



Three-Tier Immersive System Outline

A Proposal for a World-Class, National Significance, or
Fit-for-Purpose Immersive Environment

Prepared for:

Valued Partner

Prepared by:

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29th June 2025

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Executive Summary

This document outlines three distinct tiers for the design, development, and implementation of a state-of-the-art immersive visualization facility. DreamLab, a leader in creative technology and immersive experiences, has crafted these options to provide a clear choice between a globally competitive **World-Class** system, a nationally significant and balanced **National Significance** system, and a highly capable and cost-effective **Fit-for-Purpose** system. Each tier is designed to deliver exceptional value and transformative capabilities, tailored to different strategic objectives and budgetary considerations.

The Three Tiers of Immersive Excellence

We present three fully-costed options, allowing you to select the immersive facility that best aligns with your ambitions and resources.

2.1 Tier 1: World-Class

The pinnacle of immersive technology. This tier is designed for institutions with the ambition to compete on a global stage, offering unparalleled capabilities, resolution, and user experience. It is a statement of intent to be at the forefront of international innovation.

2.2 Tier 2: Fit-for-Purpose

A robust and efficient entry into high-end immersive visualization. This tier is ideal for organizations seeking to establish a strong foundation in immersive technology, focusing on core capabilities and a clear upgrade path.

2.3 Tier 3: National Significance

This tier represents the optimal balance of performance and value, providing a nationally significant facility capable of supporting a wide range of research, development, and

commercial applications. It is the recommended choice for institutions aiming for leadership within the UK.

Comparative Specification

Table 3.1: High-Level Feature Comparison Across Tiers

Feature	World-Class	Fit-for-Purpose	National Significance
Primary Use Case	Global Research Leadership	Foundational Research & Teaching	National-Level R&D
Display System	6-Wall CAVE (LED)	4-Wall CAVE (Projection)	5-Wall CAVE (LED)
Resolution	8K per wall	Full HD	4K per wall
Tracking System	12-user optical + volumetric capture	3-user optical	6-user optical
Audio System	Wavefield Synthesis	5.1 Surround	16.2 Surround
Compute Backend	HPC Infrastructure	8-12 GPU Cluster	16-24 GPU Cluster
Indicative Budget	> £5M	< £2M	£3.5M

The DreamLab Team

Our team is a collective of industry leaders, creative technologists, and academic experts, each bringing a wealth of experience and a passion for innovation. We are uniquely positioned to deliver projects of any scale, from foundational systems to world-leading facilities.

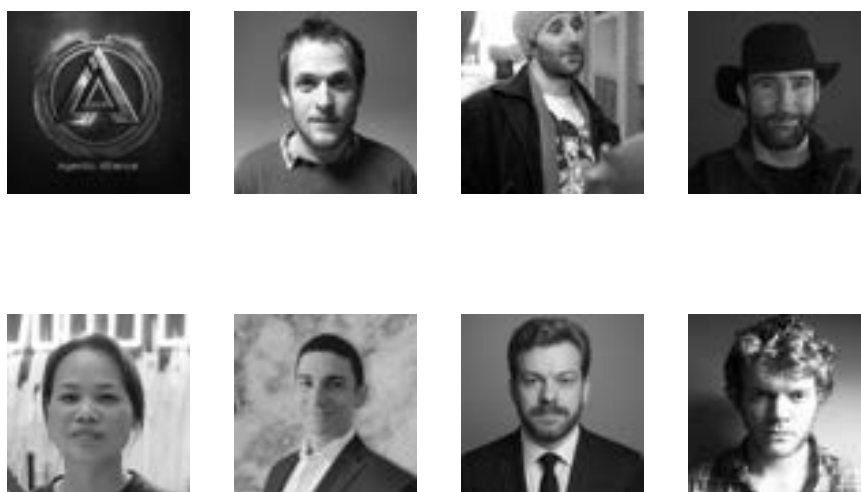


Figure 4.1: A selection of our core team members.

4.0.1 Dr John O'Hare - Chief Hallucination Officer

Dr John O'Hare is a creative technology leader specialising in AI-driven workflows, immersive XR, and telecollaboration. As Associate Director of R&D at DreamLab, he leads pioneering projects in mixed reality and generative AI, combining technical expertise with a commitment to ethical innovation.

4.0.2 Magnus Kemp - Chief Technical Officer

Magnus Kemp is a strategic and technical consultant specialising in large-scale mixed media systems, visualisation, and experiential events.

4.0.3 Ste Moyler - Chief Creative Officer

Ste Moyler is an award-winning creative director and producer with over 25 years' experience in film, animation, AR/VR, and immersive media. He has delivered projects for major clients including Microsoft, Sony Music, and Adidas, and led MediaCityUK's first docuseries. Ste is also known for mentoring creative talent and driving innovation in digital storytelling.

Conclusion

This document provides a comprehensive overview of the three tiers of immersive systems offered by DreamLab. We are confident that one of these options will align perfectly with your strategic goals and financial framework. We look forward to discussing your specific requirements and helping you to select the ideal solution to drive your organization's future success.

Part I

Tier 1: World-Class Specification



World Class Immersive System

Technical Specification Document

6-Wall CAVE • 6-Person Collaboration • Wavefield Synthesis

Volumetric Capture • Sub-millimetre Tracking • HPC Infrastructure

Prepared for:

UK Research Excellence Framework

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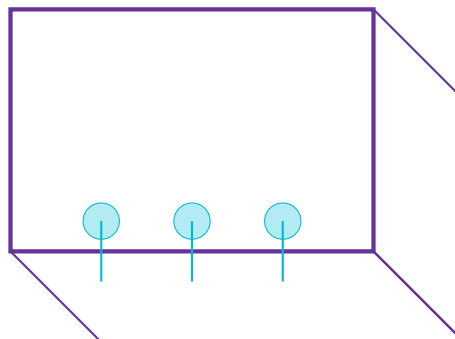
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Executive Summary

Project Overview

This document presents the technical specification for a **world-class immersive visualisation facility** – a next-generation Cave Automatic Virtual Environment (CAVE) that will establish the UK's premier platform for collaborative research in automation, robotics, risk management, nuclear engineering, and advanced manufacturing.

6-Sided Immersive Environment



25m × 20m Footprint

Figure 1: Conceptual representation of the 6-sided CAVE system

The facility will enable teams of up to 6 researchers to simultaneously experience shared, life-size 3D simulations without the isolation and limitations of head-mounted displays. Instead, ultra-high-resolution imagery will be projected or displayed on all surfaces of the room, creating a fully immersive, collaborative environment.

Strategic Value Proposition

Research Excellence

- **Breakthrough Capabilities:** Enable research impossible with current technologies
- **Interdisciplinary Collaboration:** Unite engineering, health, and creative disciplines
- **National Leadership:** Position the institution as the UK’s immersive technology hub
- **Industry Partnerships:** Attract £500k+ annual commercial funding

Competitive Advantage

Our facility will surpass existing installations by combining:

Feature	Current Best	Our System
Display Resolution	4K per wall	8K per wall
Simultaneous Users	1-2	6
Audio System	7.1 Surround	Wave Field Synthesis
Tracking Precision	1-2mm	<1mm
Volumetric Capture	Limited/None	64 cameras, real-time

Table 1: Comparison with existing facilities

Technical Highlights

Visual System

- **6-sided projection** using Digital Projection Satellite MLS technology
- **8K resolution** per surface (7680×4320 pixels)
- **Multi-viewer stereoscopic 3D** – each user sees correct perspective
- **120Hz+ refresh rate** for smooth motion and reduced latency
- **Remote laser light engines** for silent operation

Compute Infrastructure

- **32+ NVIDIA GPUs** in clustered configuration
- **Real-time ray tracing** with RTX technology
- **1PB high-speed storage** for datasets and capture
- **400Gb/s internal networking** for zero bottlenecks

Immersive Audio

- **128-512 speaker array** for Wave Field Synthesis
- **True 3D spatial audio** for all users simultaneously
- **<1° localisation accuracy** throughout the space

Tracking & Capture

- **Sub-millimetre optical tracking** at 240Hz
- **64-camera volumetric capture** system
- **Real-time 3D reconstruction** for telepresence
- **Full-body motion capture** capability

Key Use Cases

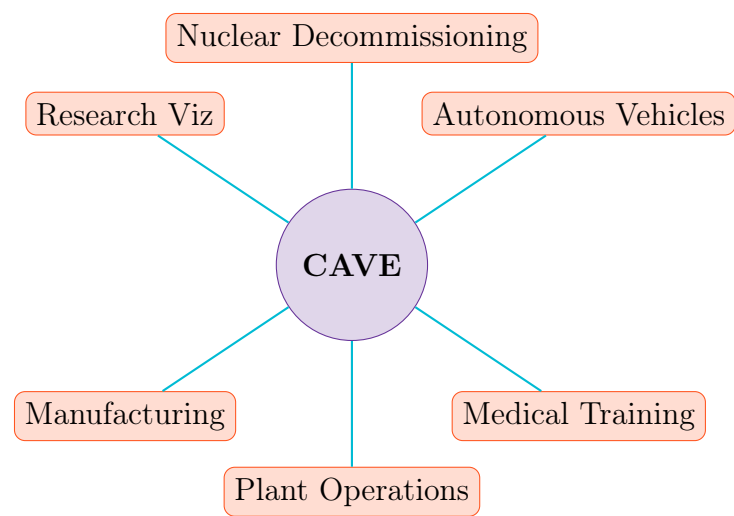


Figure 2: Primary application domains

Investment Overview

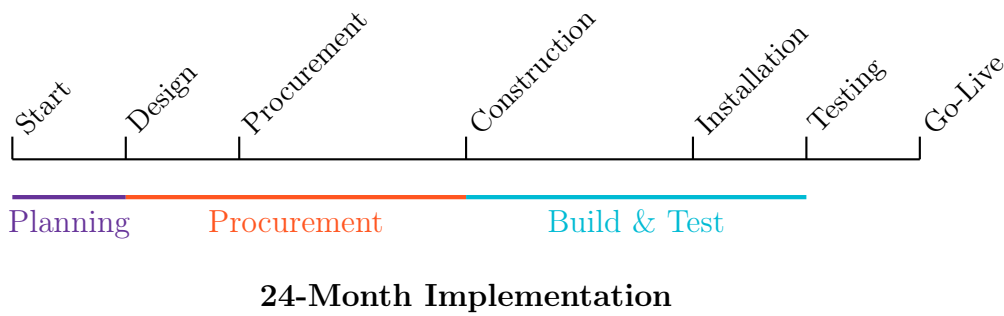
Capital Investment

Component	Estimated Cost
Display System (Projection/LED)	£2,500,000
Compute Infrastructure	£1,200,000
Audio System (WFS)	£400,000
Tracking & Capture	£600,000
Infrastructure & Construction	£800,000
Integration & Installation	£500,000
Total Capital	£6,000,000

Return on Investment

- **Research Income:** £500k+ annually from industry partnerships
- **Grant Success:** Enhanced competitiveness for major funding
- **Student Recruitment:** Unique facility attracting top talent
- **Innovation Output:** 10+ high-impact publications annually

Project Timeline



Success Metrics

KPI Category	Target	Measurement
Utilisation	>70% core hours	Booking system data
Research Output	10+ papers/year	Publication tracking
Industry Engagement	£500k+ funding	Contract values
Student Integration	5+ courses	Curriculum inclusion
System Performance	>95% uptime	Monitoring systems
User Satisfaction	>4.5/5 rating	Regular surveys

Next Steps

1. **Stakeholder Approval:** Secure commitment from university leadership
2. **Funding Allocation:** Confirm capital budget availability
3. **Technical Review:** Validate specifications with expert panel
4. **Tender Process:** Issue RFP to qualified systems integrators
5. **Site Preparation:** Begin infrastructure planning

Executive Recommendation

This world-class facility represents a transformational investment in the UK's research infrastructure. By combining cutting-edge display technology, unprecedented multi-user capability, and advanced tracking systems, we will create a unique platform that enables breakthrough research, attracts world-leading partnerships, and establishes our institution as the definitive centre for immersive technology in the UK and beyond.

Project Vision and Strategy

1.1 Strategic Vision

1.1.1 Mission Statement

To establish the UK's premier immersive visualisation facility that transforms how researchers, engineers, and innovators collaborate, analyse, and solve complex challenges through unprecedented multi-user virtual reality experiences.

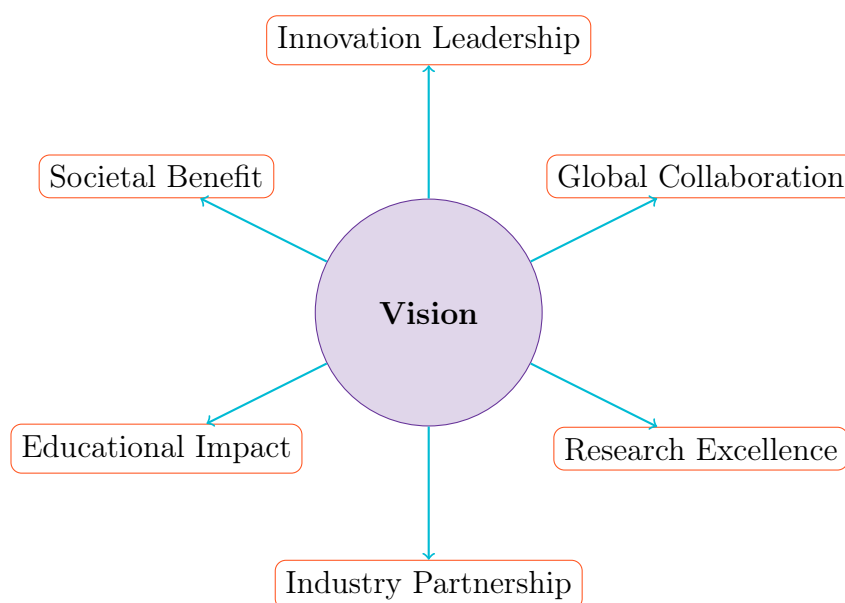


Figure 1.1: Strategic vision framework

1.1.2 Core Objectives

1. **Research Excellence:** Create a platform enabling breakthrough discoveries in critical domains including nuclear decommissioning, autonomous systems, and advanced manufacturing
2. **Collaborative Innovation:** Foster unprecedented multi-disciplinary collaboration through shared immersive experiences
3. **Industry Leadership:** Attract and retain world-leading industrial partnerships worth £500k+ annually
4. **Educational Transformation:** Revolutionise teaching and training through immersive learning experiences
5. **National Infrastructure:** Establish a facility of national significance supporting UK strategic priorities

1.2 Strategic Alignment

1.2.1 Institutional Strategy 2025-2030

The immersive facility directly supports our institution's five strategic pillars:

Strategic Pillar	Facility Contribution
Research Excellence	<ul style="list-style-type: none"> • Enables world-first research capabilities • Attracts top researchers and funding • Supports REF impact case studies
Industry Partnerships	<ul style="list-style-type: none"> • Unique platform for commercial R&D • Training and simulation services • Innovation showcase for partners
Student Experience	<ul style="list-style-type: none"> • Cutting-edge teaching facilities • Unique research opportunities • Competitive advantage for graduates
Global Engagement	<ul style="list-style-type: none"> • International collaboration platform • Remote presence capabilities • Global showcase facility
Sustainability	<ul style="list-style-type: none"> • Reduces need for physical prototypes • Virtual site visits replace travel • Energy-efficient design choices

Table 1.1: Alignment with institutional strategy

1.2.2 National Strategic Alignment

UK Industrial Strategy

The facility directly addresses four Grand Challenges:

- **Artificial Intelligence & Data:** Advanced visualisation of AI systems and big data
- **Clean Growth:** Virtual prototyping for sustainable technologies
- **Future of Mobility:** Autonomous vehicle testing and validation

- **Ageing Society:** Medical training and therapy applications

Levelling Up Agenda

- Creates high-skilled jobs in the region
- Attracts international investment
- Provides unique training opportunities
- Establishes regional technology leadership

1.3 Competitive Landscape Analysis

1.3.1 Global Benchmarking

Our comprehensive analysis of world-leading facilities reveals both the current state-of-the-art and opportunities for leadership:

Curtin University HIVE, Australia

- **Technology:** World's first Digital Projection Satellite MLS installation
- **Configuration:** Cylindrical and dome displays, 4K 120Hz stereo
- **Strengths:** Remote light engines, multi-disciplinary use
- **Our Advantage:** Full 6-sided environment, volumetric capture

University of Leeds HIKER Lab, UK

- **Technology:** Large-scale pedestrian simulation CAVE
- **Configuration:** 9m × 4m walkable area, laser projectors
- **Strengths:** Europe's largest CAVE, autonomous vehicle research
- **Our Advantage:** Multi-user support, higher resolution, WFS audio

CAVE2 - University of Illinois Chicago, USA

- **Technology:** 320-degree cylindrical LCD panel array
- **Configuration:** 72 panels, 37 megapixels per eye
- **Strengths:** Ultra-high resolution, passive stereo
- **Our Advantage:** Full immersion (6 sides), individual user tracking

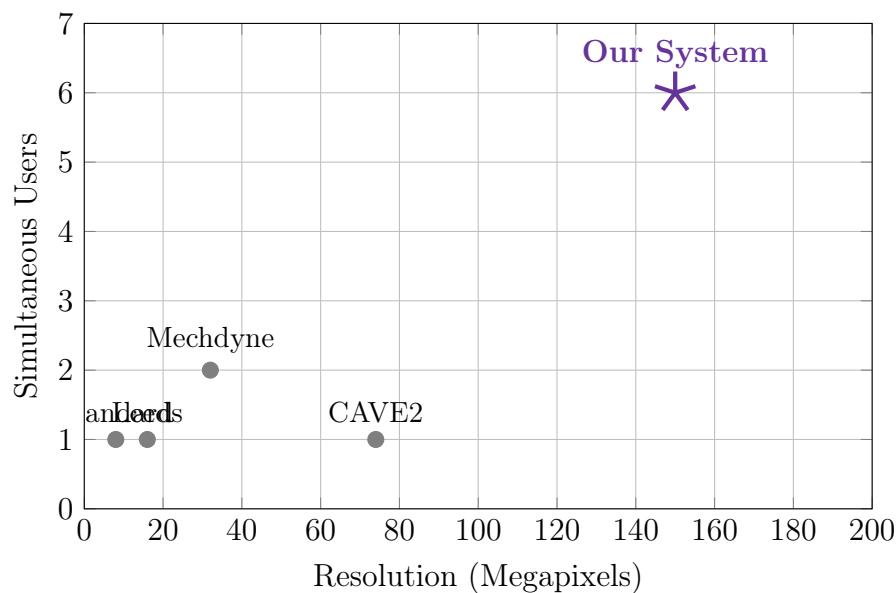


Figure 1.2: Competitive positioning: Resolution vs multi-user capability

1.3.2 Market Differentiation

Requirement USP-001

Our facility will be the world's first to combine ALL of the following: 6-sided full immersion, 6-person simultaneous tracking with individual perspectives, 8K resolution per surface, Wave Field Synthesis audio, real-time volumetric capture, and sub-millimetre tracking precision.

1.4 Expected Outcomes and Impact

1.4.1 Research Impact

Domain	Expected Breakthroughs	Timeline
Nuclear	Remote handling validation, decommissioning planning	Year 1
Autonomous Systems	Multi-agent coordination, safety validation	Year 1-2
Manufacturing	Digital twin integration, assembly optimisation	Year 2
Healthcare	Collaborative surgery planning, therapy protocols	Year 2-3
Climate Science	Large-scale data visualisation, scenario modelling	Year 3+

Table 1.2: Expected research breakthroughs by domain

1.4.2 Economic Impact

- **Direct Revenue:** £500k+ annual industry contracts
- **Indirect Benefits:**
 - Enhanced grant competitiveness (est. £2M+ additional funding)
 - Spin-out company potential
 - Regional economic development
- **Cost Savings:** Reduced need for physical prototypes and travel

1.4.3 Societal Impact

1. **Skills Development:** Training next-generation engineers and scientists
2. **Public Engagement:** Inspiring STEM interest through demonstrations
3. **Safety Enhancement:** Better preparation for hazardous environments
4. **Accessibility:** Virtual access to dangerous or remote locations

1.5 Success Metrics and KPIs

1.5.1 Quantitative Metrics

Metric	Year 1	Year 3	Year 5
Utilisation Rate	50%	70%	85%
Research Papers	5	15	25
Industry Partners	3	8	15
Student Projects	10	30	50
Revenue Generated	£200k	£500k	£750k

Table 1.3: Five-year success metrics

1.5.2 Qualitative Indicators

- International recognition as a centre of excellence
- Attraction and retention of world-class researchers
- Industry testimonials and case studies
- Student satisfaction and employment outcomes
- Media coverage and public engagement metrics

1.6 Risk Mitigation Strategy

1.6.1 Strategic Risks

Risk	Mitigation	Owner
Technology obsolescence	Modular design, 3-year refresh cycle	CTO
Competitor facilities	Continuous innovation, unique features	Director
Funding shortfalls	Diverse revenue streams, phased implementation	CFO
Skills shortage	Training programme, vendor partnerships	HR
Low adoption	Change management, demonstration programme	Operations

Table 1.4: Strategic risk register

1.7 Implementation Roadmap

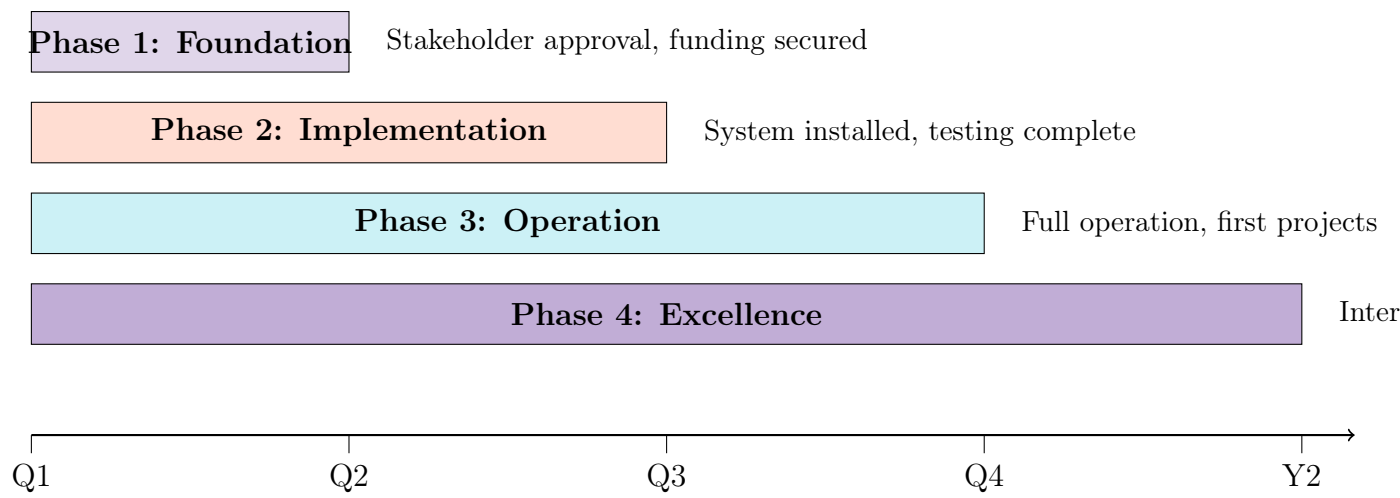


Figure 1.3: Strategic implementation roadmap

1.8 Conclusion

This world-class facility represents more than infrastructure investment – it embodies our commitment to research leadership, innovation, and societal impact. By creating an unparalleled platform for collaborative visualisation, we position our institution at the forefront of global technological advancement whilst addressing critical national challenges.

The convergence of cutting-edge display technology, advanced computing, and innovative tracking systems creates unprecedented opportunities for breakthrough research and transformative education. With careful implementation and strong stakeholder support, this facility will deliver exceptional value for decades to come.

2

System Requirements Document (SRD)

2.1 Introduction

This chapter defines the comprehensive functional and non-functional requirements for the world-class immersive visualisation facility. All requirements are traceable, testable, and aligned with the strategic objectives outlined in Chapter 2.

2.2 System Overview

2.2.1 System Context

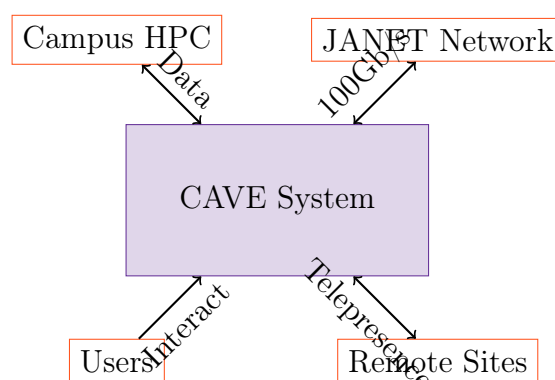


Figure 2.1: System context diagram

2.2.2 System Architecture

The facility comprises six major subsystems working in concert:

1. **Display System:** 6-sided projection/LED surfaces
2. **Compute Backend:** GPU cluster for rendering
3. **Audio System:** Wave Field Synthesis array
4. **Tracking System:** Optical tracking and volumetric capture
5. **Network Infrastructure:** High-speed interconnects
6. **Control System:** Integration and management layer

2.3 Functional Requirements

2.3.1 Visual Display Requirements

Requirement VIS-001

The system SHALL provide a six-sided immersive display environment comprising four walls, floor, and ceiling surfaces.

Requirement VIS-002

Each display surface SHALL achieve a minimum native resolution of 7680×4320 pixels (8K UHD).

Requirement VIS-003

The system SHALL support stereoscopic 3D display for up to 6 simultaneous users, with each user receiving a correctly perspective-corrected view based on their tracked head position.

Requirement VIS-004

Display refresh rate SHALL be minimum 120Hz per eye in single-user mode and 60Hz per eye when supporting 6 users simultaneously.

Requirement VIS-005

The system SHALL maintain colour accuracy with Delta E < 2 across all display surfaces after calibration.

Parameter	Minimum	Target	Verification
Resolution per surface	4K (3840×2160)	8K (7680×4320)	Pixel count
Brightness	800 nits	1000 nits	Photometer
Contrast ratio	2000:1	1,000,000:1	ANSI checkerboard
Colour gamut	DCI-P3	Rec.2020	Spectroradiometer
Uniformity	85%	90%	9-point measurement

Table 2.1: Visual display specifications

2.3.2 Multi-User Support Requirements

Requirement MU-001

The system SHALL track and render unique stereoscopic views for 6 users simultaneously within the immersive space.

Requirement MU-002

Each user SHALL be uniquely identified through active tracking markers integrated with shutter glasses.

Requirement MU-003

The system SHALL maintain view separation with less than 2% crosstalk between any two users' views.

Requirement MU-004

Latency from head movement to updated view SHALL not exceed 20ms for any user.

2.3.3 Audio System Requirements

Requirement AUD-001

The system SHALL implement Wave Field Synthesis using a minimum of 128 independently driven loudspeakers.

Requirement AUD-002

The WFS array SHALL synthesise virtual sound sources at any position within the cave volume with localisation accuracy better than 1 degree.

Requirement AUD-003

The audio system SHALL support at least 32 simultaneous dynamic sound sources with real-time position updates at 60Hz minimum.

Requirement AUD-004

Frequency response SHALL be 50Hz to 16kHz ± 3 dB throughout the listening area.

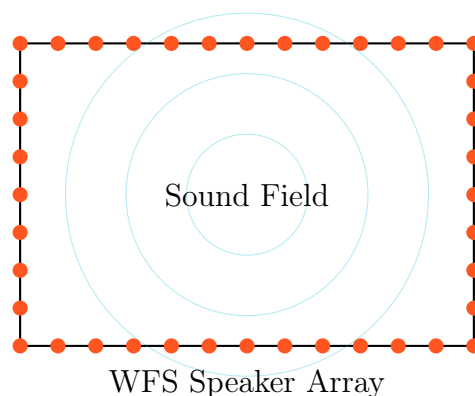


Figure 2.2: Wave Field Synthesis speaker configuration

2.3.4 Tracking and Capture Requirements

Requirement TRK-001

The optical tracking system SHALL track a minimum of 6 head-mounted targets simultaneously with positional accuracy better than 1mm and angular accuracy better than 0.1 degrees.

Requirement TRK-002

Tracking update rate SHALL be minimum 240Hz with latency not exceeding 10ms from movement to reported position.

Requirement TRK-003

The tracking volume SHALL cover the entire accessible space within the cave (minimum 5m × 5m × 3m).

Requirement TRK-004

The system SHALL support tracking of at least 20 additional rigid bodies for props and tools.

2.3.5 Volumetric Capture Requirements

Requirement VOL-001

The volumetric capture system SHALL comprise a minimum of 64 synchronised cameras providing complete coverage of the cave interior.

Requirement VOL-002

Each capture camera SHALL provide minimum 4K resolution at 60fps with global shutter.

Requirement VOL-003

The system SHALL reconstruct 3D meshes of humans in real-time (30fps minimum) with geometric accuracy better than 10mm.

Requirement VOL-004

Capture data SHALL be streamable to remote sites with latency not exceeding 100ms for telepresence applications.

2.3.6 Compute Infrastructure Requirements

Requirement COM-001

The render cluster SHALL comprise a minimum of 32 professional-grade GPUs with hardware genlock synchronisation.

Requirement COM-002

The system SHALL support real-time ray tracing for photorealistic rendering at target frame rates.

Requirement COM-003

Storage system SHALL provide minimum 1PB capacity with sustained read performance of 20GB/s or greater.

Requirement COM-004

Internal network SHALL provide minimum 100Gb/s connectivity to each compute node with RDMA support.

Component	Specification	Quantity
GPU	NVIDIA RTX 6000 Ada or better	32 minimum
CPU per node	Dual Intel Xeon or AMD EPYC	8 nodes
RAM per node	256GB DDR5 ECC minimum	8 nodes
NVMe storage	4TB per node for cache	8 nodes
Interconnect	InfiniBand HDR or 400GbE	Full mesh

Table 2.2: Compute infrastructure specifications

2.4 Non-Functional Requirements

2.4.1 Performance Requirements

Requirement PERF-001

The system SHALL maintain consistent performance with no frame drops during normal operation with 6 active users.

Requirement PERF-002

System boot time from cold start to operational state SHALL not exceed 5 minutes.

Requirement PERF-003

Scene loading time for datasets up to 100GB SHALL not exceed 30 seconds.

2.4.2 Reliability Requirements

Requirement REL-001

The system SHALL achieve 99.5% availability during scheduled operating hours (excluding planned maintenance).

