FY18 NDAA Section 1606 Complementary PNT Demonstration

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Stakeholder Day Postponed
Joint Base Cape Cod
20 Mar 2020

U.S. Department of Transportation
Volpe Center
Advancing transportation innovation for the public good

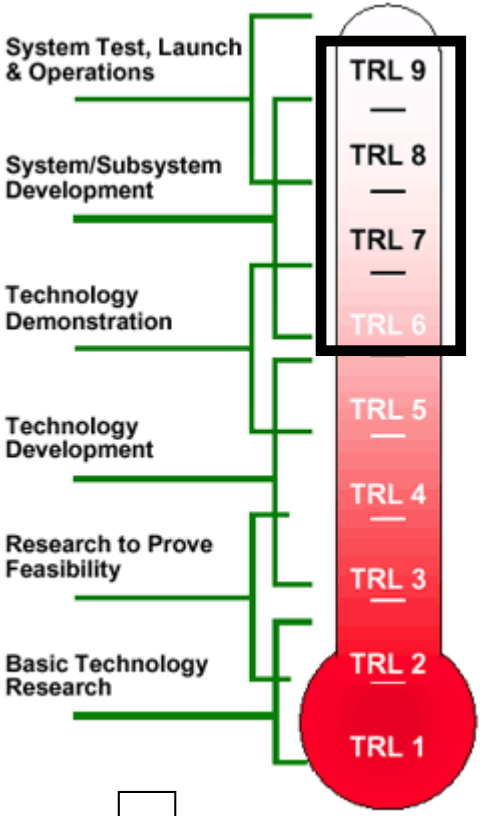
GPS Backup Demonstration Overview

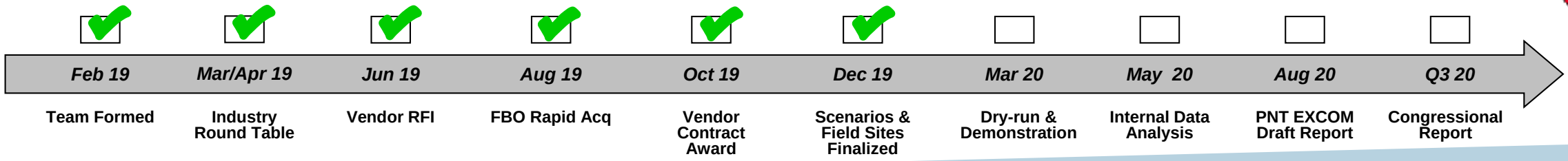
High-level Demonstration Plan Developed Under FY18 NDAA

- Joint DOT/DHS/DOD congressional briefing given Nov 2018
  - Coordination and planning efforts presented
  - DOT had yet to receive funds, transportation demonstration concept presented
  - FY20 NDAA extended period of performance to Dec 2020
- DHS Science and Technology conducted timing and positioning demonstration
  - Dec 2018 at NASA Langley/Insurance Institute for Highway Safety (IIHS) Ruckersville, VA
  - Technologies demonstrated: Locata, NextNav, Satelles (those already available at Langley)
  - Results and interim report in process
- DOT Volpe Center funded to execute demonstration Jan'19 - Dec '20

NDAA GPS Backup Demonstration Status

- Demonstration Team: 20 organizations, four field sites, six host platforms
- Executing three field campaigns, [at least] three technology demonstrations,
- Awarded 11 high TRL vendor demonstration contracts on rapid acquisition POs
- Demonstration output products:
  - Performance report with PNT roadmap and measures of effectiveness
  - PNT strategy guide and cross-departmental coordination for PNT EXCOM





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Volpe Contracted PNT Vendors

NEXTNAV

SKYHOOK

SENEN Solutions

UrsaNav
Leaders in what's now. Innovators of what's next.

Satelles

ECHO RIDGE

serco & ALION

HELLEN systems

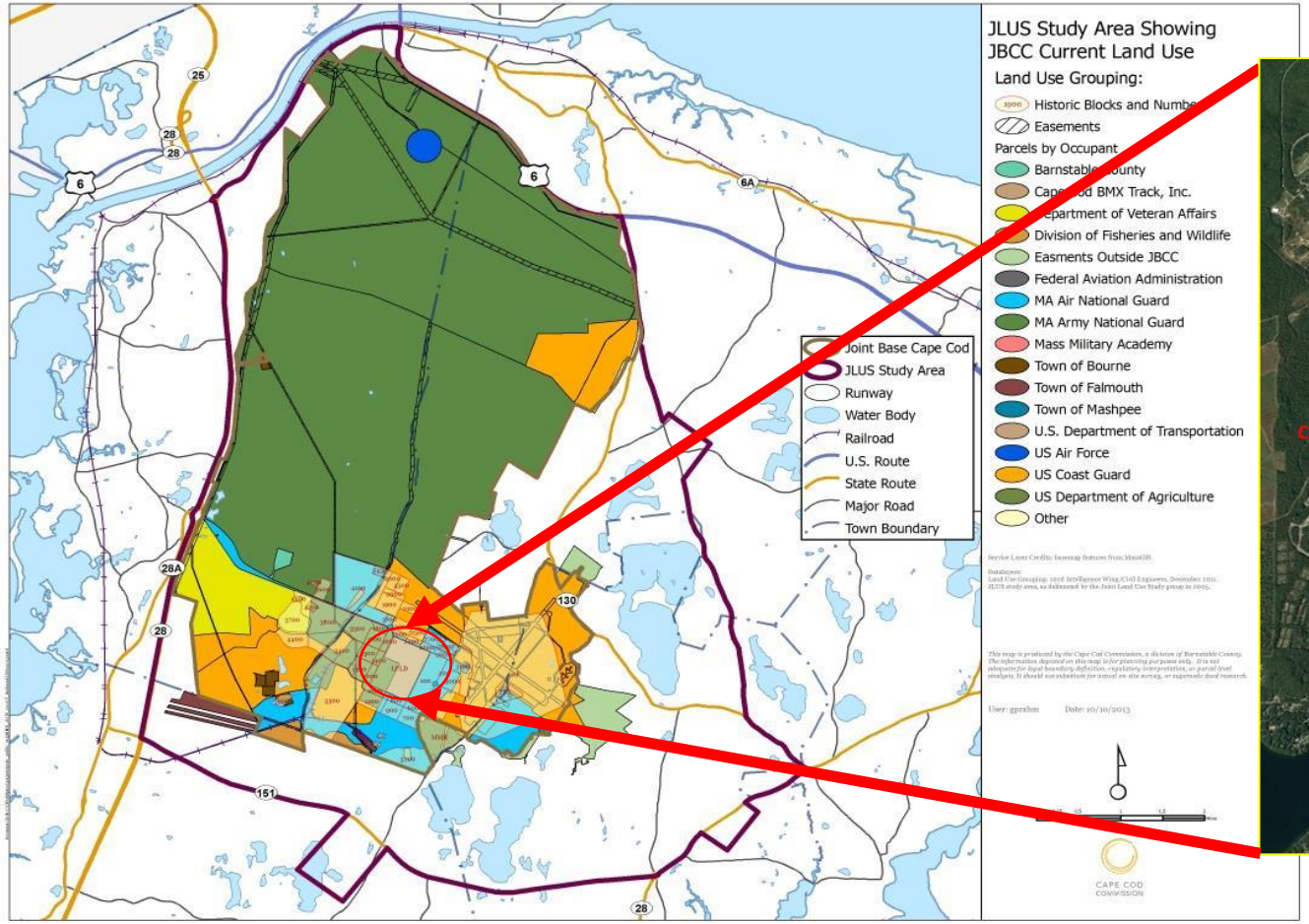
PHASORLAB
NEXT GENERATION WIRELESS TECHNOLOGIES

