Drones as First Responders Research

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Converging Mission, Innovation, and Technology

Commonwealth Cyber Initiative

VIRGINIA INNOVATION PARTNERSHIP CORPORATION
Connecting Innovators with Opportunity

GEORGE MASON UNIVERSITY

AGENDA

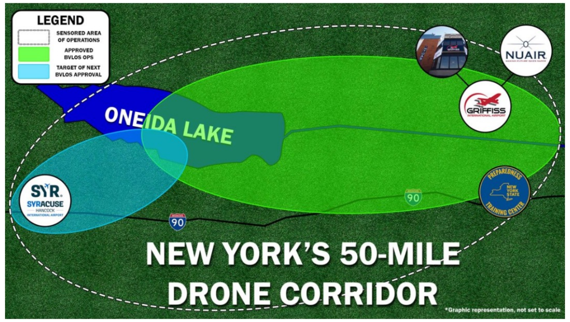
1) Unmanned Aerial Vehicles (UAVs) in Virginia
2) UAV Research at the C4I & Cyber Center
3) Drones as First Responders Research
4) Plans & Experiments

INTRODUCTION

OVERVIEW: MOTIVATION AND OBJECTIVES

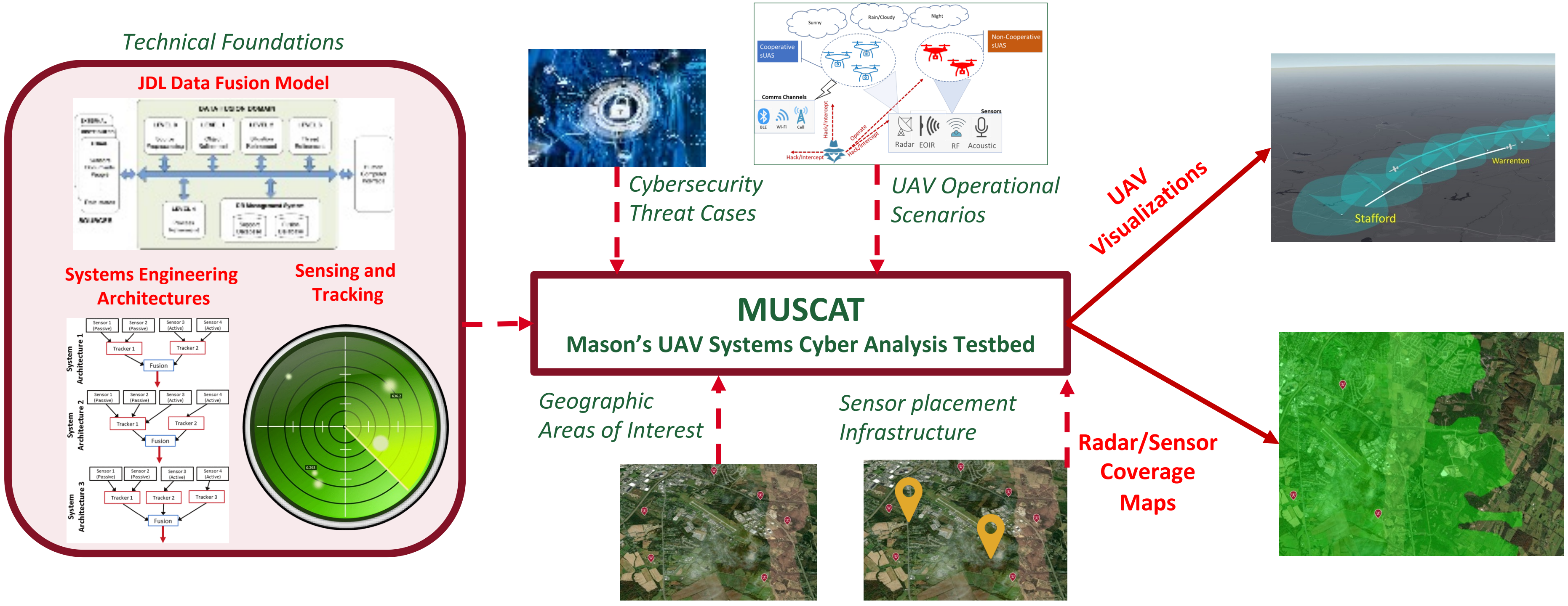
- **Motivation and Needs:**

  - **Small Unmanned Aerial Vehicles (sUAV) commercial value proposition:**
    - sUAV are becoming ubiquitous with a strong business potential to contribute rapidly to economic growth and jobs
    - Several states considering drone corridors for commercial sUAV operations
  - **sUAV Industry growth needs a secure and lightweight infrastructure consisting of communications, navigation aids and surveillance**
    - Malicious sUAS use can incur huge economic losses
  - **Technology Status-Quo:**
    - Decades of research and development in UAV enabling technologies
      - Quadcopter small fixed wings dynamics, structures, propulsion, and control
    - Recent FAA studies in Urban Traffic Mobility to enable wider urban area flight operations
    - Promising outlook to enable sUAV operations below 400 feet.
    - <u>Very limited (to almost non-existent) studies on cybersecurity related operations of sUAVs</u>

