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STREAM:

Space Temperature Regulated Efficient Aqua Module

UNIVERSITY OF TEXAS RIO GRANDE VALLEY
STREAM
SPACE TEMPERATURE REGULATED
— EFFICIENT AQUA MODULE —

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- Experimental Results
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Introduction – Problem Statement

Astronauts currently have access to hot and ambient water, but not chilled water. Due to thermal management and microgravity challenges, providing temperature-controlled potable water in space is complex. Our project develops a reliable system capable of delivering both hot and cold water on demand.

Introduction – Mission Requirements

Design requirements were derived from standards used in NASA's ECLS architecture for crewed spacecraft and planetary habitats

__Key Engineering Requirements__

Temperature Control Range – Cold temp needs to be at a target temp of 15.6 C, Hot temp of above 60 C.

Energy Efficiency – Operate with minimal power consumption to meet spacecraft power constraints.

Mass and Volume – System must be compact and lightweight for integration into space habitats and spacecraft.

Reliability – Continuous operation capability with minimal maintenance and high durability.

Use	Temperature Range	Constraints and Rationale
Rehydration of cold drinks	Maximum of 15.6°C (60°F). Cold water temperature between 2°C (35.6°F) and 7°C (44.6°F)	For missions longer than 3 days
Rehydration of food and hot drinks	Between 68.3°C (155°F) and 79.4°C (175°F)	Temperatures were selected for better rehydration of food and beverages and to maintain food temperature during the rehydration process so that the completed food product does not require additional heating. 79.4°C (175°F) water also allows the temperature of the food to remain above 68.3°C (155°F) to prevent microbial growth.
Personal hygiene	Between 29.4°C (85°F) and 46.1°C (115°F)	Supports body cleansing
Medical	Between 18°C (64.4°F) and 28°C (82.4°F)	This temperature range will prevent thermal injury and discomfort to tissues during irrigation.

Figure 1: NASA Requirements

Introduction – Design Constraints

Constraint	**Requirement**
Microgravity	Reliable fluid storage and dispensing
Hot Water	≥ 60°C
Cold Water	≤ 15.6°C
Power	Minimize energy consumption
Mass	Lightweight system
Volume	Compact footprint
Safety	Potable-water compatible materials
✓ Reliability	Long-duration mission capable

Solution – Thermal Management – TEC1 – 1215 PM

Figure 2: Cold Peltier Side

Figure 3: Hot Peltier Side

Peltier Module
Transfer Heat from one side to the other using Peltier effect

- ➢ Solid-State Cooling
- ➢ Hot & Cold Operation
- ➢ Electronic Temperature Control
- ➢ Compact Design

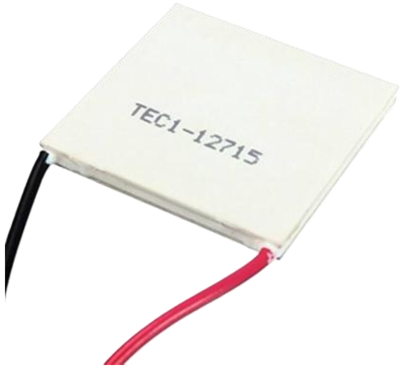


Figure 4: Peltier Module

Solution – Thermal Management - Configuration

Thermal Management Configuration

- 4 × TEC1-1215
- 1× 4 Array
- Aluminum Water Blocks
- Liquid Cooling and Heating Loop
- Temperature Adhesive Paste

