Tracking Radar Array for Single Airborne Target (TRASAT) System

Air Force Topic AF191-051

DoD SBIR Kick-off Meeting

September 30, 2019

Period of Performance: 8/28/19 – 5/27/20

Presented To:

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Presented By:

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Intellisense Systems, Inc.

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Company Background

Began Operations in February 2018

Current business is built on 3 decades of product development and technology transition experience

2018 revenues ~ $27 million USD

2019 revenue plan of ~$35M

40% SBIR, 60% Production/Tech transition

150 employees (>60 with advanced degrees)

Military veterans make up 6% of our staff

Strategic Advisory Board

ISI's Quality Management System (QMS) is certified to ISO9001:2015/AS9100D and ISO9001:2015/AS9110C. ISI operates in accordance with CMMI-DEV:ML3 standards and expects to achieve ML3 benchmark by 2019.

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What We Do

Intellisense Systems designs, develops and manufactures a wide range of standard and customized integrated electronic systems. These products become part of an OEM, prime contractor's system, or government direct procured equipment. Intellisense Systems products are used across many markets that includes military & defense, homeland security, law enforcement, and commercial.

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Market Strategy

- Pursue growth in markets that lend themselves to IntelliSense Systems capabilities and expertise
  - Build with durable discriminators
  - Program/Platform specific opportunities
  - Intelligent, rugged, light weight, low power
  - High performance and functional density
- Position IntelliSense Systems as a Value-Add Partner
- Build Customer Loyalty through our demonstrated performance
- Maintain and enhance our Technology Leadership
  - Leverage SBIRs to fuel technology and product innovations
  - Demonstrate our leadership by anticipating and satisfying our customers' needs and differentiating our products as preferred solutions
- Broaden our customer and application base where it adds additional value and capabilities to IntelliSense Systems and our customers

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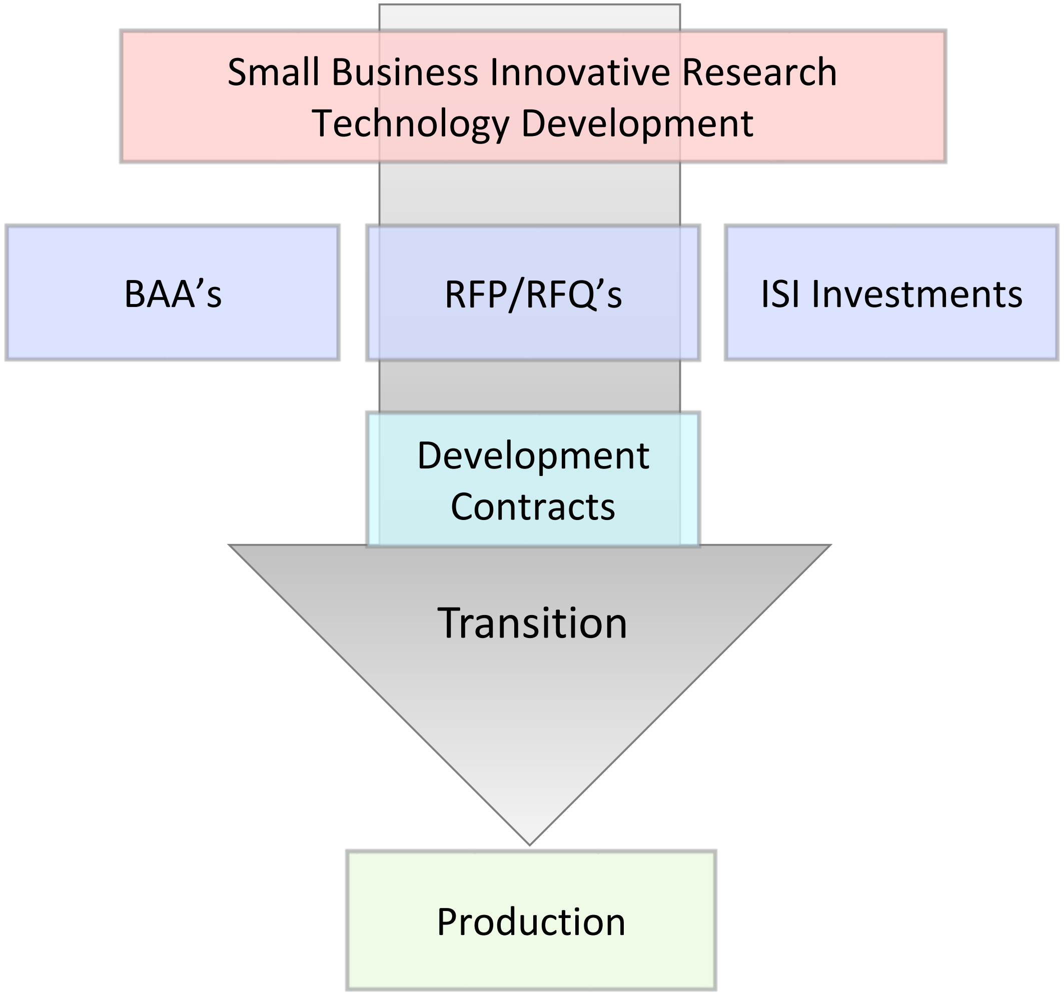
Intellisense Systems Business Model