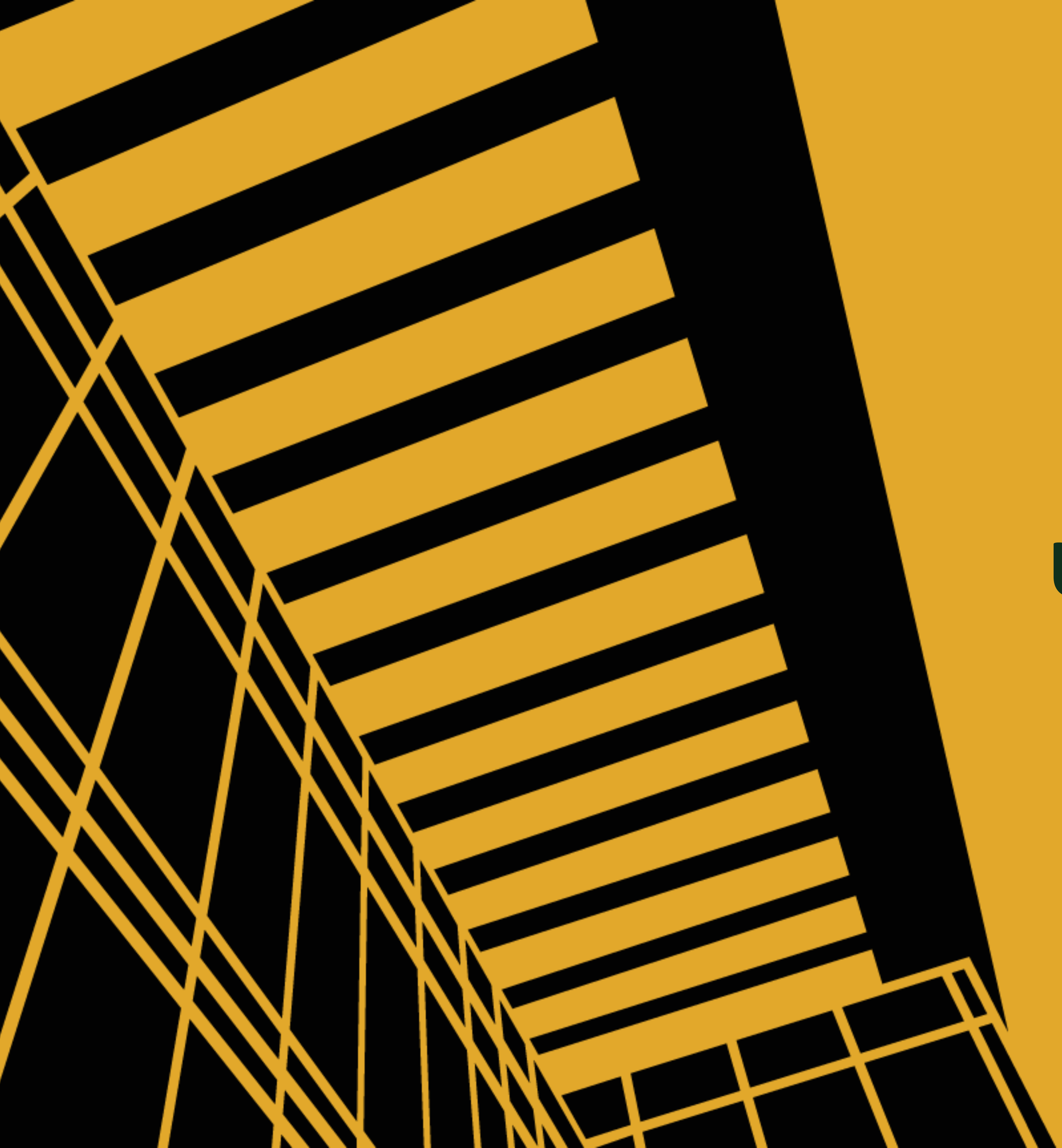


MUSCAT: MASON'S UAV SYSTEMS CYBER ANALYSIS TESTBED

Identify and rank sensor vulnerabilities with a system of systems sensing, tracking, and fusion testbed to guide infrastructure-level decision making



- Identify sUAS Operational CYSE Risks (not hardware based)
- Identify sensing and communication infrastructure
- Sense compromised sUAS and sensors through info. fusion
- Develop requirements for mitigation



UAS RESEARCH AT THE C4I & CYBER CENTER

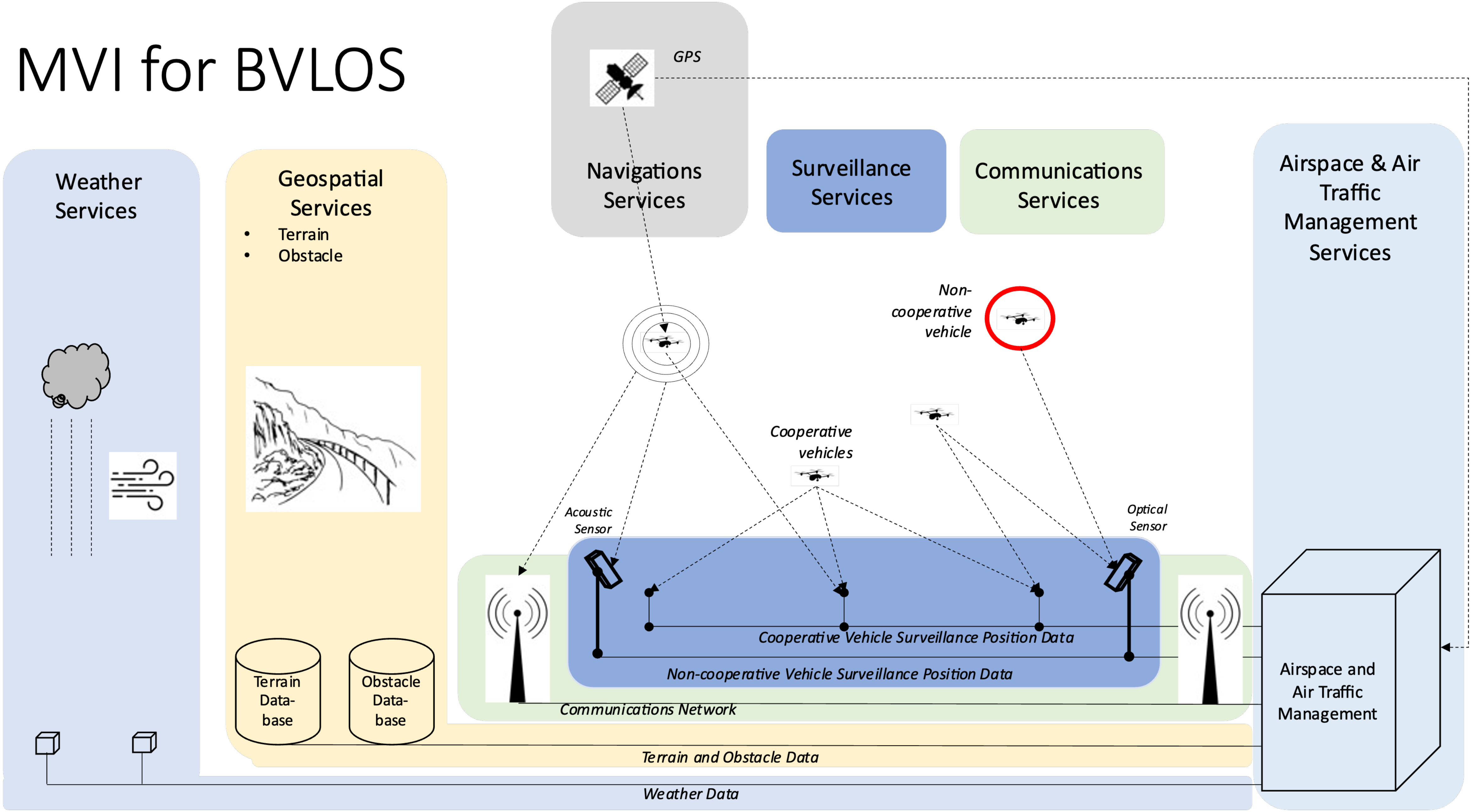
highsidetech

ENGINEERING | STRATEGY | INNOVATION

Counter Small Unmanned Aerial Systems (CsUAS) High Level Data Fusion (HLDF) Project

