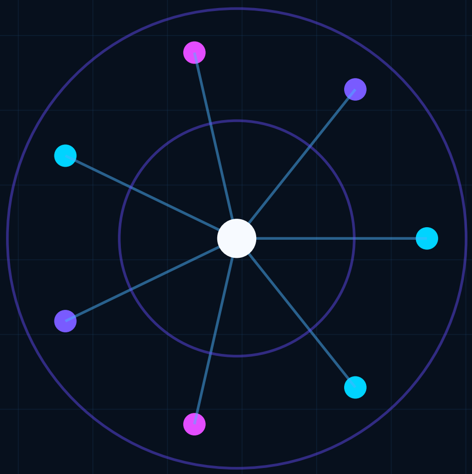
MYTHOS SYSTEMS

TECHNICAL LIBRARY / RESEARCH INTELLIGENCE

SPATIAL COMPUTING

# Spatial Computing (WebXR) & Immersive Data Visualization

Current-source review, evidence-bounded adoption decision, explicit limitations, reproducibility controls, and preserved source research note.



| PERMANENT ID | EVIDENCE | ADOPTION | FRESHNESS |
|---|---|---|---|
| RES-031 | A- | PILOT | WATCH |

Freshness review: 2026-09-17 / Next scheduled review: 2027-01-15

CANDIDATE RESEARCH REPORT / 2.1.0-CANDIDATE / PUBLIC

RESEARCH CONTROL SURFACE

# Required Research Fields

Each field remains independently reviewable; evidence strength does not imply production authority.

**EVIDENCE GRADE** — **A-**

Strength of the retained source set and technical basis.

**SOURCE AUTHORITY** — **2 registered authorities**

W3C WebXR Device API; W3C WebGPU Specification

**FRESHNESS** — **WATCH**

Reviewed 2026-09-17; dynamic sources require event-driven revalidation.

**CONFLICTS** — **VISIBLE / NOT SILENT**

Differences between specification, vendor behavior, research claims, and reproduced evidence must remain explicit.

**LIMITATIONS** — **EXPLICIT**

No certification, procurement approval, legal conclusion, or unbounded production claim is created by this report.

**REPRODUCIBILITY** — **REQUIRED**

Material claims require exact versions, representative data, failure cases, artifacts, and repeatable acceptance criteria.

**ADOPTION POSTURE** — **PILOT**

Pilot WebXR and immersive visualization for high-dimensional topology, simulation, training, and remote collaboration. Require accessibility, motion safety, fallback interfaces, and measured task value.

**REVIEW TRIGGER** — **2027-01-15**

Scheduled at 120 days; earlier on material source, vulnerability, implementation, or contradictory-evidence change.

SOURCE AUTHORITY / FRESHNESS

# Authority Register and Freshness Delta

Primary-source lineage is preserved; current-source changes are separated from unperformed implementation claims.

AUTHORITY 01

**W3C WebXR Device API**

https://www.w3.org/TR/webxr/

AUTHORITY 02

**W3C WebGPU Specification**

https://www.w3.org/TR/webgpu/

2026-09-17 FRESHNESS DELTA

Primary-source register retained and freshness controls advanced to the current review date. No new product or laboratory performance claim is introduced without reproduced evidence.

Freshness policy: scheduled review + immediate review on source supersession, material release, vulnerability, retraction, or contradictory evidence.

# Evidence Must Survive Contact With Reality

**SOURCE**
authority

**CLAIM**
bounded

**TEST**
representative

**EVIDENCE**
retained

**DECISION**
conditional

- Source authority is not implementation evidence. Product behavior, scale, security, interoperability, and operator fit remain environment-specific.

- Conflicting evidence is recorded rather than averaged away. Specification behavior, vendor implementation, preprint results, and production observations are separate evidence classes.

- Quantitative claims are informative until reproduced under documented hardware, software, data, topology, load, and failure conditions.

- Adoption posture is reversible. A stronger source set can coexist with a pilot-only or research-only recommendation when maturity, safety, economics, or operability remain unresolved.

