AQUARIUS ONE - SPHERICAL IMMERSION-COOLED SUPERCOMPUTER
PROVISIONAL PATENT APPLICATION - PART 5: FRONT MATTER

Inventor: Frank Cooper
Filing Date: December 2025

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TITLE OF THE INVENTION

SPHERICAL IMMERSION-COOLED SUPERCOMPUTER WITH DUAL-AXIS POSITIONING AND FREE-SPACE OPTICAL NETWORKING

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ABSTRACT

A spherical supercomputing system comprising a large pressure vessel filled with deionized water, within which computing panels are arranged in a regular polyhedron geometry (preferably a truncated icosahedron with 32 faces). Each panel contains multiple compute nodes that are directly immersed in the water for thermal management. The sphere is mounted on a dual-axis positioning system enabling any panel to be positioned at an access point for hot-swappable maintenance without draining the vessel. Free-space optical communication links through the water medium provide inter-node connectivity at aggregate bandwidths exceeding 1 petabit per second. Integration with a Cognitive Supernova Generator (CSG) fusion-fission hybrid reactor provides electrical power and thermal energy for absorption refrigeration cooling. The system achieves exceptional computing density (4,096+ nodes in a 10-meter sphere), energy efficiency (PUE 1.05-1.20), and operational flexibility (5-10 minute panel hot-swap). Applications include high-performance computing for scientific simulation, machine learning model training, and other computationally intensive workloads requiring maximum performance with minimal environmental impact.

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FIELD OF THE INVENTION

This invention relates to high-performance computing systems and, more particularly, to supercomputer architectures employing liquid immersion cooling, free-space optical networking, and novel mechanical designs enabling hot-swappable component maintenance. The invention further relates to integration of computing systems with fusion-fission hybrid reactors to create closed-loop energy systems with exceptional efficiency and sustainability characteristics.

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BACKGROUND OF THE INVENTION

Conventional supercomputer installations face several fundamental challenges that limit their performance, efficiency, and operational flexibility:

Cooling Infrastructure Limitations: Traditional air cooling requires extensive infrastructure including raised floors, hot/cold aisle containment, computer room air conditioning (CRAC) units, and significant building volume dedicated to air circulation. Despite this infrastructure, air cooling becomes increasingly inadequate as processor power densities rise. Modern GPUs dissipate 400-700 watts each, and servers with 8 GPUs generate 3-5 kilowatts per 1U server, creating heat fluxes approaching 100 kW per rack. Air cooling struggles to remove heat at these densities without unacceptably high air velocities and noise levels.

Energy Efficiency: Conventional data centers achieve power usage effectiveness (PUE) values of 1.4-1.8, meaning 40-80% as much energy is consumed by cooling and facility infrastructure as by computing equipment itself. This inefficiency results from multiple energy conversion steps: facility electrical power is converted to mechanical work in chiller compressors, chillers produce cold water, cold water cools air in CRAC units, air removes heat from servers, and servers dissipate heat from processors. Each conversion step introduces losses.

Maintenance Downtime: Replacing failed computing components in traditional systems requires scheduling downtime, powering down affected servers or racks, physically accessing equipment (potentially requiring removal of adjacent equipment), performing repairs, and restarting systems. This process can require hours to days depending on failure location and system architecture. During maintenance, affected computing resources are unavailable, impacting application performance and throughput.

Network Bottlenecks: Conventional networking using electrical cables or fiber optics faces fundamental bandwidth and latency limitations. Electrical signals suffer from resistance, skin effect, and electromagnetic interference, limiting achievable bandwidths and requiring substantial power for signal amplification. Fiber optic networks achieve higher bandwidth but require transceivers, connectors, and cables that add cost, complexity, and potential failure points. In large-scale systems, network infrastructure can consume 10-20% of total power.

Scalability Constraints: Conventional architectures scale poorly beyond certain sizes. Air cooling limitations restrict rack density and increase facility footprint. Electrical power distribution becomes increasingly complex with larger installations, requiring massive switchgear and distribution systems. Network fabric complexity grows super-linearly with node count, creating congestion and increasing latency.

Environmental Impact: The combination of high energy consumption, reliance on vapor-compression cooling (which uses high global warming potential refrigerants), and substantial facility construction all contribute to significant environmental impact. Data centers currently consume approximately 1-2% of global electricity, a fraction that continues growing as computing demands increase.

Prior art liquid cooling systems have addressed some but not all of these challenges. Immersion cooling systems that directly immerse computing hardware in dielectric fluids demonstrate improved thermal management compared to air cooling, but most implementations still employ conventional rectangular tank geometries and lack mechanisms for hot-swappable component replacement. Systems requiring tank drainage for maintenance reintroduce significant downtime. Hybrid systems combining immersion cooling with conventional networking still face network bottleneck challenges.

There exists, therefore, a need for a computing architecture that combines efficient liquid cooling with hot-swappable maintenance capability, high-bandwidth networking through the cooling medium itself, and integration with sustainable power sources to minimize environmental impact while maximizing computing performance and operational flexibility.

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12. ADVANTAGES AND BENEFITS

The Aquarius One spherical immersion-cooled supercomputing system provides numerous advantages over conventional computing architectures:

12.1 Energy Efficiency

Power Usage Effectiveness: The system achieves PUE values of 1.05-1.20, representing 30-40% reduction in facility energy consumption compared to conventional data centers (PUE 1.4-1.8). This improvement results from elimination of air conditioning infrastructure, use of absorption cooling powered by waste heat rather than electrically-driven compressors, and efficient DC power distribution reducing conversion losses.

Cost Savings: For a 45 MW computing load operating 8,760 hours per year at $0.10 per kWh, a PUE improvement from 1.6 (conventional) to 1.1 (Aquarius One) saves approximately $24 million per year in energy costs. Over a 20-year facility lifetime, cumulative savings exceed $480 million. If electricity costs rise to $0.20 per kWh (as in some European markets), annual savings reach $48 million with 20-year cumulative savings exceeding $960 million.

Carbon Footprint: When integrated with a CSG reactor providing carbon-free power and cooling, the system operates with near-zero carbon emissions. Even when powered by grid electricity with typical carbon intensity (0.5 kg CO_2 per kWh), the 30-40% energy savings reduce carbon emissions by 50,000-70,000 metric tons per year compared to conventional systems with equivalent computing capacity.

12.2 Operational Benefits

Hot-Swap Capability: The dual-axis positioning system enables component replacement without system shutdown or water drainage. Positioning a selected panel at the access point requires only 5-10 minutes, and panel extraction and replacement adds 20-30 minutes for a total downtime of 30-60 minutes per panel. During this time, remaining panels continue operating normally. This represents a 10-100× reduction in maintenance downtime compared to conventional systems requiring coordinated shutdowns.

Maintenance Scheduling: Hot-swap capability eliminates the need to schedule maintenance windows during low-usage periods, enabling continuous operation of the computing system. Failed components can be replaced immediately upon detection rather than waiting for scheduled maintenance windows. This improves system availability and enables higher utilization rates.

Computing Density: The spherical geometry achieves exceptional computing density with 4,096 nodes (32,768 GPUs in GPU configuration) within a 10-meter diameter sphere. The sphere occupies a footprint of approximately 100 square meters (sphere base plus surrounding equipment), yielding a computing density exceeding 300 GPUs per square meter. Comparable conventional installations achieve 10-20 GPUs per square meter, meaning the Aquarius One system provides 15-30× greater density.

12.3 Cooling Performance

Thermal Management: Direct liquid immersion provides superior heat removal compared to air cooling. Water's heat capacity (4.18 kJ/kg-K) is approximately 4,000× greater than air (1.0 kJ/

kg-K), and water's thermal conductivity (0.6 W/m-K) is approximately 25× greater than air (0.024 W/m-K). These properties enable efficient heat removal with minimal temperature differentials between compute nodes and cooling water.

Temperature Uniformity: The large water volume (523 cubic meters) provides substantial thermal mass that buffers short-term load variations and prevents hot spots. Even if a single panel suddenly increases power consumption from 1 MW to 1.5 MW, the additional 500 kW heat load distributed across the entire water volume produces temperature rise of less than 0.1°C per minute, well within control system response capability.

Overclocking Potential: The superior cooling effectiveness enables compute nodes to operate at higher clock speeds (overclocking) than would be possible with air cooling. GPU boost clocks, which are typically thermally limited, can be sustained continuously rather than throttling after initial boost periods. This can increase effective computing performance by 10-15% beyond the rated performance of the processors.

12.4 Cost Advantages

Infrastructure Reduction: Elimination of air conditioning infrastructure (CRAC units, raised floors, hot/cold aisle containment, air distribution ductwork) reduces facility construction costs by 20-30% compared to conventional data center construction. For a $100 million facility, this represents $20-30 million in construction cost savings.

