



T&E/S&T-Developed GPS/GPS-denied TSPI Technologies... Past, Present, Future

Advanced Instrumentation Systems Technology (AIST)

Tom Macdonald
AIST TSPI Consultant

ITEA 19TH Test Instrumentation Workshop
12-14 May 2015
Las Vegas, NV

Distribution Statement A: Approved for public release; distribution is unlimited.



Overview and Summary



- ***What does AIST do?***
 - AIST develops Technology Readiness Level (TRL) 3 to 6 TSPI technologies
- ***What does this briefing address?***
 - This briefing outlines the AIST methodology to identify future GPS/GPS-denied TSPI investment areas by mapping *range-user* TSPI requirements to TSPI projects
- ***What is the status of GPS/GPS-denied technology developments?***
 - *GPS-based TSPI*: Developed SoA three-frequency Ultra-high dynamic GPS (UHDGPS) brassboard. *Need range-user support to develop ASIC*
 - *GPS-denied TSPI*: Although many technologies have been developed and tested, GPS-denied developments *are not complete*
- ***What are some key T&E application areas for GPS/GPS-denied technologies?***
 - Real-time Casualty Assessment (RTCA)
 - Tracking in an urban environment
- ***What are some key required technologies?***
 - Multiple sensor data fusion algorithm
 - Tri-frequency GPS chip
 - Miniaturized navigation-grade Inertial Measurement Unit (IMU)



AIST TTA Overview

AIST will advance the field of device physics by investigating innovative materials, MEMS sensors, advanced platform-level data management, human systems integration, range environmental encroachment and novel sensor packaging technologies to support T&E of warfighting systems

TSPI

High accuracy and continuous TSPI for high speed/high dynamic and GPS-degraded environments

Advanced Sensors

Enhanced performance sensors that meet emergent T&E needs

Advanced Energy & Power

Improved energy/power density systems for T&E

Non-Intrusive Instrumentation

Advanced data acquisition and processing components designed to be embedded within the system under test

Range Environmental Encroachment

Technologies to mitigate impacts of environmental policies on test range operations

Warfighter Performance Measurement & Assessment

Technologies to assess the human-machine interface, including improved methods to measure warfighter cognitive & physical workload





