
**Transport Canada's**

**2023 Vehicle Cyber Security Conference**

February 23rd, 2023

# Cyber Lens: Machine Vision and V2X Testing for VRU and CAV Safety Applications

Divyanshu Kamboj
Area X.O, Invest Ottawa

# Safe Smart Intersections that Protect Vulnerable Road Users

- TC ERSTPP Project (8 Industry partners)
- Executing complex test scenarios in a four-season climate
- Assessing the design, testing and integration of emerging CAV, V2X and smart mobility tech in intersections and safety for vulnerable road users
- Accelerating tech development, time to market, and future adoption (policy)

AREAX.O | ZONEX.O

# *Safe Smart Intersections that Protect Vulnerable Road Users (VRUs)*

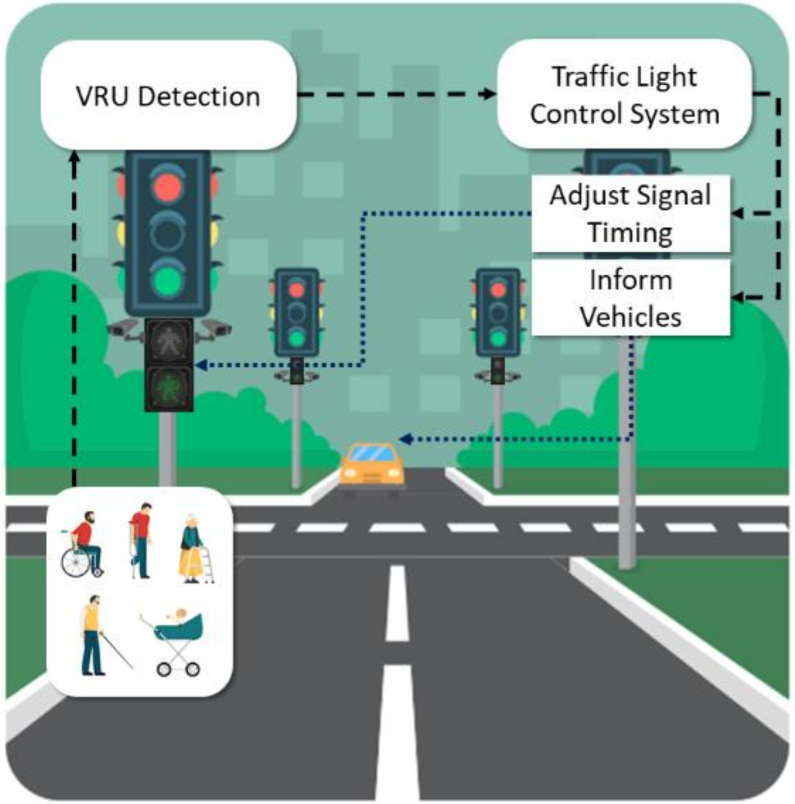
**Project is divided into four phases:**

**Phase 1**: VRU Safety Test Plan Development

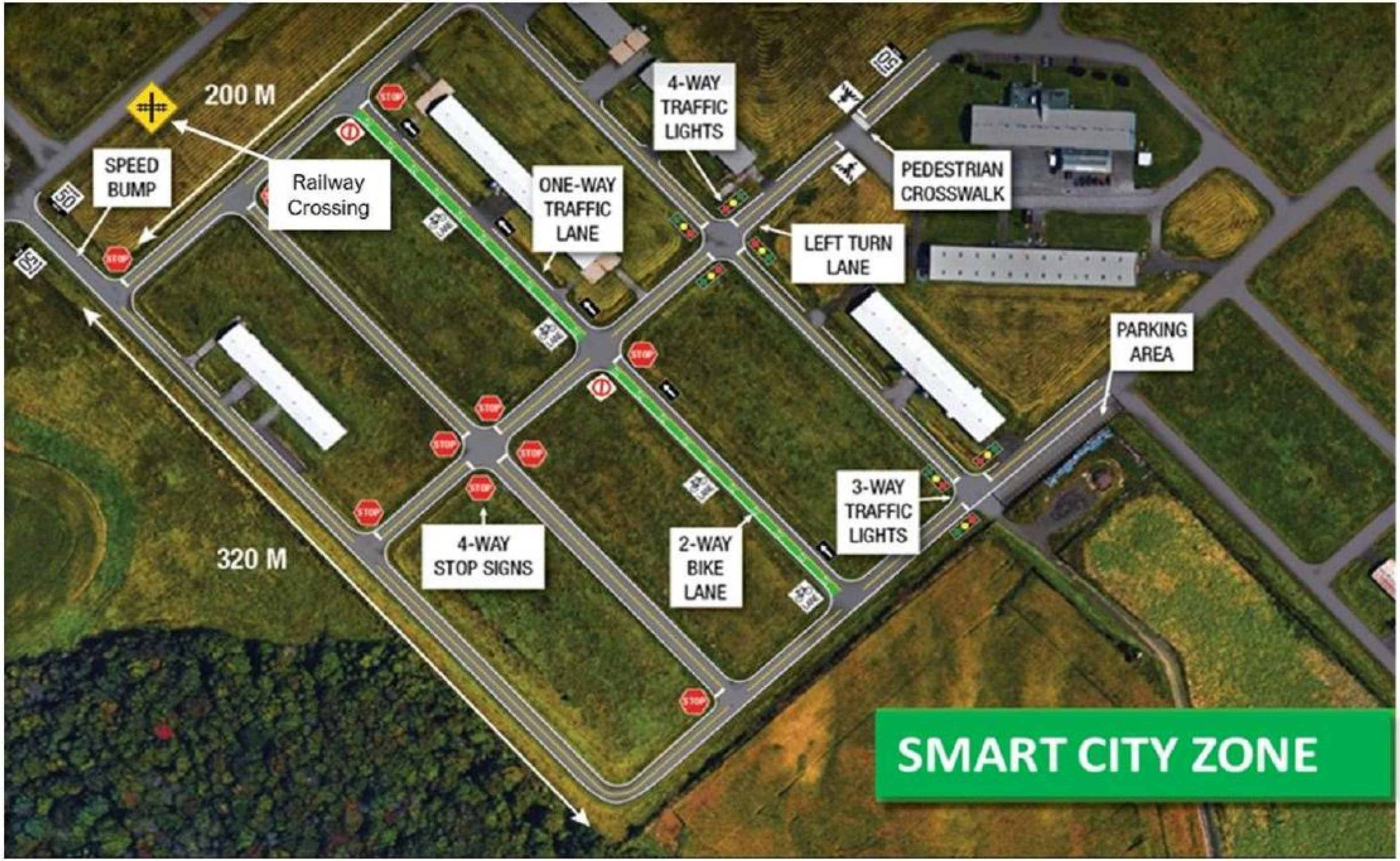
**Phase 2**: Area X.O And Kanata Smart Intersection – Testbed Preparation