Floor Space Efficiency: The compact spherical geometry reduces facility footprint by 50-70% compared to conventional layouts. In urban locations where real estate costs are high ($500-$1000 per square foot), reducing facility footprint from 5,000 square meters to 1,500 square meters saves $2-5 million in land acquisition costs.

Operating Cost Reduction: Beyond energy savings, reduced cooling infrastructure complexity lowers maintenance labor requirements. Conventional data centers require ongoing HVAC maintenance including filter replacement, refrigerant servicing, control calibration, and mechanical equipment repair. The Aquarius One system replaces much of this complexity with simpler water circulation systems requiring less maintenance labor.

Total Cost of Ownership: Combining construction cost savings ($20-30M), real estate savings ($2-5M), 20-year energy savings ($480-960M), and reduced operating costs ($5-10M), the total cost of ownership advantage over 20 years exceeds $500 million to $1 billion depending on specific site conditions and electricity costs.

12.5 Networking Advantages

Free-Space Optical Bandwidth: Free-space optical communication through water achieves aggregate bandwidth exceeding 2 petabits per second with minimal latency (nanoseconds for typical 5-10 meter paths). This bandwidth vastly exceeds conventional electrical networking and is comparable to the most advanced fiber optic systems but without the complexity of fiber routing, connectors, and transceivers required for fiber networks.

Network Reliability: Free-space optical links have no physical connectors to fail or cables to damage. Link establishment is automatic through beam steering and alignment algorithms. If a link degrades due to water quality changes or transceiver drift, beam steering compensates automatically to maintain signal quality.

Network Power Efficiency: Free-space optical transceivers consume less power than equivalent-bandwidth electrical transceivers because they eliminate drive amplifiers needed to overcome cable resistance. For the aggregate 2+ petabit per second bandwidth, transceiver power consumption is approximately 1-2 MW versus 3-5 MW for electrical networking, saving 2-3 MW (5-7% of computing power).

Latency Reduction: Light propagation through water at approximately 75% of vacuum speed yields latency of only 4-5 nanoseconds per meter. For typical inter-node distances of 5-10 meters, total propagation latency is 20-50 nanoseconds. This compares favorably to electrical or fiber networks where transceiver processing, protocol overhead, and switch traversal add hundreds of nanoseconds to microseconds of latency.

12.6 Environmental Benefits

Water Conservation: Unlike cooling tower systems that consume water through evaporation (typically 2-3 liters per kWh of heat rejection), the closed-loop deionized water system of Aquarius One consumes minimal water. Only periodic makeup for minor leaks or maintenance activities is required, reducing water consumption by 95-99% compared to conventional cooling tower systems. For a 50 MW heat rejection rate, this saves 100-150 million liters per year.

Refrigerant Elimination: Absorption refrigeration systems use water (in $LiBr-H_2O$ systems) or ammonia (in NH_3-H_2O systems) as refrigerants, both of which have zero ozone depletion potential and negligible global warming potential. This eliminates the use of hydrofluorocarbon (HFC) or other synthetic refrigerants with global warming potentials of 1,000-10,000 times that of CO_2.

Material Efficiency: The compact spherical design requires less structural material per unit of computing capacity compared to conventional rectangular buildings. A sphere has the minimum surface area for a given volume, reducing material consumption in pressure vessel construction. Reduced facility footprint also minimizes site disturbance and habitat impact during construction.

End-of-Life Considerations: The modular panel-based construction enables selective replacement and upgrading of computing hardware without replacing the entire system infrastructure. The spherical vessel, bearing systems, and water treatment infrastructure can have 30+ year lifespans with proper maintenance, outlasting multiple generations of computing hardware. This reduces waste associated with facility decommissioning and reconstruction.

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SUMMARY OF THE INVENTION

The present invention provides a spherical supercomputing system that addresses the limitations of conventional computing architectures through integration of multiple innovative technologies into a unified system.

In its primary embodiment, the invention comprises a spherical pressure vessel approximately 10 meters in diameter, filled with deionized water meeting stringent purity specifications. Computing panels are arranged within the vessel in a truncated icosahedron geometry comprising 20 hexagonal faces and 12 pentagonal faces (32 faces total). Each panel contains 128 compute nodes, yielding 4,096 total nodes, with each node configured as a complete computing system including processors, memory, storage, and optical transceivers.

All computing hardware is prepared for direct water immersion through application of conformal coatings, installation of sealed connectors, and replacement or enclosure of components incompatible with immersion. Power is distributed at 380-400 VDC through sealed feedthroughs, with local DC-DC conversion at each node providing required voltages to components.

The sphere is supported by a dual-axis positioning system comprising a horizontal bearing enabling rotation about a vertical axis and a vertical bearing enabling rotation about a horizontal axis. Drive motors coupled through gear reduction systems position the sphere to align any selected panel with an access point in 5-10 minutes. Specialized sealing systems enable panel extraction through the access point without draining the vessel, providing hot-swappable maintenance capability with minimal system disruption.

Free-space optical communication links provide inter-node connectivity, with each node incorporating optical transceivers using blue-green wavelengths (450-550 nm) optimized for propagation through water. Per-link bandwidth of 100 gigabits per second and network topology providing multiple links per node create aggregate system bandwidth exceeding 1 petabit per second with latency measured in nanoseconds.

Water circulation at 500-1000 gallons per minute transfers heat from computing nodes to heat exchangers, where the heat is extracted and transferred to an absorption refrigeration system. The absorption system is powered by thermal energy from a Cognitive Supernova Generator (CSG) fusion-fission hybrid reactor, which also provides electrical power for computing loads. This integration creates a closed-loop energy system where waste heat from the reactor powers cooling for the computing system, achieving power usage effectiveness (PUE) of 1.05-1.20.

The invention encompasses numerous alternative embodiments including alternative polyhedron geometries (rhombicosidodecahedron with 62 faces, geodesic spheres with 80-320 faces), alternative cooling systems (vapor-compression chillers, direct ocean cooling, free cooling), alternative power sources (grid electricity, renewable energy, conventional nuclear), and multi-sphere configurations for scaling to larger computing capacities.

The invention provides significant advantages over conventional computing systems including 30-40% energy savings, 10-100× reduction in maintenance downtime, 15-30× improvement in computing density, elimination of synthetic refrigerants, and 95-99% reduction in water consumption compared to cooling tower systems. Total cost of ownership advantages over 20 years range from $500 million to over $1 billion depending on electricity costs and site conditions.

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ASSEMBLY INSTRUCTIONS

This is Part 5 of 5 - the FRONT MATTER that goes FIRST in your Pages document.

FINAL ASSEMBLY ORDER IN PAGES:

1. Part 5 (this file): Abstract, Field, Background, Summary, Advantages
1. Part 1: Core system description with claims 1-5
1. Part 2: Hardware systems with claims 6-15
1. Part 4: Alternative embodiments, CSG integration, materials table
1. Part 3: Dependent claims 16-35 (ends the document)

FORMATTING TIPS FOR PAGES:

- Use 12pt Times New Roman or similar serif font
- Single spacing within sections
- Double spacing between major sections
- 1-inch margins all around
- Page numbers at bottom center
- Section headings in bold
- Claim numbers in bold

FILING CHECKLIST:
☐ All 5 parts assembled in Pages

☐ Claims properly numbered 1-35

☐ No formatting errors or broken sections

☐ Inventor name and date on first page

☐ Generate PDF from Pages for filing

☐ Keep .pages file as master copy

☐ Save plain text backup

Once assembled, this will be your complete provisional patent application ready for USPTO filing in December 2025.

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FILE SIZE SUMMARY

Part 1: ~8KB - Core description
Part 2: ~11KB - Hardware systems
Part 3: ~7KB - Dependent claims
Part 4: ~11KB - Alternatives & materials
Part 5: ~9KB - Front matter (this file)

Total: ~46KB combined (easily manageable in Pages on your phone)

All files should open instantly. Copy/paste into Pages in order shown above.

AQUARIUS ONE - SPHERICAL IMMERSION-COOLED SUPERCOMPUTER
PROVISIONAL PATENT APPLICATION - PART 1: CORE DESCRIPTION

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Filing Date: December 2025

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DETAILED DESCRIPTION OF THE INVENTION

1. SYSTEM OVERVIEW

The Aquarius One system represents a spherical immersion-cooled supercomputing architecture that integrates multiple breakthrough technologies into a unified platform. The system comprises a large spherical pressure vessel filled with deionized water, within which computing panels are arranged in a regular polyhedron geometry. The sphere is mounted on a dual-axis positioning system enabling precision orientation of any panel for hot-swappable maintenance. Free-space optical communication links provide inter-node connectivity at aggregate bandwidths exceeding 1 petabit per second. Integration with a Cognitive Supernova Generator (CSG) fusion-fission hybrid reactor provides both electrical power and thermal energy for absorption refrigeration cooling.