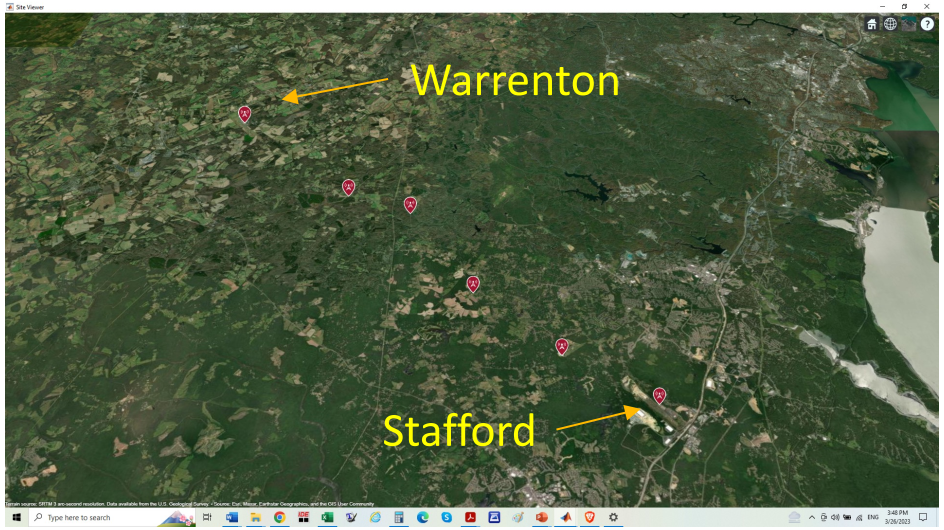
highsidetech.com

MVI for BVLOS



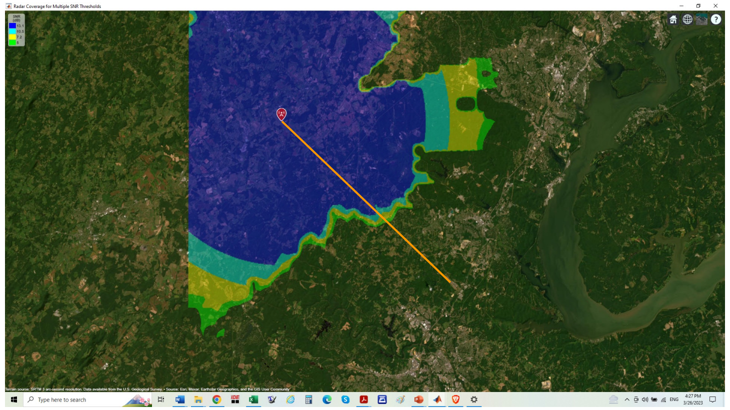
Radar Placement Analysis and Optimization (Medium-Range Radar)

- Stafford-Warrenton corridor
- Targets at 400 ft
- Detection for 30 km (16 NM) max
- Coverage for 1 to 3 radars in 6 possible locations
- Assume Class 2 UAS (40-50 lbs)



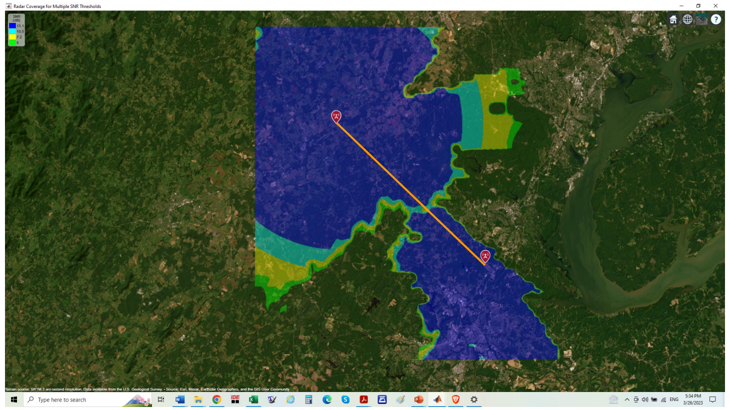
6 possible locations for medium-range radars

1 radar (Warrenton)



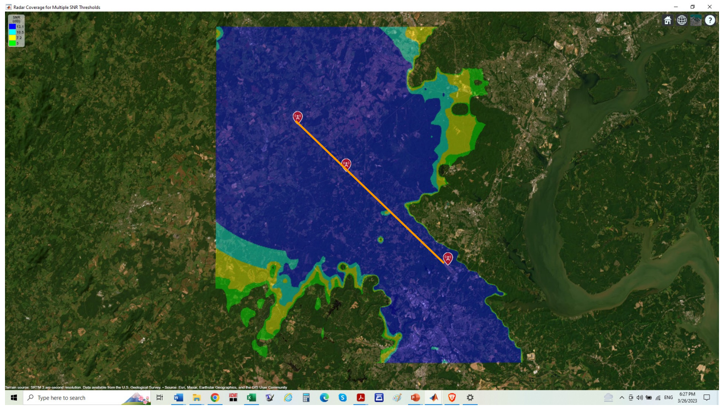
Relative coverage 65.80%

2 radars (Warrenton and Stafford)



87.93%

3 radars (Warrenton, Stafford, middle)



100.00%

DRONES AS FIRST RESPONDERS (DFR) RESEARCH

The George Mason University Team is a multi-disciplinary collaboration between:

The Center for Air Transportation Systems Research

The C4I And Cyber Center

The GMU Police and Public Safety Department

Our Team has a mix of operational Public Safety experience, engineering expertise and domain experience. We also work with the Northern Virginia Emergency System Response System (NVERS) – a collaborative partnership between local governments, the Commonwealth of Virginia, and the private sector with over 55 regional public safety organizations working on UAS issues.

Principal DFR Team

Steven Burmeister

- Associate Professor at George Mason University in the Forensic Science Program
- Part-time sworn police officer in the George Mason Police & Public Safety Department with the rank of Captain
- Served over 24 years as a Special Agent in the FBI with the majority of that time in senior executive positions.