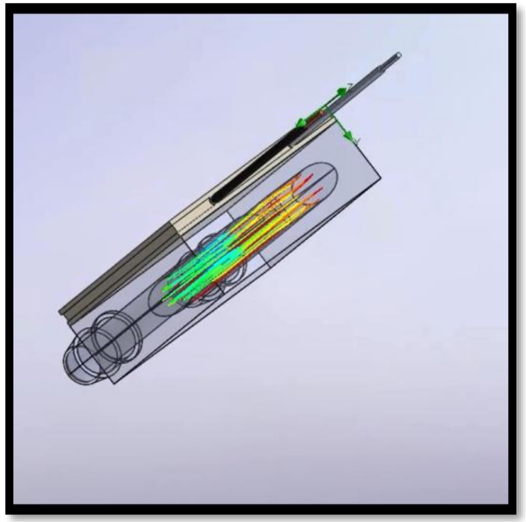


Figure 5: Water Block Flow

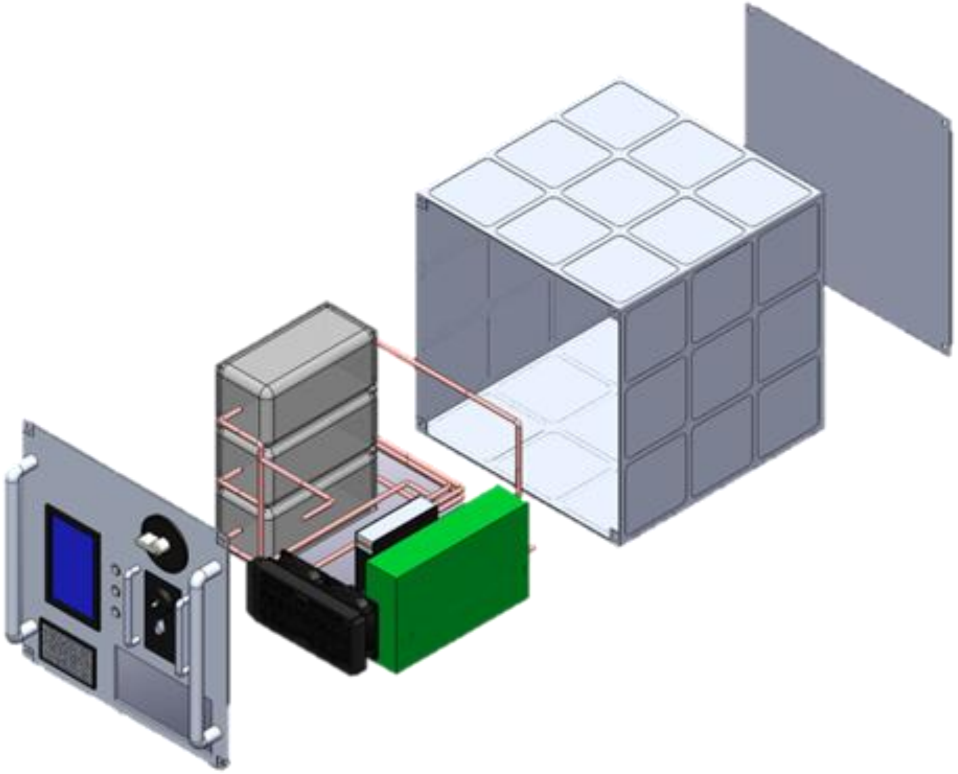


Figure 6: Prototype Exploded View

Solution – Thermal Management – Flow Diagram

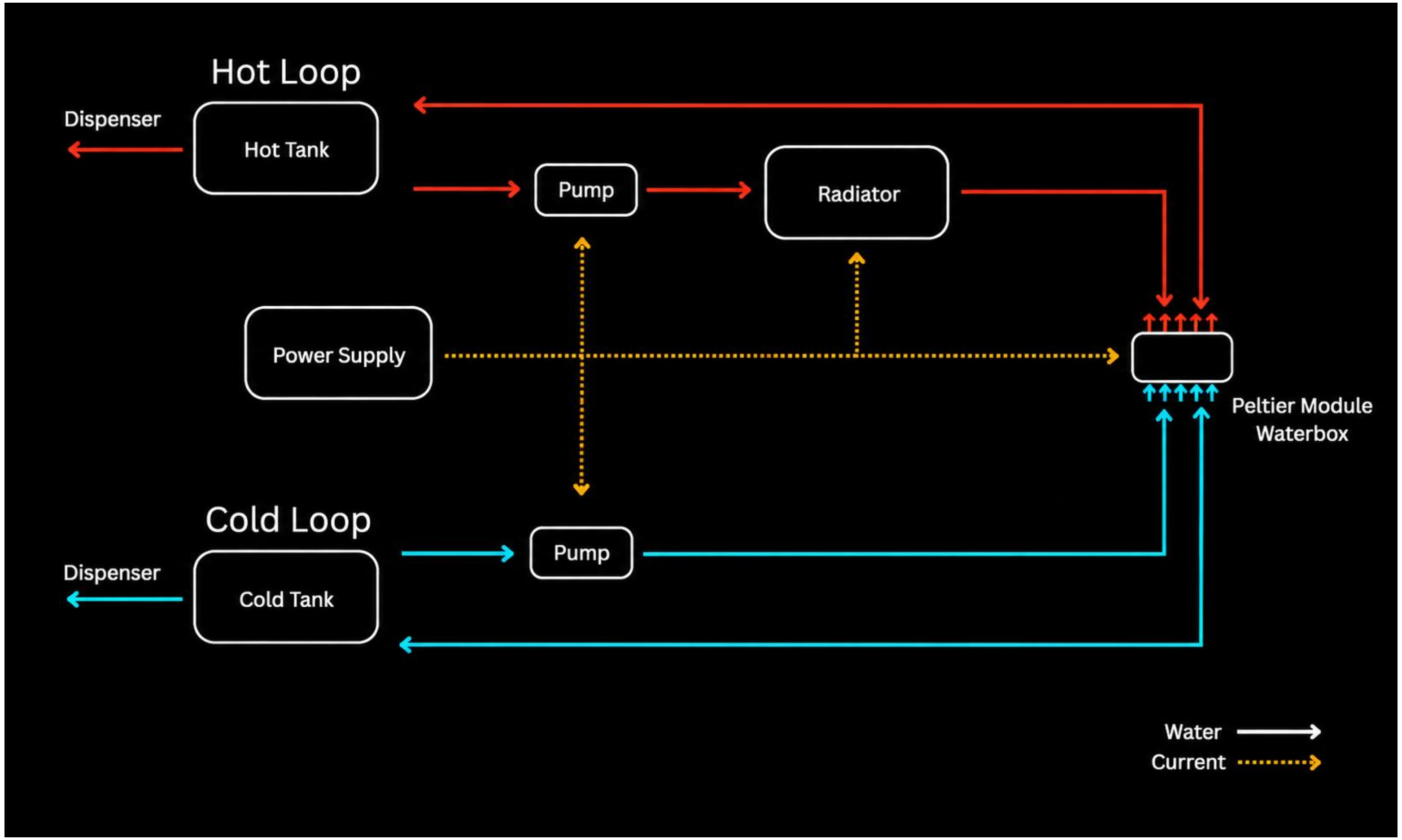


Figure 7: Flow Diagram

Water Treatment Solution – Inline Water Filter

- First stage of water treatment
- Removes sediments and particles
- Carbon filtration reduces chemical contaminants, along with odor and taste
- Protects downstream components

Figure 8: Inline Water Filter

Water Treatment Solution – UV-C Disinfection (Inline UV Unit)

- Final Stage of filtration
- Inactivates bacteria and microorganisms
- Chemical-free disinfection method
- Provides a final microbial safety barrier