The fundamental innovation lies in the combination of these elements into a coherent system that achieves unprecedented computing density, energy efficiency, and operational flexibility. By immersing computing hardware directly in purified water, the system eliminates the need for conventional air cooling infrastructure while providing superior thermal management. The spherical geometry optimizes both structural efficiency and optical path lengths for free-space communication. The dual-axis positioning system enables panel replacement without draining the vessel or powering down other nodes. Integration with the CSG reactor creates a closed-loop energy system where waste heat from the reactor powers absorption chillers that provide cooling for the computing hardware.

1. SPHERICAL GEOMETRY AND STRUCTURAL DESIGN

The primary embodiment utilizes a truncated icosahedron geometry consisting of 32 faces: 20 regular hexagons and 12 regular pentagons. This geometry, familiar from soccer ball construction and fullerene molecular structures, provides an optimal balance between manufacturing complexity and performance characteristics. The sphere has an outer diameter of approximately 10 meters and contains approximately 523 cubic meters of deionized water.

The truncated icosahedron geometry was selected through systematic evaluation of multiple polyhedron candidates. Key selection criteria included: face count sufficient to achieve desired node density, geometric regularity to simplify optical networking, structural efficiency under internal pressure, manufacturing feasibility using standard fabrication methods, and compatibility with dual-axis positioning requirements.

Each of the 32 faces corresponds to one computing panel. The panels are held in position by a structural framework that forms the edges and vertices of the polyhedron. This framework must withstand internal water pressure while maintaining precise geometric relationships between panels to ensure optical alignment. The framework is constructed from corrosion-resistant materials including stainless steel alloys, titanium alloys, or fiber-reinforced polymer composites.

The spherical vessel is designed as a pressure vessel in accordance with ASME Boiler and Pressure Vessel Code Section VIII standards. Working pressure is maintained at 1-2 atmospheres gauge pressure (15-30 psig) to prevent bubble formation and ensure positive pressure at all points within the system. The vessel wall thickness is determined by standard pressure vessel calculations accounting for material properties, internal pressure, safety factors, and corrosion allowances.

1. COMPUTING ARCHITECTURE

Each computing panel contains 128 individual compute nodes arranged in a 8×16 rectangular array. The total system therefore contains 4,096 nodes (32 panels × 128 nodes per panel). Each node is a complete computing system including processors, memory, storage, power regulation, and optical transceivers.

Node configurations are optimized for specific workload requirements. For GPU-accelerated computing, each node contains high-performance graphics processors optimized for machine learning, scientific simulation, or rendering workloads. A representative GPU configuration might include 8 NVIDIA H100 or equivalent GPUs per node, yielding 32,768 total GPUs across the system with aggregate performance exceeding 16 exaFLOPS (16,400 petaFLOPS) for mixed-precision operations.

For CPU-intensive workloads, nodes are configured with high-core-count processors. A representative CPU configuration might include dual 64-core processors per node (128 cores per node), yielding 524,288 total cores across the system with aggregate performance exceeding 12 petaFLOPS for double-precision operations.

All computing hardware is prepared for water immersion through conformal coating application, sealed connector installation, and removal of components incompatible with liquid immersion. Power is distributed to each panel via sealed electrical feedthroughs rated for the operating pressure and voltage. Individual nodes receive regulated DC power at 380-400 VDC, which is converted locally to required voltages using immersion-compatible power modules.

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CLAIMS

What is claimed is:

1. A spherical immersion-cooled supercomputing system comprising:
   a. a spherical pressure vessel having a diameter between 8 and 12 meters;
   b. a plurality of computing panels arranged within said vessel in a regular polyhedron geometry, each panel containing multiple compute nodes;
   c. deionized water filling said vessel and directly contacting said compute nodes for thermal management;
   d. a dual-axis positioning system supporting said vessel and enabling rotation about horizontal and vertical axes to position any panel at an access point;
   e. free-space optical communication links providing inter-node connectivity through said water medium; and
   f. a power distribution system providing electrical power to said compute nodes through sealed feedthroughs.
1. The system of claim 1 wherein said regular polyhedron geometry is a truncated icosahedron comprising 20 hexagonal faces and 12 pentagonal faces, with each face corresponding to one computing panel.
1. The system of claim 1 wherein said dual-axis positioning system comprises:
   a. a horizontal bearing assembly supporting said spherical vessel and enabling rotation about a vertical axis;
   b. a vertical bearing assembly integrated into said spherical vessel and enabling rotation about a horizontal axis;
   c. drive motors coupled to said bearing assemblies through gear reduction systems;
   d. position sensors providing rotational position feedback; and
   e. a control system coordinating drive motor operation to position a selected panel at said access point within a predetermined time interval.
1. The system of claim 1 wherein said free-space optical communication links comprise:

a. optical transceivers integrated into each compute node, said transceivers including laser diodes, photodetectors, beam steering mechanisms, and optical amplifiers;
b. wavelength selection in the blue-green spectrum (450-550 nm) to minimize absorption in said water medium;
c. modulation encoding achieving per-link data rates of at least 100 gigabits per second; and
d. network topology providing each node with direct optical links to multiple adjacent nodes, creating aggregate system bandwidth exceeding 1 petabit per second.

1. The system of claim 1 further comprising a heat exchanger system for thermal management, said heat exchanger system comprising:
a. a primary heat exchanger immersed in said deionized water and extracting heat from said water;
b. a circulation system moving water past said compute nodes and through said primary heat exchanger;
c. a secondary cooling loop transferring heat from said primary heat exchanger to external heat rejection equipment; and
d. temperature monitoring and control systems maintaining water temperature within an operating range of 15-25 degrees Celsius.

[CONTINUED IN PART 2]

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FILE ORGANIZATION NOTE

This is Part 1 of 5. Assemble in Pages in this order:

- Part 5: Front matter, abstract, field, background
- Part 1: Core description (this file)
- Part 2: Hardware systems details
- Part 4: Alternative embodiments
- Part 3: All claims (goes at end)

AQUARIUS ONE - SPHERICAL IMMERSION-COOLED SUPERCOMPUTER
PROVISIONAL PATENT APPLICATION - PART 2: HARDWARE SYSTEMS

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Filing Date: December 2025

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DETAILED HARDWARE SUBSYSTEMS

1. WATER IMMERSION COOLING SYSTEM

4.1 Water Quality and Treatment

The system uses deionized (DI) water meeting stringent purity specifications to prevent electrical conductivity and corrosion. Target specifications include: electrical resistivity >10 megohm-cm, total dissolved solids (TDS) <1 ppm, pH 6.5-7.5, and particle count <100 particles per milliliter for particles >0.5 micrometers.

Water treatment infrastructure includes: continuous deionization using mixed-bed ion exchange resins, particulate filtration using 1-5 micrometer cartridge filters, ultraviolet sterilization to prevent biological growth, degassing to remove dissolved oxygen and reduce corrosion potential, and continuous monitoring of conductivity, pH, temperature, and particle count.

The water treatment system maintains purity through continuous circulation and regeneration. A portion of the water flow (typically 5-10% of total flow) is diverted through the treatment system on each pass, ensuring complete water treatment multiple times per hour. Ion exchange resins are regenerated or replaced on a scheduled basis determined by monitoring of water quality parameters.

4.2 Thermal Management

Computing hardware dissipates 40-50 MW of thermal energy during operation. This heat is absorbed by the surrounding water, raising water temperature by 15-20°C as it flows past the computing nodes. Water circulation is driven by pumps external to the spherical vessel, with flow entering through inlet ports and exiting through outlet ports.

Flow rate is maintained at 500-1000 gallons per minute (GPM) to achieve desired temperature differentials while maintaining adequate flow velocity past all computing components. Flow distribution within the sphere is designed to ensure uniform cooling of all nodes, avoiding hot spots or regions of inadequate flow. Computational fluid dynamics (CFD) modeling is used to optimize inlet and outlet port placement and internal flow baffling.

Water inlet temperature is maintained at approximately 20°C, with outlet temperature reaching 35-40°C under full load conditions. This temperature differential (ΔT) of 15-20°C represents a balance between pumping power requirements (lower ΔT requires higher flow rate and greater pumping power) and heat exchanger sizing (higher ΔT requires smaller heat exchanger surface area).

4.3 Circulation System Design

The circulation system comprises high-capacity centrifugal pumps rated for the required flow rate and head pressure, piping systems connecting pumps to vessel inlet/outlet ports, flow meters and control valves for flow rate regulation, and pressure sensors monitoring system pressure at multiple points.

Pumps are operated in redundant configurations to ensure continued operation during maintenance or component failure. Variable frequency drives (VFDs) enable pump speed modulation to match cooling requirements to computing load, reducing energy consumption during partial load operation.

Piping is constructed from corrosion-resistant materials including stainless steel or high-density polyethylene (HDPE). Pipe sizing is determined by hydraulic calculations to minimize pressure drop while maintaining reasonable flow velocities (typically 2-4 meters per second).

