AQNav

WHITEPAPER

Assured Mission Execution for Loitering Attritable UAS in GPS-Denied Battlespace

Executive Summary

The joint force needs affordable ways to place sensing and effects inside contested battlespace without exposing every mission to the loss of an exquisite platform. The Department of War (DoW) uses “attritable” to describe aircraft that are purpose-designed and routinely reusable, but affordable enough to tolerate putting them at risk.

Loitering attritable unmanned aerial systems (UAS) extend that logic by combining reach, loiter, modular payloads, and limited-operator or autonomous mission execution in a relatively low-cost platform. A representative system is a modular, launch-agnostic Group 3 UAS capable of loitering, beyond-line-of-sight operations, precision strike, electronic warfare, and ISR configurations. Its capabilities include air, ground, and surface launch options, modular kinetic and non-kinetic payloads, visual positioning, satellite beyond-line-of-sight communications, and a range of several hundred nautical miles.

The value of a loitering attritable system depends on more than reaching the general battlespace. It must know where it is during ingress, remain within the intended search or loiter geometry, correlate sensor observations to geography, and arrive at the mission decision point with sufficient navigation confidence. GPS jamming or spoofing can degrade those functions without immediately causing loss of controlled flight. For a one-way configuration, navigation failure before the terminal decision point can turn a mission-critical sortie into a failed effect and reduce the operational value of the broader attritable strategy.

Loitering attritable UAS create a different PNT problem from long-endurance ISR platforms. The primary objective is not necessarily to maintain a 40-hour orbit or return a high-value aircraft to base. It is to make each launch more likely to produce its assigned mission effect under the conditions for which the platform was procured: contested access, limited operator bandwidth, intermittent communications, and an acceptable risk of loss.

Why AQNAV

SandboxAQ developed AQNav to solve this critical gap. AQNav is a software-first, fully passive Magnetic Navigation (MagNav) system that provides GPS-independent positioning by matching real-time magnetic measurements against Earth's natural crustal magnetic signature – an immutable frame of reference.

GPS jamming overwhelms satellite signals with noise, alerting the crew to switch modes. GPS spoofing mimics the signal to feed the receiver a false position without triggering that alert and, like jamming, it is executable from standoff range. AQNav does not remove this threat outright: jamming or spoofing can still force a GPS-primary platform to revert to unaided inertial navigation with unbounded drift.Instead, with AQNav, the aircraft gains a continuously available, physics-anchored absolute position reference, AQNav shields the platform against the worst effects of GPS denial.

Spoofing AQNav's reference would require an adversary to place a powerful magnet within meters of the platform's magnetometer sensors, a far more difficult attack to mount than standoff GPS denial, with a fundamentally different threat profile. MagNav still depends on a trusted, high-integrity positioning source, and that trust can break down two ways: (1) residual platform or environmental magnetic interference, or (2) a stale or low-fidelity magnetic reference map. Neither is an adversary attack; both are data-quality and data-integrity problems. AQNav accomplishes this through physics-based AI models, sensor fusion, and real-time integrity monitoring. This combination is what makes AQNav a trusted, assured Positioning and Navigation (PN) source, built on open architecture to integrate with third-party hardware where required.

Three Value Propositions for Loitering Attritable UAS:

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Keep Attritable Weapons Affordable – and Effective: The value of an attritable system depends on producing and deploying enough units to accept operational risk without requiring exquisite hardware on every vehicle. AQNav is intended to complement lower-cost sensors with a passive magnetic reference that bounds drift, reducing pressure to add higher-cost navigation hardware that typically has a drastic increase in weight.

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Reach the Mission Area When GPS Goes Dark: A one-way or recoverable loitering system cannot produce its intended effect if navigation drift prevents it from reaching the assigned area. AQNav combines magnetic map matching with inertial data during contested ingress, giving the platform navigation an independent reference when GPS is unavailable or untrusted and external navigation infrastructure is absent.

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Wait for the Mission Decision, Not the GPS Fix: Extended loiter under GPS denial can turn position uncertainty into search-area drift, degraded track maintenance, and unreliable retasking. AQNav provides continuous positioning that preserves loiter geometry and geospatial confidence.