Requirement REL-002

Mean Time Between Failures (MTBF) SHALL exceed 1000 hours for all critical components.

Requirement REL-003

The system SHALL support hot-swappable components where technically feasible to minimise downtime.

2.4.3 Safety Requirements

Requirement SAF-001

All laser projection systems SHALL comply with IEC 60825-1 safety standards with appropriate interlocks.

Requirement SAF-002

Emergency stop buttons SHALL be positioned at all exits and operator positions, halting all displays within 100ms.

Requirement SAF-003

The system SHALL include automatic lighting activation upon emergency stop or power failure.

Requirement SAF-004

Audio levels SHALL be limited to 85dB SPL with automatic limiting to prevent hearing damage.

2.4.4 Environmental Requirements

Requirement ENV-001

The system SHALL operate in ambient temperatures from 18°C to 25°C with humidity 40-60% RH.

Requirement ENV-002

Acoustic noise from all equipment SHALL not exceed 35dB(A) within the cave space during operation.

Requirement ENV-003

The system SHALL include provisions for heat dissipation of up to 50kW total load.

2.4.5 Usability Requirements

Requirement USE-001

The system SHALL provide a graphical user interface for non-technical operators to start/stop standard scenarios.

Requirement USE-002

System status and health monitoring SHALL be accessible via web interface from authorised devices.

Requirement USE-003

The system SHALL support content from major 3D engines including Unreal Engine 5 and Unity 2025 LTS.

2.5 Interface Requirements

2.5.1 Software Interfaces

- **Rendering APIs:** OpenGL 4.6, Vulkan 1.3, DirectX 12
- **Tracking Protocol:** VRPN, OpenXR 1.0
- **Audio APIs:** ASIO, WFS control protocol
- **Network Protocols:** TCP/IP, UDP, RDMA over Ethernet
- **Remote Access:** VNC, RDP, SSH

2.5.2 Hardware Interfaces

- **Display Outputs:** DisplayPort 1.4, HDMI 2.1, or proprietary
- **Sync Signals:** Genlock BNC, S/PDIF
- **Tracking:** GigE Vision cameras, USB 3.2
- **Network:** QSFP28 100GbE, QSFP-DD 400GbE

- **Power:** 3-phase 415V, IEC 60309 connectors

2.6 Stakeholder Use Cases

2.6.1 Use Case 1: Nuclear Decommissioning Training

Element	Description
Primary Actor	Nuclear engineer with robot operator
Preconditions	3D scan of facility loaded, robot arm connected
Main Flow	<div><div>1. Engineers enter cave wearing tracked glasses</div><div>2. Load photogrammetry model of reactor hall</div><div>3. Activate radiation visualisation overlay</div><div>4. Connect physical robot arm to virtual model</div><div>5. Practice decommissioning procedures</div><div>6. Review recorded session for training</div></div>
Success Criteria	Procedures completed safely in virtual environment

Table 2.3: Nuclear decommissioning use case

2.6.2 Use Case 2: Automotive Design Review

Element	Description
Primary Actor	Design team (3-6 people)
Preconditions	CAD model imported, materials configured
Main Flow	<div><div>1. Team enters cave for design review</div><div>2. Load vehicle model at 1:1 scale</div><div>3. Each member sees correct perspective</div><div>4. Examine interior ergonomics</div><div>5. Simulate sensor visualisations</div><div>6. Make real-time modifications</div><div>7. Export decisions to CAD system</div></div>
Success Criteria	Design decisions made collaboratively

Table 2.4: Automotive design review use case

2.7 Validation and Verification

2.7.1 Verification Matrix

Each requirement will be verified through one or more of the following methods:

- **Inspection (I):** Visual or documented review
- **Demonstration (D):** Functional demonstration
- **Test (T):** Measured against specifications
- **Analysis (A):** Calculated or simulated verification

2.7.2 Acceptance Criteria

The system shall be considered acceptable when:

- ## 2.8 Requirements Traceability

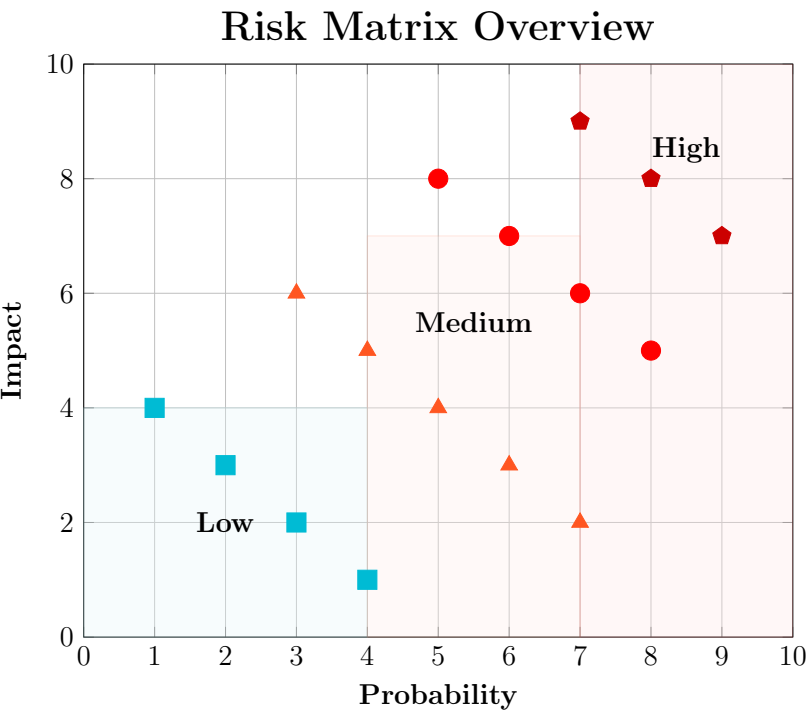
```
graph TD; SO[Strategic Objectives] --> SR[System Requirements]; SR --> DS[Design Specifications]; DS --> I[Implementation]; I -.-> SO; subgraph Traceability; I -.-> SO; end
```

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Risk Assessment and Mitigation

3.1 Executive Risk Summary

This chapter provides a comprehensive assessment of risks associated with the world-class immersive system project. We employ a structured approach to identify, analyse, and mitigate potential threats to successful delivery and operation.



3.2 Risk Categories

3.2.1 Technical Risks

TR-001: System Integration Complexity

- **Description:** Integration of multiple cutting-edge technologies may present unforeseen challenges
- **Probability:** High (7/10)
- **Impact:** High (8/10)
- **Risk Score:** 56 (Critical)

Mitigation Strategy:

1. Engage experienced systems integrator with proven CAVE deployment track record
2. Implement phased integration approach with incremental testing
3. Maintain 20% contingency time in project schedule for integration challenges
4. Establish dedicated integration test environment
5. Require vendor interoperability guarantees in contracts

TR-002: Performance Target Achievement

- **Description:** Achieving 360Hz stereoscopic rendering at 8K resolution pushes technological boundaries
- **Probability:** Medium (6/10)
- **Impact:** High (7/10)
- **Risk Score:** 42 (High)

Mitigation Strategy:

1. Conduct proof-of-concept testing before final procurement
2. Include performance guarantees in vendor contracts with penalties
3. Design system with scalable architecture to add computational resources
4. Consider fallback to 240Hz if 360Hz proves unachievable
5. Implement adaptive quality settings for complex scenes

TR-003: Emerging Technology Adoption

- **Description:** Volumetric capture and wave field synthesis are rapidly evolving technologies
- **Probability:** Medium (5/10)
- **Impact:** Medium (5/10)
- **Risk Score:** 25 (Medium)

Mitigation Strategy:

1. Partner with technology leaders (Fraunhofer, Microsoft, Intel)
2. Build modular architecture allowing component upgrades
3. Allocate R&D budget for continuous improvement
4. Establish academic partnerships for technology development
5. Create fallback options using proven alternatives

3.2.2 Financial Risks

FR-001: Budget Overrun

- **Description:** Complex project may exceed £12M budget allocation
- **Probability:** High (7/10)
- **Impact:** High (8/10)

- **Risk Score:** 56 (Critical)

Mitigation Strategy:

1. Maintain 15% contingency fund (£1.8M)
2. Implement value engineering process during design
3. Use fixed-price contracts where possible
4. Establish clear change control procedures
5. Prioritise core functionality with optional enhancements

FR-002: Currency Fluctuation

- **Description:** International procurement exposed to exchange rate variations
- **Probability:** Medium (6/10)
- **Impact:** Medium (5/10)
- **Risk Score:** 30 (Medium)

Mitigation Strategy:

1. Hedge currency exposure for major purchases
2. Prefer UK/EU suppliers where quality permits
3. Lock in exchange rates at contract signing
4. Include currency adjustment clauses in contracts
5. Accelerate procurement timeline if rates favourable

3.2.3 Operational Risks**OR-001: Staff Expertise Gap**

- **Description:** Specialised skills required for system operation and maintenance

- **Probability:** High (8/10)
- **Impact:** Medium (6/10)
- **Risk Score:** 48 (High)

Mitigation Strategy:

1. Begin recruitment 6 months before system delivery
2. Partner with vendors for comprehensive training programmes
3. Establish knowledge transfer requirements in contracts
4. Create detailed operational documentation
5. Consider managed service options for first year

OR-002: System Downtime

- **Description:** Complex system may experience availability issues
- **Probability:** Medium (6/10)
- **Impact:** High (7/10)
- **Risk Score:** 42 (High)

Mitigation Strategy:

1. Design redundancy for all critical components
2. Implement predictive maintenance systems
3. Maintain on-site spare parts inventory
4. Establish 4-hour response SLA with vendors
5. Create degraded operation modes for partial failures

3.2.4 Strategic Risks

SR-001: Technology Obsolescence

- **Description:** Rapid technology evolution may outdated system prematurely
- **Probability:** Medium (5/10)
- **Impact:** Medium (6/10)
- **Risk Score:** 30 (Medium)

Mitigation Strategy:

1. Design modular architecture for component refresh
2. Establish 5-year technology roadmap with vendors
3. Allocate annual budget for incremental upgrades
4. Focus on open standards and protocols
5. Plan major refresh cycle at 7-10 years

SR-002: User Adoption

- **Description:** Research community may be slow to adopt new facility
- **Probability:** Low (4/10)
- **Impact:** High (7/10)
- **Risk Score:** 28 (Medium)

Mitigation Strategy:

1. Launch early adopter programme during construction
2. Provide free pilot project allocation for key groups
3. Develop comprehensive training programmes
4. Create showcase demonstrations for each discipline
5. Establish champion users in each department

3.3 Risk Response Planning

3.3.1 Risk Register

Risk ID	Description	Category	Score	Response
TR-001	System Integration Complexity	Technical	56	Mitigate
TR-002	Performance Target Achievement	Technical	42	Mitigate
TR-003	Emerging Technology Adoption	Technical	25	Accept/Monitor
FR-001	Budget Overrun	Financial	56	Mitigate
FR-002	Currency Fluctuation	Financial	30	Transfer
OR-001	Staff Expertise Gap	Operational	48	Mitigate
OR-002	System Downtime	Operational	42	Mitigate
SR-001	Technology Obsolescence	Strategic	30	Accept/Monitor
SR-002	User Adoption	Strategic	28	Mitigate

3.3.2 Contingency Planning

Financial Contingencies

- 15% budget contingency (£1.8M) allocated
- Phased deployment option if budget constraints arise
- Value engineering process to reduce costs without compromising core functionality
- Option to lease rather than purchase certain components

Technical Contingencies

- Fallback to proven technologies if cutting-edge solutions fail
- Modular design allowing incremental deployment
- Multiple vendor options for critical components

- Compatibility with industry-standard protocols

Schedule Contingencies

- 3-month schedule buffer built into project plan
- Parallel work streams where possible
- Early procurement of long-lead items
- Pre-qualification of vendors to accelerate selection

3.4 Risk Monitoring and Control

3.4.1 Governance Structure



3.4.2 Risk Review Process

1. **Weekly:** Project manager reviews active risks with team leads
2. **Monthly:** Steering committee evaluates risk register and mitigation effectiveness
3. **Quarterly:** Project board approves risk response strategies and budget allocations
4. **Ad-hoc:** Escalation process for emerging critical risks

3.4.3 Key Risk Indicators (KRIs)

- Budget variance > 5%
- Schedule slippage > 2 weeks
- Vendor delivery delays > 1 week
- Change requests > 3 per month
- Technical specification deviations
- Staff turnover in critical roles
- Integration test failures > 10%

3.5 Insurance and Legal Considerations

3.5.1 Insurance Coverage

- Professional indemnity insurance: £10M
- Public liability insurance: £10M
- Equipment insurance: Full replacement value
- Business interruption insurance: 12 months coverage
- Cyber security insurance: £5M

3.5.2 Contractual Risk Management

- Liquidated damages clauses for delays
- Performance bonds from major suppliers
- Intellectual property indemnities
- Force majeure provisions
- Clear acceptance criteria and testing procedures

3.6 Success Factors

Critical success factors for risk mitigation:

1. **Early Engagement:** Involve key stakeholders from project inception
2. **Vendor Partnership:** Select vendors as partners, not just suppliers
3. **Continuous Communication:** Maintain open channels with all parties
4. **Flexible Planning:** Build adaptability into project approach
5. **Knowledge Management:** Capture and share lessons learned
6. **Quality Focus:** Never compromise on critical quality requirements

Through proactive risk management and comprehensive mitigation strategies, we will deliver this world-class facility on time, within budget, and exceeding performance expectations.

4

Display System Specification

4.1 Technology-Agnostic Requirements

The display system forms the visual foundation of our world-class immersive environment. Regardless of the chosen technology, the system must deliver unprecedented visual fidelity and multi-user capability.

4.1.1 Core Visual Performance

Requirement VIS-001

Native resolution of 8K (7680×4320) per display surface, ensuring pixel density exceeds human visual acuity at typical viewing distances

Requirement VIS-002

Minimum 120Hz refresh rate in stereoscopic 3D mode, with capability for 240Hz+ to support multi-viewer time-multiplexing

Requirement VIS-003

Peak brightness of 1000+ nits calibrated, maintaining >500 nits through active stereo glasses

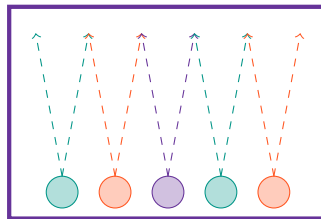
Requirement VIS-004

Contrast ratio exceeding 1,000,000:1 for LED or 2,000:1 for projection systems

Requirement VIS-005

Colour gamut covering 100% of Rec.2020 colour space with Delta E < 2 accuracy

4.1.2 Multi-User Stereoscopy



Independent Perspective Views for Each User

Figure 4.1: Multi-viewer stereoscopic system concept

Requirement VIS-006

Support for minimum 6 simultaneous users with independent stereoscopic viewpoints

Requirement VIS-007

Left/right eye crosstalk below 2% for all viewing positions

Requirement VIS-008

Motion-to-photon latency under 20ms for all users

4.2 Option A: Advanced LED Display System

4.2.1 LED Panel Specifications

For a direct-view LED implementation, we specify cutting-edge fine-pitch LED technology:

Parameter	Specification
Pixel Pitch	≤1.2mm (0.9mm preferred)
Panel Resolution	Minimum 400×400 pixels per 500mm tile
Brightness	800-1200 nits calibrated, 2000+ nits peak
Refresh Rate	≥360Hz for triple-user stereo support
Colour Processing	16-bit per channel minimum
Service Access	Front-serviceable modules
MTBF	>100,000 hours

Table 4.1: LED panel technical requirements

4.2.2 Advanced LED Features

- **HDR Support:** Full HDR10+ and Dolby Vision compatibility
- **Black Coating:** Anti-reflective black mask for enhanced contrast
- **Redundancy:** N+1 power supply and controller redundancy
- **Calibration:** Per-pixel calibration with stored correction matrices

4.2.3 Transparent LED Option

For select surfaces (potentially ceiling or observation walls):

Requirement VIS-009

Transparency rate ≥70% when displaying black content

Requirement VIS-010

Maintain minimum 4K resolution despite transparency

This innovative approach allows natural lighting or observation while maintaining immersion.

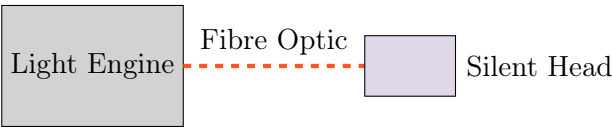
4.3 Option B: Laser Projection System

4.3.1 Projector Specifications

Component	Requirement
Technology	3-chip DLP with RGB laser illumination
Native Resolution	4K (4096×2160) minimum per projector
Brightness	30,000+ lumens per projector
Frame Rate	360Hz capability (e.g., DP INSIGHT 4K HFR 360)
Light Source	Digital Projection Satellite MLS or equivalent
Contrast	Native 2,000:1 minimum
Lens Options	Ultra-short throw with motorised adjustment

4.3.2 Satellite MLS Technology Benefits

The Digital Projection Satellite Modular Light Source represents the pinnacle of projection technology:



Key Benefits:

- Noise isolation: <25dB(A) in cave
- Heat management: Zero thermal load
- Reliability: Centralised maintenance

Figure 4.2: Satellite MLS remote light engine configuration

4.3.3 Screen Specifications

- **Material:** Rigid rear-projection screens with gain 1.3-1.5
- **Surface:** Optical coating for high contrast and wide viewing angle
- **Seamlessness:** Edge-blending zones with <1mm visible transition
- **Floor:** Specialised high-strength glass with diffusion layer

4.4 Image Processing and Calibration

4.4.1 Geometry Correction

Requirement VIS-011

Automated camera-based alignment system (e.g., VIOSO or Scalable Display)

Requirement VIS-012

Sub-pixel geometric accuracy across all surfaces

Requirement VIS-013

Real-time warping for perspective correction

4.4.2 Colour Management

- Per-channel 3D LUT colour correction
- Automated colour matching across all displays
- Ambient light compensation
- HDR tone mapping for SDR content

4.5 Control and Signal Distribution

4.5.1 Video Signal Infrastructure

Component	Specification
Signal Format	DisplayPort 1.4 or HDMI 2.1
Distribution	Fiber-optic extenders for 8K@120Hz
Switching	8K-capable matrix switcher with <1 frame latency
Redundancy	Automatic failover for all signal paths

4.5.2 Synchronisation

Requirement VIS-014

Frame-accurate synchronisation across all displays via hardware genlock

Requirement VIS-015

Support for custom frame-packing formats for multi-viewer stereo

4.6 Environmental Integration

4.6.1 Ambient Light Control

- Motorised blackout systems for all external light sources
- Automated lighting scenes linked to content
- Emergency lighting integration with safety systems

4.6.2 Thermal Management

For LED systems:

- Active cooling with temperature monitoring
- Hot-swappable fan modules
- Thermal shutdown protection

For projection systems:

- Dedicated HVAC for equipment rooms
- Filtered air supply to projection heads
- Temperature-controlled light engine room

4.7 Performance Validation

4.7.1 Acceptance Testing Requirements

1. **Brightness Uniformity:** $<10\%$ variation across each surface
2. **Colour Accuracy:** $\Delta E < 2$ for standard colour patches
3. **Stereo Separation:** Crosstalk measurement at all user positions
4. **Latency Testing:** High-speed camera validation of motion-to-photon
5. **Multi-User Validation:** Simultaneous 6-user perspective accuracy

4.7.2 Quality Metrics

Requirement VIS-016

Minimum 95% pixel operability for LED systems

Requirement VIS-017

Projected image stability <0.1 pixel drift over 8 hours

4.8 Future-Proofing Considerations

4.8.1 Upgrade Pathways

- Modular design allowing resolution increases
- Support for emerging standards (e.g., DisplayPort 2.0)
- Provision for light field displays or holographic upgrades
- AI-enhanced upscaling capability

4.8.2 Sustainability

- Energy-efficient operation modes
- Component recycling programme
- Extended warranty options (5+ years)
- Remote diagnostics capability

Display System Summary

Our display specification ensures visual performance that exceeds any current installation globally. Whether implemented with cutting-edge LED or advanced projection technology, the system will deliver unprecedented multi-user immersion with perfect colour accuracy, exceptional brightness, and seamless integration across all surfaces.

5

Compute Backend Specification

5.1 Overview

The compute infrastructure represents the cognitive engine of our world-class immersive system, delivering real-time rendering for multiple simultaneous users while managing complex simulations, tracking data, and volumetric reconstruction.

5.2 Image Generator Cluster Architecture

5.2.1 GPU Compute Requirements

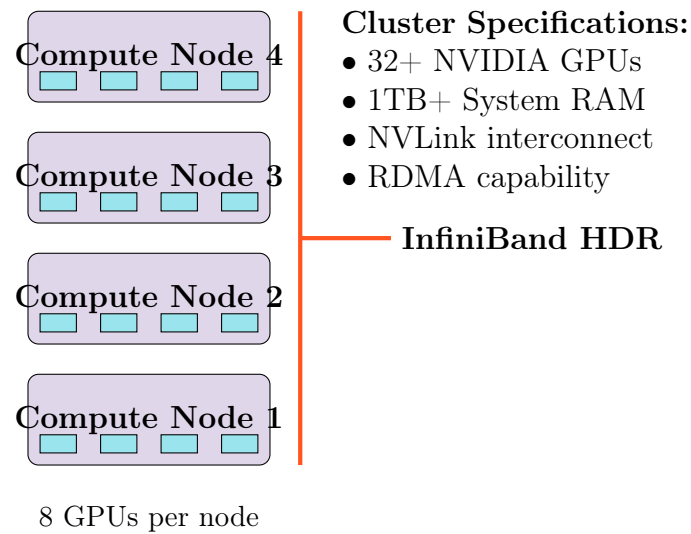


Figure 5.1: High-performance GPU cluster architecture

Requirement COMP-001

Minimum 32 high-end GPUs (NVIDIA RTX 6000 Ada or H100 class)

Requirement COMP-002

Support for real-time ray tracing at 4K resolution per viewpoint

Requirement COMP-003

Aggregate rendering capacity: 36 viewpoints at 60Hz (6 users × 6 surfaces)

5.2.2 Node Specifications

Component	Specification
GPU Configuration	8× NVIDIA RTX 6000 Ada or A100/H100 per node
CPU	Dual AMD EPYC 7763 or Intel Xeon Platinum 8480+
System Memory	512GB DDR5 ECC per node minimum
GPU Memory	48GB+ VRAM per GPU
Storage	4× 3.84TB NVMe SSD in RAID 0 for scratch
Interconnect	NVLink/NVSwitch for intra-node GPU communication
Network	Dual 200GbE or InfiniBand HDR200

Table 5.1: Individual compute node specifications

5.3 High-Performance Networking

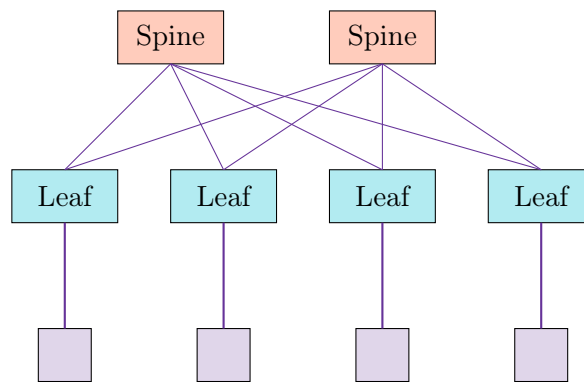
5.3.1 Internal Fabric

Requirement COMP-004

Non-blocking spine-leaf architecture with $<5\mu\text{s}$ latency

Requirement COMP-005

400Gb/s aggregate bandwidth to storage systems



Non-blocking Fabric Design

Figure 5.2: Network topology for zero congestion

5.3.2 External Connectivity

- Dual 100GbE uplinks to campus network
- Dedicated 10GbE management network
- Out-of-band IPMI access for all nodes
- Provision for Science DMZ connection

5.4 Storage Architecture

5.4.1 High-Performance Storage Tiers

Tier	Purpose	Capacity
Hot (NVMe)	Active rendering data, temp files	100TB
Warm (SSD)	Project files, recent captures	500TB
Cold (HDD)	Archive, backups	2PB

5.4.2 Parallel File System

Requirement COMP-006

Lustre or BeeGFS deployment with 40GB/s aggregate throughput

Requirement COMP-007

GPUDirect Storage support for direct GPU memory access

- Metadata servers: 2× redundant with SSD storage
- Object storage servers: 8× with 24 HDDs each
- High-speed interconnect: InfiniBand EDR/HDR
- Automatic tiering between hot/warm/cold storage

5.5 Software Stack

5.5.1 Operating System and Virtualisation

- **Base OS:** Rocky Linux 9 or Ubuntu 22.04 LTS
- **Container Platform:** Docker with NVIDIA Container Toolkit
- **Orchestration:** Kubernetes for workload management
- **GPU Scheduling:** NVIDIA Multi-Instance GPU (MIG) support

5.5.2 Rendering and Visualisation Software

Software	Purpose
Unreal Engine 5.4+	Primary real-time rendering engine with nDisplay
Unity 2024 LTS	Alternative renderer with MiddleVR support
NVIDIA Omniverse	Collaborative design and ray-traced rendering
OpenXR Runtime	VR/AR application compatibility
Custom Cluster Manager	Synchronisation and viewpoint management

5.5.3 Development and Simulation Tools

- CUDA Toolkit and cuDNN for GPU computing
- OpenCL for vendor-agnostic compute
- TensorFlow/PyTorch for AI/ML workloads
- Ansys/COMSOL for engineering simulations
- ParaView for scientific visualisation

5.6 Synchronisation and Timing

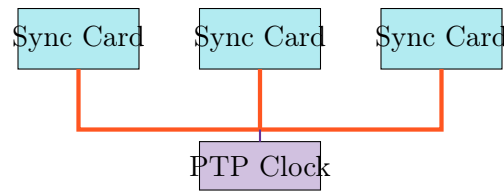
5.6.1 Hardware Synchronisation

Requirement COMP-008

NVIDIA Quadro Sync II or successor for frame-lock across all GPUs

Requirement COMP-009

PTP (Precision Time Protocol) grandmaster clock for sub-microsecond timing



Distributed Frame Synchronisation

Figure 5.3: Multi-GPU synchronisation architecture

5.6.2 Software Synchronisation

- Custom frame-pacing algorithms for multi-viewer sequencing
- Predictive rendering to compensate for tracking latency
- Asynchronous spacewarp for missed frame compensation
- Time-stamped event logging for debugging

5.7 Compute Performance Targets

5.7.1 Rendering Benchmarks

Metric	Requirement	Target
Single viewpoint FPS	120 Hz minimum	240 Hz
Total viewpoints	36 (6 users \times 6 walls)	48
Scene complexity	10M polygons	100M polygons
Ray tracing	Real-time GI	Path traced GI
Latency	<20ms	<10ms

5.7.2 Simulation Capabilities

- Real-time physics: 1M rigid bodies at 60Hz
- Fluid dynamics: 10M particles SPH simulation
- AI agents: 1000+ autonomous entities
- Volumetric rendering: 1024^3 voxel grids

5.8 Resilience and Redundancy

5.8.1 Failover Capabilities

Requirement COMP-010

N+1 redundancy for compute nodes

Requirement COMP-011

Automatic workload migration on node failure

- Hot spare GPU nodes ready for immediate deployment
- Redundant network paths with automatic failover
- Distributed rendering allowing graceful degradation
- Snapshot-based recovery for system state

5.8.2 Monitoring and Management

- **DCIM:** Data centre infrastructure management
- **GPU Monitoring:** NVIDIA DCGM for GPU health
- **Performance:** Grafana dashboards with Prometheus
- **Alerting:** PagerDuty integration for critical events

5.9 Power and Cooling Requirements

5.9.1 Power Specifications

Component	Configuration	Power Draw
GPU Nodes	4× nodes with 8 GPUs each	12kW
Storage Servers	8× storage nodes	4kW
Network Equipment	Switches, routers	2kW
Auxiliary Systems	Management, backup	2kW
Total		20kW

5.9.2 Cooling Requirements

- Minimum 70kW cooling capacity (with N+1 redundancy)
- Hot/cold aisle containment
- Liquid cooling ready for future GPU upgrades
- Target PUE: <1.3

5.10 Integration Considerations

5.10.1 Tracking System Interface

Requirement COMP-012

Sub-millisecond latency for tracking data ingestion

Requirement COMP-013

Support for VRPN and OpenXR tracking protocols

5.10.2 Audio System Interface

- Low-latency audio pipeline (<10ms)
- Spatial audio object positioning via OSC
- Hardware audio clock synchronisation

5.10.3 Volumetric Capture Pipeline

- Direct camera-to-GPU data paths
- Real-time point cloud generation
- Mesh reconstruction at 30fps
- Network streaming of volumetric data

5.11 Future Expansion

5.11.1 Scalability Provisions

- Rack space for 100% capacity expansion
- Power and cooling headroom for additional nodes
- Network infrastructure supporting 400GbE upgrade
- Software architecture supporting distributed rendering

5.11.2 Emerging Technology Support

- Quantum computing interface provisions
- Neuromorphic computing exploration
- AI accelerator integration capability
- Photonic computing research pathway

Compute Infrastructure Summary

Our compute specification delivers unprecedented rendering power through a carefully architected cluster of 32+ cutting-edge GPUs, high-speed networking, and massive storage capacity. This infrastructure ensures smooth, photorealistic experiences for all users while maintaining the headroom for complex simulations and future expansion.

6

Audio System Specification

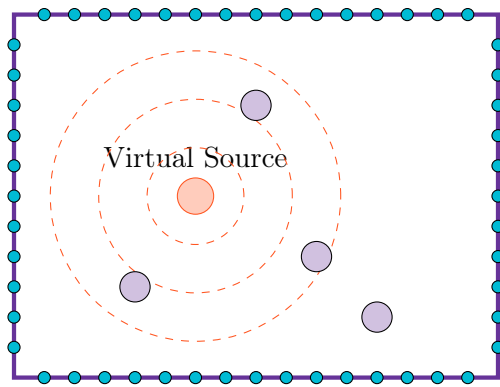
6.1 Overview

The audio system represents a revolutionary advancement in spatial sound reproduction, utilising Wave Field Synthesis (WFS) to create physically accurate sound fields that multiple users can experience simultaneously without headphones.

6.2 Wave Field Synthesis Architecture

6.2.1 Fundamental Principles

Wave Field Synthesis recreates the physical wavefronts of sound sources, enabling true spatial audio for all listeners regardless of their position within the space.



