

Advanced Quality Orbital Rehydration Assembly

AQUORA

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Advanced Technologies and Research Applications
(ASTRA) Lab



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Path to Flight

Meet the Team



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The Challenge

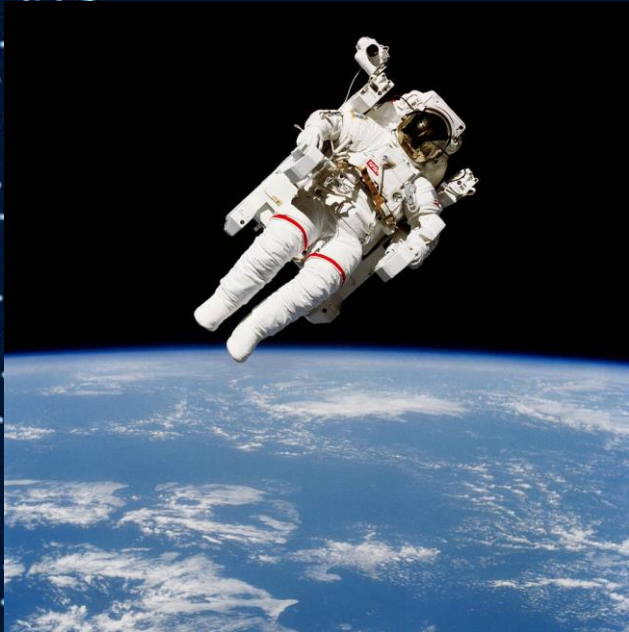
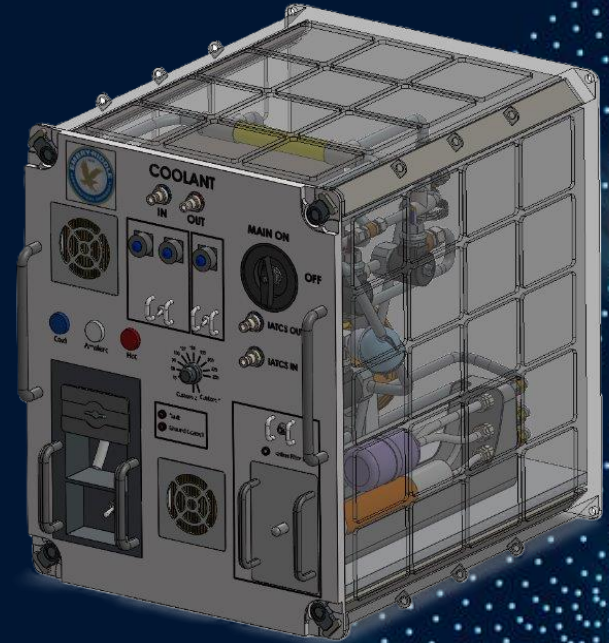


Image Source: NASA

- Current ISS PWD systems provide only hot and ambient water
- Artemis missions require improved crew comfort and habitability for long-duration surface operations
- Water storage creates microbial growth and biofilm formation concerns
- Develop a low-risk solution that provides hot, ambient, and chilled potable water while leveraging proven ISS technology

Why AQUORA?

- Modified ISS Potable Water Dispenser
- Hot, ambient, and chilled water
- Compact R-134a cooling system
- Heritage hardware lowers risk
- Improves crew hydration and comfort
- Added microbial mitigation



Design Requirements and Constraints



Efficiency

Safely and efficiently deliver temperature-controlled water between 4-8 °C



Safety

Maintain separation between refrigerant and potable water loops to preserve water quality and crew safety



Compatibility

Maintain compatibility with existing ISS potable water dispenser architecture



Waste Mitigation

Minimize waste through IATCS, allowing compatibility with existing thermal management infrastructure

Existing Potable Water Dispenser Architecture

- Centralized potable water supply
- End-use dispenser
- Hot and ambient water path
- Metered 25-250 mL dispense
- Dispensing needle interface
- ACTEX deiodination filter
- Aquisense UV monitoring
- Particulate filtration
- Rehydration mode
- Flush Iodine / Flush Water