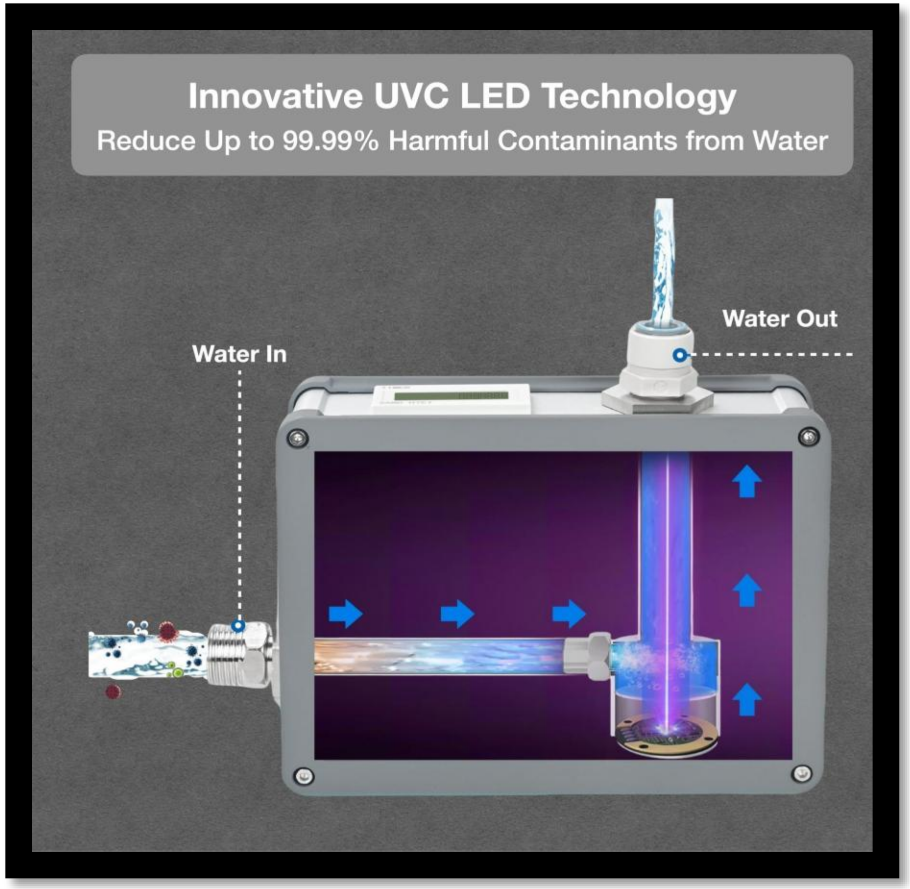


Figure 9: UV-C Inline Filter

Solution – User Interface

- Displays hot, cold, and ambient tank temperature monitoring
- Shows sensor link status, runtime, and last update time
- Provides clear system feedback: **ONLINE**, **WARNING**, or **ERROR**
- Serves as the crew-facing control layer for STREAM

