NATO SET-229 - Cooperative Navigation in GNSS Degraded / Denied Environments Demonstration and Results

(Results shown from May 2019)

- Motivation
- Background
- Demonstrations
  - *Challenges*
  - *May 2019 Dry-Run Preliminary Results*
- Benefits/Way Forward

7 Nations Involved:

- Croatia
- Italy
- Singapore
- Sweden
- Turkey
- United Kingdom
- United States

NATO SET-229 - Cooperative Navigation in GNSS Denied | Degraded Environments

History / Motivation

NATO STO Navigation Task Groups

- **NATO RTO SET 57 / RTG 30 2000-2004**

  "Emerging Military Capabilities Enabled by Advances in Navigation Sensors"

- **NATO RTO SET 114 / RTG 65 2005-2009**

  "Urban, Indoor and Subterranean Navigation Sensors and Systems"

- **NATO RTO SET 167 / RTG 2010-2015**

  "Navigation Sensors and Systems in GNSS Denied Environments"

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NATO STO Navigation Symposia

- **Istanbul, TUR; 14-16 October, 2002**
  - Emerging Military Capabilities Enabled by Advances in Navigation Sensors
- **Antalya TUR; 1-2 October, 2007**
  - Urban, Indoor and Subterranean Navigation Sensors and Syste
- **İzmir TUR; 8-9 October 2012**
  - Navigation Sensors and Systems in GNSS Denied Environments

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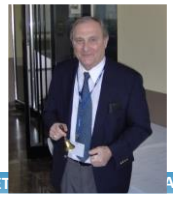
NATO STO Lecture Series

- **SET-064 / RLS Advances in Navigation Sensors and Integration Tech.**
  - 2003: GBR, TUR, FRA - 2004: St. Petersburg, Moscow RUS
- **SET-116 / RLS Low-Cost Navigation Sensors and Integration**
  - 2008 : SPA, NDL, GBR - 2009: ITA, DEU, POL
  - 2010: TUR, CHK, FRA, POR
- **SET-124 / RLS Low-Cost Navigation Sensors and Integration**
  - 2013: TUR, DEU, ITA, GBR



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NATO STO Navigation Handbooks

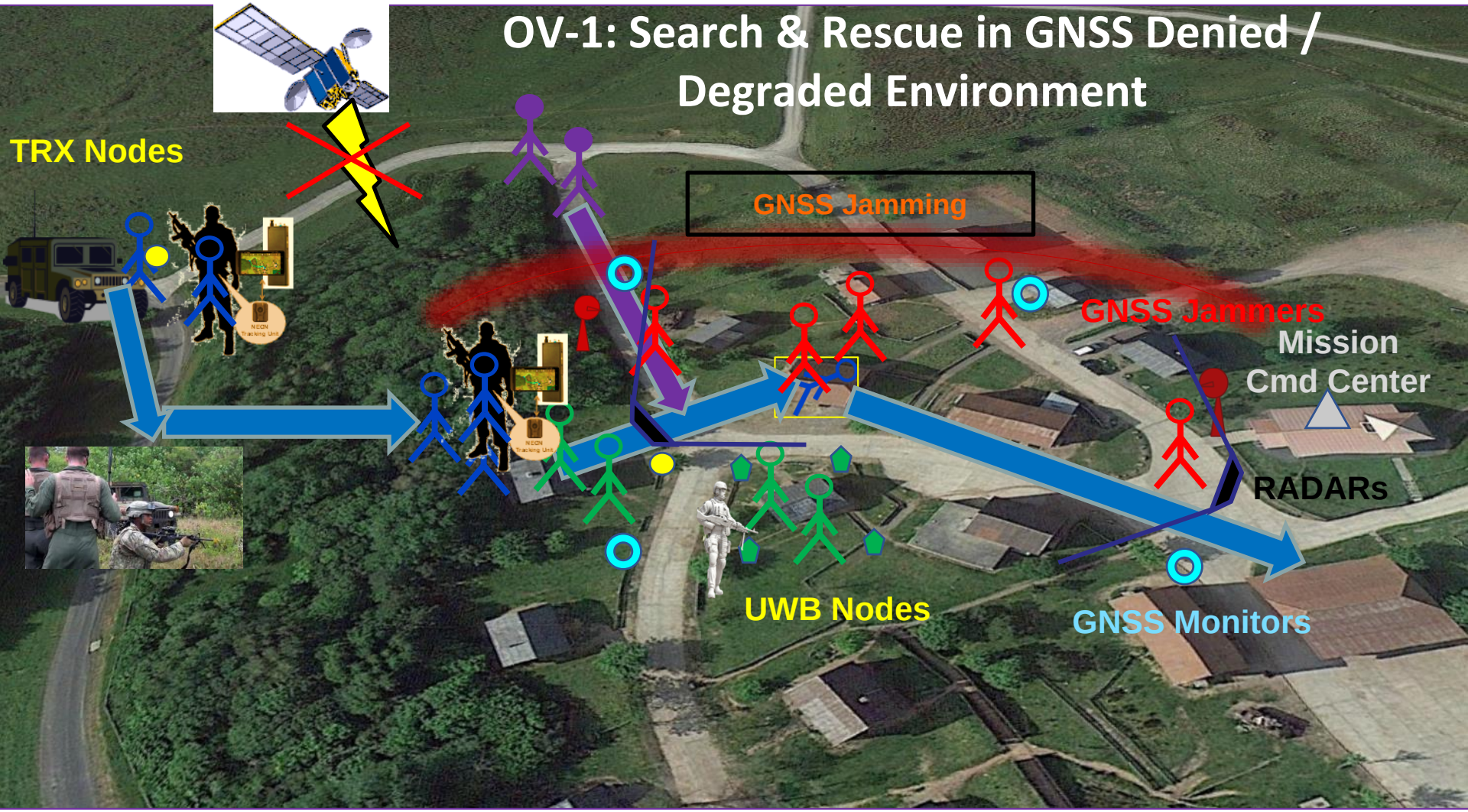
- **A handbook to quide NATO decision makers on changes on technology was prepared. (2004 – SET 065)**
- **A second handbook covering all forms of navigation technology was prepared (2010 – SET 114)**
- **A third booklet on GNSS interference, jamming and spofing was prepared including several made-up military scenarios, effects of GNSS jamming and possible Technologies that can be used to minimize effects was prepared (2016 – SET 167).**

Background

- **In light of intentional (jamming and/or spoofing) and unintentional (multipath, shading etc.) GNSS threats**, the need for robust and accurate PNT systems in GNSS degraded or denied environments is critical to ensure mission effectiveness and minimize casualties and collateral effects
- **The NATO Science and Technology Organization (STO)** generates and exploits a leading edge S&T program of work, delivering timely results and advice that advance the defense capabilities of NATO Nations, Partner Nations, and NATO in support of collective defense, crisis management, and cooperative security.
- **The NATO Sensors & Electronics Technology (SET) Panel** is eager to advance technologies in electronics and passive/active sensors (as they pertain to reconnaissance, surveillance, target acquisition, electronic warfare, communications, navigation) and to enhance sensor capabilities through multi-sensor integration/fusion in order to improve the operating capability and to contribute to fulfil strategic military results.

Background

- **As NATO war-fighters and peace-keepers continue to shift more and more towards asymmetrical warfare**, SET technologies have to focus on the military mission of saving lives, improving quality of life and extending our combat effectiveness
  - Research in SET concerns the phenomenology related to target signature, propagation and battle-space environment, electro-optics (or electro-optical, EO), radio frequency (RF), acoustic and magnetic sensors, antenna, signal and image processing, components, sensor hardening and electromagnetic compatibility
- **SET-229 on "Cooperative Navigation in GNSS Degraded and Denied Environments"** was formed to explore technologies that will enhance NATO military effectiveness, particularly in challenging indoor and urban environments
  - Implement advanced, cooperative/collaborative navigation sensor technologies and integration techniques
  - There is also a growing need to maintain PNT capabilities in the Anti-Access/Area Denial (A2/AD) environment
    - In such environments, it may be difficult for NATO forces to gain access to the battlespace and conduct military operations.