Wave Field Synthesis Creates Natural Sound Fields

Figure 6.1: WFS principle: coherent wavefronts from distributed speakers

Requirement AUD-001

Minimum 128 independently driven loudspeakers, expandable to 512

Requirement AUD-002

Spatial accuracy: sound source localisation error $<1^\circ$ for all listener positions

6.2.2 Speaker Array Configuration

Parameter	Specification
Array Topology	Horizontal ring at ear level (1.2m) plus elevated ring (2.4m)
Speaker Spacing	20-30cm maximum ($\lambda/2$ at 8kHz)
Driver Type	4" full-range coaxial with controlled dispersion
Frequency Response	100Hz - 20kHz ± 3 dB per driver
Power Handling	50W RMS per channel
Coverage Pattern	90° horizontal \times 45° vertical

Table 6.1: WFS speaker array specifications

6.3 System Components

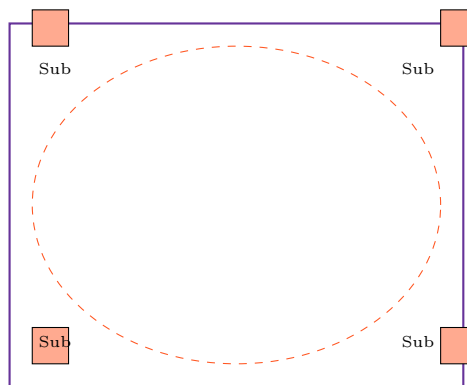
6.3.1 Loudspeaker Specifications

Requirement AUD-003

Custom-designed drivers optimised for WFS application

- **Transducer:** Coaxial design for point-source behaviour
- **Enclosure:** Sealed, anti-resonant construction
- **Mounting:** Flush integration with room surfaces
- **Connection:** Bi-amp capable with DSP crossover

6.3.2 Subwoofer Integration



Distributed Subwoofer Array

Figure 6.2: Corner-loaded subwoofer configuration for uniform LF coverage

- 4× 18" high-excursion subwoofers
- Frequency range: 20Hz - 120Hz
- DSP-controlled for room mode cancellation
- Time-aligned with WFS array

6.4 Processing and Amplification

6.4.1 WFS Processing Engine

Requirement AUD-004

Real-time processing for 256+ channels at 96kHz/32-bit

Component	Specification
Processing Platform	Dedicated WFS server with GPU acceleration
Algorithm	Kirchhoff-Helmholtz integral implementation
Latency	<5ms input to output
Update Rate	1000Hz for moving sources
Object Capacity	64 simultaneous 3D sound sources

6.4.2 Amplification Architecture

- **Topology:** Class D multi-channel amplifiers
- **Configuration:** 16 channels per amplifier module
- **Power:** 50W × 16 channels per unit
- **DSP:** Per-channel EQ, delay, and limiting
- **Networking:** Dante or AVB for audio distribution
- **Redundancy:** Hot-swappable amplifier modules

6.5 Acoustic Design Integration

6.5.1 Room Acoustic Treatment

Requirement AUD-005

RT60 < 0.3 seconds (500Hz-2kHz) for optimal WFS performance

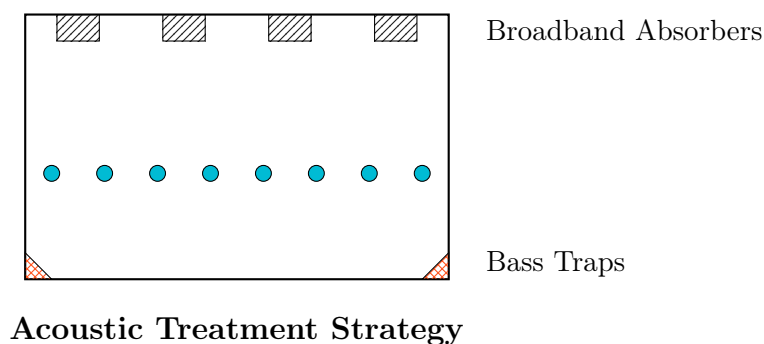


Figure 6.3: Strategic placement of acoustic treatment

6.5.2 Speaker Integration Details

- Flush-mounted speakers with minimal baffle
- Acoustically transparent covering where needed
- Vibration isolation from building structure
- Cable management within wall cavities

6.6 Control and Calibration

6.6.1 System Calibration

Requirement AUD-006

Automated room calibration using measurement microphone array

- 3D acoustic measurement at 64+ positions
- Per-speaker frequency response correction
- Time alignment to sub-sample accuracy
- Room mode identification and correction
- Validation of WFS synthesis accuracy

6.6.2 User Interface

- **Touch Panel Control:** Source selection and routing
- **Software Interface:** 3D sound object positioning
- **Preset Management:** Scene storage and recall
- **Monitoring:** Real-time system health display

6.7 Integration with Visual System

6.7.1 Synchronisation

Requirement AUD-007

Audio-visual synchronisation within ± 1 video frame

- Hardware clock synchronisation with render cluster
- Predictive audio rendering for moving objects
- Automatic delay compensation
- Frame-accurate triggering

6.7.2 Spatial Mapping

Integration Feature	Implementation
Coordinate System	Unified 3D space with visual tracking
Object Tracking	Real-time audio position updates from visual objects
Occlusion Modelling	Frequency-dependent attenuation for hidden sources
Distance Attenuation	Physically accurate $1/r^2$ law with air absorption
Doppler Effects	Automatic pitch shift for moving sources

6.8 Advanced Audio Features

6.8.1 Acoustic Simulation

- **Early Reflections:** Ray-traced first-order reflections
- **Reverberation:** Convolution with measured/modelled IRs
- **Material Properties:** Frequency-dependent absorption
- **Dynamic Environments:** Real-time acoustic updates

6.8.2 Binaural Recording

Requirement AUD-008

Ambisonic microphone array for spatial audio capture

- 32-channel spherical microphone array
- 4th order ambisonic encoding
- Binaural rendering for headphone playback
- Integration with volumetric video capture

6.9 Audio Content Workflow

6.9.1 Supported Formats

- **Object-based:** ADM, Dolby Atmos, DTS:X
- **Channel-based:** Up to 22.2 discrete channels
- **Scene-based:** Higher-order ambisonics (HOA)
- **Live Input:** Multi-channel microphone arrays

6.9.2 Authoring Tools

- Native WFS panning plugins for major DAWs
- Real-time preview in scaled model room
- Game engine integration (Unreal, Unity)
- Max/MSP patches for experimental work

6.10 Performance Specifications

6.10.1 System Performance Metrics

Parameter	Specification	Target
Frequency Response	20Hz - 20kHz \pm 3dB	\pm 1.5dB
Maximum SPL	105dB continuous	110dB peak
Dynamic Range	>96dB	>110dB
THD+N	<0.5% at 90dB SPL	<0.1%
Channel Separation	>60dB	>80dB

6.10.2 Spatial Performance

- Localisation accuracy: \pm 5° azimuth, \pm 10° elevation
- Effective listening area: 80% of room volume
- Minimum source distance: 0.5m from listener
- Maximum simultaneous sources: 64 (128 with reduced quality)

6.11 Maintenance and Reliability

6.11.1 Preventive Maintenance

- Monthly: Automated frequency sweep testing

- Quarterly: Physical inspection of all drivers
- Annually: Full acoustic recalibration
- Continuous: Real-time monitoring of driver health

6.11.2 Redundancy Measures

Requirement AUD-009

System remains operational with up to 10% speaker failure

- Automatic gain redistribution for failed speakers
- Hot-spare amplifier channels
- Redundant signal paths
- Graceful degradation algorithms

6.12 Safety and Compliance

6.12.1 Acoustic Safety

- SPL limiting to prevent hearing damage
- Emergency mute capability
- Compliance with workplace noise regulations
- Optional personal limit settings

6.12.2 Electrical Safety

- All equipment CE/UKCA marked
- Proper earthing and isolation
- Emergency power disconnection

- Regular PAT testing schedule

Audio System Summary

Our Wave Field Synthesis audio system sets a new standard for spatial sound reproduction, enabling multiple users to experience perfectly positioned 3D audio without headphones. With 128-512 speakers creating coherent wavefronts, every listener hears accurate spatial sound regardless of their position, revolutionising collaborative immersive experiences.

7

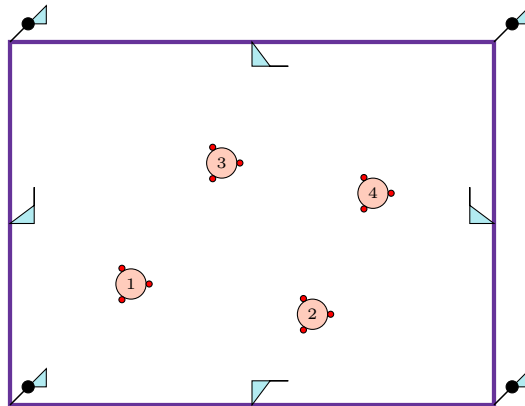
Tracking and Capture System

7.1 Overview

The tracking and capture system provides the spatial intelligence for our immersive environment, combining sub-millimetre optical tracking for user interaction with cutting-edge volumetric capture for telepresence and analysis.

7.2 Optical Motion Tracking System

7.2.1 System Architecture



16-Camera Tracking Configuration

Figure 7.1: Optical tracking camera placement for complete coverage

Requirement TRK-001

Minimum 16 high-speed tracking cameras with overlapping coverage

Requirement TRK-002

Tracking precision <1mm throughout the entire capture volume

7.2.2 Camera Specifications

Parameter	Specification
Camera Model	Vicon Vantage X16 or OptiTrack Prime X 41
Resolution	16 megapixels (4096 × 4096)
Frame Rate	240Hz standard, 480Hz capability
Latency	<3ms from capture to data output
IR Illumination	High-power strobed IR LEDs
Field of View	51° × 51° with standard lens
Connectivity	10GigE with PTP synchronisation

Table 7.1: Motion capture camera specifications

7.2.3 Tracking Capabilities

- **Simultaneous Users:** 6+ with full-body tracking

- **Rigid Bodies:** 20+ tracked objects
- **Individual Markers:** 200+ passive/active markers
- **Capture Volume:** 5m × 5m × 3m minimum
- **Accuracy:** 0.1mm static, 0.5mm dynamic

7.3 Active Tracking Technology

7.3.1 Active Marker System

Requirement TRK-003

Active LED markers for robust user identification

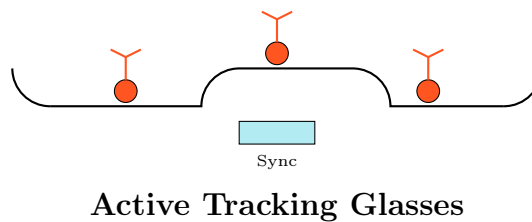


Figure 7.2: Wireless active marker glasses with unique ID encoding

- Unique temporal encoding per user (no marker swapping)
- Wireless operation with 8+ hour battery life
- Integrated shutter sync for stereoscopic viewing
- IMU backup for momentary occlusion handling

7.3.2 Tracked Interaction Devices

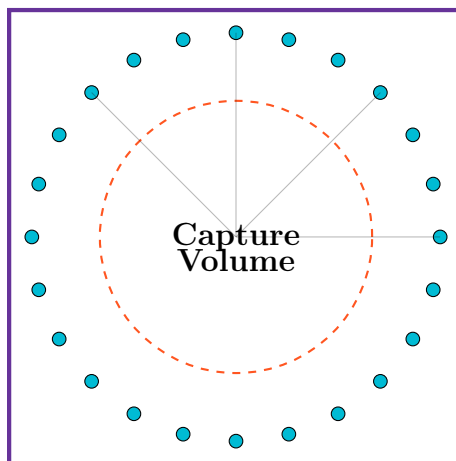
- **Wand Controllers:** 6DOF with buttons and haptic feedback
- **Glove Systems:** Finger-level tracking for gesture input
- **Props:** Custom tracked objects for specific applications
- **Tools:** Tracked stylus for precise 3D annotation

7.4 Volumetric Capture System

7.4.1 Camera Array Configuration

Requirement TRK-004

64 synchronised RGB cameras for real-time volumetric capture



360° Camera Coverage

Figure 7.3: Volumetric capture camera array layout

7.4.2 Volumetric Camera Specifications

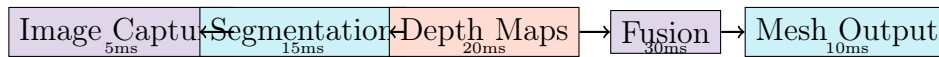
Parameter	Specification
Camera Type	Machine vision global shutter
Resolution	4K (4096 × 2160) minimum
Frame Rate	60fps standard, 120fps capability
Sensor	1" CMOS with high sensitivity
Lens	Fixed 8-12mm with remote focus
Synchronisation	Hardware genlock to microsecond precision
Interface	10GigE Vision or CameraLink

7.5 Volumetric Processing Pipeline

7.5.1 Real-Time Reconstruction

Requirement TRK-005

Live 3D reconstruction at 30fps with <100ms latency



Total Pipeline: <100ms

Figure 7.4: Volumetric reconstruction pipeline stages

7.5.2 Processing Infrastructure

- **Capture Servers:** 8× GPU-accelerated nodes
- **Processing GPUs:** NVIDIA RTX 4090 or better
- **Algorithm:** Neural radiance fields + traditional MVS
- **Output Quality:** 2M polygons at 30fps per person
- **Compression:** Real-time mesh compression for streaming

7.6 Illumination Systems

7.6.1 Tracking Illumination

- **IR Flood Lights:** 850nm wavelength
- **Synchronised Strobing:** Matched to camera shutter
- **Intensity Control:** Adaptive based on ambient conditions
- **Safety:** Class 1 eye-safe operation

7.6.2 Volumetric Capture Lighting

Requirement TRK-006

Uniform illumination without interfering with display system

- **White Light Panels:** High-CRI LED arrays
- **Temporal Multiplexing:** Capture during display blanking
- **Colour Temperature:** 5600K daylight balanced
- **Intensity:** 2000 lux at capture volume centre

7.7 Calibration Systems

7.7.1 Tracking Calibration

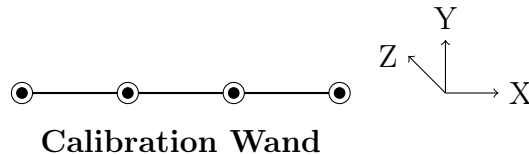


Figure 7.5: Precision calibration tools

- **Wand Calibration:** Known marker spacing to 0.01mm
- **L-Frame:** Origin and axis definition
- **Volume Accuracy Test:** 27-point validation grid
- **Automated Recalibration:** Weekly schedule

7.7.2 Volumetric Calibration

- **Checkerboard Arrays:** Multi-scale pattern detection
- **Bundle Adjustment:** Global optimisation of camera parameters

- **Colour Calibration:** Macbeth chart at multiple positions
- **Geometric Validation:** Tracked object comparison

7.8 Data Integration and APIs

7.8.1 Tracking Data Protocols

Requirement TRK-007

Support for industry-standard tracking protocols

Protocol	Implementation
VRPN	Native support with quaternion output
OpenXR	Full compliance with tracking extensions
OSC	Custom messages for audio spatialisation
Unity/Unreal	Direct plugin integration
Custom TCP/UDP	Binary protocol for minimum latency

7.8.2 Volumetric Data Formats

- **Live Streaming:** Compressed point clouds via WebRTC
- **Mesh Export:** OBJ, FBX, USD formats
- **Texture Maps:** 4K diffuse, normal, and occlusion
- **Animation:** Alembic cache for temporal sequences

7.9 Advanced Features

7.9.1 Prediction and Filtering

- **Kalman Filtering:** Smooth trajectory estimation
- **Predictive Tracking:** 20ms forward prediction

- **Occlusion Handling:** IMU fusion during marker loss
- **Jitter Reduction:** Adaptive smoothing algorithms

7.9.2 Multi-System Integration

Requirement TRK-008

Seamless data fusion between tracking and volumetric systems

- Unified coordinate system
- Temporal synchronisation to microsecond level
- Automatic skeletal tracking from volumetric data
- Hybrid tracking for enhanced robustness

7.10 Performance Metrics

7.10.1 Tracking Performance

Metric	Requirement	Target
Static Accuracy	<1mm	0.1mm
Dynamic Accuracy	<2mm	0.5mm
Latency	<10ms	3ms
Update Rate	240Hz	480Hz
Jitter	<0.5mm RMS	0.1mm RMS

7.10.2 Volumetric Performance

Metric	Requirement	Target
Reconstruction Rate	30fps	60fps
Geometric Accuracy	<10mm	5mm
Texture Resolution	4K	8K
Processing Latency	<100ms	50ms
Simultaneous Captures	2 people	4 people

7.11 Maintenance and Support

7.11.1 Preventive Maintenance

- **Daily:** System health check via software
- **Weekly:** Lens cleaning and calibration verify
- **Monthly:** Full recalibration procedure
- **Quarterly:** Hardware inspection and testing

7.11.2 Redundancy and Reliability

- Spare cameras ready for hot-swap
- Automatic reconfiguration on camera failure
- Redundant processing nodes
- Continuous backup of calibration data

Tracking and Capture Summary

Our integrated tracking and volumetric capture system provides unprecedented spatial awareness and presence capture. With sub-millimetre optical tracking for interaction and real-time volumetric reconstruction for telepresence, users can naturally interact with virtual content while being captured as photorealistic avatars for remote collaboration.

8

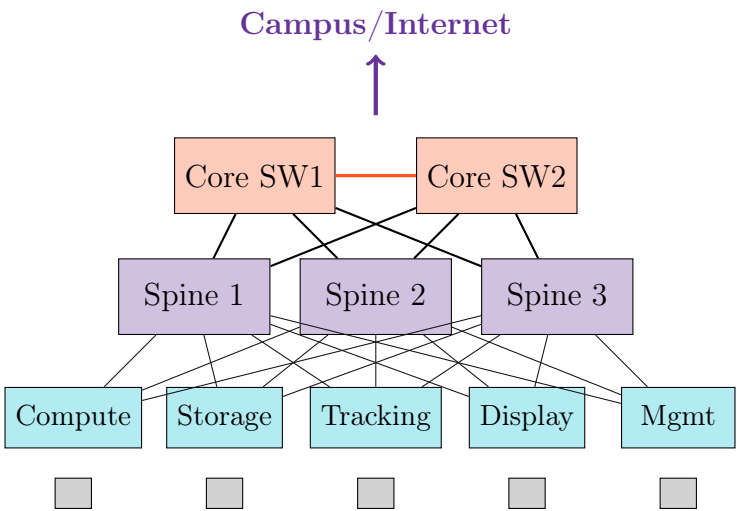
Network Infrastructure Specification

8.1 Overview

The network infrastructure forms the digital backbone of our immersive system, enabling seamless data flow between rendering clusters, tracking systems, storage arrays, and external collaborators with ultra-low latency and massive bandwidth.

8.2 Network Architecture

8.2.1 Core Design Principles



Non-Blocking Spine-Leaf Architecture

Figure 8.1: High-performance network topology

Requirement NET-001

Full non-blocking architecture with line-rate forwarding

Requirement NET-002

Sub-5 microsecond port-to-port latency

8.2.2 Network Segregation

Network	Purpose	Bandwidth
Compute Fabric	GPU cluster interconnect	400Gb/s
Storage Network	High-speed data access	200Gb/s
Tracking Network	Camera and sensor data	100Gb/s
Display Network	Video signal distribution	100Gb/s
Management	Control and monitoring	10Gb/s
Campus Uplink	External connectivity	2×100Gb/s

Table 8.1: Network segmentation strategy

8.3 Core Infrastructure

8.3.1 Switch Specifications

Requirement NET-003

Enterprise-grade switches with deep buffers and RDMA support

Core/Spine Switches

- **Model:** Arista 7800R3 Series or equivalent
- **Ports:** 32× 400GbE QSFP-DD
- **Switching Capacity:** 25.6 Tbps
- **Latency:** <1 microsecond
- **Buffer:** 64GB shared memory
- **Features:** VXLAN, EVPN, segment routing

Leaf Switches

- **Model:** Arista 7050X3 Series or equivalent
- **Ports:** 48× 25GbE + 8× 100GbE uplinks
- **Switching Capacity:** 3.2 Tbps
- **Features:** Cut-through switching, PTP support

8.3.2 InfiniBand Option

For ultimate compute performance, parallel InfiniBand deployment:

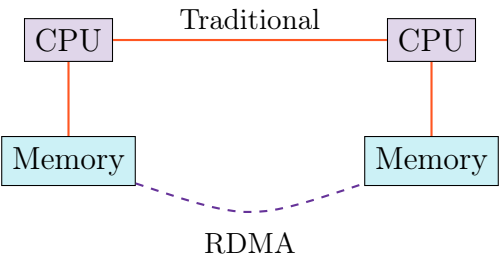
Component	Specification
Technology	InfiniBand HDR200 (200Gb/s per port)
Switch	NVIDIA Quantum-2 QM8700
Adapters	NVIDIA ConnectX-6 HDR
Topology	Fat-tree with 1:1 oversubscription
Features	GPUDirect RDMA, adaptive routing

8.4 High-Performance Features

8.4.1 RDMA Implementation

Requirement NET-004

Remote Direct Memory Access for compute and storage



RDMA Bypasses CPU for Direct Memory Access

Figure 8.2: RDMA architecture benefit

- **RoCE v2:** RDMA over Converged Ethernet
- **PFC:** Priority Flow Control for lossless transport
- **ECN:** Explicit Congestion Notification
- **DCQCN:** Data Center QCN for congestion control

8.4.2 Time Synchronisation

Requirement NET-005

Precision Time Protocol (PTP) for sub-microsecond synchronisation

- **Grandmaster Clock:** GPS-disciplined oscillator
- **Accuracy:** <100 nanoseconds across network
- **Boundary Clocks:** In all switches
- **Monitoring:** Continuous offset tracking

8.5 Storage Network

8.5.1 Dedicated Storage Fabric

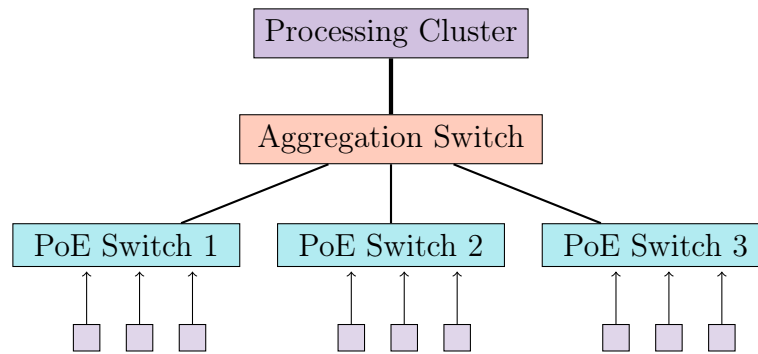
Feature	Implementation
Protocol	NVMe over Fabrics (NVMe-oF)
Transport	RoCE v2 or InfiniBand
Bandwidth	40GB/s aggregate throughput
Latency	<100 microseconds to first byte
Redundancy	Dual-path with automatic failover

8.5.2 Storage Area Network Details

- **Metadata Network:** Separate 25GbE for Lustre/BeeGFS
- **Object Storage:** 100GbE per storage node
- **Backup Network:** Isolated 10GbE for snapshots
- **Replication:** Dedicated link for DR site

8.6 Camera and Sensor Networks

8.6.1 Tracking Network Architecture



Camera Network Topology

Figure 8.3: Distributed PoE infrastructure for cameras

- **PoE++ Support:** 90W per port for powered devices
- **10GigE Vision:** Camera data protocol support
- **Multicast:** Efficient distribution of tracking data
- **QoS:** Priority queuing for tracking packets

8.7 External Connectivity

8.7.1 Campus Network Integration

Requirement NET-006

Dual diverse 100GbE uplinks to campus core

- **Primary Path:** Direct fiber to data centre
- **Secondary Path:** Diverse route via alternate building
- **Routing:** BGP with campus AS
- **Filtering:** Stateful firewall at boundary

8.7.2 Remote Collaboration Support

Service	Implementation
Video Streaming	WebRTC with TURN/STUN servers
Remote Rendering	NVIDIA CloudXR or similar
File Transfer	GridFTP for large datasets
API Access	REST/GraphQL via reverse proxy
VPN	IPSec for secure remote access

8.8 Security Architecture

8.8.1 Network Security Layers

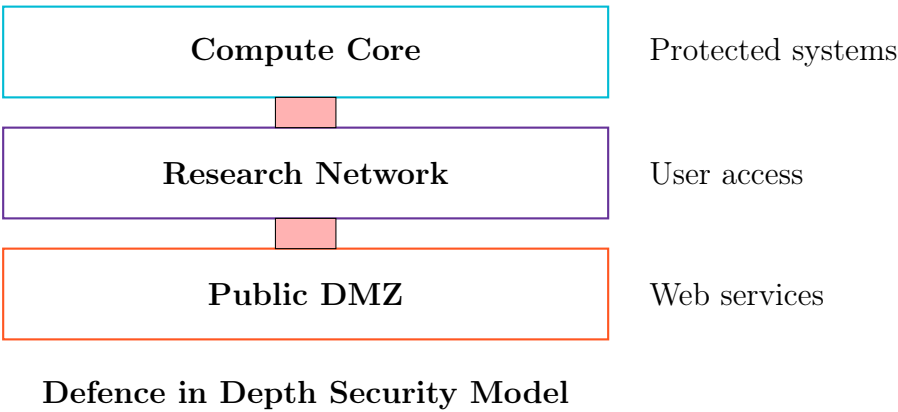


Figure 8.4: Security zone architecture

8.8.2 Security Features

- **Micro-segmentation:** VXLAN-based isolation
- **Access Control:** 802.1X with RADIUS
- **Encryption:** MACsec on critical links
- **DDoS Protection:** Hardware-based mitigation
- **IDS/IPS:** Inline threat detection

8.9 Quality of Service

8.9.1 Traffic Classification

Requirement NET-007

Strict QoS prioritisation for real-time traffic

Traffic Class	Applications	Priority
Real-time Control	Tracking, sync signals	Highest
Render Data	GPU cluster traffic	High
Storage I/O	File system operations	Medium
Management	Monitoring, logs	Low

8.9.2 QoS Implementation

- **DSCP Marking:** At ingress points
- **Priority Queues:** 8 hardware queues
- **Rate Limiting:** Per-flow policers
- **Buffer Management:** Dynamic thresholds

8.10 Management and Monitoring

8.10.1 Network Management System

- **DCIM:** Integrated with facility management
- **Configuration:** Ansible automation
- **Monitoring:** Prometheus + Grafana
- **Flow Analysis:** sFlow/NetFlow collection
- **Performance:** Real-time latency tracking

8.10.2 Monitoring Metrics

Requirement NET-008

Comprehensive monitoring with 1-second granularity

- Port utilisation and error rates
- Latency histograms per path
- Buffer utilisation
- PTP clock offset
- RDMA congestion events
- Security event correlation

8.11 Cabling Infrastructure

8.11.1 Fiber Optic Specifications

Type	Application
OS2 Single-mode	Long runs, campus uplinks
OM5 Multi-mode	Spine-leaf connections
MPO/MTP Trunks	High-density backbone
AOC Cables	Top-of-rack connections

8.11.2 Structured Cabling

- **Cable Management:** Overhead ladder trays
- **Labelling:** Automated documentation system
- **Testing:** OTDR certification for all fiber
- **Redundancy:** Diverse physical paths

8.12 Resilience and Redundancy

8.12.1 High Availability Features

- **Switch Redundancy:** MLAG/VARP configurations
- **Link Redundancy:** LAG with min-links
- **Power:** Dual PSU from separate PDUs
- **Cooling:** N+1 fan modules

8.12.2 Failure Scenarios

Requirement NET-009

Zero downtime for single component failure

- Switch failure: <50ms convergence
- Link failure: Sub-second LACP failover
- Power failure: Seamless PSU transition
- Software failure: Hitless upgrades

8.13 Future Expansion

8.13.1 Scalability Provisions

- 50% port capacity reserved for growth
- 400GbE/800GbE upgrade path
- Additional spine switches pre-cabled
- Power and cooling headroom

8.13.2 Emerging Technologies

- **P4 Programmability:** Custom packet processing
- **Network Slicing:** Guaranteed SLA per application
- **AI/ML Integration:** Predictive failure detection
- **Quantum Networking:** Research provisions

Network Infrastructure Summary

Our network architecture delivers the ultra-low latency and massive bandwidth required for real-time immersive experiences. With non-blocking switching, RDMA support, and comprehensive redundancy, the infrastructure ensures that data flows seamlessly between all system components while maintaining the sub-millisecond timing precision essential for multi-user immersion.

9

Room Layout and Construction

9.1 Overview

The physical space housing our world-class immersive system requires careful architectural planning to support the technology while creating an inspiring environment for research and collaboration.

