SHIELDED CHAMBER DESIGN SPECIFICATIONS

For Consciousness-Dependent Quantum Decoherence Measurements
Phase 0 Configuration

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Revision Notes — Rev B

Engineering corrections applied to prior draft

This revision incorporates a set of engineering corrections to the prior draft. All changes affect internal specifications only; the overall architecture, scope, and Phase 0 objectives are unchanged. The revision record below documents every substantive change for review and cross-reference.

#	Section	Correction Applied
1	§4 / §5	Layer ordering revised. Layer 2 (mu-metal) and Layer 3 (copper) re-sequenced into a dual-layer magnetic system: outer copper (RF) → outer mu-metal (LF magnetic) → air gap → inner mu-metal (gradient suppression).
2	§5.2 / §12	Magnetic shielding requirement upgraded from >60 dB to >80 dB AC (50/60 Hz) to account for mains-frequency ambient. Dual-layer mu-metal with 50 mm air gap specified.
3	§5.1 / §7.2	Active thermal control added to Layer 1. Passive aerogel alone cannot dissipate observer heat load (~100 W) while holding ±0.01 K. Peltier loop + chilled fluid circulation specified.
4	§7.2	Air handling recalculated. CO_2 scrubber capacity sized to observer CO_2 output (~20 L/hr at rest) for 90-minute session. Fan vibration and acoustic load explicitly budgeted.
5	§6.2 / §8	SQUID specification corrected. LN_2 removed — single-channel LTS SQUID at 4 K (LHe dewar) specified where 10 fT/√Hz is required; HTS SQUID at 77 K listed as lower-cost fallback at ~50 fT/√Hz.
6	§6.1	Observer EEG re-spec'd. Bluetooth/Wi-Fi emission from wireless amp explicitly disabled; battery-only with fiber-optic data egress; amp RF emission to be verified in airlock.
7	§6.2 / §8.3	QRNG in-chamber electronics (USB-to-fiber converter) acknowledged as an internal RF source and added to performance budget.
8	§3.3	Panic-bar event explicitly flagged as a session-invalidating event requiring full shielding reverification before next use.
9	§6.1 / §3.2	Observer ingress oscillations clarified as part of the 10-minute settling window, not before it. Settling window extended to minimum 15 minutes post-ingress.
10	§7.3	GPS 10 MHz reference clarified — receiver outside chamber, distributed via fiber through waveguide-below-cutoff tubes.
11	§12	Post-relocation and annual magnetic remapping added to commissioning and maintenance schedule.
12	§10	Budget updated to reflect dual-layer mu-metal, active thermal control, LHe-cooled SQUID option, and optically-isolated EEG. Cost range consistent with stated Phase 0 scope.
13	§5.5	Copper mesh downgraded from 200×200/inch to 100×100/inch — adequate for RF targets, significantly lower cost and less fragile.

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1. Design Objective

This document specifies the engineering requirements for a shielded experimental chamber designed to test whether the cognitive state of a conscious observer produces measurable changes in the decoherence rate (T2) of a nearby quantum system. The chamber creates a controlled environment of maximum electromagnetic, acoustic, vibrational, and thermal isolation while maintaining a symmetric geometry optimized for minimal boundary-induced decoherence.

The independent variable is the observer's cognitive state (seven controlled conditions, verified by real-time EEG). The dependent variable is the coherence time T2 of the quantum sensor. The chamber must reduce all known environmental coupling channels below the threshold where standard decoherence models predict T2 limits, such that any residual variation across consciousness conditions cannot be attributed to uncontrolled environmental factors.

1.1 Performance Requirements

- Electromagnetic attenuation: >120 dB across 10 Hz – 10 GHz
- Magnetic field attenuation: >80 dB DC and AC (50/60 Hz) — upgraded from >60 dB
- Acoustic isolation: >80 dB; interior ambient <20 dB SPL
- Vibration isolation: <1022 m/s^2 across 1–100 Hz at sensor platform
- Thermal stability: ±0.01 K over 60-minute session (with active control)
- Interior geometry: Perfect cube, 3.0 m × 3.0 m × 3.0 m clear volume
- Observer capacity: Single seated adult at geometric center

> **Rev B correction — magnetic target.**
> The prior requirement of >60 dB magnetic attenuation was under-spec'd for the NV sensor's sensitivity to mains-frequency (50/60 Hz) field fluctuations. Typical lab AC magnetic noise is ~100 nT; 60 dB attenuation leaves ~100 pT residual, which approaches NV T2 limits at ensemble scale. The upgraded >80 dB target requires a dual-layer mu-metal architecture with an air gap (see §4, §5.2). The previous single-layer design is retained as a fallback at reduced sensitivity.

