PHAROS

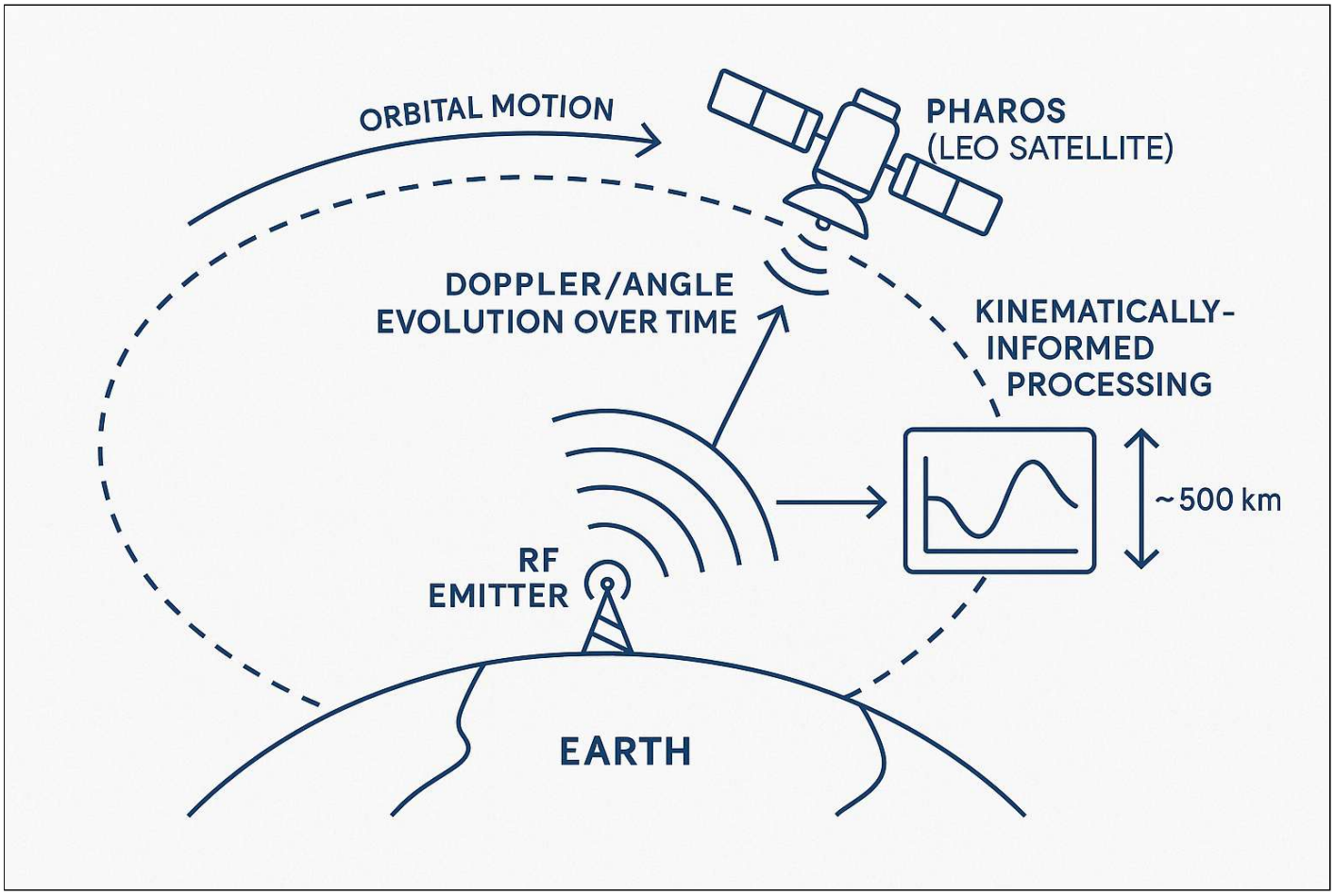
Kinematically-Informed Single-Satellite Agile Geolocation

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

Core Technology: Intelligent Kinematic Sensing

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 technological pillars include:

- **Kinematic Geolocation Engine:** Measures the evolution of Angle of Arrival (AOA) and the unique **Doppler frequency shift signature** (shape, zero-crossing, rate of change) with exceptional precision using proprietary phase-coherent tracking techniques effective even in challenging low Signal-to-Noise Ratio (SNR) environments.
- **Adaptive Antenna Scanning:** An intelligent, high-gain antenna with a wide field of regard dynamically steers its beam, guided by information-theoretic principles, to focus on the most valuable observation geometries during a pass, maximizing measurement quality and geolocation accuracy.
- **Multi-Modal Sensor Fusion:** Sophisticated 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 onboard estimator combines physics-based filtering (Extended Kalman Filter) with Neural Network intelligence. This allows PHAROS to adaptively assess measurement quality in real-time and optimize the solution for enhanced robustness and accuracy across diverse operating conditions.
- **Real-Time Edge Computing:** An efficient, radiation-tolerant onboard processor enables rapid analysis (target <350 ms processing loop), delivering low-latency geolocation results directly from orbit.
- **Standard Data Handling:** Processed data and optional raw captures are downlinked via standard S/X-Band protocols, compatible with commercial ground station networks.

Key Capabilities & Benefits

- **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 dramatically reduces mission lifecycle costs compared to constellations.
- **Deployment Agility:** Faster time-to-orbit and operational readiness.
- **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 12U CubeSat or ESPA-class platforms.
- **High Sensitivity:** Engineered to detect **weak or intermittent signals** in **noisy, contested, or cluttered** RF environments.

Performance Highlights & Characteristics

Geolocation Accuracy:
Target < 500 m CEP90; **Goal < 100 m CEP90** (Conditions Permitting)

Primary Operating Bands:
C-Band (4-8 GHz) & X-Band (8-12 GHz) - Optimal accuracy/SWaP balance.

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

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

Payload Size, Weight, and Power (SWaP):
Highly optimized for small satellite integration. Typical payload ranges for C/X-Band: **~4-12 kg mass**, **~50-70 W average power**, fits standard **6U-12U CubeSat / ESPA** volume allocations.

Doppler Precision:
Sub-Hz instantaneous frequency tracking capability.

Processing Latency:
Target < 350 ms onboard loop; Target < 1 min solution availability.

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

Note: SWaP estimates are approximate for primary C/X-Band configurations and vary based on final design and mission requirements. S-Band options available (typically requiring ESPA-class). Ku/Ka bands represent areas for future capability expansion. Accuracy influenced by signal characteristics, pass geometry, and atmospheric conditions.

Diverse Applications

PHAROS delivers dual-use, critical RF situational awareness across defense, intelligence, and commercial sectors, capable of geolocating 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 – HAB Demonstration

Near-term High-Altitude Balloon (HAB) campaign to demonstrate key hardware subsystems (antenna pointing, RF chain, processing emulation) and core algorithms (adaptive scanning, AOA) in a relevant near-space 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 in the operational space environment. This phase leverages HAB 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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