OV-1: Search & Rescue in GNSS Denied / Degraded Environment
TRX Nodes
GNSS Jamming
GNSS Jammers
Mission Cmd Center
RADARs
UWB Nodes
GNSS Monitors

NATO STO – SET 229
Co-operative Navigation in GNSS Denied or Degraded Environments Demonstration

UK – DSTL & Jamming

UK SET-229 Lead - Rob Handley, DSTL, UK MOD

UK Jamming component of SET-229 Demo

- **(U//FOUO) L1 GPS C/A + GLONASS (to defeat US (TRX) and Croatia (Geolux) GNSS receivers).**
- **Jammer power under software control.**
  - Tailored to meet needs of Singapore jamming detection system.
- **Remote control from the FIBUA church.**

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GNSS Monitoring System

Country: Singapore

Presented by Ong Chee Kiong, DSTA

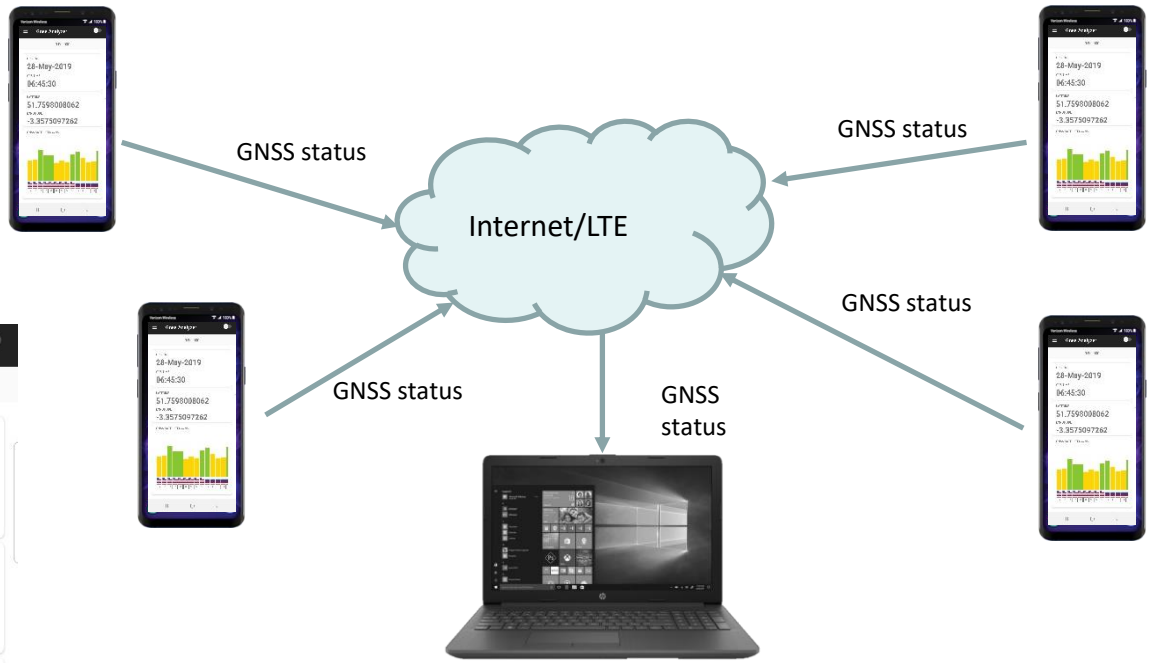
- ***Challenge***: GNSS is critical for many C4ISR operations. The lack of GNSS situation awareness would have adverse impact on the efficiency and effectiveness of these operations.

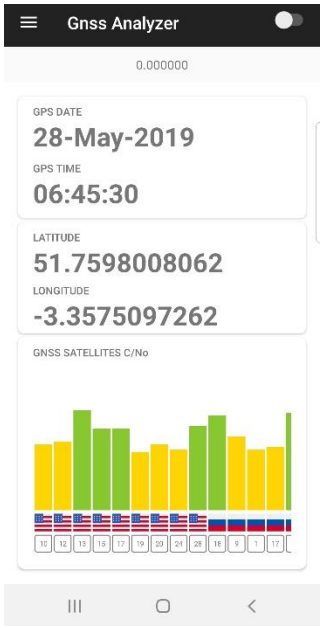
- ***Approach***: To provide an effective means of GNSS signal integrity monitoring through:

CROWD SOURCING	ANDROID API	DISTRIBUTED NODES
		

DSTA Defence Science & Technology Agency

GNSS Monitoring System





- Distributed monitoring of GNSS status using mobile devices: (C/No, Pseudo range rate, clock drift, etc)
- Data analytics to provide situation awareness associated with the monitoring.

DSTA Defence Science & Technology Agency

GNSS Monitoring System

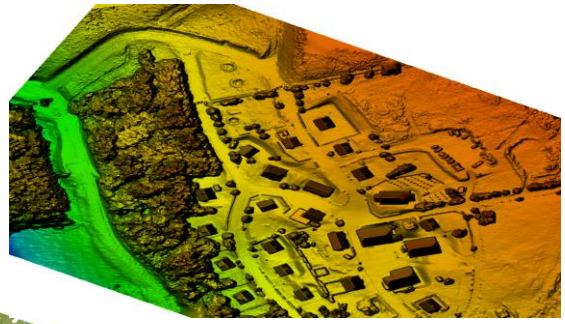
Interfere

Sensor

DSTA Defence Science & Technology Agency

Collaborative navigation
Outdoor mapping

- **Photogrammetry-based 3D model from 500 aerial images**
- **High accuracy points from RTK GPS used for geo-referencing**
- **3D model, orthomosaic and DEM**



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FOI

Outdoor mapping

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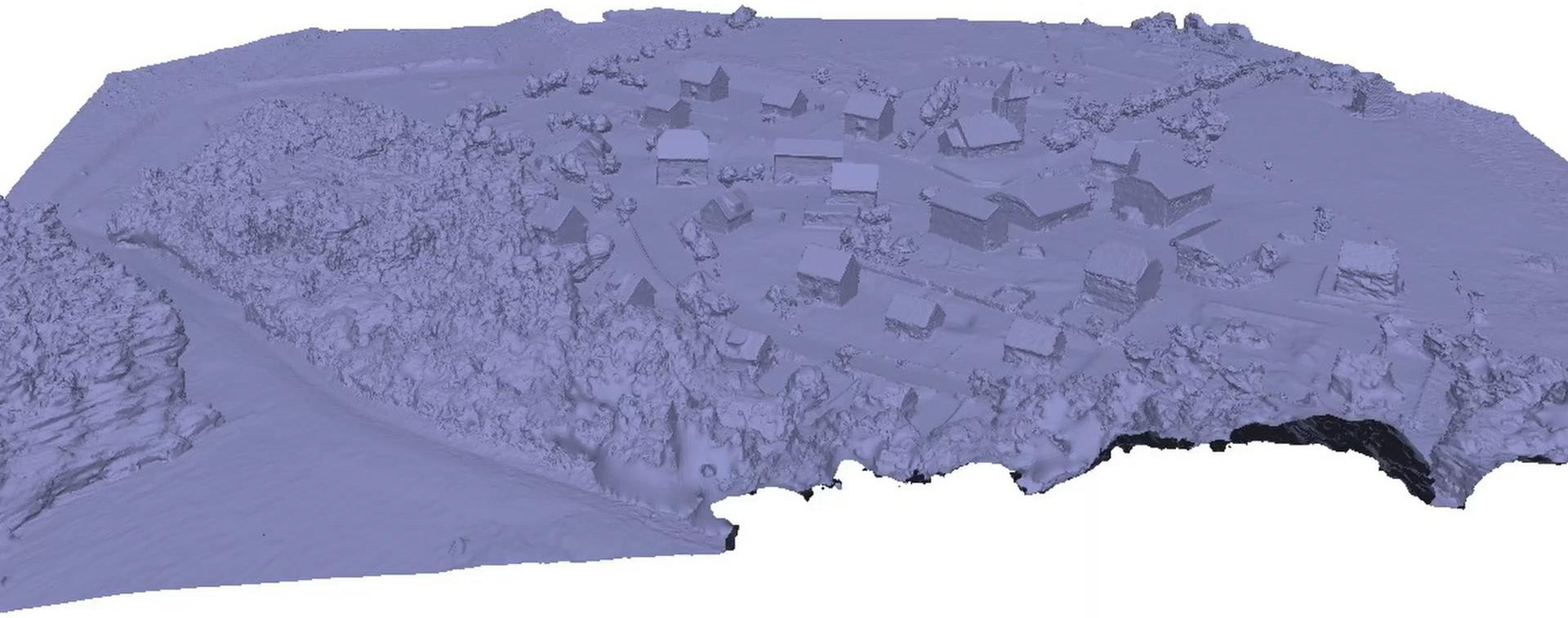