# Decision Gate and Validation Plan

ADOPTION POSTURE

## PILOT

Pilot WebXR and immersive visualization for high-dimensional topology, simulation, training, and remote collaboration. Require accessibility, motion safety, fallback interfaces, and measured task value.

| | |
|---|---|
| **1 / SOURCE** | Pin exact versions, publication state, retrieved artifacts, and source hashes. |
| **2 / PROTOTYPE** | Demonstrate the core mechanism with representative data and instrumented execution. |
| **3 / FAILURE** | Exercise malformed input, dependency loss, stale state, overload, recovery, rollback, and misuse. |
| **4 / BASELINE** | Compare against an incumbent, classical, or simpler architecture using the same workload. |
| **5 / ACCEPT** | Record acceptance criteria, residual limitations, owner, expiration, and revalidation triggers. |

EXPIRATION / REVIEW TRIGGER

Next scheduled review: 2027-01-15 (120-day cadence). Review sooner after material source revision, breaking implementation release, critical vulnerability, retraction, benchmark contradiction, changed workload, or changed legal/safety boundary.

# 8. Complete Source Research Note

**SOURCE-LINEAGE NOTICE**

The following material preserves the complete original source note, excluding only the conversational wrapper and outer Markdown fence. Legacy status labels and absolute language are retained for traceability and do not override the candidate status, limitations, or adoption decision in this edition.

Document ID: RES-031 Version: 1.0.0 (Definitive Registry Edition) Status: Published Research Note Classification: Public Organization: Mythos Systems (MYTHOS AI) Owner: Aaron Stovall Effective Date: 2026-07-16 Applies To: Spatial computing architects, 3D graphics engineers, UI/UX designers building volumetric data interfaces, and AI engineers visualizing high-dimensional agent state spaces Companion Standards: MYTHOS-UX-0004 (Spatial Computing & 3D Engine Integration), MYTHOS-WEB-0001 (WebGPU & WebLLM), MYTHOS-UX-0001 (AI-Native Interface & Accessibility), MYTHOS-AI-0001 (Agentic Frameworks)

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The architecture of data visualization has failed. Organizations attempt to monitor massive, distributed AI agent telemetry, network topologies, and multi-dimensional knowledge graphs using 2D web dashboards. The human brain is not optimized to parse thousands of rows of logs or flat line charts; it is evolved to perceive depth, motion, and spatial relationships. When an engineer stares at a 2D screen trying to understand a cascading microservice failure, they are cognitively blind.

Furthermore, early attempts at "VR data visualization" relied on WebGL 1.0 and 2D-in-3D billboards (floating React panels in virtual reality). This paradigm causes UI jank, breaks depth perception, and induces physical nausea.

Spatial Computing, powered by WebGPU and the WebXR API, shatters this flat paradigm. It enables true volumetric data visualization—rendering 100,000+ real-time data points as 3D objects in space.

This research note defines the architectural dynamics of Immersive Data Visualization. It dissects the mechanics of utilizing WebGPU compute shaders for spatial data culling, the strict biological enforcement of sub-20ms motion-to-photon latency to prevent vestibular mismatch, and the use of WebXR spatial anchors to bind digital state to physical reality. Understanding these dynamics is a prerequisite for building the sovereign, cognitive command centers mandated by the Mythos UX Standards.

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To understand immersive visualization, we must move from flat DOM rendering to hardware-accelerated, volumetric rendering pipelines.

## 1.1 WebGPU (The Compute & Render Engine)

WebGL is a state-machine API tied to 20-year-old OpenGL paradigms. WebGPU is a modern, low-overhead API that maps directly to Vulkan, Metal, and Direct3D 12.

- The Advantage: WebGPU introduces general-purpose compute shaders. Instead of the CPU calculating positions for 100,000 data points and sending them to the GPU, the raw data is loaded into a GPU buffer. A WebGPU compute shader executes in parallel across thousands of threads to calculate physics, spatial hashing, and culling, directly feeding the vertex shader. This eliminates the CPU-to-GPU bottleneck.

## 1.2 WebXR (The Spatial Abstraction Layer)

WebXR is the API that connects the web browser to XR hardware (Meta Quest, Apple Vision Pro, PC VR).

- The Mechanic: WebXR provides the `XRSession`, which handles the immersive render loop. It delivers `XRViewerPose` data—the exact position and orientation of the user's head and eyes—every frame. The renderer uses this pose to calculate the stereoscopic view matrices.