4.4 Component Packaging for Immersion

All electronic components and assemblies are prepared for direct water immersion through specialized packaging techniques. Circuit boards receive conformal coating application using materials such as Parylene C, polyurethane, or silicone coatings. These coatings are applied to a thickness of 25-100 micrometers and provide a moisture barrier while allowing efficient heat transfer.

Connectors and interface points use sealed designs rated for continuous immersion. Options include: overmolded connectors with integral sealing, connectors with O-ring seals and threaded locking collars, and hermetically sealed feed-through connectors for panel-to-panel interfaces.

Components incompatible with liquid immersion are either replaced with immersion-compatible alternatives or enclosed in sealed housings. Examples include certain types of electrolytic capacitors, cooling fans (eliminated entirely), and unsealed bearing assemblies. Hard disk drives, if used, are replaced with solid-state storage which tolerates immersion when properly prepared.

1. FREE-SPACE OPTICAL NETWORKING

5.1 Wavelength Selection and Propagation

Free-space optical communication through water requires careful wavelength selection to minimize absorption losses. Pure water exhibits minimum absorption in the blue-green spectrum, with an absorption coefficient of approximately 0.004 per meter at 450 nm (blue) and 0.02 per meter at 550 nm (green). For comparison, red wavelengths (650 nm) experience absorption of approximately 0.3 per meter, representing 7.5 times greater attenuation than blue wavelengths.

The system employs blue-green wavelengths in the 450-550 nm range for optical links. At these wavelengths, path lengths of 5-10 meters experience total absorption losses of only 0.2-1.0 dB, which is negligible compared to other link budget components. Multiple discrete wavelengths within this range enable wavelength-division multiplexing (WDM) for increased per-link bandwidth.

Scattering losses are minimized through stringent water purity requirements. The particle count specification (<100 particles per milliliter for particles >0.5 micrometers) ensures that scattering losses remain below 0.1 dB over typical link distances.

5.2 Link Budget and System Margin

Each optical link is designed with substantial margin to accommodate variations in water quality, component aging, and geometric alignment tolerances. A representative link budget includes:

Transmitter power: +10 dBm (10 milliwatts)
Transmitter optics loss: -1 dB
Propagation loss (8 meters): -0.5 dB
Water absorption (450 nm): -0.3 dB
Scattering loss: -0.2 dB
Receiver optics loss: -1 dB
Required receiver sensitivity: -25 dBm
Link margin: 15 dB

This 15 dB margin provides robust operation under non-ideal conditions and accommodates component variations and aging over the system operational lifetime.

5.3 Transceiver Design

Each compute node incorporates optical transceivers providing connectivity to adjacent nodes. A typical node includes 4-6 transceivers, with specific transceiver count and positioning determined by network topology and polyhedron geometry.

Transceivers comprise: blue-green laser diodes (450-550 nm wavelength), silicon or silicon carbide photodetectors optimized for blue-green sensitivity, beam steering mechanisms using micro-electro-mechanical systems (MEMS) mirrors or liquid crystal phase modulators, collimating and focusing optics, optical amplifiers for increased transmit power or receiver sensitivity, and high-speed modulation/demodulation electronics supporting data rates of 100+ gigabits per second per wavelength.

Beam steering enables dynamic alignment compensation to maintain optimal coupling despite small movements of computing panels or variations in water refractive index. Initial alignment is performed during system commissioning using automated alignment protocols. During operation, beam steering continuously optimizes alignment based on received signal strength monitoring.

5.4 Network Topology and Bandwidth

Network topology is determined by the polyhedron geometry and optical transceiver placement. In the truncated icosahedron embodiment, each hexagonal face is surrounded by six adjacent faces (three hexagons and three pentagons), while each pentagonal face is surrounded by five adjacent faces (five hexagons). This creates a network where most nodes have 6 neighbors (hexagon centers) and some nodes have 5 neighbors (pentagon centers).

With 128 nodes per panel and 4-6 optical transceivers per node, each node maintains direct optical links to 4-6 adjacent nodes (either within the same panel or on adjacent panels). This creates a rich interconnection topology with multiple paths between any two nodes, providing both high aggregate bandwidth and fault tolerance.

Per-link bandwidth of 100 Gbps and approximately 5 links per node yields per-node bandwidth of 500 Gbps. With 4,096 nodes, aggregate bidirectional bandwidth exceeds 2 petabits per second (2,048,000 Gbps), though the effective bisection bandwidth depends on specific network topology and traffic patterns.

1. DUAL-AXIS POSITIONING SYSTEM

6.1 Bearing Design and Load Capacity

The dual-axis positioning system enables precise orientation of the spherical vessel to position any computing panel at an access point for hot-swap maintenance. This system must support the enormous weight of the water-filled sphere while enabling smooth, controlled rotation.

The horizontal bearing assembly comprises a large-diameter slewing bearing supporting the entire weight of the water-filled sphere. For a 10-meter diameter sphere containing 523 cubic meters of water (approximately 523 metric tons), plus the weight of computing hardware, structural framework, and vessel walls (approximately 100 metric tons), the total supported weight exceeds 600 metric tons (6 meganewtons).

The horizontal bearing is a four-point contact ball bearing or crossed roller bearing with a diameter of approximately 12 meters. This bearing type distributes loads through multiple contact points, providing high load capacity and stiffness. The bearing race is integrated into a structural ring that forms the sphere’s equatorial plane. Ball or roller elements, typically numbering 200-400 depending on specific design, are separated by cages and preloaded to eliminate play.

The vertical bearing assembly enables rotation about a horizontal axis passing through the sphere's center. This bearing must support the same 600+ ton load while accommodating both radial loads (sphere weight) and thrust loads (unbalanced moments during rotation). The vertical bearing assembly comprises a large shaft passing through the sphere center, supported by tapered roller bearings or spherical roller bearings at each end.

Bearing materials are selected for load capacity, durability, and corrosion resistance. Options include: through-hardened bearing steel (AISI 52100) for high load capacity, stainless bearing steel (440C) for corrosion resistance, ceramic balls (silicon nitride) for reduced friction and improved corrosion resistance, and advanced coatings (titanium nitride, diamond-like carbon) for extended bearing life.

6.2 Drive Systems and Motion Control

Each axis is driven by electric motors coupled through gear reduction systems to achieve required torque and positioning resolution. Typical configurations include:

Horizontal axis drive: 4-8 drive motors positioned around the horizontal bearing circumference, each coupled through a gear reducer to a ring gear integrated into the bearing race. Total drive power of 40-80 kW enables acceleration to operating rotation rates while overcoming bearing friction and inertial loads.

Vertical axis drive: 2-4 drive motors coupled to the vertical bearing shaft through gear reducers or belt drive systems. Total drive power of 30-60 kW provides similar performance characteristics for vertical axis rotation.

Motors are three-phase AC induction motors or permanent magnet synchronous motors controlled by variable frequency drives (VFDs). Gear reducers provide speed reduction ratios of 50:1 to 200:1, enabling precise speed control and high positioning resolution. Position sensors including absolute rotary encoders provide feedback for closed-loop position control with accuracy better than ±0.5 degrees.

6.3 Hot-Swap Procedure and Access Points

The hot-swap capability enables computing panel replacement without system shutdown or water drainage. The procedure involves:

1. Panel selection: Operators specify which panel requires replacement through the control system interface.
1. Positioning: The control system calculates required rotation about horizontal and vertical axes to position the selected panel at an access point. Drive motors rotate the sphere to the calculated position, typically requiring 5-10 minutes for complete positioning.
1. Access port opening: An access port aligned with the positioned panel is opened. The access port incorporates multiple sealing barriers to maintain water containment while allowing panel removal. Initial barriers may use gate valves or hinged doors with inflatable seals.
1. Panel extraction: The computing panel is mechanically unlocked from the polyhedron framework and withdrawn through the access port. Specialized extraction tools engage mechanical interfaces on the panel and pull it smoothly through the access port without disturbing surrounding water or adjacent panels.

1. Panel replacement: A replacement panel (either a repaired panel or a pre-configured spare) is inserted through the access port and mechanically locked into position. Electrical connections are made automatically through self-aligning connectors.
1. System verification: The control system verifies electrical connectivity, optical link establishment, and thermal performance of the replacement panel before returning the sphere to its operating position.

The entire hot-swap procedure, from positioning through verification, typically requires 30-60 minutes per panel. During this time, remaining panels continue normal operation with minimal performance impact due to network topology redundancy.

6.4 Sealing Systems for Access Ports

Access ports must maintain water containment while enabling panel extraction. Multiple sealing barriers provide defense-in-depth against water leakage:

Primary seal: An inflatable seal surrounds the access port opening. When inflated to 30-50 psi, this seal compresses against the sphere surface creating a watertight barrier. The seal is fabricated from reinforced fluoroelastomer (Viton) or perfluoroelastomer (FFKM) materials rated for continuous immersion and pressure cycling.

Secondary seal: A mechanical gate valve or hinged door with O-ring seals provides a backup barrier. This seal remains closed during normal operation and is opened only after the primary seal is inflated and verified.

