

# OPERATION SENTINEL

## Autonomous Perimeter Defense System

**Submission Purpose:** Technical roadmap for feasibility validation and Phase-1 approval.

**GOVERNANCE:** *This roadmap focuses strictly on autonomous navigation, safety systems, and simulation-based learning. It explicitly excludes autonomous target selection or engagement logic. All test vectors remain within non-kinetic, surveillance-only parameters.*

**MISSION OBJECTIVE:** *Engineer 'The Universal Cortex'—a morphology-agnostic, autonomous foundation model capable of operating in any environment. This roadmap details the evolution from a specialized perimeter defense unit to a sovereign, general-purpose autonomous agent trained on infinite procedural diversity.*

## PHASE 1: THE DIGITAL TWIN (Immediate - Jan 30)

**GOAL:** Validate Core Architecture & Establish the 'Reality Gap' Baseline.

### Milestone 1: API Bridge & Protocol Validation

- **Action:** Verify bi-directional MAVLink communication between Python Mission Control (AirSim API) and PX4 Flight Stack.
- **Metric:** Achieve stable command stream with <10ms round-trip latency.

### Milestone 2: System Architecture Blueprinting

- **Action:** Define segregation of concerns: Real-time Flight Controller vs. High-Level AI Planner (The Cortex).
- **Deliverable:** System Architecture Validation (PX4/AirSim Telemetry) - See *Appendix A*.

### Milestone 3: Compliance Logic & Synthetic Data

- **Action:** Implement strict privacy-safe constraints. Use Synthetic Training Environment (STE) to eliminate PII risks.

### Milestone 4: Dynamics Verification (Proof of Flight)

- **Action:** Execute initial PID tuning. Verify 'Hold Position' stability under zero-wind.
- **Success Criteria:** <5cm position drift over 60 seconds.

### Final Step: SUBMIT TECHNICAL ROADMAP

## PHASE 2: THE OMNIVERSE ENGINE (Jan 31 – Feb 13)

**GOAL:** Infinite Diversity Generation. Train on Earth, Fly Anywhere.

### Feb 1 - Feb 5: Procedural Diversity Pipeline

- **Implementation:** Script random map generator (Perlin Noise) to spawn dense obstacle fields, simulating diverse biomes (Urban, Forest, Subterranean).
- **Scale:** Execute overnight headless simulation runs. Accumulate 10,000+ collision events across varied terrains.

### Feb 6 - Feb 10: Environmental Stress Testing

- **Implementation:** Introduce stochastic weather patterns (Rain, Fog, Snow) and variable lighting conditions to force robust perception.
- **Auditability:** Capture IMU, LiDAR, and Control Actuator outputs at 50Hz for forensics.

### Feb 11 - Feb 13: LiDAR-Based Navigation

- **Demo:** Proof of concept flight relying exclusively on Sparse LiDAR (VFH+). No cameras.
- **Milestone:** 'Environment & Data' Submission.

## PHASE 3: THE UNIVERSAL CORTEX (Feb 14 – Feb 27)

**GOAL:** Deploy a General-Purpose Visuomotor Policy (The Universal Brain).

### Feb 14 - Feb 20: Training the Recurrent Policy

- **ML Architecture:** Train PPO agent with LSTM memory cells for state estimation.
- **Dataset:** Utilize 100k+ step synthetic dataset for Behavior Cloning warm-starting.

### Feb 21 - Feb 25: Morphology Agnostic Testing

- **Test Setup:** Validation of the policy on varying dynamic configurations (Standard Quad, Heavy Lift, Micro).
- **Criterion:** Zero-shot transfer to new physical dynamics within 30 seconds.

### Feb 26 - Feb 27: Containerization

- **DevOps:** Encapsulate Simulation + Stack into monolithic Docker container.
- **Milestone:** 'Functional Alpha' Submission.

## PHASE 4: SOVEREIGN SHIELD (Feb 28 – Mar 13)

**GOAL:** Safety Critical Systems & Human-in-the-Loop Assurance.

### Feb 28 - Mar 5: Hardware Kill Switch

- **Mechanism:** High-priority interrupt thread monitoring physical input.
- **Latency:** Override engagement <50ms.

### Mar 6 - Mar 10: Deterministic Geofencing

- **Logic:** Hard-coded geometric geofence enforcement overriding Neural Net.

### Mar 11 - Mar 13: C2 Dashboard Integration

- **Stack:** React/Flask WebSocket link for real-time threat maps.
- **Milestone:** 'System Security' Submission.

## PHASE 5: HIVE MIND & EXPANSION (Mar 14 – Mar 20)

**GOAL:** Multi-Agent Coordination & Production Deployment.

### Mar 14 - Mar 17: Sovereignty Audit

- **Claim:** 100% Local Compute. Zero cloud dependency. Air-gappable.