Advanced TSPI Needs

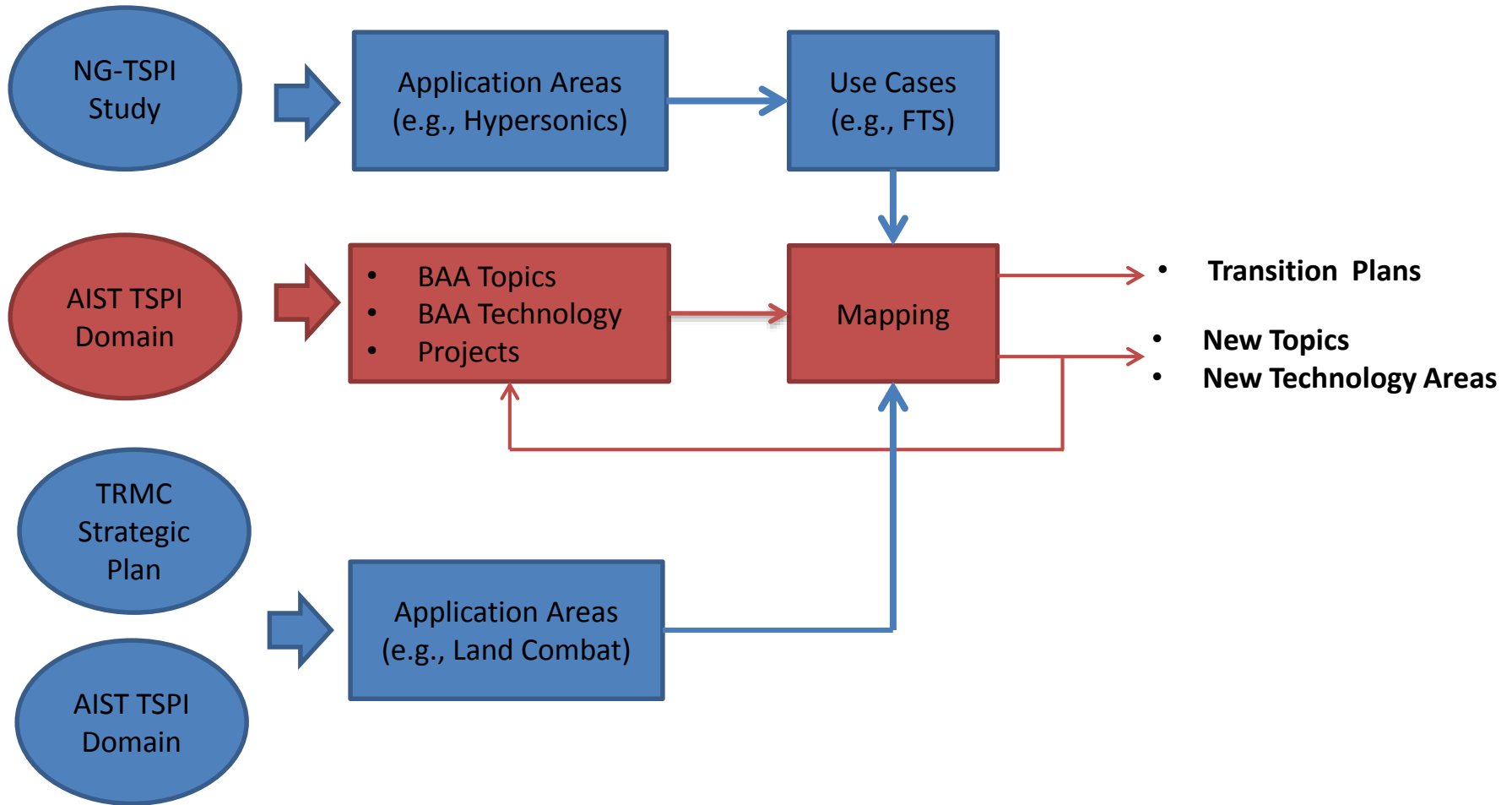


- **Time Space Position Information (TSPI) for Individual Warfighters without GPS**
- **High-Dynamic Conditions**
 - Small High Dynamic Guided Weapons
 - Hypersonic Munitions
- **Undersea TSPI**
 - Rapidly Deployable Undersea Range
 - High Speed Underwater Projectile
 - Station Keeping Buoy
 - Undersea Transducers
- **Automatic End-game Scoring**
- **Real-time Casualty Assessment (RTCA)**
- **Hypervelocity Impact Location**
- **Future Technology Opportunities**
 - ASIC GPS Receiver
 - MEMS Inertial Measurement Units
 - Precision Guided Munitions
 - Chem/Bio Cloud Tracking
 - Low-Observable Systems





Methodology to Identify Future GPS/GPS-denied Investment Areas





Next Generation-TSPI Study Application Areas



- 15 Application Areas, reduced to 11 Application Areas...26 Use Cases developed for the 11 Application Areas

Application Area			
1	Ballistic Missiles	9	Directed Energy
2	Ground Forces	10	System of Systems
3	Air-to-Air Munitions	11	Naval Surface, Littoral, and Underwater
4	Air-to-Surface Munitions		
5	Surface-to Air Munitions	12	Guidance and Navigation
6	Surface-to-surface Munitions	13	UAV/UGV
7	Air Vehicles	14	Low Observables (Stealth)
8	Hypersonics	15	Non-solid Entities

Dropped



AIST TSPI Projects



- AIST TSPI projects to address Next Generation-TSPI shortfalls

Name	Description
WITS	Boot-mounted IMUs, inter-boot RF rangers, GPS system
IDRL	Inertial Doppler, RF ranger, IMU, GPS system
WLPS	UWB-based RF rangers
UHDGPS	Advanced three-frequency civil GPS receiver
ASYGPS	Distributed GPS/RF ranger system

Name	Description
TRI-NAV	GPS, IMU, Low-frequency multilateration system
NFER-SOLD	Near-field EM ranging using AM signals-of-opportunity
PAWS	6-DOF for munitions based on carrier phase difference of radar signals
IOGPS	Novel technology of employing GPS-based multilateration within buildings
TRAC	Fibre optic-based posture , head, weapon tracker system

Past project

On-going project



Mapping of TSPI Projects/BAA to Next Generation-TSPI Use Cases (Example)