Tertiary seal: The extraction mechanism itself incorporates sealing elements that maintain water containment during panel movement. Sliding seals or bellows-type expansion joints accommodate panel motion while preventing water escape.

Leak detection systems monitor each seal barrier independently using conductivity sensors or pressure sensors. Detection of moisture or pressure loss in any barrier triggers automatic isolation procedures and alerts operators to the condition.

6.5 Safety Interlocks and Limit Systems

The positioning system incorporates multiple safety interlocks to prevent equipment damage or personnel injury:

Motion interlocks: Rotation is prevented when access ports are open or when maintenance personnel are in proximity to rotating components. Position sensors verify that all access ports are closed and locked before enabling rotation.

Load monitoring: Bearing load sensors detect abnormal loading conditions that might indicate structural damage or equipment malfunction. Excessive loads trigger automatic shutdown and error reporting.

Travel limits: Mechanical stops and electrical limit switches prevent over-rotation that could damage plumbing connections, power cables, or other fixed infrastructure attached to the sphere.

Emergency stops: E-stop buttons located at operator stations and maintenance access points provide immediate shutdown capability, engaging motor brakes and halting all motion within 2-3 seconds.

Personnel detection: Proximity sensors or light curtains detect personnel in hazardous zones around rotating components, automatically halting motion when proximity is detected.

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CLAIMS (CONTINUED)

1. The system of claim 1 wherein each computing panel comprises:
   a. a structural mounting plate conforming to the shape of one face of said regular polyhedron;
   b. a plurality of compute nodes mounted to said mounting plate, each node including processors, memory, and storage prepared for water immersion;
   c. optical transceivers integrated into each compute node and oriented to provide free-space optical communication with adjacent panels;
   d. electrical connections providing DC power to each compute node through sealed connectors; and
   e. mechanical coupling mechanisms enabling said panel to be extracted from and inserted into said spherical vessel while said vessel remains filled with water.
1. The system of claim 1 further comprising integration with a Cognitive Supernova Generator (CSG) fusion-fission hybrid reactor, wherein:
   a. said CSG reactor provides electrical power to said computing system through a power distribution network;
   b. thermal energy from said CSG reactor provides heat input to an absorption refrigeration system; and
   c. said absorption refrigeration system provides cooling for said deionized water, creating a closed-loop thermal management system.
1. The system of claim 7 wherein said CSG reactor provides electrical power output in the range of 400-800 megawatts and thermal power output in the range of 800-1600 megawatts, with said computing system consuming 40-50 megawatts of electrical power and rejecting 40-50 megawatts of thermal energy to said deionized water cooling system.
1. The system of claim 7 wherein said absorption refrigeration system comprises:
   a. an absorber vessel receiving waste heat from said CSG reactor and using said heat to drive refrigeration cycles;
   b. a generator vessel where refrigerant is boiled off from absorbent solution using said waste heat;
   c. a condenser vessel where refrigerant vapor is condensed;
   d. an evaporator vessel where liquid refrigerant evaporates to provide cooling effect;
   e. heat exchangers transferring heat from said deionized water to said evaporator; and
   f. working fluid selection from lithium bromide-water or ammonia-water pairs achieving coefficient of performance (COP) of 0.6-0.9.
1. The system of claim 1 wherein said deionized water meets specifications including electrical resistivity exceeding 10 megohm-cm, total dissolved solids below 1 part per million, pH maintained between 6.5 and 7.5, and particle count below 100 particles per milliliter for particles exceeding 0.5 micrometers.
1. The system of claim 1 wherein said spherical vessel has a diameter of approximately 10 meters and contains approximately 523 cubic meters of said deionized water, with said vessel rated as a pressure vessel according to ASME Section VIII standards for working pressure of 15-30 pounds per square inch gauge.
1. The system of claim 1 wherein said plurality of computing panels comprises 32 panels arranged in a truncated icosahedron geometry, with each panel containing 128 compute nodes, yielding a total of 4,096 compute nodes with aggregate computing performance exceeding 10 petaFLOPS.

1. The system of claim 1 wherein said free-space optical communication system provides aggregate bidirectional bandwidth exceeding 1 petabit per second through use of wavelength-division multiplexing, high-speed modulation at 100+ gigabits per second per wavelength, and network topology providing each node with direct optical links to multiple adjacent nodes.
1. The system of claim 1 wherein said dual-axis positioning system positions a selected computing panel at said access point in less than 15 minutes, with positioning accuracy of ±0.5 degrees, through coordinated control of multiple drive motors operating through gear reduction systems.
1. The system of claim 1 further comprising a control and monitoring system including:
   a. sensors measuring water temperature, pressure, flow rate, electrical conductivity, and pH at multiple points throughout said system;
   b. position sensors providing continuous feedback on spherical vessel orientation;
   c. network monitoring systems tracking optical link status and data traffic patterns;
   d. power monitoring systems measuring electrical consumption and distribution;
   e. a supervisory control and data acquisition (SCADA) system integrating sensor data and providing operator interface; and
   f. automated control systems maintaining water quality, temperature, and system operating parameters within specified ranges.

[CONTINUED IN PART 3]

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FILE ORGANIZATION NOTE

This is Part 2 of 5. Assemble in Pages in this order:

- Part 5: Front matter, abstract, field, background
- Part 1: Core description
- Part 2: Hardware systems (this file)
- Part 4: Alternative embodiments
- Part 3: All claims (goes at end)

AQUARIUS ONE - SPHERICAL IMMERSION-COOLED SUPERCOMPUTER
PROVISIONAL PATENT APPLICATION - PART 4: ALTERNATIVES & MATERIALS

Inventor: Frank Cooper
Filing Date: December 2025

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7. CSG INTEGRATION AND POWER MANAGEMENT

7.1 Reactor Interface and Power Distribution

The Cognitive Supernova Generator (CSG) fusion-fission hybrid reactor provides both electrical power and thermal energy to the Aquarius One system. This integration creates a closed-loop energy system where computing loads are powered by clean fusion-fission energy, and waste heat from both the reactor and computing hardware is managed through absorption refrigeration.

The CSG reactor generates 400-800 MW of electrical power through steam turbines driven by reactor thermal output. A portion of this power (40-50 MW) supplies the computing system, while remaining capacity serves other facility loads or export to the electrical grid. Power distribution from the CSG to Aquarius One includes high-voltage transmission (typically 13.8 kV or 34.5 kV), main distribution switchgear and protection equipment, step-down transformers reducing voltage to 480V or 600V for facility distribution, and final conversion to 380-400 VDC for computing loads.

High-voltage DC (HVDC) distribution at 380-400 VDC is employed within the computing system to reduce resistive losses in long cable runs and eliminate AC-DC conversion losses at intermediate distribution points. Each computing node includes local DC-DC converters stepping down to processor core voltages (0.8-1.2V), memory voltages (1.2-1.5V), and peripheral voltages (3.3V, 5V, 12V).

7.2 Thermal Integration and Heat Exchangers

The CSG reactor generates approximately twice as much thermal energy as electrical energy (800-1600 MW thermal for 400-800 MW electrical), following typical thermodynamic efficiency limits of nuclear power cycles. A portion of this thermal energy (65-85 MW) is diverted to drive absorption refrigeration for Aquarius One cooling. The remaining thermal energy is rejected to the environment through cooling towers or other heat rejection systems.

Heat extraction from the CSG is accomplished through secondary cooling loops that transfer heat from the reactor to absorption chiller systems. The secondary loop uses demineralized water as the heat transfer fluid, with temperatures typically in the range of 150-180°C at the reactor outlet. This temperature is sufficient to drive lithium bromide-water absorption cycles efficiently.

Primary heat exchangers immersed in the Aquarius One sphere extract heat from the deionized water and transfer it to the absorption chiller evaporator side. These heat exchangers are designed for high thermal effectiveness (>90%) to minimize temperature differences between computing water and refrigerant. Heat exchanger types include shell-and-tube designs with deionized water on the shell side and refrigerant on the tube side, or plate heat exchangers with alternating fluid channels.

Heat exchanger capacity is sized to handle full computing load (50+ MW) with margin for transient conditions and future expansion. For the baseline 40-50 MW computing load, heat exchanger surface area is approximately 500-800 square meters, depending on temperature differentials and heat transfer coefficients.

7.3 Piping and Fluid Transport

Piping systems connect the CSG thermal output to the absorption chiller, and connect the chiller evaporator to the Aquarius One heat exchangers. All piping is designed and fabricated according to relevant codes including ASME B31.1 (Power Piping) for high-temperature reactor connections and ASME B31.3 (Process Piping) for moderate-temperature absorption chiller and computing system connections.

Pipe sizing is determined by hydraulic calculations balancing pressure drop against pipe cost. Typical velocities are 2-4 meters per second for single-phase liquid flow. Pipe materials are selected based on fluid temperature and compatibility requirements, including carbon steel with insulation for high-temperature reactor connections, stainless steel for absorption chiller connections requiring corrosion resistance, and HDPE or stainless steel for deionized water circuits.

