# GPS-Based Navigation & Positioning Challenges in Communications-Enabled Driver Assistance Systems

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Institute of Navigation Alberta Section June 2 2009

# GM Vehicle-to-Vehicle (V2V) Technology and Demo Fleet

(5 min video)

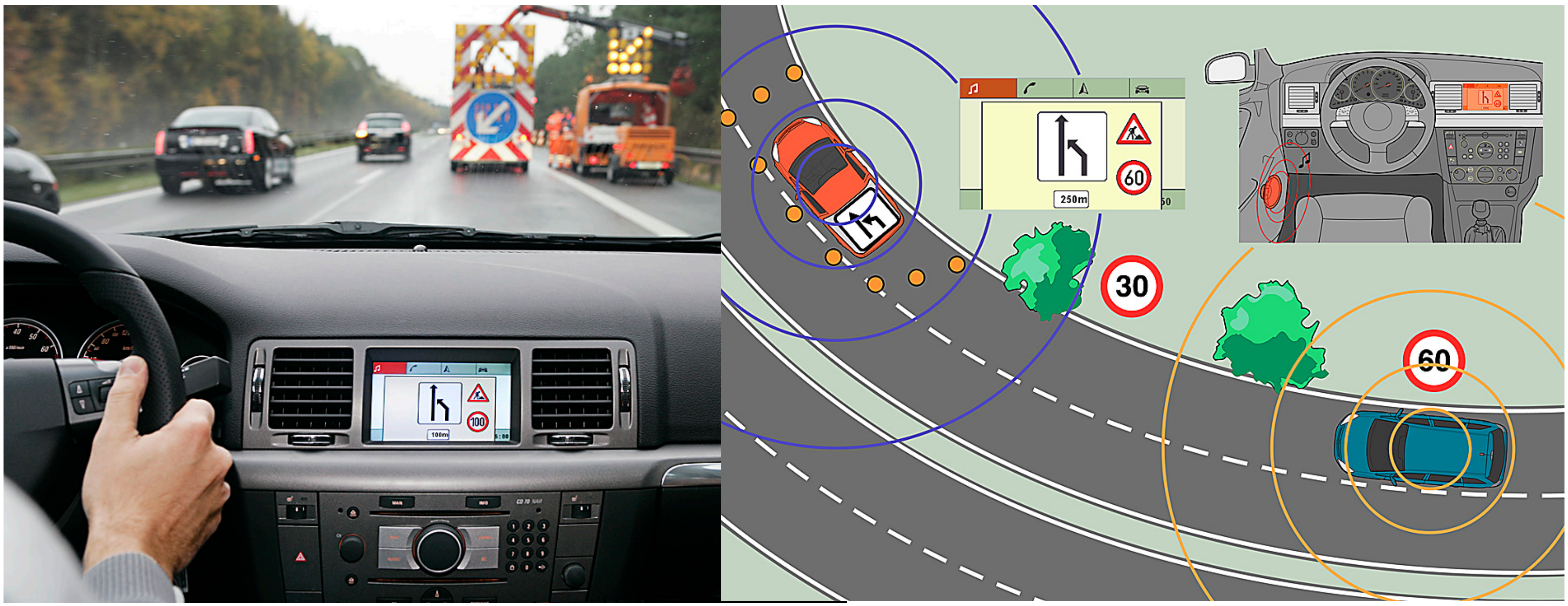
# GM Vehicle-to-Vehicle (V2V) Technology Development

- Demo fleet first demonstrated in 2005
- Fleet of 6 communicating vehicles
- 360 degree collision warning system
- Demonstration platform for DSRC-based active safety features
- Public demonstrations in more than 10 U.S. cities


**Vehicle capabilities:**
- Automatic braking
- Directional seat vibration system
- Motorized seatbelts

# Vehicle-to-Vehicle Activities in Europe

- Fleet of 4 communicating vehicles
- Demonstration platform for DSRC-based active safety features
- Public demonstrations in 8 European countries



# Dedicated Short Range Communication (DSRC)

- Dedicated to ITS (Intelligent Transportation Systems) applications
  - Allocation of 75 MHz around 5.9 GHz in U.S.
  - Potential allocation of 30 MHz around 5.9 GHz in Europe
- Supports low-latency line of sight and non-line of sight applications
- Provides multiple channels for broadband, real-time, long-range, bi-directional, secure communication
- Facilitates the development of ad-hoc V2V network architectures
- Standards development in the following communities
  - IEEE 802.11p – lower layer wireless protocols
  - IEEE 1609 – upper layer wireless protocols + security
  - **SAE J2735 – wireless messaging standards**

# GM in V2V Collaborative R&D

DaimlerChrysler Research and Technology North America, Inc.