Focus on Successful Transition of Technology to Commercial Products

- ISO9001, AS9100D and AS9110C Certified
- Weather Sensors Manufactured under a Program of Record
- Production Line for Aircraft and Ground Vehicle Displays
- Transitioning Wearable Equipment Technology
- Certified Independent Financial Audits
- Managed under EVMS & CMMI-MLIII (In process)



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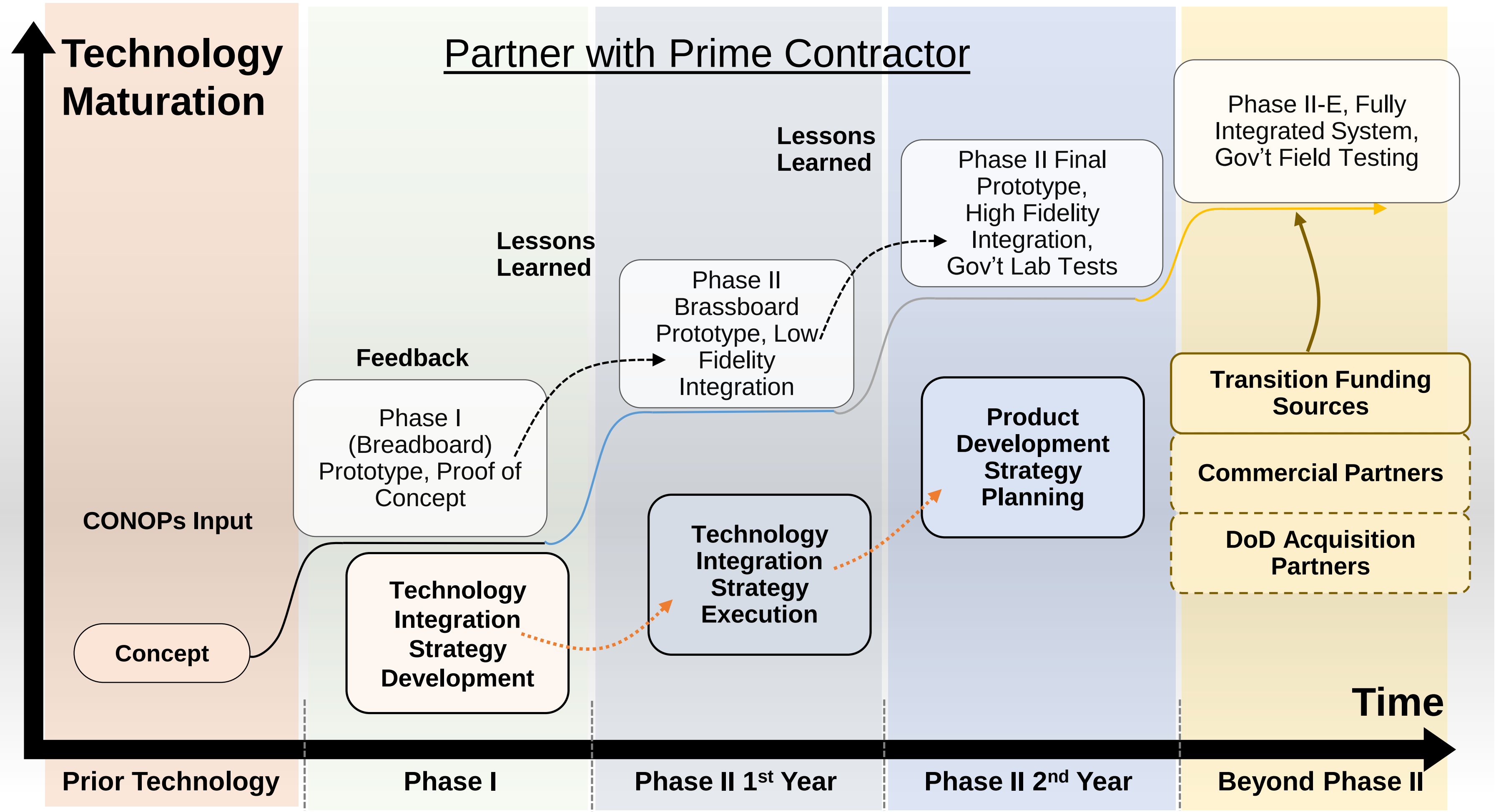
Technology Transition Roadmap