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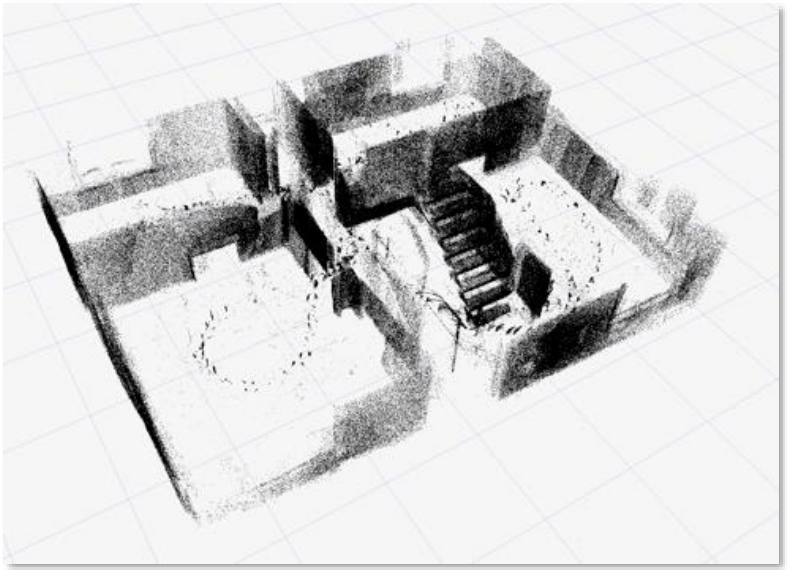
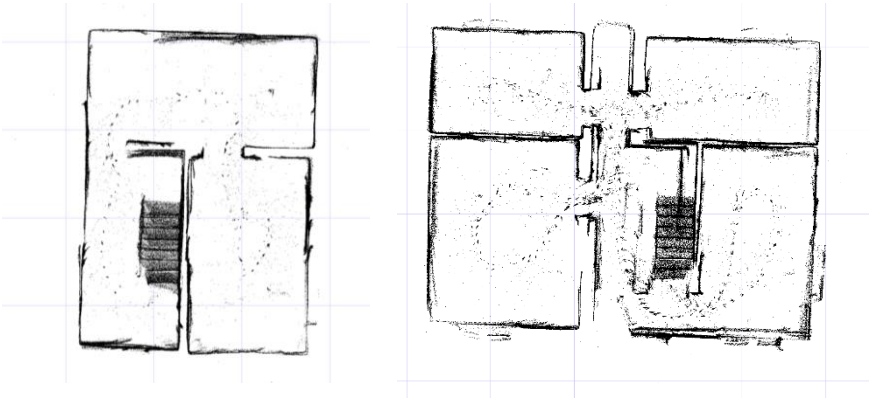
Collaborative navigation
Indoor mapping

- Camera-based system for positioning and mapping
- Creates 3D model and map in real-time, while moving through building





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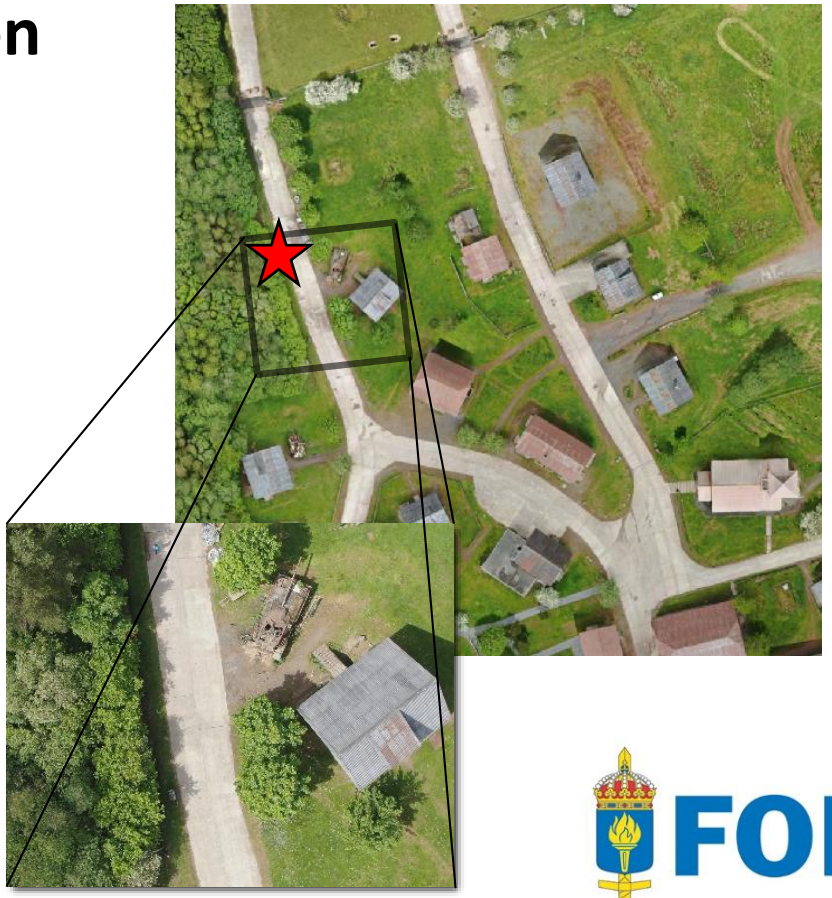
Collaborative navigation
UAV positioning and moving object detection

- **UAV estimates own position by matching images from camera to georeferenced map**
- **Moving objects on ground detected in images from same camera**
- **Detections of blue units used to improve their position accuracy**