### 1.3 Volumetric UI vs. 2D-in-3D

Legacy VR applications render 2D HTML menus as textures on flat planes in 3D space. This causes text to blur when the user moves closer and breaks the sense of presence.

- The Volumetric Paradigm: Data is rendered as true 3D objects. A network topology is a web of glowing nodes in physical space. A microservice latency heatmap is a 3D terrain that the user can walk around. Depth, parallax, and scale are the primary methods of information transfer, not text.

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While spatial computing unlocks human-centric data parsing, it introduces severe physical and biological constraints that flat web development ignores.

### 2.1 The Motion-to-Photon Latency Limit

The most critical constraint in XR is biological. Motion-to-photon latency is the time between the user moving their head and the screen updating to reflect the new perspective.

- The Flaw: If this latency exceeds 20 milliseconds, the brain detects a mismatch between the vestibular system (inner ear) and the visual system. The result is simulation sickness (nausea, dizziness).
- The Mitigation: The WebXR render loop MUST execute at 72Hz to 120Hz. The application logic MUST NOT block the render thread. Heavy AI telemetry processing MUST be offloaded to Web Workers or a dedicated edge compute node.

### 2.2 The VRAM and Fill Rate Ceiling

Rendering 100,000 unique data points at 90Hz in stereoscopic 4K requires massive fill rate and VRAM.

- The Flaw: If each data point is a complex 3D mesh (e.g., a 1,000-poly sphere), the GPU will choke on vertex processing, dropping the frame rate below 72fps, causing nausea.
- The Mitigation: The architecture MUST utilize imposters (billboards) or GPU instancing. All 100,000 data points are rendered as instances of a single, low-poly quad or point sprite. The specific data variation (color, size) is passed via instance buffers.

### 2.3 The Focus Conflict (Vergence-Accommodation)

In physical reality, when you look at a near object, your eyes cross (vergence) and your lenses focus (accommodation). In current XR headsets, the focal distance is fixed (usually 1.5 meters).

- The Flaw: If a UI element is placed 5 centimeters from the user's virtual face, their eyes cross, but the lens tries to focus at 1.5 meters. This causes severe eye strain and headaches.
- The Mitigation: Volumetric UI elements MUST be placed between 1 meter and 5 meters from the user to minimize the vergence-accommodation conflict.

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To overcome the physical constraints of XR hardware, the architecture must utilize advanced rendering techniques and physical context.

### 3.1 Foveated Rendering (The Performance Multiplier)

The human eye only sees high detail in the center of the retina (the fovea).

- The Mechanic: Eye-tracking hardware on the XR headset determines exactly where the user is looking. The WebGPU renderer renders the center 20% of the screen at full 4K resolution. The peripheral 80% is rendered at drastically reduced resolution (e.g., 25%).
- The Impact: GPU compute requirements drop by 60%. This allows the system to maintain 120fps while rendering massive datasets, without the user perceiving any quality loss.

### 3.2 Late-Latching (Defeating Latency)

Reading the head pose at the start of the frame, processing logic, and then rendering takes too long. By the time the frame is displayed, the user's head has moved further, causing latency jitter.

- The Mechanic: Late-latching (or late-stage reprojection) allows the renderer to update the camera rotation matrix milliseconds before the frame is submitted to the display, based on the latest IMU (Inertial Measurement Unit) data. This shaves critical milliseconds off the motion-to-photon latency, ensuring the 20ms bound is never breached.

### 3.3 Spatial Anchors (Persistent Digital State)

A spatial computing command center is most powerful when it maps to the physical world.

- The Mechanic: WebXR provides the `XRAnchor` API. An anchor is a coordinate system that the headset's SLAM (Simultaneous Localization and Mapping) algorithm tracks against physical features (walls, desks).
- The Impact: An engineer can place a 3D model of the server rack failure on their physical desk. They can walk away, go get coffee, come back, and the 3D model is still hovering exactly where they left it, bound to the physical desk. This creates a persistent, spatially-aware operational environment.

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The fundamental shift of spatial computing is the decoupling of data density from cognitive overload.