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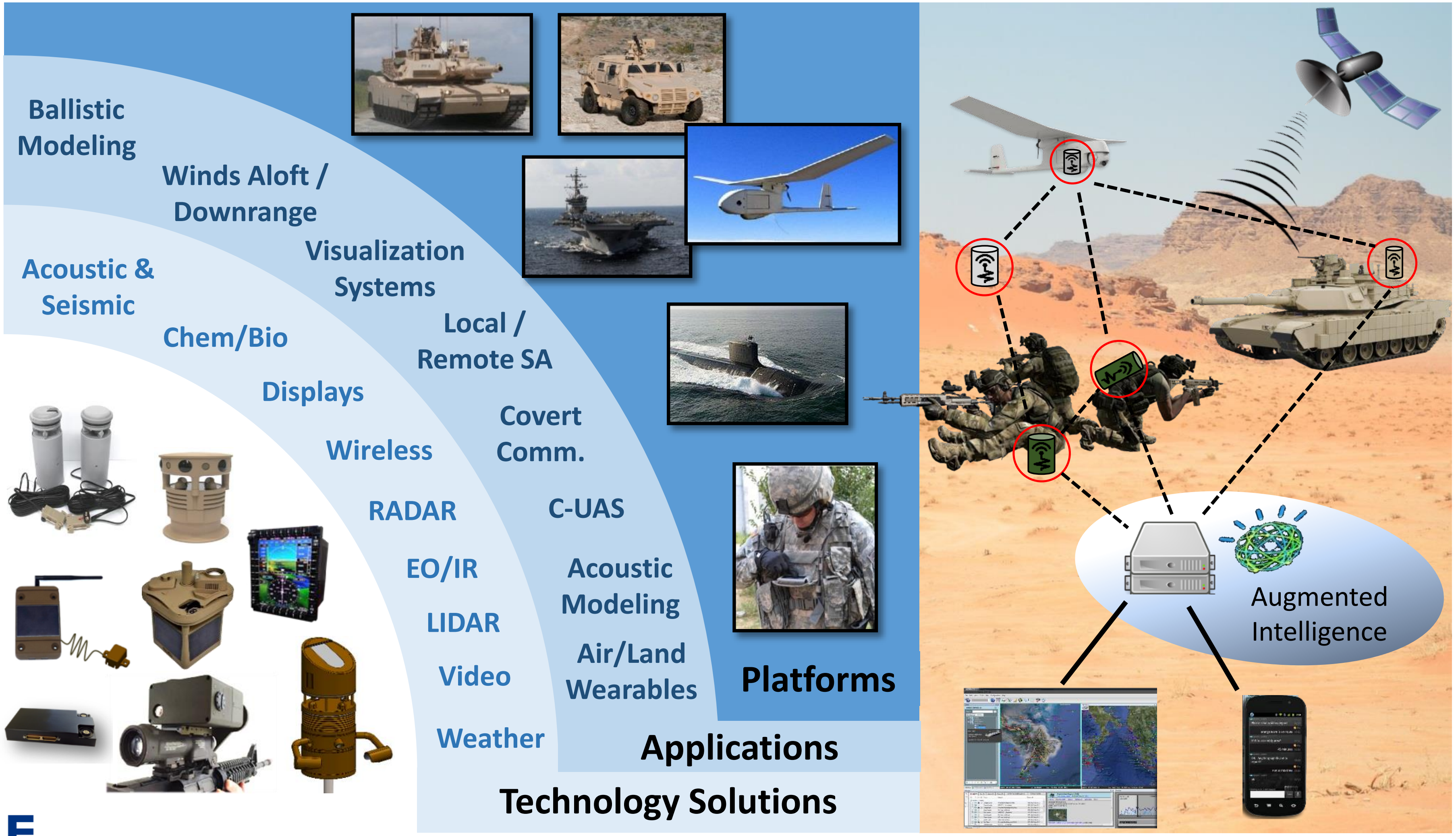
Technology Vision



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Delivering Critical Technologies to our Customers…

Micro Weather Sensor

Visualization/Displays

Night Vision, Laser Range Finders, Sights

Soldier Power & Data Management

Ballistic Fire Control MET Sensing

Maritime Deployable Weather Sensor

EO/IR & LIDAR Sensing

Augment Intelligence Algorithms

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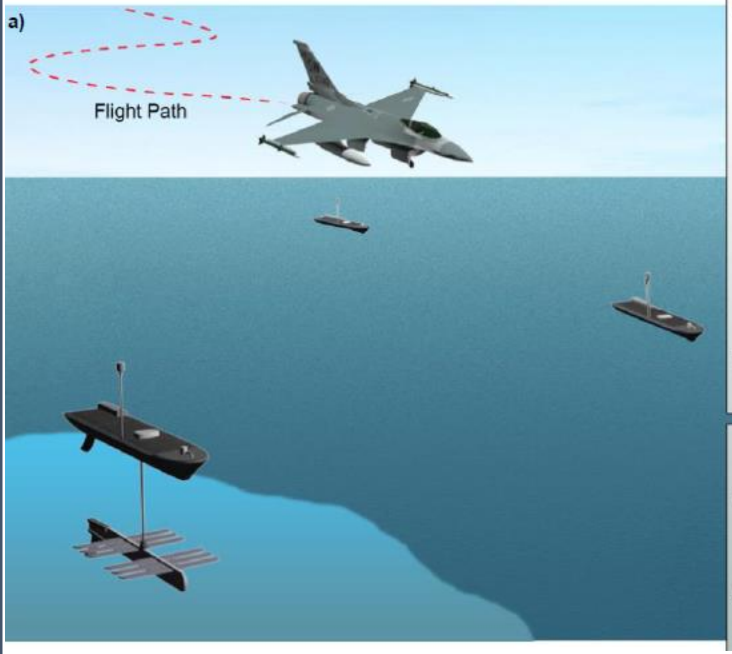
…Where, When at an Affordable Price