Number*	Use Case	BAA Technology Area	BAA Topic	AIST Projects (past, present)
1.1	BMD Critical Measurements and CM Testing			
1.2	BMD Multiple Kill Vehicle Scoring			
1.3	BMD Impact Scoring			
2.1	Position Tracking of Warfighters and their Systems			
2.3	Position Tracking of Mechanized Battalion (Urban)			
3.1	Guided Air-to-Air Weapons			
3.3	C&C and TSPI of Aerial Target Drones			
4.1	Air-to-Surface PCM in a GPS-jammed Environment			

*Numbers refer to use cases within Applications Areas

Legend: AIST Projects/BAA that address Use Case



Example: Mapping UHDGPS Capabilities to NG-TSPI Use Case Requirements



Use Case, #		UHDGPS Capability								
		Hybrid	Fast TTF	High Accuracy	Anti-jam	High dynamics*	NLOS	Stealth (passive)	High Sensitivity	Large Area
BMD Multiple Kill Vehicle Scoring	1.2	Yellow		Blue		Blue	Green			
BMD Impact Scoring	1.3	Yellow	Blue			Blue				Green
Position tracking of Warfighters	2.1			Blue	Blue				Yellow	
Guided air-to-air weapons	3.1		Blue	Blue	Blue		Green		Yellow	Green
C&C and TSPI aerial targets	3.3				Blue					
Air-to-surface PGM	4.1			Blue	Blue					
Guided air-to-air weapons	4.3		Blue		Blue		Green			

Legend:	GPS Capability	UHDGPS Capability	TBD UHDGPS Capability
----------------	-----------------------	--------------------------	------------------------------