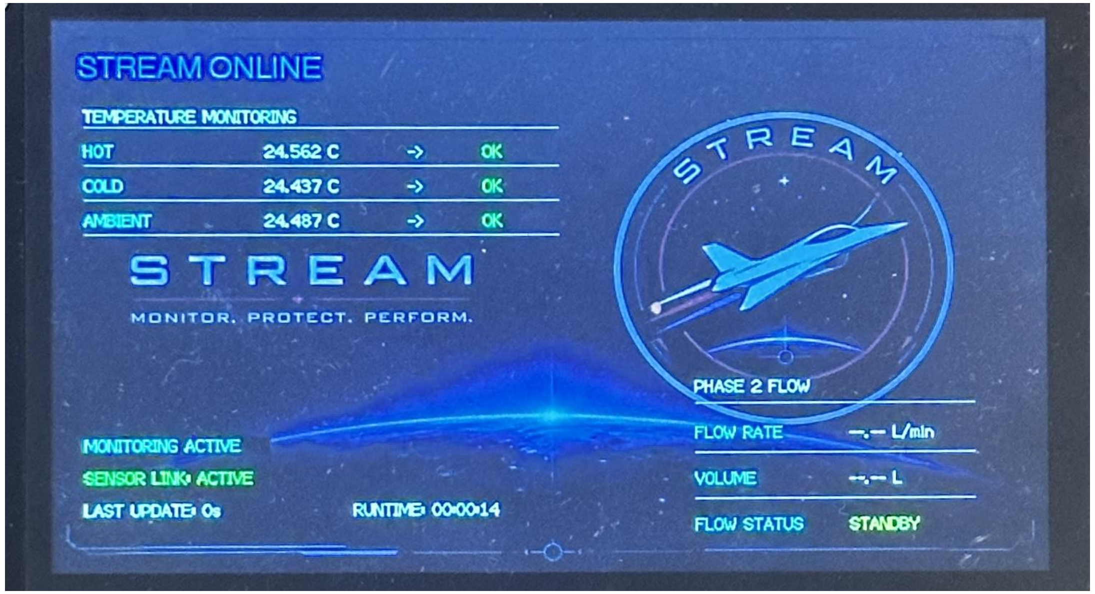


Figure 10: User Interface

Figure 11 : Temperature Sensor Input

Solution – Dispensing System

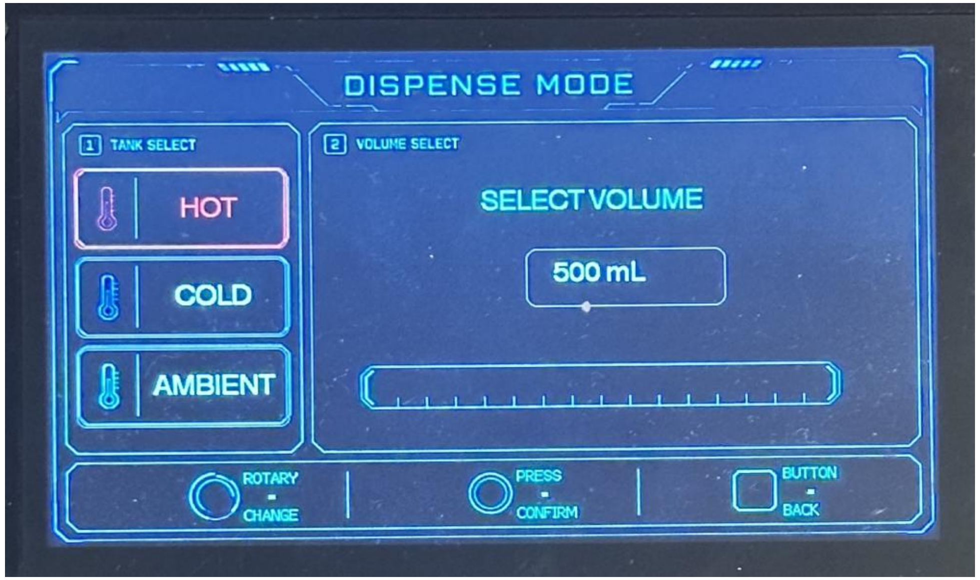


Figure 12: Amount Water Available

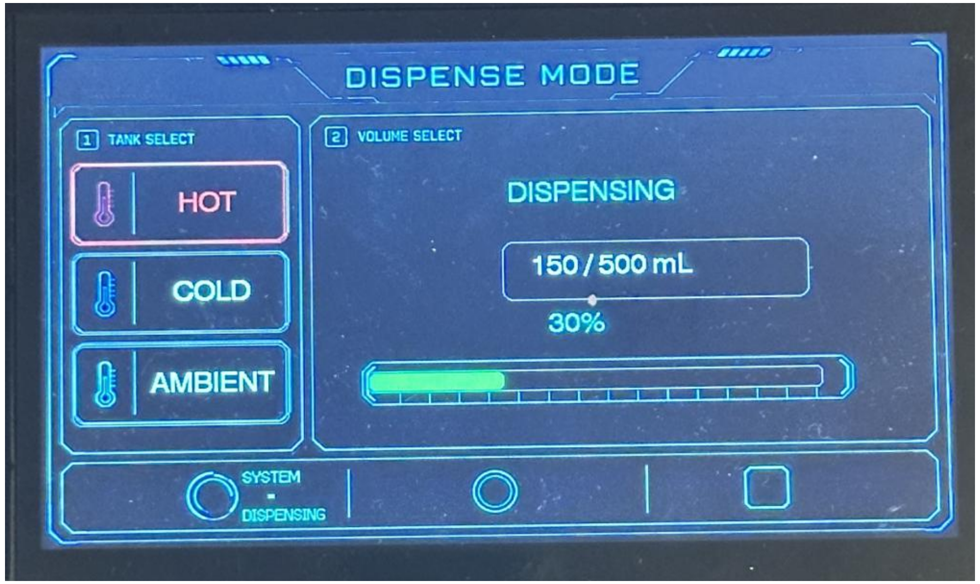


Figure 13: Dispensed Water Selected

- ➢ Allows selection of hot, cold, or ambient water source
- ➢ Provides target volume selection before dispensing
- ➢ Displays dispense progress using volume and percentage feedback
- ➢ Prepared for future integration with pumps, solenoid valves, and flow sensors

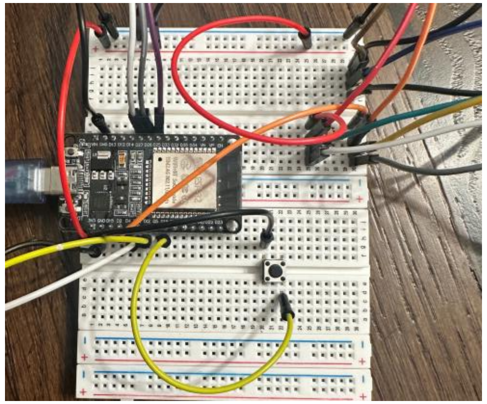


Figure : 14 ESP32 Control Node

Solution – Fault Handling & System Feedback

- Detects invalid or unavailable sensor readings
- Displays a clear **ERROR** state instead of continuing with invalid data
- Keeps sensor link and system status visible for troubleshooting
- Supports crew awareness during abnormal operating conditions

Figure 15: Display Error

Error-state display showing invalid sensor data feedback while maintaining system status information.

System States
Normal: ONLINE

Caution: WARNING

Fault: ERROR

Crew Action: Check sensor connection/status

Solution – Tank Insulation

Aerogel Insulation

- Low thermal conductivity
- (~0.013 – 0.02 W/mk)
- High thermal resistance at low thickness (10mm)
- Lightweight and structural adaptable
- Performs well in vacuum environment
- Supports dual-mode operation (heating and cooling)