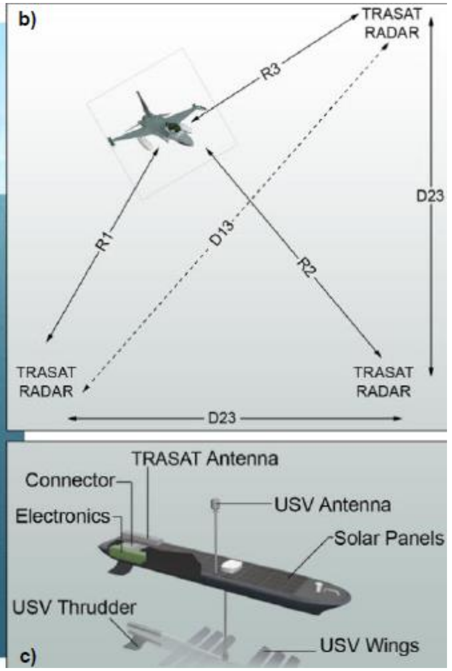
Tracking Radar Array for Single Airborne Target (TRASAT) System

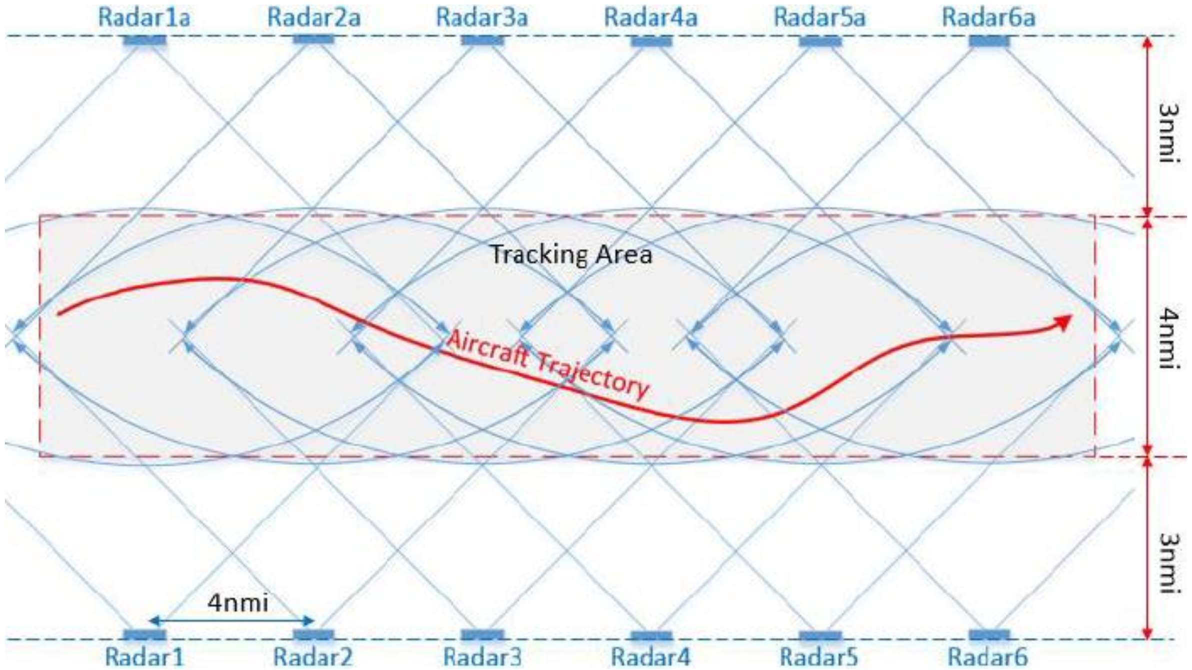
Review of Air Force Needs

- The Air Force is seeking a means to improve target tracking over water ranges utilizing unmanned surface vehicles (USVs). The intended target is aircraft flying at subsonic speed at altitudes of up to 6,000 m.
- Testing on water ranges is currently limited by the inability of land-based and barge-based radars to track over-the-horizon. Full use of the Gulf of Mexico is required for test missions requiring system under test tracking. The development of a micro-single target track (STT) ground-to-air radar system for use on an unmanned surface vehicle would significantly increase target tracking coverage over water.
- Using a fleet of autonomous USVs would enable the Air Force to leave the radar systems in the sea for long periods of time between the tests and wake and configure them for testing on demand. However, currently, no existing system can address this need.
- The STT system would need to be optimized for an unmanned surface vehicle that is approximately 10 feet long and 2 feet wide. The system must weigh less than 100 pounds and fit within a 6 inch by 12 inch by 12 inch payload box.