* <2 km/s, <100 g



Mapping of AIST TSPI BAA/Projects to Strategic Plan and TRAG Inputs

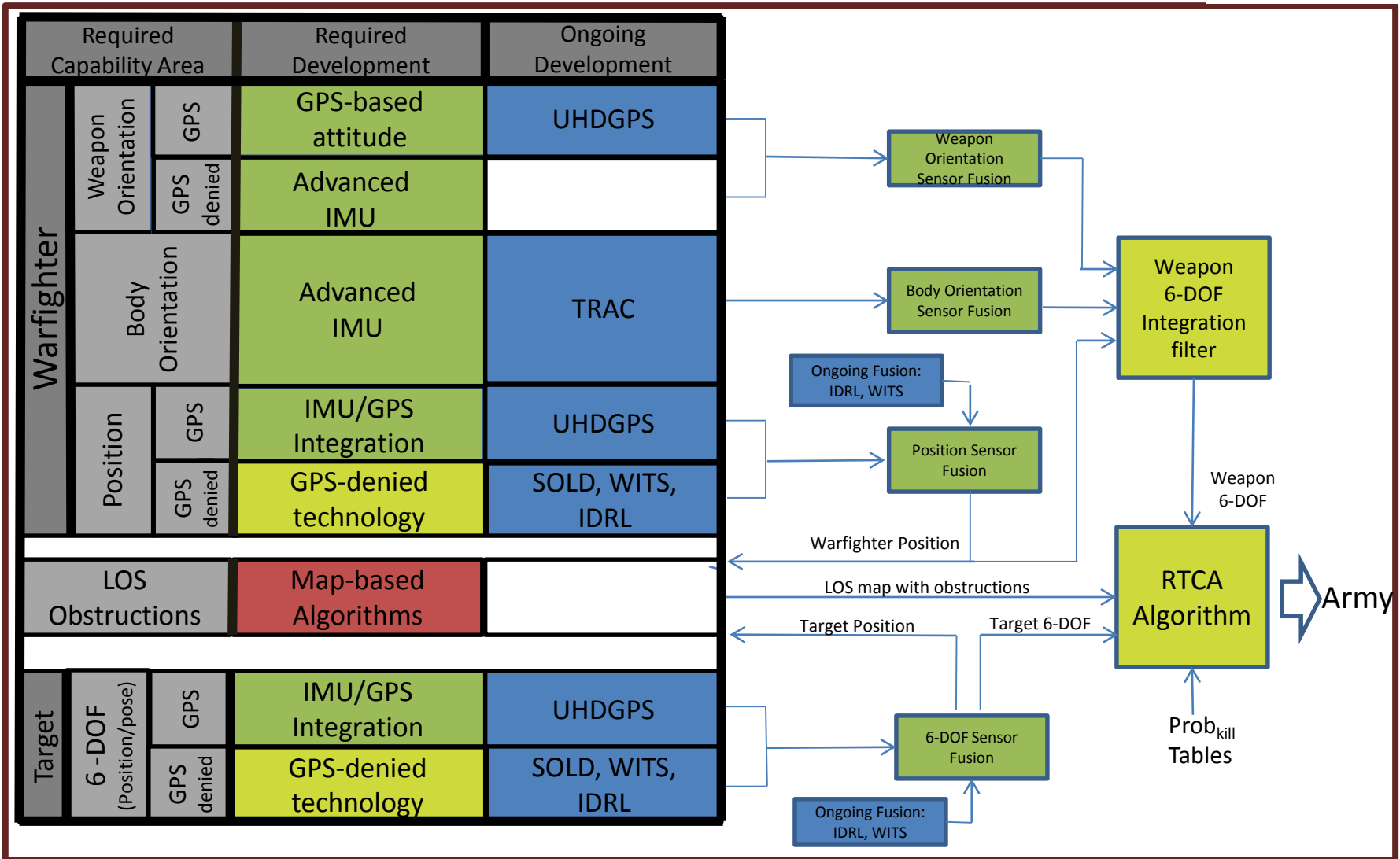


Source	T&E Application	Page	Reference	Need	TSPI BAA Technology Area	TSPI BAA Topic	AIST TSPI Projects (past, present)
2010 Strategic Plan	Land combat	A3-1	Item #1	Capture operator position, weapon position, ground truth	<ul style="list-style-type: none"> Advanced IMUs Data Fusion GPS receivers RF ranging 	<ul style="list-style-type: none"> GPS-denied Munition/warhead characterization 	<ul style="list-style-type: none"> TRAC
2010 Strategic Plan	Land combat	A3-2	Item #3	GPS-denied in urban environment including RTCA	<ul style="list-style-type: none"> Advanced IMUs Data Fusion GPS receivers RF ranging 	<ul style="list-style-type: none"> RTCA GPS-denied 	<ul style="list-style-type: none"> WITS IOGPS IDRL SOLD
2010 Strategic Plan	Sea Combat	A4-9		Advanced Gun System (AGS), Long Range Land Attack Projectile (LRLAP), and EMRG need advanced TSPI.	<ul style="list-style-type: none"> GPS receivers 	<ul style="list-style-type: none"> Highly dynamic guided weapons 	<ul style="list-style-type: none"> UHDGPS
2010 Strategic Plan	Targets and Threats	B11-6		End-game vector scoring, including seaborne targets	<ul style="list-style-type: none"> GPS receivers 	<ul style="list-style-type: none"> Automatic EGS 	<ul style="list-style-type: none"> UHDGPS
TRAG 2015 inputs to BoD(ES)	Tactical Engagement		slide 5	Pairing		<ul style="list-style-type: none"> RTCA GPS-denied 	<ul style="list-style-type: none"> WITS IOGPS IDRL SOLD UHDGPS

Legend: AIST TSPI projects/BAA that address Strategic Plan and TRAG inputs



Example: Warfighter-Warfighter RTCA Required Development



Development Legend

None Ongoing	Past/present project	BAA Enabling Technology	BAA Topic	Required Development
--------------	----------------------	-------------------------	-----------	----------------------



AIST, Domain: Advanced TSPI Warfighter Inertial Tracking System (WITS)



ENSCO, Inc., Springfield, VA



Battery enclosure Sensor package

FY15 Accomplishments

- ✓ Test Readiness Review 25 Feb 2015
- Update hardware and software
- Reduced SWaP System build and test
- Demonstration Testing
- Final Report

Deliverables (Mo/Yr)

- Four prototype WITS units, user manuals and executable SW. User demo and test report. (Aug/15)

Description: Develop self-contained, wide-area, accurate, continuous, and integrate-able TSPI technology that can operate seamlessly where GPS is unavailable, such as indoors, urban environments, underground, etc., as well as outdoors. Implement distance measuring radio that achieves accurate boot-to-boot ranging.

Enables: Precise location measurement over 2 hours.