Image Source: Leidos

System-Level Trade Studies

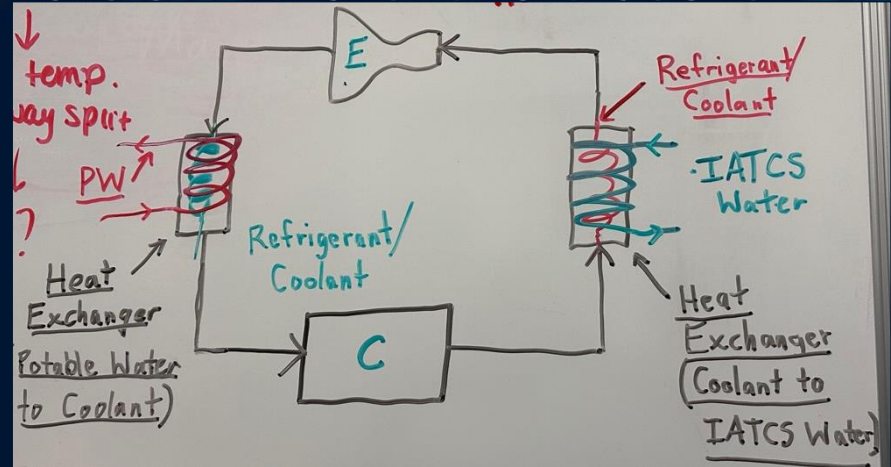


Image Source: ASTRA Lab

Refrigerant Trade Study

Refrigerant			R-134a			R-404a			R-744 (CO2)		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Thermal Conductivity (l)	0.3	W/m-K	0.081	3	0.9	0.0683	2	0.6	0.081	3	0.9
Boiling Point	0.1	deg C	-26.3	3	0.3	-46.5	2	0.2	-78	1	0.1
Sat. Pressure at 25C (l)	0.25	kPa	666.06	3	0.75	1255	2	0.5	6370	1	0.25
Latent Heat of Vap.	0.2	kJ/kg	216	2	0.4	202.1	1	0.2	234.5	3	0.6
Volumetric Refrigeration Capacity	0.15	kJ/m^3	3,340	1	0.15	5,745	2	0.3	24,640	3	0.45
Overall Value					2.5			1.8			2.3

- The refrigerant is the main driver of vapor-compression system
- Major parameters include thermal conductivity, saturation pressure, and volumetric refrigeration capacity.
- **Winner was R-134a, Tetrafluoroethane**



Image Source: UltraCool

Heat Exchanger Trade Study

Heat Exchanger			VPE A22-2 HX-01041			Exergy Shell & Tube 10 Series			ChillX Stainless Steel (10 Ton)		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Max Pressure	0.2	bar	124.1	3	0.6	104	2	0.4	36	1	0.2
Max Internal Surface Area	0.1	m^2	0.3849	3	0.3	0.016	1	0.1	0.15	2	0.2
Material Yield Strength	0.2	MPa	240	3	0.6	170	2	0.4	170	2	0.4
Max Temperature	0.25	deg C	200	2	0.5	425	3	0.75	30	1	0.25
Longest Dimension	0.25	mm	508	1	0.25	226	3	0.75	360.7	2	0.5
Overall Value					2.25			2.4			1.55

- Used for both evaporator and condenser
- Parameters prioritized includes max temperature, longest dimension, and max pressure
- Higher scores given to those with more favorable values
- **Winner was Exergy's Shell & Tube 10 Series**



Image Source: Exergy

Compressor Trade Study

Compressor			RIGID HVAC QX1901VDL			Aspen A-9			Lando Chillers LD-MC 024		
Parameter	Weight	Units	Mag.	Score	Value	Mag.	Score	Value	Mag.	Score	Value
Cooling Capacity	0.2	W	450	2	0.4	455	2	0.4	625	3	0.6
Mass	0.15	kg	0.72	2	0.3	0.68	3	0.45	1.3	1	0.15
Max Variable Speed	0.25	rpm	6500	3	0.75	6500	3	0.75	6300	2	0.5
Min Evaporator Temperature	0.15	deg C	5	3	0.45	-22	1	0.15	5	3	0.45
Operating Voltage	0.25	V	12	3	0.75	24	1	0.25	12	3	0.75
Overall Value					2.65			2			2.45