ISI's Solution: The TRASAT







The TRASAT system enables tracking of an airborne target during the test flight. TRASAT radars are positioned in a scalable dual-line array configuration along the target trajectory with overlapping FOV and multilateration is applied using data from at least three radars to calculate the target position with <10 m accuracy in three coordinates at ranges of up to 7 nmi and target altitude up to 6,000m. The TRASAT tracker collects and fuses data from all of the radars in the array and computes the composite target flight trajectory. The compact radars, installed on a USV, utilize the USV's power, GPS, and communication systems and control its movements to compensate for the hydrodynamic forces.

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ISI's Solution: The TRASAT (cont.)

- The radar system operates in X-band and includes two linear antenna arrays that enable electronic beamsteering capability in horizontal direction and monopulse operation for accurate elevation determination of the low altitude target. The planar antenna with total size 11 in. × 11 in. Each array has a fan-type beam: electronically controllable 7° beamwidth in horizontal direction and a fixed 20° in vertical direction. TRASAT is expected to consume <50 W and can be powered by the USV's solar panels.
- TRASAT, designed specifically to track targets from USVs, is tolerant to the inherent instability of USVs caused by hydrodynamic forces. The USV's pitch, roll, and yaw movements will have little effect on the trilateration accuracy until they exceed ±5° in vertical and ±10° in horizontal (yaw) deviations from the nominal position, which might shift the radar's FOV. To operate in high wave sea condition TRASAT will utilize mechanical stabilization of the antenna panel. We expect that simple gimbal mechanism which will keep antenna plane in nominal position (±2° accuracy) will satisfy TRASAT requirements.
- TRASAT incorporates a stabilization algorithm that utilizes the USV's built-in movement and position controls to mitigate the hydrodynamic forces and uses USV pitch/roll/yaw sensors. TRASAT also uses the USV's GPS and communication equipment to upload radar data to the control center.

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Advantages over Current Approach

The proposed system has the following advantages over the current approach in terms of benefits to users:

- **Compact radar** that easily fits into the USV's payload box (6 in. × 12 in. × 12 in.) and is based on commercially available COTS. The radar **reduces the system's size, weight, power, and cost (SWaP-C),** and **simplifies the design** without affecting the tracking accuracy by using **a broad, fixed elevation beam**.
- **Scalable architecture** enabled by the independent operation of the system radars.
- **Composite FOV (over-the-horizon tracking)** provides **high accuracy** measurement of the target position using a **multi-radar array**: **<10 m** in all three coordinates.
- **Optimized** server-based **single-target tracking algorithm** that uses advanced computation-efficient algorithms for data association and state estimation.
- **System design tolerant to instability of the USV**, which greatly simplifies the stabilization task, improves system robustness, and decreases the system cost.
- **Electronically steerable** (no moving parts) **antenna arrays** increase the system accuracy, reliability, and agility, and decreases the SWaP-C compare with mechanically beamsteering radars. **Dual 1D linear array configuration** allows reduce system cost comparing to 2D phase array systems.
- **Accurate low altitude measurement** by using **phase monopulse** technique**.**

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Phase I Work Plan

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Phase I Goals and Objectives

The overall goal of this project is to address the Air Force need by developing and, for the first time, demonstrating the feasibility of TRASAT. The following specific objectives have been established to reach this goal.

Phase I Objectives:

Objective 1. Definition of system requirements.

Objective 2. Development of the system architecture.

Objective 3. Feasibility analysis of the system architecture.

Objective 4. Definition of the commercial market for TRASAT.

Project Focus:

1. Detection of aerial vehicles in the high-volume test region by using low SWaP-C radar units.
2. High and low altitude 3D target position determination
3. Modeling and simulation of the multistatic radar configuration
4. Tracking algorithm development

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Project Tasks

Task 1. ***Define the System Requirements and Design Concepts (Objective 1)***

ISI will determine hardware requirements for micro-radar system in consultation with the Air Force team. Based on the system requirements, ISI will evaluate design concepts and approaches, using quantitative and qualitative analysis, and select those that would enable the radar system to meet the Air Force requirements.

Task 2. ***Develop the System Architecture and Simulation Models (Objective 2)***

ISI will develop simulation models of the TRASAT system components and the selected design concepts. Using MATLAB simulations, ISI will evaluate the TRASAT system performance and develop the system architecture, including definition of the main components.

Task 3. ***Develop the Tracking Algorithm (Objective 2)***

ISI will select the best STT algorithm for TRASAT multistatic approach and model it in MATLAB. The algorithm will include data fusion from multiple radars, multilateration target 3D position calculation, and target tracking.

Task 4. ***Define the Radar to USV and to TRASAT Center Interfaces (Objective 2)***

ISI will define radar unit interfaces to the USV Command and Control Unit and communication interfaces between radar units and TRASAT system center (server) to provide the system control and transfer radar data to TRASAT center.

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Project Tasks (cont.)

Task 5. ***Determine Feasibility of TRASAT System (Objective 3)***

ISI will develop MATLAB model of the TRASAT multistatic configuration to optimize the configuration and radar unit parameters. ISI will demonstrate the feasibility of TRASAT approach using system simulations and lab experiments.

Task 6. ***Explore Commercial Potential, Technology Transition, and Product Viability (Objective 4)***

ISI will explore the potential to transfer TRASAT to military systems and civilian applications. Market research will identify the most promising applications of the TRASAT system. Sources of Phase II and Phase III guidance and matching funds will be identified early in the project, and these early business partners will be involved throughout development and commercialization.