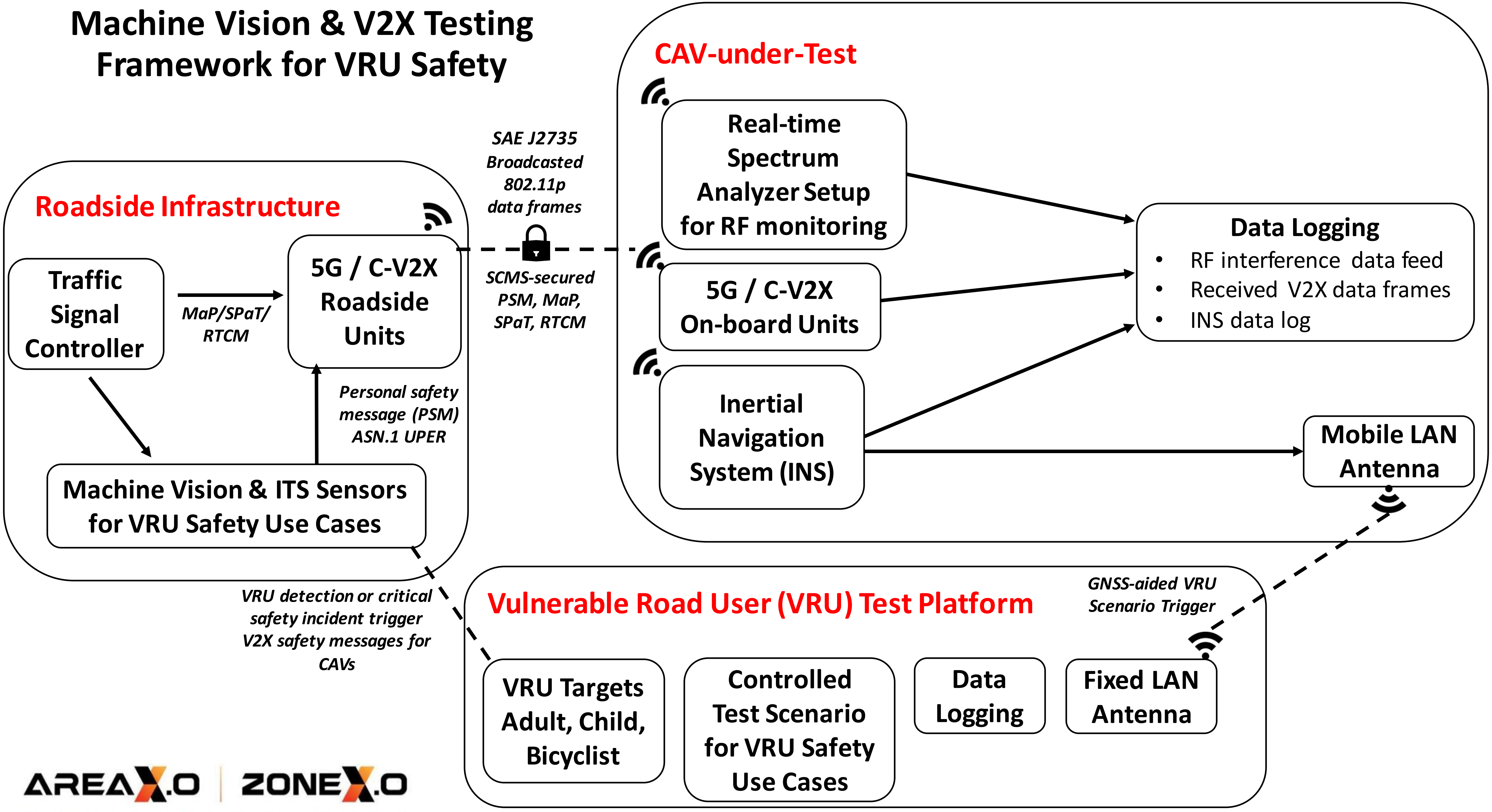
**Phase 3**: V2X And Machine Vision Testing and Data Collection for VRU safety at Area X.O

**Phase 4**: Public Demonstration, Data Analysis, and Final Report




AREA X.O | ZONE X.O


200 M
SPEED BUMP
Railway Crossing
ONE-WAY TRAFFIC LANE
4-WAY TRAFFIC LIGHTS
PEDESTRIAN CROSSWALK
LEFT TURN LANE
PARKING AREA
3-WAY TRAFFIC LIGHTS
2-WAY BIKE LANE
4-WAY STOP SIGNS
320 M
SMART CITY ZONE