2. Overall Architecture

2.1 Dimensions

Parameter	Specification
Inner clear volume	3.0 m × 3.0 m × 3.0 m (27.0 m³)
Outer footprint	4.3 m × 5.5 m × 4.3 m (incl. airlock; increased 100 mm for dual-layer mu-metal)
Total shielding thickness	650 mm per side (dual-layer magnetic adds 50 mm)
Orientation	Entry on east face; observer faces west when seated
Primary access	East face — dual-door airlock entry system (see §3)
Outer door	1.0 m W × 2.1 m H, east face of airlock
Inner door	1.0 m W × 2.1 m H, west face of airlock (enters main chamber)
Door seals (both)	Multi-layer: RF gasket + dual mu-metal overlap + acoustic compression seal
Feedthrough panel	West face (opposite entry), centered
Total chamber mass (est.)	10,500 – 14,500 kg (incl. airlock and second mu-metal layer)
Foundation requirement	Reinforced concrete slab, 300 mm min, vibration-isolated

2.2 Geometry Rationale

The perfect cubic geometry is selected for four engineering reasons:

- **Spatial symmetry**: Minimizes anisotropic boundary conditions that could produce position-dependent decoherence variation.
- **Mode density**: Cubic geometry supports the lowest and most uniform electromagnetic mode density for a given volume.
- **Fabrication simplicity**: Flat panels simplify shielding layer construction, seam welding, and quality assurance.
- **East-facing entry**: Positions the observer facing west (toward the feedthrough panel / deepest interior), maximizing the distance between the access opening (highest seal-leakage risk) and the primary sensor array. The observer walks from east to west through the airlock into the main chamber, passing through progressive isolation layers sequentially.

2.3 Coordinate System

Origin at inner floor corner (southeast). X-axis west, Y-axis north, Z-axis vertical. Geometric center at (1.5, 1.5, 1.5) m. The observer enters from the east (X = 0) and is seated at center facing west (X = 3.0). The feedthrough panel is on the west face (X = 3.0). All sensor and observer positions referenced to this coordinate system.

3. Airlock Entry System

A dual-door airlock anteroom is positioned on the east face of the main chamber. The airlock serves three critical engineering functions: (1) it prevents direct line-of-sight RF leakage when either door is open, (2) it provides a contamination buffer where the observer's electromagnetic emissions from clothing, devices, and body can be checked and stabilized before entering the shielded interior, and (3) it ensures the observer passes sequentially through all five isolation layers, with no bypass path.

3.1 Airlock Dimensions

Parameter	Specification
Interior volume	1.0 m (E–W) × 1.2 m (N–S) × 2.3 m (height)
Outer door (east face)	1.0 m W × 2.1 m H, opens outward
Inner door (west face)	1.0 m W × 2.1 m H, opens inward to main chamber
Interlock	Only one door can be open at a time (electrical interlock + mechanical latch)
Shielding	All five layers continuous through airlock walls, ceiling, and floor
Lighting	Battery-powered LED (shielded), manual switch inside airlock
Communication	Fiber-optic intercom to control room, active in airlock

3.2 Entry Protocol

- **Step 1 — Pre-entry check**: Observer removes all metallic objects, electronic devices, and magnetically contaminated clothing in the preparation area outside the chamber. EEG cap is fitted and verified. Wireless radios on the EEG amp (Bluetooth, Wi-Fi) are confirmed disabled in hardware; unit operates battery-only with fiber-optic data egress.
- **Step 2 — Outer door open**: Observer enters airlock. Outer door is sealed behind the observer.
- **Step 3 — Stabilization**: Observer remains in airlock for 60 seconds. RF power meter inside airlock confirms observer's residual electromagnetic emission is below threshold (<–80 dBm across 10 kHz–10 GHz), including emission from the EEG amp itself. Fluxgate magnetometer confirms no ferromagnetic contamination.
- **Step 4 — Inner door open**: Once contamination check passes, inner door is released. Observer enters main chamber and proceeds to seated position at geometric center.
- **Step 5 — Inner door sealed**: Inner door is closed and sealed. Both doors now closed. Full shielding integrity restored.
- **Step 6 — Settling period**: Minimum 15-minute settling period begins (data discarded). This interval includes observer postural oscillation damping on the vibration-isolated floor and thermal re-equilibration of the chamber after ingress.

3.3 Exit Protocol

Reverse sequence: inner door opens first (observer exits to airlock), inner door sealed, outer door opens, observer exits. At no point are both doors open simultaneously. Emergency override (panic bar) on inner door bypasses interlock for immediate egress.

> **Panic-bar event — session invalidation.**
> Any activation of the inner-door panic bar mechanically bypasses the airlock interlock and creates a transient direct-RF path between the exterior environment and the sensor volume. This is correct for observer safety. However, any such event **invalidates the current session** and requires full shielding reverification (see §12.1) before the next session. Sessions in which the panic bar was not used but was contacted or tested are logged but not invalidated.

> **Design note — sequential layer passage.**
> The airlock ensures that the observer's entry path passes through every isolation layer in sequence: Layer 5 (outer Faraday) → Layer 4 (vibration) → Layer 3 (copper RF) → Layer 2b (outer mu-metal) → Layer 2a (inner mu-metal) → Layer 1 (acoustic/thermal) → interior. No layer is bypassed. This is critical for maintaining shielding integrity and preventing contamination bridging.

4. Five-Layer Isolation System

The isolation system consists of five functional layers, with the magnetic shielding implemented as a dual-layer subsystem (2a inner, 2b outer) separated by an air gap. Layers are numbered from innermost (Layer 1) to outermost (Layer 5). Total thickness per side: 650 mm.