Lance Sherry

- Director of the GMU Center for Air Transportation Systems Research
- Associate Professor in the GMU Systems Engineering and Operations Research Department
- Over 30 years experience in the aviation industry

Michael R. Hieb

- Research Professor in the GMU C4I & Cyber Center
- Chaired NATO Technical Working Group on Military Simulation and C4I Interoperability
- Led projects for DARPA, NATO, US Army & DHS (Counter UAS)

Drones as a First Responder Concept

The concept of **Drones as a First Responder (DFR)**
- Reduces fatalities
- allows agencies to put “eyes on an event”
- Expedite medical treatment
- Use public safety resources efficiently

Uncertainties in Dispatch:
- Location?
- Which direction of highway?
- Which lane?
- Location of occupants?
- Extent of injuries?
- Haz mat spill?

The **benefits** are:
- quicker response (i.e., reduced fatalities)
- increased safety to the public and first
- efficient use of scarce resources
- lower costs

DFR Traffic Incident Use Case

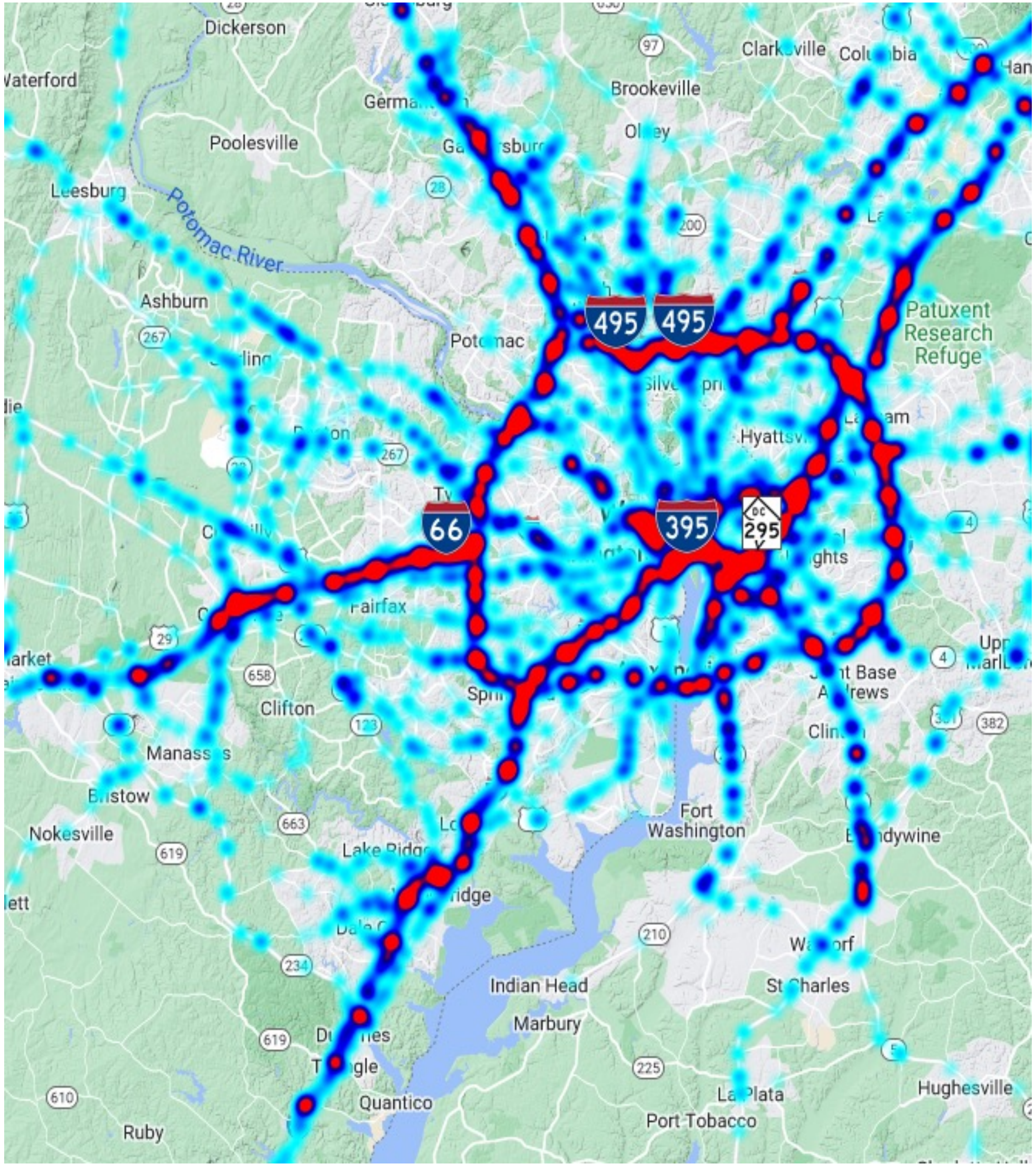
Imagine a truck collision on a busy interstate. It’s unknown how many other vehicles or the whether the drivers are trapped. Traffic cameras are unable to provide clarity due to the accident location.

