Psionic Scout Card for Trident Spectre 2022:
SurePath aPNT: GPS Denied Environments

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Capability

Capability Name: SurePath aPNT: GPS Denied Environments.

Capability Type: Prototype.

Specification Type: System (hardware and software).

Export Controlled: Controlled by US Munitions List (USML) / ITAR (export license required)

Intellectual Property: Specially Negotiated License

Patents: US 10935670, US 9007569

Submission Area: Command, Control, Communications & Computers (C4)

Tags: Command, Control, Communications & Computers (C4); GPS Denied; GPS Denied OPS; UAV GPS Deprived Navigation; Navigation Technology

Tech Weight: < 7 pounds, Tech Dimensions: 5.5” x 2.5” x 7.5”, Tech Power: ~ 20 watts (estimated)

Platform: Mobile, OS: Agnostic, Networking: LAN-based

Primary Sponsor: Winterdel Matsikure, DIA

Secondary Sponsor: Ricky Massaro, USACE

Description

SurePath is a Doppler lidar dead-reckoning aPNT capability using redundant 4-channel design and self-contained Inertial Navigation System (INS) that measures an LPI/LPD lidar return in the 5-100 mW range, housed in a MIL STD 810 ruggedized housing for navigating in GPS degraded or denied environments, with no accelerometer or gyro needed. Current vehicle mounted prototype dimensions: 4.5”x 2.5” x 6”. Weight: Approx. 5 lbs. (Dismounted version will be smaller.)

SurePath Alternative Precision Navigation & Timing (aPNT) capability benefits actual SOF ops and supports ops by providing LPI/LPD, anti-spoof/anti-jam navigation to the warfighter in contested, near-peer environments. SurePath allows for SOF operators and assets to safely navigate to, from, and on target when GPS is degraded or unavailable.

SurePath, tested at APG in July 2021 and PNTAX 2021, delivers precise, long range navigation without GPS or external signals. Figure 1 shows performance against other INS systems. A SurePath prototype (5.5”x2.5”x7.5”, <7 lbs) is available for testing. Our current hardware roadmap (Figure 2) shows significant reductions in size, weight and power to less than 2”x2”x2” under a NASA funded contract with an estimated production volume available in Q2 2024.

After more than 1,000mi of road-testing (Figure 3), the system is ready to be tested in an airborne configuration. The system has been mounted to a helicopter and demonstrated the ability to measure distance to the ground and velocity with extreme accuracy. The system provides high altitude navigation up to 35,000'. The next test will be using SurePath mounted to an airborne vehicle, such as a drone, to demonstrate navigation without GPS or external signals.

How It Works:

SurePath accurately measures radial velocity vectors (+/- 1cm/sec) via the reflected energy from an object from the ground. SurePath is comprised of an electro-optical enclosure, an optical fixture (4 telescopes), an IMU, and Psionic navigation filter.

SurePath is a Frequency Modulated Continuous Wave (FMCW) implementation and is a significant improvement over the standard Amplitude Modulated (AM) Time Of Flight (TOF) lidar by making measurements in the frequency domain. SurePath has a range of ~10 km with high fidelity signal returns and large Signal to Noise Ratio (SNR), providing highly accurate ground speed and relative distance.

Psionic demonstrated SurePath to COL Kioutas, AFC PM PNT, at the OIL at APG in July 2021. SurePath demonstrated navigational accuracy to within the error of commercial GPS navigating on various terrains within 16m of GPS.

Applicability:

Psionic proposes to demonstrate SurePath INS navigational capabilities aboard a UAV and ground vehicle for TS 22 in a GPS denied environment to provide data to assess the value SurePath provides as a viable alternative navigational solution for GPS denied environments.

Differentiator

SurePath Alternative Precision Navigation & Timing (aPNT) capability benefits actual SOF ops and supports ops by providing LPI/LPD, anti-spoof/anti-jam navigation to the warfighter in contested, near-peer environments. SurePath allows for SOF operators and assets to safely navigate to, from, and on target when GPS is degraded or unavailable.

Psionic offers a velocity centric INS with accuracy equal to GPS without GPS or any signal of convenience to for reference to navigate. This INS accuracy is attributed to the velocity accuracy the PNDL provides which is a product of the lidar technology. SurePath is unique and the attributes which distinguish SurePath capabilities from other INS capabilities are summarized below:

- PNDL's ability to calculate accurate velocity is based upon Maxwell's equations. These equations describe how electric and magnetic fields propagate, interact, and how they are

influenced by objects. Much like gravity is a law and a universal concept, Maxwell's equations are the laws of the universe to govern the behavior of electric and magnetic fields.