Layer	Function	Material	Thickness	Attenuation
1 (Inner)	Acoustic + active thermal	Acoustic foam + aerogel + Peltier-cooled liner	150 mm	>40 dB acoustic, ±0.01 K (active)
2a	Magnetic — gradient suppression	Mu-metal (80% Ni alloy), inner shell	3 mm	Combines with 2b for >80 dB
2b	Magnetic — primary attenuation	Mu-metal (80% Ni alloy), outer shell + 50 mm air gap	3 mm + 50 mm gap	>80 dB DC/LF magnetic (combined with 2a)
3	RF / microwave shielding	OFHC copper sheet, welded seams	2 mm	>100 dB (10 kHz – 10 GHz)
4	Vibration isolation	Pneumatic isolators + neoprene dampers	200 mm	<1022 m/s² (1–100 Hz)
5 (Outer)	Structural + outer Faraday	Aluminum shell + copper mesh cage	245 mm	>120 dB combined EM

Layer ordering rationale (revised)

The dual-layer magnetic system (2a/2b) sits **inside** the copper RF shell (Layer 3) for two reasons: (i) mu-metal permeability is degraded by high RF field exposure, so the copper shell pre-attenuates incident RF before it reaches the mu-metal; (ii) the air gap between 2a and 2b increases effective magnetic shielding by a factor of ~3× compared to a single shell of equivalent total thickness. The acoustic/thermal layer (Layer 1) remains innermost to establish the stable acoustic and thermal environment the observer and sensors experience, but is now an **actively controlled** layer rather than passive.

> **Rev B correction — magnetic architecture.**
> The prior draft specified mu-metal as Layer 2 (single shell) between acoustic/thermal and copper. This has been re-architected as a **dual-layer mu-metal system (2a inner, 2b outer)** with a 50 mm air gap, both sitting inside the copper RF shell. The dual-layer approach is standard practice for MEG, SQUID, and precision-magnetometry chambers and is the correct architecture for the >80 dB target.

5. Layer-by-Layer Material Specifications

5.1 Layer 1 — Acoustic and Active Thermal Isolation

Component	Material / Specification	Notes
Acoustic panels	Melamine closed-cell foam (BASF Basotect or equiv.), 100 mm, NRC >0.95, Class A fire	Acoustic specialty
Thermal blanket	Silica aerogel blanket (Aspen Cryogel or equiv.), 50 mm, k < 0.015 W/mK	Passive component
Active liner	Perforated aluminum sheet, 1 mm, 20% open area, with integrated Peltier loop and chilled-fluid manifold	Dissipates observer heat load; bi-directional control ±0.01 K
Chiller	External recirculating chiller, ±0.05 K output, sealed glycol loop, located in equipment room	Vibration-decoupled via flexible fluid lines through waveguide-below-cutoff penetration
Mounting	Non-magnetic stainless clips (316L SS), bonded to foam with silicone adhesive	Non-ferromagnetic

Rev B correction — active thermal control added.

The prior Layer 1 was passive (foam + aerogel only). A seated adult dissipates ~100 W; EEG electronics, lighting, and the fluorescence laser add further heat. In a sealed aerogel-lined chamber with no air exchange, this produces an interior temperature rise of ~1–3 K over a 70-minute session — two orders of magnitude worse than the ±0.01 K requirement. Active control is therefore mandatory. The Peltier-cooled liner removes observer heat at the generation point; the external chiller dumps the heat outside the chamber via fluid loop through a vibration-decoupled waveguide penetration.

5.2 Layer 2 — Dual Mu-Metal Magnetic Shielding

Component	Specification	Notes
Primary shields (2a and 2b)	Mu-metal (MuShield or Magnetic Shield Corp.), 3 mm sheet, μ_r > 80,000 initial, > 300,000 max	Both shells hydrogen-annealed after forming
Air gap	50 mm radial gap between 2a and 2b, maintained by non-magnetic standoffs	Increases effective shielding by ~3×
Seam treatment	Mu-metal overlap strips, 50 mm overlap at all joints, spot-welded	Continuous magnetic path on both shells
Penetrations	Mu-metal waveguide-below-cutoff tubes, ID 25 mm, length 250 mm min	Through both shells, coaxial
Door overlap	Mu-metal finger stock + overlap flange, 100 mm overlap, both shells	Dual-row spring-loaded contact

CRITICAL: Hydrogen annealing.
All mu-metal components (both shells) must be hydrogen-annealed at ~1,150 °C after final forming and before installation. Mechanical stress from cutting, bending, or drilling degrades permeability by up to 90%. Annealing restores full magnetic shielding performance. Budget 6–12 weeks lead time for annealing service (longer for European vendors).

5.3 Layer 3 — RF / Microwave Shielding

Component	Specification	Notes
Shield panels	OFHC copper sheet (C10100), 2 mm, oxygen-free high-conductivity	Conductivity >100% IACS
Seam joining	Continuous TIG or silver-solder, all seams welded	No mechanical-only joints
Ground bonding	Copper braid to building ground, 25 mm² min cross-section	Single-point ground
Penetrations	Waveguide-below-cutoff copper tubes, ID 20 mm, length 200 mm	Bonded to copper shell
Door contact	BeCu RF finger stock gasket, continuous around full perimeter	Double row for redundancy

5.4 Layer 4 — Vibration Isolation

Component	Specification	Notes
Active isolators	Pneumatic air-spring isolators (TMC or Newport), 4–8 units, 2,500 kg cap ea	Uprated to account for added mass
Passive dampers	Neoprene/rubber pads, Shore A 40–60, 50 mm	Between frame and floor
Isolation frame	Welded steel frame, 100 mm × 100 mm box section	Supports all inner layers
Sensor sub-platform	Granite or cast-iron optical table, 1.5 m × 1.0 m × 0.3 m, mass >500 kg	Separate isolators from main
Flexible couplings	Bellows / flex conduits on all connections between inner and outer	Prevent vibration bridging