January 8, 2023 I495 Virginia

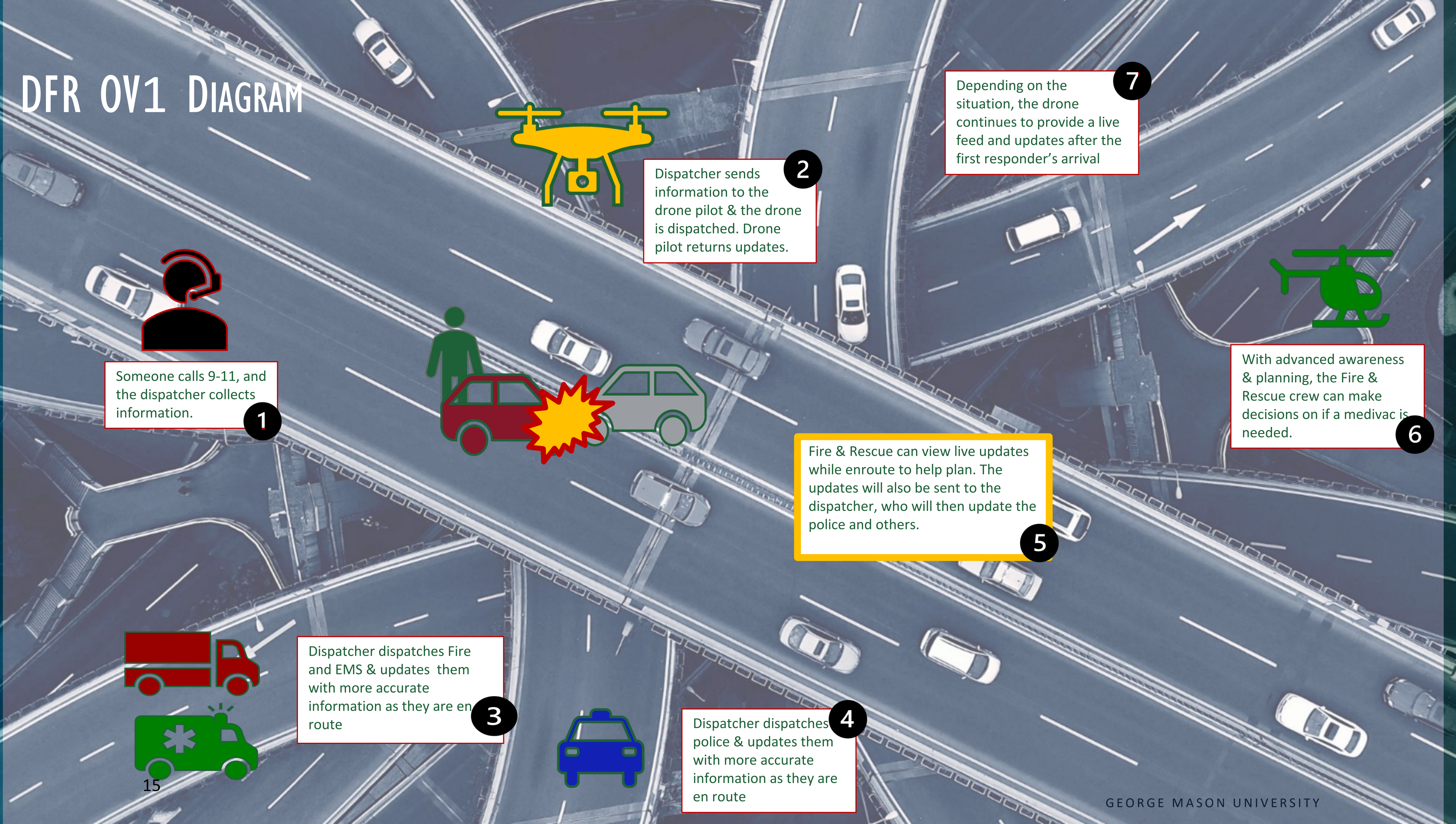
DFR Use Traffic Incident Use Case

- From December 2018 through December 2021 WTOP News Radio in Washington DC compiled accident data of interstates in Virginia
- Over 91,000 incidents over the 4 years were documented
- WTOP Developed a thermal map of incidents. (Red = high volume , etc.)

https://wtop.com/local/2021/12/the-most-crash-prone-dc-region-roads-as-reported-by-wtop/



DFR OV1 Diagram



Current Response Process

- Calls are received by 911 dispatch centers.
- Determinations are made as to whose jurisdiction will handle the emergency.

Based on information the following Response package is dispatched.

Entrapment	No Entrapment
Incident Lanes	***Incident Lanes***
Police	Police
Battalion Chief	Engine truck
EMS Unit	Rescue truck
Rescue Truck	Advanced Medic Unit
Engine truck	
Advanced Medic Unit	
Opposite lanes	***Opposite lanes***
Engine truck	Engine truck
Advanced Medic Unit	Advanced Medic Unit

Complementary GMU Research – Student Capstone Project for System Engineering & Operations Research (Spring 23)

Goal:

Model and perform Engineering and Economic Cost Benefit analysis of DFR using selected Use Cases

Tasks:

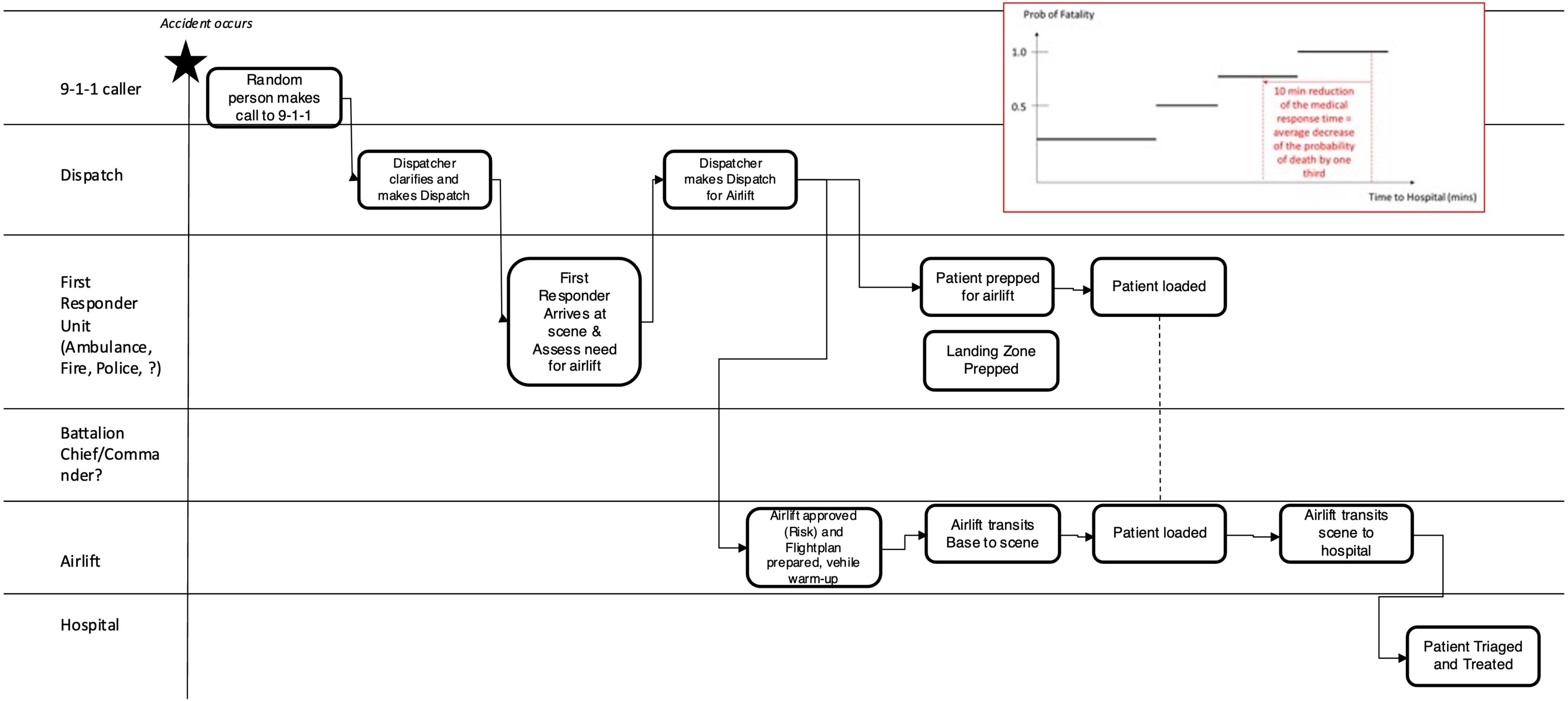
Develop **executable, stochastic model** of AS-IS Highway Accident Response