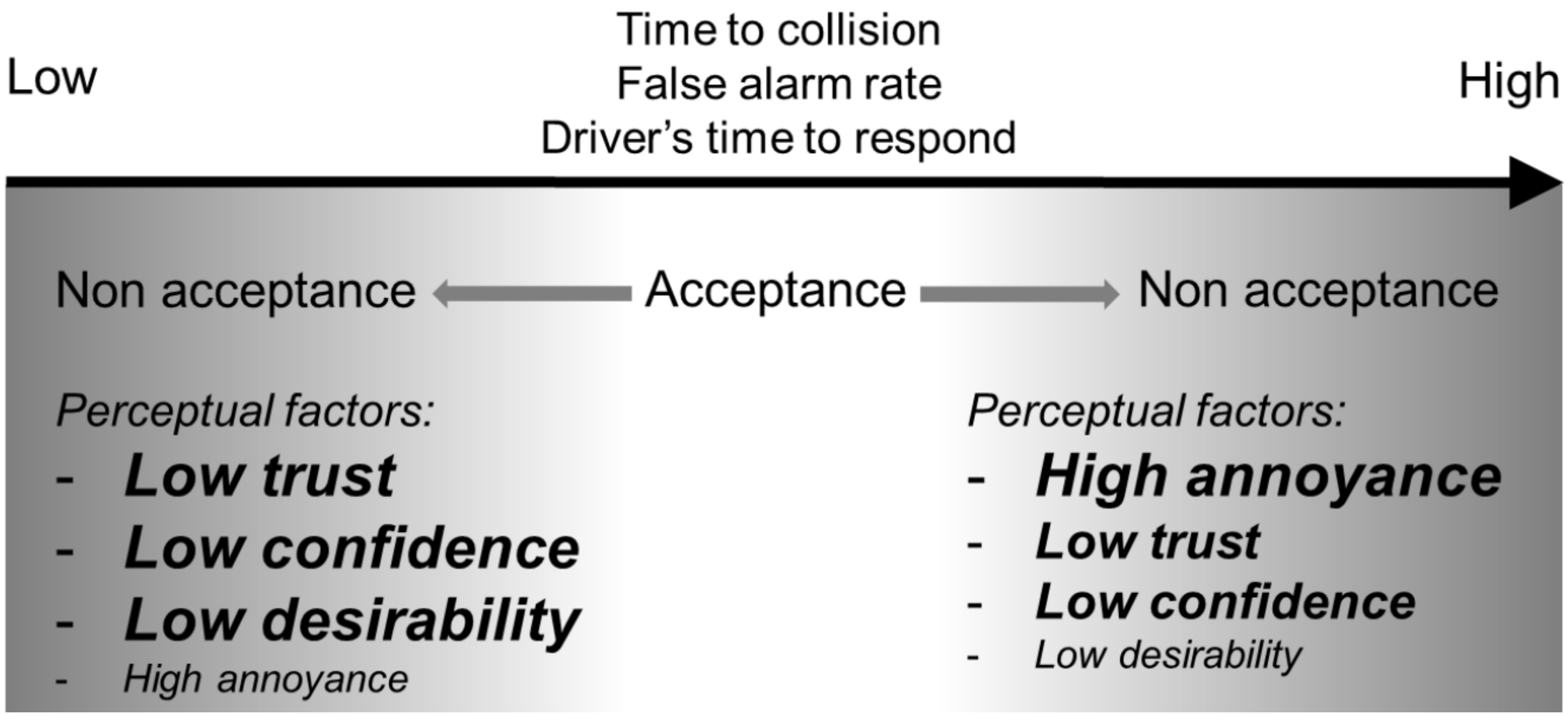


Machine Vision & V2X Testing Framework for VRU Safety
Roadside Infrastructure
Traffic Signal Controller
MaP/SPaT/ RTCM
5G / C-V2X Roadside Units
Personal safety message (PSM) ASN.1 UPER
Machine Vision & ITS Sensors for VRU Safety Use Cases
SAE J2735 Broadcasted 802.11p data frames
SCMS-secured PSM, MaP, SPaT, RTCM
CAV-under-Test
Real-time Spectrum Analyzer Setup for RF monitoring
5G / C-V2X On-board Units
Inertial Navigation System (INS)
Data Logging
• RF interference data feed
• Received V2X data frames
• INS data log
Mobile LAN Antenna
VRU detection or critical safety incident trigger V2X safety messages for CAVs
Vulnerable Road User (VRU) Test Platform
GNSS-aided VRU Scenario Trigger
VRU Targets Adult, Child, Bicyclist
Controlled Test Scenario for VRU Safety Use Cases
Data Logging
Fixed LAN Antenna
AREAX.O | ZONEX.O

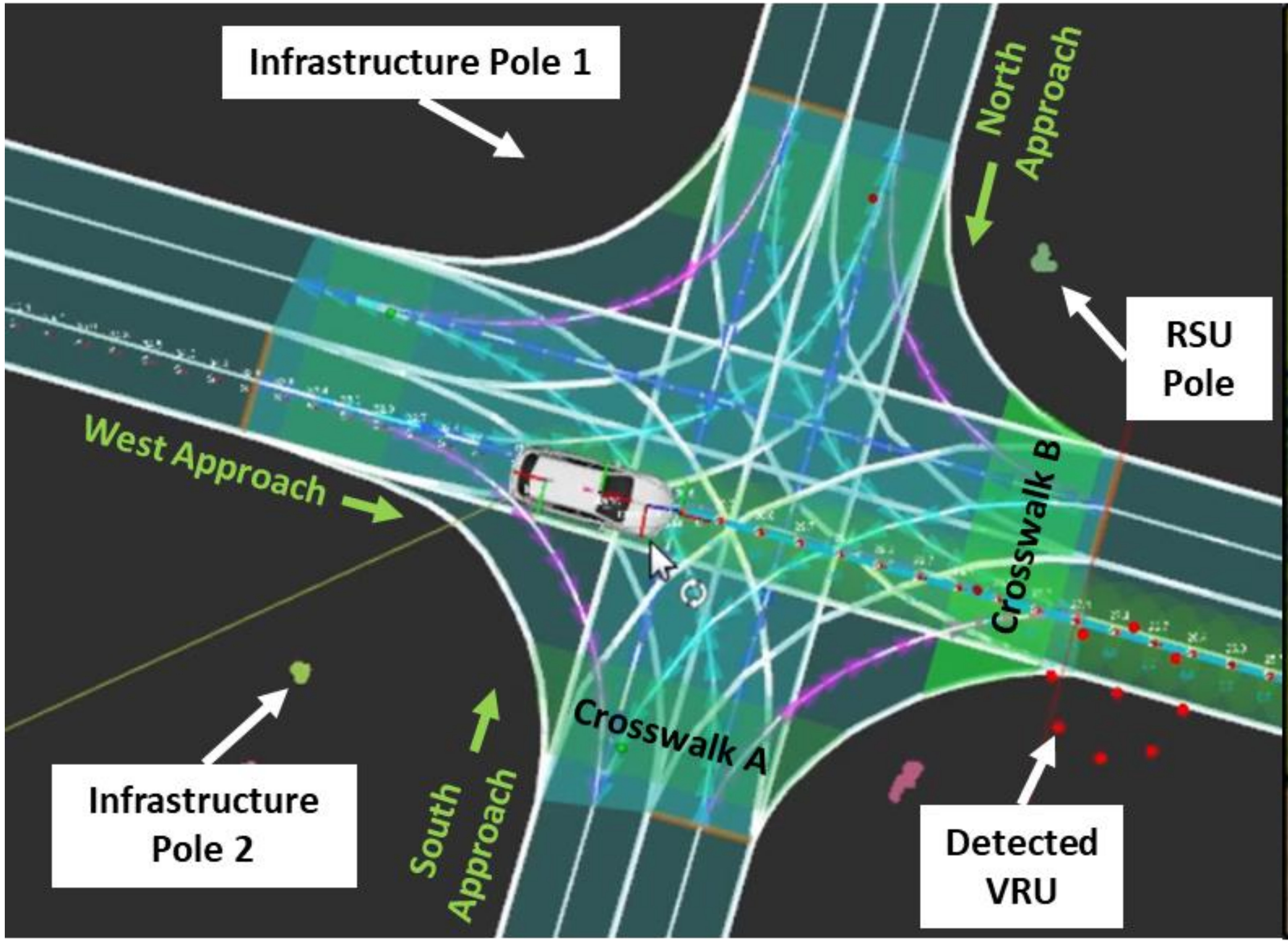
# AVSC Best Practice for Metrics and Methods for Assessing Safety Performance of Automated Driving Systems (ADS)