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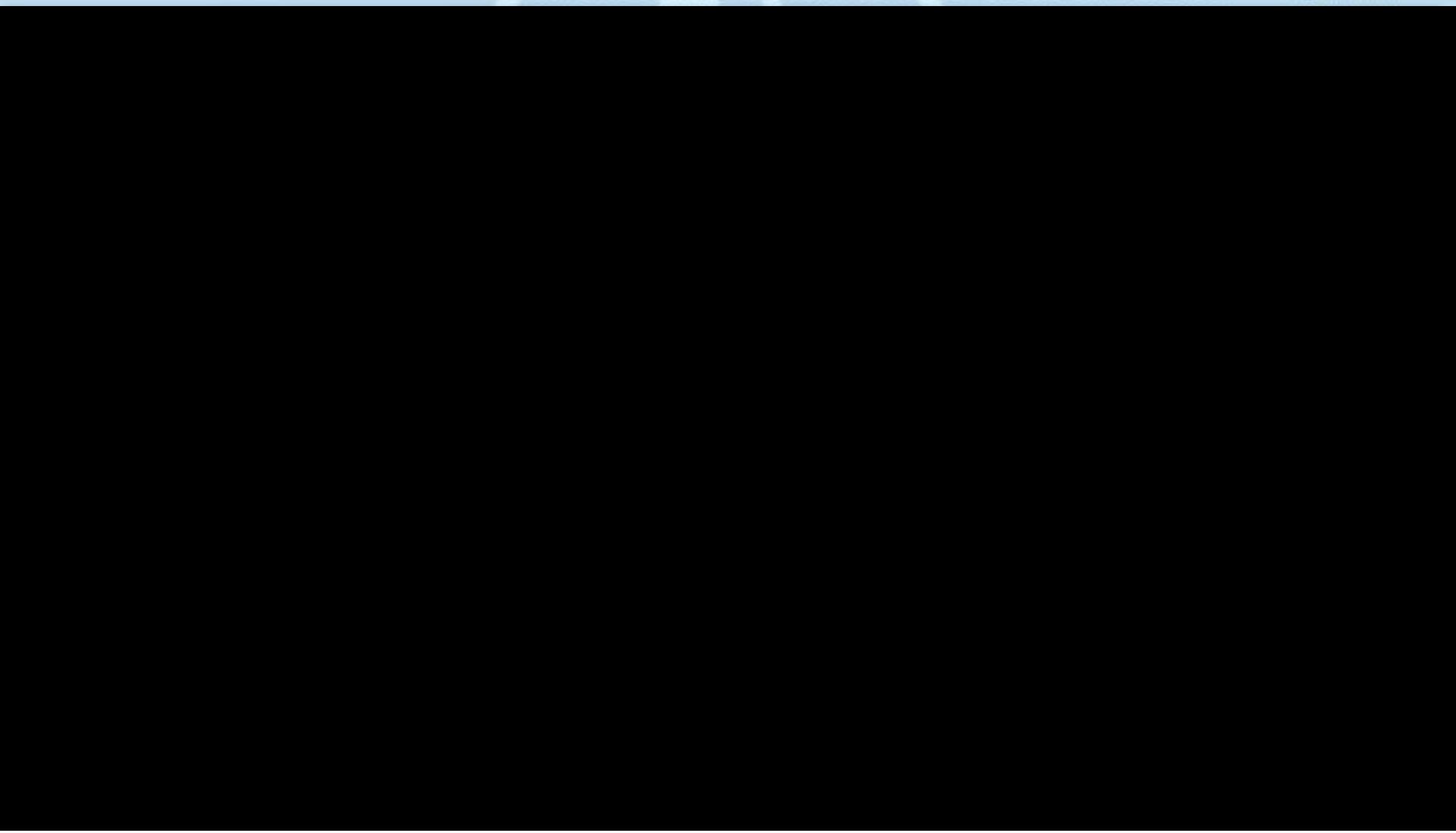

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Collaborative navigation Vehicle/UAV/UGV/dismount

- **Small UGV or dismounted**
- **Large vehicle has better navigation**
- **UAV has navigation improved by image-matching**

Improved UGV navigation by sharing data:

- 1) landmarks (better nav. on host vehicle)
- 2) tracks from UAV (UAV use image-matching with map)

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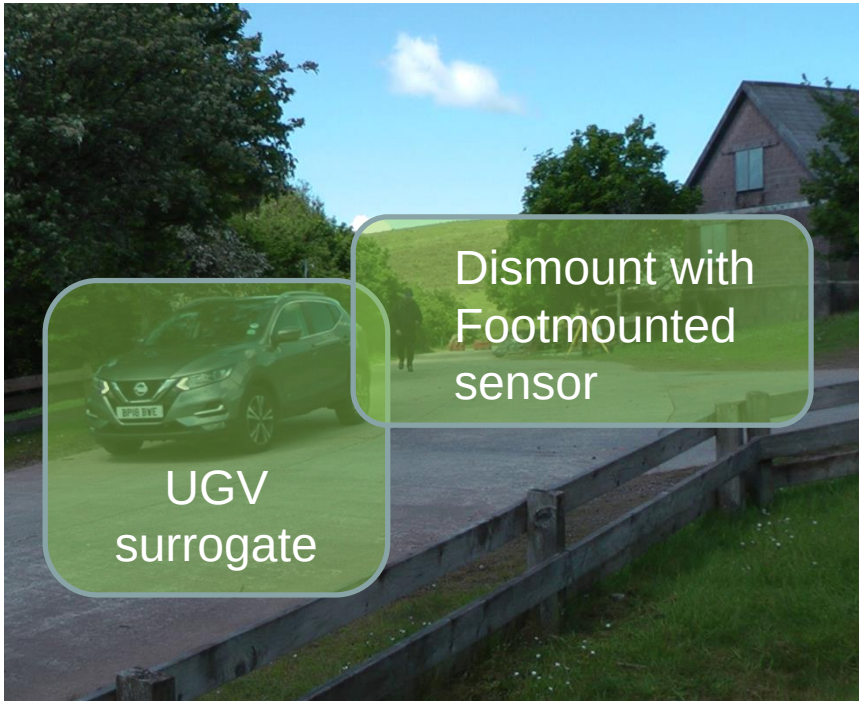
Casualty evacuation scenario

Live demo not possible

- Postprocessing of collected data from dryrun using car as surrogate of casevac UGV



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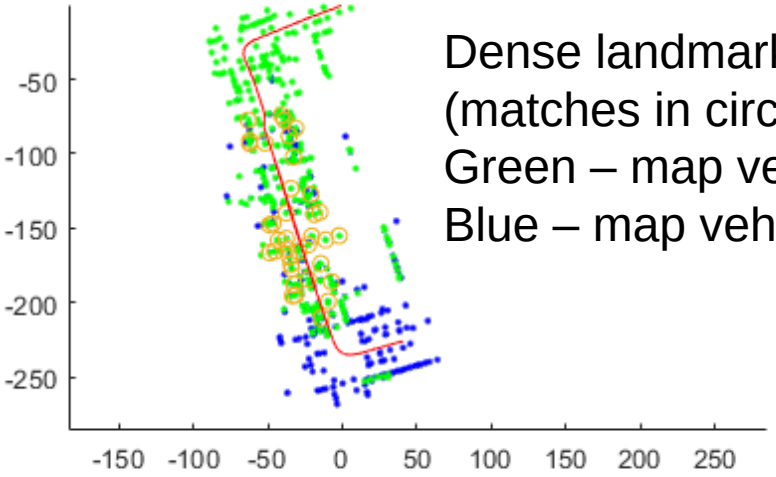
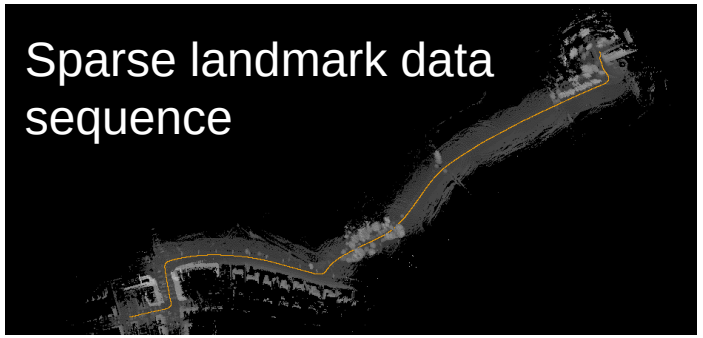
UGV launched from host vehicle

Live demo not possible

- Earlier collected data



Dense landmark data
(matches in circles)
Green – map vehicle 1
Blue – map vehicle 2