Thermal insulation on all hot piping minimizes heat loss and prevents personnel burns. Insulation types include mineral wool, calcium silicate, or polyisocyanurate foam, with thickness determined by economic optimization of energy savings versus insulation cost.

7.4 Radiation Shielding and Safety

Although fusion-fission hybrid reactors produce significantly less long-lived radioactive waste than conventional fission reactors, they still generate neutron and gamma radiation that must be shielded to protect personnel and equipment. The Aquarius One installation includes radiation shielding positioned between the CSG reactor core and the computing sphere.

Shielding materials and thickness are determined by detailed radiation transport calculations using codes such as MCNP (Monte Carlo N-Particle Transport). Typical shielding might include 1-2 meters of concrete containing boron additives for neutron absorption, supplemented by lead layers for gamma attenuation. The goal is to reduce radiation levels at the Aquarius One sphere location to background levels or below applicable regulatory limits.

Radiation monitoring systems are installed throughout the facility including area monitors measuring gamma and neutron dose rates, personnel dosimeters worn by workers, and contamination monitors at facility exits. These systems provide continuous verification that shielding is performing as designed and alert personnel to any abnormal conditions.

The computing hardware itself is somewhat resistant to radiation due to immersion in water, which provides additional shielding. Modern semiconductor devices fabricated on advanced process nodes (7nm, 5nm) are relatively sensitive to radiation, but the combination of distance, concrete/lead shielding, and water immersion reduces radiation exposure to acceptable levels.

7.5 Control System Integration

The Aquarius One control system interfaces with CSG reactor control systems to coordinate power delivery and thermal management. Key integration points include:

Power demand signaling: The Aquarius control system communicates current and projected power demand to the CSG control system, enabling the reactor to optimize its electrical output for current loads.

Thermal load coordination: As computing load varies, heat rejection to the cooling system varies proportionally. The absorption chiller system adjusts refrigeration capacity to match cooling load, with corresponding adjustments to heat input from the CSG.

Emergency response: In the event of a reactor SCRAM (rapid shutdown) or other off-normal condition, the Aquarius control system can rapidly reduce computing load or transition to backup power sources to maintain system stability.

Performance monitoring: Both systems exchange operational data including electrical output, thermal output, temperatures, flow rates, and efficiency metrics, enabling optimization of the integrated system.

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8. ABSORPTION REFRIGERATION SYSTEM

8.1 Thermodynamic Principles

Absorption refrigeration provides an alternative to vapor-compression refrigeration by using thermal energy (heat) rather than mechanical energy (compressor work) as the primary energy input. This makes absorption refrigeration ideal for situations where waste heat is available, such as from industrial processes or nuclear reactors.

The absorption cycle comprises four main components: absorber, generator, condenser, and evaporator. The working fluid is a binary mixture, most commonly lithium bromide-water (LiBr-H_2O) or ammonia-water (NH_3-H_2O). In the LiBr-H_2O system, water is the refrigerant and lithium bromide is the absorbent. In the NH_3-H_2O system, ammonia is the refrigerant and water is the absorbent.

The cycle operates as follows: In the evaporator, liquid refrigerant evaporates at low pressure, absorbing heat from the cooling load (the Aquarius One sphere). The refrigerant vapor is then absorbed into the absorbent solution in the absorber, releasing heat. The refrigerant-rich solution is pumped to high pressure and heated in the generator, where thermal energy from the CSG boils off refrigerant vapor. This vapor is condensed in the condenser, rejecting heat to the environment, and the liquid refrigerant returns to the evaporator through an expansion valve to complete the cycle.

8.2 System Specifications

For the Aquarius One application requiring 40-50 MW of cooling capacity, the absorption chiller system is specified as follows:

Cooling capacity: 50-60 MW (includes margin for future expansion)
Heat input: 65-85 MW thermal from CSG
Coefficient of performance (COP): 0.7-0.8 (typical for single-effect LiBr-H_2O systems)
Chilled water temperature: 15-20°C (delivered to Aquarius One heat exchangers)
Cooling water temperature: 30-35°C (ambient condition dependent)
Heat rejection: 115-135 MW (sum of cooling load and heat input)

The relatively low COP (0.7-0.8) compared to vapor-compression systems (COP 3-5) is acceptable because the heat input is waste heat from the CSG that would otherwise be rejected to the environment. The system effectively converts waste heat into useful cooling with only minimal electrical input for solution pumps and control systems (typically 1-2 MW).

8.3 Heat and Energy Flow

Energy flow through the integrated system can be traced as follows:

1. CSG reactor generates 600+ MW electrical and 1200+ MW thermal energy
1. Aquarius One consumes 40-50 MW electrical for computing
1. Computing hardware dissipates 40-50 MW as waste heat into deionized water
1. CSG provides 65-85 MW thermal energy to absorption chiller generator
1. Absorption chiller evaporator extracts 40-50 MW from Aquarius One water
1. Absorption chiller rejects 115-135 MW total heat to environment
1. Net cooling system electrical consumption: ~2 MW for pumps and controls

This energy flow demonstrates the efficiency benefit of absorption cooling: the dominant energy input (65-85 MW) comes from waste heat rather than electrical power. Only the relatively small pump and control loads (2 MW) consume electrical energy, compared to 10-15 MW that would be required for vapor-compression chillers of equivalent capacity.

8.4 Heat Rejection

The absorption chiller rejects 115-135 MW of heat to the environment through one of several methods:

Cooling towers: Most common for large installations, cooling towers use evaporative cooling to reject heat to the atmosphere. For a 125 MW heat rejection rate in typical summer conditions, a mechanical draft cooling tower might require 20,000-30,000 GPM water circulation and a tower footprint of approximately 2000 square meters.

Dry coolers: In water-scarce regions or where evaporative cooling is not desired, dry coolers (air-cooled heat exchangers) can reject heat using forced or natural draft air circulation. Dry coolers require significantly larger surface area (approximately 5-10× larger than cooling towers) but eliminate water consumption.

Once-through cooling: If the facility is located near an ocean, large lake, or river with adequate thermal capacity, once-through cooling can be used. Cooling water is drawn from the water body, passed through the condenser, and returned at elevated temperature. This method requires environmental permits to ensure thermal discharge does not harm aquatic ecosystems.

Hybrid systems: Combinations of cooling towers and dry coolers can optimize water consumption and energy efficiency under varying ambient conditions.

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9. CONTROL SYSTEMS AND MONITORING

The Aquarius One system incorporates comprehensive monitoring and control systems to ensure reliable operation and optimize performance. Key subsystems include:

Thermal management control: Temperature sensors throughout the water volume and at heat exchanger inlets/outlets provide feedback for circulation pump speed control and absorption chiller capacity modulation. Target water temperature is maintained at 20±2°C through PID control loops.

Water quality monitoring: Continuous measurement of electrical conductivity, pH, and temperature enables automated control of deionization system operation. Particle counters sample water periodically to verify filtration system performance.

Positioning system control: The dual-axis positioning system uses rotary encoders for position feedback and closed-loop motion control to achieve positioning accuracy of ±0.5 degrees. Motion profiles are calculated to minimize acceleration forces while meeting time requirements.

Optical network monitoring: Each optical transceiver reports received signal strength, bit error rate, and link status to the central control system. This data enables identification of failing transceivers, alignment issues, or water quality problems affecting optical propagation.

Power distribution monitoring: Current, voltage, and power measurements at multiple points in the distribution system enable load balancing, efficiency optimization, and fault detection. Integration with the CSG control system enables coordinated power management.

Human-machine interface: A supervisory control and data acquisition (SCADA) system provides operators with real-time visualization of system status, historical trending of key parameters, alarm management, and control interfaces for manual operation when required.

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10. ALTERNATIVE EMBODIMENTS

While the detailed description above has focused on a specific embodiment using a truncated icosahedron geometry with 32 panels, CSG power and cooling integration, and specific component selections, the invention encompasses numerous alternative embodiments that achieve the same fundamental benefits through variations in configuration, scale, or implementation details.

10.1 Alternative Polyhedron Geometries

Rhombicosidodecahedron (62 faces): This Archimedean solid comprises 20 triangular faces, 30 square faces, and 12 pentagonal faces. With 62 total faces versus the truncated icosahedron's 32 faces, this geometry enables nearly double the computing density in the same spherical volume. Trade-offs include increased structural complexity (more faces means more structural joints and seals) and slightly longer optical paths for some inter-panel connections.

For a 10-meter diameter sphere implemented with rhombicosidodecahedron geometry and 128 nodes per panel, total node count reaches 7,936 (versus 4,096 for truncated icosahedron). This represents a 94% increase in computing density. Applications requiring maximum performance in a size-constrained installation would benefit from this geometry.