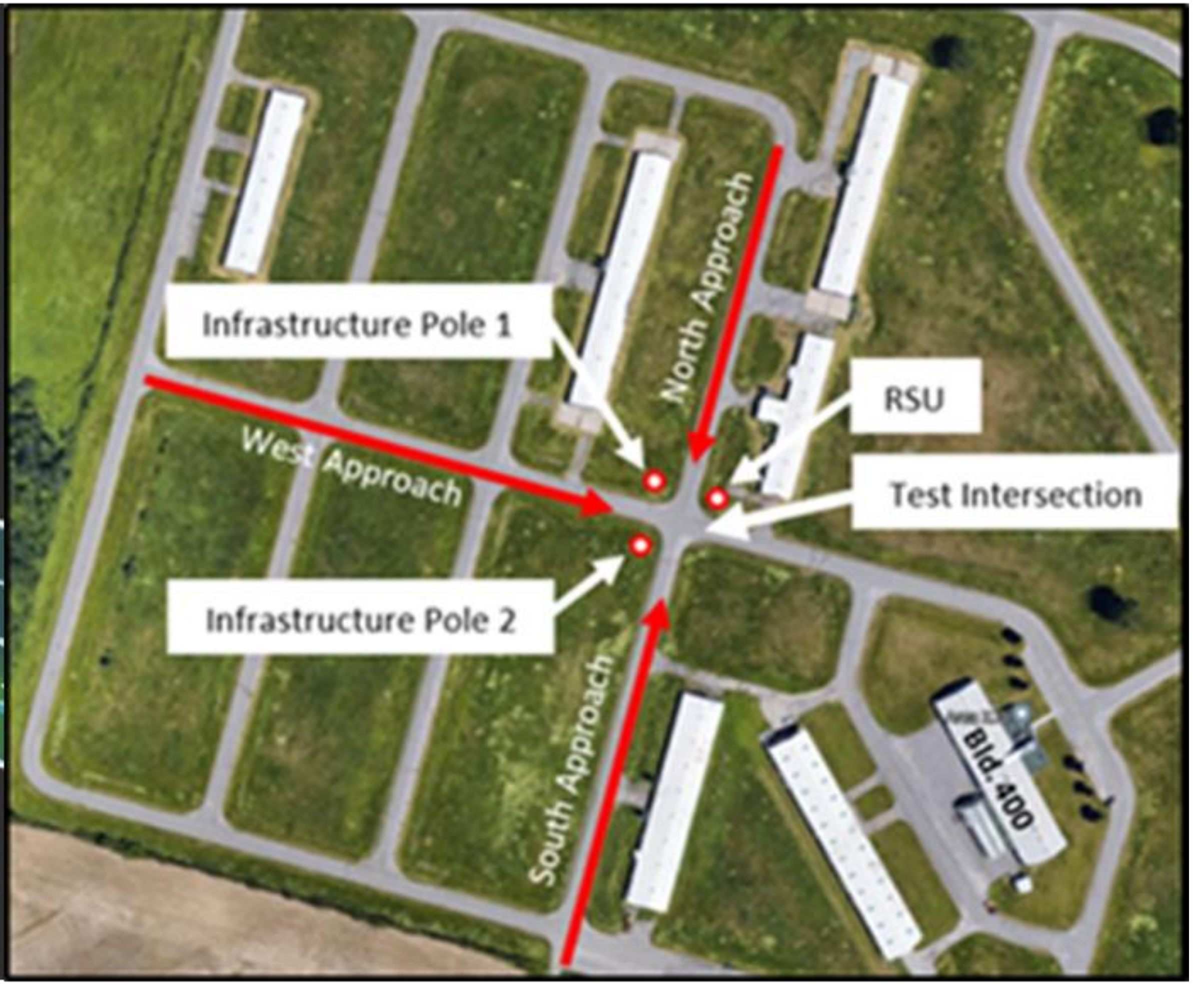
| Category[5] | Safety Performance Metrics | Description |
|---|---|---|
| Crashes | Crash severity and frequency | Contact that the subject vehicle has with an object, either moving or fixed, at any speed resulting in fatality, injury or property damage. |
| Compliance with traffic regulations | Severity and frequency of citable offense | A citable violation of traffic regulations pertaining to DDT performance. |
| Maintain a safety envelope | Longitudinal and lateral distance (may be a function of contextual modifiers) | A violation of a kinematically defined state space around a vehicle that represents a buffer between the subject vehicle and other objects in the environment. The separation threshold may be contextually modified, e.g., based on the time to a collision (TTC) between the vehicle and other objects if they continued on their current trajectories [18]. The threshold may also be contextually modified by absolute velocity of the ADS or other road users. |
| Exhibit contextually safe vehicle motion control | Acceleration (longitudinal and lateral) | High acceleration events (both positive and negative) are measured based on the rate and duration of events, i.e., as the summation of all instances and duration of time that the subject vehicle accelerates above a threshold value. |
| | Jerk (longitudinal and lateral) | High jerk events (both positive and negative) are measured based on the rate and duration of events, same as acceleration. |
| Object and event detection and response (OEDR) | OEDR reaction time | The time it takes for the ADS to initiate a measurable response following the onset of an initiating event in the context of scenario-based testing.[6] |