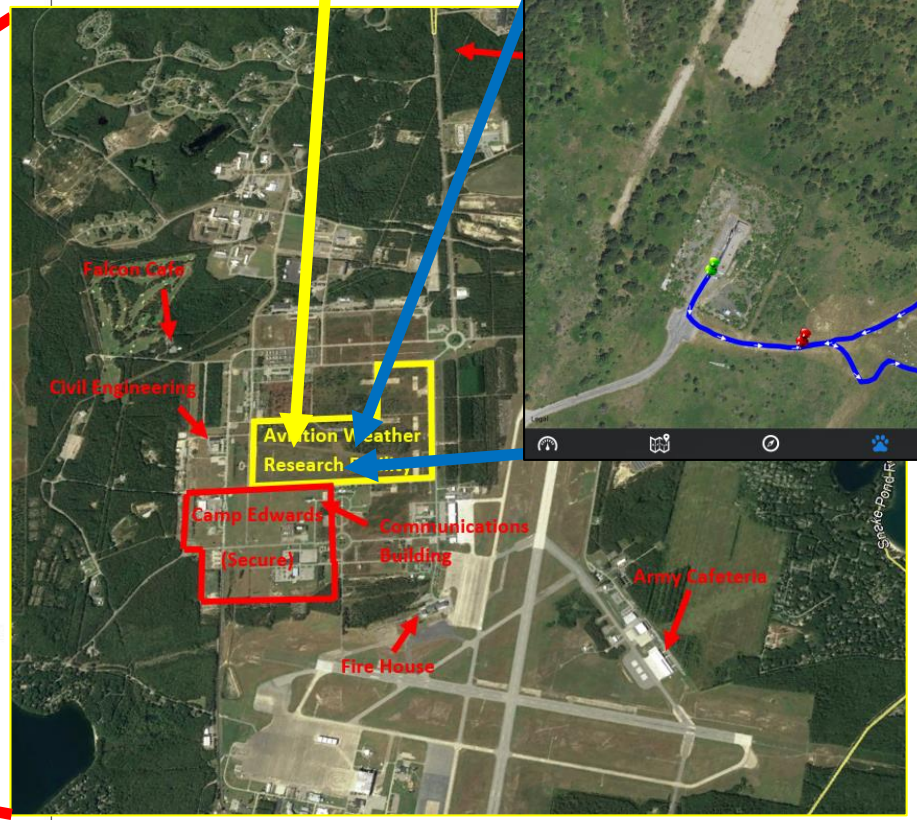
TRX systems

opnt. TIME PROVISIONING

Joint Base Cape Cod (JBCC) Volpe Field Facility

150 Acres
Volpe Test Facility





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Demonstration Plan (JBCC)

Scenario	Monday	Tuesday	Wednesday	Thursday	Friday
72-Hour Bench Static Timing	72 Hours			As Needed	
eLoran Reference Station offset				All Day	
Dynamic Outdoor Positioning w/Hold		3.5 Hours (AM)			3.5 Hours (AM)
Static Outdoor Positioning	4.5 Hours (AM-PM)				4.5 Hours (AM)
Static Outdoor Timing	4.5 Hours (AM-PM)				4.5 Hours (AM)
Static Indoor Positioning			1.5 Hour (PM)	1.5 Hour (PM)	
Static Indoor Timing			4.5 Hour (PM)	4.5 Hour (PM)	
Static Basement Timing			2 Hours (AM)	2 Hours (AM)	
3D Pos.		4 Hours (AM-PM)	4 Hours	4 Hours	4 Hours

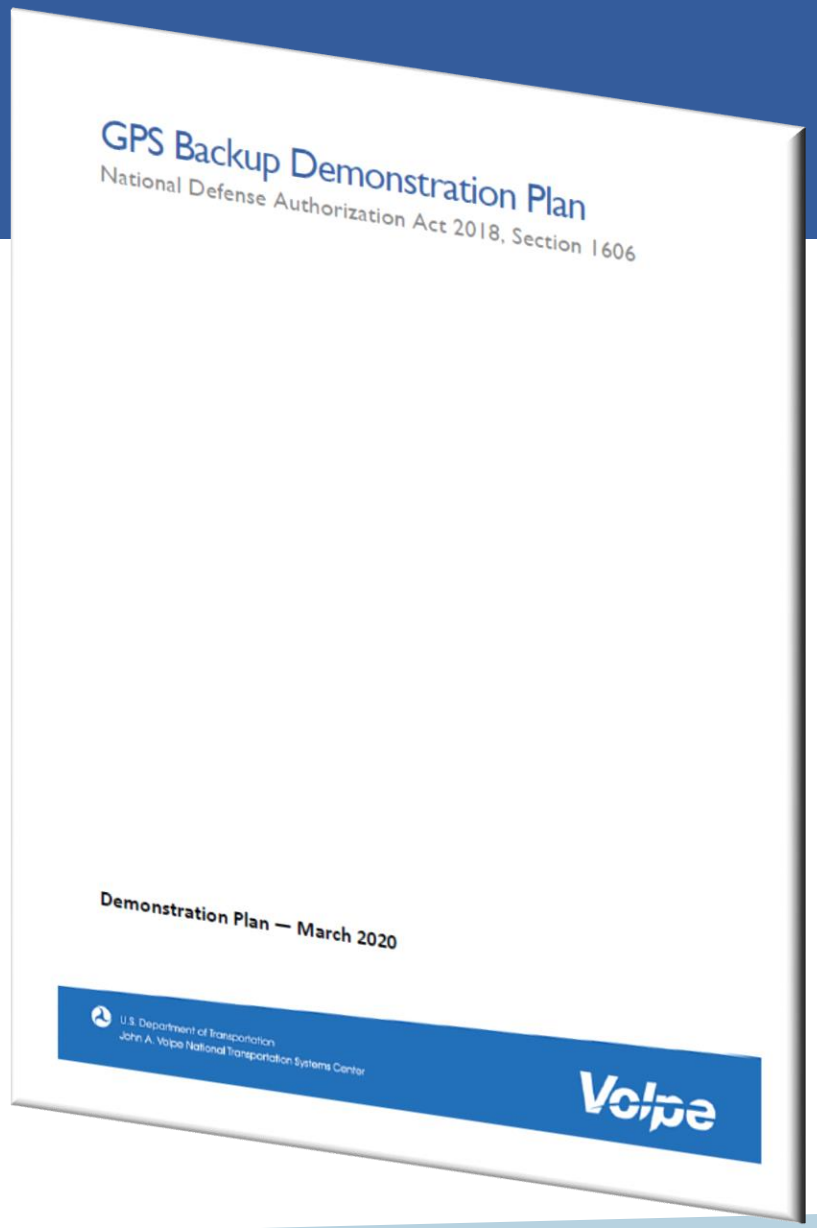
Planned Day
Make-up Day

Scenario	Monday	Tuesday	Wednesday	Thursday	Friday
72-Hour Bench Static Timing	72 Hours				
eLoran Reference Station offset					All Day
Static Basement Timing				4 Hours (AM)	