Current Status: Phase 3 - Mature hardware and software into prototype implementation

Transition Partner / Date: ATEC Ft. Hood/4th QTR FY15

Phase/mos	\$K	Mo/Yr	TRL	Status
Ph 1/9		Sep/11/Jun/12	4	Complete
Ph 2/21		Jun/12-Apr/14	5	Complete
Ph 3/16		Apr/14-Aug/15	6	Current

Key Future Events:

- Demonstration Test at Ft Hood Jun 2015
- Final Report Aug 2015

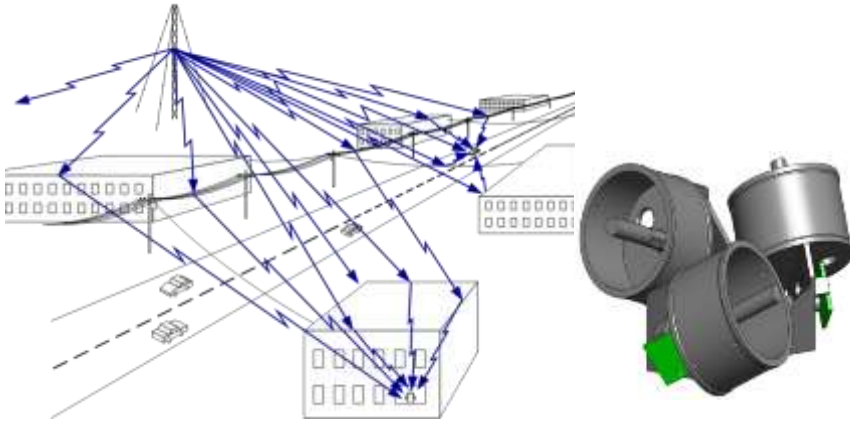


AIST, Domain: Advanced TSPI

Near-Field Electromagnetic Ranging

Signal-of-Opportunity Location Devices (NFER SOLD)

Q-Track Corporation, Huntsville, AL



Description: A NFER “Signal-of-Opportunity Location Device” (SOLD) employs the distinctive near-field patterns of AM Band Signals-of-Opportunity in a GPS-denied environment in conjunction with an RF fingerprinting algorithm to yield enhanced location accuracy indoors.

Enables: Achievement of reliable sub-meter location and long term calibration stability under conditions of arbitrary orientation and diurnal variation

Current Status: Phase 2 – Brassboard Implementation and Testing

FY15 Accomplishments

- ✓ Interim Project Review (IPR) Mar 3, 2015
- Implement Brassboard
- Beacon Design
- Integration
- Field Testing
- Prototype Preliminary Design

Deliverables (Mo/Yr)

- 16 of 25 prototype NFER SOLD units complete with software, source code, documentation, and manuals. Demonstration and Final Report. (Dec/16)

Transition Partner / Date: ATEC Ft. Hood/ 1st QTR FY17

Phase/mos	\$K	Mo/Yr	TRL	Status
Ph 1/19		Mar/13-Oct/14	4	Complete
Ph 2/13		Oct/14-Nov/15	5	Current
Ph 3/14		Nov/15-Dec/16	6	

Key Future Events:

- Test Readiness Review July 2015
- Field Evaluation Aug 2015
- Critical Design Review Oct 2015



AIST, Domain: Advanced Sensors Orientation and Posture TRACking System (TRAC)

Luna Innovations Inc. Blacksburg, VA



Description: TRAC will design, develop, and transition a lightweight Orientation and Posture TRACking system (TRAC) that integrates into the uniform/fatigues/ equipment of a warfighter. TRAC will develop fiber optic shape sensing technology that accurately provides dynamic measurements.

Enables: Accurate display of posture, head orientation, and respective orientations of warfighters and their equipment.

Current Status: Phase 2-Develop Gen II TRAC System

Transition Partner / Date: Aberdeen Test Center/ 3rd Qtr FY16

FY15 Accomplishments

- ✓ Test Readiness Review (TRR) 16 Dec 2014
- Transition Activity Testing
- Phase 3 Decision Meeting
- Final Report

Deliverables (Mo/Yr)

- Two prototype systems. Demonstration in an operational environment, test data and Final Report (Aug/16)

Phase/mos	\$K	Mo/Yr	TRL	Status
Ph 1/12		May/13-May/14	4	Complete
Ph 2/16		May/14-Aug/15	5	Current
Ph 3/12		Sep/15-Aug/16	6	

Key Future Events:

- Critical Design Review (CDR) Jun 2015
- Phase 3 Decision Meeting Jul 2015
- Final Report Aug 2015