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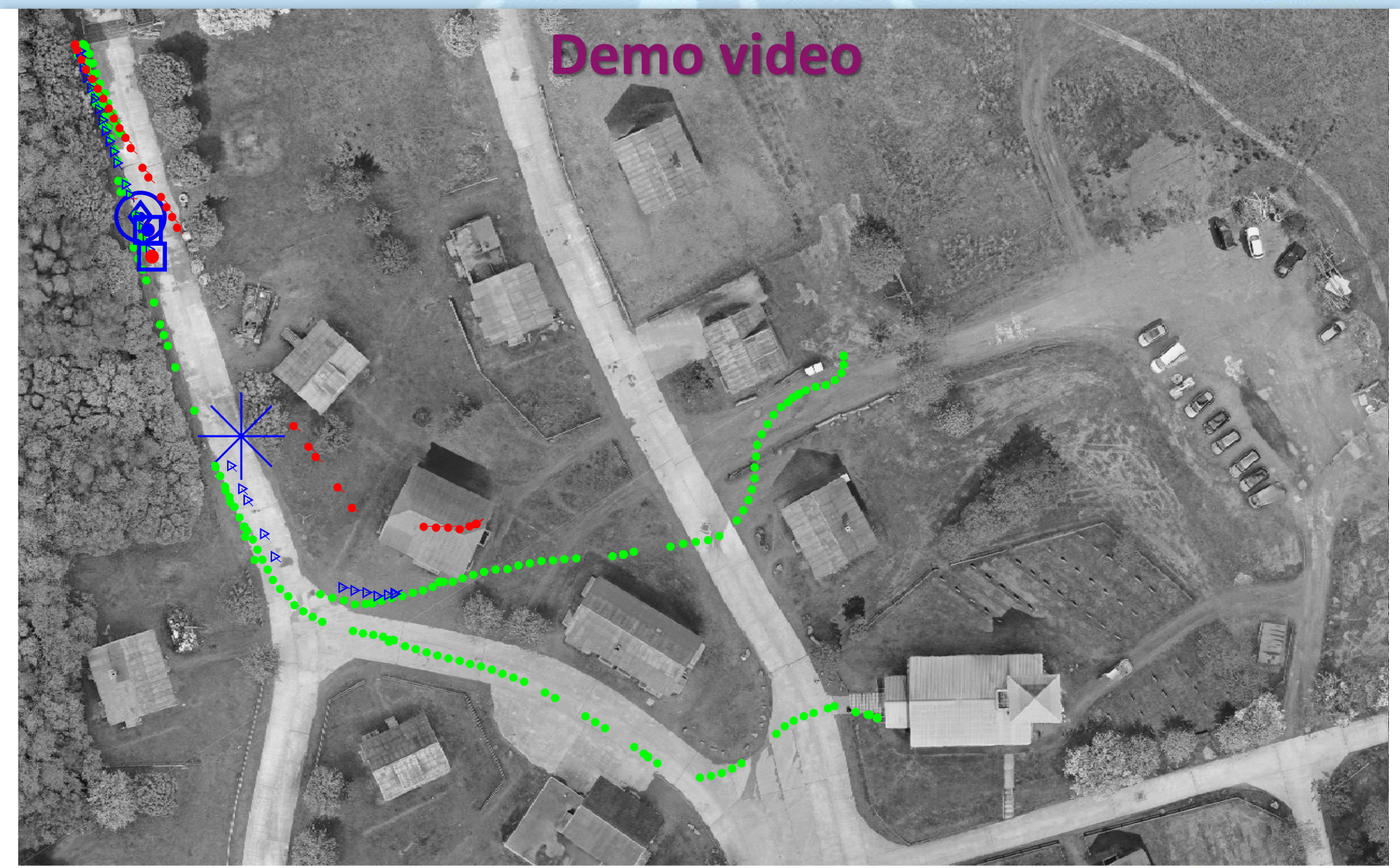
Demo video



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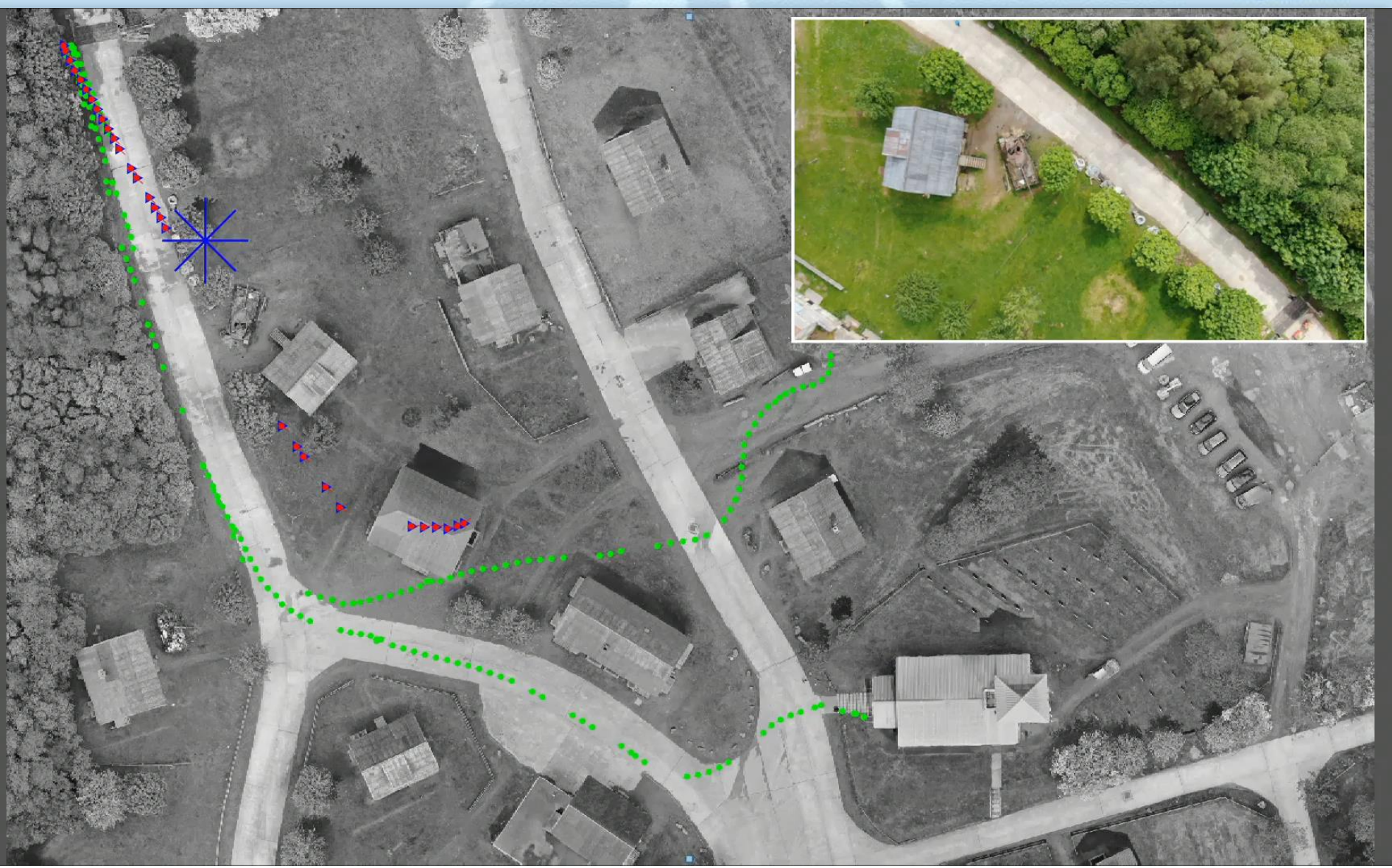

