Test and Evaluation/Science and Technology Program
Advanced Instrumentation Systems Technology (AIST)

Precise TSPI of Guided Munitions
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An independent system providing high-rate, high-accuracy TSPI from launch to impact for T&E of guided munitions

RF electronics on the system under test (SUT) and on the ground provide full 6-DOF tracking for T&E
PAWS Team

*Sponsor:* Test Resource Management Center
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Advanced Instrumentation Systems Technology

*Contractor:* ENSCO, Inc.

*Partner:* Army Research Laboratory
Lethality Division
Guidance Technologies Branch
PAWS Goals

• Precise, accurate, and high-rate TSPI for guided munitions
• Continuous six-degree of freedom (6-DOF) TSPI from launch to impact
• Independent of GPS
• Accuracy that exceeds the navigation and guidance performance of the guided munition
• Fully automated data analysis with prompt first-look
• Minimal cost and operational burden
S&T Strategy

- RF-only measuring scheme to minimize electronics package and improve robustness to high shock of launch

- Develop and demonstrate with 120 mm mortar body and ARL-developed reusable instrumented test article (RITA)

- General-purpose capability – mid-body or other customized integration possible for future

- PAWS Weapons Component (WC) currently implemented as a screw-in replacement to a conventional mortar fuze

PAWS is an entirely RF-based TSPI capability
No inertial or other sensors are required
Key Enabling Technology

Round-trip time-of-flight RF ranging enables PAWS

RF ranging transaction overview:

– *Radio A* transmits a request packet to *Radio B*

– *Radio B* receives the packet, computes ranging observables, and transmits a response packet back to *Radio A* with observables in payload

– *Radio A* receives the response packet and computes additional ranging observables to complete round-trip transaction

A **rapid** process, each round-trip transaction typically 2 ms

An **accurate and precise** process with distance measurements having centimeters-level performance and implementable on resource-constrained hardware
PAWS Components

PAWS-WC (weapons component)
- Ranging radio transceiver
- Five antennas – one nose cone and four annular antennas
- Self-contained power
- Integrated into replacement for a standard fuze

PAWS-GC (ground component)
- Ranging radio transceiver
- Wide-beam antennas
- Storage for raw data

The data products of PAWS are:
- Continuous history of projectile 6-DOF from launch to impact
- 100% raw data storage on PAWS-GC
PAWS-WC

Components:
- Custom five-channel, gun-hardened, miniaturized ranging radio
- Five custom antennas
- Rechargeable Li-Po battery
PAWS-GC

• Man-portable ground stations
• System interface for command, control, and data
  – COTS data link for networked operation
• Synchronized using ranging
  – Ranging-disciplined reference oscillator
• Single measuring antenna
• 100% data logging on board
  – Data automatically transferred back to controller node for processing on laptop
• Antenna mounted on mast
  – Adjustable height for hilly terrain
  – Design allows for wider angle visibility
PAWS makes multiple physical measurements between the GC’s and the WC’s during flight:

✓ Round-trip time-of-flight providing distance,
✓ Interferometric measurements providing attitude of the WC,
✓ Relative velocity measurements between GC and WC, and
✓ Measurements of attitude rate on the PAWS-WC.

All of these measurements are made in each RF transaction. Measurements are combined in a Kalman filter to estimate the 6-DOF states of the projectile through flight.

Automatic computation of position and attitude using GPS-independent, RF-only measurements
Concept of Operation

**Pre-test**
- Deploy 4 GC’s on test range
- Initialize GC’s and GC network
- Prepare and initialize WC’s
- Verify communication between components → system ready
- Launch mortar

**During test**
- GC’s range to WC’s throughout test
- GC’s range intermittently to each other throughout test for time synchronization
- Measurement data stored at each GC

**Post-test**
- Measurement data is downloaded to a central GC
- Data processed to present quick-look results (seconds)
- Data post-processed for refined results (minutes)
Spin and Shock Tests

✓ Attitude measurement performs as expected when spun

✓ Single measurement dropped on launch shock

Performance Spin Test: Roll Rate

PAWS-WC in test fixture

PAWS-GC antenna
Positioning Test

2-D positioning test with pre-surveyed GCs and ground truth points.
Positioning Test Video
“Soft Launch” Tests at ARL

Air cannon launched ballistic trajectories
Soft Launch Test Results

PAWS Position Output (Smoothed)

- 6 successful launches at 2 different launch Quadrant Elevation
- Positioning Results meet expectations

✓ Measurements performed as expected

✓ 6 successful launches at 2 different launch Quadrant Elevation
✓ Positioning Results meet expectations
Current Status

- Designed, implemented, and tested prototype GC and WC
- Verified WC performance at high spin rate
- Verified WC performance through launch shock
- Quantified expected system performance in a software simulator
- Validated expected system performance with lab and field testing

TRL-5 system and software successfully developed and tested
PAWS Technology

Key technologies:
- Accurate, high-rate measurement of position via RF measurements
- Accurate, high-rate measurement of orientation via RF carrier phase measurements
- Integrated into replacement for standard fuze
- Fully automated computation of SUT 6-degree of freedom TSPI

Capabilities:
- High-precision 6-DOF TSPI – *Complete, accurate TSPI*
- Independent of GPS – *Well-suited for GPS jamming tests*
- Integrates via replacement fuze – *Standard, easy-to-use*
- Automatic results – *No engineering analysis required*

High-accuracy TSPI for guided munitions
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