Planned Day
Make-up Day

JBCC Field Campaign

- 2 Weeks of Scenarios
- 5 Vendor Technologies
  - Hellen Systems
  - PhasorLab
  - Serco & Alion
  - Satelles
  - UrsaNav



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2D Platform & Reference System (JBCC)

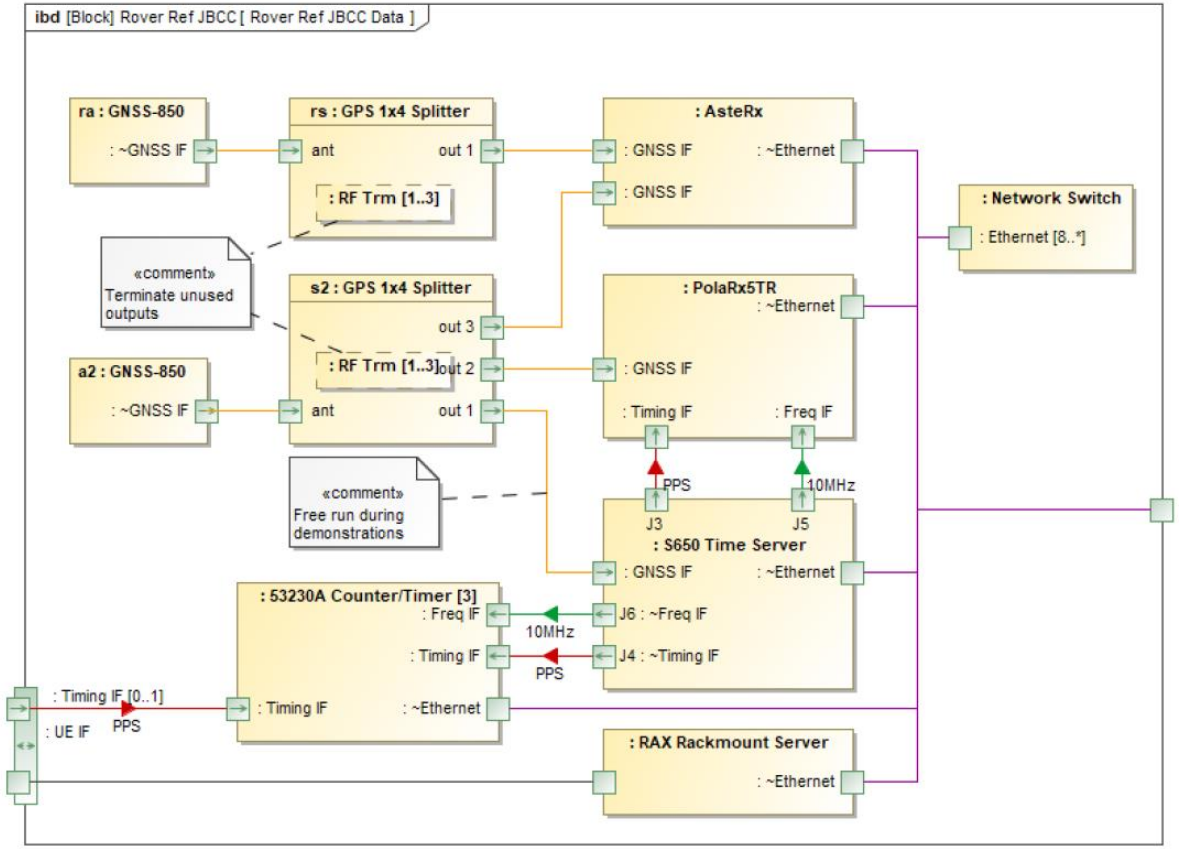


Figure 4: Rover Reference System Diagram JBCC

3D Platform & Reference System (JBCC)

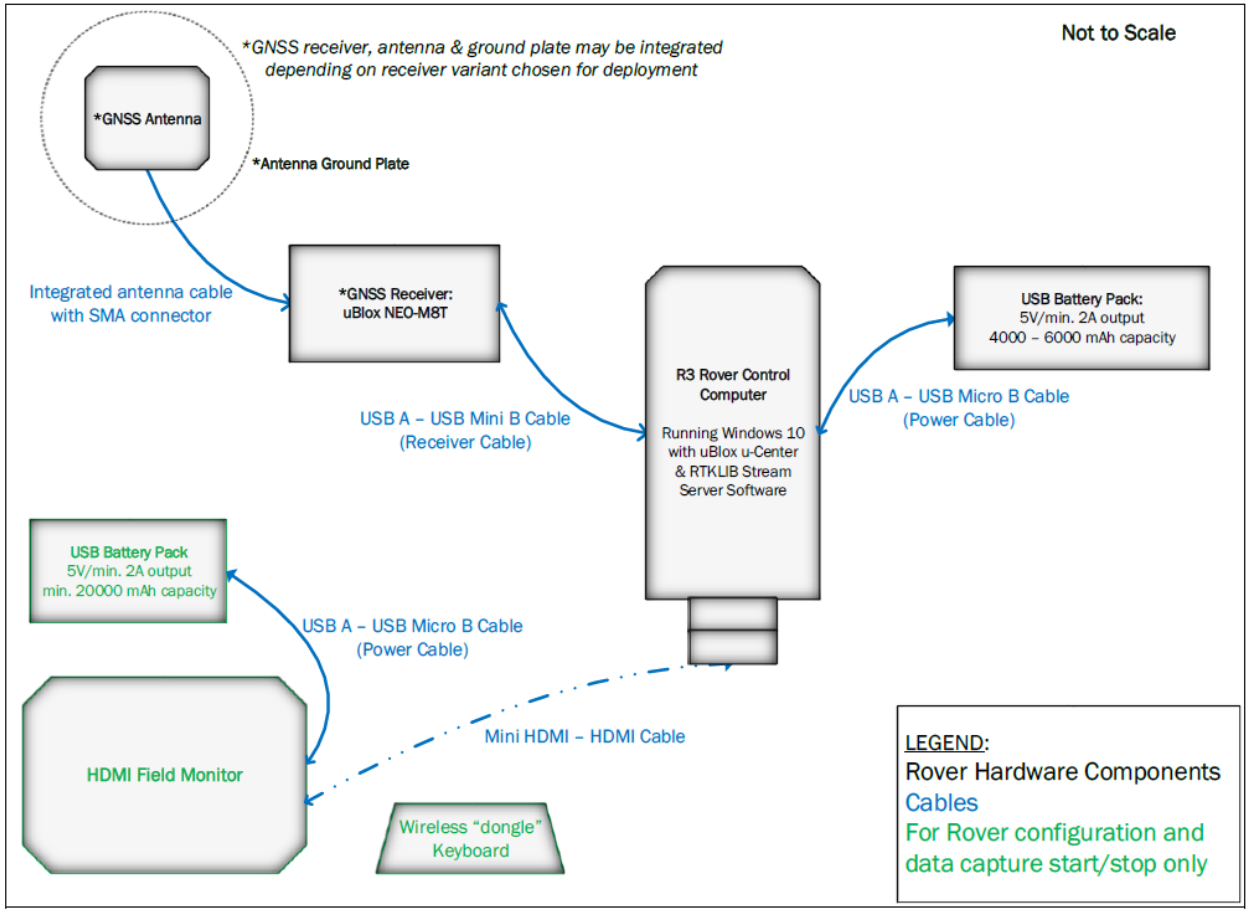
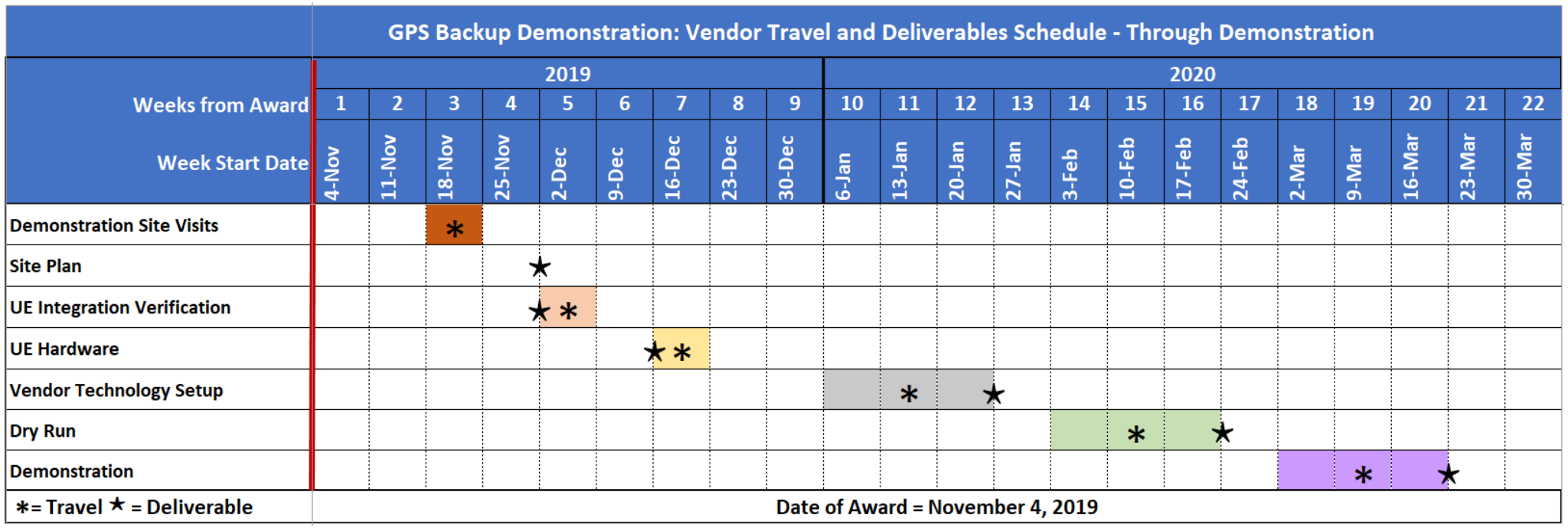