- Develop TO-BE executable, stochastic model of TO-BE Highway Accident Response (using DFR)
- Adjust AS-IS process steps for DFR
- Adjust time distributions for DFR
- Perform Cost Benefit analysis

Students:

Ariel Watson
Tarek Jarrouje
Felix Ruble
Rabah Hamad

Example of Analysis of DRF in Incident Dispatch Process (Airlift Required)



PLANS & EXPERIMENTS

Experiments – June 2023

- **Validate Sensor Models via CUAS Sensors**
  - ❑ Developed Series of controlled tests
    - Specify Altitude & flight plans
    - Specify Number of UAS
  - ❑ GMU Police will fly their UAS
    - Experienced Part 107 pilots
    - Will use DFR Scenario
    - Plan to use Fairfax West Campus & Stafford Lab
  - ❑ Real Sensor Data will enable
    - Verification & Validation
    - Data Analysis of Sensor Effectiveness
    - Testing data for Sensor Fusion

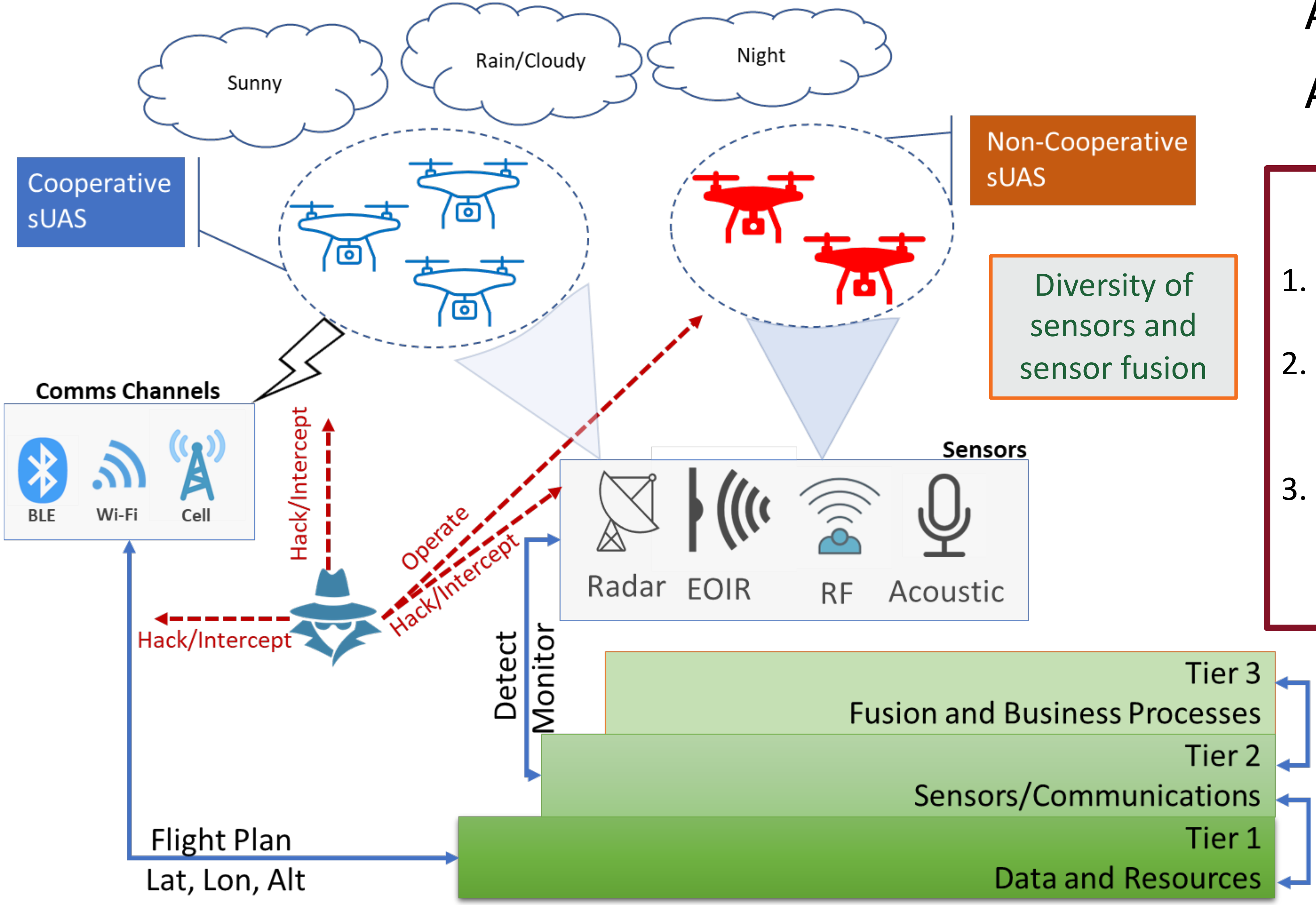
ADDITIONAL INFORMATION

Planned Testbed Work

- **Sensor Modeling for sUAV**
  - Customize Generic Sensor Models
    - Put in specifications of sensors that will be used in experiments
  - Develop Comparison Metrics and Algorithms
    - Compare & rank different sensor placements
    - Metrics will include sensor coverage and resilience
  - Tracking fusion from active, passive and Remote ID sensors