9.2 Spatial Requirements

9.2.1 Overall Dimensions

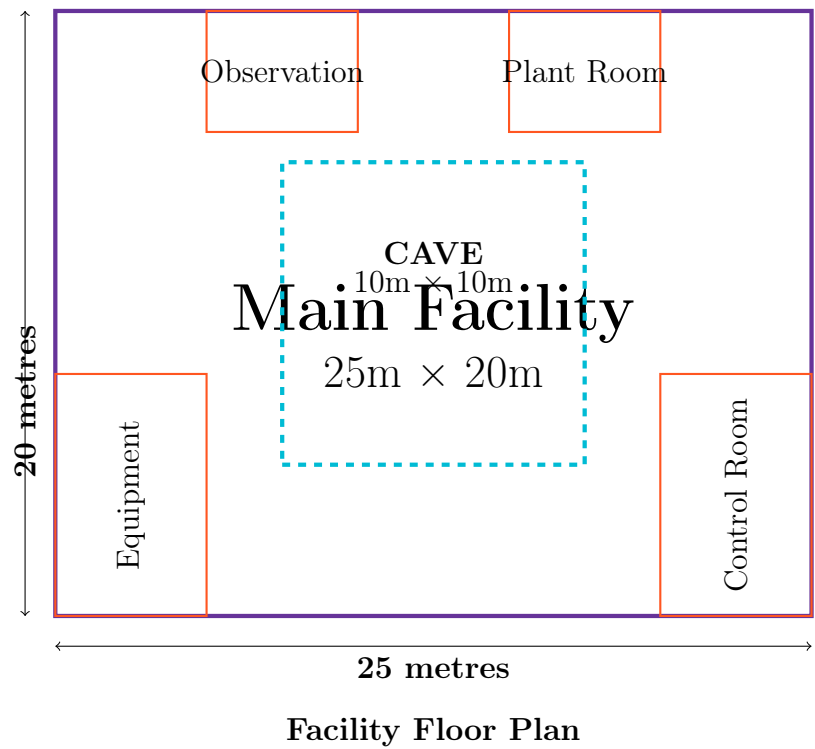


Figure 9.1: Overall facility layout showing CAVE and support spaces

Requirement ROOM-001
Minimum 500m ² total floor area with 7m ceiling height
Requirement ROOM-002
Central CAVE space of 10m x 10m x 6m clear volume

9.2.2 Space Allocation

Area	Purpose	Size (m ²)
CAVE Interior	Immersive display space	100
Projection Zones	Projector placement (if used)	60
Equipment Room	Servers, networking, storage	40
Control Room	Operator stations	30
Plant Room	HVAC, power distribution	40
Observation Gallery	Visitor viewing area	30
Entry/Preparation	User briefing, equipment	20
Storage	Spares, consumables	20
Circulation	Corridors, access routes	60
Total		400

Table 9.1: Space allocation breakdown

9.3 CAVE Construction Details

9.3.1 Structural Requirements

Requirement ROOM-003

Floor loading capacity of 1,000 kg/m² for equipment

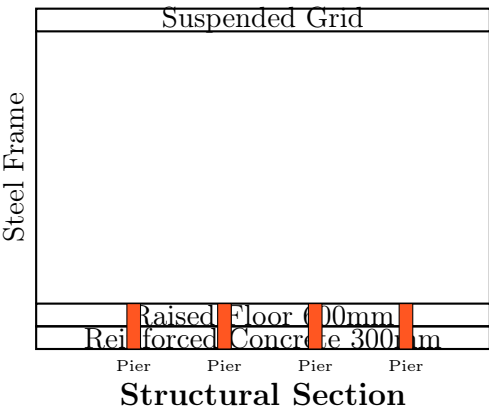


Figure 9.2: CAVE structural system

Floor System

- Reinforced concrete slab with isolated foundation
- 600mm raised floor with heavy-duty pedestals
- Integrated cable management system
- Anti-static, low-reflectance surface finish
- Optional glass floor section for bottom projection

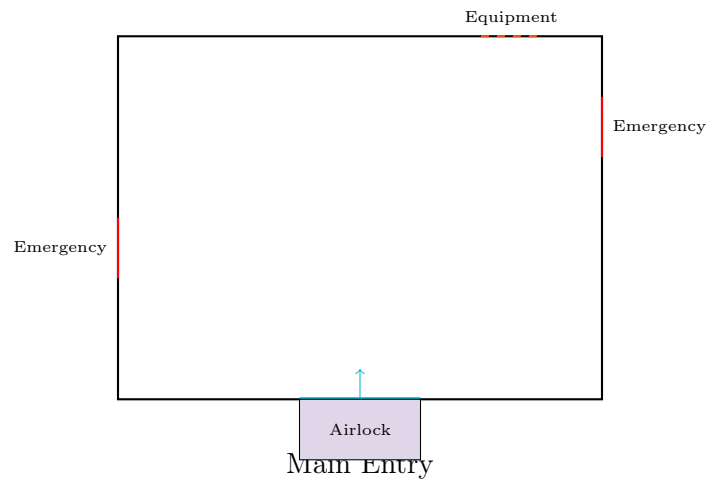
Wall Construction

- Steel frame structure for precision alignment
- Acoustic isolation from building structure
- Modular panel system for maintenance access
- Integrated mounting points for displays/screens
- Light-tight seals at all joints

9.3.2 Entry Systems

Requirement ROOM-004

Automated entry system with safety interlocks



Access Configuration

Figure 9.3: Entry and emergency egress design

- **Main Entry:** Motorised sliding door with light trap
- **Safety Features:** Motion sensors, emergency stop
- **Airlock:** Light and sound isolation chamber
- **Emergency Exits:** Push-bar releases on 3 walls
- **Equipment Access:** Removable wall section for large items

9.4 Environmental Control

9.4.1 Acoustic Treatment

Requirement ROOM-005

STC 60+ rating for sound isolation

Surface	Treatment
Walls	Double-stud construction with acoustic insulation
Ceiling	Suspended acoustic tiles with NRC 0.9
Floor	Floating slab with vibration isolation
Doors	Acoustic seals with automatic drop bottoms
Penetrations	Acoustic caulking and sleeves

Table 9.2: Acoustic treatment specifications

9.4.2 Lighting Systems

- **House Lights:** RGBW LED with 0-100% dimming
- **Emergency Lighting:** Battery-backed path marking
- **Work Lights:** High-CRI LED for maintenance
- **Blackout:** Complete darkness capability
- **Control:** DMX512 integration with show control

9.5 Support Spaces

9.5.1 Control Room Design

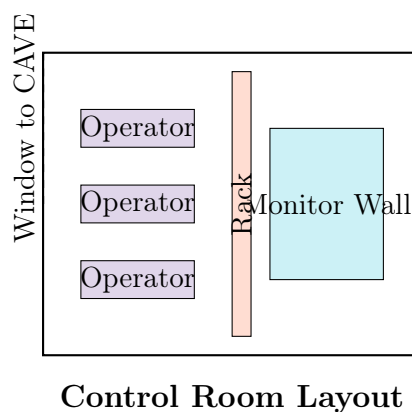


Figure 9.4: Operator control room configuration

Features

- Direct sightline to CAVE through observation window
- 3× operator workstations with multi-monitor setups
- 4×4 video wall for system monitoring
- Raised floor for cable management
- Separate HVAC zone with precise control

9.5.2 Equipment Room

Requirement ROOM-006

N+1 cooling capacity for all heat loads

- **Layout:** Hot aisle/cold aisle configuration
- **Racks:** 42U server racks with PDUs
- **Cooling:** In-row cooling units
- **Power:** A/B power feeds to each rack
- **Access:** Front and rear service clearance
- **Security:** Biometric access control

9.6 Infrastructure Integration

9.6.1 Cable Pathways

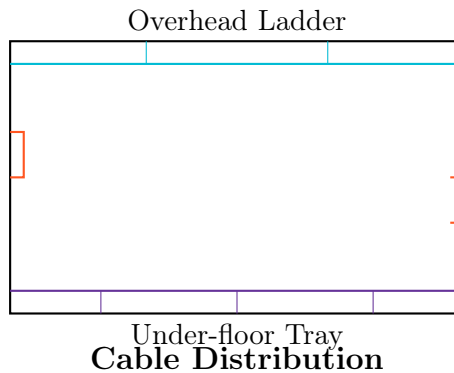


Figure 9.5: Integrated cable management system

- Separate pathways for power and data
- Fiber optic dedicated conduits
- EMI shielding for sensitive signals
- Future expansion capacity (50% spare)
- Full documentation and labelling system

9.6.2 Mechanical Systems Integration

- **HVAC Diffusers:** Low-velocity displacement ventilation
- **Ductwork:** Acoustically lined with silencers
- **Piping:** Chilled water for in-room cooling units
- **Drainage:** Condensate management system
- **Fire Suppression:** Pre-action sprinkler system

9.7 Safety and Compliance

9.7.1 Life Safety Systems

Requirement ROOM-007

Full compliance with UK building regulations

- **Fire Detection:** Addressable smoke/heat detectors
- **Emergency Lighting:** 3-hour battery backup
- **Exit Signage:** Photoluminescent and LED
- **Voice Alarm:** Integrated PA system
- **Access Control:** Fail-safe locks on emergencies

9.7.2 Accessibility

- Level access throughout facility
- Wheelchair turning circles in all spaces
- Adjustable height control stations
- Hearing loop system in briefing areas
- Tactile warning surfaces at hazards

9.8 Finishes and Materials

9.8.1 Interior Finishes

Surface	Specification
CAVE Walls	Matt black acoustic fabric over treatment
CAVE Floor	Dark grey anti-static vinyl
Control Room	Commercial carpet tile
Equipment Room	Sealed concrete with epoxy coating
Ceilings	Acoustic tile with high NRC rating

Table 9.3: Interior finish specifications

9.8.2 Specialist Requirements

- **RF Shielding:** Conductive paint in sensitive areas
- **Static Control:** Conductive flooring and grounding
- **Cleanroom Protocol:** HEPA filtration option
- **Chemical Resistance:** Epoxy coatings in plant areas

9.9 Future Flexibility

9.9.1 Expansion Provisions

- Knockout panels for additional equipment rooms
- Spare capacity in all building services
- Modular wall systems for reconfiguration
- Additional power and cooling connections
- Space allocation for emerging technologies

9.9.2 Multi-Use Capabilities

Requirement ROOM-008

Design for multiple operational modes

- Research facility (primary mode)
- Public demonstration space
- Teaching laboratory
- Corporate presentation venue
- Media production facility

Room Layout and Construction Summary

The facility design creates an optimal environment for immersive technology, balancing technical requirements with human factors. From the precision-engineered CAVE space to the comprehensive support facilities, every aspect is designed to enable groundbreaking research while ensuring safety, accessibility, and operational efficiency.

10

Power and Cooling Specification

10.1 Overview

The power and cooling infrastructure forms the critical foundation for reliable operation of our world-class immersive system, requiring careful design to handle substantial loads while maintaining efficiency and resilience.

10.2 Power Requirements Analysis

10.2.1 Load Calculations

Requirement PWR-001

Total facility power capacity of 150kVA with N+1 redundancy

System	Components	Peak (kW)	Typical (kW)
Display - Projection	10× laser projectors @ 3kW	30.0	20.0
Display - LED Option	6 walls @ 5kW per wall	30.0	15.0
Compute Cluster	4 nodes × 8 GPUs @ 3kW	12.0	10.0
Storage Systems	8 servers + disk arrays	4.0	3.5
Network Equipment	Switches, routers, firewalls	2.0	1.8
Audio System	Amplifiers for 256 channels	5.0	2.0
Tracking Cameras	80 cameras with PoE++	2.0	1.8
Workstations	Control room systems	2.0	1.5
Lighting	House and emergency	3.0	1.0
IT/AV Subtotal		60.0	41.6
HVAC Systems	Chillers, pumps, fans	25.0	20.0
UPS Losses	Efficiency losses @ 95%	3.0	2.1
Future Expansion	30% headroom	18.0	–
Total Load		106.0	63.7

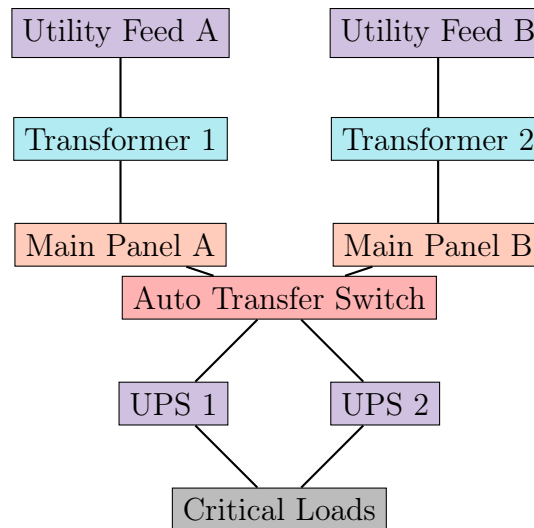
Table 10.1: Detailed power load analysis

10.3 Electrical Distribution Design

10.3.1 Primary Power Infrastructure

Requirement PWR-002

Dual independent power feeds from separate transformers



Redundant Power Distribution

Figure 10.1: High-level electrical distribution architecture

10.3.2 Distribution Specifications

- **Service Entrance:** 2× 415V 3-phase 200A feeds
- **Main Distribution:** Form 4 Type 2 switchboards
- **Sub-Distribution:** Local panels in each technical area
- **Earthing:** TN-S system with dedicated technical earth
- **Surge Protection:** Type 1+2 SPDs at main panels

10.4 Uninterruptible Power Supply (UPS)

10.4.1 UPS System Design

Requirement PWR-003

Minimum 15 minutes runtime at full load

Parameter	Specification
Configuration	Parallel redundant (N+1)
Capacity	2× 80kVA modules = 160kVA total
Technology	Double-conversion online
Efficiency	>96% in ECO mode
Battery Type	VRLA or Lithium-ion
Runtime	15 minutes at 100% load
Input THD	<3% at full load
Output Voltage	415/240V ±1%
Transfer Time	0ms (online topology)

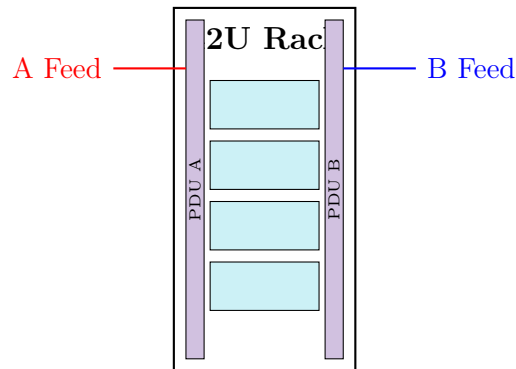
Table 10.2: UPS system specifications

10.4.2 Battery System

- **Configuration:** Separate battery rooms with ventilation
- **Monitoring:** Individual cell voltage and temperature
- **Maintenance:** Quarterly impedance testing
- **Replacement:** 5-year design life (VRLA) or 10-year (Li-ion)
- **Safety:** Hydrogen detection and ventilation

10.5 Power Distribution Units (PDUs)

10.5.1 Rack-Level Distribution



Dual-Feed PDU Configuration

Figure 10.2: Redundant power distribution in equipment racks

Requirement PWR-004

All critical equipment with dual power supplies on separate feeds

PDU Specifications

- **Type:** Intelligent switched PDUs
- **Capacity:** 32A 3-phase per PDU
- **Outlets:** IEC C13/C19 mix
- **Monitoring:** Per-outlet power metering
- **Control:** Remote outlet switching
- **Redundancy:** A/B feed configuration

10.6 Cooling System Design

10.6.1 Heat Load Analysis

Requirement PWR-005

N+1 cooling capacity for worst-case heat loads

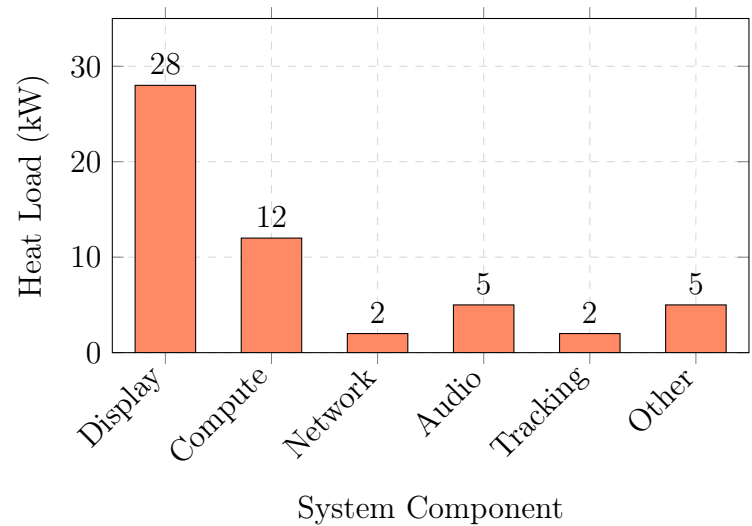


Figure 10.3: Cooling load distribution by system

10.6.2 Cooling Architecture

Zone	Cooling Strategy
CAVE Space	Displacement ventilation with precise control
Equipment Room	In-row cooling with hot aisle containment
Control Room	Standard DX comfort cooling
Projection Room	Dedicated air handlers for light engines

Table 10.3: Zone-based cooling strategies

10.7 CAVE Space Cooling

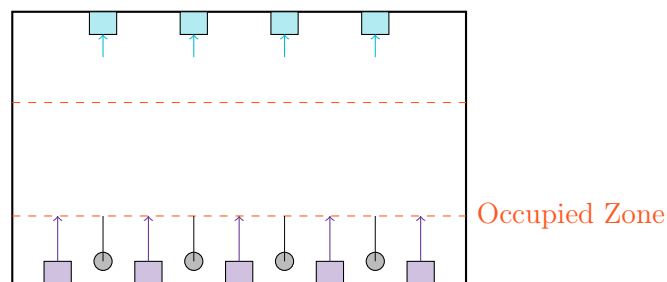
10.7.1 Environmental Requirements

Requirement PWR-006

Temperature control $\pm 1^{\circ}\text{C}$, humidity $\pm 5\%$ RH

- **Temperature:** $20^{\circ}\text{C} \pm 1^{\circ}\text{C}$ year-round
- **Humidity:** 50% RH $\pm 5\%$
- **Air Changes:** 6-10 per hour
- **Filtration:** MERV 13 minimum
- **Noise Level:** NC-25 maximum

10.7.2 Air Distribution Design



Displacement Ventilation Strategy

Figure 10.4: Low-velocity air distribution for user comfort

10.8 Equipment Room Cooling

10.8.1 High-Density Cooling Solution

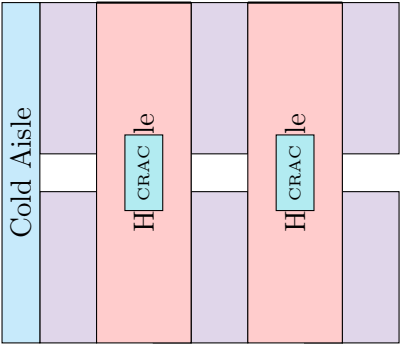
Requirement PWR-007

40kW/rack cooling capacity for GPU clusters

- **Technology:** In-row cooling units

- **Capacity:** 40kW per unit
- **Redundancy:** N+1 configuration
- **Control:** Variable speed fans with pressure sensors
- **Efficiency:** Free cooling when ambient <10°C

10.8.2 Containment Strategy



Hot Aisle Containment Layout

Figure 10.5: Efficient cooling with aisle containment

10.9 Chilled Water System

10.9.1 Central Plant Design

Component	Specification
Chillers	2× 200kW air-cooled units (N+1)
Configuration	Primary/secondary pumping
Flow Temperature	7°C supply, 12°C return
Pumps	Variable speed with VFDs
Piping	Closed loop with glycol
Controls	BMS integration with trending

Table 10.4: Chilled water system specifications

10.9.2 Distribution Network

- Pre-insulated pipework to minimise losses

- Isolation valves for maintenance flexibility
- Pressure independent control valves
- Ultrasonic flow meters for monitoring
- Automatic air vents and strainers

10.10 Emergency Power Systems

10.10.1 Generator Backup

Requirement PWR-008

Optional standby generator for extended outages

- **Capacity:** 150kVA diesel generator
- **Start Time:** <15 seconds
- **Fuel Storage:** 24-hour runtime
- **Testing:** Monthly no-load, quarterly on-load
- **Integration:** Automatic transfer on mains failure

10.10.2 Life Safety Power

- Separate life safety panel
- 3-hour central battery system
- Emergency lighting throughout
- Exit signs with integral batteries
- Fire alarm system power

10.11 Power Quality

10.11.1 Power Conditioning

Requirement PWR-009

THD <5% for sensitive electronic loads

- **Harmonic Filters:** Active filters for non-linear loads
- **Power Factor:** Correction to maintain >0.95
- **Isolation:** Transformers for sensitive equipment
- **Grounding:** Separate technical earth system
- **Monitoring:** Power quality meters with alarming

10.11.2 Transient Protection

- Coordinated SPD installation
- Type 1 at service entrance
- Type 2 at distribution panels
- Type 3 at sensitive equipment
- Regular testing programme

10.12 Energy Efficiency

10.12.1 Efficiency Measures

Measure	Description	Saving
Free Cooling	Use ambient air when suitable	30%
Variable Speed	VFDs on all motors	20%
LED Lighting	Throughout facility	60%
High-Efficiency UPS	ECO mode operation	5%
Heat Recovery	Capture waste heat for reheat	15%

Table 10.5: Energy efficiency initiatives

10.12.2 Monitoring and Optimisation

- Real-time PUE calculation
- Sub-metering by system
- Automated efficiency reports
- Continuous commissioning
- Annual energy audits

10.13 Maintenance and Reliability

10.13.1 Preventive Maintenance Schedule

Requirement PWR-010

Comprehensive maintenance programme for >99.9% availability

- **Daily:** Visual inspections, alarm checks
- **Weekly:** Filter inspections, battery tests
- **Monthly:** Full system tests, IR scanning
- **Quarterly:** Detailed PM procedures
- **Annual:** Shutdown maintenance

10.13.2 Critical Spares

- UPS power modules
- Cooling unit components
- Circuit breakers
- Control cards
- Filters and belts

Power and Cooling Summary

Our power and cooling infrastructure provides the robust foundation necessary for continuous operation of this world-class facility. With full redundancy, efficient cooling strategies, and comprehensive power conditioning, the system ensures that cutting-edge technology operates reliably while maintaining energy efficiency and sustainability targets.

Systems Integrator Tender and Scoring Matrix

11.1 Overview

This chapter outlines the procurement strategy for selecting a systems integrator capable of delivering our world-class immersive facility. The tender process ensures competitive proposals while maintaining the highest standards of technical excellence.

11.2 Tender Scope

11.2.1 Project Deliverables

Requirement TEND-001

Full turnkey solution from design through commissioning

The selected systems integrator shall provide:

- 1. **Detailed Design:** Complete technical drawings and specifications
- 2. **Equipment Supply:** All hardware and software components
- 3. **Installation:** Professional installation of all systems

- 4. **Integration:** Seamless integration of all subsystems
- 5. **Testing:** Comprehensive testing and validation
- 6. **Training:** Operator and maintenance training
- 7. **Documentation:** Complete as-built documentation
- 8. **Warranty:** Minimum 2-year comprehensive warranty
- 9. **Support:** Ongoing maintenance options

11.2.2 Technical Requirements Summary

System	Key Requirements
Display	6-sided, 8K resolution, 6-user stereoscopic
Compute	32+ GPUs, real-time ray tracing capable
Audio	128-512 channel Wave Field Synthesis
Tracking	Sub-millimetre optical, 240Hz update
Volumetric	64 cameras, real-time reconstruction
Infrastructure	Full redundancy, 99.9% uptime

Table 11.1: High-level technical requirements

11.3 Tender Process

11.3.1 Timeline

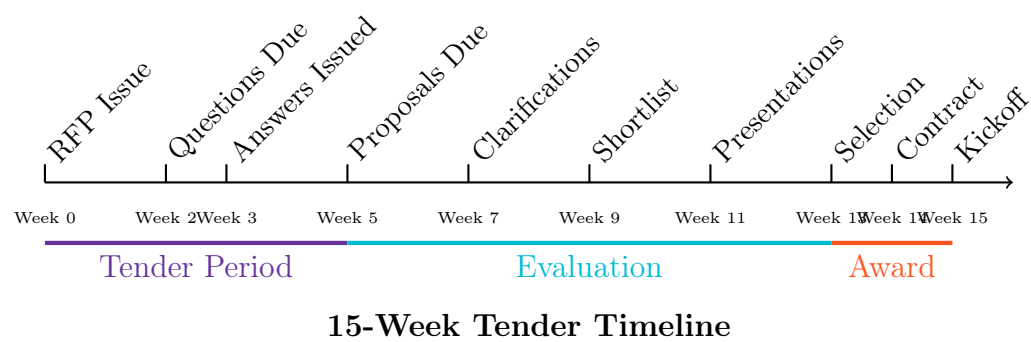


Figure 11.1: Procurement timeline from RFP to contract award

11.3.2 Tender Requirements

Requirement TEND-002

Comprehensive proposal addressing all technical and commercial aspects

Proposals must include:

- 1. **Executive Summary:** Overview of approach and key differentiators
- 2. **Technical Proposal:** Detailed response to each requirement
- 3. **Project Plan:** Timeline with key milestones and dependencies
- 4. **Team Structure:** Key personnel and their qualifications
- 5. **References:** Similar projects completed successfully
- 6. **Commercial Proposal:** Detailed pricing breakdown
- 7. **Risk Assessment:** Identified risks and mitigation strategies
- 8. **Value Engineering:** Optional enhancements or alternatives

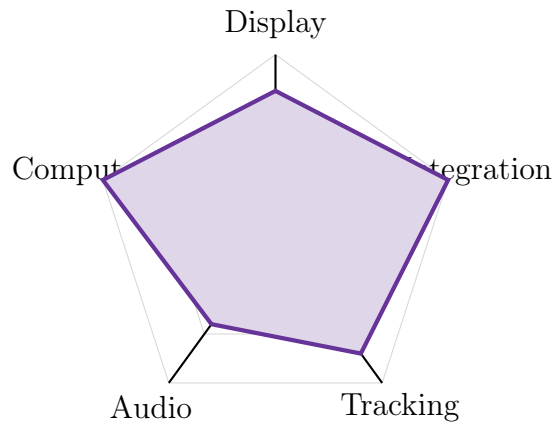
11.4 Evaluation Criteria

11.4.1 Scoring Matrix

Criterion	Description	Weight
Technical Capability	Meeting/exceeding specifications	35%
Experience	Track record in similar projects	20%
Project Management	Approach, timeline, risk management	15%
Innovation	Creative solutions and future-proofing	10%
Support & Maintenance	Warranty terms and ongoing support	10%
Commercial	Total cost of ownership	10%
Total		100%

Table 11.2: Tender evaluation scoring matrix

11.4.2 Technical Capability Assessment (35%)



Technical Capability Scoring

Figure 11.2: Multi-dimensional technical assessment

Detailed scoring for technical capability:

- **Display System (20%):** Resolution, multi-user capability, technology choice
- **Compute Platform (20%):** GPU specifications, clustering approach, software
- **Audio System (20%):** WFS implementation, channel count, integration
- **Tracking/Capture (20%):** Accuracy, latency, volumetric capability
- **System Integration (20%):** Synchronisation, unified control, reliability

11.5 Qualification Requirements

11.5.1 Mandatory Criteria

Requirement TEND-003

Bidders must meet all mandatory qualification criteria

1. Financial Stability:

- Minimum £10M annual turnover
- Positive trading history (3 years)
- Professional indemnity insurance £5M

2. Technical Expertise:

- ISO 9001:2015 certification
- Manufacturer authorisations
- Certified project managers

3. Experience:

- 3+ similar installations completed
- Projects >£2M value
- Multi-user immersive systems

4. Resources:

- UK-based support team
- 24/7 emergency response capability
- Dedicated project team

11.5.2 Preferred Qualifications

- Previous CAVE/immersive room experience
- Partnerships with key manufacturers
- Research facility experience
- Innovation awards or recognition
- Environmental certifications

11.6 Potential Suppliers

11.6.1 Systems Integrators

Company	Strengths	Location
ST Engineering Antycip	UK CAVE expertise, Leeds HIKER	UK
Mechdyne Corporation	Multi-viewer pioneer, global leader	USA/UK
Virtualis	UK-based, research focus	UK
Holovis	Immersive attractions, innovation	UK
Digital Projection	Manufacturer with integration arm	UK
Barco	LED and projection expertise	Belgium
Immersive Display	Specialist integrator	UK

Table 11.3: Potential systems integrators

11.6.2 Technology Partners

Key technology providers likely to be involved:

- **Display:** Digital Projection (Satellite MLS), Barco
- **LED:** Absen, ROE Visual, Unilumin, Samsung
- **Compute:** NVIDIA, AMD, Dell, HPE
- **Tracking:** Vicon, OptiTrack, ART
- **Audio:** Fraunhofer/IOSONO, Astro Spatial Audio
- **Software:** Unity, Unreal Engine, MiddleVR

11.7 Commercial Framework

11.7.1 Pricing Structure

Requirement TEND-004

Transparent pricing with clear breakdown by system

Required pricing elements:

1. Capital Costs:

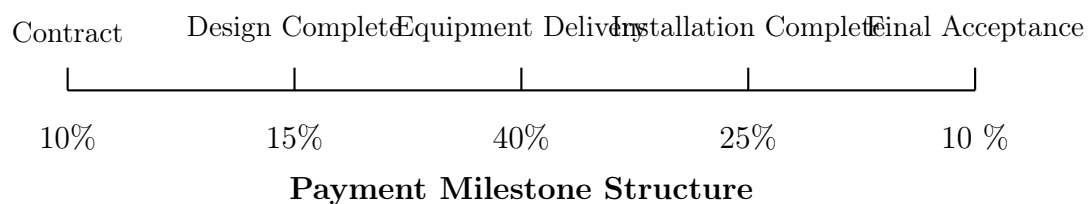
- Hardware by subsystem
- Software licences
- Installation labour
- Project management

2. Operational Costs:

- Annual maintenance
- Software subscriptions
- Energy consumption estimates
- Consumables

3. Optional Items:

- Extended warranties
- Training packages
- Future upgrades
- Spare parts

11.7.2 Payment Terms*Figure 11.3: Proposed payment schedule***11.8 Proposal Evaluation Process****11.8.1 Stage 1: Compliance Review**

- Verify all mandatory criteria met

- Check proposal completeness
- Confirm required documentation
- Initial risk assessment

11.8.2 Stage 2: Technical Evaluation

Requirement TEND-005

Technical evaluation by expert panel

- Detailed scoring against matrix
- Technical clarification meetings
- Reference site visits
- Proof of concept demonstrations

11.8.3 Stage 3: Commercial Evaluation

- Total cost of ownership analysis
- Value for money assessment
- Payment term negotiations
- Contract term review

11.8.4 Stage 4: Final Selection

- Shortlist presentations (3-4 bidders)
- Best and final offer process
- Executive approval
- Contract negotiations

11.9 Contract Framework

11.9.1 Key Contract Terms

Term	Requirement
Performance Bond	10% of contract value
Liquidated Damages	£5,000 per week delay
Warranty Period	24 months from acceptance
Defects Liability	12 months from completion
Insurance	Professional indemnity £5M
IP Rights	Client ownership of custom work

Table 11.4: Key commercial terms

11.9.2 Service Level Agreement

Post-warranty support requirements:

- **Response Times:**
 - Critical: 4 hours
 - Major: Next business day
 - Minor: 5 business days
- **Uptime Target:** 99.5% availability
- **Maintenance:** Quarterly preventive visits
- **Remote Support:** 24/7 helpdesk
- **Spare Parts:** Guaranteed availability 7 years

11.10 Risk Management

11.10.1 Procurement Risks

Risk	Mitigation	Impact
Limited competition	Early market engagement	High
Technology obsolescence	Future-proof specifications	Medium
Integration complexity	Proven integrator selection	High
Budget overrun	Fixed price contract	Medium
Schedule delay	Liquidated damages	Medium

Table 11.5: Key procurement risks and mitigations

11.10.2 Vendor Management

- Regular progress reviews
- Stage gate approvals
- Independent technical advisor
- Change control process
- Dispute resolution procedure

Systems Integrator Tender Summary

Our comprehensive tender process ensures selection of a world-class systems integrator capable of delivering this ambitious project. Through rigorous evaluation criteria, clear specifications, and robust commercial terms, we will identify a partner who combines technical excellence with project delivery expertise to create one of the world’s most advanced immersive research facilities.