Task 7. ***Manage Program and Submit Reports***

ISI will undertake program management and reporting, as well as communication with the Technical Point of Contact (TPOC). ISI will prepare and submit reports and attend a kick-off meeting in accordance with contractual requirements. The final report will contain a summary of the work performed as well as recommendations for work to be performed in Phase II.

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Performance Schedule

TASK SCHEDULE	MONTHS AFTER PROJECT INITIATION								
	1	2	3	4	5	6	7	8	9
1. Define the System Requirements and Design Concepts	→	→	→						
2. Develop the System Architecture and Simulation Models		→	→	→					
3. Develop the Tracking Algorithm		→	→	→	→				
4. Develop the Stabilization Solution and Define USV I/F			→	→	→				
5. Determine Feasibilty of TRASAT System				→	→	→			
6. Explore Commercial Potential	→	→	→	→	→	→	→	→	→
7. Manage Program and Submit Reports	→	→	→	→	→	→	→	→	→
Milestones	1					2			3

1. Kick-off Meeting
2. Technical Review
3. Final Report

Period of Performance: 8/28/19 – 5/27/20

Funding: $149,999

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Technical Discussion

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Define the System Requirements and Design Concepts (Task 1)

- ISI will determine hardware requirements for micro-radar system in consultation with the Air Force team. Based on the system requirements, ISI will select design concepts and approaches that would enable the radar system to meet the Air Force requirements.
- Determine aircraft under test parameters, such as flight altitude range, maximum velocity, trajectory uncertainty, and expected radar cross section (RCS).
- Define sea level conditions applicable for TRASAT operation.
- Determine possibility to locate beacon on the aircraft under test and implement beacon signal reception for the aircraft positioning.
- Analyze possibility to implement a bistatic radar configuration to improve target detection and tracking.
- Determine optimal multistatic radar configuration considering C-SWaP limitations.
- Define USV platform characteristics and on the board equipment applicable for TRASAT operation.

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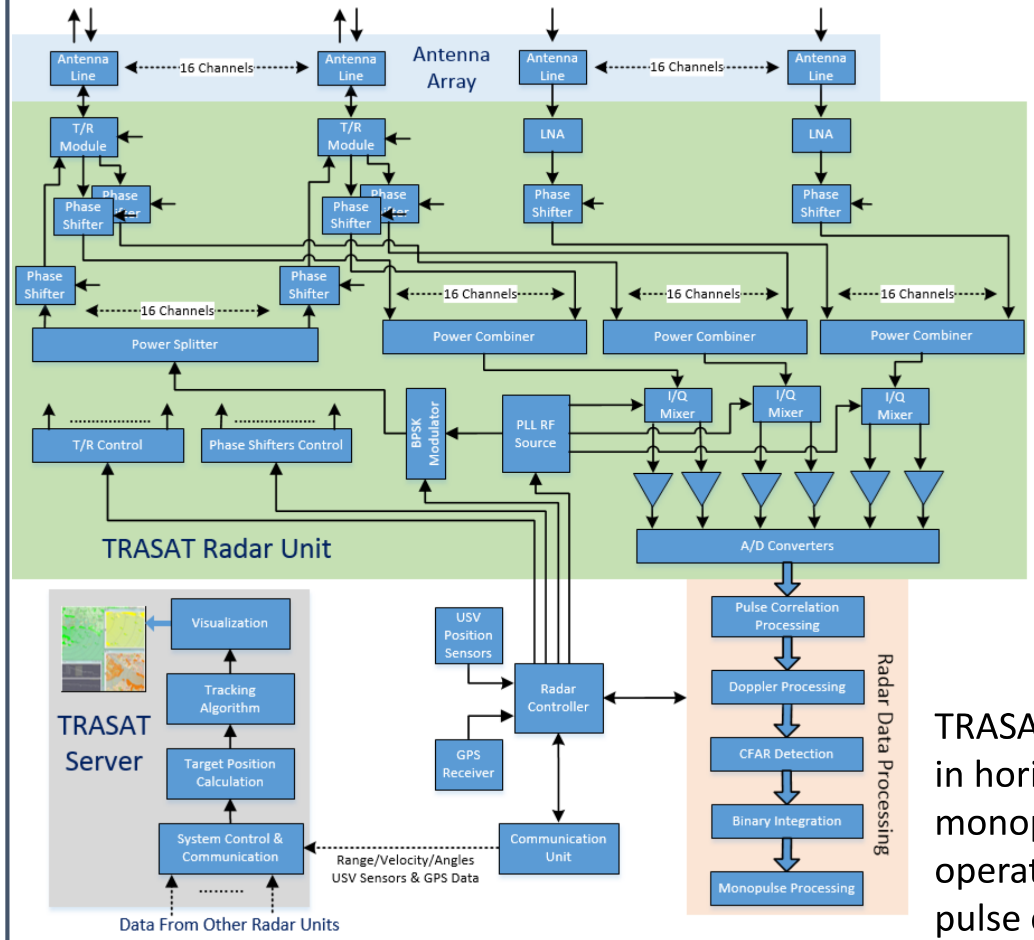
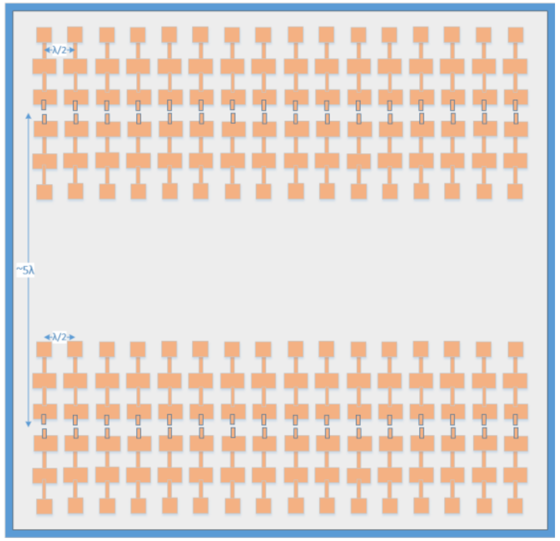
Define the System Architecture and Simulation Model (Task 2)





