Pharos Spaceborne System

Kinematically-Informed Single-Satellite Agile Geolocation

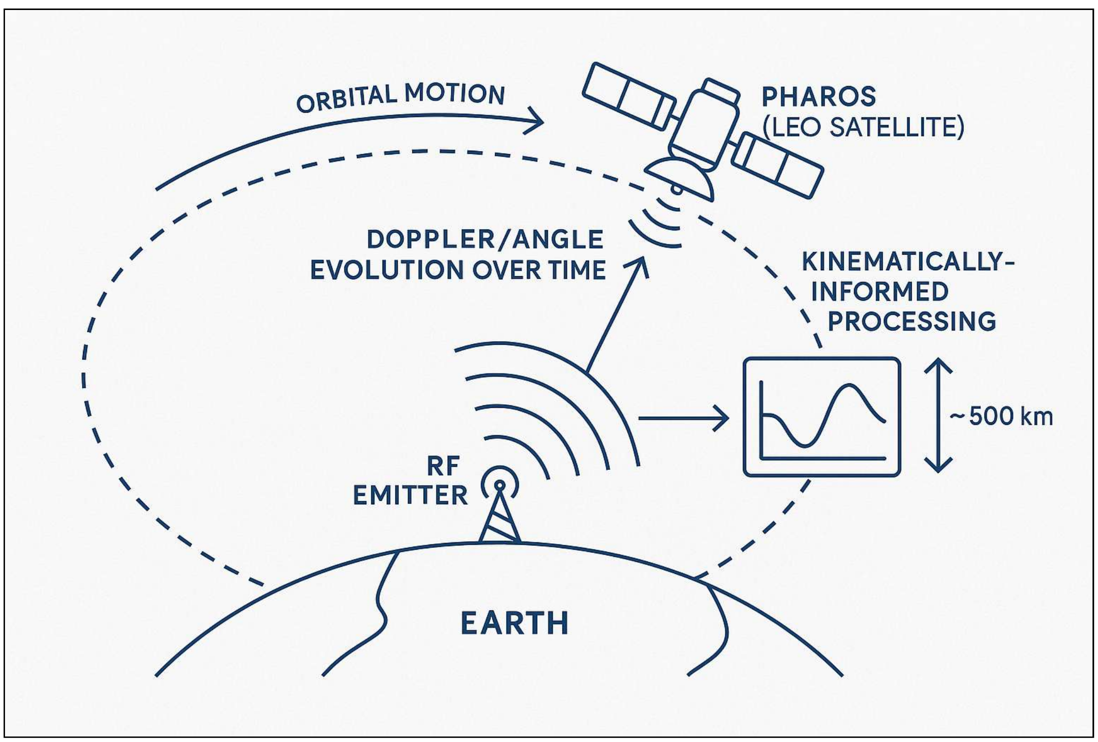
***Specifications:** All information presented herein represents design goals or target values for the future spaceborne system and is subject to change based on ongoing design, development, and testing. Technology Readiness Level (TRL) for the space-adapted system is currently low, pending results from the precursor Airborne Demonstration.*

Pharos geolocates RF emitters with high accuracy, targeting sub-100m performance using just a single satellite—achieving what previously required complex multi-satellite constellations.

A New Paradigm in RF Geolocation

Valence Intel Systems introduces Pharos, a revolutionary approach to Radio Frequency (RF) emitter geolocation from space. Moving beyond the constraints of traditional multi-satellite systems, Pharos utilizes a single, agile Low Earth Orbit (LEO) satellite. By intelligently harnessing the satellite's orbital motion and employing state-of-the-art signal processing and machine learning, Pharos delivers **precise, responsive, and resilient geolocation** for diverse applications critical to national security and commercial operations.

This innovative system replaces the need for instantaneous spatial diversity (multiple satellites flying in formation) with **temporal kinematic diversity** (observations from one satellite over time), unlocking significant advantages in deployment cost, speed, and operational flexibility.