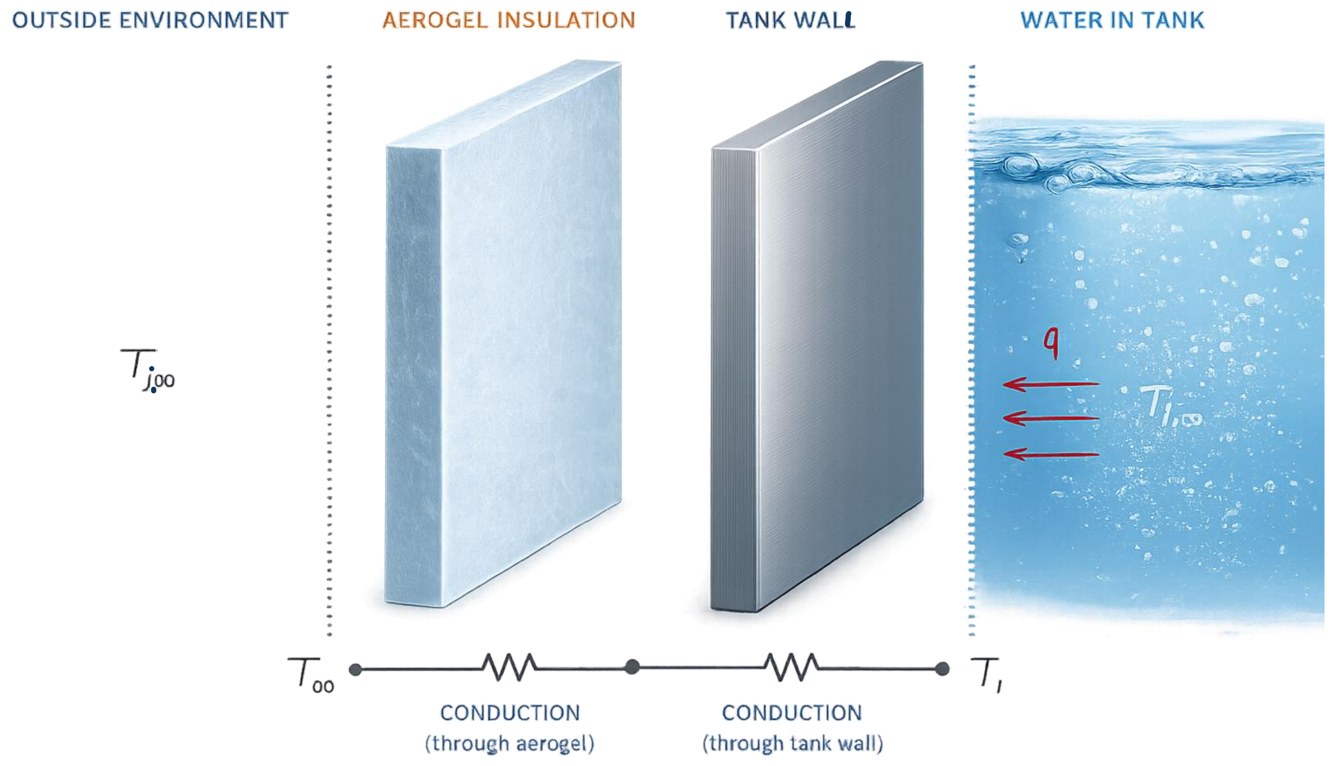


Figure 16: Aerogel Insulation

Verification and Validation – Test Setup

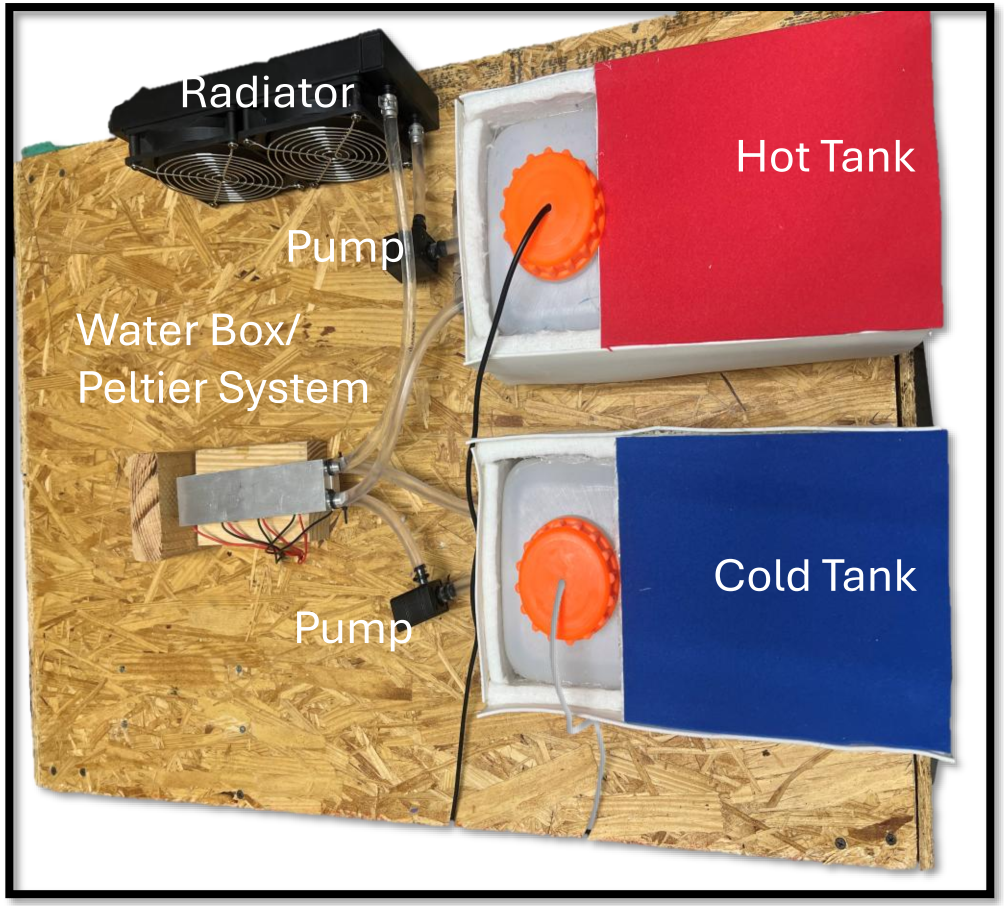


Figure 17: Prototype Setup

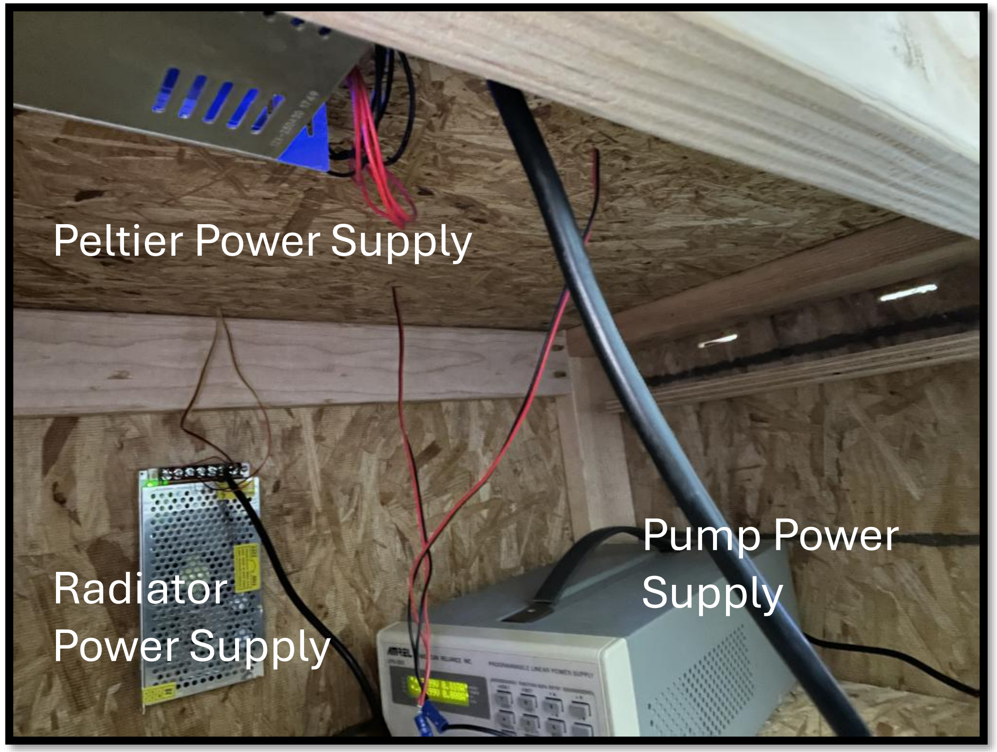


Figure 18: Power Supply Setup

Verification and Validation – Experimental Results – Flow Rate

Test Objective
- Determine whether selected flow rate allows simultaneous heating and cooling
- Evaluate thermal system efficiency under continuous circulation

Findings
- Increasing flow rate improved heat transfer performance
- Flow rate chosen maintained continuous water circulation while allowing system to achieve target temperatures
- Demonstrated a balance between the heat transfer performance and system power requirements.