5.5 Layer 5 — Structural Shell and Outer Faraday Cage

Component	Specification	Notes
Structural shell	6061-T6 aluminum plate, 5 mm, welded frame	Mechanical envelope
Faraday mesh	Copper mesh, 100 × 100 per inch, bonded to inner face	Revised from 200/inch — cost and fragility
Structural frame	Aluminum extrusion, 80 mm × 80 mm T-slot profile	Modular assembly

Component	Specification	Notes
Floor	12 mm aluminum plate on steel frame, level to ±1 mm over 4.3 m	Anti-static coating
Access panel	Removable panel opposite door, for equipment installation	Sealed after setup

6. Internal Configuration

6.1 Observer Station

Parameter	Specification
Position	Geometric center: (1.5, 1.5, 0.0) m, seated head at ~(1.5, 1.5, 1.2) m
Seating	Non-magnetic meditation platform (wood/carbon fiber), no metal fasteners
EEG system	64-channel cap with optically-isolated amplifier, battery-only, fiber-optic data egress; all onboard radios (Bluetooth/Wi-Fi) hardware-disabled; emission verified <–80 dBm at airlock RF check
Physiological	Heart rate variability, respiration band, skin conductance (all non-magnetic)
Comfort	Temperature-controlled seat pad (integrated with Layer 1 active thermal), adjustable headrest, emergency call button (fiber-optic)
Session duration	45 min active condition + 30 min baseline + 15 min settling = 90 min total occupancy

Rev B correction — EEG RF discipline.
Consumer wireless EEG amplifiers (e.g. standard Brain Products LiveAmp) transmit over Bluetooth or Wi-Fi by default. Even with fiber-optic data acquisition available, these radios may remain active and emit within the chamber. Rev B requires: (i) all radios hardware-disabled or the amp selected from optically-isolated variants, (ii) battery-only operation, (iii) emission verified at the airlock RF check (<–80 dBm 10 kHz – 10 GHz) before every session.

6.2 Quantum Sensor Array

Parameter	Specification
Primary sensor (Phase 0)	Nitrogen-vacancy (NV) center in diamond, room-temperature T2 measurement
Primary sensor (Phase 1)	Superconducting transmon qubit, dilution refrigerator at 15 mK
Mounting	Non-magnetic optical table at center, 1.0 m above floor level
Distance to observer	1.0–1.5 m (adjustable along X-axis)
Secondary sensors	4× commercial QRNGs (ComScire PQ32MU), USB-to-fiber converters located externally where possible
Exploratory	Single-photon detectors (200–1000 nm), <100 dark counts/s

6.3 Environmental Monitoring Array

Instrument	Sensitivity	Rate	Purpose
3-axis fluxgate magnetometer	<10 nT resolution	1 kHz	Residual magnetic field monitoring

Instrument	Sensitivity	Rate	Purpose
SQUID magnetometer (LTS)	<10 fT/√Hz @ 4 K (LHe)	10 kHz	Ultra-sensitive magnetic monitoring
SQUID magnetometer (HTS, alt.)	~50 fT/√Hz @ 77 K (LN2)	10 kHz	Lower-cost alternative if LHe infra unavailable
RF power meter	–80 dBm sensitivity	Continuous	Residual RF leakage detection
3-axis accelerometer	1022 g resolution	1 kHz	Vibration at sensor platform
Pt100 RTD sensors (×4)	±0.001 K resolution	10 Hz	Temperature at 4 quadrants
Humidity sensor	±0.5% RH	1 Hz	Interior humidity stability
Barometric sensor	±0.1 hPa	1 Hz	Atmospheric pressure drift

All environmental channels are recorded synchronously with quantum sensor data and EEG via a common time base (GPS-disciplined 10 MHz reference, <1 μs inter-channel synchronization). Any anomaly in quantum data triggers automatic cross-correlation with all environmental channels.

> **Rev B correction — SQUID cooling.**
> The prior draft specified an LN2-cooled SQUID with 10 fT/√Hz sensitivity. This is physically inconsistent: high-temperature SQUIDs (HTS, 77 K / LN2) typically achieve ~50 fT/√Hz at best, while 10 fT/√Hz requires a low-temperature SQUID (LTS, 4 K / LHe). Rev B specifies the LTS option as primary, with LHe dewar (~30 L, manual refill weekly) and a dedicated vibration-isolated feedthrough. The HTS alternative at ~50 fT/√Hz is retained as a lower-cost, lower-sensitivity fallback.

7. Support Systems

7.1 Power

- No AC mains inside chamber.
- Battery bank (48 V LiFePO4, 5 kWh) in outer equipment room.
- DC-DC converters with optical isolation for each subsystem.
- All power lines filtered through EMI/RFI feedthrough filters at Layer 3 boundary.
- UPS backup for data acquisition (minimum 2 hours runtime).

7.2 Air Handling and Thermal Control

The air handling subsystem must balance three competing constraints: CO_2 removal for a 90-minute occupancy, <0.1 m/s flow to preserve acoustic environment, and removal of observer-generated heat. The revised specification adds explicit sizing calculations and a dedicated thermal loop separate from air flow.