- **Cyber Security Threat Modeling**
  - Against Sensors
    - Loss of active, passive or Remote ID tracks
    - Track should be maintained by remaining sensors
  - Against sUAV
    - Loss of RF ID – track maintained by remaining sensors
    - Source of emissions (jamming or other types of interference) may be detected by ESM sensors (AoA)

A CONOPS FOR SUAS Analysis

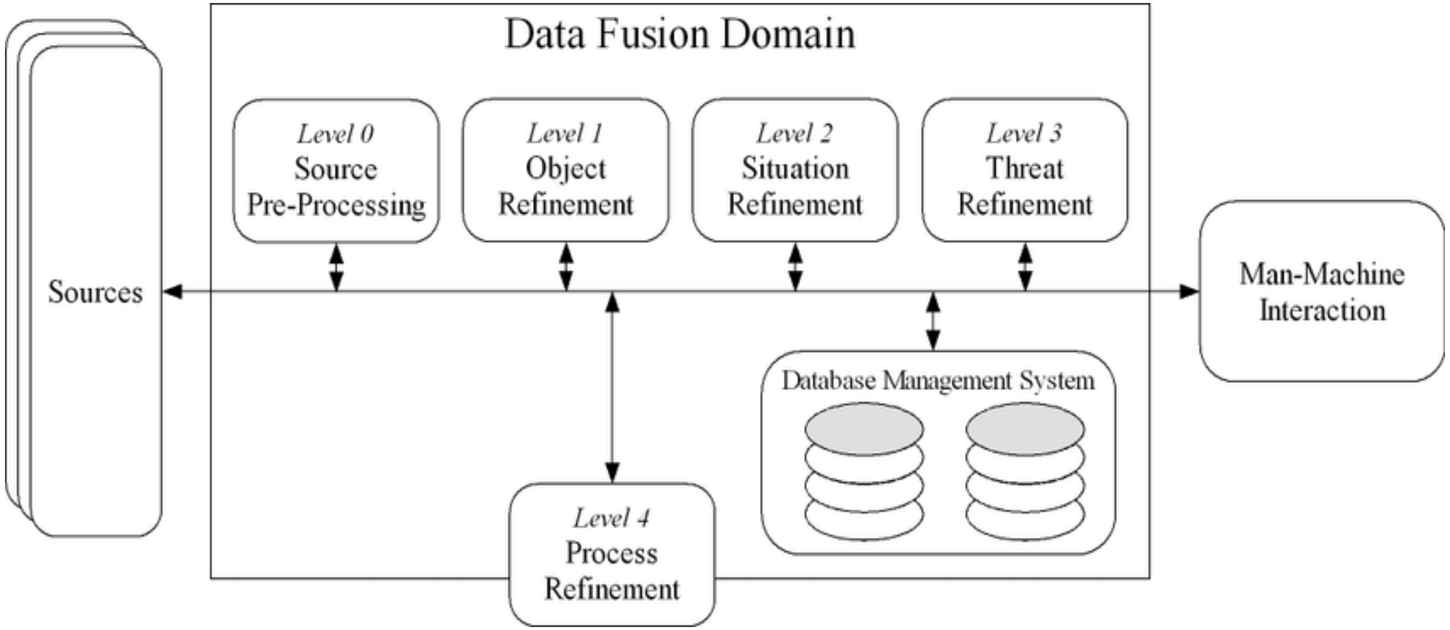


Cyber Resilience in sUAS Operations

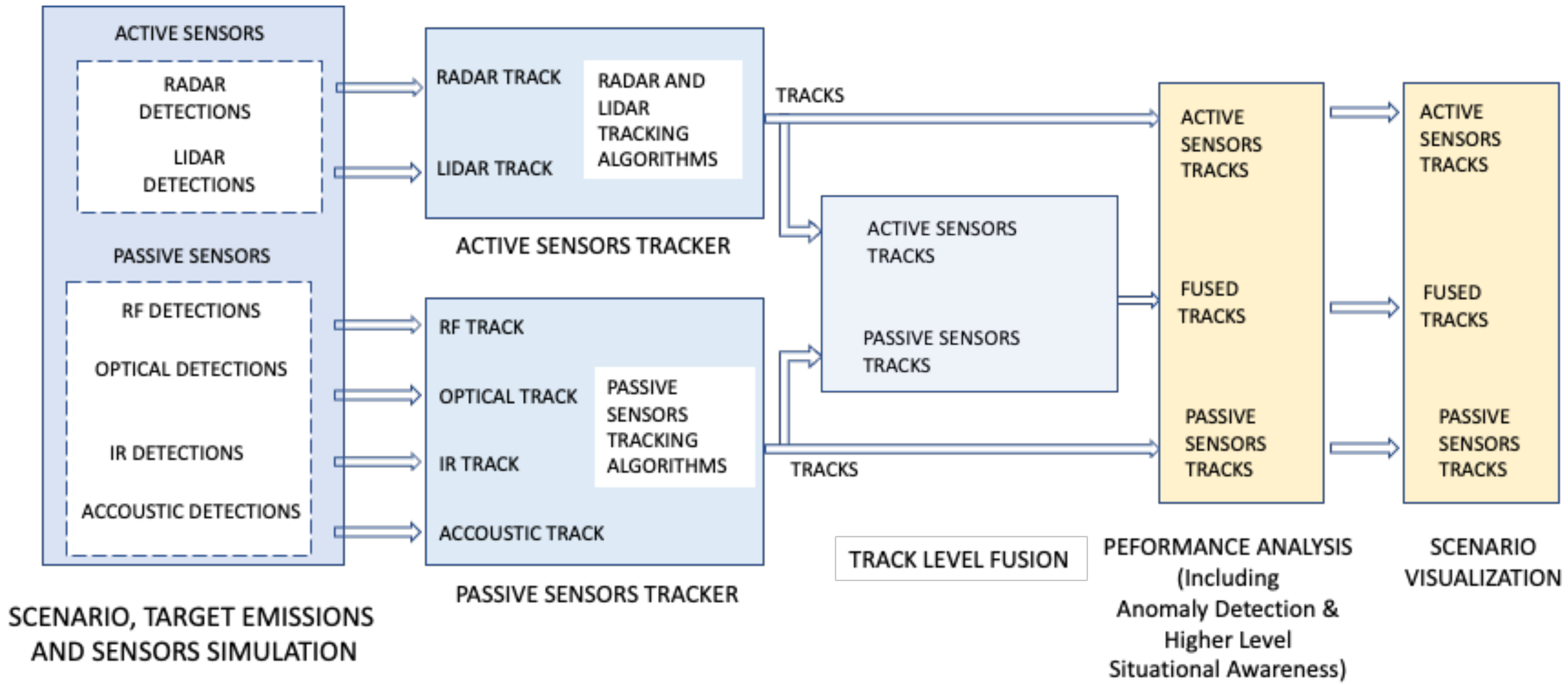
1. Avoiding attacks by:
    - Diversity of sensors
2. Minimizing effects if attacked by:
    - Tracking and fusion
3. Locating sources of interference by:
    - Passive systems