The Pharos Advantage: Efficiency Meets Performance

Traditional space-based RF geolocation relies on complex, costly constellations requiring precise formation flying. Pharos disrupts this model by leveraging the inherent physics of orbital motion. A single Pharos satellite observes a ground emitter across thousands of kilometers of baseline during one pass (~7.5 km/s), gathering rich kinematic data unavailable to static or slow-moving observers. This fundamental shift enables superior efficiency and capability.

Pharos vs. Traditional Constellations

Feature	Pharos (Conceptual Goal)	Traditional Constellations
Satellite Count	**1**	3–6+
Geolocation Accuracy Goal	**< 100m CEP90**	Variable (often 500m - 5km+)
Responsiveness	**Low Latency (Onboard Processing Goal)**	Higher Latency (Often Ground Processing)
Deployment Time	**Rapid (Single Launch)**	Longer (Multiple Launches, Phasing)
Cost Profile	**Lower Lifecycle Cost (Target)**	High Lifecycle Cost
Resilience	**Inherently More Resilient (Target)**	Vulnerable to Formation Disruption
Target Platform	**6U-12U CubeSat / ESPA-Class**	Larger, Dedicated Platforms

Core Technology: Intelligent Kinematic Sensing (Conceptual)

Pharos determines emitter locations by precisely measuring subtle changes in received signals caused by the satellite's rapid movement relative to the ground source. Key conceptual technological pillars include:

- **Kinematic Geolocation Engine:** Aims to measure the evolution of Angle of Arrival (AOA) and the unique **Doppler frequency shift signature** with exceptional precision, targeting effectiveness even in challenging low Signal-to-Noise Ratio (SNR) environments.
- **Adaptive Antenna Scanning:** Conceptual design includes an intelligent, high-gain antenna (dish or array) with a wide field of regard that dynamically steers its beam to focus on the most valuable observation geometries during a pass, maximizing measurement quality and geolocation accuracy.
- **Multi-Modal Sensor Fusion:** Sophisticated conceptual algorithms fuse AOA, Doppler, Doppler Rate, and SNR measurements with high-precision satellite position and velocity data (PVT) into a unified, accurate solution.
- **Hybrid Physics-ML Estimation:** A powerful conceptual onboard estimator combines physics-based filtering (Extended Kalman Filter) with Neural Network intelligence, enhancing robustness and accuracy across diverse operating conditions.
- **Real-Time Edge Computing:** An efficient, radiation-tolerant onboard processor enables rapid analysis, delivering low-latency geolocation results directly from orbit.

Key Capabilities & Benefits (Targeted)

- **High-Accuracy Geolocation:** Engineered for high accuracy, targeting <100m CEP90 performance from a single satellite.
- **Rapid Responsiveness:** Onboard processing enables low-latency detection and localization (Target: < 1 min solution availability).

- **Cost-Effectiveness:** Single satellite architecture targets dramatically reduced mission lifecycle costs compared to constellations.
- **Deployment Agility:** Faster time-to-orbit and operational readiness compared to multi-satellite systems.
- **Inherent Resilience:** Simplified architecture offers reduced vulnerability.
- **Wideband Adaptability:** Core architecture supports multiple frequency bands, optimized for C-Band and X-Band performance.
- **Smallsat Optimized:** Designed for deployment on cost-effective 6U-12U CubeSat or ESPA-class platforms.
- **High Sensitivity:** Target: High sensitivity for weak or intermittent signals in relevant RF environments.

Performance Highlights & Conceptual Characteristics

Geolocation Accuracy Goal:
< 100 m CEP90 (Conditions Permitting)

Target Primary Operating Bands:
C-Band (4-8 GHz) & X-Band (8-12 GHz)

Conceptual Target Platform:
6U-12U CubeSat / ESPA-Class Small Satellite.

Target Operating Altitude:
Low Earth Orbit (LEO), ~500 km - 650 km.