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UWB Indoor Positioning

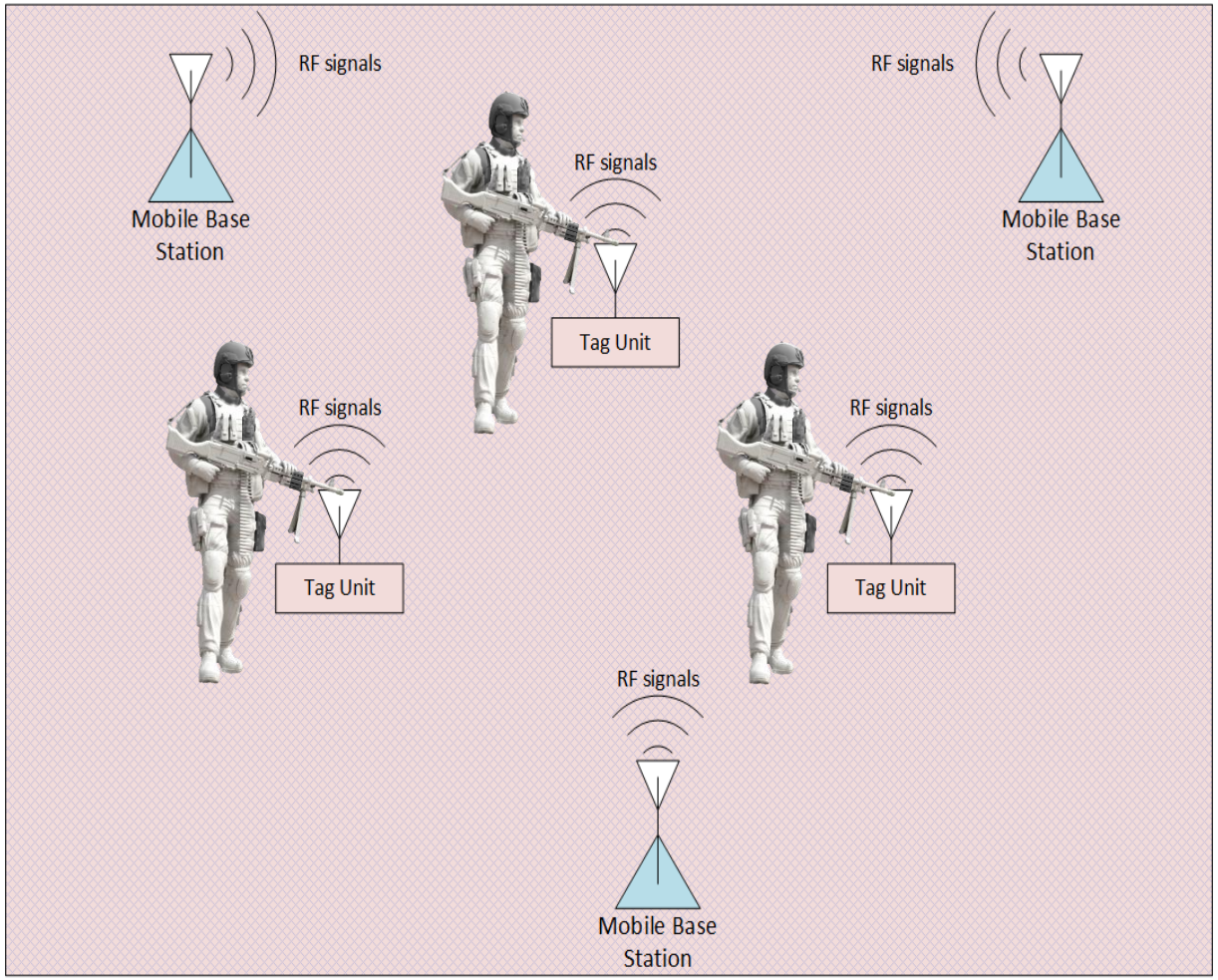
Country: TURKEY

PI: Serkan ZOBAR, ASELSAN

- ***Challenge:*** While GPS based Outdoor Positioning is greatly advanced, Indoor Positioning is still an open issue due to
  - Unavailability or degradation of GPS
  - Complexity of indoor environment
- ***Solution | Payout:*** Ultra Wide Band (UWB) technology for Indoor Positioning provides:
  - Centimeter-level positioning accuracy
  - Large bandwidth
  - Low transmit power
  - Immunity to multipath fading

aselsan

UWB Real-Time Indoor Positioning Technology



- Mobile Base Stations
- Tag Units
- Ultra wide band RF signaling

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UWB Indoor Positioning Demo

- In the scenario, UWB team serves as ‘Pre-installed Overwatch Team’

- Once the Overwatch Team enters the observation building (surronded by UWB base stations), the positions of 3 team members is transmitted to and visible in the Mission Command Center (MCC)

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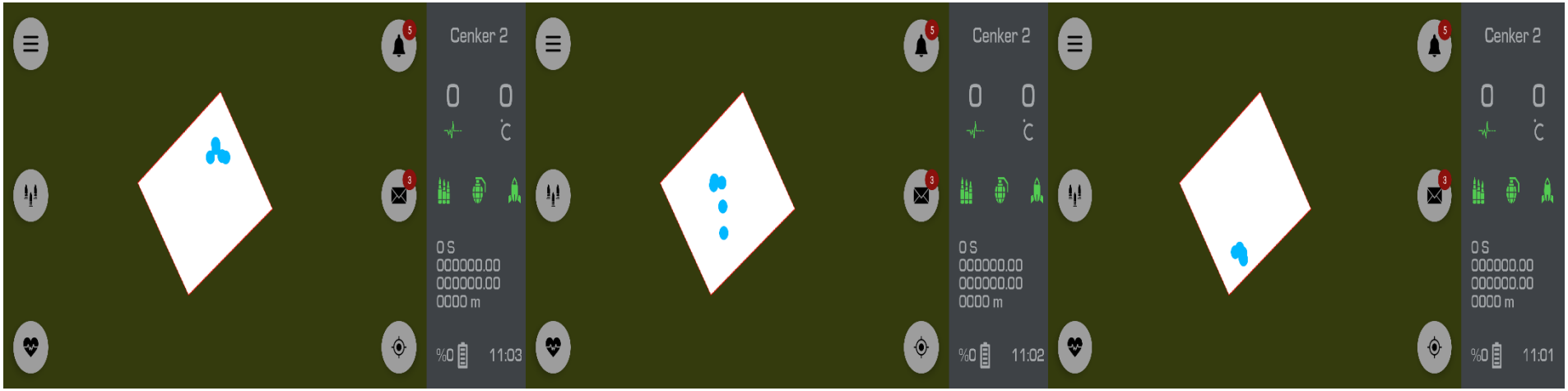

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Wireless Time Transfer

Country: USA

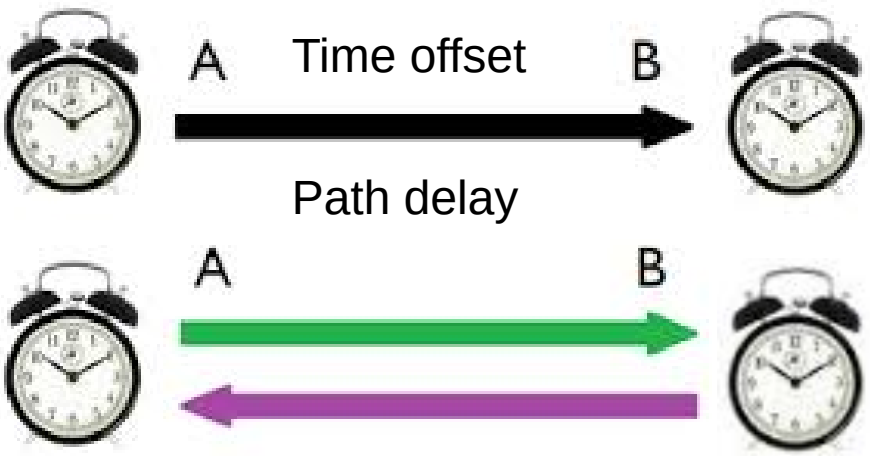
Presented by Dr. Yoonkee Kim, US Army CCDC-C5ISR Center

- ***Challenge:*** Many C4ISR systems which require precise time synchronization to function properly are dependent on GNSS for accurate time -- GNSS vulnerability is an issue

- ***Approach:*** Provide an alternate time transfer mechanism to allow systems within an Area of Regard (AOR) to be synchronized even in GNSS-challenged environments

- ***Payout:*** Always synchronized C4ISR network allows all weather/ terrain operation without GNSS dependency