# Automated Driving System's
# Object and Event Detection and Response (OEDR)

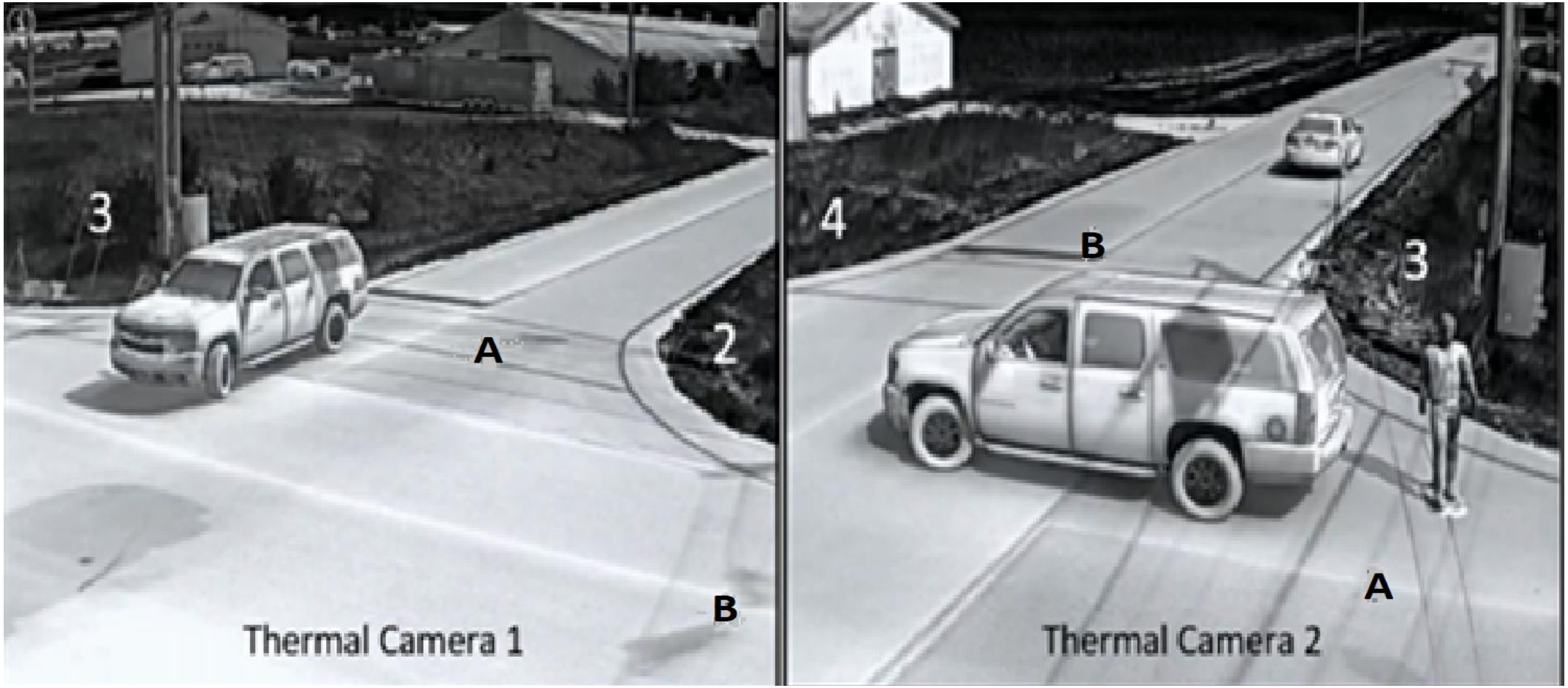


# Machine Vision & V2X Testing Framework for VRU Safety

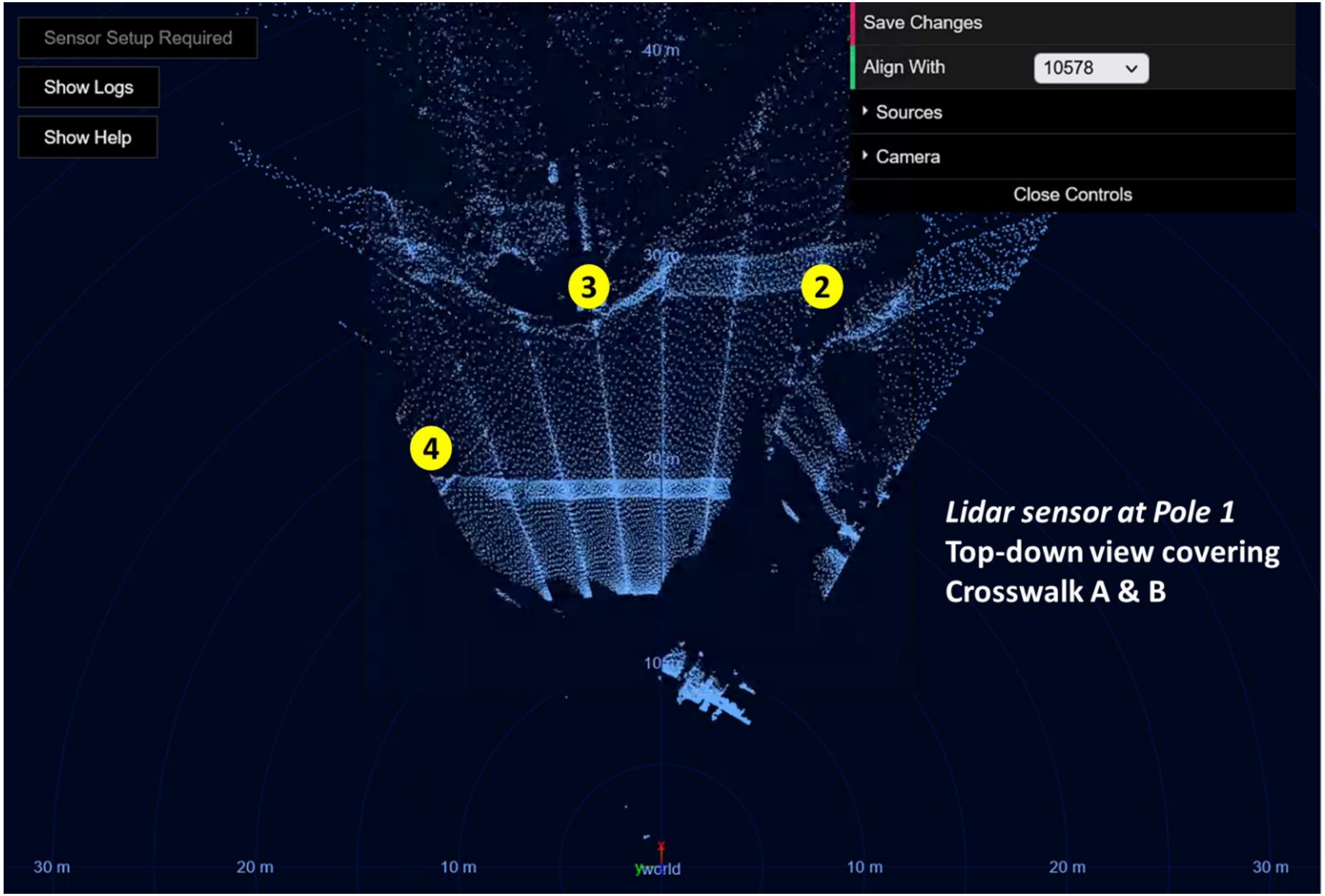



AREAX.O | ZONEX.O




| ID | Class | Certainty | Size | Position | Velocity | Direction | Sender | Zone |
|---|---|---|---|---|---|---|---|---|
| 2434f | Person | 100% | 1.0 m2 | lat 45.31970966<br>long -75.75761638 | 5.68 kph | 291.50 deg | Bosch thermal 2 | N/A |
| 2433d | Car | 100% | 4.1 m2 | lat 45.31969121<br>long -75.75760319 | 6.75 kph | 295.77 deg | Bosch thermal 2 | N/A |