Estimated Payload SWaP (C/X-Band):

Mass: ~4 kg - 12 kg (Target range)

Volume: ~3.5U - 8U (Target range, fits 6U-12U/ESPA)

Orbit Average Power (OAP): ~50 Watts (Target)

Peak Power: ~60 - 80 Watts (Estimate)

Doppler Precision Goal:
Sub-Hz instantaneous frequency tracking capability

Processing Latency Goal:
Target < 1 min solution availability

Target Operational Lifetime:
3-5 years (Platform Dependent)

Note: SWaP estimates are approximate conceptual targets for primary C/X-Band configurations and vary based on final design and mission requirements. Accuracy influenced by signal characteristics, pass geometry, platform stability, and atmospheric conditions.

Platform Integration & Interface (Conceptual Requirements)

Mechanical Interface:
Standard CubeSat deployer interface (e.g., CDS rails) or ESPA standard bolt pattern (Targeting compatibility)

Power Interface:
Standard bus voltages (e.g., 28V nominal, 12V, 5V, 3.3V target); MIL-STD-704 compliance desired

Data Interface (Logical):
SpaceWire or Ethernet preferred (Target); LVDS, UART options considered

Command & Control (C2) Interface:
RS422/485 or CAN preferred (Target); I2C option considered

Estimated Data Volume:
Target < 5 GBytes/day (Leveraging edge processing)

Maximum Data Rate (Payload -> Bus):
Target > 50 Mbps (Sufficient for health, status, and processed results)

Thermal Interface:
Defined conductive path(s); Target Interface Temp Range: -20°C to +60°C (Estimate); Avg. Heat Dissipation: ~50 W (Estimate)

Pointing Accuracy (Required from Bus):
< 0.1 degrees (3-sigma Goal, for coarse pointing/stable base)

Pointing Stability/Jitter (Required from Bus):
< 0.05 degrees/sec (Goal, TBC)

Pointing Knowledge (Required from Bus):
< 0.05 degrees (Goal, TBC)

Compliance Intent:
CCSDS PUS (Planned); Space EMC/EMI Standards (e.g., MIL-STD-461 tailored); ITU Spectrum Compliance; MOSA Principles (Goal)

Diverse Potential Applications

Pharos aims to deliver dual-use, critical RF situational awareness across defense, intelligence, and commercial sectors, targeting a wide range of emitters within its operating bands:

Defense & Intelligence

- Detecting & locating radar systems (Air Defense, Naval, Fire Control)
- Pinpointing tactical communications (Radios, Datalinks)
- Rapid interference identification & geolocation
- Tracking assets via emissions
- Supporting treaty monitoring
- Augmenting Signals Intelligence (SIGINT)

Commercial & Civil

- Interference hunting (GNSS, Satcom, Mobile, Broadcast)
- Spectrum mapping & management
- Unauthorized transmitter location
- Search & Rescue support (Emergency Beacons)
- Asset tracking validation (AIS/ADS-B anomaly detection)

Development Status & Roadmap

Current: TRL 3 – Validated in Simulation

Concept validated via modeling & simulation. Feasibility established. Foundational algorithms and performance demonstrated analytically.

Next Milestone: TRL 5/6 – Airborne Demonstration

Near-term Airborne campaign (UAS) to demonstrate key hardware subsystems and core algorithms (AOA-dominant) in a relevant environment. Critical risk reduction phase.

Goal: TRL 6/7 – LEO Demo Mission

Planned Low Earth Orbit (LEO) demonstration mission to prove end-to-end system performance and accuracy goals (Doppler-dominant) in the operational space environment. This phase leverages Airborne campaign lessons learned.

Future: Operational Capability

Maturation towards scalable operational deployment and capability expansion based on successful LEO demonstration.

Valence Intel Systems is actively executing this phased approach to mature the Pharos technology rapidly and reliably.

Contact Us

Learn more about how Pharos can meet your RF geolocation needs.

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