Two-Way Time Transfer Technology



One way: IRIG-B, WWV, WWVB, GPS/GNSS, LORAN

Two way: NTP, PTP, TWTT via geostationary satellite, fiber, wired or wireless

Synchronization

The process of setting two or more clocks to the same time

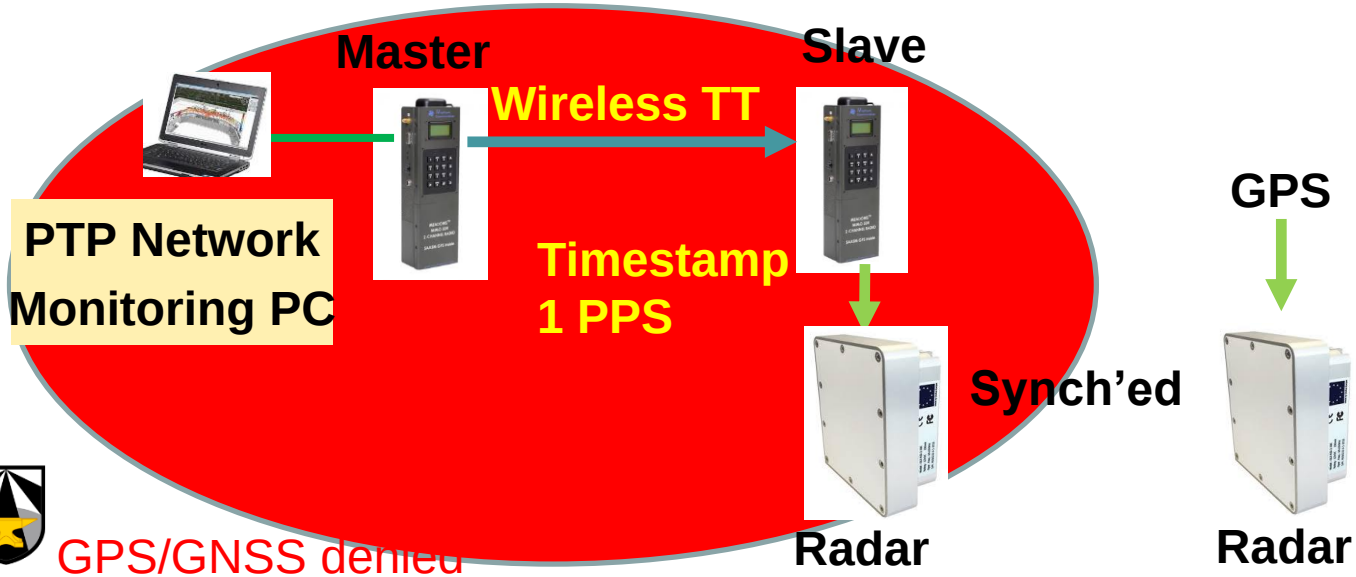
One way vs Two way

- One way works where path delay is predetermined
- Two way works even if path delay changes dynamically since round trip allows measurement of offset and path delay

Wireless Time Transfer Demo

- Two scenarios demonstrate a wireless time transfer using Precision Time Protocol (PTP) with <1 microsecond accuracy for radars and radios, allowing them to synchronize and communicate in GPS/GNSS-denied environments

Demo: Synchronization of Croatian security radars



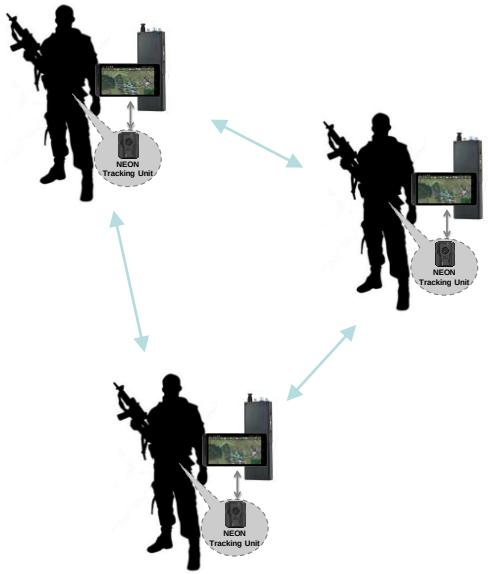
NEON Location Service with TAK

Situational Awareness
Shares PLI over TAK configured network

TW Mesh Radio

Collaborative Nav
Accurate UWB ranging and constraint sharing with other tracked persons

NEON UWB

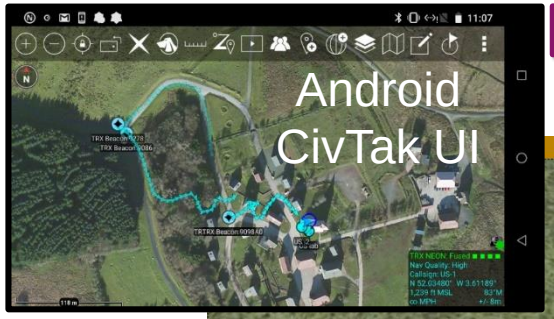


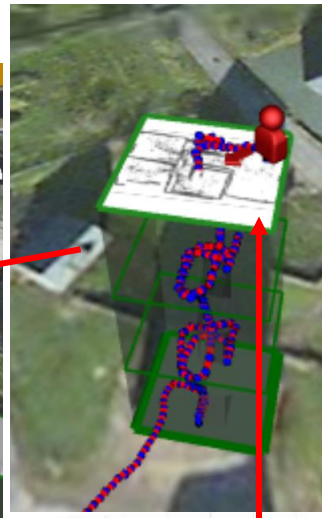
- Resilient to jamming and spoofing - NEON tracker contains motion sensors to track user when GPS is unavailable or unreliable
- Supports enhanced PNT inputs including location constraint sharing, dropped beacons, user correction
- Runs offline – Mission data sets (map data) is not required but may be sideloaded when available.

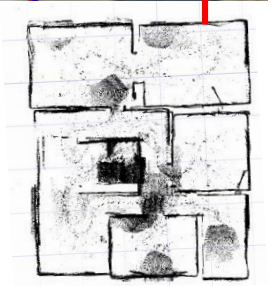
NEON ATAK plug-in available on TAK Maps
(https://takmaps.com/)

Demonstration Scenario with Movie

Replay NEON 3D Command UI







Floor plan images from Sweden

Drop UWB Beacons and turn off GNSS (simulated jamming)

Drop UWB Beacon and TrellisWare radio

Roke's Exploration Navigation System

Country: UK PI: Dr. James Revell, Roke Manor Research Ltd

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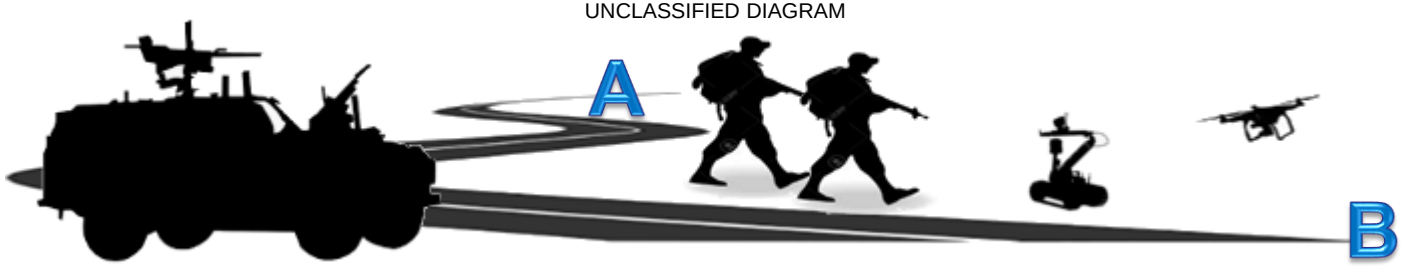

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- ***Challenge:*** Accurate location information in GNSS Denied/Degraded
- ***Solution:*** The Roke Exploration Navigation System (RENS) is a fully-functional prototype of a next generation real-time, independent, navigation capability for the military
  - RENS uses a monocular camera and IMU to provide position and orientation information without reliance on:

~~*GPS/GNSS*~~	~~*Prior Information*~~
~~*Beacons*~~	~~*Active Sensors*~~
~~*Surveyed Infrastructure*~~	~~*Loop closure events*~~