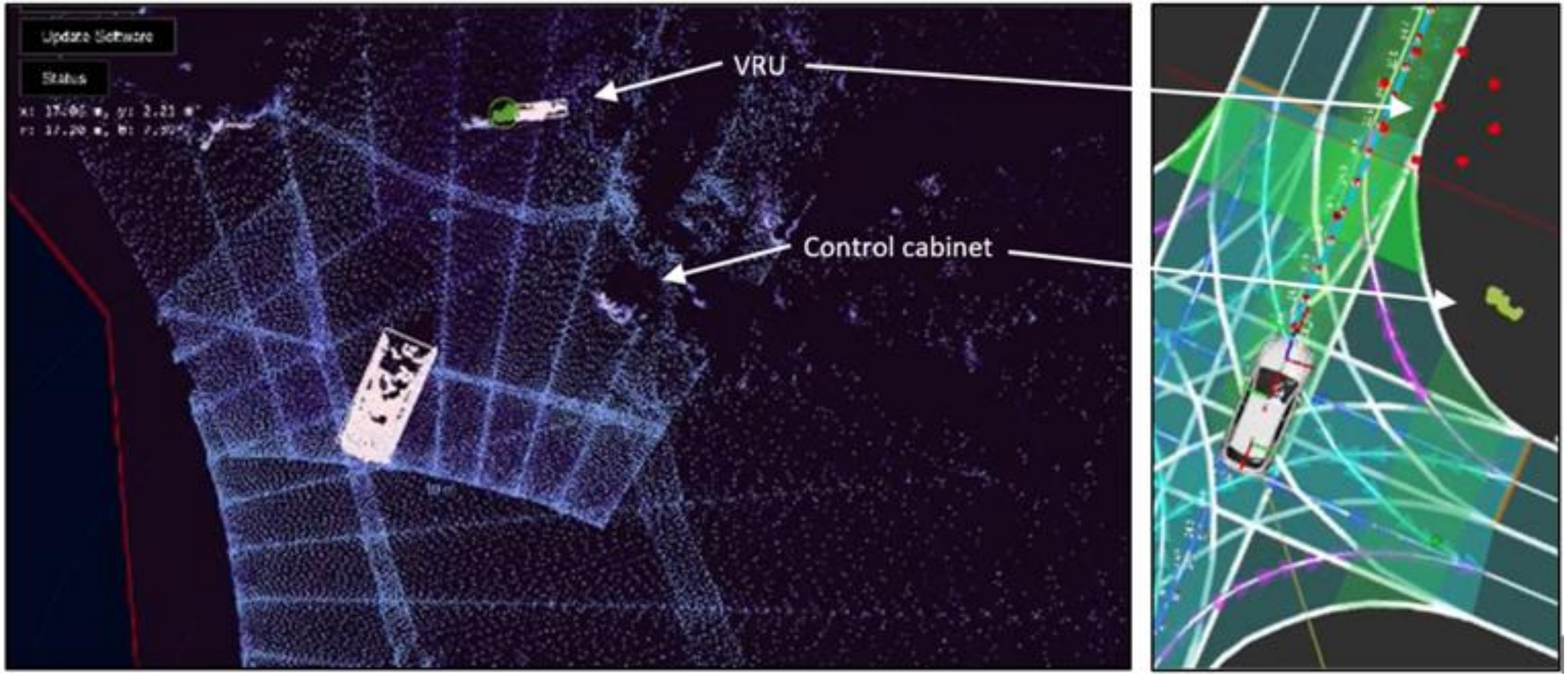



AREAX.O | ZONEX.O


*Lidar sensor at Pole 2*
**Top-down view covering Crosswalk B**

AREAX.O | ZONEX.O

# VRU views from Pole-mounted LiDAR and CAV



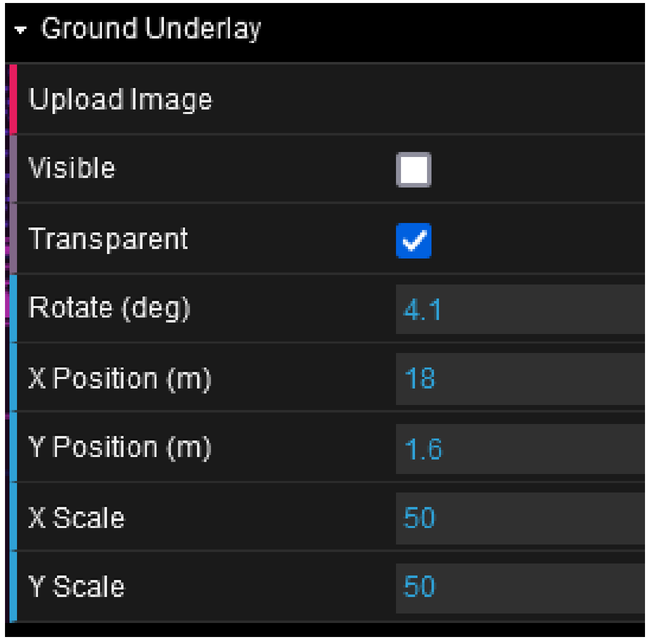

AREAX.O | ZONEX.O

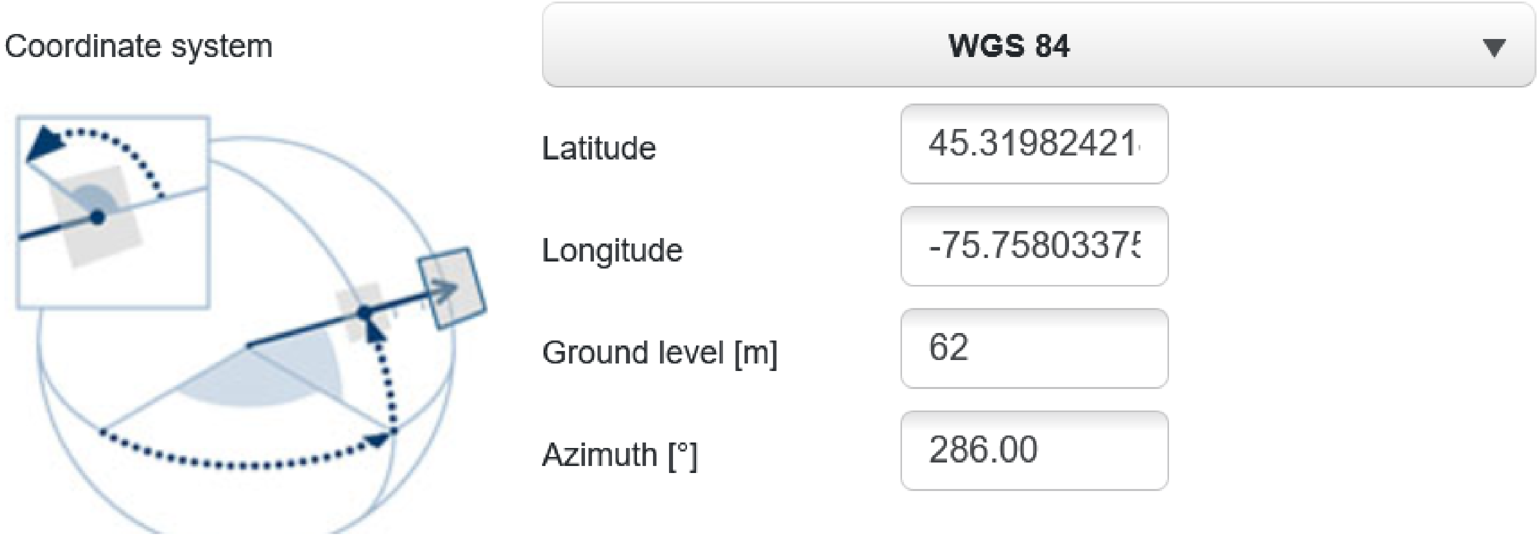

# City of Ottawa

*Candidate location to train machine learning algorithms by NRC, for VRU or object detection*

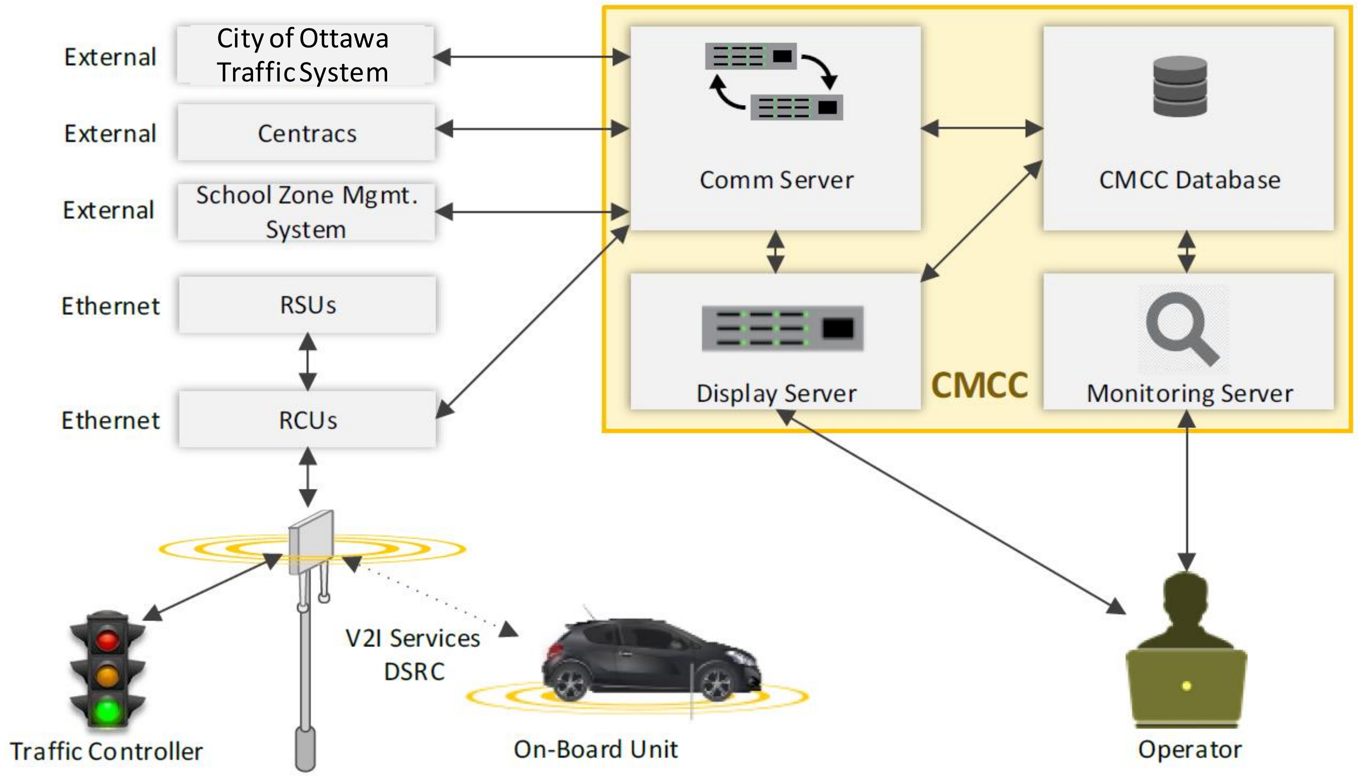
- Bounding boxes were drawn around each VRU present inside the ROI
- VRUs outside of the ROI were not annotated.

