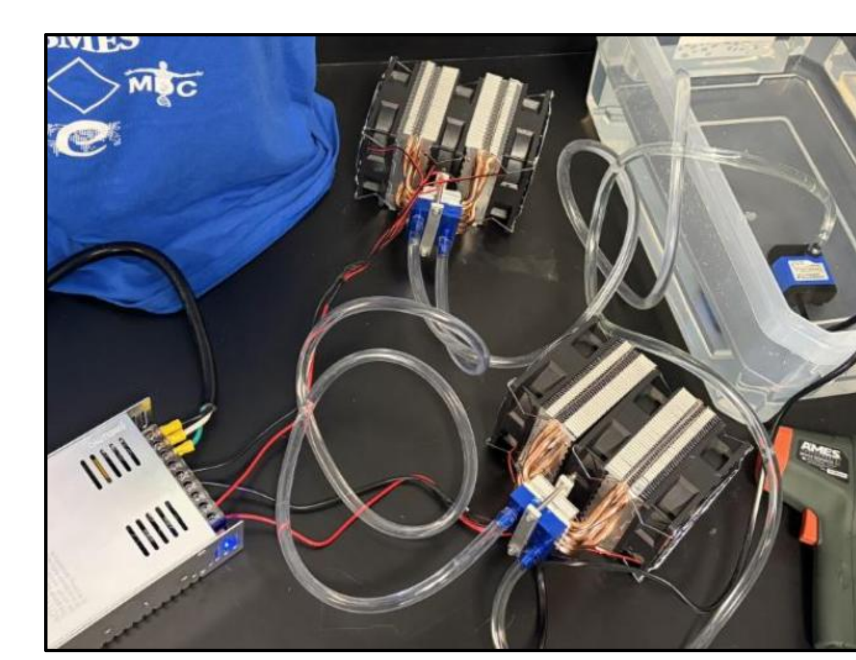

Figure 6: Two-module flow-through thermoelectric testbed used to validate water-loop integration and inform final PHAT architecture.