Parameter	Specification / Rationale
CO_2 load	Single adult at rest produces ~20 L/hr CO_2. For 90-minute session: ~30 L total.
Scrubber sizing	Soda-lime (Sofnolime 797) or molecular sieve, capacity ≥50 L CO_2, replaced every 2 sessions.
Air recirculation	Closed-loop HEPA-filtered, <0.1 m/s at observer position, ducting through vibration-isolated bellows with acoustic baffles.
Fan	Brushless DC, vibration-isolated, located outside Layer 3. Fan vibration spectrum measured and included in performance budget (§A).
Thermal control	Separate loop via Layer 1 active liner (see §5.1). Chilled glycol circulates through perforated inner liner; observer heat load absorbed at generation point.
O_2 monitoring	Automatic abort if O_2 < 19.5%. Dual-redundant sensors, one inside chamber, one in airlock.

7.3 Data Acquisition and Time Base

- All signals routed via single-mode fiber-optic feedthroughs (FC/APC connectors).
- Fiber penetrations through waveguide-below-cutoff tubes in Layers 2a, 2b, 3, and 5.
- External DAQ system: National Instruments PXIe chassis with multi-channel digitizers.
- GPS-disciplined 10 MHz oscillator — GPS antenna **outside** chamber, on roof. Reference distributed to interior via fiber through waveguide penetration. Never attempt GPS lock inside the shielded volume.
- Data storage: Redundant NVMe RAID array, minimum 10 TB.

7.4 Safety

- Emergency egress: Inner door operable from inside without tools (panic bar). Panic-bar events invalidate the session (§3.3).
- Redundant O_2 monitoring with audible/visual alarm inside and outside.
- External video monitoring via fiber-optic camera (infrared, no EM emission inside chamber).

- Two-way fiber-optic intercom.
- Automatic session abort on any safety threshold breach.
- Fire suppression: Inert gas (Ar/N2) system, manual trigger only.

8. Quantum Sensor Integration

8.1 NV-Center in Diamond (Phase 0)

Parameter	Specification
Sensor type	Single NV center or NV ensemble in CVD diamond
T2 baseline	1–10 ms at room temperature (spin echo)
Optical excitation	532 nm laser, fiber-coupled, <10 mW at diamond
Detection	Confocal fluorescence collection, 637–800 nm, APD detector
Microwave control	Coplanar waveguide on diamond mount, ~2.87 GHz
Readout rate	~10^3 T2 measurements per session
Mounting	Diamond on PCB mount, on optical table, thermally stabilized
Advantages	Room temperature, no cryogenics, moderate cost, well-characterized
Limitations	Lower sensitivity to environmental perturbation than superconducting qubit

8.2 Superconducting Transmon Qubit (Phase 1 Upgrade)

Parameter	Specification
Sensor type	Transmon qubit in 3D aluminum cavity
T2 baseline	50–200 μs at 15 mK
Operating temp	15 mK (dilution refrigerator required)
Readout	Dispersive readout via microwave cavity, HEMT amplifier chain
Cryostat	Dry dilution refrigerator (BlueFors LD or equiv.)
Footprint	1.0 m × 1.0 m floor, 2.0 m height (including vibration frame)
Cryogenic lines	Through dedicated vibration-isolated feedthroughs
Advantages	Maximum sensitivity to environmental perturbation
Limitations	Cost (~€200K – €500K for cryostat), complexity, specialized operators

8.3 QRNG Array

Parameter	Specification
Units	4× ComScire PQ32MU (32 Mbps each)
Interface	USB via fiber-optic USB extender; converter unit located **outside** chamber where possible. Any in-chamber converter shielded in local Faraday enclosure and included in §A performance budget.

Parameter	Specification
Mounting	Non-magnetic rack adjacent to optical table
Data volume	~14.4 GB per unit per 60-min session
Analysis	Entropy, autocorrelation, mean deviation; NIST SP 800-22 suite

Rev B correction — in-chamber electronics.

The USB-to-fiber converter required by the QRNG chain is active electronics that emits in the RF range. Rev B requires that converters be located outside the chamber where cable-length tolerances permit. Where an in-chamber converter is unavoidable, it must be enclosed in a local Faraday shield bonded to Layer 3, and its emission spectrum characterized and included in the performance budget.

9. Mechanical Drawings (Descriptive)

Formal CAD drawings to be produced in SolidWorks or Fusion 360 during detailed design phase. The following text descriptions define the required drawing set.

9.1 Drawing List

Drawing No.	Title	View	Content
TSP-001	Chamber Assembly — Plan View	Top-down, Z = 1.5 m section	All 5 layers (incl. dual mu-metal), airlock, feedthroughs, observer + sensor positions
TSP-002	Chamber Assembly — Elevation	South-facing section, Y = 1.5 m	Layer stack-up, floor structure, ceiling, height dimensions
TSP-003	Chamber Assembly — Cross Section	West-facing section, X = 1.5 m	Entry axis view, airlock detail, cable routing
TSP-004	Airlock Assembly	Plan + section detail	Dual-door arrangement, interlock, RF check station, seal details
TSP-005	Layer 2a/2b — Dual Mu-Metal	Exploded isometric	Panel layout, 50 mm air-gap standoffs, seam overlaps, annealing callouts
TSP-006	Layer 3 — Copper Shell	Exploded isometric	Panel layout, weld seam map, grounding, RF gasket details
TSP-007	Layer 4 — Isolation Platform	Plan + elevation	Isolator positions, frame, flexible coupling routes
TSP-008	Internal Layout	Isometric cutaway	Observer station, optical table, sensor mounts, cable routing, Layer 1 thermal manifold
TSP-009	Door Assemblies (Inner + Outer)	Section detail	Multi-layer seal stack, hinge, latch, panic bar, interlock wiring
TSP-010	Feedthrough Panel (West Face)	Section detail	Waveguide-below-cutoff tubes, fiber connectors, filter mounts, thermal fluid penetration
TSP-011	Foundation Plan	Plan view	Concrete slab, isolation trench, grounding grid, utilities