- Psionic exclusively licenses this lidar technology from NASA for ground, air, and space vehicle commercialization. No other source is available for providing the lidar technology NASA developed and refined the prior 13 years for autonomous lunar landings.
- Psionic developed a navigational filter which integrates the lidar velocities with IMU data to provide vehicle position at a 50 Hz rate. Accurate velocity precludes the need for the IMU to integrate the effects of accelerations and attitude changes and the results are excellent navigational performance with greatly reduced positional error. This navigational filter was developed by Psionic and refined via extensive field testing to maximize performance.
- SurePath is a self-sustaining GPS denied INS solution. Subsequent to initialization, no external inputs are required for accurate navigational performance.
- SurePath is not susceptible to jamming and spoofing since it is a self-contained system that does not require external signals.

Readiness Levels

Current: TRL 7, MRL 9, IRL 8

TRL 1, May 2010: NASA performed initial experiments with lidar technology focused on autonomous lunar landing and basic principals were observed and analyzed. These experiments formed the basis for PNDL which is an integral component for the SurePath INS.

TRL 7, September 2021: SurePath INS participates in the PNT Assessment Exercises 21 (PNTAX 21) sponsored by APNT/Space performed within WSMR. PNTAX 21 provides a GPS denied operational environment to demonstrate new technologies and SurePath is demonstrated in this GPS denied environment.

TRL 9, July 2022: SurePath ARES INSs successfully completes system operation and evaluation as demonstrated during Trident Spectre 22 (TS 22). The actual application of the SurePath ARES technology is in its final form and performed under mission conditions.

MRL 1, November 2020: PNDL architecture revised and updated for the reduced SWaP-C TDM ARES architecture. Bill of Material was developed and laboratory experiments conducted to trade off component performance and manufacturing implications (cost, size, power, etc.) were identified and resolved.

MRL 9, April 2022: Low-Rate Initial Production (LRIP) capability demonstrated with the delivery of two SurePath ARES systems to PM PNT.

MRL 10, January 2023: Full Rate Production capability established via documentation and procedure update based upon LRIP experiences. Lessons learned and lean production practices from LRIP fabrication and delivery are incorporated into the manufacturing processes.

IRL 1, September 2020: PNDL reduced SWaP-C TDM ARES conceptual block diagram and interfaces between modules and sub-assemblies identified and characterized.

IRL 8, June 2022: Test and demonstration in the system environment accomplished by PM PNT. Two delivered SurePath ARES systems in May 2022 are scheduled for operational test and evaluation using operational vehicles selected by PM PNT.

IRL 9, August 2022: SurePath ARES INSs successfully completes successful system operation and evaluation as demonstrated during TS 22. The actual application of the SurePath ARES technology is in its final form and performed under mission conditions.

Images, Videos, and Supplemental Documentation

Figure 1: SurePath Performance Compared to INS Sensors

Figure 2: SurePath Hardware Roadmap

Figure 3: SurePath Road Test

Additional Image: SurePath Operations for Aerial Navigation

Additional Image: Psionic SurePath System Attributes

Video: https://youtu.be/SNfuejVJJ8I

Datasheet: SurePath Specifications and Performance Results

White Paper: Psionic SurePath INS Technology

Custom Questions from ORG

1. Benefits to SOF or Tactical Intelligence: SurePath aPNT capability benefits actual SOF ops and supports ops by providing LPI/LPD, anti-spoof and anti-jam navigation to the warfighter in contested, near-peer environments in GPS denied environments without external signals or beacons. The benefit is a self-contained, viable replacement for GPS. Service is guaranteed, cannot be spoofed or jammed and is available worldwide. Laser emission is low power and tightly collimated, making it stealthy and undetectable.