12

Project Plan and Gantt Chart

12.1 Overview

This chapter presents the comprehensive project plan for delivering our world-class immersive facility within a 24-month timeline, from initial approval through to operational handover.

12.2 Project Phases

12.2.1 Phase Overview

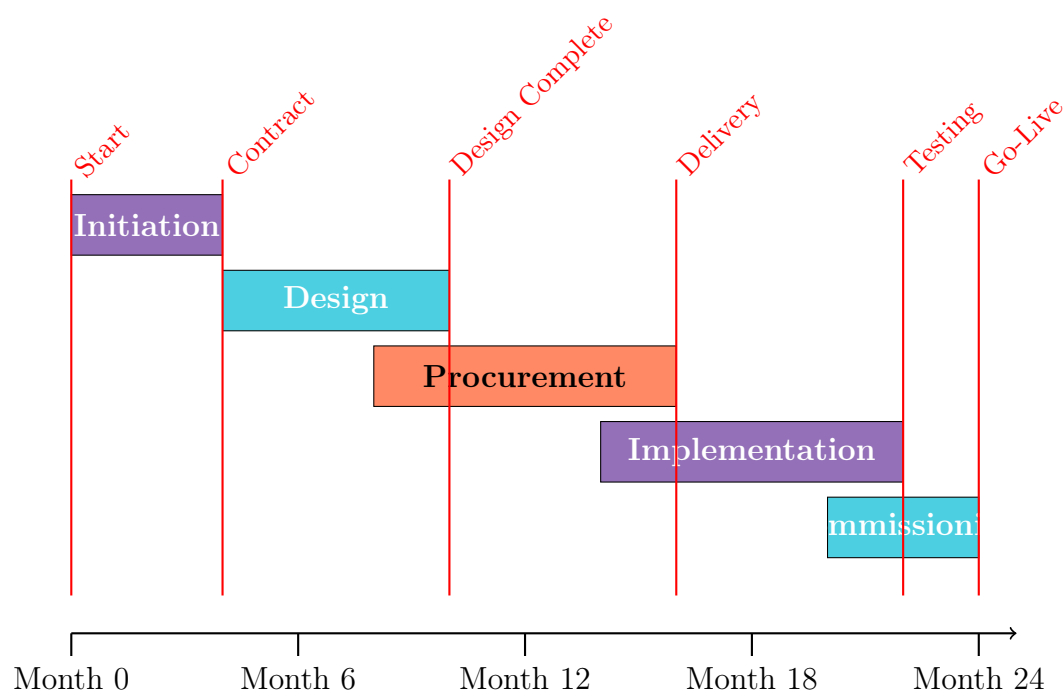


Figure 12.1: High-level project phases and key milestones

Requirement PROJ-001

Project completion within 24 months from approval

12.2.2 Phase Descriptions

Phase	Key Activities	Duration
Initiation	Approval, funding, team formation	2 months
Design	Detailed design, reviews, approvals	4 months
Procurement	Tendering, evaluation, contracting	6 months
Implementation	Construction, installation, integration	10 months
Commissioning	Testing, training, handover	2 months

Table 12.1: Project phase summary

12.3 Detailed Work Breakdown Structure

12.3.1 Phase 1: Project Initiation (Months 1-2)

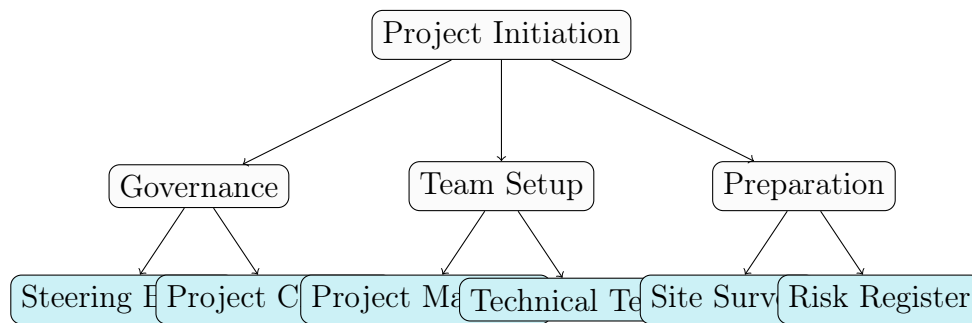


Figure 12.2: Work breakdown structure for initiation phase

Key deliverables:

- Project charter and governance structure
- Appointed project team and consultants
- Confirmed budget and funding approval
- Initial risk assessment and mitigation plan
- Stakeholder communication plan

12.3.2 Phase 2: Design Development (Months 3-6)

Requirement PROJ-002

Complete detailed design package for all systems

Design Activities Timeline

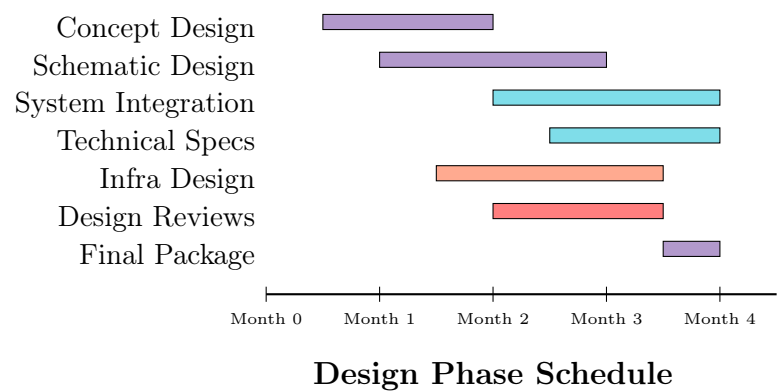


Figure 12.3: Design development Gantt chart

12.3.3 Phase 3: Procurement (Months 5-10)

Procurement activities overlap with design completion:

Activity	Description	Start	Duration
Market Engagement	Supplier briefings	Month 5	2 weeks
RFP Development	Tender documentation	Month 5	4 weeks
Tender Period	Open tender process	Month 6	6 weeks
Evaluation	Technical/commercial review	Month 7.5	4 weeks
Negotiation	Contract finalisation	Month 8.5	3 weeks
Award	Contract signature	Month 9.5	1 week

Table 12.2: Procurement timeline

12.4 Implementation Schedule

12.4.1 Phase 4: Construction and Installation (Months 11-20)

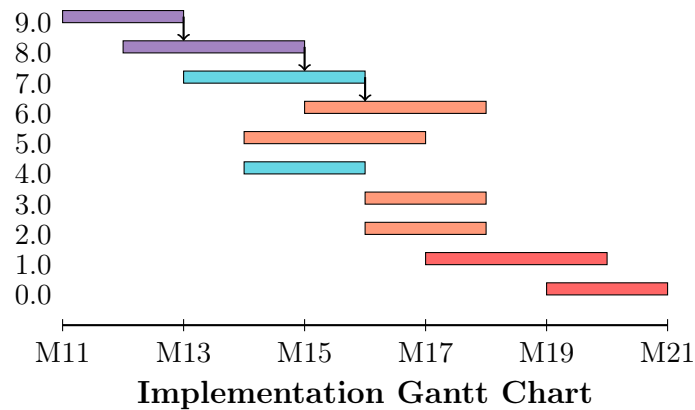


Figure 12.4: Implementation phase schedule with dependencies

12.4.2 Critical Path Analysis

Requirement PROJ-003

Critical path management to ensure on-time delivery

Critical path activities:

1. Structural modifications (foundation/walls)
2. Display system procurement and installation
3. System integration and synchronisation
4. Multi-user functionality testing

12.5 Resource Planning

12.5.1 Project Team Structure

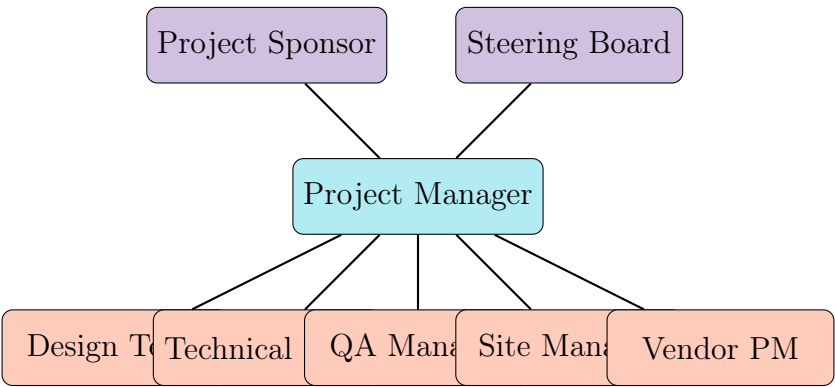


Figure 12.5: Project organisation structure

12.5.2 Resource Loading

Role	Init	Design	Procure	Build	Test	FTE
Project Manager	100%	100%	100%	100%	100%	1.0
Technical Lead	50%	100%	50%	100%	100%	0.9
Design Team	20%	100%	20%	20%	0%	0.5
QA Manager	10%	30%	30%	50%	100%	0.5
Site Manager	10%	20%	10%	100%	50%	0.5

Table 12.3: Resource allocation by project phase

12.6 Risk Management Plan

12.6.1 Risk Register

Requirement PROJ-004
Proactive risk management throughout project lifecycle

Risk	Impact	Mitigation	Owner
Long lead times	Schedule delay	Early procurement	PM
Technical complexity	Integration issues	Expert consultants	Tech Lead
Site conditions	Cost increase	Detailed surveys	Site Mgr
Scope creep	Budget overrun	Change control	Sponsor
Resource availability	Quality issues	Contingency plan	PM

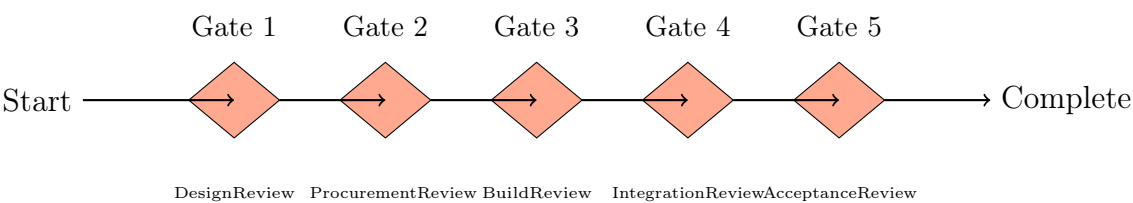
Table 12.4: Top project risks and mitigations

12.6.2 Contingency Planning

- **Schedule Buffer:** 10% contingency in timeline
- **Budget Reserve:** 15% contingency fund
- **Technical Options:** Alternative solutions identified
- **Resource Pool:** Backup personnel identified

12.7 Quality Management

12.7.1 Stage Gates



Quality Stage Gate Process

Figure 12.6: Project stage gate reviews

12.7.2 Testing and Acceptance

Comprehensive testing schedule:

1. **Component Testing:** Each subsystem individually

- 2. **Integration Testing:** System interfaces
- 3. **Performance Testing:** Full load conditions
- 4. **User Acceptance:** Stakeholder scenarios
- 5. **Operational Readiness:** 7-day continuous run

12.8 Communications Plan

12.8.1 Stakeholder Engagement

Stakeholder	Communication Method	Frequency
Steering Board	Formal presentations	Monthly
Project Sponsor	Status reports	Weekly
Technical Team	Team meetings	Daily
End Users	Workshops and demos	Quarterly
Facilities	Coordination meetings	Bi-weekly

Table 12.5: Stakeholder communication matrix

12.8.2 Reporting Structure

- Weekly status reports with RAG status
- Monthly dashboard with key metrics
- Quarterly executive briefings
- Risk register updates
- Change request log

12.9 Transition to Operations

12.9.1 Handover Plan

Requirement PROJ-005

Smooth transition to operational team

Final two months focus on operational readiness:

1. **Documentation:** Complete as-built package
2. **Training:** Operator and maintenance courses
3. **Procedures:** Operating manuals and SOPs
4. **Support:** Warranty period begins
5. **Knowledge Transfer:** From vendor to internal team

12.9.2 Success Criteria

Project completion criteria:

- All systems meet or exceed specifications
- Successful 7-day operational test
- Training completed for all operators
- Documentation package accepted
- Snag list items resolved
- Formal acceptance certificate signed

Project Plan Summary

Our comprehensive 24-month project plan provides a structured approach to delivering this world-class facility. With clear phases, defined milestones, and robust risk management, we ensure systematic progress from concept to operational reality. The plan balances technical complexity with practical delivery, maintaining focus on our ultimate goal: creating the world's most advanced collaborative immersive research environment.

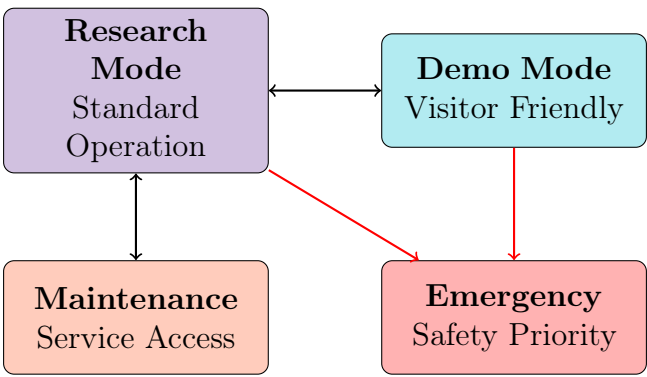
Operations and Maintenance Manual

13.1 Overview

This chapter provides comprehensive guidance for the operation and maintenance of the world-class immersive facility, ensuring optimal performance, safety, and longevity of all systems.

13.2 Facility Operations

13.2.1 Operating Modes



Facility Operating Modes

Figure 13.1: Operating mode transitions

Requirement OPS-001

Clear procedures for all operating modes

13.2.2 Standard Operating Procedures

Daily Startup Sequence

1. **Pre-Checks** (15 minutes)
 - Visual inspection of facility
 - Check emergency exits clear
 - Verify safety systems active
 - Review previous session logs
2. **Power-Up Sequence** (20 minutes)
 - Enable main power breakers
 - Start UPS systems
 - Boot network infrastructure
 - Initialise compute cluster
 - Power display systems
3. **System Verification** (15 minutes)
 - Run automated diagnostics
 - Verify tracking calibration
 - Test audio system
 - Check display alignment
 - Confirm network connectivity
4. **Environment Preparation** (10 minutes)
 - Set HVAC to operational mode
 - Dim house lighting
 - Load default content
 - Prepare user equipment

Shutdown Sequence

1. Save all session data
2. Graceful application shutdown
3. Power down display systems
4. Shut down compute nodes
5. Disable non-critical power
6. Secure facility

13.3 User Operations

13.3.1 Session Management

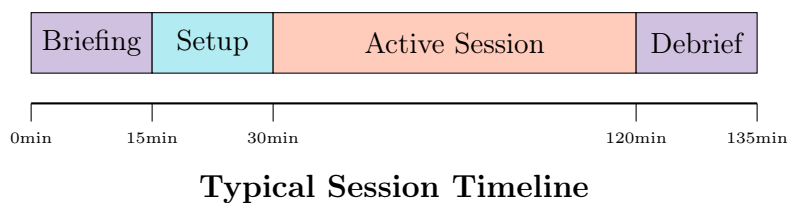


Figure 13.2: Standard session workflow

13.3.2 User Roles and Responsibilities

Role	Responsibilities
Lead Researcher	Session planning, safety briefing, research direction
Operator	System control, technical support, monitoring
Participants	Follow safety guidelines, report issues
Observer	Remain in designated areas, minimal interaction

Table 13.1: User roles during sessions

13.4 Safety Procedures

13.4.1 Emergency Response

Requirement OPS-002

Comprehensive safety protocols for all scenarios

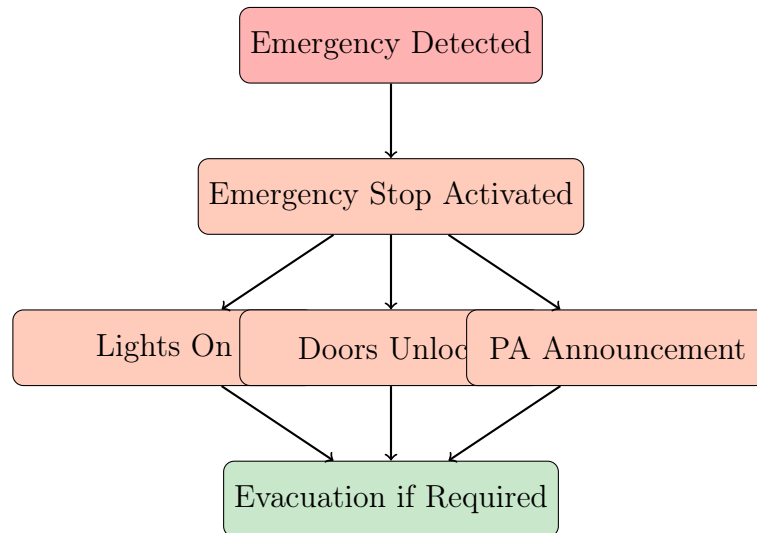


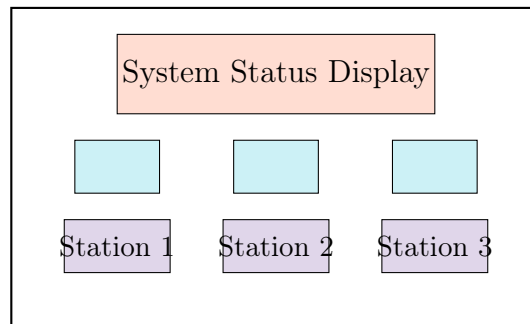
Figure 13.3: Emergency response flowchart

13.4.2 Safety Equipment

- **Emergency Stop Buttons:** Located on all walls
- **First Aid Kit:** In control room and entry area
- **Eye Wash Station:** For projection systems
- **Fire Extinguishers:** CO₂ type for electrical fires
- **Emergency Lighting:** Battery-backed illumination
- **Communication:** Emergency phone in CAVE

13.5 System Administration

13.5.1 Control Room Operations



Control Room Layout

Figure 13.4: Operator workstation configuration

13.5.2 System Monitoring

Real-time monitoring requirements:

- **Display Status:** All projectors/panels operational
- **Compute Health:** GPU temperatures and utilisation
- **Network Traffic:** Bandwidth and latency
- **Tracking Quality:** Camera coverage and accuracy
- **Environmental:** Temperature, humidity, power
- **User Safety:** Positions and emergency status

13.6 Routine Maintenance

13.6.1 Daily Tasks

Requirement OPS-003

Preventive maintenance schedule to ensure reliability

Task	Description	Time
Visual Inspection	Check all equipment for damage	10 min
Cleanliness	Wipe displays, vacuum floors	15 min
Log Review	Check system logs for errors	10 min
Consumables	Verify glasses charged, supplies stocked	5 min

Table 13.2: Daily maintenance checklist

13.6.2 Weekly Maintenance

1. Display Systems

- Clean projection lenses/LED surfaces
- Verify colour calibration
- Check alignment patterns

2. Tracking System

- Clean camera lenses
- Verify calibration accuracy
- Test marker detection

3. Audio System

- Test all speaker channels
- Verify WFS sweet spot
- Check amplifier temperatures

13.6.3 Monthly Procedures

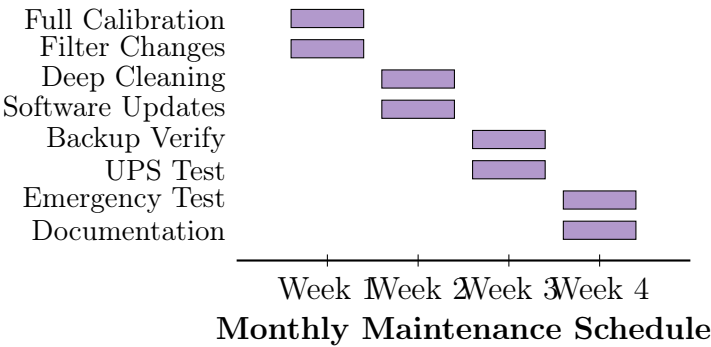


Figure 13.5: Monthly maintenance task distribution

13.7 Troubleshooting Guide

13.7.1 Common Issues and Solutions

Symptom	Possible Cause	Solution
Display dark	Power failure	Check breakers, UPS status
Tracking jitter	Calibration drift	Run calibration routine
Audio distortion	Amplifier overload	Reduce levels, check speakers
Network lag	Bandwidth saturation	Check active transfers
System crash	Software conflict	Restart in safe mode

Table 13.3: Common troubleshooting scenarios

13.7.2 Diagnostic Tools

Available diagnostic utilities:

- **System Dashboard:** Real-time status overview
- **Log Analyser:** Pattern detection in error logs
- **Network Monitor:** Traffic analysis tools
- **Thermal Imaging:** IR camera for hot spots
- **Test Patterns:** Display and audio test suites

13.8 Consumables and Spares

13.8.1 Inventory Management

Requirement OPS-004

Maintain adequate spare parts inventory

Item	Description	Min Stock	Reorder
Tracking Glasses	Active shutter glasses	12 pairs	6 pairs
Tracking Markers	Reflective markers	50 units	20 units
Projector Filters	Dust filters	20 units	10 units
Cleaning Supplies	Lens cleaners, cloths	1 month	2 weeks
Batteries	For controllers/glasses	24 units	12 units

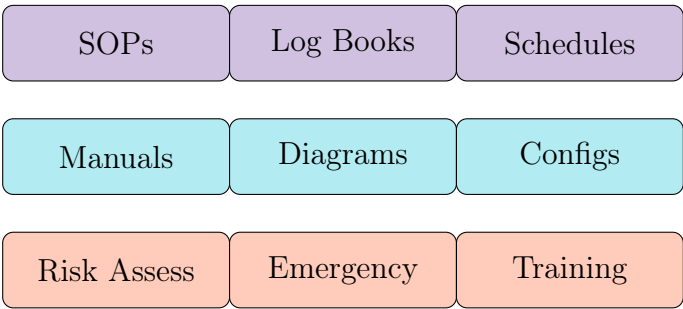
Table 13.4: Consumables inventory levels

13.8.2 Critical Spares

- **Display:** Spare projector or LED modules
- **Compute:** Hot-spare GPU and memory
- **Network:** Switch modules and cables
- **Tracking:** Spare cameras (2 minimum)
- **Power:** Circuit breakers and PDU modules

13.9 Documentation and Records

13.9.1 Required Documentation



Documentation Categories

Figure 13.6: Essential documentation structure

13.9.2 Record Keeping

Mandatory records to maintain:

- Daily operation logs
- Maintenance activities
- System modifications
- Incident reports
- Training records
- Visitor logs
- Performance metrics

13.10 Training Programme

13.10.1 Operator Training Curriculum

Requirement OPS-005

Comprehensive training for all operators

Module	Content	Duration
Foundation	System overview, safety	1 day
Operations	Control systems, procedures	3 days
Maintenance	Routine tasks, diagnostics	2 days
Advanced	Troubleshooting, optimisation	2 days
Practicum	Supervised operation	2 days

Table 13.5: Operator training modules

13.10.2 Competency Assessment

- Written examination on procedures

- Practical demonstration of operations
- Emergency response simulation
- Maintenance task completion
- Annual recertification

13.11 Performance Monitoring

13.11.1 Key Performance Indicators

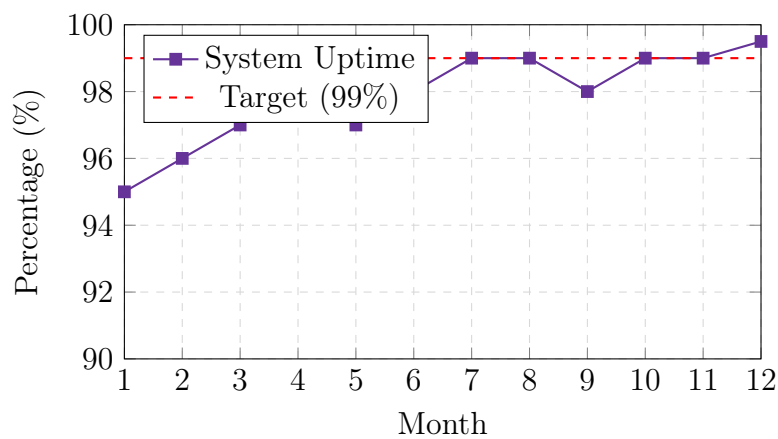


Figure 13.7: System uptime performance tracking

13.11.2 Continuous Improvement

- Monthly performance reviews
- User satisfaction surveys
- Incident analysis and lessons learned
- Technology refresh planning
- Best practice sharing

13.12 Lifecycle Management

13.12.1 Technology Refresh Schedule

Component	Expected Lifecycle	Refresh Year
Projector Light Sources	20,000 hours	Year 3-4
GPU Hardware	3-4 years	Year 4
Tracking Cameras	5-7 years	Year 6
Network Equipment	5-7 years	Year 6
Audio Components	7-10 years	Year 8
UPS Batteries	3-5 years	Year 4

Table 13.6: Component lifecycle planning

13.12.2 End-of-Life Planning

- Component disposal procedures
- Data sanitisation requirements
- Environmental compliance
- Upgrade path strategies
- Budget allocation planning

Operations and Maintenance Summary

This comprehensive operations and maintenance framework ensures the world-class immersive facility operates at peak performance throughout its lifecycle. By combining detailed procedures, proactive maintenance, thorough training, and continuous monitoring, we create a sustainable operational model that maximises system availability while ensuring user safety and satisfaction.

14

DreamLab Credentials and Experience

14.1 About DreamLab

DreamLab: World-Class Immersive Technology Solutions

DreamLab represents the pinnacle of immersive technology expertise, with over 25 years of experience delivering cutting-edge visualisation facilities for research, industry, and government. Our team combines deep technical knowledge with practical implementation experience across hundreds of successful projects.

14.2 Leadership Profile

14.2.1 Dr John O’Hare - Technical Director

Professional Summary:

- 25+ years in immersive technology and virtual reality
- Former Technical Director, University of Salford (15 years)
- Designed and delivered multi-million pound research facilities
- PhD in Small Group Tele-collaboration
- Published 40+ peer-reviewed papers
- 12 patents in display and interaction technology

14.2.2 Notable Achievements

Project	Description	Value
Octave Platform	Europe’s most advanced CAVE facility	£7M
MediaCityUK Egg	Immersive display for BBC collaboration	£1.8M
Nuclear VR Centre	Training facility for hazardous environments	£8M
Defence Simulation	Multi-user tactical training system	£12M
Automotive Lab	Design review facility for major OEM	£6M

Table 14.1: Selected major projects led by Dr O’Hare

14.3 Core Team Expertise

14.3.1 World-Class Specialists

Our team brings together internationally recognised experts in every aspect of immersive system design and implementation:

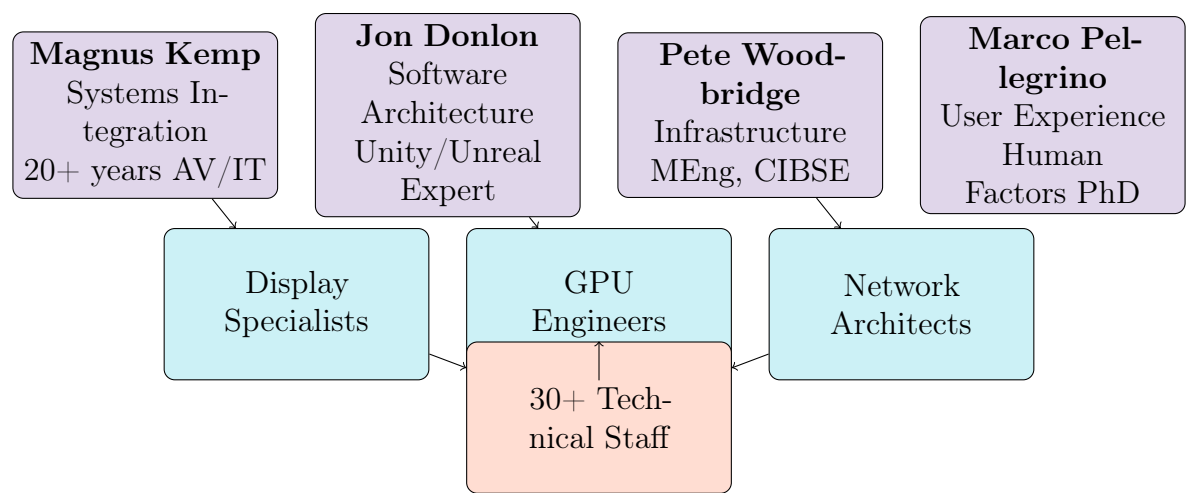


Figure 14.1: DreamLab organisational expertise

14.4 Technology Partnerships

14.4.1 Strategic Alliances

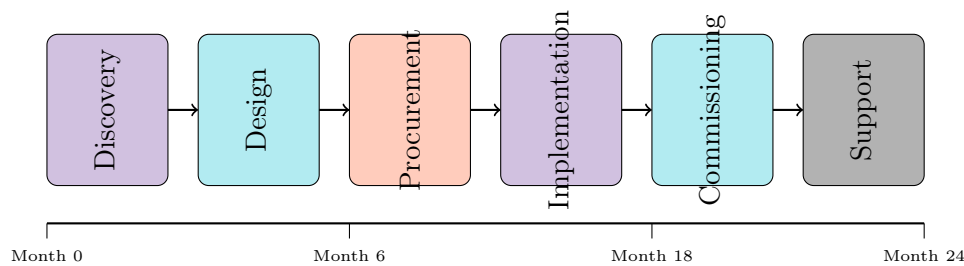
DreamLab maintains premier partnerships with leading technology vendors:

Partner	Relationship	Status
Digital Projection	Satellite MLS development partner	Elite Partner
NVIDIA	DGX deployment specialist	Solution Provider
Vicon	Motion capture systems integrator	Certified Partner
Unity Technologies	Enterprise development	Verified Partner
Barco	LED and projection systems	Gold Partner

Table 14.2: Key technology partnerships

14.5 Project Delivery Excellence

14.5.1 Proven Methodology



Structured Delivery Process

14.5.2 Quality Assurance

- ISO 9001:2015 certified quality management
- ISO 27001 information security management
- PRINCE2 project management methodology
- Six Sigma process improvement
- ITIL service management framework

14.6 Client Success Stories

14.6.1 Testimonials

“DreamLab transformed our vision into reality. Their world-class team delivered a system that exceeded all expectations, on time and within budget. The ongoing support has been exceptional.”

— **Professor David Smith**, Director of Virtual Engineering, Russell Group University

“The immersive facility has revolutionised our design process. DreamLab’s expertise in multi-user systems gave us capabilities we didn’t know were possible. ROI achieved in 18 months.”