The planar antenna (11 in. × 11 in.) includes two 1D linear arrays, one for both transmit and receive and another for receive only. Each array has a fan-type electronically controllable 7° horizontal beam and a fixed 20° vertical beam. Broad vertical beam allow to cover wide range of the target altitudes and present low-cost alternative to expensive 2D phase array design. Additional gimbal mechanism allow antenna center adjustment to target elevation angle and for compensation of the radar platform instability. Two antennas on receive are used for phase-type monopulse operation for accurate elevation determination of the low altitude target.

TRASAT radar system operates in X-band and provides electronic beamsteering capability in horizontal direction. One of the receive array has dual phase shifter chain for horizontal monopulse operation in radar tracking mode. The radar will apply pulse compression operation with high (about 20%) duty cycle to maximize radar sensitivity. Bi-phase intra-pulse coding with different codes for different radar units will use to simplify the units separation. Using PLL synthesizer as radar carrier source allows frequency agility mode to reduce target RCS fluctuation and improve probability of detection. We plan to use commercially available integrated T/R modules with 4W transmit output.

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Define the System Architecture & Simulation Model (Task 2) (cont.)

- We plan to develop MATLAB model, which will include target model, sea clutter model, USV platform model, radar model, multistatic radar configuration model, and tracking model.
- Target model will have variable trajectory, altitude, velocity, and realistic RCS distribution of target of interest defined by Air Force.
- Sea clutter model will cover variable sea level conditions for low grazing angles and variable range to target.
- USV model will describe behavior of the Wave Glider (WG) under different sea condition. Stabilization mechanism of the WG platform and its position and tilt (pitch/roll/yaw) accuracy will be modeled based on inputs from Liquid Robotics.
- Radar model will be based on the TRASAT radar parameters and modes of operation.
- Multistatic radar configuration model will calculate target position using multilateration algorithm and output data from target model, sea clutter model, USV platform model, and radar model.
- Tracking model will calculate results of multistatic radar configuration model by using the tracking algorithm selected in Task 1.

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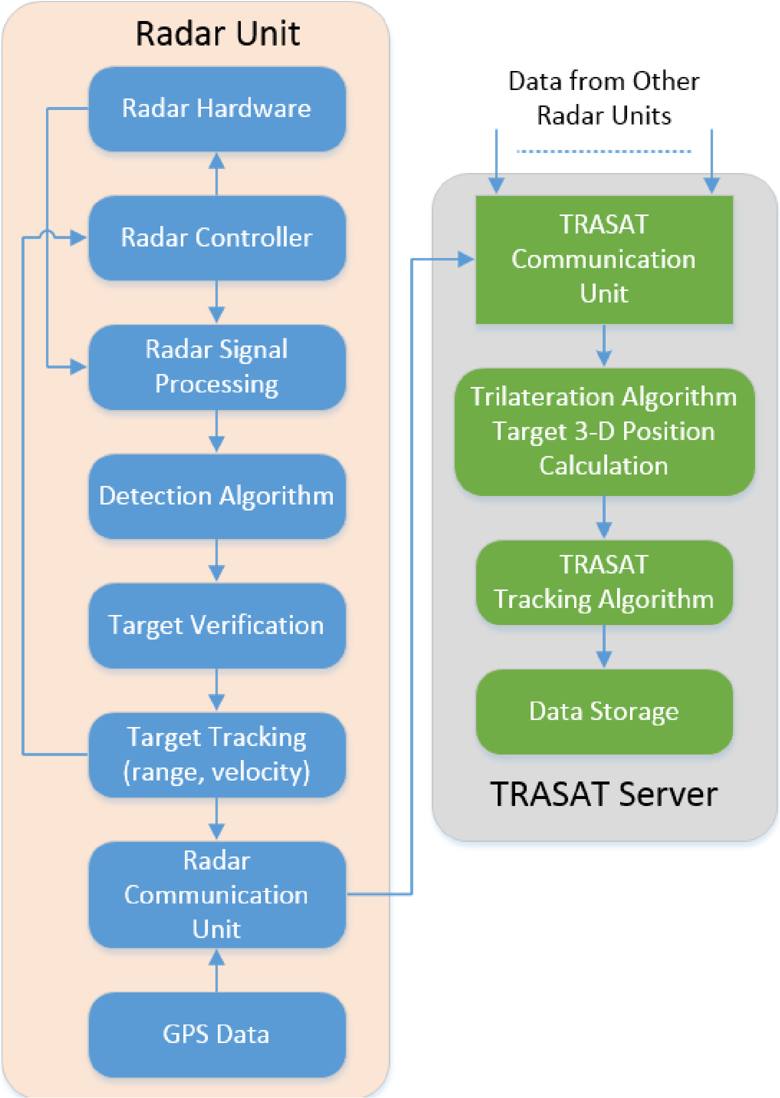
Develop the Tracking Algorithm (Task 3)