Architecture

Software-first Integration

AQNav operates within an Open Container Initiative (OCI)-compliant Docker container hosted directly on existing platform compute. Requiring zero additional compute hardware, AQNav ingests data from existing platform sensors, applies proprietary AI/ML electromagnetic interference (EMI) removal, and outputs continuous Position, Velocity, and Attitude (PVA) solutions via open-architecture protocols.

How AQNav Works: Physics + AI

AQNav processes raw sensor data through a streamlined three-stage pipeline:

Sense → Denoise → Estimate

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Sense: Onboard magnetometers capture and Ingest raw magnetic data from the surrounding environment.

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Denoise: A physics-informed AI stack removes platform EMI (which can exceed the crustal field signal by >1,000x) and solar/ionospheric EMI using integrated space-weather modules.

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Estimate: Fuses the clean crustal field magnetic signal and onboard magnetic reference maps with inertial data to output continuous PVA along with real-time covariance and integrity bounds.

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CONOPS: Group 3 Loitering Attritable UAS Mission

Strategic Context & Core Capability

A representative Group 3 loitering attritable UAS launches from an air, ground, or surface host to reach a contested mission area beyond the practical reach of a crewed platform or forward unit. It transits to the assigned area, establishes a search or loiter geometry, and conducts a mission or proceeds through a one-way mission decision.

AQNav runs in the background from mission initialization, providing an independent magnetic reference that the platform's navigation and integrity architecture can evaluate alongside GPS and INS. When GPS becomes unavailable, untrusted, or degraded, AQNav preserves position confidence through ingress, loiter, and the approach to the mission decision point.

Scheme of Maneuver (Operational Execution)

Execution spans five operational phases:

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Phase I (Pre-Flight): Theater magnetic reference maps are loaded alongside standard mission planning products.

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Phase II (Ingress and Loiter): The platform transits to the assigned area and establishes its approved search, surveillance, electronic-warfare, or mission geometry. AQNav runs continuously in the background as a backup absolute reference navigation source upon takeoff.

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Phase III (Contested Transit): Upon entering degraded corridors, AQNav's integrity engine compares all navigation sources and confirms the loss of GPS integrity. AQNav automatically shifts flight management to AQNav-aided INS, maintaining route accuracy without dependence on any external infrastructure (e.g., satellites, beacons, or VOR/TACAN) or signals that can be jammed, spoofed or denied.

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Phase IV (Preserve Attritable Value): AQNav maintains the position reference needed for sensor use, track maintenance, geospatial confidence, and the approach to the terminal mission phase.

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Phase V (Recover or Complete the Mission): For a recoverable configuration, AQNav continues to contribute position references during egress and return. For a one-way configuration, AQNav's value is concentrated before the irreversible terminal decision: it helps the platform and/or operator determine whether the platform has retained sufficient navigation confidence to continue, transition to another approved mode, or report that the mission cannot be completed as planned.

Desired End State: A representative loitering attritable UAS reaches and operates within its assigned mission area through a defined GPS-degraded condition with an additional, integrity-monitored navigation reference available to the approved platform architecture. The system preserves the opportunity for useful loiter, sensing, recovery, or mission effect.

Technical Specification and Adoption Pathway

Specification	Detail
Performance	Best Accuracy: 74 m Average Representation: ~0.5 nm (~925 m)
Sensor-agnostic	Magnetometers: scalar and vector types. IMU/INS: MEMS, tactical, and navigation grades.
Software Interfaces	ASPN-I, MavLink, and Onboard API for third-party interfaces
Physical Interfaces	MIL-STD-1553, ARINC-429, RS-232/422/485, Ethernet, USB
Compute	CPU: 1 CPU core (depending on configuration) RAM: < 2 GB Latency: < 10ms
Output Solution	Continuous PVA; position plus bounded-uncertainty estimate (covariance / 1-sigma)
Output Destinations	Mission Computer, Flight Management System, Electronic Flight Bag
Architecture (MOSA)	AQNav is built to the Modular Open Systems Approach (MOSA) that DoD acquisition policy increasingly requires: it integrates through open, published interfaces rather than a proprietary stack, adapts to whatever hardware and API the platform already has, and does not replace or lock out the existing navigation architecture.
Integrity	Per-fix covariance / 1-sigma, integrity monitoring with protection levels, fault detection and exclusion, graceful degradation

AQNav

Integrate AQNav into your navigation stack.

www.sandboxaq.com/solutions/aqnav