MUSCAT: TECHNICAL FOUNDATIONS

- MUSCAT is grounded in system of systems engineering and sensor/information fusion practices:
  - ❑ Flexible and lightweight sensing infrastructure implementation with multiple sensors
    - Radar (active and passive), acoustic, infrared, LiDAR
    - Flexible sensor placement and coverage analysis
  - ❑ Theoretical foundations and functional architecture based on JDL Data Fusion Model
    - Measurement generation and sensor fusion



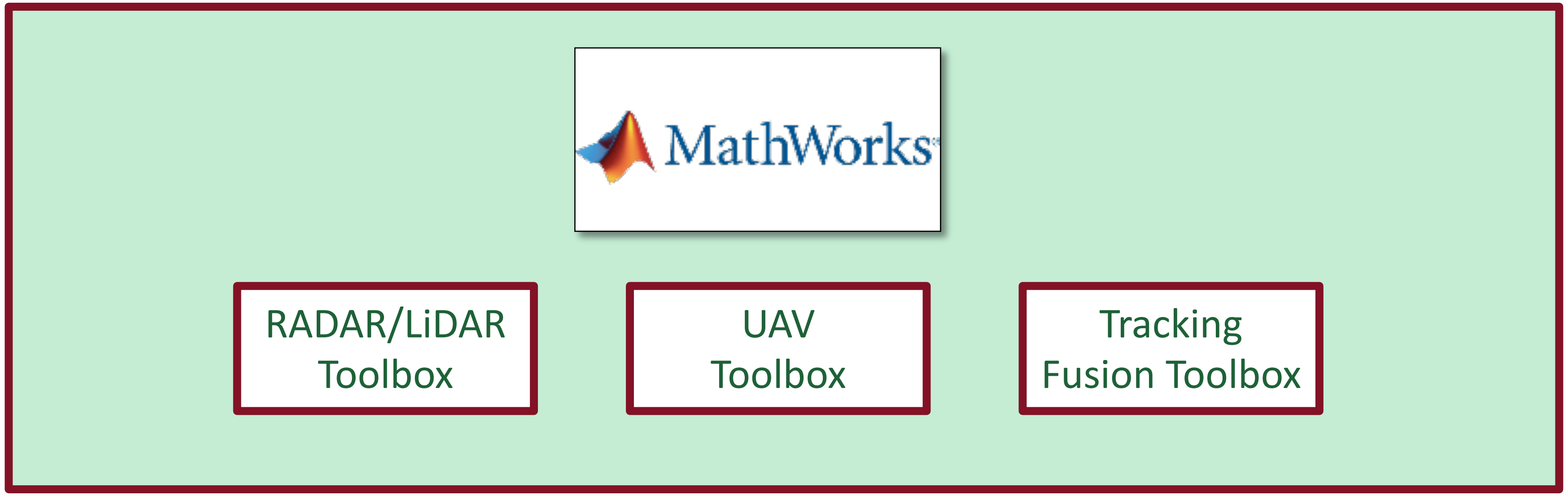
EXAMPLE: TRACK-LEVEL SENSOR FUSION FOR DETECTING UAS



Adapted from MATLAB (2022) Documentation of Track-Level Fusion of Radar and Lidar Data in Simulink
https://www.mathworks.com/help/driving/ug/track-level-fusion-of-radar-and-lidar-data-in-simulink.html

MUSCAT: TECHNICAL FOUNDATIONS (CONTD.)

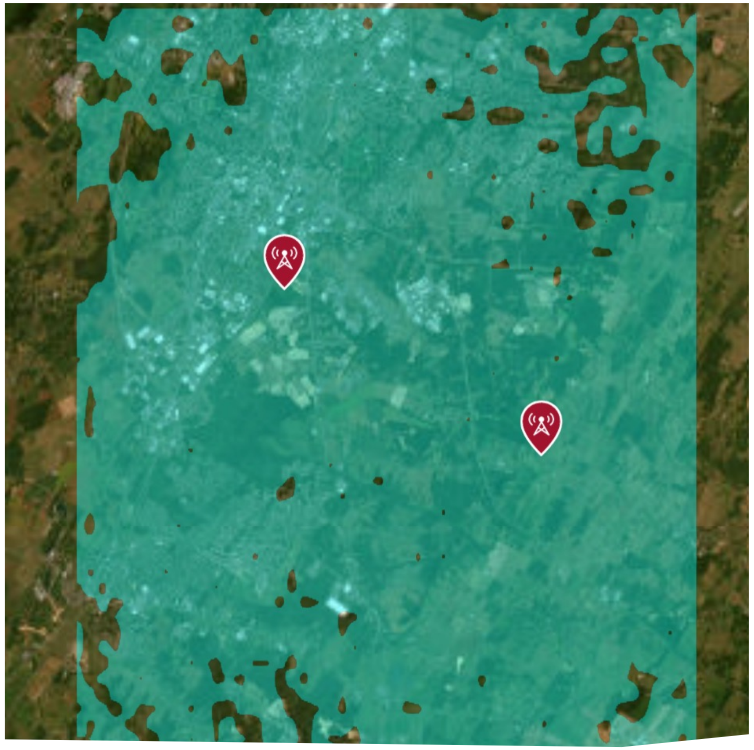
- MUSCAT is grounded in system of systems engineering and sensor/information fusion practices:
  - ❑ System of systems architecture for sensor fusion
    - Centralized, distributed, and hybrid architectures
    - Measurement fusion and track-to-track fusion
    - Build situational awareness for cooperative and non-cooperative sUAS
- Flexible scenario implementation for sUAV operations and cybersecurity threats
  - ❑ MUSCAT is built in MATLAB
  - ❑ Leverages multiple toolboxes



Multi-Sensor Coverage – Radar and ADS-B

- Finding gaps and studying the overlap of coverage in a multi-sensor scenario helps the decision-making (especially at early stages – i.e., conceptual phase – where there is no much information about the solution)

ADS-B



RADAR

RADAR + ADS-B

Radar+ADS-B

Gap