2. Operational Scenario/ Need Statement: GPS is easily jammed and/or spoofed by relatively unsophisticated enemies. SurePath aPNT capability provides an LPI/LPD, anti-spoof/anti-jam method of navigating to, from, and on target without the use of GPS. SurePath measures distance (+/- 5cm) and radial velocity vectors (+/- 1cm/sec) via the reflected energy from an object from the ground.
3. Project Description: SurePath is a Doppler lidar dead-reckoning aPNT capability using redundant 4-channel design and self-contained Inertial Navigation System (INS) that measures an LPI/LPD lidar return in the 5-100 mW range, housed in a MIL STD 810 ruggedized housing for navigating in GPS degraded or denied environments, with no accelerometer or gyro needed. Current vehicle mounted prototype dimensions: 4.5”x 2.5” x 6”. Weight: Approx. 5 lbs. (Dismounted version will be smaller.)
4. Is this capability currently fielded? Not fielded
5. Novelty: Provides a new capability
6. Comparable Technologies: None known. GPS and Inertial Measurement Units (IMU) provide a similar capability, but all require external RF signals to determine location, increasing the probability of detection and interception. SurePath is completely self-contained with no external signals needed for navigation. SurePath eliminates the accumulation of accelerometer errors in inertial instrument-based navigation systems which are continuously integrated to estimate velocity.
7. Existing General Requirement: Operational Deficiency Report (ODR)
8. Which Requirement? SurePath aPNT maps to existing ODRs for aPNT capabilities for NSW forces navigating in GPS denied environments.
9. Previously attended Trident Spectre? Never attended
10. Requested Validation Level: Technical Assessment, Functional Assessment, Vulnerability Assessment
11. Operational Modes: Active Mode
12. Offensive Capability: No
13. Experiment or Demonstration? Both
14. GOV Funded Program? No
15. Measurements of Performance:

    Dismounted: 5 mWatt optical output measuring data at 5 Hz through 4 channels drawing ~3 Watts of power. Weight: ~1lb. Max Alt: 7 ft. Max speed: 25 mph.

Tactical UAS: 100 mWatt optical output measuring data at 10-50 Hz through 4 channels drawing ~15 Watts of power. Weight: ~5 lbs. Max alt: 5,000 ft. Max speed: 175 mph

aPNT Accuracy: Industrial grade INS systems: 20 km drift over 10 min, 3,900 km over 1 hour

SurePath: 15m drift over 10 min, 400m over 1 hour

16. Critical Operational Issue: SurePath allows for SOF operators and assets to safely navigate to, from, and on target when GPS is degraded or unavailable. COIs are the measurement of SurePath performance compared to a navigational standard such as GPS. Figures 2 and 3 provide representative plots of this data. The data is time tagged and analyzed to assess operational success. When operational success is threatened by the loss of GPS resulting in the inability to navigate, SurePath restores PNT.
17. Resource/Asset Requirements:

    Ground: SurePath unit, power source (COTS rechargeable Lithium batteries), TS22' participants for field testing, GPS- enabled control participants, ATAK COP integration, starting location input (manual or automatic).

    Tactical UAS: SurePath Unit, Vanilla unmanned Grp III UAS w/ power integration, starting location input (manual or automatic).

18. System Survivability: Redundant 4-channel processing eliminates data processing errors. MIL STD 810 qualified housing protects critical components. Output power and data processing are scalable to account for increased platform speed (~75 Watts at 500-1,000 Hz allows for up to 1,500 MPH). NASA employs SurePath lidar for lunar landers. SurePath's ability to provide PNT in GPS denied environments to successfully navigate affords greater maneuverability and situational awareness resulting in improved survivability.
19. Force Protection: LPI/LPD: Low power, focused laser emissions are virtually undetectable by enemy EW and A2/AD capabilities. Completely self-contained navigation system is anti-jam and anti-spoof. Increased power and measurement rates allow for infil/exfil at increased speeds. MIL STD 810 qualified housings prevents damage to system internals during ops.
20. Sustainment: Final form-factor will integrate into a photonic integrated circuit in ruggedized housing and is essentially maintenance free but needs battery refresh depending on power source. Psionic plans to perform qualification testing in accordance with military standards such as MIL-STD 810G to improve sustainment attributes such as availability and reliability.
21. Energy: Ground: ~3 Watts, Tactical UAS: ~15 Watts
22. Software Size: Min: 0.01 Megabytes, Max: 0.01 Megabytes. Software for system contains 4,269 SLOC.