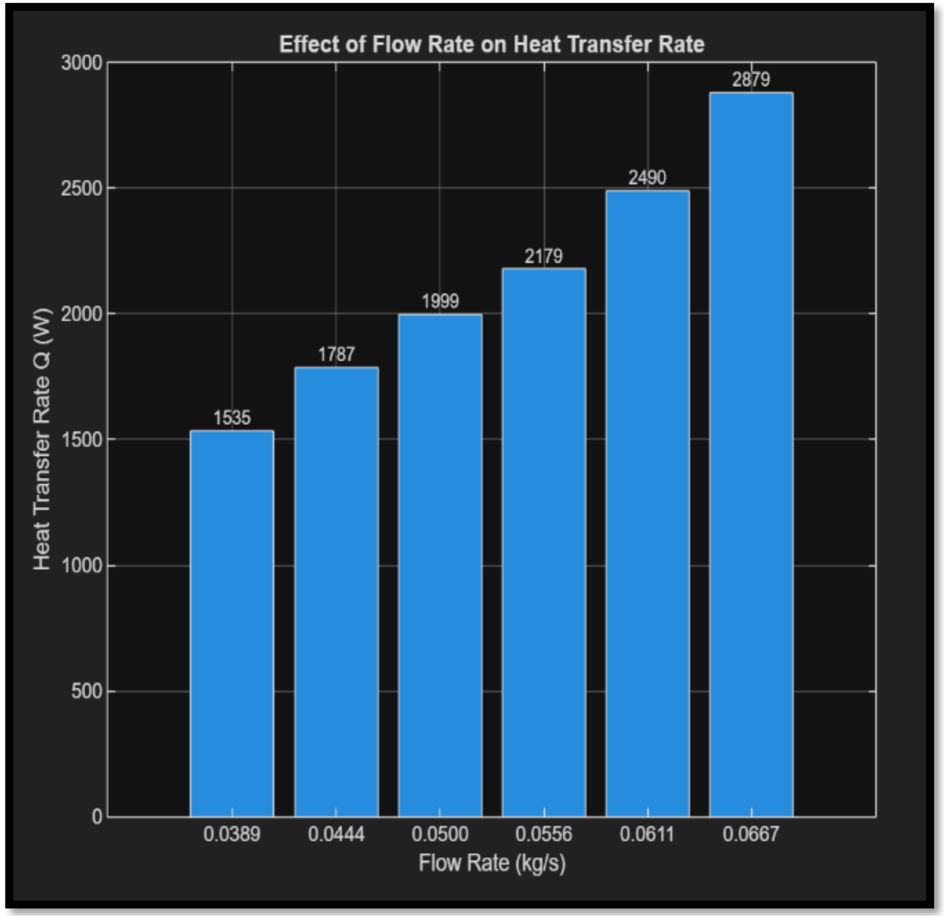


Figure 19: Heat Transfer Rate vs. Flow Rate

Verification and Validation – Experimental Results – Heat Exchanger

Testing Results

- Hot tank temperature increased from 21.4 to 60.1 C
- Cold tank temperature decreased from 20.5 to 13.5
- Simultaneous heating and cooling was demonstrated

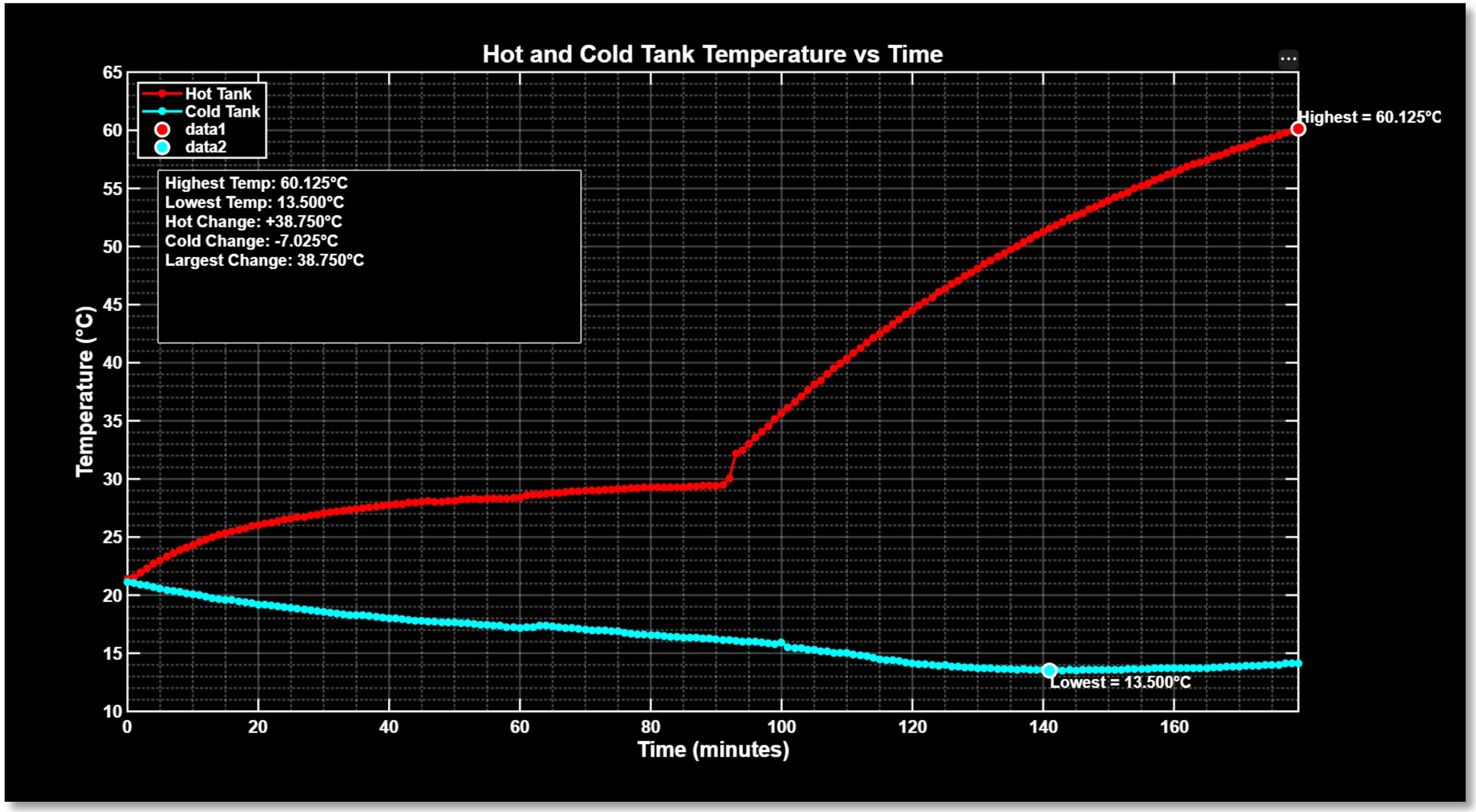


Figure 20: Temperature vs. Time

Verification and Validation – Experimental Results – Filtration System

Verification Results:

