AQNav

WHITEPAPER

Contested Logistics for Long-Range Aerial Refueling and Airlift

Executive Summary

Contested logistics is the decisive operational challenge of great power competition. Title 10 U.S.C. § 2926(h) defines a contested logistics environment as one where an adversary "presents challenges in all domains and directly targets logistics operations, facilities, and activities," and joint doctrine is direct about the stakes: sustainment "determines the depth to which the joint force can conduct decisive operations" (JP 3-0).

Aerial refueling is the most stressed node within this system. As General Jacqueline D. Van Ovost, Commander of USTRANSCOM, stated in testimony before the House Armed Services Committee: "The air refueling fleet remains our most stressed fleet under wartime conditions" and "the lifeblood" of the joint force's ability to project power. The KC-46A Pegasus is the U.S. Air Force's (USAF) primary tanker recapitalization program and the aircraft most directly answering that stress.

The KC-46A uses GPS as its primary navigation source, supported by and integrated with inertial navigation and conventional radio aids. The aircraft was designed with anti-jam GPS receivers and has participated in USAF degraded-GPS testing. A KC-46 mission would not necessarily abort immediately after losing GPS; inertial and radio aids can support continued operation for a period, but the documented consequence is reduced navigation margin and greater risk to timing-sensitive rendezvous and terminal operations.

A tanker that cannot establish a trusted position cannot hold its assigned track, meet its Air Refueling Control Time (ARCT), or operate under reduced separation in dense, contested airspace. Today, that trusted position comes almost entirely from GPS, a signal adversaries can deny, jam, or spoof from standoff range. Contested logistics is, first and foremost, an assured navigation problem. Without it, mobility capacity cannot translate into combat power at the point of need.

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, shielding 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 Aerial Refueling Platforms:

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Maintain Mission Track Across Oceanic Corridors: Eliminates accumulated inertial drift during multi-hour oceanic transits where no ground-based navigation aids exist to reset the Inertial Navigation System (INS), and no visual landmarks are available to guide navigation.

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Expand Usable Operational Airspace: Tanker survivability and sortie generation increase or decrease relative to the orbit distance from the threat. RAND's KARMA model shows that tanker-orbit placement affects receiver fuel requirements, tanker flight-hour efficiency, and the number of receiver sorties that can be supported or scrubbed. AQNav restores platform access to orbits and corridors currently closed by GPS denial, expanding the range of viable orbit geometries and preserving fleet throughput and sustainment rates.

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Detect and Reject Misleading Navigation Information: Unlike jamming, which overwhelms the signal and alerts the crew to switch modes, spoofing mimics it and covertly corrupts navigation without triggering that alert. AQNav provides a highly spoof-resistant, physics-anchored reference source that natively rejects false GPS position inputs.

Architecture

Software-first Integration

AQNav operates within an Open Container Initiative (OCI)-compliant Docker container hosted directly on existing platform compute, including: Mission Computers, Flight Management Systems (FMS), or Electronic Flight Bags (EFBs). Requiring zero additional compute hardware, AQNav ingests data from existing platform magnetometers and IMUs, 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: USAF Aerial Tanker Platform

Strategic Context & Core Capability

To project joint power in Anti-Access/Area Denial (A2/AD) environments, the tanker requires Assured Positioning, Navigation, and Timing (alt-PNT) independent of GNSS/GPS. Its effectiveness in these environments depends on orbit placement, defensive systems, distributed basing, and resilient navigation. Near contested Air Refueling Control Points (ARCPs), adversary electronic attack, jamming, and spoofing threaten to disrupt receiver rendezvous and force mission aborts. AQNav addresses this critical challenge by providing an assured navigation solution that functions as the tanker's absolute position reference in place of GPS, available anywhere in the world. Fused with the platform's INS, it continuously bounds inertial drift, enabling confident multi-hour transits and expanding operational airspace.

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 (Mission Start): 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 (Refueling Rendezvous): The tanker holds station and services all assigned receivers, entering and exiting the corridor as though the contested environment were never a factor.

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Phase V (Return to Base): AQNav continues to provide independent position references throughout the return leg, supporting approaches into main operating bases or austere Agile Combat Employment (ACE) airfields without ground or satellite navigation aids.

Desired End State

An assured navigation capability that guarantees tanker availability, restores access to contested corridors, and ensures seamless joint force sustainment under total electromagnetic attack.

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