- The compressor is the component that provides work to the system boosting pressure and temperature of low pressure, medium temperature vapor
- Most important parameters include maximum variable speed, operating voltage, and cooling capacity
- **Winner is RIGID's HVAC Mini Compressor QX1901VDL**



Image Source: RIGID

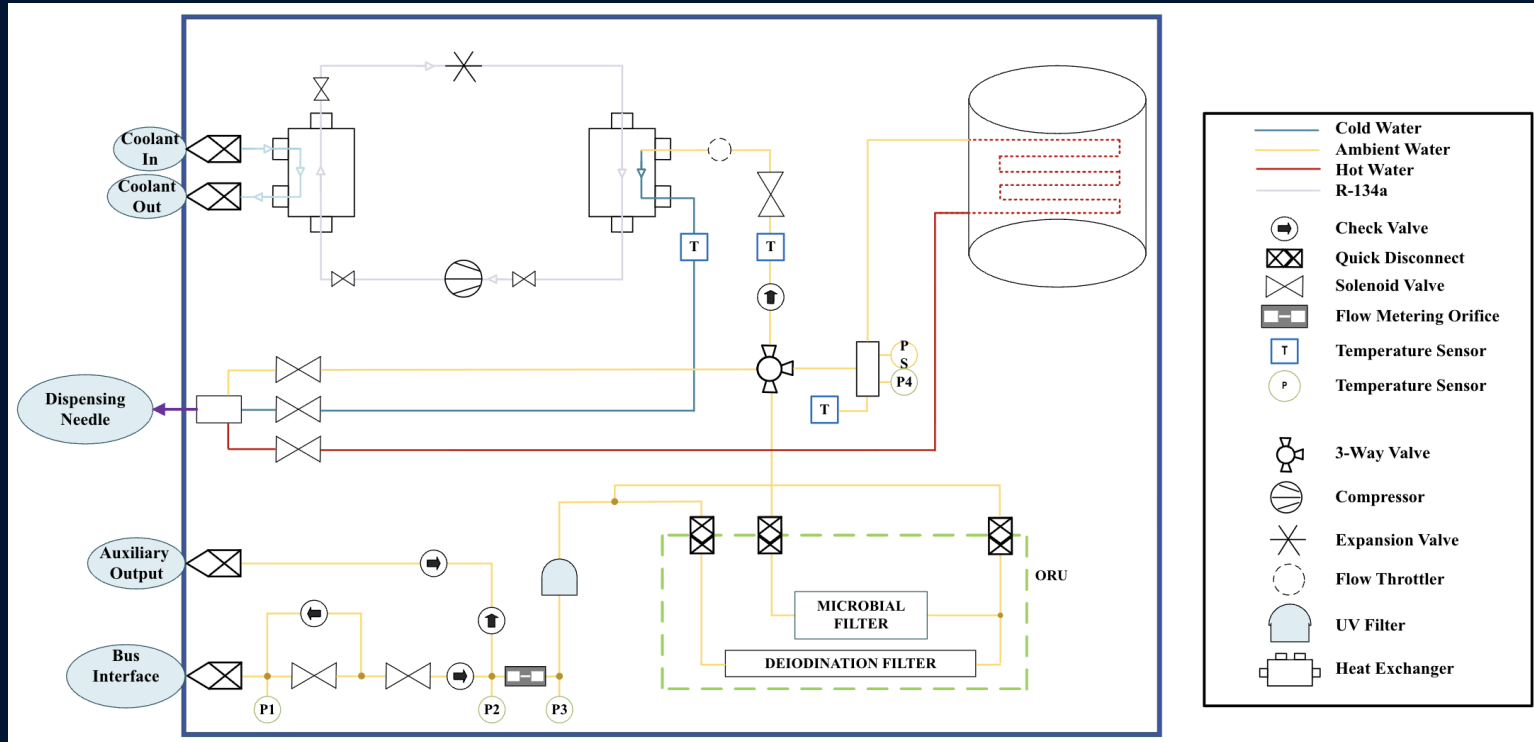
Component Selection Summary

Component	Selection
Refrigerant	R-134a
Evaporator	Exergy Shell & Tube 10 Series
Condenser	Exergy Shell & Tube 10 Series
Compressor	RIGID HVAC QX1901VDL
Pipes	Stainless Steel 316L
Solenoid Valve	STC 2S050
Temperature Sensor	ATC Semitec BTS5
Flow Control Valve	Bürkert Type 2875