- ➢ Confirmed proper flow path through filtration and UV-C stages
- ➢ Verified integrity of tubing and fittings
- ➢ Confirm UV-C light activated through water pressure

Validation Results:

- ➢ Water remained within acceptable pH range (6-7)
- ➢ System delivered continuous potable water flow
- ➢ Filtration and sterilization architecture functioned as intended

Figure 21: Filtration Setup

Verification and Validation – Experimental Results – Filtration System

Both Filters

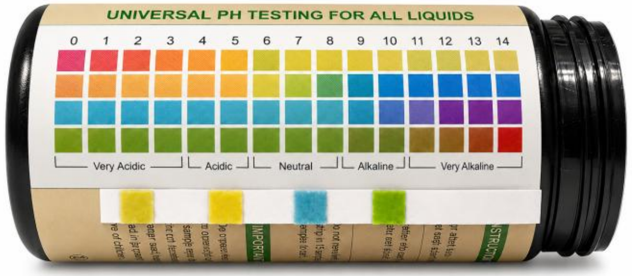


Figure 22: pH Strip for Both Filters

Inline Water Filter

Figure 23: pH Strip for Inline Water Filter

Tap/ Garden hose

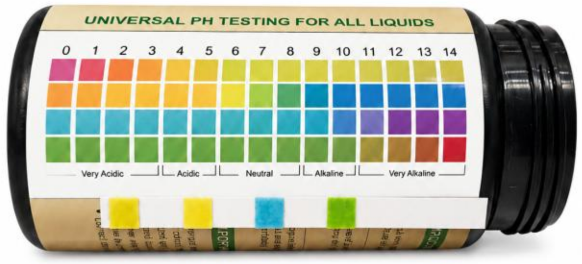


Figure 24: pH Strip for Tap/Garden Hose

- Ph stayed the same (Ph 6-7) since there is no additives and only disinfecting microorganisms

Verification and Validation – Performance Assessment

Performance Assessment

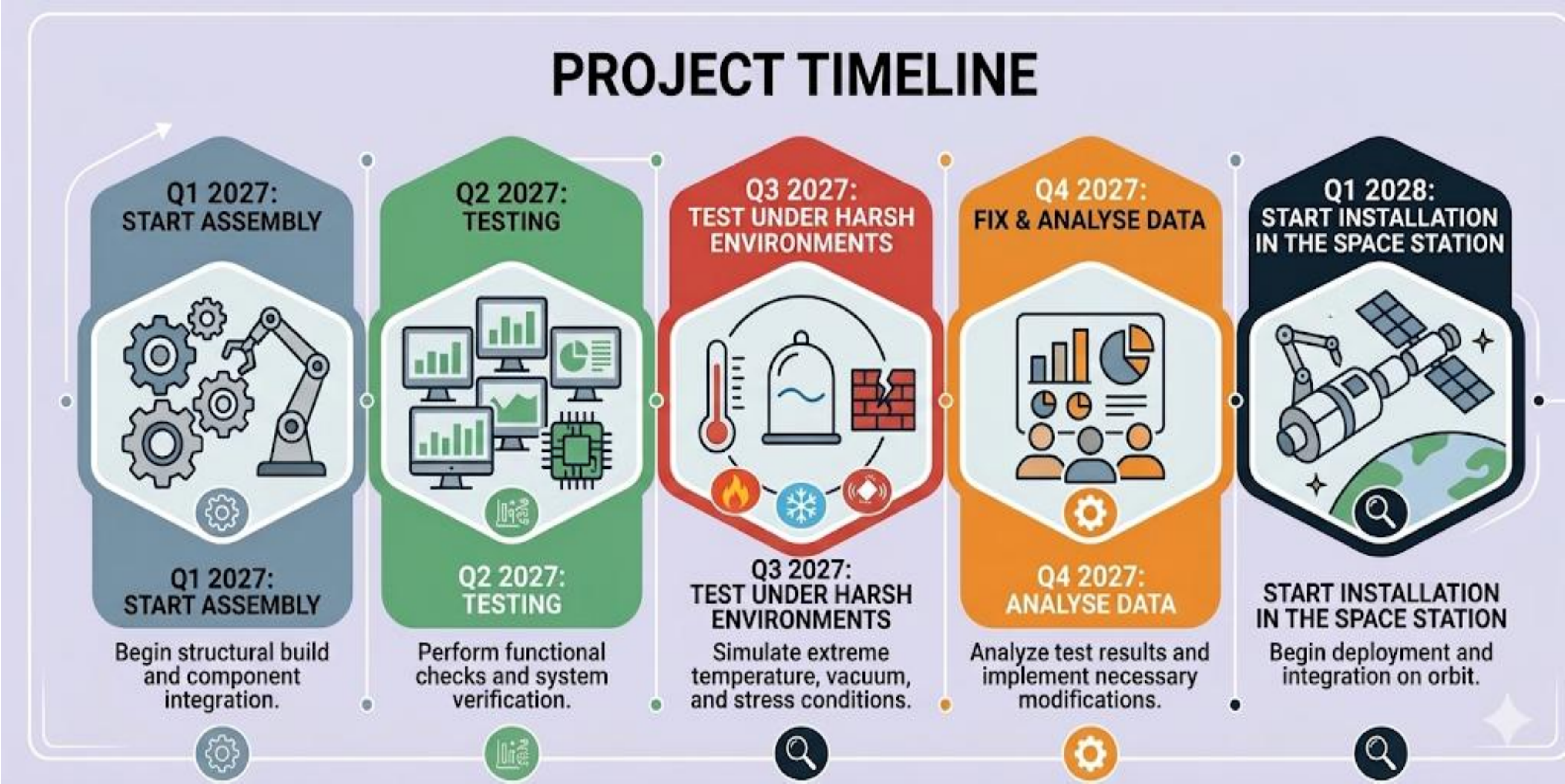
- Peltier based heat exchanger provided stable thermal control while reaching the required temperature.
- System achieved the requirement for hot water and cold water and can achieve high temperature changes with optimization
- Temperature trends remained consistent throughout t testing as the heating and cooling were stable
- This Peltier based Heat exchanger demonstrated the ability for a dual temperature results from one component