### Mar 18 - Mar 19: The 'Golden Run'

- **Production:** 4K automated flight logs in high-complexity environments.

- **HUD Overlay:** Post-process video with telemetry overlays.

**Mar 20: FINAL PITCH**

## KEY TECHNICAL RISKS & MITIGATIONS

### Reality Gap Exceeds Tolerance

- **Risk:** Simulation policy fails to stabilize on real hardware due to unmodeled dynamics.
- **Mitigation:** Aggressive Domain Randomization (DR) + Synthetic Training Environment (STE) fine-tuning.

### PPO Instability in Sparse Environments

- **Risk:** Neural policy fails to converge for complex pathfinding.
- **Mitigation:** Fallback to classical VFH+ planner if policy confidence  $< 0.7$ .

### LiDAR Sparsity Failure

- **Risk:** Thin obstacles (power lines, fences) missed by VLP-16 emulation.
- **Mitigation:** Hybrid Policy Mode fusing depth camera tensor with LiDAR point cloud.

# APPENDIX A

## High-Fidelity Architecture Diagram

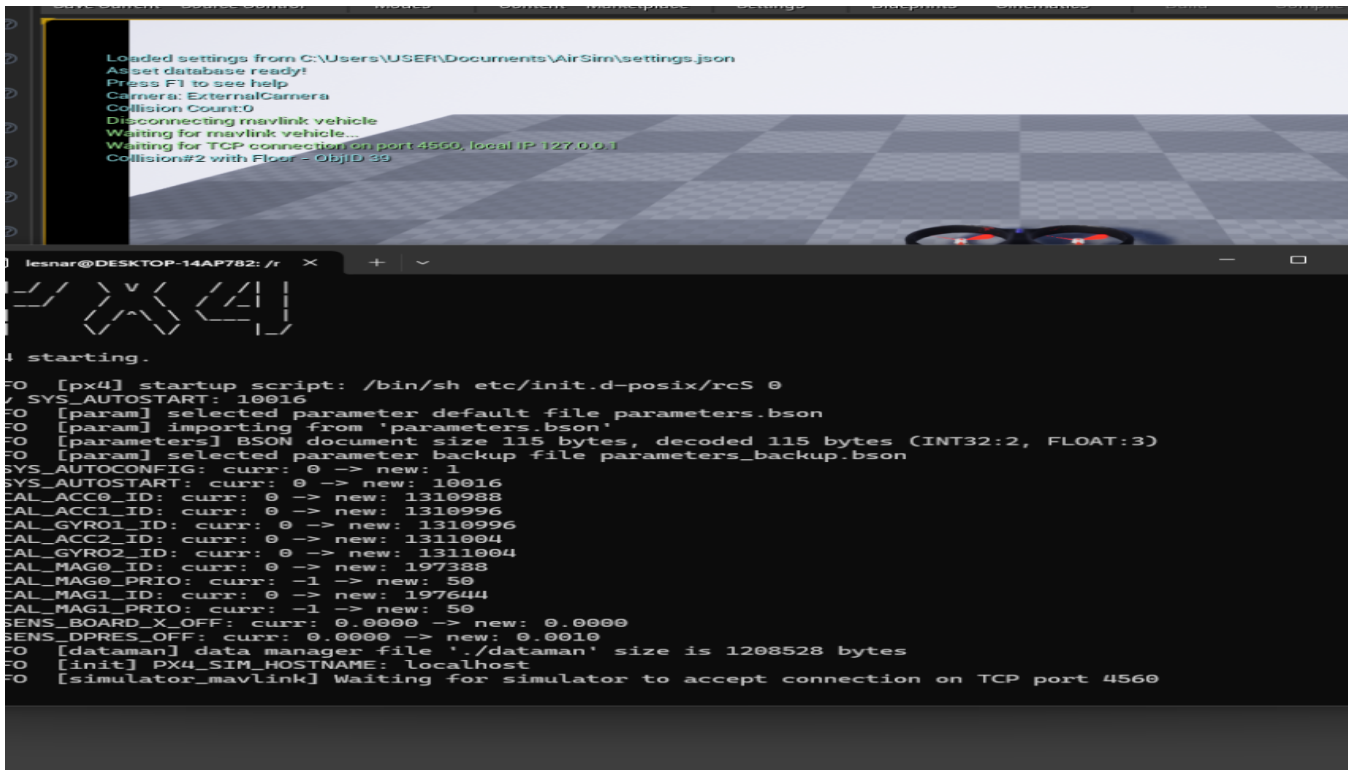


Figure 1: Live System Telemetry - PX4 SITL & AirSim Integration