Figure 6: R3 Reference System Diagram JBCC

Demonstration Vendor Scope and Schedule

				Technologies							Demo Platforms				
				In Situ	Terrestrial RF				Satellite	Fiber Optic	Fixed		Moving		
VIP Demo	day	start	end	Map Match	LF (Loran)	MF (R-mode)	VHF (passive)	WiFI (2.4 GHz)	L-Band (LEO)	PTP	Outdoor	Indoor	Static	2D (van)	3D (uas)
LaRC	13-Mar	9:00	16:00	x			x	x	x	x	x	x	x	x	x
JBCC	20-Mar	9:00	16:00		x	x		x	x		x	x	x	x	x
		Vendors		TRX	Hellen Systems	Serco	NextNav	PhasorLab	Echo Ridge	OPNT					
					UrsaNav			Skyhook	Satelles	Seven Solutions					



Demonstration Outdoor Scenarios (2D JBCC)

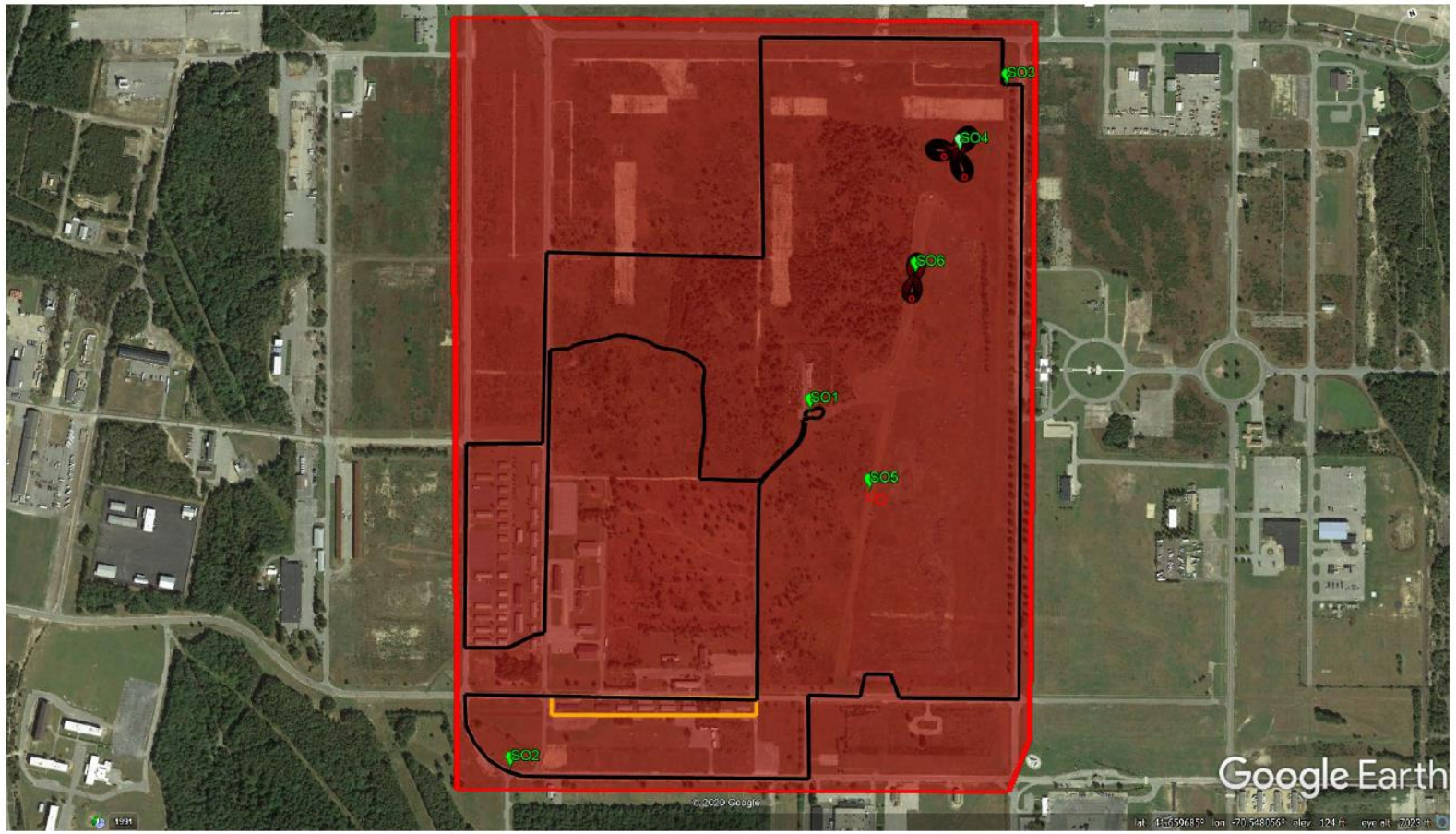


Figure 9: JBCC Dynamic Van Position with Hold Scenario

- Red area – fully instrumented
- Black track – van routes
- Green points – static points
- Orange box – dismount area