Overview and Summary

- **What does AIST do?**
 - AIST develops Technology Readiness Level (TRL) 3 to 6 TSPI technologies
- **What does this briefing address?**
 - This briefing outlines the AIST methodology to identify future GPS/GPS-denied TSPI investment areas by mapping *range-user* TSPI requirements to TSPI projects
- **What is the status of GPS/GPS-denied technology developments?**
 - *GPS-based TSPI*: Developed SoA three-frequency Ultra-high dynamic GPS (UHDGPS) brassboard. *Need range-user support to develop ASIC*
 - *GPS-denied TSPI*: Although many technologies have been developed and tested, GPS-denied developments *are not complete*
- **What are some key T&E application areas for GPS/GPS-denied technologies?**
 - Real-time Casualty Assessment (RTCA)
 - Tracking in an urban environment
- **What are some key required technologies?**
 - Multiple sensor data fusion algorithm
 - Tri-frequency GPS chip
 - Miniaturized navigation-grade Inertial Measurement Unit (IMU)



Acknowledgement & Disclaimer



- **This material is based upon work supported by the Test Resource Management Center (TRMC) Test and Evaluation/Science & Technology (T&E/S&T) Program through the Naval Undersea Warfare Center, Newport Division, Contract No. N00178-04-D-4109-N416.**
- **Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Test Resource Management Center (TRMC) Test and Evaluation/Science & Technology (T&E/S&T) Program and/or the Naval Undersea Warfare Center, Newport Division.**



Advanced Instrumentation Systems Technology Points of Contact



- **Executing Agent**
 - Dr. George Shoemaker, Naval Undersea Warfare Center, 1176 Howell St, Bldg 1351, Newport, RI 02841-1708, 401-832-5304, george.shoemaker@navy.mil
- **AIST Deputy Executing Agent**
 - Ms. Gail Holmes, Naval Undersea Warfare Center, 1176 Howell St, Bldg 1351, Newport, RI 02841-1708, 401-832-6972, gail.holmes@navy.mil
- **AIST Technical Project Lead**
 - Dr. Sheila Jones, Naval Undersea Warfare Center, 1176 Howell St., Bldg 1351, Newport, RI 02842-1708, 401-832-4406, sheila.jones@navy.mil
- **AIST Requirements, Plans & Programs**
 - Mr. James E. Hooper, Sakonnet Technology Group, 95310 Mackinas Circle, Fernandina Beach, FL 32034-5066, 904-310-9174, james.e.hooper.ctr@navy.mil
- **OSD/ AT&L TRMC-T&E/S&T Program, Advanced Instrumentation Systems Test Technology Lead**
 - Mr. Robert Williams, 4800 Mark Center Dr. Suite 07J22, Alexandria, VA 22350-3700, 571.372.2754, robert.m.williams22.ctr@mail.mil
- **Financial Support**
 - Mary Wheeler, Purvis Systems, Inc., 401-832-7046, mary.c.wheeler.ctr@navy.mil
- **Subject Matter Experts**
 - Mr. Tom Macdonald, MacroVision, Reading, MA, macrovision@verizon.net
 - Mr. Al Sciarretta, CNSTI Inc., Springfield, VA, asciarretta@cnsti.com
 - Dr. Paul Fortier, UMASS Dartmouth, pfortier@umassd.edu
 - Dr. Howard Michel, UMASS Dartmouth, hmichel@umassd.edu
 - Dr. Rebecca Grier, IDA, rgrier@ida.org
 - Mr. Roger Davis, Resource Management Concepts, Inc., Atlantic Test Range, roger.davis@rmcweb.com



Background



NG-TSPI Application Areas



- 45 Use Cases were examined. For logistical reasons, the Study Team addressed the Application Areas in separate groups

January 2009 Workshop
70 Participants

Ballistic Missiles
Ground Forces
Munitions

- **Air-to-Air**
- **Air-to-Surface**
- **Surface-to-Air**
- **Surface-to-Surface**

Address in above:

