

Title: State-Based Browser-Native Simulation: Enabling Secure, Scalable M&S at the Edge via WebGPU

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Abstract: Modeling and simulation (M&S) infrastructure for defense environments faces significant challenges regarding bandwidth constraints, security classification requirements, and accessibility across distributed networks. Traditional visualization systems rely on remote rendering and video streaming, which introduce latency, high bandwidth consumption, and security vulnerabilities incompatible with classified or constrained operational environments. This paper presents a novel approach to distributed M&S utilizing browser-native technologies to transmit simulation state data rather than rendered pixels.

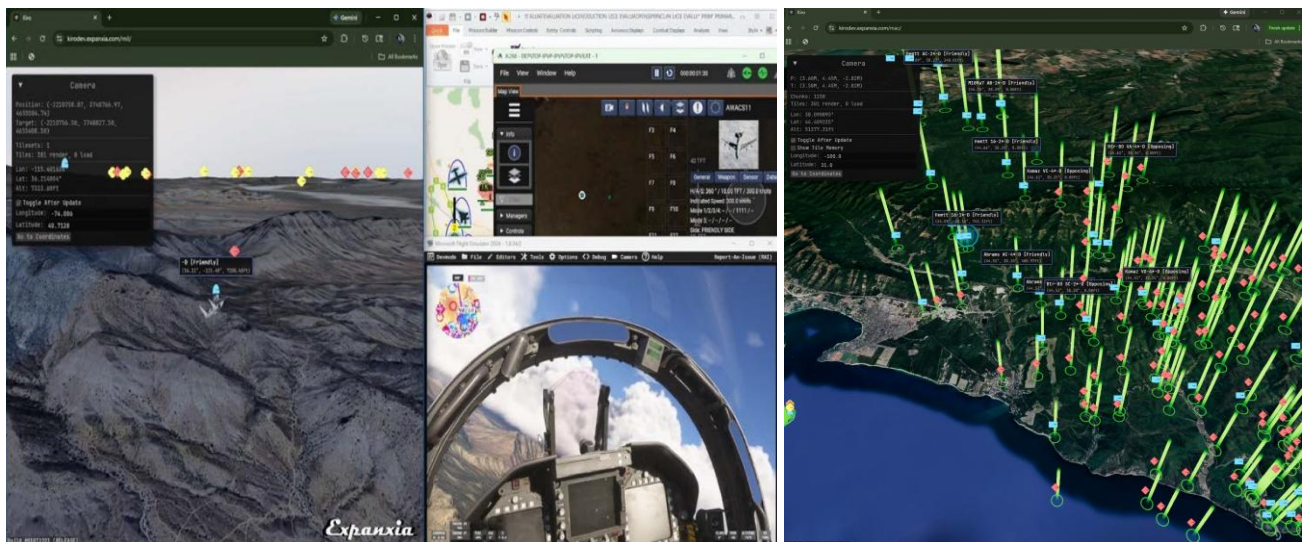
The proposed architecture leverages WebGPU and WebAssembly to execute high-fidelity 3D visualization directly within standard web browsers without requiring specialized client hardware or video streaming infrastructure. By decoupling rendering from computation, the system transmits only essential simulation state updates—such as entity position, behavior logic, and sensor outputs. This state-based streaming methodology reduces network requirements by orders of magnitude compared to traditional cloud visualization, enabling operation across low-bandwidth links and air-gapped networks.

This emerging capability supports critical warfighter needs in M&S at the edge and secure data infrastructure. The platform enables theater-scale distributed simulations that can be accessed from any modern browser, democratizing access to high-fidelity digital twin environments for command and control (C2) analysis, mission rehearsal, and electronic warfare experimentation. Security is maintained through FIPS-140 compliant encryption and QUIC-based protocols, ensuring compatibility with CUI and classified networks while supporting disconnected operational modes.

Furthermore, this architecture facilitates the integration of autonomous systems and AI agents within secure environments. The low-latency state synchronization allows for real-time interaction between human operators and autonomous entities in multi-domain settings (Air, Land, Maritime, Cyber). This capability accelerates simulation-driven acquisition by providing a scalable testbed for validating autonomous behaviors against complex threat models without exposing sensitive data over public networks.

By shifting from video-based streaming to state-based distributed simulation, this technology enables secure, massive-scale operational environments that are deployable in constrained or disconnected settings. The result is an emerging M&S toolset that enhances force preparation and decision support while maintaining rigorous security standards required for modern defense operations.

Projected track for submission: Emerging Capabilities



Actual Browser 3D Multi-Domain Sensor and Simulation (Not AI Generated, No Cloud)

The diagram illustrates the architecture of the KDR system. It includes a 'Sensor -> State Adapter Microservices' block, an 'Authoritative Central Engagement State Core' block, and a 'Deterministic Replay Engine' block. A 'Low Bandwidth (State Deltas) No Video Streaming No Client Installation' block is also shown. The diagram is overlaid on a 3D terrain map.

KDR Broadcaster

Server Connection

P: 127.0.0.1 Port: 8433 Connect Disconnect

Server Recording OFF

Scenario D: auto-generated if empty

Start Recording Stop & Save Reform

Server Recordings Get Recordings

Click to load	Duration	Size	Actions
mac-vol_20200209_062328.dcr	11:52:361	696	38.7 MB Save Del
mac-vol_20200209_063446.dcr	04:50:518	1	679.7 KB Save Del
mac-vol_20200209_062414.dcr	04:16:303	1	582.9 KB Save Del
mac-vol_20200209_061614.dcr	04:11:842	1	548.5 KB Save Del

Recording File

mac-vol_20200209_063446.dcr Scenario: mac-vol Duration: 00:04:58 Hosts: 1

Playback Controls

Play Stop Pause Next Previous Interpolation: Enabled

00:01:27 00:04:58

0.25x 0.5x 1x 2x 4x 8x 15x 32x

Recording Time: 01:30:43.230759 Playback Position: 00:01:27.321310 Elapsed: 00:01:40