System Overview

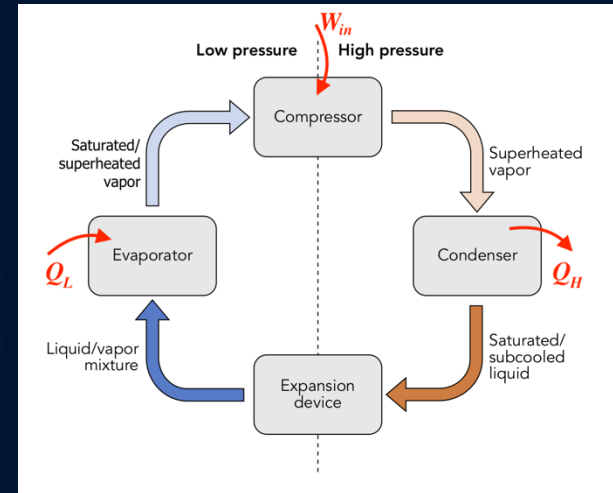


Functional Architecture



Refrigeration Cycle

- AQUORA uses vapor-compression refrigeration cycle to cool potable water
- Commonly used in refrigeration and air conditioning systems
- Compressor
 - Increases pressure of refrigerant
 - High pressure, high temperature vapor
- Condenser
 - Rejects heat from refrigerant
 - High pressure, medium temperature liquid
- Expansion Valve
 - Decreases pressure of refrigerant
 - Low pressure, low temperature liquid
- Evaporator
 - Absorbs heat into refrigerant
 - Low pressure, medium temperature vapor



The AQUORA Dispenser

- Evaporator and condenser both use shell-and-tube heat exchangers
- ISS Internal Active Thermal Control System (IATCS) coolant loop is used as heat sink for condenser
 - Currently used on the ISS FRIDGE
- Evaporator
 - Potable water flows through shell side and refrigerant flows through tube side
 - Refrigerant absorbs heat from potable water
- Condenser
 - IATCS coolant flows through shell side and refrigerant flows through tube side
 - IATCS coolant absorbs heat from refrigerant

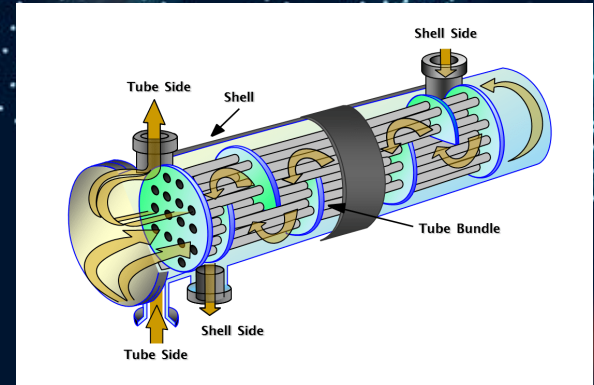


Image Source: Arveng Training & Engineering



Image Source: NASA

Past Control Systems

Current Challenges

- Past spacecraft water systems show biofilm-forming microorganisms such as *Burkholderia cepacia*, *Ralstonia pickettii*, *Sphingomonas spp.*, and *E. coli*
 - These organisms can survive in low-nutrient environments and create persistent biofilms

Recycled Solutions

- NASA's current PWD relies on iodine disinfection and UV monitoring systems
- AQUORA incorporates these systems as the foundation of microbial control
- Studies show that biofilm forming microorganisms can persist within spacecraft water systems despite existing treatments