TRASAT tracking algorithm operates at two levels:

- Radar unit level, which allows each radar unit to verify and track the target. At this level, radar controller, placed on a USV platform, classifies detected targets to separate weapon under test from birds or other objects and clutter. Doppler capability of the TRASAT radar is critical for target verification. After the target under test is verified, the radar will use monopulse technique to track the target.
- Server level of the tracking algorithm is executed on the TRASAT server (in the control center), which collects data from individual radar units, calculates target's 3-D position by using multilateration algorithm, and then tracks the target trajectory by using Kalman filter to filter out noise and accidental errors. This level of the tracking operates on multistatic radar data and provides an accurate trajectory of the target.



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Define the Radar to USV and to TRASAT Center Interfaces (Task 4)

- ISI will study WG's electrical connections and software protocols and define TRASAT interfaces to WG Command and Control Unit. This will also include the connectivity and use of power supplied by WG. We plan to include an additional battery to support power draw by the radar during test. The battery, which fits in the payload box next to the radar's electronic unit, will be pre-charged by WG solar panels that supply up to 20 W for continuous consumption by TRASAT radar. Based on this study, we will define the use of WG native embedded software and the addition of TRASAT specific functionality including communication and control.
- We will investigate applicability of the GPS receiver installed on WG. If accuracy of the WG positioning system is insufficient for TRASAT operation, a more accurate GPS receiver will be installed on the WG as part of the TRASAT equipment or as an add-on to the WG control electronics.
- We plan to utilize WG's broadband global area network (BGAN) equipment to provide control of the multiple radar units from TRASAT control center, and to transfer radar unit's data to the center. If Iridium satellite communication is used to upload data to the server, the time of data upload will be significantly longer than the test due to the message length and transmission window limitations.
- ISI began collaborating with Liquid Robotics and will attend Payload Developer's Training at the end of October. We also got access to Wave Glider ICD, white papers, and other documentation.

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Determine Feasibility of TRASAT System (Task 5)

- ISI will determine feasibility of the TRASAT technology based on results of simulating the TRASAT model developed in Task 2. The test will use variable target parameters (RCS, velocity, altitude, and trajectory specifics) in combination with the selected radar multistatic configuration, hardware design, and signal processing to verify the TRASAT approach feasibility.
- Additionally, ISI will conduct lab experiments with radar components using vendors' design evaluation kits and ISI's custom design.
- The results of this task will be presented to the Air Force team as demonstration of feasibility of TRASAT technology and reported in detail in the Final Report.

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Project Team

Mr. Victor Khodos, Sr. RF Engineer
Principal Investigator

Mr. Alexander Genusov, Director, Electronic Systems Development
Architect and Project Manager

Dr. Alireza Behbahani, Research Scientist
Modeling and simulation

Dr. Min-Yi Shih, VP and General Manager
Program management

Mark Thompson, Director, Business Development
Commercialization and technology transition

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Commercialization Strategy and Transition

Product Vision. TRASAT radar will be installed on USVs and used for tracking an airborne target during tests. The compact radar device will fit into the USV instrumentation box (size), weigh <10 lb and consume <120 W of power during operation. The TRASAT multi-radar system will be capable of providing continuous tracking of a single target by using a large scale formation of USV-based radars along the known trajectory of the target under test. TRASAT tracking software will provide highly accurate 3D position of the target (<10 m accuracy) during its flight.

Target Military/Government Applications. TRASAT's primary application is in DT&E for long range airborne targets over water ranges. Other DT&E applications will benefit from the scalability of the TRASAT radar system. TRASAT will be adapted for security and surveillance applications that can benefit from a multi-sensor detection and tracking system, such as those used by the DoD, especially the Navy and U.S. Coast Guard.

Target Commercial Applications. TRASAT can be used for commercial DT& with minimal/no modifications. TRASAT can also be used in security of oil rigs and offshore platforms and in ground based installations to replace big and expensive radar systems with a scalable array of miniature low-cost radars.

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Program Management and Deliverables

- Kickoff meeting
- Interim progress reports
- Periodic discussions of the development and simulation/test results
- Conference minutes
- Presentation material
- Draft final report
- Final report
- Invention report
- Close-up meeting

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- **Q&A**

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