23. Software Power Requirements: N/A. Software for system contains 4,269 SLOC.
24. Hardware Frequency: Min: 5 Hertz, Max: 50 Hertz
25. Hardware Power Requirements: Ground: ~3 Watts 5 Hz, Tactical UAS: ~15 Watts 10-50 Hz.
26. Networked: Optional
27. COP Integration: SurePath integrates into TAK and is compatible with most COPs in service today, to include the new NSWDG Advanced Mission Planning System (AMPS). SurePath integrates into COP tools as a data layer displaying SOF elements / platforms tracks to, from, and on target.
28. Classification: No, fully UNCLASS
29. Clearances: Secret

Images

Psionic SurePath Performance Compared to INS Sensors by Grade

Grade / Time	10 Minutes	1 Hour (60 Minutes)
Consumer	200 km (200,000 m)	39,000 km (39,000,000 m)
Industrial	20 km (20,000 m)	3,900 km (3,900,000 m)
Tactical	2 km (2,000 m)	400 km (400,000 m)
Navigation	100 m	10 km (10,000 m)
Psionic SurePath™	**15 m**	**400 m**

Industry data: VectorNav (2021); Psionic data (2021)

Figure 1: SurePath Performance Compared to INS Sensors

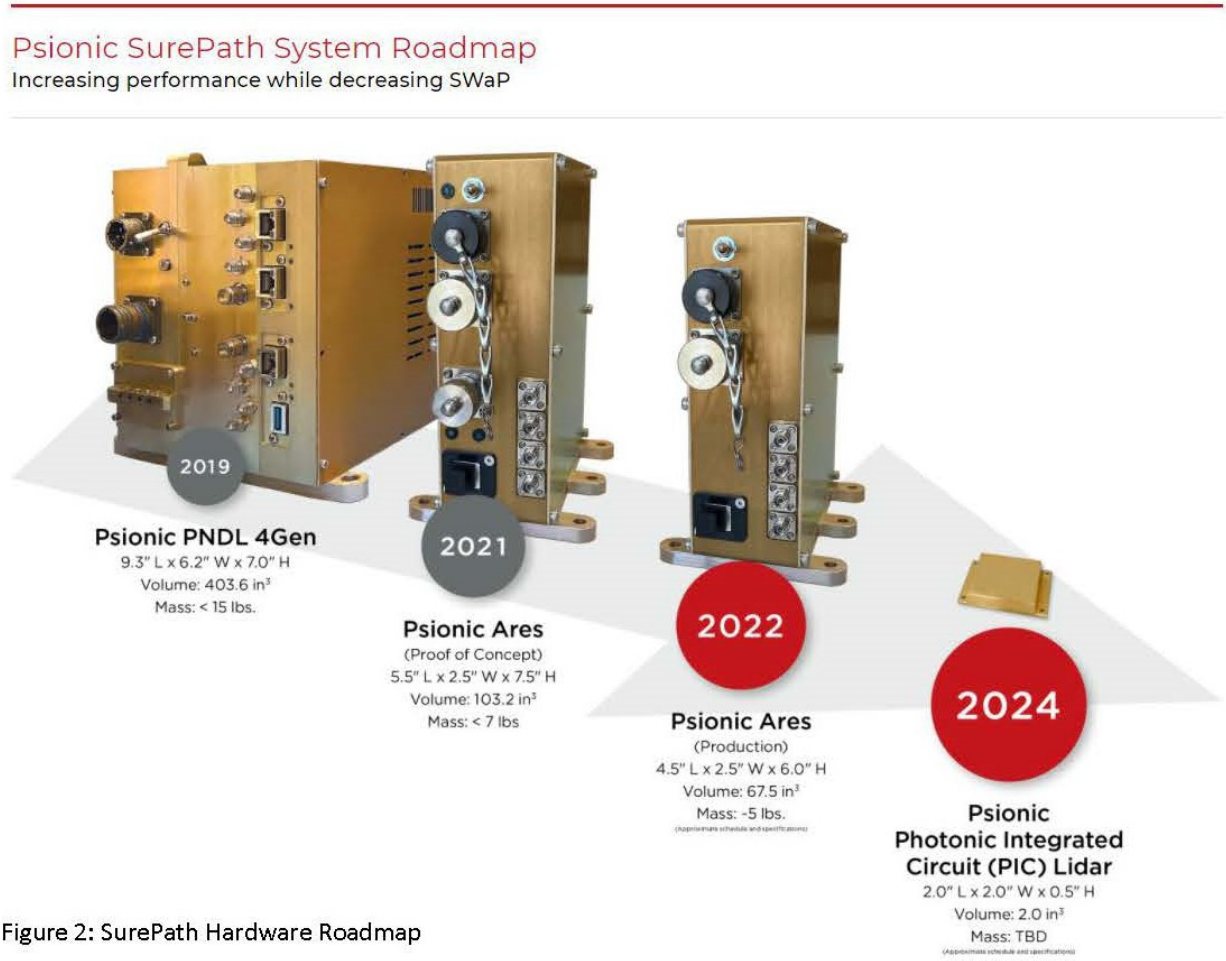

Figure 2: SurePath Hardware Roadmap

Psionic continues to reduce the PNDL size, weight, power and cost (SWaP-C) for applications which require velocity only and Figure 1 displays the technology roadmap with Ares representing this current configuration.

2021: SurePath Ares Architecture

- 96% Reduction in Optical Power
- 80% Reduction in Power Consumption
- 75% Reduction in Volume
- 70% Reduction in Mass
- No Degradation to resolution or accuracy

These improvements are the product of Ares architecture which is a Time Division Multiplexing approach for transmitting/receiving (T/R) the tightly collimated laser beams. PNDL provides four sources and separate channels to each of the four telescopes for T/R. Ares provides one source which is time multiplexed between the four channels and telescopes for T/R. Extensive testing was performed to ensure the switching time between the four channels was adequate to maintain the PNDL velocity accuracy and results indicate the TDM architecture is viable and exhibits no degradation when compared to PNDL performance. The Ares architecture provides PNT in GPS-Denied environments for terrain, aerial and dismounted manpack applications.

Figure 2: SurePath Hardware Roadmap

Psionic SurePath provides precision navigation in GPS degraded or denied environments with no external signals of any kind. Backs up GPS in APNT systems.

Off-Road Test	
Location	Military Test Facility
Date	July 2021
Distance / Duration	1.6 Miles / ~12 Minutes

Surface Road Test	
Location	Hampton, Virgina
Date	July 2021
Distance / Duration	3.75 Miles / ~12 Minutes