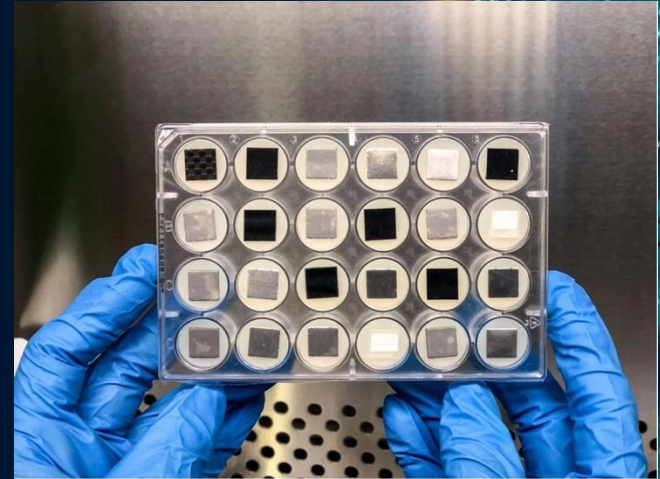


Image Source: NASA

Sonication Concept Introduction

Why Sonication?

- To supplement existing controls, AQUORA proposes ultrasonic piezoelectric actuators to reduce biofilm formation
- Sonication creates localized mechanical vibrations
 - These discourage microbial attachment and biofilm growth
- Studies from medical devices show that sonication-based methods can demonstrate up to a 10,000-fold reduction in biofilms

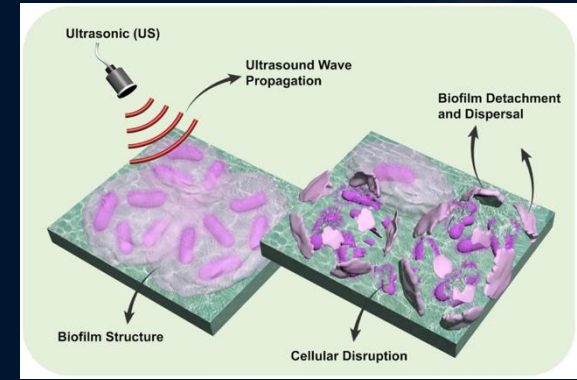


Image Source: Frontiers

Sonication Concept

How It Works

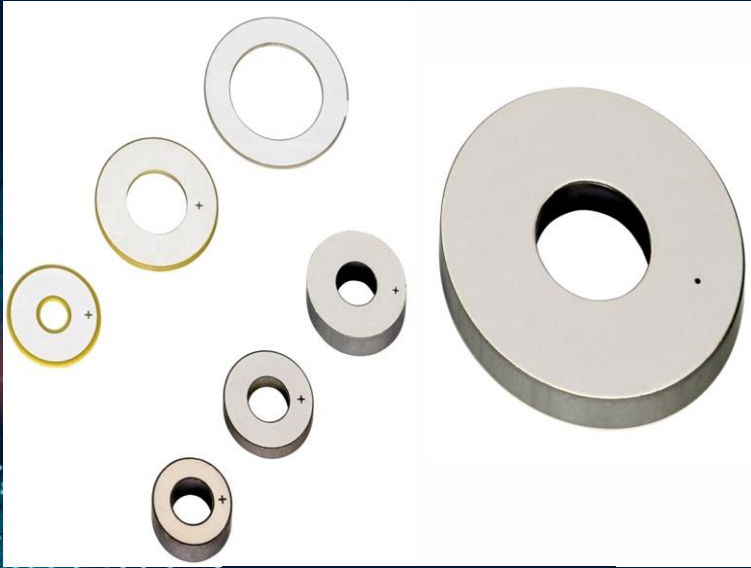


Image Source: PI-USA

- Piezoelectric ring actuators mounted on biofilm-prone tubing and manifolds
- Ultrasonic drivers power the actuators to generate vibrations through the tubing walls
- Mechanical disturbance discourages the microbial attachment
 - This means biofilm formation is disrupted
- Proposed frequency: 30 seconds every 20 minutes

Future Microbial Testing



Prototype Evaluation

- Integrate sonication subsystem into an AQUORA prototype
- Measure biofilm reduction, water quality, temperature rise, pressure drops, free gas generation, and power consumption



ISS Validation

- Test the prototype aboard the ISS
- Assess long-duration performance in microgravity
- Determine suitability for integration into future AQUORA systems

Mass, Volume, and Power

Component	Mass (kg)	Volume (cm ³)	Power (W)	Heat Rejection (W)
Evaporator	0.15	102	0	-163.7
Compressor	0.72	200	75-150	164
Condenser	0.15	102	0	196.4
Expansion Valve	0.64	25	0	0

Engineering Assumptions



ECLSS

Centralized ECLSS potable water system, allows AQUORA to be only an end-use dispenser.