Demonstration Outdoor Scenarios (3D JBCC)

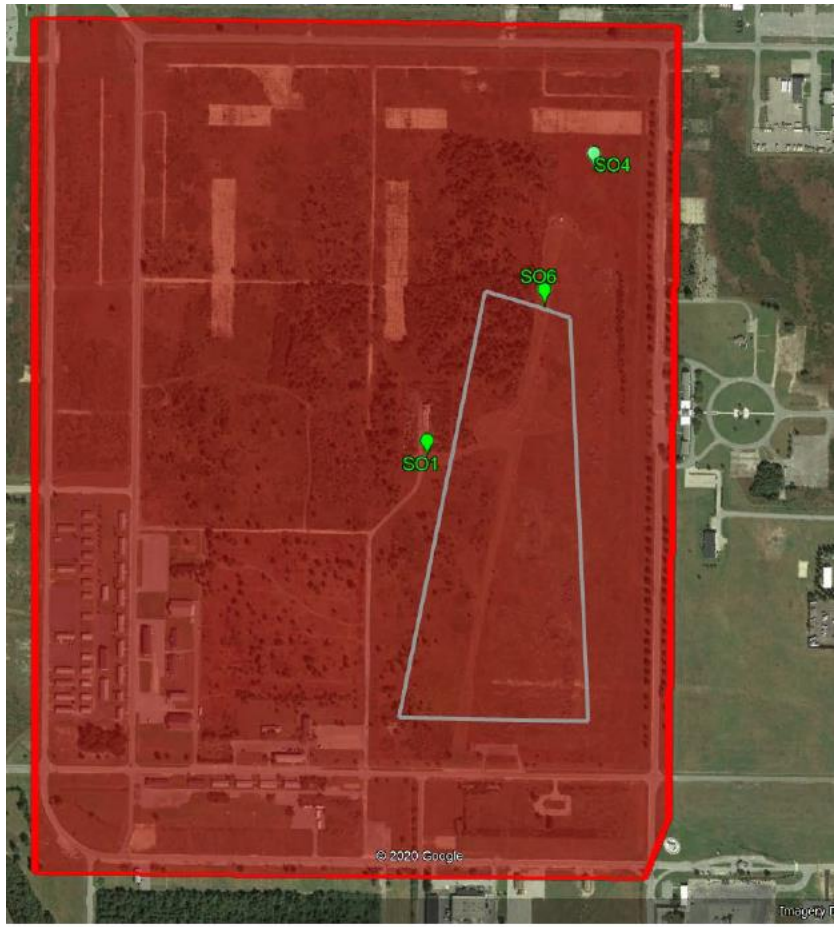


Figure 13: JBCC UAS Grey Route and Points

Figure 15: JBCC 3-Petal UAS Shape

Demonstration Indoor/Denied Scenarios (JBCC)

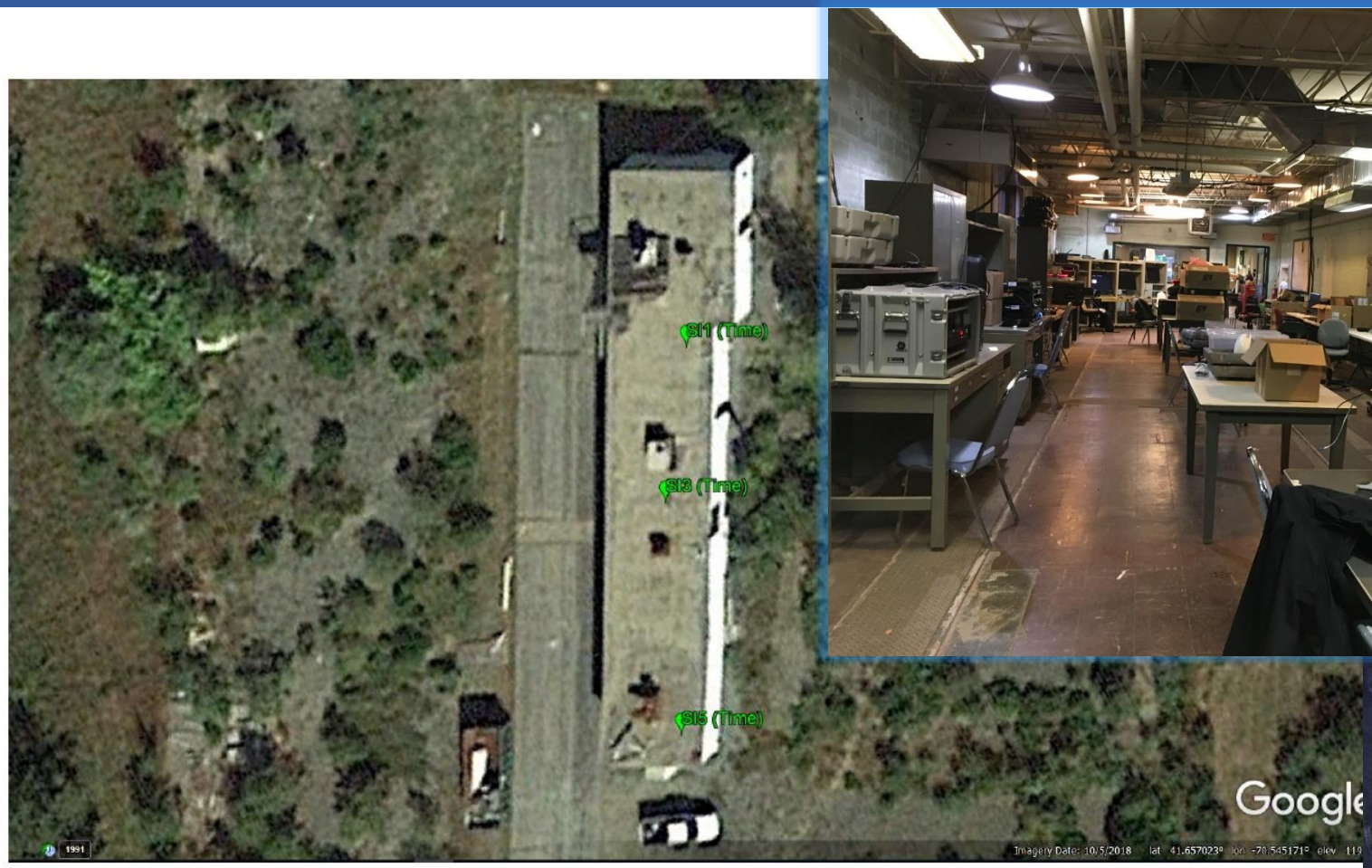


Figure 12: JBCC Static Indoor Timing Scenario

LF Reference Station Offset Scenarios (JBCC)