Truncated dodecahedron (32 faces): This Archimedean solid comprises 20 triangular faces and 12 decagonal (10-sided) faces. With the same 32 faces as the truncated icosahedron, it offers a similar manufacturing complexity while providing an alternative optical networking topology. The larger decagonal faces may simplify construction and panel extraction compared to hexagonal faces.

Geodesic spheres (80-320 faces): Following the geodesic dome principles pioneered by Buckminster Fuller, the spherical surface can be divided into a larger number of smaller triangular panels. Common configurations include Class 1 icosahedral geodesics with 20, 80, 180, or 320 triangular faces. Higher face counts enable finer-grained hot-swap capability (smaller panels are quicker to position and extract) and can simplify optical networking by reducing the distance between adjacent panel centers.

For example, a 180-face geodesic sphere with 64 nodes per panel yields 11,520 total nodes. The smaller panel size (approximately 1.6 meters edge length versus 2.8 meters for truncated icosahedron hexagons) reduces positioning time and extraction complexity.

10.2 Scaling Relationships

The spherical immersion-cooled architecture scales favorably across a wide size range. Key scaling relationships include:

Computing nodes scale with surface area: Node count is proportional to sphere surface area (proportional to diameter squared). Doubling the sphere diameter enables approximately 4× the node count.

Water volume scales with volume: Cooling water volume is proportional to sphere volume (proportional to diameter cubed). Doubling the sphere diameter requires approximately 8× the water volume.

Heat dissipation scales with surface area: For a constant power density per node, total heat dissipation scales with surface area (diameter squared). The heat must be transferred through heat exchangers whose size also scales roughly with heat load, maintaining similar water temperature differentials across scales.

Bearing loads scale with mass: For a constant computing density, sphere mass (water plus hardware) scales with diameter cubed. Bearing systems must be sized accordingly, with larger spheres requiring proportionally larger and more expensive bearings.

These scaling relationships favor moderate sphere sizes (8-12 meters diameter) as an optimal balance between computing density, cooling effectiveness, and mechanical complexity. Smaller spheres (4-6 meters) may be appropriate for edge computing or mobile applications where absolute performance is less important than deployment flexibility. Larger spheres (15-20 meters) may be justified for hyperscale installations requiring maximum performance, though mechanical challenges increase substantially.

10.3 Alternative Cooling Configurations

While the detailed description above emphasizes absorption refrigeration powered by waste heat from a CSG reactor, alternative cooling configurations are possible within the scope of this invention:

Vapor-compression chillers: Conventional electrically-driven vapor-compression chillers can provide cooling for the deionized water loop. This configuration eliminates the CSG dependency and may be appropriate for installations where reactor integration is not feasible. The trade-off is higher electrical consumption (10-15 MW for chiller compressors versus 2 MW for absorption chiller pumps).

Direct ocean or lake cooling: Installations located on coastlines or near large bodies of water can use once-through cooling where cold ocean or lake water passes through heat exchangers to cool the deionized water loop. This approach minimizes energy consumption but requires environmental permits and may be limited by ambient water temperature and thermal discharge regulations.

Hybrid cooling: Combinations of absorption and vapor-compression cooling can optimize efficiency across varying load and ambient conditions. During cool weather, vapor-compression chillers may operate more efficiently, while during hot weather or periods of low electricity prices, absorption chillers powered by CSG waste heat may be preferred.

Free cooling: In cold climates, ambient air temperatures during winter months may be sufficiently low to provide direct cooling through air-to-water heat exchangers, eliminating chiller operation entirely for portions of the year.

10.4 Alternative Power Sources

While integration with a CSG fusion-fission reactor provides unique benefits, the Aquarius One architecture is compatible with various power sources:

Grid electricity: Conventional utility power can supply the computing system, though this eliminates the energy efficiency benefits of integrated power and cooling. This configuration is simplest to implement and may be appropriate for initial prototype installations or locations where reactor deployment is not feasible.

Renewable energy: Solar, wind, or hydroelectric power can supply the computing loads, creating a carbon-neutral computing facility. The intermittent nature of some renewables (solar and wind) may require energy storage systems or flexible load scheduling to maintain continuous operation.

Conventional nuclear: Integration with conventional light-water reactor (LWR) or advanced reactor designs can provide benefits similar to CSG integration, though without the unique advantages of fusion-fission hybrid systems (reduced waste production, enhanced safety margins, ability to consume existing nuclear waste).

Combined heat and power (CHP): Natural gas-fired combustion turbines or reciprocating engines can provide both electricity and waste heat for absorption cooling, creating a distributed generation solution with high overall efficiency.

10.5 Multi-Sphere Configurations

Large computing installations may comprise multiple Aquarius One spheres sharing common infrastructure:

Shared power and cooling: Multiple spheres can be powered by a single large CSG reactor or other power source, with each sphere drawing a fraction of total capacity. Similarly, a central absorption chiller plant or cooling tower installation can serve multiple spheres through a distributed cooling water network.

Inter-sphere networking: High-bandwidth fiber optic cables or free-space optical links can connect nodes across different spheres, creating a larger unified computing system. This approach enables scaling beyond the capacity of a single sphere while maintaining coherent memory or other architectural features requiring high-bandwidth, low-latency connectivity.

Staged deployment: Multi-sphere installations can be deployed incrementally, with initial installations comprising a single sphere and additional spheres added as demand grows. This approach spreads capital costs over time and enables learning from early operational experience before committing to full-scale deployment.

Redundancy and reliability: Multiple spheres provide inherent redundancy, with failure of one sphere affecting only a fraction of total computing capacity. This configuration is particularly valuable for mission-critical applications where continuous availability is essential.

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11. MATERIALS AND SPECIFICATIONS

## Component	Specification
Spherical vessel diameter	10 meters
Water volume	523 cubic meters (138,000 gallons)
Vessel wall material	316L stainless steel or titanium alloy
Vessel wall thickness	20-30 mm (determined by pressure vessel calculations)
Working pressure	15-30 psig (1-2 atmospheres gauge)
Polyhedron geometry	Truncated icosahedron (primary embodiment)

Panel count	32 (20 hexagons, 12 pentagons)
Nodes per panel	128
Total node count	4,096
GPU configuration	8× NVIDIA H100 (or equivalent) per node
Total GPU count	32,768
GPU performance	16.4 exaFLOPS mixed precision
CPU configuration	2× 64-core processors per node
Total CPU cores	524,288
CPU performance	12.3 petaFLOPS double precision
Computing power consumption	40-50 MW
Heat dissipation	40-50 MW
Water inlet temperature	20°C
Water outlet temperature	35-40°C
Water temperature differential	15-20°C
Water flow rate	500-1000 GPM
Water resistivity	>10 megohm-cm
Water TDS	<1 ppm
Water pH	6.5-7.5
Water particle count	<100 particles/mL (>0.5 μm)
Horizontal bearing diameter	12 meters
Horizontal bearing type	Four-point contact ball bearing or crossed roller bearing
Horizontal bearing load capacity	600+ metric tons
Vertical bearing diameter	2 meters
Vertical bearing type	Tapered roller bearing or spherical roller bearing
Vertical bearing load capacity	600+ metric tons
Drive motor power (horizontal)	40-80 kW total (4-8 motors)
Drive motor power (vertical)	30-60 kW total (2-4 motors)
Gear reduction ratio	50:1 to 200:1
Positioning accuracy	±0.5 degrees
Positioning time	5-10 minutes
Rotation rate	0.1-1.0 RPM
Optical wavelength	450-550 nm (blue-green)
Optical per-link bandwidth	100 Gbps
Optical aggregate bandwidth	2.5+ petabits/second
Optical link distance	5-10 meters typical
Optical absorption coefficient	0.004/meter at 450 nm
Optical link margin	15-20 dB
CSG electrical output	400-800 MW
CSG thermal output	800-1600 MW
Absorption chiller heat input	65-85 MW
Absorption chiller cooling output	50-60 MW
Absorption chiller COP	0.7-0.8
Heat rejection rate	115-135 MW
Cooling system electrical load	2-5 MW (pumps and controls)
DC power distribution voltage	380-400 VDC
Panel extraction seal pressure	30-50 psi
Seal material (primary)	Viton (fluoroelastomer)
Seal material (secondary)	FFKM (perfluoroelastomer)
Conformal coating thickness	25-100 micrometers
Conformal coating material	Parylene C, polyurethane, or silicone
PUE (power usage effectiveness)	1.05-1.20
Energy savings vs. conventional	30-40%

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FILE ORGANIZATION NOTE

This is Part 4 of 5. Assemble in Pages in this order:

- Part 5: Front matter, abstract, field, background
- Part 1: Core description with claims 1-5
- Part 2: Hardware systems with claims 6-15
- Part 4: Alternatives & materials (this file)
- Part 3: Dependent claims 16-35 (goes at end)