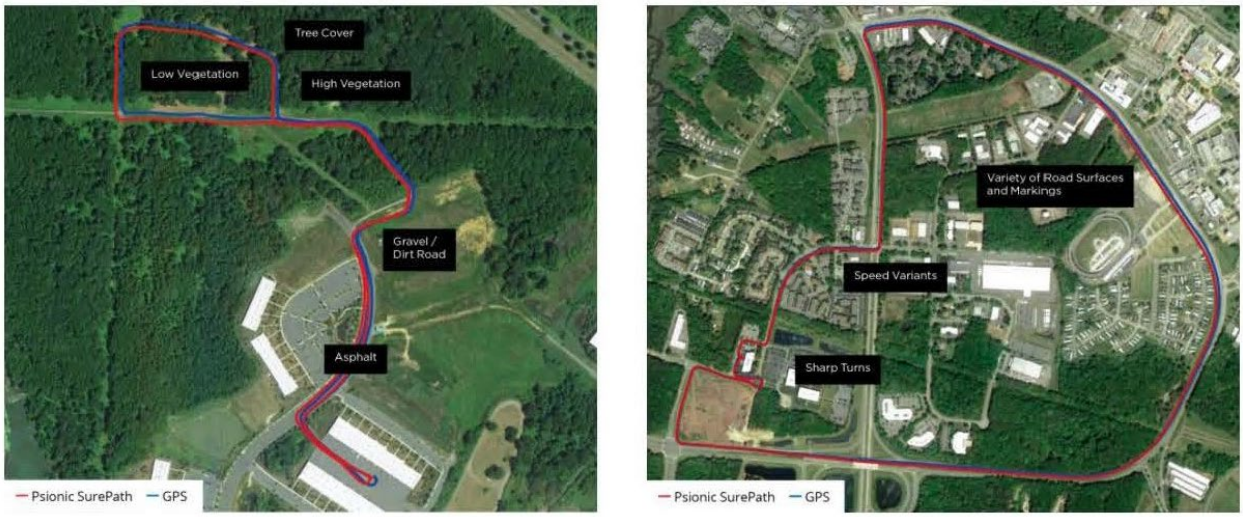

Figure 3: SurePath Road Test

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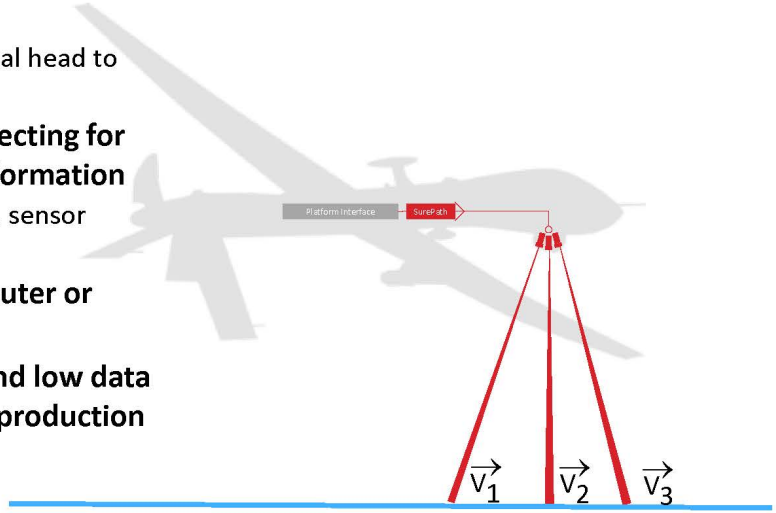
PSIONIC DEFENSE

SurePath™ Operations for Aerial Navigation

- **Optical sensors directly measure three or more independent radial velocity vectors (V_1, V_2, V_3)**
  - Reflected energy from the surface (ground, foliage, etc.) provides velocity measurement due to the optical frequency shift
  - The change in frequency of the optical signal is a function of the relative velocity between the aircraft and the reflecting surface
  - The measured velocities are combined with accelerations and angle rates to estimate position
- **Integrated low-cost IMU provides sufficient platform information**
  - Low-cost triaxial IMU is integrated into the optical head to provide accelerometer and rate gyro data
- **Psionic Navigation Filter processes data, correcting for biases, sensor location and provides state information**
  - Navigation filter is tuned for each platform type, sensor location, rotational axis, etc.
- **Navigation data is transmitted to flight computer or autonomy stack**
- **Proven architecture with simple interfaces and low data rate provides rapid systems development to production**

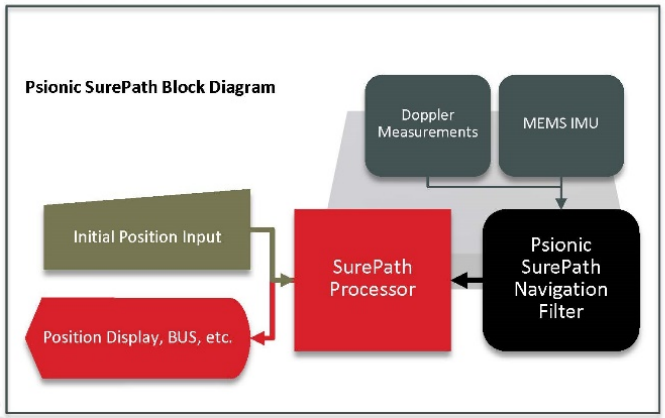


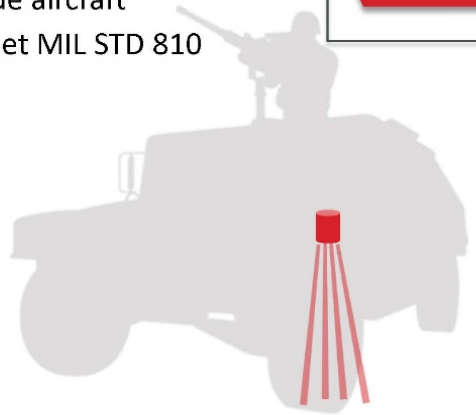
SurePath Operations for Aerial Navigation

PSIONIC DEFENSE

Psionic SurePath System Attributes

- Self-contained Inertial Navigation System (INS)
- 4-channel design improves reliability
- Eliminates accelerometer and rate gyro drifts (measurement error/noise)
- Requires initial state (position and heading)
- Provide indication when GPS is degraded/denied
- 1 – 50 Hz measurement rate for ground vehicles and low-altitude aircraft
- To be ruggedized to meet MIL STD 810





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SurePath System Attributes