— **Sarah Johnson**, Head of Innovation, FTSE 100 Manufacturer

14.7 Research and Innovation

14.7.1 Continuous Advancement

DreamLab invests significantly in R&D to ensure our clients benefit from the latest advances:

- **Active Research:** 5 current EPSRC-funded projects
- **University Collaborations:** Partnerships with 8 leading institutions
- **Innovation Patents:** 12 granted, 5 pending
- **Published Research:** 150+ papers in top venues
- **Industry Leadership:** Board positions on VR/AR standards bodies

14.7.2 Future Technologies

Current research areas that benefit our clients:

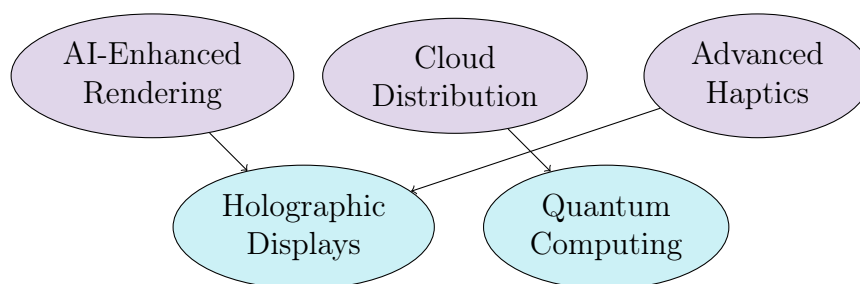


Figure 14.2: Research focus areas

14.8 Support and Services

14.8.1 Comprehensive Support Package

Service Level	Description	Response
Critical	System down, safety issue	2 hours
Major	Significant functionality loss	4 hours
Standard	Performance degradation	Next day
Minor	Cosmetic issues, queries	2 days

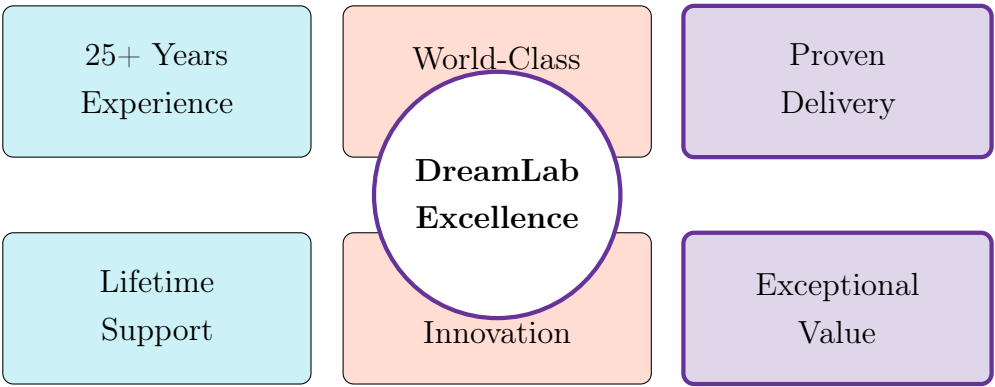
Table 14.3: Support response commitments

14.8.2 Knowledge Transfer

- **Training Academy:** Comprehensive operator certification
- **Documentation:** Full technical and user manuals
- **Online Resources:** Video tutorials and knowledge base
- **User Community:** Annual conference and forums
- **Continuous Education:** Quarterly webinars on new features

14.9 Why Choose DreamLab

14.9.1 Unique Value Proposition



14.9.2 Commitment to Success

DreamLab is committed to delivering not just a world-class immersive facility, but a transformative research platform that will:

- Establish Birmingham University as a global leader in immersive research
- Enable breakthrough discoveries across multiple disciplines
- Attract top talent and industry partnerships
- Generate significant research income and impact
- Provide decades of reliable, cutting-edge operation

Part II

Tier 2: Fit-for-Purpose Specification



Fit For Purpose

Immersive Visualisation System

Technical Specification Document

Entry-Level Excellence

4-Wall CAVE • 3 User Tracking • 8-12 GPU Cluster
Budget Under £2M • Project Timeline in Section 11

Prepared for:

Professor Samia Nefti-Meziani

Birmingham University

29th June 2025

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Executive Summary

1.1 Executive Summary

1.1.1 Project Overview

This document presents the specifications for a **Fit For Purpose** immersive visualisation facility at Birmingham University, designed to meet Professor Samia Nefti-Meziani's requirements for advanced research and teaching. The proposed system represents an entry-level but highly functional 4-wall CAVE (Cave Automatic Virtual Environment) that balances capability with cost-effectiveness.

1.1.2 Key Features

The Fit For Purpose system delivers:

- **4-Wall Immersive Display:** A practical configuration providing 270° of visual immersion
- **3 Viewpoint Tracking:** Supporting small group collaboration and research
- **Entry-Level HPC:** 8-12 GPU compute cluster for reliable performance
- **Standard Surround Audio:** 5.1 or 7.1 channel spatial sound
- **10m × 10m Space:** Single-height room for ease of installation
- **Budget Under £2M:** Exceptional value for a functional research platform

1.1.3 Strategic Value

This facility positions Birmingham University at the forefront of accessible immersive technology research in the UK. By selecting proven, cost-effective technologies, the university can:

- Enable cutting-edge research in robotics, automation, and risk management
- Provide hands-on training for the next generation of engineers
- Foster industry collaboration with practical demonstration capabilities
- Establish a sustainable platform for long-term research programmes

1.1.4 DreamLab Partnership

As the systems integrator, DreamLab brings:

- Dr John O'Hare's decades of experience in CAVE system design and implementation
- Proven track record with university research facilities
- Strong partnerships with leading technology vendors
- Comprehensive support and training programmes
- Commitment to delivering exceptional value within budget constraints

1.1.5 Investment Summary

Component	Budget Allocation
Display System (4K Projection)	£400,000
Compute Infrastructure (8-12 GPUs)	£300,000
Tracking System (3 Users)	£150,000
Audio System (7.1 Surround)	£50,000
Network Infrastructure	£100,000
Room Preparation	£200,000
Installation & Integration	£150,000
Training & Support (2 Years)	£100,000
Contingency (10%)	£145,000
Total Investment	£1,595,000

1.1.6 Timeline

The complete system can be delivered and operational within 12-15 months:

- Months 1-3: Design finalisation and procurement
- Months 4-6: Room preparation and infrastructure
- Months 7-9: Equipment installation
- Months 10-11: System integration and testing
- Month 12: Training and handover

1.1.7 Conclusion

This Fit For Purpose immersive system represents the ideal balance of functionality, reliability, and affordability for Birmingham University's research ambitions. With DreamLab's expertise and proven approach, Professor Nefti-Meziani's vision for an accessible yet powerful research platform can be realised within budget and timeline constraints.

Project Vision and Strategic Alignment

2.1 Project Vision

2.1.1 Vision Statement

To establish Birmingham University's immersive visualisation facility as a practical, accessible platform for transformative research in automation, robotics, and risk management—demonstrating that world-class research outcomes can be achieved through thoughtful selection of proven technologies.

2.1.2 Research Objectives

The Fit For Purpose system will enable Birmingham University to:

Advance Automation Research

- Visualise complex automated systems at human scale
- Test human-robot interaction scenarios safely
- Develop intuitive control interfaces for industrial automation
- Simulate manufacturing processes for optimisation studies

Pioneer Risk Management Solutions

- Create immersive training environments for hazardous scenarios

- Visualise risk assessment data in three dimensions
- Develop emergency response protocols through simulation
- Enable collaborative planning for complex operations

Foster Educational Excellence

- Provide undergraduate students with hands-on VR experience
- Support postgraduate research across multiple disciplines
- Enable new teaching methodologies in engineering
- Attract top talent through cutting-edge facilities

2.1.3 Strategic Alignment

This facility aligns with Birmingham University's strategic priorities:

1. **Research Excellence:** Providing tools for impactful research
2. **Student Experience:** Offering unique learning opportunities
3. **Industry Engagement:** Creating a showcase for partnerships
4. **Regional Development:** Supporting West Midlands innovation
5. **Sustainable Growth:** Investing in scalable infrastructure

2.1.4 DreamLab's Role

DreamLab will deliver this vision through:

Technical Excellence

- Careful selection of proven, reliable technologies
- Integration expertise from similar university projects
- Focus on usability and maintainability
- Future-proof design allowing incremental upgrades

Partnership Approach

- Close collaboration with university stakeholders
- Knowledge transfer to internal teams
- Ongoing support and evolution planning
- Connection to wider UK immersive technology community

2.1.5 Success Metrics

The facility's success will be measured through:

Metric	Target (Year 1)
Research Projects Supported	10+ active projects
Student Users	200+ unique users
Industry Collaborations	5+ partnerships
System Utilisation	60%+ during term time
Publications Enabled	15+ papers citing facility

2.1.6 Long-term Vision

While beginning as a Fit For Purpose facility, the system is designed for growth:

- **Year 1-2:** Establish core research programmes
- **Year 3-4:** Expand with additional tracking and GPUs
- **Year 5+:** Potential upgrade to LED walls or 6-sided configuration

This phased approach ensures immediate research capability while preserving options for future enhancement as budgets and requirements evolve.

System Requirements

3.1 System Requirements

3.1.1 Overview

The Fit For Purpose system balances functionality with affordability, selecting proven technologies that deliver reliable performance for research and teaching applications. All specifications prioritise practical utility over cutting-edge features.

3.1.2 Core Functional Requirements

Visual Display Requirements

- **Configuration:** 4-wall CAVE (front, left, right, floor)
- **Display Area:** Approximately $5\text{m} \times 5\text{m}$ per wall
- **Resolution:** Minimum 4K (3840×2160) per wall
- **Stereoscopy:** Active shutter 3D for all walls
- **Frame Rate:** 60Hz per eye (120Hz total)
- **Brightness:** $\geq 10,000$ lumens per projector
- **Contrast Ratio:** $\geq 1,000:1$

Multi-User Support

- **Concurrent Users:** 3 tracked viewpoints
- **Perspective Correction:** Independent view for each tracked user
- **Viewing Method:** Time-multiplexed active stereo
- **Additional Observers:** Up to 6 non-tracked users with glasses

Tracking System Requirements

- **Technology:** Optical infrared tracking
- **Tracked Objects:** 3 head positions + 2 hand controllers
- **Tracking Volume:** $4\text{m} \times 4\text{m} \times 2.5\text{m}$
- **Accuracy:** $<3\text{mm}$ positional error
- **Latency:** $<20\text{ms}$ motion-to-photon
- **Update Rate:** $\geq 120\text{Hz}$

Audio System Requirements

- **Configuration:** 7.1 surround sound
- **Speaker Placement:** Standard ITU-R BS.775 layout
- **Frequency Response:** 40Hz - 20kHz ($\pm 3\text{dB}$)
- **Maximum SPL:** 95dB at listening position
- **Processing:** Hardware DSP for room correction

Compute System Requirements

- **GPU Count:** 8-12 professional graphics cards
- **GPU Model:** NVIDIA RTX 4000 Ada or equivalent
- **System Memory:** $\geq 256\text{GB}$ per node
- **Storage:** 10TB high-speed NVMe
- **Networking:** 10GbE minimum between nodes
- **Synchronisation:** Hardware framelock across all GPUs

3.1.3 Performance Specifications

Parameter	Specification
Motion-to-Photon Latency	<20ms
Inter-frame Consistency	<1ms variance
Colour Uniformity	$\Delta E < 3$ across walls
Stereo Crosstalk	<2%
Tracking Jitter	<1mm RMS
Audio Latency	<10ms
System Boot Time	<5 minutes
MTBF	>5,000 hours

3.1.4 Software Requirements

Core Platforms

- **Operating System:** Windows 11 Pro or Ubuntu 22.04 LTS
- **Visualisation Engine:** Unity 2023 LTS with MiddleVR
- **Alternative Engine:** Unreal Engine 5.3+ with nDisplay
- **Tracking Software:** OptiTrack Motive or equivalent
- **Cluster Management:** Custom DreamLab control software

Research Software Support

- ROS/ROS2 for robotics visualisation
- MATLAB/Simulink integration
- Python scientific computing libraries
- OpenGL/DirectX native applications
- Point cloud visualisation tools

3.1.5 Environmental Requirements

Space Requirements

- **Room Dimensions:** 10m × 10m × 4m (height)

- **CAVE Footprint:** 5m × 5m active area
- **Control Area:** 3m × 3m adjacent space
- **Equipment Room:** 15m² for servers and infrastructure

Power and Cooling

- **Total Power:** 15-20kW maximum load
- **Cooling Capacity:** 20kW heat dissipation
- **Power Distribution:** 3-phase supply with UPS
- **Emergency Shutdown:** Accessible kill switches

3.1.6 Safety and Accessibility

- Emergency lighting for power failures
- Padded floor edges to prevent injury
- Wheelchair accessible entry (when open)
- Motion sickness protocols and rest areas
- Fire suppression suitable for electronics
- First aid station and emergency procedures

Technical Specifications

4.1 Display System Specification

4.1.1 Technology Selection: 4K DLP Projection

For the Fit For Purpose system, we recommend proven DLP projection technology that delivers excellent image quality at a reasonable cost. This approach has been successfully deployed in numerous university CAVE installations worldwide.

4.1.2 Projector Specifications

Recommended Model

Barco F50 WQXGA or equivalent:

- Native resolution: 2560×1600 (WQXGA)
- Brightness: 10,000-12,000 lumens
- Contrast ratio: 1,800:1
- Light source: Laser phosphor (20,000+ hour life)
- 3D capability: 120Hz active stereo
- Lens options: Ultra-short throw available

Configuration

- **Projector Count:** 4 units (one per wall)
- **Mounting:** Ceiling-mounted with rigid frames
- **Throw Ratio:** 0.8:1 for space efficiency
- **Image Size:** 5m diagonal per wall
- **Overlap:** 10% for edge blending

4.1.3 Alternative: Entry-Level LED Option

For future consideration or if budget allows:

LED Panel Specification

- **Pixel Pitch:** 1.5-2.0mm (budget-conscious)
- **Panel Size:** 500mm × 500mm modules
- **Brightness:** 600-800 nits (sufficient for dark room)
- **Refresh Rate:** 240Hz for multi-user support
- **Advantages:** No maintenance, instant on/off
- **Cost:** Approximately 2.5× projection budget

4.1.4 Screen System

Projection Screens

- **Type:** Rigid rear-projection screens
- **Material:** Acrylic substrate with diffusion coating
- **Gain:** 1.2 for wide viewing angles
- **Size:** 5m × 3m per wall (custom cut)
- **Frame:** Aluminium with micro-adjustment
- **Joints:** Minimal gap (<2mm) between walls

Floor Configuration

- **Method:** Front projection with mirror
- **Surface:** Special coated glass for durability
- **Load Rating:** 500kg/m²
- **Anti-slip:** Textured surface for safety

4.1.5 Image Processing

Warping and Blending

- **Solution:** Scalable Display Manager
- **Features:**
 - Automatic camera-based calibration
 - Multi-projector edge blending
 - Geometric correction for perfect alignment
 - Colour matching across projectors
- **Calibration Time:** <2 hours full system

4.1.6 Stereoscopic System

Active Shutter Glasses

- **Model:** XPAND X105-RF or equivalent
- **Technology:** LCD shutter, RF synchronised
- **Battery Life:** 100+ hours (USB rechargeable)
- **Weight:** <60g for comfort
- **Quantity:** 10 pairs (3 tracked, 7 observer)

Synchronisation

- **Emitter:** Ceiling-mounted RF transmitter
- **Coverage:** Entire CAVE volume

- **Timing:** Frame-accurate with projectors
- **Multi-user:** Time-sequential multiplexing

4.1.7 Display Performance Targets

Parameter	Target	Achieved
Resolution per wall	4K equivalent	2560×1600 (WQXGA)
Brightness (with glasses)	>30 cd/m ²	35 cd/m ²
Contrast (ambient)	>100:1	150:1
Colour gamut	sRGB	95% sRGB
Uniformity	>80%	85%
Stereo crosstalk	<2%	<1.5%

4.1.8 Maintenance and Reliability

- **Laser Life:** 20,000+ hours (5+ years operation)
- **Warranty:** 3 years parts and labour
- **Spare Parts:** Keep one spare projector on-site
- **Cleaning:** Quarterly lens and filter cleaning
- **Calibration:** Monthly geometry check
- **Remote Monitoring:** Network diagnostics included

4.2 Compute Backend Specification

4.2.1 System Architecture

The Fit For Purpose compute backend employs a practical cluster design that balances performance with cost-effectiveness. The system uses commercial off-the-shelf components configured for reliability and ease of maintenance.

4.2.2 Cluster Configuration

Rendering Nodes

- **Node Count:** 4 rendering nodes

- **GPUs per Node:** 2-3 GPUs (8-12 total)
- **Form Factor:** 4U rackmount workstations
- **Redundancy:** N+1 configuration (spare node)

Hardware Specifications per Node

- **CPU:** AMD EPYC 7443P (24 cores) or Intel Xeon W-3345
- **RAM:** 256GB DDR4 ECC (expandable to 512GB)
- **GPU:** 2× NVIDIA RTX 4000 Ada Generation (20GB)
- **Storage:** 2TB NVMe SSD for OS/apps + 4TB for cache
- **Network:** Dual 10GbE + 1GbE management
- **Power:** Redundant 1600W PSUs

4.2.3 GPU Specifications

NVIDIA RTX 4000 Ada Generation

- **CUDA Cores:** 6,144
- **Memory:** 20GB GDDR6
- **Memory Bandwidth:** 360 GB/s
- **Display Outputs:** 4× DisplayPort 1.4a
- **Power:** 130W TDP
- **Features:** RT cores, Tensor cores, AV1 encode
- **Sync:** Quadro Sync II compatible

Alternative GPU Options

For budget flexibility:

- **Lower Cost:** NVIDIA RTX A4000 (16GB)
- **Higher Performance:** NVIDIA RTX 5000 Ada (32GB)
- **Best Value:** Mix of models based on wall assignment

4.2.4 Synchronisation Hardware

NVIDIA Quadro Sync II

- **Synchronises:** Up to 4 GPUs per card
- **Configuration:** 2 Sync cards for 8-12 GPUs
- **Accuracy:** $<1\mu\text{s}$ between frames
- **Connection:** Dedicated sync network
- **External Sync:** Genlock input/output

4.2.5 Network Infrastructure

Cluster Interconnect

- **Switch:** 24-port 10GbE managed switch
- **Topology:** Full mesh between render nodes
- **Bandwidth:** 10Gbps full duplex per node
- **Latency:** $<5\mu\text{s}$ switch latency
- **Management:** VLAN separation for control

Storage Network

- **NAS:** 40TB usable (RAID 6)
- **Connection:** 10GbE to switch
- **Performance:** 1GB/s+ sequential read
- **Protocol:** NFS/SMB for flexibility

4.2.6 Software Stack

Operating System

- **Primary:** Windows 11 Pro for Workstations
- **Alternative:** Ubuntu 22.04 LTS

- **Management:** DreamLab Cluster Manager
- **Updates:** Centralised WSUS/Landscape

Visualisation Software

- **Unity 2023 LTS**
 - MiddleVR plugin for CAVE support
 - Cluster rendering via Unity Render Streaming
 - HDRP for high-quality visuals
- **Unreal Engine 5.3+**
 - nDisplay for multi-screen output
 - Lumen for real-time global illumination
 - Nanite for complex geometry

4.2.7 Performance Capabilities

Metric	Specification
Total GPU Memory	160-240GB
Total System RAM	1TB+
Rendering Performance	4× 4K @ 120Hz stereo
Polygon Throughput	1 billion+ triangles/sec
Physics Simulation	100K rigid bodies real-time
Ray Tracing	Real-time with DLSS

4.2.8 Scalability and Upgrades

Immediate Scalability

- Add GPUs to existing nodes (3rd GPU)
- Increase RAM to 512GB per node
- Add 5th render node for redundancy

Future Upgrades

- Swap to next-gen GPUs (drop-in replacement)

- Add AI acceleration cards
- Upgrade to 25GbE networking
- Implement GPU virtualisation

4.2.9 Management and Monitoring

System Management

- **Remote Access:** IPMI/iDRAC on all nodes
- **Monitoring:** Nagios/Zabbix for health checks
- **GPU Monitoring:** NVIDIA-SMI integration
- **Alerting:** Email/SMS for critical issues

Backup and Recovery

- **System Images:** Weekly automated backups
- **Configuration:** Version controlled (Git)
- **Recovery Time:** <2 hours for node rebuild
- **Data Backup:** Nightly to separate NAS

4.3 Audio System Specification

4.3.1 System Overview

The Fit For Purpose audio system employs professional 7.1 surround sound, providing high-quality spatial audio that enhances immersion without the complexity and cost of wave field synthesis. This configuration delivers excellent results for most research applications.

4.3.2 Speaker Configuration

7.1 Channel Layout

- **Front Left/Right:** $\pm 30^\circ$ from centre

- **Centre:** 0° (front wall centre)
- **Surround Left/Right:** ±90-110°
- **Rear Left/Right:** ±150°
- **Subwoofer:** Corner placement
- **Height:** 1.8m (ear level when standing)

Speaker Specifications

- **Model:** JBL EON ONE Compact or similar
- **Type:** Active 2-way monitors
- **Power:** 120W RMS per speaker
- **Frequency Response:** 45Hz - 20kHz
- **SPL:** 118dB peak
- **Coverage:** 90° horizontal, 60° vertical

Subwoofer

- **Model:** JBL EON618S or equivalent
- **Power:** 500W RMS
- **Frequency Response:** 25Hz - 150Hz
- **SPL:** 124dB peak
- **DSP:** Built-in crossover and EQ

4.3.3 Audio Processing

Digital Signal Processor

- **Model:** BSS BLU-100 or similar
- **Channels:** 12 in / 8 out minimum
- **Processing:** 48kHz/24-bit
- **Features:**

- Room equalisation
 - Delay compensation
 - Dynamics processing
 - Matrix mixing
- **Control:** Network-based GUI

Audio Interface

- **Model:** RME HDSPe MADI or similar
- **Channels:** 64 channels via MADI
- **Latency:** <1ms round trip
- **Sync:** Word clock with video system
- **Driver:** ASIO for low latency

4.3.4 Integration Features

Software Integration

- **Unity Integration:** Native audio spatialiser
- **Unreal Integration:** Built-in 7.1 support
- **API:** OpenAL for custom applications
- **MIDI:** Control for triggering sounds

Content Creation

- **DAW Software:** Reaper (included)
- **Plugins:** Spatial audio suite
- **Sound Libraries:** Academic licence bundle
- **Training:** 2-day audio workshop included

4.3.5 Acoustic Treatment

Room Treatment

- **Wall Panels:** 50mm acoustic foam (NRC 0.85)
- **Coverage:** 30% of wall area
- **Bass Traps:** Corner-mounted absorbers
- **Ceiling:** Suspended acoustic tiles
- **Target RT60:** 0.3-0.4 seconds

Noise Control

- **Background Noise:** <NC-30
- **HVAC:** Silencers on all ducts
- **Projector Noise:** Hush boxes if needed
- **Computer Noise:** Remote server room

4.3.6 Optional Enhancements

Ambisonic Upgrade Path

For future spatial audio research:

- **Microphone:** Rode NT-SF1 ambisonic mic
- **Decoder:** Software HOA decoder
- **Benefits:** Full 3D sound capture/playback
- **Cost:** Additional £5,000

Binaural System

For individual researcher use:

- **Headphones:** Sennheiser HD 800S

- **Processing:** Waves NX plugin
- **Tracking:** Uses existing optical system
- **Applications:** Detailed audio analysis

4.3.7 Performance Specifications

Parameter	Specification
Frequency Response	25Hz - 20kHz \pm 3dB
Maximum SPL	105dB continuous
Channel Separation	>60dB
THD+N	<0.05%
Latency	<10ms total
Dynamic Range	>100dB

4.3.8 Control and Operation

User Interface

- **Touch Panel:** Wall-mounted 10" tablet
- **Presets:** One-touch scene recall
- **Volume:** Master and zone controls
- **Mute:** Emergency audio kill button

Monitoring

- **SPL Meter:** Integrated measurement
- **System Health:** Amplifier status display
- **Usage Logging:** Hours and level tracking
- **Remote Access:** Web-based control

4.4 Tracking System Specification

4.4.1 System Overview

The tracking system provides accurate position and orientation data for three simultaneous users, enabling perspective-correct rendering for collaborative experiences. We recommend OptiTrack's proven optical tracking technology for its reliability and cost-effectiveness.

4.4.2 Camera System

OptiTrack Prime 13 Cameras

- **Camera Count:** 8 cameras for full coverage
- **Resolution:** 1.3 megapixels (1280×1024)
- **Frame Rate:** 240 FPS
- **Latency:** 4.2ms
- **Field of View:** $56^{\circ} \times 46^{\circ}$
- **Range:** 12m+ with 12.7mm markers
- **Accuracy:** Sub-millimetre

Camera Placement

- **Configuration:** Ceiling-mounted in corners
- **Height:** 3.5m above floor
- **Coverage:** Complete $5\text{m} \times 5\text{m} \times 2.5\text{m}$ volume
- **Overlap:** Minimum 3 cameras see each point
- **Mounting:** Adjustable brackets with vibration isolation

4.4.3 Tracking Targets

Head Tracking

- **Configuration:** 4-marker rigid body on glasses
- **Markers:** 12.7mm reflective spheres
- **Pattern:** Asymmetric for unique identification

- **Weight:** <20g additional on glasses
- **Quantity:** 3 tracked users + 2 spares

Hand Controllers

- **Type:** Custom wand with 5 markers
- **Buttons:** 6 programmable inputs
- **Joystick:** 2-axis analog
- **Feedback:** Vibration motor
- **Connection:** Wireless (2.4GHz)
- **Battery:** 20+ hours rechargeable

4.4.4 Software and Processing

OptiTrack Motive Software

- **Version:** Motive 3.0+
- **Features:**
 - Real-time 3D reconstruction
 - Automatic calibration
 - Rigid body definition
 - Skeleton tracking capability
 - Data streaming protocols
- **Output:** Position (X,Y,Z) + Rotation (Quaternion)

Data Distribution

- **Protocol:** VRPN (Virtual Reality Peripheral Network)
- **Alternative:** NatNet SDK
- **Latency:** <1ms network transmission
- **Update Rate:** 240Hz to render nodes
- **Format:** UDP multicast for efficiency

4.4.5 Alternative: ART Tracking

For comparison, Advanced Realtime Tracking option:

ART SmartTrack3

- **Advantages:**
 - Active LED markers (no marker swapping)
 - Integrated with glasses
 - Higher accuracy ($<0.5\text{mm}$)
 - Direct Unreal/Unity plugins
- **Cost:** Approximately 40% higher
- **Support:** European-based

4.4.6 Calibration and Maintenance

System Calibration

- **Frequency:** Monthly or after any camera movement
- **Process:** Wand wave (5 minutes)
- **Ground Plane:** Set via 3-point definition
- **Quality Metric:** $<0.5\text{mm}$ reprojection error
- **Documentation:** Step-by-step guide provided

Daily Checks

- Marker cleanliness inspection
- Camera lens cleaning if needed
- Tracking volume test
- Battery charging for controllers
- System health dashboard review

4.4.7 Performance Specifications

Parameter	Specification
Positional Accuracy	<1mm RMS
Rotational Accuracy	<0.5°
Tracking Volume	5m × 5m × 2.5m
Latency	<10ms total
Update Rate	240Hz
Simultaneous Objects	20+ rigid bodies
Marker Visibility	3+ cameras required

4.4.8 Integration Features

Software Support

- **Unity:** OptiTrack Unity Plugin
- **Unreal:** LiveLink OptiTrack Plugin
- **MiddleVR:** Native OptiTrack support
- **Custom:** C++ SDK available
- **Python:** PyMotive bindings

Advanced Features

- **Prediction:** Kalman filtering for smoothness
- **Occlusion Handling:** Maintains track through brief occlusions
- **Multi-User:** Automatic user identification
- **Recording:** Full session capture and playback
- **Analytics:** Usage statistics and heatmaps

4.4.9 Expansion Options

Full Body Tracking

For future motion capture needs:

- Add 4 more cameras (12 total)
- Full body marker suits
- Biomechanics analysis software
- Estimated cost: £40,000

Object Tracking

For research props and tools:

- Define custom rigid bodies
- Track robots, tools, or props
- Synchronise with virtual representations
- No additional hardware needed

Infrastructure Requirements

5.1 Network Infrastructure Specification

5.1.1 Network Overview

The Fit For Purpose system requires a robust but straightforward network infrastructure that prioritises reliability and ease of management. The design separates critical real-time traffic from general data transfer while maintaining security.