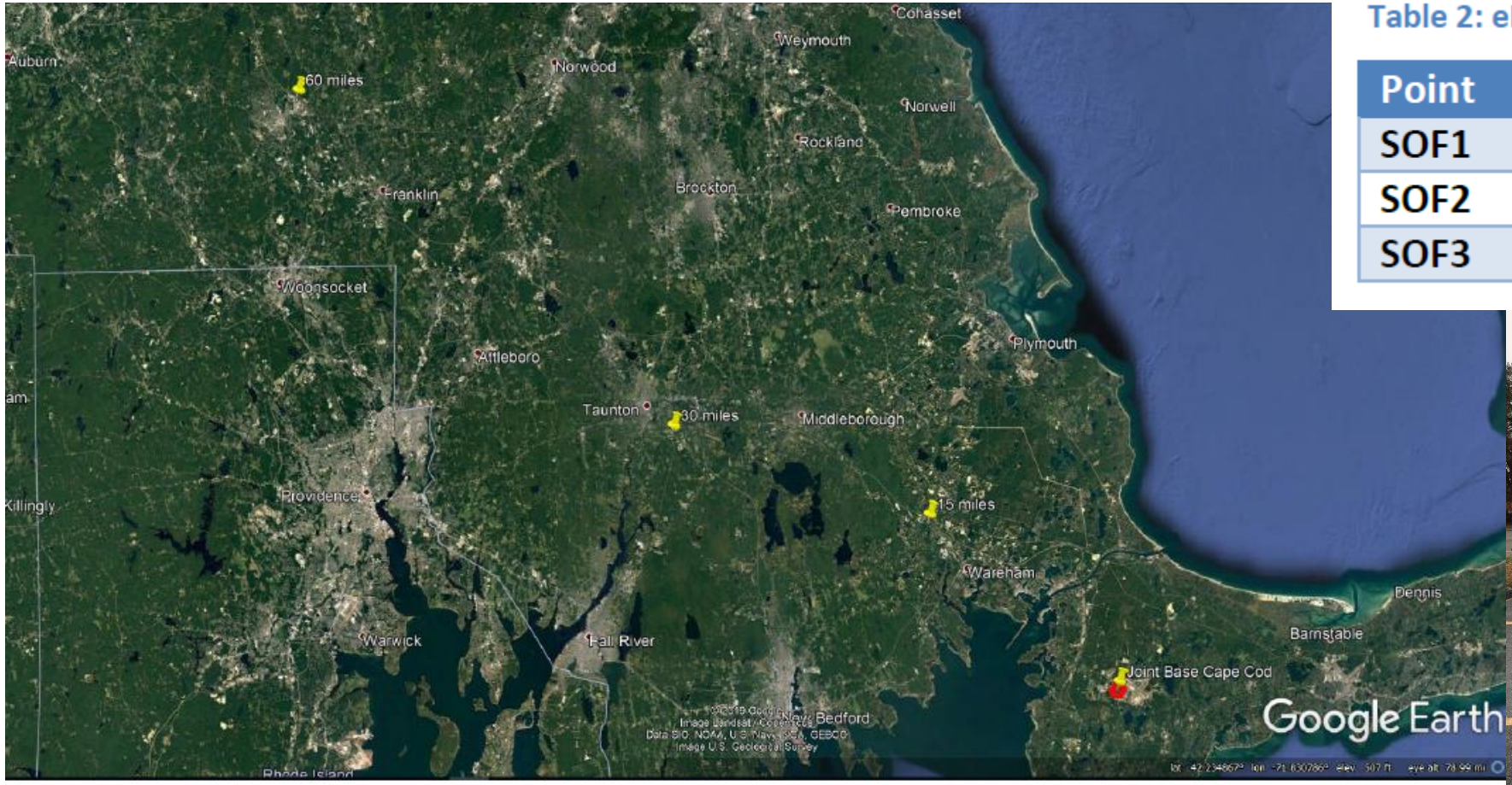


Figure 17: eLoran Reference Station Offset Scenario Positions

Table 2: eLoran Reference Offset Positions

Point	Location
SOF1	41.802306° -70.771671°
SOF2	41.875072° -71.062101°
SOF3	42.160462° -71.499288°

HELLEN systems

Application Timing

Type of Technology: eLORAN

Location/Base of Operations: Middleburg, VA

Partner Company(s): Harris Corporation, Microsemi, Maquerie Capital, Booz|Allen|Hamilton, Continental Electronics, Crown Consulting Inc.

RF Bands: LF band 90-110 kHz (previously Loran-C)

Technology Readiness Level or TRL (Transmitter/UE): 9/8

Technology Description: "Enhanced LORAN or eLORAN is a next generation LORAN technology and is the most suitable backup to GPS.

- 3 million times stronger than GPS
- High Power/Low Bandwidth signal is highly resilient to jamming, spoofing or interference
- Can penetrate through buildings, underground and underwater
  - Low cost alternative source of PNT
  - Highly scalable for widespread adoption
  - Terrestrial system versus space based
  - Digital signal
  - Wireless, Stratum 1 independent source of timing"

What is PNT?

Why is it important?

Why eLORAN?

PHASORLAB
NEXT GENERATION WIRELESS TECHNOLOGIES

Application: Positioning and Timing

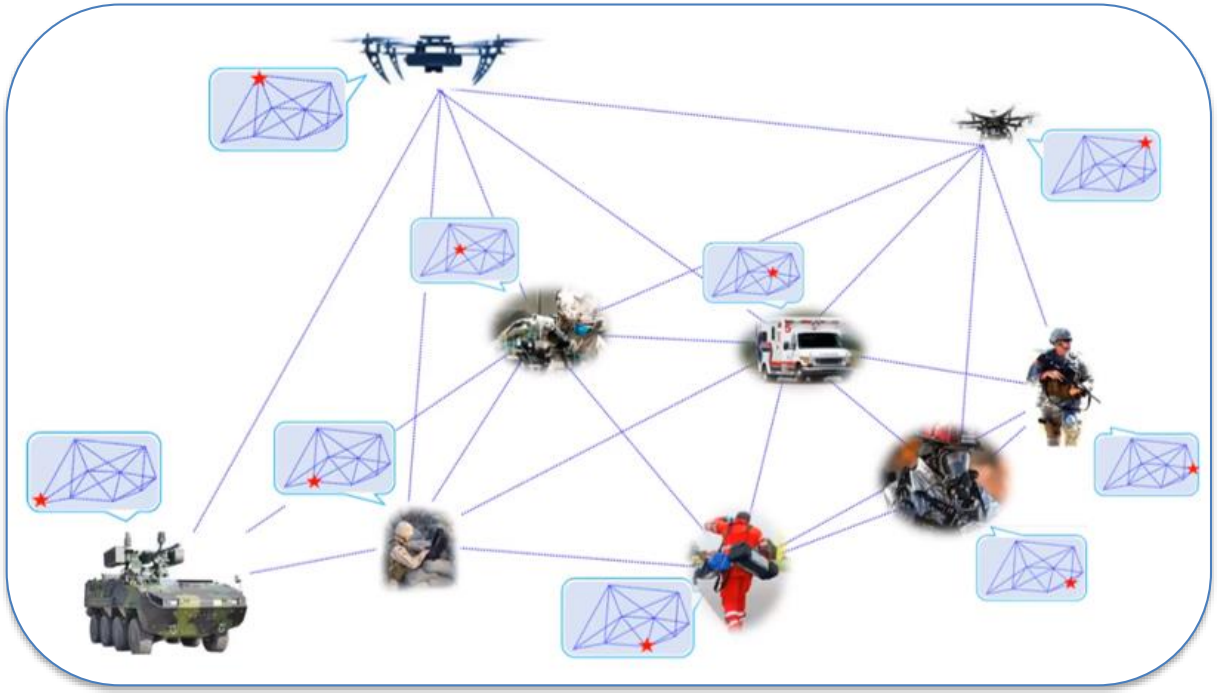
Type of Technology: Self-Organizing Mesh Network for PNT (Hyper Sync Net for Position, Navigation and Timing)