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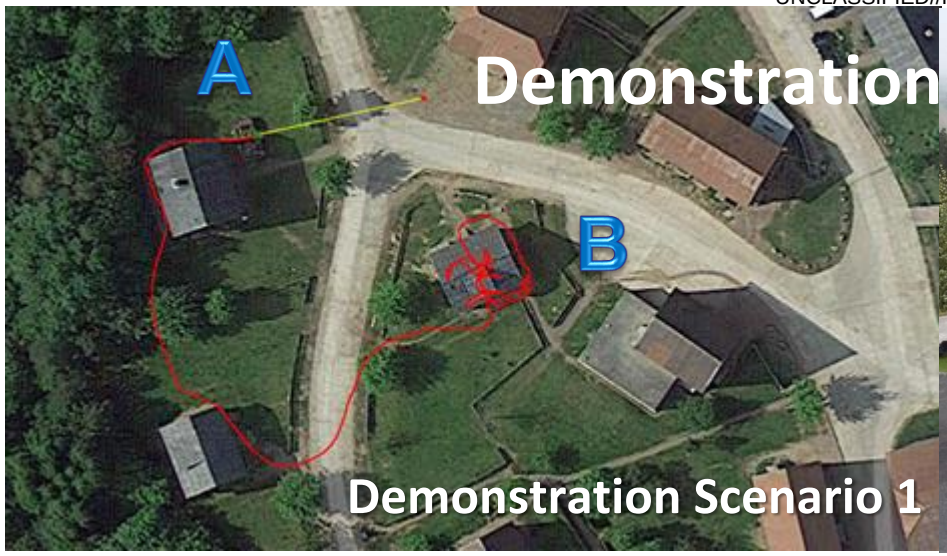
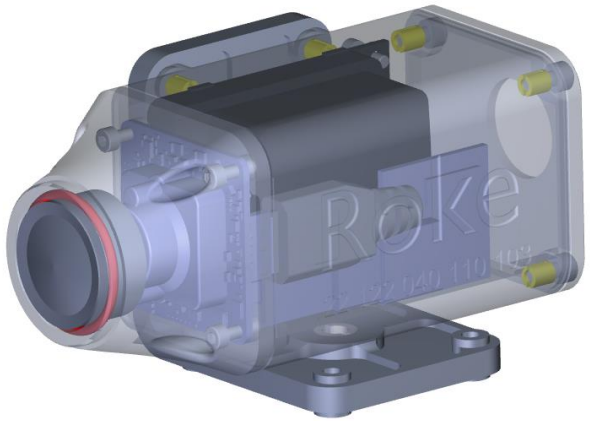
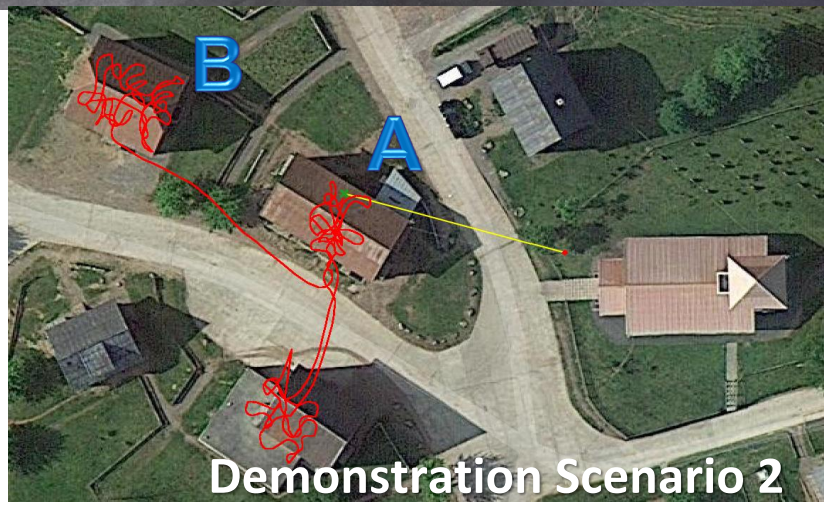
Demonstration Scenarios







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Ground Surveillance Radar Target Tracking

Country: CROATIA

PI: Tomislav Grubesa, Geolux d.o.o.

- ***Challenge:*** Real-Time Blue/Red Force tracking for objects/personnel (targets) in hostile locations is extremely difficult without location, tracking, and communication devices

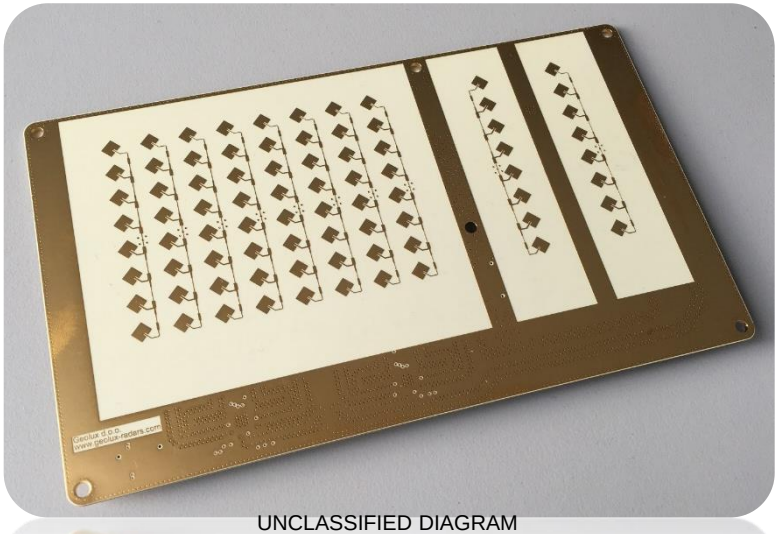
- ***Approach***: Use small movable low power ground surveillance radars that will detect all moving targets in monitored area

- ***Payout***: Ability to automatically detect and track any moving object in day/night and all-weather conditions with minimal infrastructure and equipment – greatly improving a team's situational awareness capabilities

FMCW SDR Digital Beamforming Technology

- SDR (Software Defined Radio) / NO movable parts
- High FPGA processing power
- Complex processing, detection & tracking algorithms
- Low output power < 27dBm – safe for humans
- 150m / 90° coverage area for 0,75m^2 target

- Detection & Tracking
  - Possible for all moving targets even in very cluttered terrains
- Easy to use
  - Fixed installation for perimeter security applications
  - Mobile version mounted on tripod / rapid deployment



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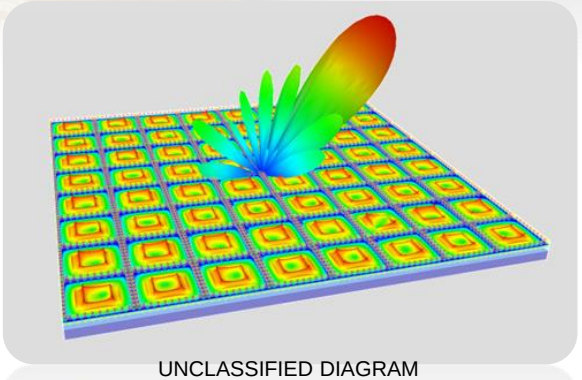

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Geolux

Tracking with Multiple Radars

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GPS/GNSS
(location/time sync)

ALTERNATIVE
(location/time sync)

GPS/GNSS denied

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- Radar tracks are relative to the radar location
- Precise radar location → precise target geo-location
- Tracking with multiple radars – location & time sync important
- **With precise radar locations & precise time synchronization it is possible to create a composite image from multiple radars for better tracking precision & better system sensitivity**

Geolux

Summary

- **Very Successful Demo**
  - Search & Rescue in GNSS challenged environment using Cooperative / Collaborative PNT solutions

- **Excellent Multi-National Teamwork**
  - 7 Nations

- **Follow On Activities:**
  - SET-275 Symposium – Welcome to Split, Croatia
  - SET-274 Lecture Series
    - TBD – hoping Spring 2022
  - SET-309 - NATO PNT Open System Architecture & Standards to Ensure PNT in NAVWAR Environments
    - Start Date: January 2022