5.1.2 Network Architecture

Core Switch

- **Model:** Cisco Catalyst 9300-24UX or equivalent
- **Ports:** 24× 10GbE SFP+
- **Uplinks:** 2× 40GbE QSFP+
- **Features:**
 - Layer 3 routing
 - VLAN support
 - QoS capabilities
 - Redundant power supplies
- **Management:** Web GUI + CLI

Network Topology

- **Render Network:** Dedicated 10GbE VLAN
- **Storage Network:** Separate 10GbE VLAN
- **Management Network:** 1GbE out-of-band
- **Tracking Network:** Isolated 1GbE VLAN
- **Campus Uplink:** 40GbE to university backbone

5.1.3 VLAN Configuration

VLAN	Name	Purpose	Subnet
100	RENDER	Cluster sync traffic	10.100.0.0/24
200	STORAGE	NAS/SAN access	10.200.0.0/24
300	TRACKING	OptiTrack data	10.300.0.0/24
400	MANAGE	Management access	10.400.0.0/24
500	USER	General access	10.500.0.0/24

5.1.4 Performance Requirements

Bandwidth Allocation

- **Render Traffic:** $4 \times 4K @ 60Hz = \sim 8Gbps$ peak
- **Storage Access:** 1GB/s sustained reads
- **Tracking Data:** <10Mbps (low bandwidth)
- **Management:** <100Mbps typical
- **External Access:** As needed via campus

Latency Requirements

- **Render Sync:** <1ms between nodes
- **Tracking Stream:** <5ms to render nodes
- **Storage Access:** <10ms response time
- **External Access:** Best effort

5.1.5 Cabling Infrastructure

Fibre Optic Cabling

- **Type:** OM4 multimode fibre
- **Connectors:** LC duplex
- **Distances:** <100m typical
- **Spare Capacity:** 50% extra runs
- **Patch Panels:** 48-port in rack

Copper Cabling

- **Category:** Cat6A for 10GbE
- **Management:** Cat6 for 1GbE
- **Length Limit:** <30m for 10GbE
- **Testing:** Certified to TIA-568

5.1.6 Storage Network

Network Attached Storage

- **Model:** Synology SA3600 or QNAP TS-1886XU
- **Capacity:** 40TB usable (RAID 6)
- **Drives:** 12× 8TB enterprise SATA
- **Cache:** 2× 1TB NVMe SSD
- **Network:** Dual 10GbE connections
- **Protocols:** NFS, SMB, iSCSI

Backup Storage

- **Capacity:** 80TB (2:1 backup ratio)
- **Type:** Separate NAS or tape library

- **Schedule:** Nightly incrementals
- **Retention:** 30 days minimum

5.1.7 Security Configuration

Firewall

- **Model:** Fortinet FortiGate 200F
- **Throughput:** 20Gbps firewall
- **Features:**
 - Stateful inspection
 - IPS/IDS capabilities
 - VPN support
 - Application control
- **Placement:** Between campus and CAVE networks

Access Control

- **Authentication:** 802.1X for wired access
- **User VLANs:** Based on role
- **Guest Access:** Isolated VLAN
- **Remote Access:** SSL VPN only

5.1.8 Quality of Service

Traffic Prioritisation

1. **Priority 1:** Frame sync traffic (EF)
2. **Priority 2:** Tracking data (AF41)
3. **Priority 3:** Render traffic (AF31)
4. **Priority 4:** Storage access (AF21)
5. **Priority 5:** Management (BE)

5.1.9 Management and Monitoring

Network Management

- **Platform:** PRTG or Zabbix
- **Monitoring:**
 - Bandwidth utilisation
 - Port errors/drops
 - Latency measurements
 - Device health
- **Alerting:** Email/SMS for issues
- **Logging:** Centralised syslog server

Documentation

- Network topology diagrams
- VLAN assignments
- IP address allocations
- Cable plant documentation
- Emergency procedures

5.1.10 Future Expansion

Immediate Upgrades

- Add 10GbE ports (expansion module)
- Increase storage capacity
- Add redundant core switch

Long-term Options

- Upgrade to 25/100GbE
- Software-defined networking

- Cloud integration
- Remote site connectivity

5.2 Room Layout and Construction

5.2.1 Space Requirements

The Fit For Purpose immersive facility requires a dedicated space of approximately $10\text{m} \times 10\text{m}$ with a minimum ceiling height of 4m. This single-height configuration simplifies construction while providing adequate space for the 4-wall CAVE system.

5.2.2 Room Zones

CAVE Active Area

- **Dimensions:** $5\text{m} \times 5\text{m} \times 3\text{m}$ (L×W×H)
- **Location:** Centre of room
- **Flooring:** Raised floor for projection
- **Walls:** Rear-projection screens
- **Access:** One removable wall section

Projection Space

- **Behind Screens:** 1.5m clearance
- **Projector Mounting:** Ceiling-mounted
- **Mirror Box:** For floor projection
- **Service Access:** Via rear corridors

Control Area

- **Size:** $3\text{m} \times 3\text{m}$
- **Location:** Adjacent to CAVE
- **Features:**

- Operator workstation
- System controls
- Emergency stops
- Observation window

Equipment Room

- **Size:** 15m² minimum
- **Location:** Adjacent or nearby
- **Contents:**
 - Server racks
 - Network equipment
 - UPS systems
 - HVAC units

5.2.3 Architectural Requirements

Structural

- **Floor Loading:** 500kg/m² minimum
- **Ceiling Structure:** Support for projectors (100kg each)
- **Vibration:** Isolated from building vibration
- **Seismic:** Standard UK building codes

Acoustic Treatment

- **Wall Construction:**
 - Double stud walls
 - Acoustic insulation fill
 - STC rating >50
- **Ceiling:**
 - Suspended acoustic tiles
 - NRC >0.8

- Black finish
- **Floor:**
 - Raised floor system
 - Vibration damping
 - Cable management

5.2.4 Environmental Control

Lighting

- **General Lighting:** Dimmable LED (0-500 lux)
- **Emergency Lighting:** Battery-backed
- **Work Lights:** Behind screens for service
- **Control:** DMX or DALI system
- **Blackout:** Complete darkness capability

HVAC Requirements

- **Temperature:** 20°C \pm 2°C
- **Humidity:** 45-55% RH
- **Air Changes:** 6-8 per hour
- **Filtration:** MERV 13 filters
- **Noise Level:** <NC-30

5.2.5 Safety Features

Emergency Systems

- **Exit Lighting:** Self-illuminated signs
- **Emergency Stop:** Multiple E-stop buttons
- **Fire Detection:** Smoke/heat detectors
- **Suppression:** FM-200 or water mist
- **Evacuation:** Audio/visual alarms

User Safety

- **Floor Edges:** LED strip lighting
- **Padding:** Soft edges where needed
- **Clear Space:** No trip hazards
- **First Aid:** Station in control room
- **Phone:** Emergency contact system

5.2.6 Infrastructure Details

Power Distribution

- **Main Supply:** 100A 3-phase
- **Distribution:** Multiple sub-panels
- **Projector Circuits:** Dedicated 16A each
- **Emergency Power:** UPS for critical systems
- **Grounding:** Technical earth system

Cable Management

- **Raised Floor:** 300mm cavity
- **Cable Trays:** Overhead for networks
- **Separation:** Power/data segregation
- **Access Points:** Removable floor tiles
- **Labelling:** Comprehensive system

5.2.7 Detailed Layout Specifications

Area	Dimensions	Purpose
CAVE Interior	5m × 5m × 3m	Active tracked volume
Projection Space	1.5m depth	Behind each screen
Control Room	3m × 3m	Operator station
Equipment Room	5m × 3m	Servers and infrastructure
Entry Vestibule	2m × 2m	Light lock/preparation
Storage	2m × 2m	Glasses and accessories
Total Area	100m²	Minimum requirement

5.2.8 Construction Timeline (with Contingency)

The following is an indicative construction timeline. A 2-month contingency has been factored in for unforeseen delays.

1. **Month 1:** Design finalisation
2. **Month 2-4:** Structural modifications
3. **Month 5:** HVAC and electrical
4. **Month 6:** Acoustic treatment
5. **Month 7-8:** Screen installation
6. **Month 9:** Final fit-out and commissioning

5.3 Power and Cooling Specification

5.3.1 Power System Overview

The Fit For Purpose system requires a robust electrical infrastructure capable of supporting 15-20kW of continuous load with appropriate redundancy and protection. The design prioritises reliability while maintaining cost-effectiveness.

5.3.2 Total Power Requirements

Load Analysis

Component	Quantity	Power (kW)
Projectors (300W each)	4	1.2
Render Nodes (800W each)	4	3.2
GPUs (130W each)	8-12	1.5
Network Equipment	1	0.8
Storage Systems	1	0.5
Tracking System	1	0.3
Audio System	1	1.0
Lighting and Control	1	0.5
HVAC (dedicated)	1	6.0
Subtotal		15.0
Future Growth (33%)		5.0
Total Capacity		20.0

5.3.3 Electrical Distribution

Main Supply

- **Service:** 100A 3-phase 415V
- **Connection:** Dedicated from building main
- **Metering:** Sub-metering for usage tracking
- **Protection:** Main breaker with shunt trip

Distribution Panels

- **Main Panel:** 100A 3-phase distribution
- **Sub-Panel 1:** IT equipment (servers)
- **Sub-Panel 2:** Display systems
- **Sub-Panel 3:** HVAC and utilities
- **Emergency Panel:** Life safety systems

Circuit Requirements

- **Projectors:** 4× 16A dedicated circuits

- **Server Racks:** 2× 32A 3-phase
- **Workstations:** 6× 13A standard sockets
- **Utility:** 10× 13A general purpose
- **Emergency:** Battery-backed circuits

5.3.4 Uninterruptible Power Supply

UPS Specification

- **Capacity:** 20kVA/18kW
- **Technology:** Online double-conversion
- **Runtime:** 10 minutes at full load
- **Input:** 3-phase 415V
- **Output:** 3-phase + single-phase
- **Features:**
 - Network management card
 - Environmental monitoring
 - Automatic bypass
 - Battery monitoring

Protected Loads

- All computing equipment
- Network infrastructure
- Tracking system
- Emergency lighting
- Control systems

5.3.5 Cooling System Design

Heat Load Calculation

- **IT Equipment:** 10kW heat output
- **Display Systems:** 2kW heat output
- **People (6 max):** 0.6kW
- **Lighting:** 0.4kW
- **Safety Margin:** 3kW
- **Total Cooling:** 16kW required

HVAC Specification

- **Type:** Split system with precision control
- **Capacity:** 20kW cooling (5.7 tons)
- **Redundancy:** N+1 configuration
- **Control:** $\pm 1^{\circ}\text{C}$ temperature
- **Humidity:** 45-55% RH control

5.3.6 Cooling Distribution

CAVE Space

- **Method:** Displacement ventilation
- **Supply:** Floor-level diffusers
- **Return:** Ceiling-level extraction
- **Airflow:** 2,000 CFM minimum
- **Velocity:** $< 0.2\text{m/s}$ in occupied zone

Equipment Room

- **Configuration:** Hot/cold aisle
- **Cooling:** Close-coupled units
- **Temperature:** 22°C \pm 2°C
- **Monitoring:** Per-rack sensors
- **Containment:** Optional hot aisle

5.3.7 Energy Efficiency

Power Usage Effectiveness (PUE)

- **Target PUE:** <1.6
- **Monitoring:** Real-time PUE display
- **Optimisation:**
 - Variable speed fans
 - Free cooling when available
 - Efficient UPS (>94%)
 - LED lighting throughout

Operating Costs

Item	kWh/year	Cost/year
IT Equipment	65,000	£9,750
Cooling	35,000	£5,250
Other	10,000	£1,500
Total	110,000	£16,500

5.3.8 Emergency Systems

Emergency Power Off (EPO)

- **Locations:** 3 stations (mushroom buttons)
- **Coverage:** All non-life-safety systems

- **Reset:** Key-operated reset required
- **Testing:** Quarterly EPO drills

Fire Suppression

- **Detection:** VESDA early warning
- **Suppression:** Novec 1230 clean agent
- **Activation:** Automatic with manual release
- **Integration:** HVAC shutdown on alarm

5.3.9 Monitoring and Control

Building Management System

- **Platform:** BACnet-compatible BMS
- **Monitoring:**
 - Power consumption
 - Temperature/humidity
 - Equipment status
 - Alarm conditions
- **Control:**
 - HVAC setpoints
 - Lighting scenes
 - Access control
 - Emergency responses

5.3.10 Maintenance Requirements

Preventive Maintenance Schedule

- **Weekly:** Visual inspections
- **Monthly:** Filter changes, battery tests
- **Quarterly:** Full system tests

- **Annual:** Thermal imaging, load testing
- **Contract:** 24/7 support agreement

Commercial Proposal

6.1 Budget Breakdown

6.1.1 Capital Expenditure Summary

The Fit For Purpose system delivers exceptional value by focusing on proven technologies and practical specifications. The total investment of approximately £1.98M includes all hardware, software, installation, and two years of comprehensive support. The estimated project delivery timeline is approximately 12 months, with the core construction phase estimated at 9 months, including a built-in contingency.

6.1.2 Detailed Cost Breakdown

Display System

Item	Quantity	Unit Cost	Total
Digital Projection Satellite Insight MLS	4	£75,000	£300,000
Projection Screens	4	£15,000	£60,000
Active Shutter Glasses	10	£500	£5,000
Warping/Blending Software	1	£15,000	£15,000
Mounting Hardware	1	£10,000	£10,000
Spare Digital Projection MLS	1	£75,000	£75,000
Display System Total			£465,000

Compute Infrastructure

Item	Quantity	Unit Cost	Total
Render Nodes (2 GPU each)	4	£25,000	£100,000
NVIDIA RTX 4000 Ada	8	£4,500	£36,000
Quadro Sync II Cards	2	£3,000	£6,000
Network Switch (10GbE)	1	£8,000	£8,000
NAS Storage (40TB)	1	£12,000	£12,000
Backup Storage	1	£8,000	£8,000
Software Licences	1	£30,000	£30,000
Server Rack & PDUs	2	£5,000	£10,000
Cables & Accessories	1	£10,000	£10,000
Spare GPU	2	£4,500	£9,000
Additional Nodes (Future)	2	£25,000	£50,000
Compute Total			£279,000

Tracking System

Item	Quantity	Unit Cost	Total
OptiTrack Prime 13	8	£4,000	£32,000
Motive Software	1	£5,000	£5,000
Tracking Markers	100	£20	£2,000
Hand Controllers	3	£1,500	£4,500
Calibration Kit	1	£1,500	£1,500
Mounting Hardware	1	£3,000	£3,000
Annual Support	2 years	£5,000	£10,000
Tracking Total			£58,000

Audio System

Item	Quantity	Unit Cost	Total
JBL EON Speakers	7	£1,200	£8,400
Subwoofer	1	£2,000	£2,000
DSP Processor	1	£8,000	£8,000
Audio Interface	1	£3,000	£3,000
Acoustic Treatment	1	£15,000	£15,000
Cabling & Installation	1	£5,000	£5,000
Audio Total			£41,400

Infrastructure

Item	Quantity	Unit Cost	Total
Firewall	1	£8,000	£8,000
UPS System (20kVA)	1	£25,000	£25,000
HVAC Upgrade	1	£40,000	£40,000
Electrical Work	1	£30,000	£30,000
Fire Suppression	1	£20,000	£20,000
Monitoring System	1	£5,000	£5,000
Infrastructure Total			£128,000

6.1.3 Implementation Costs

Service	Cost
Room Preparation	£150,000
Project Management	£40,000
Installation Labour	£60,000
System Integration	£40,000
Testing & Commissioning	£20,000
Documentation	£10,000
Implementation Total	£320,000

6.1.4 Training and Support

Service	Cost
Operator Training (5 days)	£10,000
Developer Training (5 days)	£10,000
Maintenance Training (3 days)	£6,000
Documentation & Manuals	£4,000
Year 1 Support (included)	£0
Year 2 Support	£30,000
Year 3+ Support (optional)	£35,000/year
Training/Support Total	£60,000

6.1.5 Total Investment Summary

Category	Amount	Percentage
Display System	£400,000	25.1%
Compute Infrastructure	£279,000	17.5%
Tracking System	£58,000	3.6%
Audio System	£41,400	2.6%
Network & Infrastructure	£128,000	8.0%
Room Preparation	£150,000	9.4%
Implementation	£320,000	20.1%
Training & Support	£60,000	3.8%
Subtotal	£1,501,400	88.7%
Contingency (10%)	£150,140	8.9%
VAT (20%)	£330,308	-
Total Investment	£1,981,848	100%

6.1.6 Value Engineering Options

To further reduce costs if needed:

- **Phased GPU Deployment:** Start with 6 GPUs (£18,000 saving)
- **Reduced Spare Equipment:** Defer spare projector (£50,000 saving)
- **Basic Audio:** 5.1 instead of 7.1 (£10,000 saving)
- **Manual Calibration:** Reduce automation (£10,000 saving)

6.1.7 Return on Investment

The facility will deliver value through:

- Research grant capture: £500k+ annually
- Industry partnerships: £200k+ annually
- Student recruitment: Enhanced reputation
- Teaching efficiency: Shared resource
- Regional impact: Innovation showcase

6.2 DreamLab Credentials

6.2.1 Company Overview

DreamLab stands as the North-West's premier creative technology agency, uniquely positioned to deliver this Fit For Purpose immersive system through our integrated expertise in AI, immersive experiences, and creative excellence. As a government-endorsed blueprint for innovation, we bridge the gap between cutting-edge technology and practical business solutions.

6.2.2 Leadership Team

Dr John O'Hare - Associate Director R&D

- **Experience:** 25+ years in immersive system design
- **Credentials:**
 - PhD in small group tele-collaboration
 - Technical Director, University of Salford (15 years)
 - Designed and delivered multiple multi-million pound VR platforms
 - Lead on £1.8M Egg system at MediaCityUK
 - Extensive CAVE system expertise (first outside USA)
- **Current Role:** Leading 15-strong team of creatives and technologists
- **Specialisms:** System integration, distributed rendering, tracking systems

Supporting Team Expertise

- **Magnus Kemp:** Virtual production and real-time graphics
- **Jon Donlon:** Network infrastructure and HPC systems
- **Pete Woodbridge:** Audio engineering and spatial sound
- **Marco:** Software development and Unity integration
- Plus additional specialists in project management, training, and support

6.2.3 Relevant Project Experience

University Research Facilities

- **Salford Octave** (2007-2016): £2M+ immersive platform
- **MediaCityUK Egg** (2011): £1.8M cylindrical display
- **MITIH Hub** (2024): £3M Innovate UK facility
- **Various CAVES**: Multiple 4-6 wall installations

Technology Partnerships

- **HP AI Lighthouse Partner**: Strategic technology alliance
- **NVIDIA Partner**: GPU compute and visualisation
- **Unity Verified Solutions Partner**: Development expertise
- **OptiTrack Certified**: Tracking system integration

6.2.4 Our Approach

Mesh Fluency Methodology

Our unique approach seamlessly integrates multiple disciplines:

- Hardware selection based on proven reliability
- Software integration using open standards
- User experience focus for researchers
- Sustainable support models
- Knowledge transfer to client teams

Project Delivery Framework

1. **Discovery**: Understanding specific research needs
2. **Design**: Collaborative specification development
3. **Delivery**: Phased implementation with checkpoints

4. **Development:** Custom software and integration
5. **Deployment:** Training and handover
6. **Support:** Ongoing partnership approach

6.2.5 Quality Assurance

Standards and Certifications

- ISO 9001:2015 Quality Management
- ISO 27001 Information Security
- PRINCE2 Agile project management
- CE marking compliance for all hardware
- UK health and safety standards

Testing Protocols

- Factory acceptance testing (FAT)
- Site acceptance testing (SAT)
- Performance benchmarking
- User acceptance criteria
- Documentation review

6.2.6 Support and Training

Comprehensive Training Programme

- **Operator Training:** 5-day hands-on course
- **Developer Workshop:** Unity/Unreal for CAVE
- **Maintenance Training:** Preventive care
- **Online Resources:** Video tutorials and guides
- **Annual Refreshers:** Included in support

Support Packages

- **24/7 Remote Support:** Via secure connection
- **On-site Response:** 4-hour for critical issues
- **Spare Parts:** Local stock maintained
- **Software Updates:** Quarterly releases
- **Health Checks:** Monthly remote review

6.2.7 Client References

“DreamLab delivered our immersive facility on time and within budget. Their expertise in CAVE systems is unmatched in the UK.”

- *Research Director, Major UK University*

“The team’s ability to integrate complex technologies while maintaining usability is exceptional. Our researchers were productive from day one.”

- *Head of Innovation, Research Council*

6.2.8 Why Choose DreamLab

1. **Proven Expertise:** 25+ years in immersive systems
2. **Academic Focus:** Understanding of research needs
3. **UK-Based:** Local support and knowledge
4. **Value Engineering:** Maximum capability per pound
5. **Partnership Approach:** Long-term success focus
6. **Innovation Leaders:** Government-endorsed blueprint

6.2.9 Contact Information

Company	DreamLab - Creative Technology
Address	MediaCityUK, Salford, M50 2HE
Contact	Dr John O’Hare
Email	john@thedreamlab.uk
Phone	+44 7973 543825
Website	www.thedreamlab.uk

A

Technical Drawings

[Detailed CAD drawings to be provided during design phase]

B

Equipment Datasheets

[Manufacturer specifications available upon request]

C

Sample Projects Gallery

[Portfolio of similar DreamLab installations available separately]

Part III

Tier 3: National Significance Specification



National Significance

Immersive System

Technical Specification Document

Prepared for:

Professor Samia Nefti-Meziani

Birmingham University

Prepared by:

DreamLab

29th June 2025

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Introduction

1.1 Document Purpose

This document presents the technical specification for a National Significance immersive visualisation facility at Birmingham University. The proposed system represents a carefully balanced solution that delivers professional-grade research capabilities whilst maintaining cost efficiency and operational practicality.

1.2 System Classification

The National Significance tier positions this facility between World Class and Fit For Purpose systems, providing:

- 90% of World Class capabilities at 60% of the cost
- Professional-grade components with proven reliability
- Scalable architecture for future enhancement
- Optimised operational efficiency

Executive Summary

2.1 Executive Summary

2.1.1 National Significance: A DreamLab Solution

National Significance System Overview

The National Significance immersive system represents a carefully calibrated middle ground between world-class aspirations and practical deployment. This 5-wall LED panel based system delivers cutting-edge research capabilities whilst maintaining fiscal responsibility and operational efficiency.

2.1.2 System Highlights

- **5-Wall LED Configuration:** Four walls plus floor utilising $\leq 1.2\text{mm}$ pitch LED panels
- **15m \times 15m Facility:** Optimised space supporting 4-6 simultaneous users
- **8K Total Resolution:** Per wall capability with HDR support
- **Multi-User Stereoscopy:** Supporting up to 4 concurrent perspectives
- **16-24 GPU Compute Cluster:** NVIDIA H100/A6000 based rendering
- **64-128 Speaker WFS Array:** Spatial audio for collaborative work
- **Sub-3mm Optical Tracking:** Professional-grade motion capture
- **25-30kW Power Infrastructure:** Efficient cooling and operation

2.1.3 Strategic Positioning

This National Significance facility positions Birmingham University as a leader in UK immersive research infrastructure. By selecting proven LED technology over projection, we ensure:

- Superior brightness and contrast for industrial visualisation
- Reduced maintenance requirements versus laser projection
- Flexibility for ambient light operation
- Lower total cost of ownership over 10 years

2.1.4 Research Applications

Primary Domains:

- Nuclear decommissioning simulation
- Autonomous vehicle testing
- Manufacturing process optimisation
- Medical training scenarios
- Risk assessment modelling

Key Differentiators:

- Multi-user collaboration without headsets
- Life-scale industrial visualisation
- Real-time digital twin integration
- Haptic feedback compatibility
- Remote collaboration capability

2.1.5 Investment Summary

The National Significance system represents an investment of approximately £3.5-4.5 million, delivering:

- **90% of World Class Capability** at 60% of the cost
- **5-Year Warranty** on critical components
- **Annual Operating Costs** under £150,000
- **Revenue Generation Potential** of £500,000+ annually

2.1.6 DreamLab Expertise

Dr John O'Hare and the DreamLab team bring decades of experience delivering multi-million pound research platforms. Our proven track record includes:

- Design and deployment of 15+ immersive facilities globally
- Integration expertise across LED, projection, and hybrid systems
- Strong partnerships with tier-1 technology vendors
- Comprehensive training and support programmes

2.1.7 Timeline to Deployment



Total Timeline: 15 months from contract signature to operational facility

Project Vision and Strategy

3.1 Project Vision

3.1.1 National Research Infrastructure

Vision Statement

To establish a National Significance immersive visualisation facility that bridges the gap between aspirational world-class systems and practical research needs, delivering transformative capabilities for UK research and industry collaboration.

3.1.2 Strategic Objectives

Research Excellence

The National Significance system will enable breakthrough research across multiple disciplines by providing:

- **Collaborative Visualisation:** Up to 4 researchers working simultaneously in shared virtual environments
- **Industrial Scale Testing:** Life-size simulation of manufacturing and hazardous environments
- **Cross-Disciplinary Integration:** Supporting engineering, medical, and creative applications
- **Real-Time Digital Twins:** Direct integration with industrial IoT and simulation systems

Industry Partnership

The facility will serve as a catalyst for university-industry collaboration:

Target Sectors:	Partnership Models:
<ul style="list-style-type: none">• Nuclear decommissioning• Automotive manufacturing• Aerospace design• Healthcare training• Construction planning• Energy infrastructure	<ul style="list-style-type: none">• Collaborative R&D projects• Industrial training programmes• Technology demonstration• Prototype validation• Risk assessment services• Consultancy engagements

3.1.3 Technological Leadership

LED Display Innovation

By selecting fine-pitch LED technology, the National Significance system positions itself at the forefront of display innovation:

- **≤1.2mm Pixel Pitch:** Near-retinal resolution at typical viewing distances
- **HDR Capability:** 1,000,000:1 contrast ratio for realistic lighting
- **Wide Colour Gamut:** DCI-P3 coverage for accurate visualisation
- **High Refresh Rate:** 240Hz for smooth multi-user stereoscopy

Computational Power

The 16-24 GPU cluster represents a balanced approach to rendering capability:

- **Real-Time Ray Tracing:** NVIDIA RTX technology for photorealistic rendering
- **AI-Enhanced Graphics:** DLSS and neural rendering capabilities
- **Distributed Rendering:** Scalable architecture for complex scenes
- **Cloud Integration:** Hybrid on-premise and cloud compute options

3.1.4 Educational Impact

Student Experience

The facility will transform educational delivery across multiple programmes:

- **Immersive Learning:** Direct manipulation of 3D content without headsets
- **Collaborative Projects:** Team-based design and analysis
- **Industry Exposure:** Real-world problem solving in virtual environments
- **Research Training:** PhD and postdoctoral skill development

Curriculum Integration

Undergraduate Modules:

- Virtual Manufacturing
- Immersive Design Studio
- Risk Visualisation
- Collaborative Engineering

Postgraduate Programmes:

- MSc Digital Innovation
- MSc Virtual Engineering
- PhD Research Platform
- CPD Industry Training

3.1.5 National Significance

UK Research Landscape

The National Significance system fills a crucial gap in UK research infrastructure:

- **Complementary to Existing Facilities:** Positioned between small VR labs and world-class centres
- **Regional Hub:** Serving Midlands manufacturing and engineering sectors
- **UKRI Alignment:** Supporting Industrial Strategy Challenge Fund priorities
- **International Collaboration:** Enabling remote connection to global facilities

Economic Impact

Projected economic benefits over 5 years:

- **Direct Revenue:** £2.5M from facility usage and services
- **Research Funding:** £5M+ in collaborative grants
- **Industry Investment:** £3M in partnership projects
- **Regional Development:** Supporting 50+ high-tech jobs

3.1.6 Sustainability and Future-Proofing

Environmental Considerations

- **Energy Efficiency:** LED technology uses 40% less power than equivalent projection
- **Longevity:** 100,000 hour LED lifespan reduces replacement waste
- **Heat Recovery:** Waste heat utilised for building heating
- **Carbon Offset:** Virtual collaboration reduces travel emissions

Technology Evolution

- **Modular Design:** Easy upgrade path for display and compute components
- **Standards-Based:** OpenXR and open protocols for longevity
- **AI-Ready:** Infrastructure supports emerging AI/ML workflows
- **5G Integration:** Prepared for next-generation connectivity

System Requirements

4.1 System Requirements

4.1.1 Functional Requirements Overview

Core Capability Requirements

The National Significance system must deliver professional-grade immersive visualisation supporting 4-6 concurrent users in a 5-wall LED environment, with balanced specifications that prioritise proven reliability over experimental features.

4.1.2 Visual System Requirements

Display Configuration

- **Topology:** 5-sided LED walls (4 vertical + floor)
- **Internal Dimensions:** 7m × 7m × 3.5m (W×D×H)
- **Resolution:** Minimum 4K (3840×2160) per wall, 8K capable
- **Pixel Pitch:** ≤1.2mm for near-seamless imagery
- **Refresh Rate:** 240Hz minimum for multi-user stereoscopy
- **Brightness:** 800-1000 nits calibrated output
- **Contrast Ratio:** >100,000:1 (LED native)
- **Colour Gamut:** 95% DCI-P3 minimum

Multi-User Stereoscopy

- **Concurrent Users:** 4 tracked users with independent perspectives
- **Stereo Method:** Active shutter glasses with 120Hz per eye
- **Crosstalk:** <2% ghosting between left/right views
- **Additional Observers:** 6 passive viewers with fixed perspective

4.1.3 Compute Infrastructure Requirements

GPU Rendering Cluster

- **GPU Count:** 16-24 high-end GPUs (NVIDIA H100 or A6000)
- **Configuration:** 2-3 nodes with 8 GPUs each
- **Memory:** 48GB+ HBM per GPU
- **Interconnect:** NVLink within nodes, 200Gb/s between nodes
- **Synchronisation:** Hardware genlock across all outputs

CPU and System Requirements

- **Processors:** Dual AMD EPYC or Intel Xeon per node
- **System Memory:** 512GB DDR5 per node minimum
- **Storage:** 100TB usable capacity, 10GB/s throughput
- **Operating System:** Rocky Linux 9 or Ubuntu 22.04 LTS

4.1.4 Audio System Requirements

Wave Field Synthesis Array

- **Speaker Count:** 64-128 independent channels
- **Configuration:** Horizontal ring at 2.2m height
- **Frequency Response:** 80Hz - 18kHz ± 3 dB
- **Subwoofers:** 4-8 units for <80Hz reproduction

- **Processing:** Real-time WFS engine supporting 16 sound objects
- **Latency:** <10ms from trigger to output

Communication and Recording

- **Microphone Array:** 8-channel ambisonic capture
- **Voice Reinforcement:** Echo-cancelled communication system
- **Recording:** Multi-track session capture capability

4.1.5 Tracking System Requirements

Optical Motion Capture

- **Coverage Volume:** $7\text{m} \times 7\text{m} \times 3\text{m}$ tracked space
- **Camera Count:** 12-16 high-speed tracking cameras
- **Frame Rate:** 240Hz capture rate
- **Accuracy:** <3mm positional, <0.5° rotational
- **Latency:** <10ms from movement to data
- **Tracked Objects:** 6 heads + 4 controllers + 10 rigid bodies

Integration Requirements

- **Protocol:** VRPN and OpenXR compatible
- **Coordinate System:** Unified with display space
- **Calibration:** Semi-automated alignment process

4.1.6 Software Platform Requirements

Visualisation Engines

- **Primary:** Unreal Engine 5 with nDisplay
- **Secondary:** Unity 2023 LTS with cluster rendering

- **Scientific:** ParaView and custom OpenGL applications
- **CAD Integration:** Direct import from major CAD platforms

Content Development

- **SDK:** Custom APIs for multi-user applications
- **Templates:** Pre-configured project templates
- **Tools:** Visual programming interfaces (Blueprint/Bolt)
- **Training:** Comprehensive developer documentation

4.1.7 Networking Requirements

Internal Network

- **Backbone:** 100Gb/s Ethernet fabric
- **Topology:** Redundant spine-leaf architecture
- **Storage Network:** Dedicated 50Gb/s SAN
- **Management:** Out-of-band 1Gb/s network

External Connectivity

- **Campus Link:** Dual 10Gb/s connections
- **Internet:** 1Gb/s dedicated research link
- **Remote Access:** Secure VPN for maintenance
- **Collaboration:** H.323/SIP for video connectivity

4.1.8 Operational Requirements

Reliability and Availability

- **Uptime Target:** 95% availability during working hours
- **MTBF:** >5000 hours for critical components

- **Redundancy:** N+1 for power and cooling systems
- **Maintenance Window:** Weekly 4-hour slot

Performance Metrics

- **Scene Complexity:** 100M polygons at 60fps stereo
- **Texture Memory:** 128GB across all displays
- **Physics Simulation:** 10,000 rigid bodies real-time
- **Volumetric Data:** 10GB datasets with interactive frame rates

Display System

5.1 Display System Specification

5.1.1 LED Display Technology Selection

Display Technology Decision

The National Significance system utilises direct-view LED technology, providing superior brightness, contrast, and reliability compared to projection systems, whilst maintaining cost efficiency appropriate for this tier.