# LiDAR, Thermal Camera Positioning Calibration



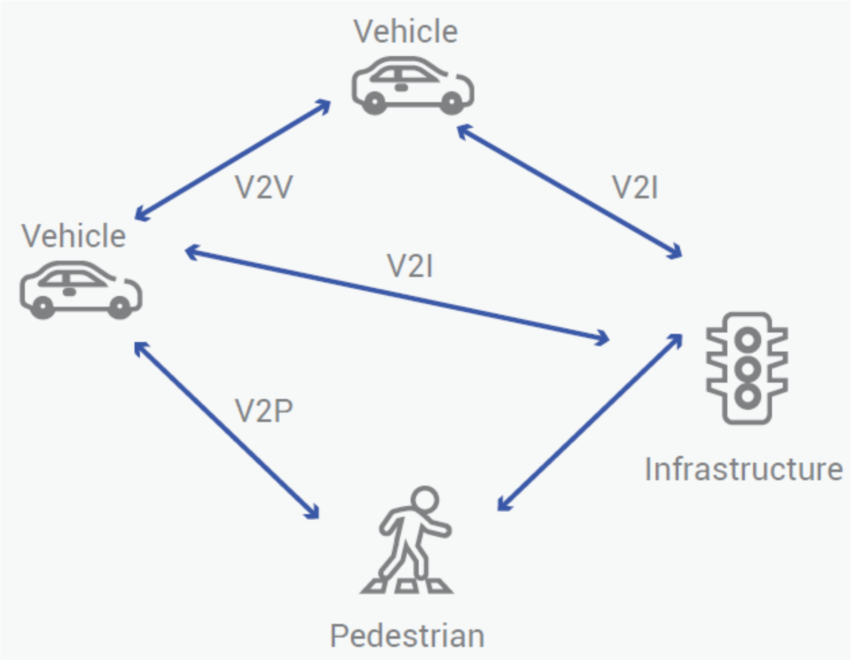
# Cloud-based Traffic/V2X Data API Engine

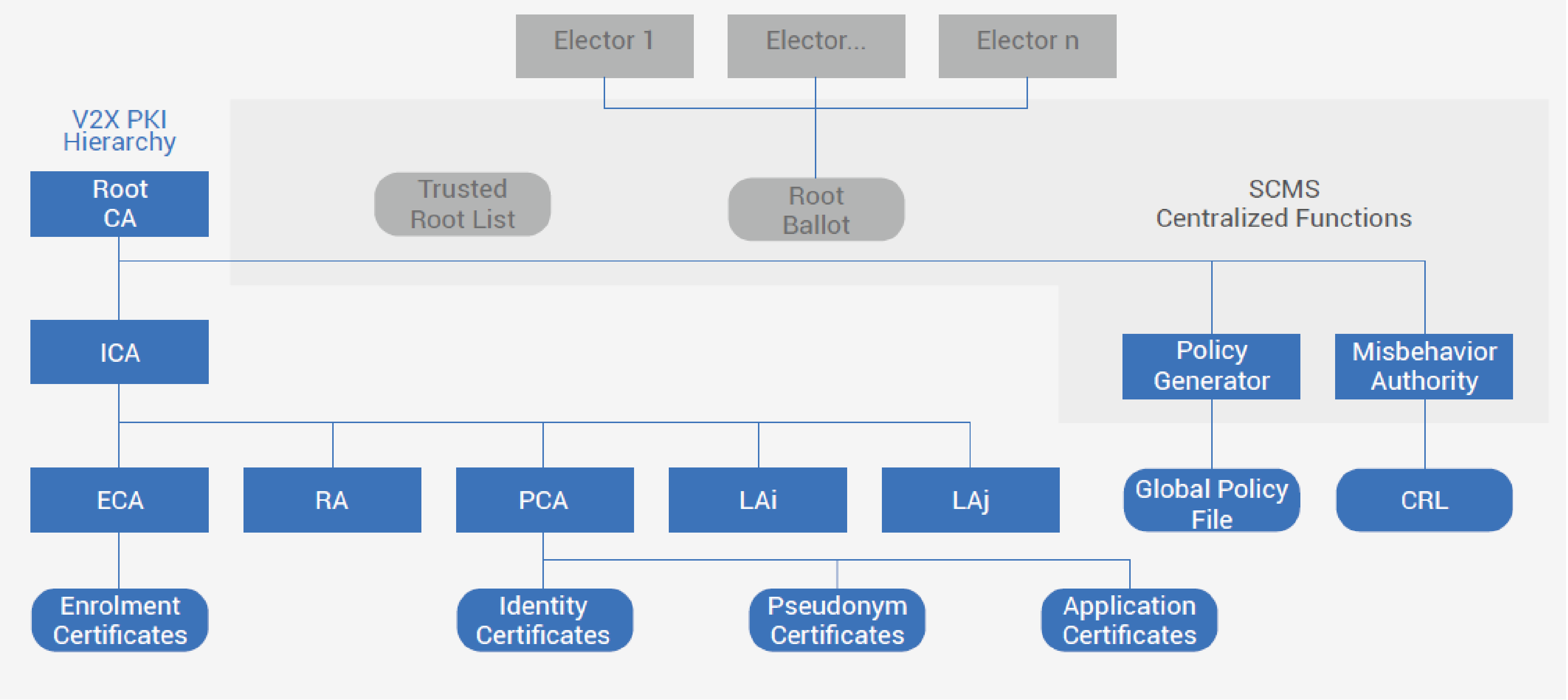



```
Pedestrian ⌄ {
    id                      integer
                            title: Id
                            readOnly: true

                            Unique ID of the pedestrian

    position                LatLonInformation ⌄ {
                                latitude*           number
                                                    title: Latitude
                                                    maximum: 90
                                                    minimum: -90
                                longitude*          number
                                                    title: Longitude
                                                    maximum: 180
                                                    minimum: -180
                                elevation           number
                                                    title: Elevation
                                                    readOnly: true
                                                    x-nullable: true

                            }
    speed                   number
                            title: Speed
                            readOnly: true

                            Speed of the pedestrian in meters per second

    heading                 number
                            title: Heading
                            readOnly: true

                            Heading of the pedestrian in degrees

    type                    string
                            title: Type
                            readOnly: true

                            The type of the pedestrian

                            Enum:

                             > Array [ 3 ]

}
```

# Security Credential Management System (SCMS)

SCMS is designed by US-DOT sponsored Crash Avoidance Metrics Partners LLC (CAMP), with certificate management protocols standardized in IEEE 1609.2, SCMS is a complex distributed PKI utilizing offline roots and intermediate CAs in conjunction with subordinate Enrolment CAs (ECAs) and Pseudonym CAs (PCAs) that issue end-entity certificates. A centralized SCMS Manager governs collective CA certificate management policies, coordinates misbehavior detection, ballots trusted roots and disseminates trusted root and certificate revocation lists.