ITACS

Heat rejection via the Internal Thermal Control System (ITACS), enables chilled water without a dedicated cooling system.



Compatibility

Compatible with existing spacecraft water systems, supporting hot, ambient, and chilled dispensing.



Comfort

Strict crew comfort and reliability needs, so components are low-noise and aligned with heritage PWD/xPWD system

Verification Matrix

Verification Objective	Method	Success Criteria
Cold Water Delivery	Prototype testing	4–8°C water output
Thermal Balance	Heat transfer measurements	~196 W heat rejection
IATCS Compatibility	Thermal loop testing	Meets surface limits
Fluid Isolation	Leak and pressure testing	No leakage detected
Water Quality Recovery	Dormancy and flush testing	Safe return to service

Validation Approach



Prototype Testing

Verify cold-water delivery and thermal performance



Integrated System Testing

Evaluate isolation, controls, and water quality recovery



ISS Demonstration

Assess operational performance in microgravity environment

Risk Matrix

	C1	C2	C3	C4	C5
5	Yellow	Red	Red	Red	Red
4	Yellow	Yellow	Red	R5	Red
3	Green	Yellow	R4	R2, R3	R1
2	Green	Green	R6	R7	Red
1	Green	Green	Green	Yellow	Yellow
Components					

- **R1:** Biofilm formation → Flushing & stagnation control
- **R2:** Refrigerant leak → Sealed loop & leak testing
- **R3:** Heat rejection failure → Thermal monitoring & isolation
- **R4:** Control errors → Feedback control & fault detection
- **R5:** Qualification uncertainty → Verification & testing
- **R6:** Valve failure → Fail-safe valves & flow checks
- **R7:** Compressor vibration → Isolation & acoustic testing

Development Timeline

Year 1

Phase I: Concept Development & Requirements Definition

Requirements, Trade Studies, Thermal Modeling, and PDR

Year 2

Phase II: Prototype Development & Testing

Prototype Fabrication, Refrigeration Testing, and Microbial Validation

Year 3

Phase III: Integrated Engineering Model Development

Engineering Model Integration, Performance Testing, and CDR

Year 4

Phase IV: Qualification & Environmental Testing

Thermal Vacuum, Vibration, and Reliability Testing

Development Timeline Cont.

Year 5

Phase V: Flight
Certification & Habitat
Integration

Flight Qualification,
Software Validation, and
FRR

Year 6

Phase VI: Artemis
Deployment &
Operational Validation

Artemis Deployment &
Operational Validation

A horizontal orange line with two orange circular markers. The first marker is positioned under the Year 5 section, and the second marker is positioned under the Year 6 section.

Budget Assessment

Development Cost Breakdown

Category	Cost
Hardware & Subsystem Development	\$4.8M
Testing & Facilities	\$3.4M
Personnel	\$6.4M
Program Costs	\$2.7M
Total DT&E Cost	\$17.3M

Prototype Hardware Cost: \$24K

Cost Strategy

- Reuses ISS PWD/xPWD heritage architecture
- Minimizes redesign and certification effort
- Focuses development on the cold-water subsystem
- Budget based on Vendor component pricing, Bureau of Labor Statistics salary data, and Environmental testing estimates

Future Mission Integration

Artemis Habitats

- AQUORA would produce hot, ambient, and cold potable water for lunar base inhabitants

Long Duration Space Travel

- AQUORA would support extended crew operations with increased flexibility
- AQUORA could be scaled for future larger habitats and deep space exploration



Image Source: NBC News

Conclusion

- AQUORA improves the existing ISS Potable Water Dispenser by adding a new cold-water subsystem and microbial mitigation methods
- By using existing hardware and microbial control strategies, crew members can operate a familiar system without extensive additional training
- The cold-water subsystem will improve crew comfort, hydration, and habitability for long-duration Artemis missions
- New microbial mitigation concept uses sonication to ensure safer water systems
- These enhancements add a simple solution for potable water in outer space



**Any
Questions?**



Image Sources: NASA