9.2 Plan View Description (TSP-001)

Top-down cross-section at Z = 1.5 m (mid-height). Shows concentric square layers from outside in: Layer 5 aluminum shell (outermost, dark gray), Layer 4 isolation frame (hatched), Layer 3 copper shell (copper-colored), Layer 2b outer mu-metal (light gray), 50 mm air gap, Layer 2a inner mu-metal (light gray), Layer 1 acoustic/thermal panels (white) with thermal manifold overlay. Airlock extension on east face shown with dual doors and interlock annotation. Interior shows observer platform at center (circle, Ø 0.8 m), optical table 1.0 m west of center (rectangle, 1.5 m × 1.0 m), QRNG rack north of optical table. Feedthrough panel on west face. Observer entry path shown as dashed arrow from east through airlock to center. All dimensions in millimeters.

9.3 Elevation Description (TSP-002)

South-facing cross-section at Y = 1.5 m. Shows floor assembly (foundation slab, isolation mounts, floor plate), five functional layers (with 2a/2b shown as two distinct shells separated by air gap) rising vertically, ceiling assembly. Airlock visible on east side with dual doors. Observer seated figure (outline) at center facing west. Optical table with NV-center sensor at 1.0 m height, positioned west of observer. Overhead cable/fiber routing tray at 2.7 m. Air handling duct entry at ceiling level with acoustic baffle detail. Thermal fluid penetration shown on west face. Cryostat position indicated (Phase 1 dashed outline) with vibration isolation frame. All dimensions in millimeters.

10. Bill of Materials and Cost Estimates

All costs are estimates in EUR for Phase 0 configuration (NV-center sensor, LTS SQUID, no dilution cryostat). Costs assume single-unit procurement; volume discounts may apply for some items. Supplier quotes required for final budget.

10.1 Shielding Materials

Item	Qty	Unit Cost (€)	Total (€)	Notes
Mu-metal sheet, 3 mm (Layer 2a + 2b)	120 m²	250/m²	30,000	Dual-layer, incl. hydrogen annealing
OFHC copper sheet, 2 mm	60 m²	120/m²	7,200	C10100 grade
Aluminum plate, 5 mm	110 m²	45/m²	4,950	6061-T6
Copper mesh, 100/inch	110 m²	18/m²	1,980	Faraday layer (reduced from 200/inch)
Acoustic foam panels	55 m²	80/m²	4,400	Basotect or equiv.
Aerogel blanket, 50 mm	55 m²	150/m²	8,250	Cryogel Z or equiv.
Perforated Al liner + thermal manifold	55 m²	180/m²	9,900	Integrated Peltier + fluid channels
RF finger stock gasket	20 m	60/m	1,200	BeCu, door + panels
Mu-metal finger stock (dual)	20 m	90/m	1,800	Both door shells
Air-gap standoffs (non-magnetic)	Lot	—	1,500	Between 2a and 2b
Subtotal — Shielding Materials			**71,180**	

10.2 Structural and Mechanical

Item	Qty	Unit Cost (€)	Total (€)	Notes
Aluminum T-slot extrusion	250 m	15/m	3,750	80×80 mm (incl. airlock)
Pneumatic isolators	6 units	2,500 ea	15,000	TMC or Newport, uprated
Neoprene pads	12 units	150 ea	1,800	Floor isolation
Steel isolation frame	1 set	4,000	4,000	Welded box section
Optical table (granite)	1 unit	8,000	8,000	1.5 m × 1.0 m × 0.3 m
Outer door assembly (east)	1 unit	5,000	5,000	Multi-layer, outward-opening

Item	Qty	Unit Cost (€)	Total (€)	Notes
Inner door assembly (east)	1 unit	6,500	6,500	Multi-layer with dual mu-metal, inward
Door interlock system	1 unit	2,500	2,500	Electrical + mechanical
Airlock shielding extension	1 set	5,500	5,500	All layers continuous, dual mu-metal
Airlock RF check station	1 unit	1,500	1,500	RF meter + fluxgate
Feedthrough panels	2 units	2,200 ea	4,400	West face, waveguide tubes + connectors + thermal
Recirculating chiller + glycol loop	1 system	4,500	4,500	External, ±0.05 K output
Hardware / fasteners	Lot	—	2,000	Non-magnetic where required
Subtotal — Structural			**64,450**	

10.3 Sensors and Instrumentation

Item	Qty	Unit Cost (€)	Total (€)	Notes
NV-center diamond sensor kit	1 unit	15,000	15,000	Incl. optics + MW source
ComScire PQ32MU QRNG	4 units	1,350 ea	5,400	32 Mbps each
64-ch EEG, optically-isolated	1 system	18,000	18,000	Radios disabled, fiber egress
SQUID magnetometer (LTS, 4 K)	1 unit	28,000	28,000	Single-channel LTS + LHe dewar
LHe dewar + transfer line	1 set	4,500	4,500	~30 L, weekly refill logistics
Fluxgate magnetometer	1 unit	3,000	3,000	3-axis
Single-photon detectors	2 units	6,000 ea	12,000	APD, 200–1000 nm
Pt100 RTD sensors	4 units	200 ea	800	0.001 K resolution
Accelerometer (3-axis)	1 unit	2,500	2,500	Seismic-grade
RF power meter	1 unit	1,500	1,500	Broadband
Subtotal — Sensors			**90,700**	