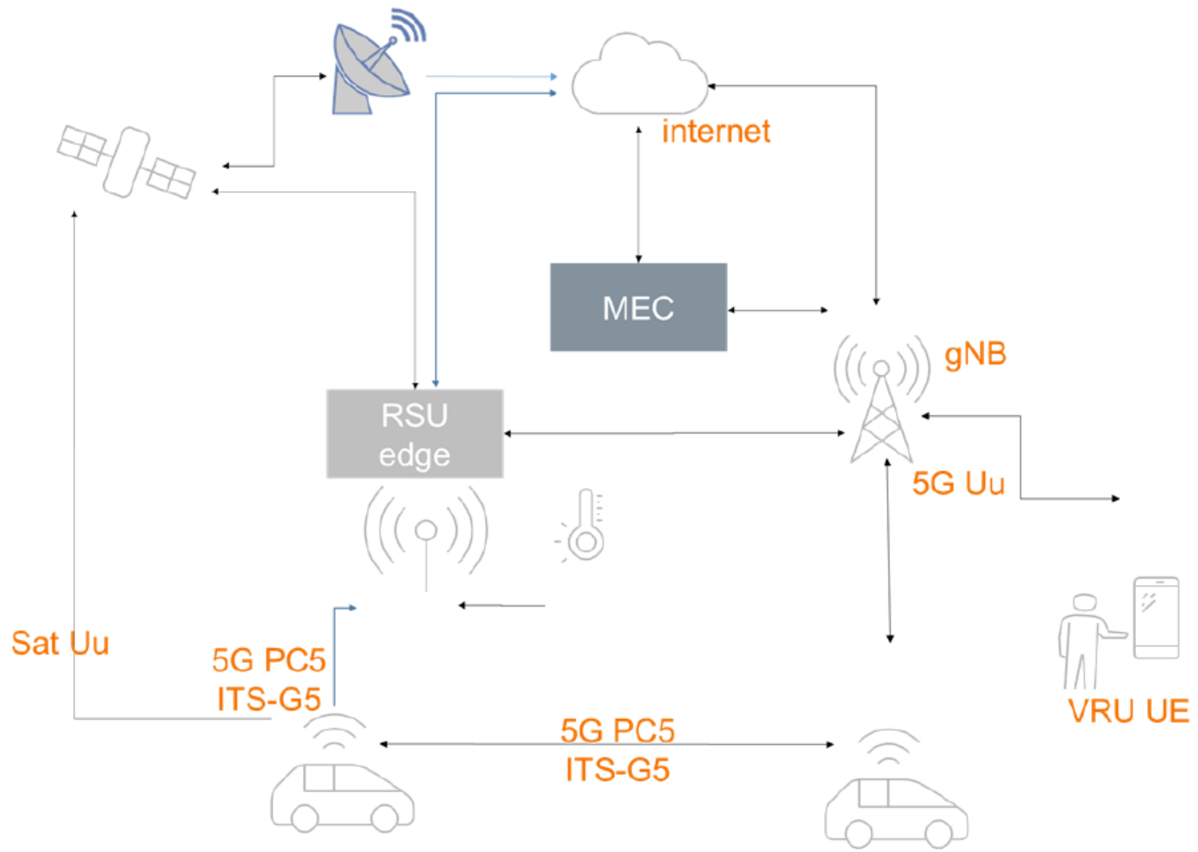



AREAX.O | ZONEX.O

# 5G / C-V2X Cybersecurity Testing

- Wedge Networks Cybersecurity and Real-time Threat Prevention
- Supported by the Government of Canada and EUREKA Cluster, Wedge Network is chair of the Canadian Cluster supporting the CELTIC-NEXT, 5G-SAFE-PLUSa
- Wedge Absolute Real-time Protection™ (WedgeARP™) platform - real-time threat prevention to secure 5G-Enabled road safety services, from CAV to transportation services infrastructures, software and proprietary algorithms for V2X Anomaly detection and response
- Wedge network will be working with AreaX.O to provide demonstration and testing support for 5G Enabled Road Safety and Cybersecurity Authentication and threat prevention.
- **AreaX.O supporting the work by providing the advanced 5G hosting environment.**




AREAX.O | ZONEX.O

# Potential Cyber Attacks in V2X Communications

| Attack | Property | Ease of attack | Detection probability |
|---|---|---|---|
| Eavesdropping | Confidentiality | High | Low |
| GPS Spoofing | Authentication, Privacy | High | Low |
| Alteration/Replay | Integrity, Authentication | High | Low |
| Magnetic | Privacy, Integrity, Availability, Real-time Constraint | High | Low-Driver, High-System |
| Identity tracking | Location, Privacy | High | Low-at High Traffic Density |
| Sybil | Authentication, Availability | High | Moderate |
| Denial of service | Authentication, Availability | High | High |
| Timing | Availability, Real-time Constraint | High | High |

| Attack | Property | Ease of attack | Detection probability |
|---|---|---|---|
| Bogus information | Integrity, Authentication | Moderate | Low-Driver, Moderate-System |
| Black hole | Availability, Confidentiality, Integrity | Moderate | Moderate |
| Man-in-the-middle | Confidentiality, Integrity, Authentication | Moderate | Moderate |
| Injection | Integrity | Moderate | Moderate-Driver, High-System |
| Blinding | Privacy, Integrity, Real-Time constraint | Moderate | High |
| Illusion | Authentication, Integrity | Low | Low-Driver/System |
| Impersonation | Integrity, Authentication | Low | High |

# Technology Testing & Validation Domain # 1

## Machine Vision and Deep Learning

| Target Outcomes | Success Indicators |
|---|---|
| Contribute VRU detection and classification data sets to improve machine vision- and deep learning-based applications to enhance VRU safety at road intersections | Benchmark performance of detection rates, miss rates, precision, false positive rates, and false negative rates against other machine learning algorithms |
| Understand minimum triggering conditions for delivery of VRU safety messages to CAVs | Pass or fail criteria for VRU detection, classification, and notification based on parameters like GPS geofencing, motion vector filters, and machine vision algorithms |

AREAX.O | ZONEX.O

# Technology Testing & Validation Domain # 2

## RF Communications Fabric

| Target Outcomes | Success Indicators |
|---|---|
| Monitor RF interference and understand the spectrum usage for VRU safety applications, particularly in non-line of sight and diverse radio environments | Success is measured by the ability to detect and locate short duration or transitory sources of interference in the C-V2X from other radio frequency signals in the test environment, including 5G FR1 / FR2 sources and others |
| Analyze end-to-end CV2X communication metrics between RSU and OBU, and in-vehicle logs of the V2X message handler inside the CAV. | Following metrics are targeted for analysis from site data collection:<br>• Transmit to receive message latencies<br>• Application end-to-end latency<br>• Received Signal Strength Indicator (RSSI)<br>• Reference Signal Received Power (RSRP)<br>• Over the air message size |

AREAX.O | ZONEX.O

# Technology Testing & Validation Domain # 3

## CAV Collision Avoidance

| Target Outcomes | Success Indicators |
| --- | --- |
| Analyze time-to collision (TTC) measurements between CAV and VRU | Based on the specified ODD and environmental conditions for a given test scenario, remaining TTC values between CAV and VRU can be analyzed with respect to the observed minimum risk maneuver (MRM) performed by the CAV, upon receipt of the VRU safety message. |
| Observe CAV response latencies for minimum risk maneuver (MRM), upon receipt of VRU safety messages | Pass / fail criteria for module to interpret the VRU safety message, and CAV by-wire sensor modules to perform the MRM in a VRU safety scenario. Analyses of in-vehicle platform latencies with regards to CAV by-wire activation for vehicle control, based on timely interpretation of the VRU safety messages |

www.AreaX0.com

# How Can We Help You Achieve Your Innovation Goals?

**Kelly Daize**

**kdaize@investottawa.ca**

**Divyanshu Kamboj**

**dkamboj@investottawa.ca**