Location/Base of Operations: Nashua, NH

Partner Company(s): N/A

RF Bands: 2.4 to 2.42 GHz

Technology Readiness Level (Transmitter/UE): 7/7



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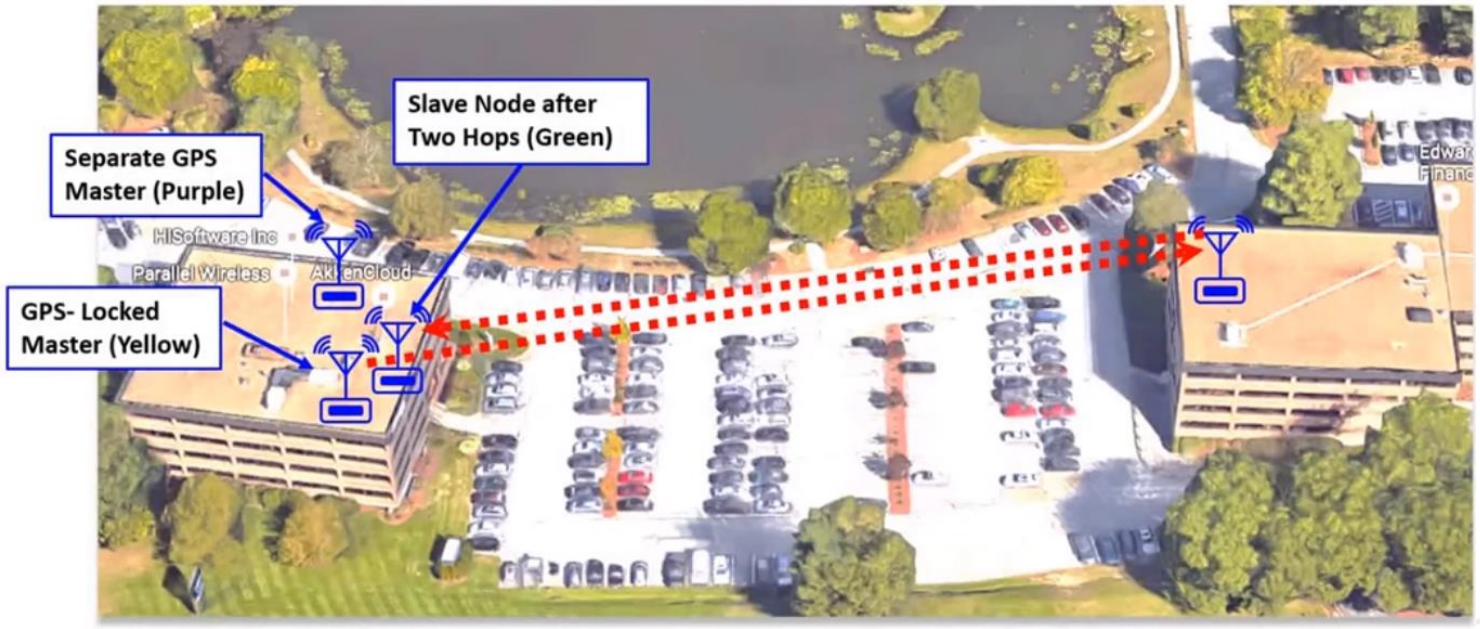
Technology Description(s):

- **Hyper Sync Network:** Providing superior time and carrier synchronization accuracy better than networks relying on GPS or IEEE 1588

- **Hyper Sync Net for Positioning:** Hyper Sync Net is capable of maintaining time synchronization of better than 1 nanosecond and frequency synchronization of better than 1 ppb



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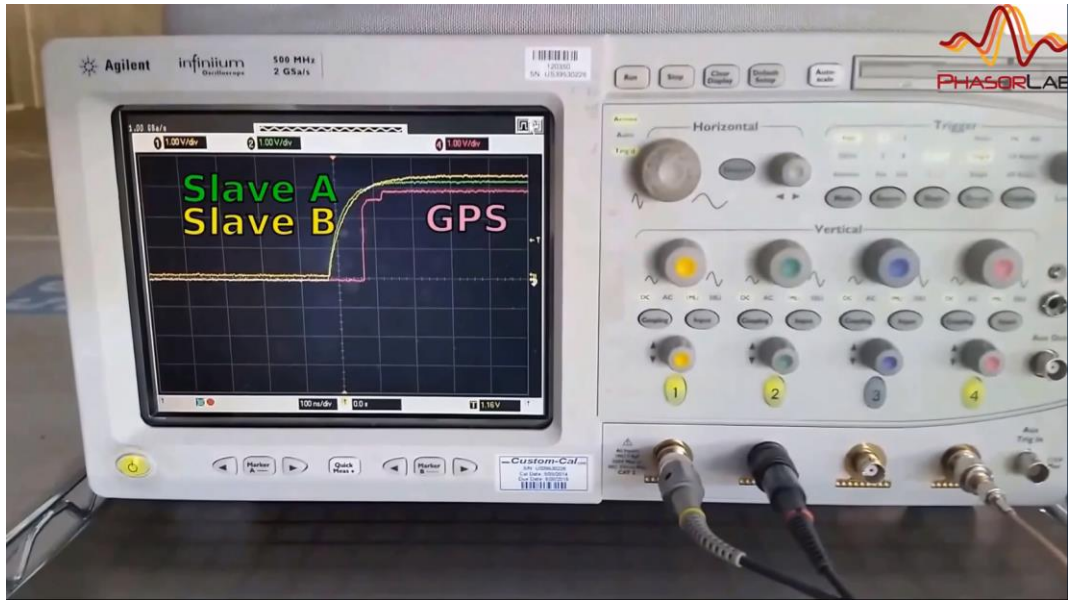
NEXT GENERATION WIRELESS TECHNOLOGIES

Technology Description(s) Continued:

- **Single-Reference 3-D Positioning:** Our unique technology for measuring the Angle-of-Arrival of RF carrier signals can eliminate the need for a phased array antenna system for measuring AoA

- **Instantaneous and High-Sensitivity Doppler Shift Measurement (Accurate Speed Measurement):** Our Hyper Sync Net is capable of capturing instantaneous Doppler shift separate from the true carrier frequency offset



Satelles

Application: Timing

Type of Technology: Satelles Satellite Time and Location (STL) Technology

Location/Base of Operations: Herndon, VA

Partner Company(s): N/A

RF Bands: Satellites transmit in L-Band between 1616-1626.5 MHz

Technology Readiness Level (Transmitter/UE): 9/9

Image: Satelles

Technology Description: Satellite Time and Location (STL) leverages Iridium's satellite infrastructure to broadcast signals that were designed by Satelles to enable precision time and frequency measurements.