10.4 Support Systems

Item	Qty	Unit Cost (€)	Total (€)	Notes
DAQ system (NI PXIe)	1 chassis +4 cards	25,000	25,000	Multi-channel digitizer
GPS 10 MHz reference + fiber distrib	1 unit	2,500	2,500	Time base, external antenna
Battery bank (48 V, 5 kWh)	1 unit	3,000	3,000	LiFePO4
DC-DC converters + filters	Lot	—	2,000	Optically isolated
HEPA air handler + CO2 scrubber	1 system	5,500	5,500	Closed-loop, sized for 90 min
Fiber-optic USB extenders	6 units	400 ea	2,400	For QRNGs + EEG
Fiber cables + connectors	Lot	—	1,500	Single-mode, FC/APC
Safety systems (O2, intercom, camera)	Lot	—	3,000	Redundant
Workstation + storage	1 sys	4,000	4,000	Control room
Subtotal — Support			**48,900**	

10.5 Labor and Integration

Item	Duration	Rate (€/day)	Total (€)	Notes
Chamber fabrication	35 days	500	17,500	Skilled metalworker + assistant
Shielding installation (dual)	20 days	600	12,000	Specialist RF/magnetic, extra for dual mu-metal
Sensor integration	10 days	800	8,000	Quantum sensor specialist
SQUID + cryogenics integration	5 days	900	4,500	LHe system and vibration isolation
DAQ integration + calibration	10 days	600	6,000	Systems engineer
Commissioning + verification	12 days	600	7,200	Full-system testing
Subtotal — Labor			**55,200**	

10.6 Budget Summary

Category	Cost (€)
Shielding Materials	71,180
Structural and Mechanical (incl. airlock)	64,450
Sensors and Instrumentation	90,700
Support Systems	48,900
Labor and Integration	55,200
Contingency (15%)	49,565
TOTAL PHASE 0 ESTIMATE	**€379,995**

Budget note — scope and scaling.

The full Phase 0 estimate of ~€380K reflects the corrected engineering scope (dual mu-metal, active thermal, LTS SQUID, optically-isolated EEG). This sits above the original €150K target but below Phase 1 scale. Three distinct configurations are now recognized: **(i) Micro-Pilot** (€2K–€5K, QRNG desktop only, no chamber); **(ii) Minimal Phase 0** (~€120K–€180K, 1.5 m cube, single mu-metal, NV + QRNG only, no SQUID); **(iii) Full Phase 0** (~€350K–€400K, as spec'd above). The Silence Experiment paper should cite the configuration being funded, not a range.

11. Fabrication Sequence

Total estimated fabrication timeline: 18–24 weeks from material procurement to first calibration session (extended from prior estimate to accommodate dual-layer mu-metal annealing and active thermal integration).

Phase	Duration	Activities	Dependencies
1. Procurement	8–12 weeks	Order mu-metal (both shells + annealing), copper, aluminum, isolators, sensors, SQUID, chiller	Budget approval
2. Foundation	1–2 weeks	Pour/verify reinforced concrete slab, install grounding grid	Site access
3. Outer shell	2 weeks	Assemble Layer 5 aluminum frame and panels, install Faraday mesh	Foundation complete
4. Vibration system	1 week	Install isolation frame, pneumatic isolators, passive dampers	Outer shell complete
5. Copper shell	1–2 weeks	Install Layer 3 copper panels, weld seams, install feedthroughs	Isolation frame stable
6. Outer mu-metal (2b)	1 week	Install Layer 2b panels (annealed), overlap seams, penetrations	Copper shell complete
7. Air-gap standoffs	0.5 week	Install non-magnetic standoffs establishing 50 mm radial gap	Layer 2b complete
8. Inner mu-metal (2a)	1 week	Install Layer 2a panels (annealed), overlap seams, coaxial penetrations	Standoffs complete
9. Acoustic + active thermal	1.5 weeks	Install aerogel, acoustic foam, Peltier liner, fluid manifold, perforated face	Layer 2a complete
10. Door + airlock	2 weeks	Install airlock structure, dual doors with dual mu-metal seals, interlock wiring	All layers complete
11. Internal fit-out	1–2 weeks	Optical table, sensor mounts, observer platform, cable routing	Chamber sealed
12. Systems integration	2 weeks	DAQ, power, air handling, SQUID cryogenics, chiller, safety, fiber	Internal fit-out
13. Commissioning	2 weeks	EM survey, magnetic field mapping, vibration spectra, thermal verification, T2 baseline	Full integration

12. Integration and Commissioning

12.1 Shielding Verification

- **Electromagnetic**: Sweep 10 Hz – 10 GHz with calibrated signal generator outside, spectrum analyzer inside. Confirm >120 dB attenuation at all frequencies.
- **Magnetic (DC)**: DC field mapping with fluxgate at 27 grid points (3×3×3). Confirm residual field <50 nT.
- **Magnetic (AC)**: AC magnetic sweep 0.1–100 Hz with explicit 50/60 Hz characterization. Confirm >80 dB attenuation (upgraded from >60 dB).
- **Acoustic**: Pink noise source outside at 90 dB SPL. Measure interior with calibrated microphone. Confirm <20 dB SPL interior.
- **Vibration**: Measure floor vibration spectra with and without active isolation engaged. Confirm <1022 m/s^2 at sensor platform across 1–100 Hz. Separately characterize fan vibration contribution.
- **Thermal**: 24-hour thermal recording with no occupant, then 90-minute recording with occupant simulator (100 W thermal dummy). Confirm ±0.01 K stability at sensor position in both conditions.