- **GPS-Denied**
- **Targets**
- **IEDs**

Jun 2009 Naval TIM
22 Participants

Naval Undersea and Littoral

August 2009 TIM
35 Participants

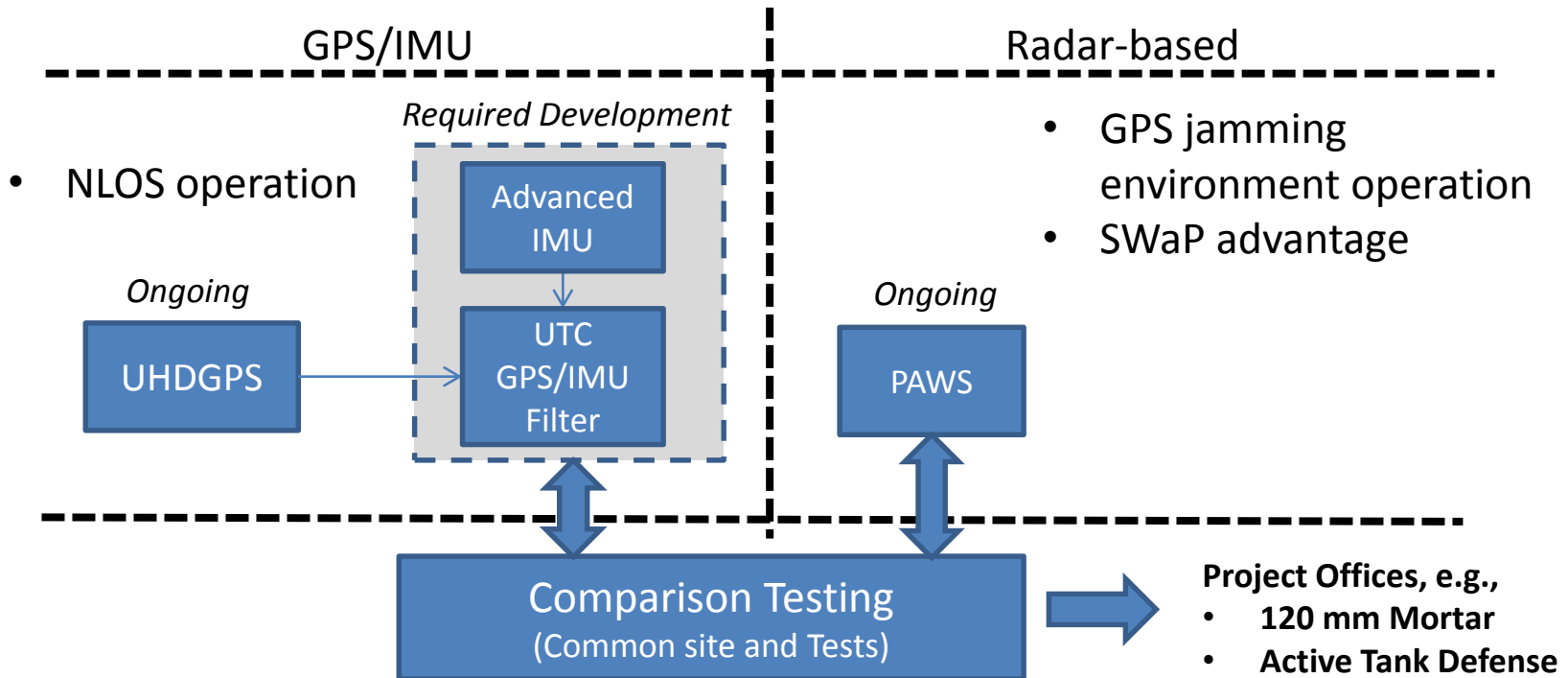
Air Vehicles
Hypersonic
Directed Energy
System of Systems
Guidance and Navigation
UAV / UGV
Low Observable (Stealth)



Two-prong approach to provide precise position and attitude for a highly-spinning munition/mortar



Technology	TSPI		Comments
	Position	Attitude	
Radar-based	Precision Ranging	Carrier-phase difference between nose and ring-mounted antennas	Conformal C-band antennas
GPS/IMU	GPS	IMU	Conformal L-band GPS & DL antennas





New TSPI Application Areas



- **BMD**
 - Track large number of payloads
 - Off-board sensors –enhanced accuracy
- **Sub-munition Dispense**
 - Need to track missile: UHDGPS set
 - Need to track sub-munitions: MOTR-type tracker (accuracy <1 m) to cue optical tracker
 - Up to 1000 5 cm-50 cm size items
 - Discrimination between debris and munitions
- **Active Defense --Defend armored vehicles from RPG, mortars, missiles**
 - Track up to six RPG's, mortars, missiles
 - Radars/KTMs are a very expensive solution
- **Littoral Warfare**
 - Transition from deep water to shallow water to dry land
 - Limited on-board instrumentation
 - Vastly different communication media