- Multi-Dimensional Parsing: A 2D dashboard can show "Latency" and "Throughput." A 3D volumetric graph can show Latency (X-axis), Throughput (Y-axis), Geographic Region (Z-axis), Error Rate (Color), and Payload Size (Node Size), all simultaneously. The human brain instantly perceives the outlier cluster in 3D space.
- Muscle Memory: Engineers can organize their physical workspace. Logs go on the left wall, real-time metrics float above the desk, and the AI agent's cognitive trace wraps around them in a sphere. This spatial mapping leverages human muscle memory, allowing the engineer to react to anomalies faster.
- Physical AI Telemetry: For physical robots (`MYTHOS-ROB-0001`), the telemetry is inherently 3D. Viewing a robot's LiDAR point cloud and planned trajectory in a 2D top-down map is abstract. Viewing it as a 1:1 scale 3D hologram in front of you is visceral and immediate.

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To deploy Spatial Computing in production, the Mythos Architecture enforces strict WebGPU pipeline isolation, hardware discovery, and deterministic frame budgets.

### 5.1 The Deterministic Frame Budget

The WebXR render loop is sacred. It MUST NOT be blocked by network requests or LLM inference.

- The Mitigation: The architecture MUST separate the Data Plane from the Render Plane. A Web Worker continuously fetches AI telemetry and updates a `SharedArrayBuffer`. The WebGPU render loop reads from this buffer synchronously every frame. If the network drops, the render loop continues smoothly, simply displaying the last known state.

### 5.2 Dynamic Level of Detail (LOD)

When rendering 100,000 data points, not all points are equally important.

- The Mitigation: The compute shader MUST implement a dynamic LOD algorithm. Data points representing healthy services are clustered into a single low-detail aggregate. When an anomaly occurs (e.g., a spike in errors), the compute shader dynamically splits that cluster into high-detail individual nodes, drawing the user's visual attention to the failure.

### 5.3 Sovereign Anchor Persistence

Spatial anchors must survive device restarts and be shareable among multiple operators.

- The Mitigation: The architecture MUST map `XRAnchor` UUIDs to the Mythos Source of Truth (NetBox/Mnemosyne). If Operator A places an AI diagnostic hologram on the server room wall, the anchor is saved to the cloud. Operator B, wearing a different headset, walks into the room and the hologram instantly materializes in the exact same physical location.

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The strategy of constraining human-computer interaction to flat, 2D monitors is a relic of the computing limitations of the 20th century. As AI and distributed systems generate multi-dimensional, high-density telemetry, the 2D interface becomes a cognitive bottleneck. By leveraging WebGPU and WebXR, we transform data visualization from a reading exercise into a spatial, physical experience. By strictly enforcing sub-20ms latency, foveated rendering, and physical spatial anchors, we unlock the human brain's innate ability to perceive depth and navigate complex realities, creating the ultimate sovereign command center.

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A 2D dashboard is a window; spatial computing is a room.
A flat chart is a bottleneck; a 3D volumetric graph is a landscape.
A dropped frame is a lag; a 20ms latency violation is nausea.
A digital object in a vacuum is temporary; a spatial anchor is permanent.

The data is multi-dimensional; the interface must be absolute.

> Screens may be flat.
> Spatial perception must be absolute.
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End of Research Note RES-031

# 9. Source Register

| Source | Authority and Status | Freshness Control |
|---|---|---|
| W3C WebXR Device API<br>https://www.w3.org/TR/webxr/ | Primary web specification<br>Living specification<br>Published: Living | Validated: 2026-07-22<br>Review on material revision, withdrawal, supersession, or scheduled report review. |
| W3C WebGPU Specification<br>https://www.w3.org/TR/webgpu/ | Primary web standard<br>Living W3C specification<br>Published: Living | Validated: 2026-07-22<br>Review on material revision, withdrawal, supersession, or scheduled report review. |

# 10. Lineage, Review, and Publication Record

| Record | Value |
|---|---|
| Original source file | RES-031_Spatial_Computing_WebXR_Immersive_Data_Visualization.md |
| Original source words | 1772 |
| Upgrade type | Enterprise research report; source and freshness validation; limitations; adoption decision; reproducibility plan |
| Generated on | 2026-07-22 |
| Current status | Candidate Research Report |
| Publication authority | Formal Mythos approval not yet recorded |
| Next review | 120 days or event-driven trigger, whichever occurs first |