12.2 Quantum Sensor Baseline

- **NV-center**: Measure T2 (spin echo) with empty chamber. Establish baseline over minimum 100 measurements. Record mean, standard deviation, and drift.
- **QRNG**: Run all 4 units for 24 hours with empty chamber. Run NIST SP 800-22 test suite. Confirm all units pass all tests. Establish baseline entropy and autocorrelation statistics.
- **SQUID**: 24-hour noise floor characterization, confirm sensitivity meets specification (10 fT/√Hz LTS or 50 fT/√Hz HTS).
- **Single-photon detectors**: 24-hour dark count measurement. Confirm <100 counts/s. Characterize count rate stability.

12.3 System Integration Test

- Simultaneous recording of all channels (quantum sensor, QRNGs, EEG, SQUID, all environmental monitors) for 60 minutes with empty chamber.
- Verify time synchronization: <1 µs inter-channel offset.
- Verify data integrity: no dropped samples, no buffer overflows.
- Verify artifact detection pipeline: inject known environmental perturbation and confirm cross-correlation detection.

12.4 Ongoing Verification Schedule

Event	Actions Required
Annual	Full re-commissioning sweep (§12.1). Mu-metal degrades with mechanical stress and aging; annual magnetic remapping mandatory.
Post-relocation	Any physical move of the chamber invalidates prior commissioning. Full re-verification required before next session.
Post-mechanical-shock	Any event involving chamber impact, drop, or seismic activity >MMI IV. Full re-verification.

Event	Actions Required
Post-panic-bar event	Shielding continuity check minimum (EM sweep + magnetic sweep). Full re-verification if any anomaly found.
Session-to-session	Airlock RF check per §3.2 step 3. No recommissioning required if check passes.

Rev B addition — ongoing verification.

Mu-metal shielding is permanent-metal-stress-sensitive and degrades with use, vibration, and time. Without a scheduled reverification program, a chamber that passed commissioning can drift significantly over 12–24 months without detectable symptoms until a session anomaly emerges. The schedule above makes that drift observable and correctable on a known cadence.

13. Phase Scaling Notes

Parameter	Micro-Pilot	Minimal Phase 0	Full Phase 0	Phase 1
Inner volume	Desktop	1.5 m cube	3.0 m cube (spec'd)	4.0–5.0 m cube
Location	Any quiet room	Quiet lab	University lab	Underground (≥1,000 m)
Shielding	None (or portable RF)	Single mu-metal + copper	Dual mu-metal + copper + active thermal	5-layer + rock overburden
Quantum sensor	None (QRNG only)	NV-center	NV-center	Superconducting transmon
QRNG	1× ComScire PQ4000KU	2× PQ32MU	4× PQ32MU	4× PQ32MU
EEG	Consumer (optional)	32-ch wireless	64-ch optically-isolated	256-ch, fully optical
Env. monitors	Temperature only	Basic (4 ch)	Full array + LTS SQUID	Full array + multi-channel SQUID
Budget	€2K–€5K	€120K–€180K	€350K–€400K	€500K–€2M
Timeline	2–4 weeks	3–4 months	6–9 months	2–3 years
Goal	Execution demo, prelim	Detect large effects (d > 0.5)	Detect medium effects (d > 0.3)	Definitive test, full statistical power

Appendix A — Performance Budget

The following table summarizes the expected contribution of each noise channel to T2 limitation, and the isolation provided by the revised chamber design. The design target is that chamber-limited T2 exceeds the intrinsic T2 of the quantum sensor by at least 10×, ensuring that any observed T2 variation is sensor-intrinsic or consciousness-state-dependent, not chamber-limited.

Noise Channel	Unshielded	Chamber Attenuation	Residual	T2 Impact
RF / Microwave (10 kHz – 10 GHz)	~–30 dBm ambient	> 120 dB	< –150 dBm	Negligible
DC magnetic field	~50 µT (Earth)	> 80 dB (dual mu-metal)	< 5 nT	Below NV T2 limit
AC magnetic (50/60 Hz)	~100 nT lab	> 80 dB (dual mu-metal)	< 10 pT	Below NV T2 limit
Acoustic	~40 dB SPL	> 80 dB combined	< –40 dB SPL	Negligible
Vibration (1–100 Hz)	~102^3 m/s^2	> 60 dB (active+passive)	< 1022 m/s^2	Negligible
Fan vibration (contribution)	Varies	Decoupled via bellows	< 1022 m/s^2	Negligible (verified in commissioning)
Thermal drift	±1 K lab	Active control	±0.01 K	Below NV T2 limit
In-chamber electronics (EEG, QRNG conv.)	Variable	Local Faraday + airlock RF gate	< –80 dBm	Negligible (verified per session)
Cosmic rays	~1/cm^2/min	None (Phase 0)	~1/cm^2/min	Flagged in data

Cosmic ray note.
Phase 0 (surface location) does not attenuate cosmic rays. Cosmic ray events are flagged in quantum sensor data by coincidence with scintillator veto counter (optional addition, ~€5K). Phase 1 underground location provides >102 cosmic ray attenuation via rock overburden.

END OF DOCUMENT

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