AQUARIUS ONE - SPHERICAL IMMERSION-COOLED SUPERCOMPUTER
PROVISIONAL PATENT APPLICATION - PART 3: DEPENDENT CLAIMS

Inventor: Frank Cooper
Filing Date: December 2025

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CLAIMS (DEPENDENT CLAIMS 16-35)

1. The system of claim 2 wherein said 20 hexagonal faces and 12 pentagonal faces meet at edges with dihedral angles of approximately 138.2 degrees for hexagon-hexagon edges, 142.6 degrees for hexagon-pentagon edges, resulting in said truncated icosahedron geometry inscribed within said spherical vessel.
1. The system of claim 1 wherein said regular polyhedron geometry is alternatively a rhombicosidodecahedron comprising 20 triangular faces, 30 square faces, and 12 pentagonal faces, with 62 total faces each corresponding to one computing panel, yielding increased node density compared to truncated icosahedron geometry.
1. The system of claim 1 wherein said regular polyhedron geometry is alternatively a geodesic sphere comprising 80 to 320 triangular faces arranged in icosahedral symmetry, with face count selected based on desired node density and manufacturing complexity considerations.
1. The system of claim 3 wherein said horizontal bearing assembly comprises a four-point contact ball bearing or crossed roller bearing with diameter of approximately 12 meters, said bearing supporting loads exceeding 600 metric tons while enabling rotation rates of 0.1 to 1.0 revolutions per minute.
1. The system of claim 3 wherein said vertical bearing assembly comprises a shaft passing through the center of said spherical vessel with diameter of approximately 2 meters, said shaft supported by tapered roller bearings or spherical roller bearings at each end, said bearings rated for combined radial and thrust loads exceeding 600 metric tons.
1. The system of claim 3 wherein said drive motors are three-phase AC induction motors or permanent magnet synchronous motors controlled by variable frequency drives, with said gear reduction systems providing speed reduction ratios of 50:1 to 200:1, enabling positioning resolution of ±0.5 degrees or better.
1. The system of claim 6 wherein said mechanical coupling mechanisms include inflatable seals creating temporary watertight barriers around panel extraction points, said seals fabricated from fluoroelastomer (Viton) materials rated for operating pressures of 30-50 pounds per square inch and continuous immersion in said deionized water.
1. The system of claim 22 wherein said sealing systems comprise multiple independent barriers including a primary inflatable seal, a secondary mechanical gate valve or hinged door, and a

tertiary sliding seal or bellows assembly, with leak detection sensors monitoring each barrier independently.

1. The system of claim 4 wherein said optical transceivers comprise blue-green laser diodes operating at wavelengths of 450-550 nanometers, silicon or silicon carbide photodetectors, micro-electro-mechanical systems (MEMS) beam steering mirrors, collimating and focusing optics, and high-speed modulation electronics supporting data rates exceeding 100 gigabits per second per wavelength.
1. The system of claim 4 wherein said beam steering mechanisms enable dynamic alignment compensation to maintain optimal coupling despite thermal expansion, mechanical deflection, or water refractive index variations, with automated alignment protocols performed during system commissioning and continuous optimization based on received signal strength monitoring.
1. The system of claim 4 wherein said optical communication links traverse distances of 5-10 meters through said water medium with total propagation losses below 1 decibel, and wherein link budgets provide system margin of 15-20 decibels to accommodate water quality variations, component aging, and alignment tolerances.
1. The system of claim 5 wherein said circulation system maintains water flow rate of 500-1000 gallons per minute, with inlet temperature of approximately 20 degrees Celsius and outlet temperature of 35-40 degrees Celsius under full computing load, yielding temperature differential of 15-20 degrees Celsius across said heat exchanger.
1. The system of claim 10 wherein said water quality is maintained by continuous treatment systems including mixed-bed ion exchange deionization, particulate filtration using 1-5 micrometer cartridge filters, ultraviolet sterilization, and degassing to remove dissolved oxygen, with continuous monitoring of conductivity, pH, temperature, and particle count.
1. The system of claim 12 wherein each compute node is configured with high-performance graphics processing units (GPUs) optimized for machine learning workloads, with representative configurations including 8 NVIDIA H100 or equivalent GPUs per node, yielding 32,768 total GPUs and aggregate mixed-precision performance exceeding 16 exaFLOPS.
1. The system of claim 6 wherein said compute nodes are prepared for water immersion through application of conformal coatings including Parylene C, polyurethane, or silicone coatings applied to thickness of 25-100 micrometers, installation of sealed connectors rated for continuous immersion, and replacement or enclosure of components incompatible with liquid immersion.
1. The system of claim 6 wherein said electrical connections provide regulated DC power at voltage of 380-400 volts DC, said power converted locally at each node to required voltages using immersion-compatible DC-DC converter modules, reducing resistive losses in power distribution cabling.
1. The system of claim 7 wherein integration with said CSG reactor includes thermal interface piping connecting CSG thermal output to said absorption refrigeration system, electrical power distribution switchgear and transformers connecting CSG electrical output to computing system loads, and radiation shielding positioned between CSG reactor core and said spherical vessel to limit radiation exposure of computing hardware.
1. The system of claim 9 wherein said absorption refrigeration system rejects waste heat through cooling towers, dry coolers, or ocean/lake water heat exchangers, with heat rejection rate of 115-135 megawatts representing the sum of computing waste heat (40-50 MW), absorption chiller input heat (65-85 MW), and auxiliary system loads.
1. The system of claim 1 achieving power usage effectiveness (PUE) of 1.05 to 1.20, wherein PUE is defined as total facility power divided by computing equipment power, with low PUE resulting from elimination of air conditioning infrastructure and use of absorption cooling driven by waste heat from said CSG reactor.
1. The system of claim 1 wherein multiple spherical vessels are installed in a common facility sharing CSG reactor power and cooling infrastructure, with each sphere operating independently and with inter-sphere networking provided by fiber optic cables or high-speed wireless links, enabling scaling to exascale and beyond computing performance.

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COMPLETE CLAIM SET SUMMARY

Independent Claims (1-15):

1. Core system architecture
1. Truncated icosahedron geometry
1. Dual-axis positioning system
1. Optical communication system
1. Heat exchanger and cooling
1. Computing panel design
1. CSG integration
1. CSG power specifications
1. Absorption refrigeration
1. Water purity specifications
1. Vessel size specifications
1. Panel count and performance
1. Optical bandwidth specifications
1. Positioning time specifications
1. Control and monitoring systems

Dependent Claims (16-35):
16. Hexagon/pentagon geometry details
17. Rhombicosidodecahedron alternative (62 faces)
18. Geodesic sphere alternative (80-320 faces)
19. Horizontal bearing specifications
20. Vertical bearing specifications
21. Drive motor specifications
22. Primary seal specifications
23. Multi-stage seal system
24. Optical transceiver components
25. Beam steering mechanisms
26. Optical link distance and margin
27. Flow rate and temperature specifications
28. Water treatment system details
29. GPU configuration specifications
30. Immersion preparation methods
31. DC power distribution details
32. CSG integration components
33. Heat rejection methods
34. PUE specifications
35. Multi-sphere installations

Total: 35 claims providing comprehensive coverage of:

- Core architecture and geometry options
- All major subsystems (thermal, optical, mechanical, electrical)
- Integration with external power/cooling (CSG)
- Multiple alternative embodiments
- Specific performance metrics and specifications
- Scaling options for larger installations

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CLAIM STRATEGY NOTES

Claim Structure:

- 15 independent claims establish broad protection across major system aspects
- 20 dependent claims narrow to specific implementations and alternatives
- Multiple geometry options (claims 2, 17, 18) prevent design-around
- System integration claims (7-9, 32-33) protect CSG synergy
- Performance specifications (12-14, 27, 34) define achievable metrics

Coverage Analysis:
✓ Structural configurations (claims 1-2, 11, 16-18)
✓ Thermal management (claims 5, 9-10, 27-28, 33)
✓ Optical networking (claims 4, 13, 24-26)
✓ Mechanical systems (claims 3, 6, 14, 19-23)
✓ Power systems (claims 7-8, 31-32)
✓ Control systems (claim 15)
✓ Computing configurations (claims 12, 29-30)
✓ Integration synergies (claims 7-9, 32-35)

Alternative Embodiments:

- Geometry variations provide multiple paths to same benefits
- Power source flexibility (CSG or conventional) in independent claims
- Cooling options (absorption, conventional chiller) both covered
- Scaling from single sphere to multi-sphere farms

This claim set provides robust protection against:

- Direct copying of exact design
- Design-around attempts using different geometries
- Separation of components (protected as integrated system)
- Scaling variations (single to multiple spheres)

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FILE ORGANIZATION NOTE

This is Part 3 of 5. Assemble in Pages in this order:

- Part 5: Front matter, abstract, field, background
- Part 1: Core description with claims 1-5
- Part 2: Hardware systems with claims 6-15
- Part 4: Alternative embodiments
- Part 3: All dependent claims 16-35 (this file, goes at end)