Planning – TRL

TECHNOLOGY READINESS LEVEL (TRL) DEVELOPMENT ROADMAP

Phase	TRL	Description
Phase 1		**TRL 1:** Basic Principles Observed and Reported. **TRL 2:** Technology Concept and/or Application Formulated. **TRL 3:** Analytical and Critical Experimental Proof-of-Concept Demonstration.
Phase 2		**TRL 4:** System/Component and/or Breadboard Validation in Laboratory Environment. **TRL 5:** System/Component and/or Breadboard Validation in Relevant Environment.
Phase 3		**TRL 6:** System Model/Prototype Demonstration in Relevant Environment. **TRL 7:** System Prototype Demonstration in a Space Environment.
Phase 4		**TRL 8:** Actual System Completed and 'Flight Qualified' Through Test and Demonstration. **TRL 9:** Actual System 'Flight Proven' Through Successful Mission Operations.

Planning – Path to Flight



Planning – Budget

PROJECT BUDGET BREAKDOWN

TASK	COST ($)	TOTAL COST	DESCRIPTION
Engineering & Design	350,000	---	Design the simplest and most efficient system possible.
Testing	300,000	---	Ensure the system functions properly on the space station.
Materials & Manufacturing	80,000	---	Research the highest quality and most affordable materials to make the system efficient.
Safety Testing	150,000	---	Test thoroughly for any possible risks and issues.
Software & UI	100,000	---	Create software to help monitor and control the systems.
Integration	90,000	---	Integrate the water dispenser into the space station.
Total	**1,070,000**	**---**	**Total Cost: 1,070,000**

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Planning – Risk Management

PROJECT RISK ASSESSMENT

ID	POSSIBLE RISK	SYSTEM AFFECTED	METHOD	PLAN
1	Pump Failure	Dispensing	Mitigate	Ensure the pumps are properly powered and prevent any possible damage to them.
2	Water Contamination	Filtration	Test	Constantly test the water to make sure the filtration system is working properly.
3	Display Failure	Dispensing	Mitigate	Ensure the highest quality display is installed, so it can display the condition of the water dispenser.
4	Tank Insulation Failure	Insulation	Research	Research different materials that will achieve great results in conserving both cold and hot temperatures in the tanks.
5	Peltier Failure	Heating/Cooling	Mitigate	Ensure the best quality Peltiers are installed and make sure they are placed corresponding to their hot and cold sides.

Summary – Conclusion

➢ Developed a temperature-regulated potable water dispenser

➢ Achieved hot and cold-water delivery using Peltier modules

➢ Integrated filtration, dispensing, and user interface systems

➢ Validated thermal and flow performance through testing

➢ STREAM demonstrates potential for future lunar habitats

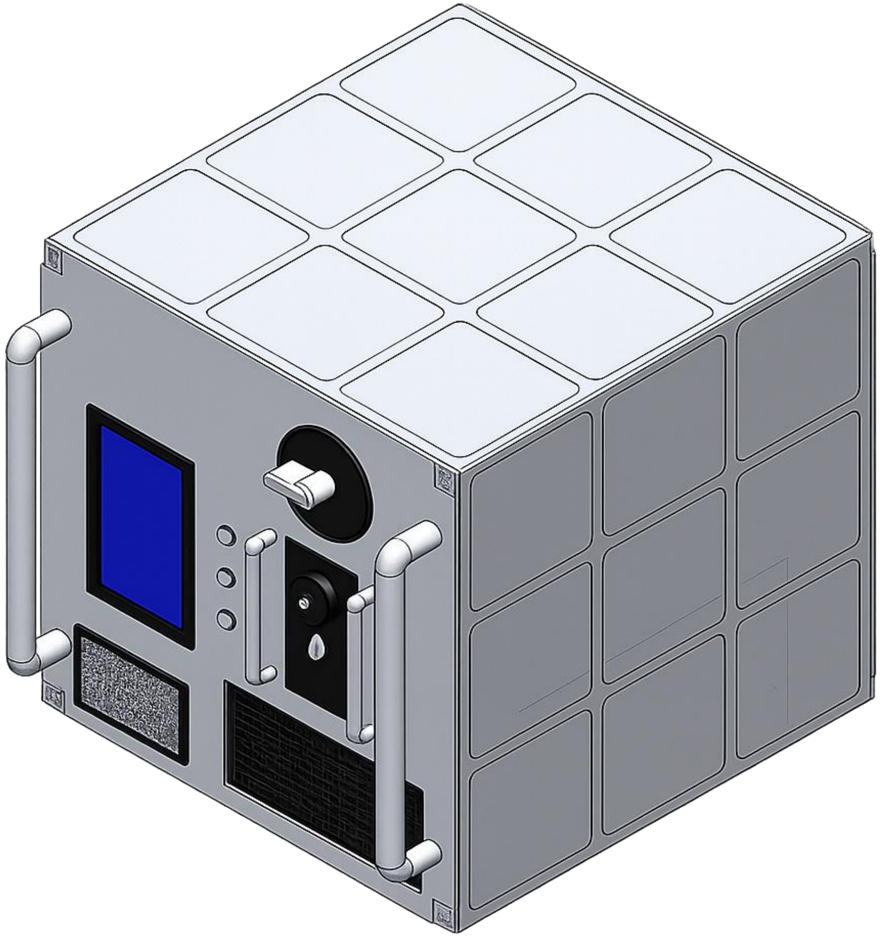

Figure 25: Complete Prototype Assembly

Summary – Future Work

- ➢ Improve thermal efficiency through enhanced insulation
- ➢ Reduce system power consumption and mass
- ➢ Conduct extended reliability and endurance testing
- ➢ Evaluate performance in lunar-like environments
- ➢ Integrate with future habitat life-support systems

Thank you