These measurements can be used by a receiver for a variety of purposes, including:

- Transferring sub-microsecond timing, independent of GNSS
- Aiding GNSS acquisition
- Augmenting GNSS measurements when not enough GNSS satellites are in view

These high power signals are able to penetrate into many indoor and underground environments.

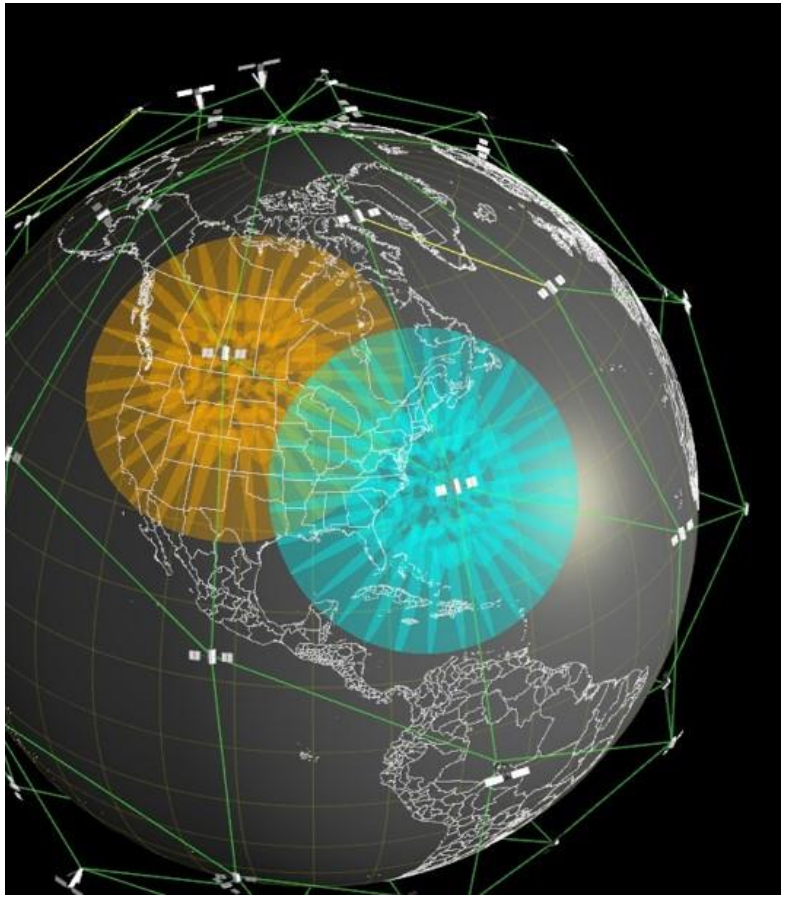


Image: Satelles

serco & ALION

Application: Positioning and Timing

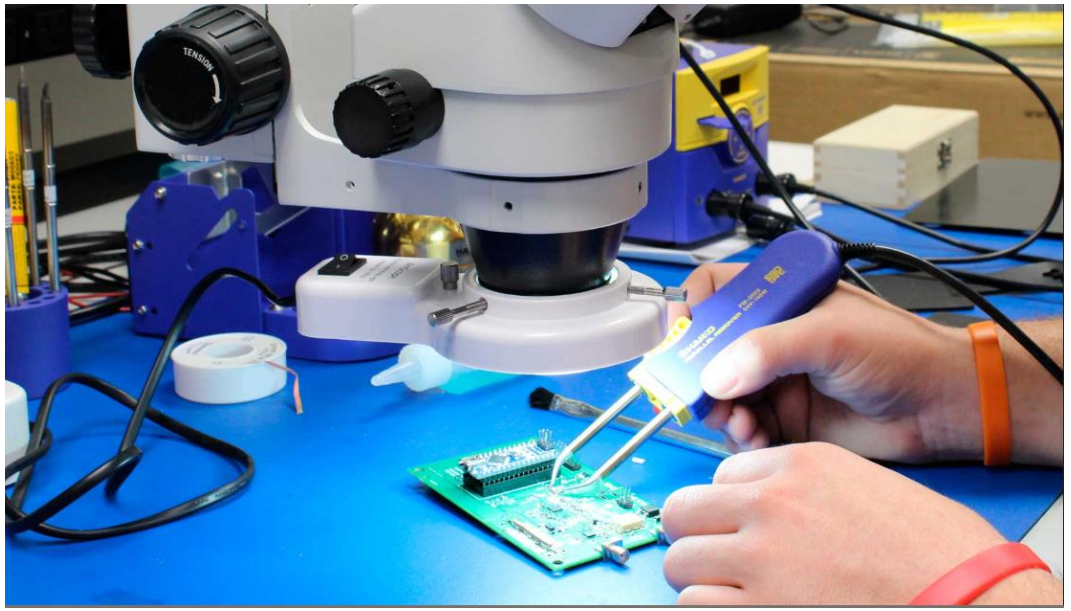
Type of Technology: Time-Of-Arrival (TOA) positioning using terrestrial Signal-of-Opportunity (SOoP)

Location/Base of Operations: Herndon, VA

Partner Company(s): Alion Science and Technology Corporation

RF Bands: Differential GPS (DGPS) in the MF band in the 283.5-325 KHz maritime channels

Technology Readiness Level (Transmitter/UE): 6/6



serco & ALION

Technology Description: Proposed GPS-alternative technology is Time-Of-Arrival (TOA) positioning using terrestrial Signal-of-Opportunity (SOOP) transmissions from Differential GPS (DGPS) in the MF band in the 283.5-325 kHz maritime channels

- Alion has developed an MF prototype receiver for DGPS
- During 2015-2016 Alion developed and tested a prototype MF R-Mode ranging receiver for the German Federal Waterways and Shipping Administration (WSV).

SYSTEM DESIGN & PROTOTYPING

We analyze, design, and develop hardware and software prototypes of systems and subsystems, in line with specific requirements and the results of our research and testing.

DEVELOPMENT & INTEGRATION

Alion's engineers integrate subsystems, components, and subassemblies, including firmware, hardware, software, and inter-component or inter-system communications.

UrsaNav

Leaders in what's now. Innovators of what's next.

Application: Timing

Type of Technology: eLORAN

Location/Base of Operations: North Billerica, MA

Partner Company(s): N/A

RF Bands: LF band 90-110 kHz (previously Loran-C)

Technology Readiness Level (Transmitter/UE): 8/8

UrsaNav
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Technology Description: eLoran provides PNT and frequency services like those of GPS, but with very different failure modes. An issue that disrupts GPS is unlikely to disrupt eLoran.

- Unique characteristics of eLoran enable its use in environments where GPS is unusable.
- eLoran uses pulsed signals at a center frequency of 100 kHz designed to allow receivers to distinguish between the groundwave and sky wave components in the received composite signal.
- eLoran signals can be used over very long ranges (e.g., 1,000+ nm from eLoran transmission sites) without fading or uncertainty in the time of arrival measurement related to sky waves.