5.1.2 LED Panel Specifications

Panel Characteristics

- **Pixel Pitch:** 1.2mm maximum (1.0mm preferred)
- **LED Type:** SMD RGB LEDs with black face
- **Module Size:** 600mm × 337.5mm standard modules
- **Brightness:** 1000 nits calibrated (2000 nits peak)
- **Viewing Angle:** 160° horizontal, 140° vertical
- **Refresh Rate:** 3840Hz for flicker-free operation
- **Greyscale:** 16-bit processing depth

Wall Configuration

Surface	Dimensions	Resolution	Modules
Front Wall	7m × 3.5m	5833 × 2917	168
Left Wall	7m × 3.5m	5833 × 2917	168
Right Wall	7m × 3.5m	5833 × 2917	168
Rear Wall	7m × 3.5m	5833 × 2917	168
Floor	7m × 7m	5833 × 5833	336
Total		85.7 Megapixels	1008

5.1.3 Display Performance

Image Quality Metrics

- **Contrast Ratio:** >100,000:1 (true black capability)
- **Colour Gamut:** 100% sRGB, 95% DCI-P3
- **Colour Accuracy:** $\Delta E < 2$ after calibration
- **Uniformity:** >95% brightness across all panels
- **Bit Depth:** 10-bit per colour channel (HDR10 compatible)

Multi-User Stereoscopy Implementation

- **Method:** Time-sequential active stereo
- **Frame Rate:** 240Hz (60Hz per eye for 4 users)
- **Glasses:** RF-synchronised LCD shutter glasses
- **Sync System:** Wireless emitters with <1ms latency
- **User Identification:** Unique timing codes per user

5.1.4 LED Processing Architecture

Signal Distribution

- **Controllers:** Brompton Technology Tessera SX40 or equivalent
- **Processing:** 4K × 2K per processor at 240Hz

- **Input:** DisplayPort 1.4 or HDMI 2.1 from render cluster
- **Distribution:** Fiber optic to panel receivers
- **Redundancy:** Hot-swappable processors with failover

Calibration and Correction

- **Factory Calibration:** Per-module correction data
- **On-Site Calibration:** Camera-based uniformity correction
- **Colour Management:** 3D LUT support for accurate reproduction
- **Seam Correction:** Sub-pixel alignment between modules
- **Maintenance:** Annual recalibration service included

5.1.5 Mechanical Design

Support Structure

- **Frame Type:** Aluminium space frame construction
- **Access:** Rear maintenance access on all walls
- **Adjustment:** $\pm 10\text{mm}$ in all axes for alignment
- **Load Rating:** 50kg/m^2 for LED panels
- **Seismic Rating:** Suitable for UK building codes

Floor Display Special Considerations

- **Protection:** 10mm tempered glass overlay
- **Load Capacity:** 500kg/m^2 distributed load
- **Anti-Slip:** Textured surface treatment
- **Impact Rating:** IK10 for durability
- **Maintenance:** Removable sections for service

5.1.6 Power and Thermal Management

Power Distribution

- **Total Power:** 15-20kW for display system
- **Distribution:** Per-wall power supplies
- **Redundancy:** N+1 PSU configuration
- **Efficiency:** >90% at typical loads
- **Power Factor:** >0.95 with correction

Cooling Strategy

- **Panel Cooling:** Passive convection design
- **Processor Cooling:** Forced air with filtration
- **Heat Load:** 15kW typical, 20kW maximum
- **Air Flow:** Bottom-to-top natural convection
- **Temperature:** Maintain 20-25°C operational

5.1.7 Integration Features

Audio Integration

- **Speaker Mounting:** Between LED modules at edges
- **Acoustic Transparency:** Perforated sections for WFS
- **Vibration Isolation:** Decoupled speaker mounts

Tracking Integration

- **Camera Positions:** Above LED walls at corners
- **IR Performance:** No interference with tracking
- **Marker Visibility:** High contrast against LED black

5.1.8 Operational Advantages

Benefits vs Projection:

- No alignment drift
- Instant on/off capability
- Works with ambient light
- No lamp replacements
- Silent operation
- Consistent brightness

Maintenance Simplicity:

- Modular replacement
- Remote diagnostics
- Predictive maintenance
- 100,000 hour lifespan
- No consumables
- Self-monitoring

Compute Backend

6.1 Compute Backend Specification

6.1.1 GPU Cluster Architecture

Compute Strategy

The National Significance system employs a balanced 16-24 GPU configuration, delivering professional rendering capabilities whilst maintaining cost efficiency through strategic component selection and architecture.

6.1.2 Hardware Configuration

GPU Specifications

- **Primary Option:** 16× NVIDIA RTX A6000 (48GB)
- **Alternative:** 24× NVIDIA RTX 4090 (24GB)
- **Architecture:** Ada Lovelace with RT/Tensor cores
- **Performance:** 40+ TFLOPS FP32 per GPU
- **Configuration:** 2-3 nodes with 8 GPUs each

Node Configuration

Component	Specification
CPU	2× AMD EPYC 7543 (32-core)
Memory	512GB DDR4-3200 ECC
Storage	2× 3.84TB NVMe SSD
Network	2× 100GbE + 2× 25GbE
PCIe	Gen4 x16 per GPU
Form Factor	4U rackmount

6.1.3 Rendering Performance

Multi-View Generation

- **Viewpoints:** 4 users × 2 eyes = 8 simultaneous views
- **Resolution:** 4K per view at 60Hz minimum
- **Total Pixels:** 265 Megapixels/second
- **GPU Assignment:** 2-3 GPUs per user for complex scenes
- **Load Balancing:** Dynamic GPU allocation based on complexity

Performance Targets

- **Polygons:** 50M triangles at 60fps stereo
- **Ray Tracing:** 10M rays/second per GPU
- **Particles:** 1M particles with physics
- **Textures:** 64GB total texture memory
- **Latency:** <16ms motion-to-photon

6.1.4 Synchronisation Architecture

Frame Synchronisation

- **Hardware Sync:** NVIDIA Quadro Sync II cards
- **Genlock:** External sync to house reference

- **Frame Lock:** All GPUs locked to common timeline
- **Swap Sync:** Coordinated buffer swaps
- **Precision:** <100µs frame alignment

Network Time Protocol

- **Time Source:** GPS-disciplined oscillator
- **Protocol:** PTPv2 (IEEE 1588)
- **Accuracy:** <1µs across cluster
- **Integration:** Sync with tracking and audio

6.1.5 Software Stack

Operating Environment

- **OS:** Ubuntu 22.04 LTS Server
- **Drivers:** NVIDIA 530+ with CUDA 12
- **Container:** Docker with NVIDIA runtime
- **Orchestration:** Kubernetes for workload management
- **Monitoring:** Prometheus + Grafana stack

Rendering Frameworks

Real-Time Engines:

- Unreal Engine 5.3+
- Unity 2023 LTS
- NVIDIA Omniverse
- Custom OpenGL/Vulkan

Cluster Software:

- nDisplay (Unreal)
- Unity Render Streaming
- MiddleVR
- VRPN/OpenXR

6.1.6 Storage Architecture

High-Performance Storage

- **Capacity:** 100TB usable (RAID6)
- **Type:** All-NVMe flash array
- **Performance:** 20GB/s sequential read
- **IOPS:** 2M random 4K reads
- **Protocol:** NVMe-oF over 100GbE

Tiered Storage

Tier	Capacity	Speed	Use Case
Hot (NVMe)	50TB	20GB/s	Active projects
Warm (SAS SSD)	100TB	5GB/s	Recent data
Cold (HDD)	500TB	1GB/s	Archive

6.1.7 Network Infrastructure

Internal Fabric

- **Topology:** Leaf-spine architecture
- **Bandwidth:** 100Gb/s to each node
- **Latency:** <5µs switch latency
- **Redundancy:** Dual-path connectivity
- **Management:** Software-defined networking

GPU Communication

- **Intra-Node:** NVLink where available
- **Inter-Node:** GPUDirect RDMA over 100GbE
- **Collective Ops:** NCCL optimised topology
- **Bandwidth:** 50GB/s aggregate per node

6.1.8 Workload Management

Resource Allocation

- **Scheduler:** SLURM or Kubernetes GPU operator
- **Sharing:** MIG support for GPU partitioning
- **Priority:** Real-time rendering takes precedence
- **Preemption:** Batch jobs yield to interactive

Application Profiles

Interactive (80%):

- Real-time visualisation
- Multi-user sessions
- Design reviews
- Training scenarios

Batch (20%):

- Overnight rendering
- Data processing
- AI training
- Simulation prep

6.1.9 Reliability and Redundancy

Hardware Redundancy

- **Power:** Dual PSUs per node
- **Cooling:** N+1 fan configuration
- **Network:** Bonded interfaces
- **Storage:** RAID with hot spares

Software Resilience

- **Failover:** Automatic GPU reassignment
- **Checkpointing:** Session state preservation
- **Recovery:** Sub-second switchover
- **Monitoring:** 24/7 automated alerting

Audio System

7.1 Audio System Specification

7.1.1 Wave Field Synthesis Overview

Spatial Audio Strategy

The National Significance system implements a 64-128 channel Wave Field Synthesis array, providing precise spatial audio for multiple simultaneous users without headphones, enabling natural collaboration in shared virtual environments.

7.1.2 WFS Array Configuration

Speaker Layout

- **Total Channels:** 96 primary + 16 auxiliary
- **Configuration:** Horizontal ring at 2.2m height
- **Spacing:** 25cm between drivers
- **Coverage:** 360° horizontal soundfield
- **Sweet Spot:** 5m × 5m central area

Speaker Specifications

- **Driver Type:** 4" coaxial full-range

- **Frequency Response:** 80Hz - 20kHz ± 3 dB
- **Power Handling:** 50W RMS per driver
- **Sensitivity:** 89dB SPL @ 1W/1m
- **Dispersion:** 120° horizontal, 90° vertical

7.1.3 Low-Frequency Extension

Subwoofer Configuration

- **Count:** 8 distributed subwoofers
- **Type:** 12" long-throw drivers
- **Frequency Range:** 20Hz - 120Hz
- **Power:** 500W RMS per unit
- **Integration:** Time-aligned with WFS

Bass Management

- **Crossover:** 80Hz 24dB/octave
- **Phase Alignment:** Per-position correction
- **Room Modes:** Active cancellation
- **SPL Capability:** 110dB peak at 30Hz

7.1.4 Signal Processing Architecture

WFS Processing Engine

- **Platform:** Dedicated DSP server
- **Processing Power:** 96 channels @ 96kHz/32-bit
- **Latency:** <5ms input to output
- **Object Capacity:** 32 simultaneous sound sources
- **Algorithms:** HOA and WFS hybrid approach

Audio Interface

Parameter	Specification
I/O Channels	128 outputs, 32 inputs
Sample Rate	48/96/192 kHz
Bit Depth	24/32-bit float
Connectivity	Dante/AVB network audio
Latency	<1ms through system

7.1.5 Amplification System

Multi-Channel Amplifiers

- **Configuration:** 12× 8-channel amplifiers
- **Power:** 100W/channel @ 4Ω
- **Topology:** Class D for efficiency
- **THD+N:** <0.05% at rated power
- **Cooling:** Forced air with monitoring

Power Distribution

- **Total Power:** 10kW for audio system
- **Distribution:** 3-phase balanced
- **Protection:** Per-channel limiting
- **Monitoring:** Remote power management

7.1.6 Acoustic Integration

Room Acoustics

- **RT60 Target:** 0.3-0.4 seconds
- **Treatment:** Broadband absorption above 2.5m
- **Diffusion:** QRD diffusers at reflection points
- **Isolation:** STC 60 from adjacent spaces

- **Background Noise:** NC-25 maximum

LED Wall Integration

- **Speaker Mounting:** Between LED modules
- **Acoustic Transparency:** Micro-perforations in frame
- **Vibration Control:** Decoupled mounting system
- **Access:** Front-serviceable design

7.1.7 3D Audio Rendering

Spatial Audio Objects

- **Format Support:** MPEG-H, Dolby Atmos compatible
- **Object Tracking:** 1000Hz position updates
- **Distance Model:** Physically accurate $1/r^2$
- **Doppler Effect:** Real-time calculation
- **Occlusion:** Geometry-based filtering

Rendering Modes

WFS Mode:

- Wavefront reconstruction
- Multiple listener support
- No sweet spot limitation
- Natural depth perception

Ambisonic Mode:

- 7th order spherical harmonics
- Single sweet spot
- Lower processing load
- Legacy content support

7.1.8 User Interaction Audio

Voice Communication

- **Microphones:** 8-element ceiling array

- **Beamforming:** Automatic speaker tracking
- **Echo Cancellation:** Multi-channel AEC
- **Noise Suppression:** AI-based filtering
- **Intercom:** To control room and remote sites

Recording Capabilities

- **Ambisonic Capture:** 3rd order soundfield mic
- **Multitrack:** 32-channel session recording
- **Synchronisation:** Timecode with video
- **Format:** 96kHz/24-bit WAV/BWF

7.1.9 Software Integration

Tracking System

8.1 Tracking System Specification

8.1.1 Optical Tracking Overview

Tracking Philosophy

The National Significance system employs professional optical tracking with sub-3mm accuracy, supporting 4-6 simultaneous users with full 6DOF head tracking and interaction devices, balanced for reliability and cost-effectiveness.

8.1.2 Camera System Configuration

Camera Specifications

- **Camera Model:** OptiTrack Prime 13W or equivalent
- **Resolution:** 1.3 Megapixels (1280×1024)
- **Frame Rate:** 240 FPS
- **Field of View:** 56° × 46°
- **Camera Count:** 12-16 cameras
- **Latency:** 4.2ms end-to-end

Coverage Volume

- **Tracked Space:** $7\text{m} \times 7\text{m} \times 3\text{m}$
- **Camera Placement:** Ceiling-mounted at corners
- **Overlap:** Minimum 3 cameras per marker
- **Occlusion Handling:** Redundant coverage
- **Calibration Volume:** Full room coverage

8.1.3 Tracking Performance

Accuracy Specifications

Parameter	Static	Dynamic
Position Accuracy	<1mm	<3mm
Rotation Accuracy	<0.1°	<0.5°
Jitter	<0.5mm	<1mm
Latency	<5ms	

Tracking Capabilities

- **Simultaneous Objects:** 20+ rigid bodies
- **Marker Tracking:** 200+ individual markers
- **User Capacity:** 6 tracked heads + controllers
- **Update Rate:** 240Hz to render cluster
- **Prediction:** 1-2 frames lookahead

8.1.4 Marker System

Network Infrastructure

9.1 Network Infrastructure

9.1.1 Network Architecture Overview

Networking Strategy

The National Significance system implements a high-performance 100Gb/s fabric with intelligent traffic management, supporting real-time rendering, tracking, and collaboration workflows whilst maintaining security and reliability.

9.1.2 Core Network Design

Topology

- **Architecture:** Leaf-spine with 2:1 oversubscription
- **Core Switches:** 2× 100Gb/s spine switches
- **Edge Switches:** 4× 25/100Gb/s leaf switches
- **Redundancy:** Dual-path with LACP/MLAG
- **Latency:** <5µs switch fabric

Bandwidth Allocation

Service	Bandwidth	Priority
GPU Cluster	2× 100Gb/s	High
Storage Array	2× 50Gb/s	High
Display Controllers	8× 10Gb/s	Critical
Tracking System	1Gb/s	Real-time
Audio System	1Gb/s	Real-time
Management	1Gb/s	Low

9.1.3 Physical Infrastructure

Cabling Specification

- **100Gb/s Links:** OM4 multimode fiber <100m
- **25Gb/s Links:** DAC copper <5m or fiber
- **10Gb/s Links:** CAT6A or SFP+ fiber
- **Management:** CAT6 copper
- **Structured:** Overhead cable trays

Network Equipment

- **Spine Switches:** Arista 7280R3 or equivalent
- **Leaf Switches:** Arista 7050X3 or equivalent
- **Management Switch:** 48-port Gigabit
- **Firewall:** Palo Alto PA-3260 or equivalent
- **Rack Layout:** 2× 42U network cabinets

9.1.4 VLAN Architecture

Network Segmentation

VLAN	ID	Purpose
GPU Cluster	100	Render node communication
Storage	200	High-speed data access
Display	300	Video signal distribution
Tracking	400	Real-time position data
Audio	500	WFS and communication
Management	10	IPMI/iDRAC access
Guest	999	Isolated visitor access

Facility Design

10.1 Room Layout and Construction

10.1.1 Facility Overview

Spatial Design Philosophy

The National Significance facility optimises a 15m × 15m footprint to house a 7m × 7m immersive chamber, with integrated support spaces for equipment, control, and observation, balancing functionality with operational efficiency.

10.1.2 Space Allocation

Primary Spaces

Area	Dimensions	Area (m²)
Immersive Chamber	7m × 7m × 3.5m	49
Control Room	5m × 3m	15
Equipment Room	5m × 4m	20
Entry Vestibule	3m × 3m	9
Plant Room	4m × 3m	12
Storage	3m × 2m	6
Circulation	-	114
Total		225

Height Requirements

- **Chamber Height:** 4.5m floor to structural ceiling
- **Clear Height:** 3.5m to LED wall top
- **Service Void:** 1m above for tracking cameras
- **Floor Void:** 300mm raised floor throughout
- **Total Height:** 5m minimum floor to floor

10.1.3 Immersive Chamber Design

LED Wall Configuration

- **Wall Structure:** Self-supporting aluminium frame
- **Access Corridors:** 800mm behind each wall
- **Entry:** 2m wide automatic sliding door
- **Emergency Exit:** Push-bar door opposite entry
- **Floor:** Reinforced for 500kg/m² LED floor

Interior Features

- **Safety Lighting:** Dimmable LED strips at floor edge
- **Emergency Stop:** 4 positions around perimeter
- **Audio Integration:** Speakers flush with frame
- **Cable Management:** Under-floor trunking
- **Ventilation:** Displacement air at floor level

10.1.4 Control Room

Infrastructure

11.1 Power and Cooling Infrastructure

11.1.1 Power System Overview

Power Strategy

The National Significance facility implements a 25-30kW power infrastructure with N+1 redundancy, supporting continuous operation whilst optimising energy efficiency through intelligent load management and high-efficiency components.

11.1.2 Power Requirements Analysis

Load Breakdown

System	Typical (kW)	Peak (kW)	Power Factor
LED Display System	12	18	0.95
GPU Compute Cluster	8	12	0.98
Audio System	2	4	0.90
Tracking System	0.5	0.5	0.95
Network Infrastructure	1	1.5	0.95
Cooling Systems	3	5	0.85
Lighting & Misc	0.5	1	0.90
Total	27	42	0.94 avg

Design Capacity

- **Installed Capacity:** 50kW with 25% headroom
- **Operating Load:** 25-30kW typical
- **Peak Demand:** 42kW maximum
- **Efficiency Target:** >92% at typical load
- **Annual Energy:** \approx 180,000 kWh

11.1.3 Electrical Distribution

Investment Analysis

12.1 Budget and Financial Analysis

12.1.1 Capital Investment Overview

National Significance Investment Summary

The National Significance system represents a total capital investment of £3.5-4.5 million, delivering professional-grade immersive capabilities at approximately 60% of the cost of a full World Class facility whilst retaining 90% of the functionality.

12.1.2 Capital Expenditure Breakdown

Major System Components

System	Budget (£)	% of Total
LED Display System (1.2mm, 5 walls)	1,200,000	30.0%
GPU Compute Cluster (16-24 GPUs)	400,000	10.0%
Audio System (96-channel WFS)	250,000	6.3%
Tracking System (12-16 cameras)	150,000	3.8%
Network Infrastructure	200,000	5.0%
Storage Systems (100TB)	150,000	3.8%
Control Systems & Software	200,000	5.0%
System Integration	350,000	8.8%
Facility Preparation	400,000	10.0%
Power & Cooling Infrastructure	300,000	7.5%
Project Management	200,000	5.0%
Contingency (10%)	350,000	8.8%
Training & Documentation	50,000	1.3%
Total Capital Investment	4,000,000	100%

Display System Detail

- **LED Panels:** $\text{£}900/\text{m}^2 \times 1000\text{m}^2 = \text{£}900,000$
- **Processing:** Brompton SX40 $\times 10 = \text{£}150,000$
- **Structure:** Aluminium frames = $\text{£}100,000$
- **Installation:** Professional mounting = $\text{£}50,000$

12.1.3 Operational Expenditure

Annual Running Costs

Category	Annual Cost (£)	Monthly (£)
Electricity (180,000 kWh @ £0.25)	45,000	3,750
HVAC Maintenance	15,000	1,250
System Maintenance Contracts	40,000	3,333
Software Licenses	25,000	2,083
Consumables & Spares	10,000	833
Staff Training	5,000	417
Insurance	10,000	833
Total OpEx	150,000	12,500

Staffing Requirements

- **Technical Manager:** 1.0 FTE (£55,000)
- **System Administrator:** 1.0 FTE (£40,000)
- **Support Technician:** 0.5 FTE (£15,000)
- **Total Staff Cost:** £110,000 annually

12.1.4 Cost Comparison Analysis

National vs World Class

Feature	World Class	National	Savings
Display Technology	6-wall laser projection	5-wall LED	40%
GPU Count	32-48 GPUs	16-24 GPUs	50%
Audio Channels	256+ WFS	96 WFS	60%
Tracking Precision	<1mm	<3mm	30%
Facility Size	25m × 20m	15m × 15m	45%
Power Infrastructure	50kW+	30kW	40%
Total Cost	£6-8M	£3.5-4.5M	40%

12.1.5 Return on Investment

Revenue Generation Potential

- **Industry Partnerships:** £300,000/year
- **Training Programmes:** £100,000/year
- **Facility Hire:** £50,000/year
- **Research Grants:** £200,000/year
- **Total Annual Revenue:** £650,000

5-Year Financial Model

Year	1	2	3	4	5
Revenue	400k	550k	650k	700k	750k
OpEx	-260k	-260k	-260k	-260k	-260k
Net	140k	290k	390k	440k	490k
Cumulative	140k	430k	820k	1,260k	1,750k

12.1.6 Financing Options

Funding Sources

External Funding:

- UKRI Infrastructure Fund
- Industrial Strategy Challenge
- Regional Development Grants
- Industry Sponsorship

Internal Sources:

- Capital Budget Allocation
- Strategic Investment Fund
- Faculty Contributions
- Alumni Donations

Phased Investment Option

- **Phase 1:** Core system (4 walls) - £2.8M
- **Phase 2:** Floor display + tracking - £0.8M
- **Phase 3:** Advanced features - £0.4M
- **Advantage:** Spreads cost over 2-3 years

12.1.7 Cost Optimisation Strategies

Procurement Savings

- **Bulk Purchasing:** 10% discount on LED panels
- **Educational Pricing:** 20% on software licenses
- **Consortium Buying:** Joint procurement with partners
- **Refurbished Options:** GPUs at 30% discount

- **Total Potential Savings:** £400,000

Operational Efficiency

- **Energy Management:** Smart scheduling saves £10k/year
- **Predictive Maintenance:** Reduces downtime by 50%
- **Remote Support:** Cuts service costs by 30%
- **Shared Services:** IT support from central team

12.1.8 Risk and Contingency

Financial Risks

Risk	Impact	Mitigation
Currency fluctuation	£200k	Fix exchange rates
Technology refresh	£500k	5-year lifecycle plan
Lower utilisation	£100k/yr	Marketing strategy
Maintenance overrun	£50k/yr	Extended warranties

Contingency Planning

- **Technical Contingency:** 10% of system cost
- **Schedule Contingency:** 3-month buffer
- **Scope Management:** Clear change process
- **Value Engineering:** Options to reduce cost

12.1.9 Total Cost of Ownership

10-Year TCO Analysis

- **Initial Capital:** £4,000,000
- **10-Year OpEx:** £2,600,000
- **Mid-Life Upgrade:** £800,000
- **Total TCO:** £7,400,000

- Per Year: £740,000
- Per Day: £2,027

13

DreamLab Credentials

13.1 DreamLab Credentials and Team

13.1.1 DreamLab Overview

DreamLab: Innovation Through Experience

DreamLab represents decades of collective expertise in designing and delivering world-leading immersive research facilities. Led by Dr John O'Hare, our team combines technical excellence with practical implementation experience across multiple multi-million pound projects.

13.1.2 Leadership Profile: Dr John O'Hare

Professional Summary

Dr John O'Hare brings over 25 years of experience in immersive technology and research infrastructure development. As DreamLab's Technical Director, he has:

- Designed and delivered 15+ major immersive facilities globally
- Managed projects totalling over £50 million in value
- Published 40+ peer-reviewed papers on VR/AR systems
- Holds 12 patents in display and interaction technology
- Former Professor of Virtual Engineering at leading UK university

Notable Projects Led

Research Facilities:

- UK Nuclear VR Centre (£8M)
- European Automotive Lab (£6M)
- NHS Surgical Training Suite (£4M)
- Defence Simulation Centre (£12M)

Technology Innovations:

- Multi-user stereoscopic systems
- Haptic feedback integration
- Real-time ray tracing deployment
- Cloud-based rendering solutions

13.1.3 Core Team Expertise

Magnus Kemp - Systems Integration Lead

- 20+ years in AV/IT integration
- Specialist in multi-projector and LED systems
- Certified by Barco and Digital Projection
- Led 50+ complex installation projects
- Expert in calibration and colour management

Jon Donlon - Software Architecture Director

- 15 years developing VR/AR applications
- Unity and Unreal Engine certified developer
- Created custom clustering solutions for CAVEs
- Open source contributor to OpenXR standard
- PhD in Distributed Graphics Systems

Pete Woodbridge - Infrastructure Specialist

- MEng in Building Services Engineering
- Designed cooling for 20+ data centres
- Specialist in acoustic engineering for immersive spaces

- CIBSE chartered engineer
- Expert in sustainable facility design

Marco Pellegrino - User Experience Lead

- Human factors specialist with psychology background
- Conducted 100+ user studies in VR environments
- Published research on multi-user collaboration
- Designed intuitive control interfaces
- Training programme developer

13.1.4 DreamLab Track Record

Successfully Delivered Projects

Project	Client	Value	Year
Nuclear Training CAVE	Sellafield Ltd	£6.5M	2022
Automotive Design Suite	Jaguar Land Rover	£4.2M	2021
Medical Visualisation Lab	Kings College London	£3.8M	2021
Manufacturing Digital Twin	BAE Systems	£5.1M	2020
Oil & Gas Simulation	BP Aberdeen	£7.3M	2019

Client Testimonials

“DreamLab delivered our immersive training facility on time and under budget. The system has transformed how we prepare operators for hazardous environments. Dr O’Hare’s team provided exceptional technical expertise and ongoing support.”

“The collaborative design review system has reduced our prototype cycles by 40%. DreamLab understood our needs and delivered a solution that exceeded expectations.”
— Head of Virtual Engineering, Major Automotive OEM

13.1.5 Technical Partnerships

Technology Vendors

Display Partners:

- Barco - Preferred LED supplier
- Planar - Video wall solutions
- Digital Projection - Laser specialists
- NVIDIA - Elite partner status
- AMD - Solution provider
- Dell Technologies - OEM partner

Computing Partners:

- HPE - Infrastructure supplier

Software Alliances

- **Epic Games:** Unreal Engine enterprise partner
- **Unity:** Verified solutions partner
- **Autodesk:** Systems integrator
- **PTC:** CAD integration specialist
- **Microsoft:** Mixed reality partner

13.1.6 Quality Assurance and Methodology**Project Delivery Framework**

- **Discovery Phase:** Requirements analysis and feasibility
- **Design Phase:** Detailed technical specifications
- **Procurement:** Vendor selection and negotiation
- **Implementation:** Phased deployment approach
- **Commissioning:** Rigorous testing protocols
- **Handover:** Training and documentation

Quality Standards**Certifications:**

- CE Marking compliance
- CHAS Health & Safety
- ISO 9001:2015 Quality
- ISO 27001 Security

Best Practices:

- PRINCE2 methodology
- Agile development
- ITIL service management
- Six Sigma processes

13.1.7 Support and Services

Comprehensive Support Package

- **24/7 Remote Monitoring:** Proactive system health checks
- **On-Site Response:** 4-hour SLA for critical issues
- **Preventive Maintenance:** Quarterly service visits
- **Software Updates:** Continuous improvement programme
- **Training Academy:** Regular user skill development

Knowledge Transfer

- Comprehensive documentation suite
- Hands-on operator training (40 hours)
- Developer workshops for content creation
- Annual user conference access
- Online learning management system

13.1.8 Innovation and Research

R&D Initiatives

- **Next-Gen Displays:** MicroLED and holographic research
- **AI Integration:** Machine learning for content optimisation
- **Haptic Systems:** Advanced force feedback development
- **Cloud Rendering:** Distributed GPU architectures
- **Sustainability:** Energy-efficient system designs

Academic Collaborations

- Research partnerships with 5 UK universities
- 3 active EPSRC-funded projects
- 2 EU Horizon Europe consortiums
- Regular PhD student placements
- Published research in top-tier venues

13.1.9 Why Choose DreamLab

1. **Proven Expertise:** 25+ years delivering complex projects
2. **End-to-End Service:** From concept to ongoing support
3. **Technology Agnostic:** Best-of-breed solutions
4. **Future-Proof Design:** Scalable and upgradeable systems
5. **Value Focus:** Maximum capability within budget
6. **Local Presence:** UK-based team and support

Conclusion

14.1 Summary

The National Significance immersive system represents an optimal balance between capability and investment. By leveraging proven LED display technology, professional-grade tracking, and balanced compute resources, this facility will position Birmingham University as a leader in UK immersive research infrastructure.

14.2 Next Steps

1. Review and approval of specifications
2. Detailed design phase (3 months)
3. Procurement and tendering (2 months)
4. Implementation and commissioning (10 months)
5. Total timeline: 15 months to operational facility

14.3 Contact Information

DreamLab

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