**Crash Avoidance Metrics Partnership (CAMP)**

**VSC-A: Vehicle Safety Communications – Applications**

- Developed under a cooperative agreement with USDOT
- Interoperable and scalable architectures that enable future deployment.
- Emphasis on resolving current communication and positioning issues
- 3 year project (December 2006 to November 2009)

# Interoperable Application Development in VSC-A

- Emergency Electronic Brake Light (EEBL)
- Forward Collision Warning (FCW)
- Intersection Movement Assist (IMA)
- Blind Spot Warning + Lane Change Warning (BSW + LCW)
- Do-Not-Pass Warning (DNPW)
- Control Loss Warning (CLW)


# Extending V2V Technology to Vehicle-to-Infrastructure (V2I) Systems

- **Similar to V2V technology except:**
  - Sender is a fixed entity
  - Intersection sends local maps (with lane, stop line markings, etc.) and traffic signal states

- **Vehicles position themselves to lane level and informs/ warns drivers on:**
  - Traffic signal state changes
  - Possible signal violations
  - Even direct lane changes if necessary

# GM in V2I Collaborative R&D

DaimlerChrysler
Research and Technology North America, Inc.

GM

TOYOTA

Ford

**Crash Avoidance Metrics Partnership (CAMP)**

**CICAS-V: Cooperative Intersection Collision Avoidance System**

- Developed under a cooperative agreement with USDOT
- Avoid violations at Traffic Signals and Stop Signs
- 4 year project (December 2006 to June 2010)

- Two functional intersections in MI and CA
  - RTK-based GPS with RTCMv3.0
  - Better than 0.5 m positioning accuracy achieved



5th/ El Camino (CA) & 10 Mile/Orchard Lake (MI) CICAS-V Intersections

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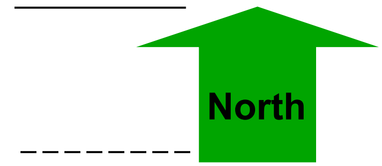
# VSC-A & CICAS-V Positioning Requirements & Scope

- CICAS-V
  - Absolute positioning requirements:
    - Lane Level: <1 m (95 %) open-sky conditions

- VSC-A
  - Relative positioning requirements:
    - Lane Level: <1 m (95 %) open-sky conditions
  - Absolute positioning accuracy: < 5 m (95%)

- GPS is the technology of choice to meet these requirements

# Concept of Operation

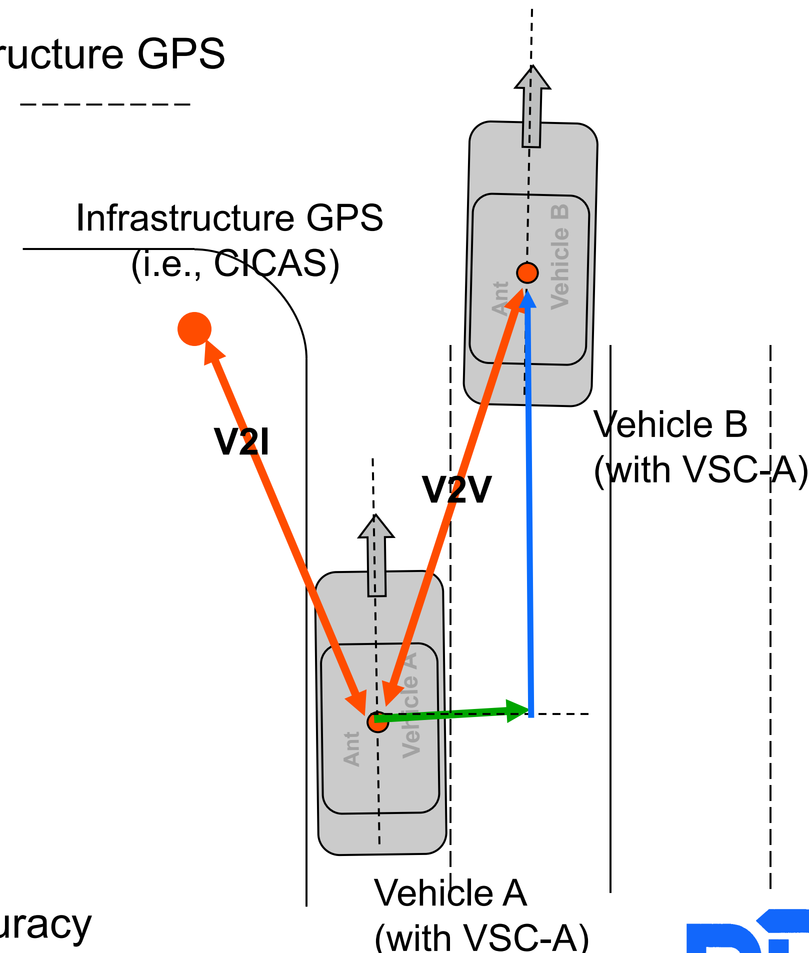



**Available Positioning Information**

- ❑ Vehicle GPS information
  - ❑ Standalone Position, Heading
- ❑ Relative vectors to other vehicles and infrastructure GPS
  - ❑ V2V and V2I (red) vectors
  - ❑ Accurate to better than 1 m
- ❑ Location of infrastructure GPS
  - ❑ Pre-surveyed and accurate Lat, Lon

**Modes of Operation**

- ❑ CICAS-V
  - ❑ Estimate vehicle position
  - ❑ Better than 1 m **absolute accuracy**
- ❑ VSC-A
  - ❑ Estimate across and along distances
  - ❑ Better than 1 m **relative accuracy**
- ❑ CICAS-V & VSC-A
  - ❑ Better than 1 m **relative & absolute** accuracy



# SAE Standards – Current Status

## SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary

(I): Periodic Heartbeat Message (required)

(II): Variable Rate Message (optional)

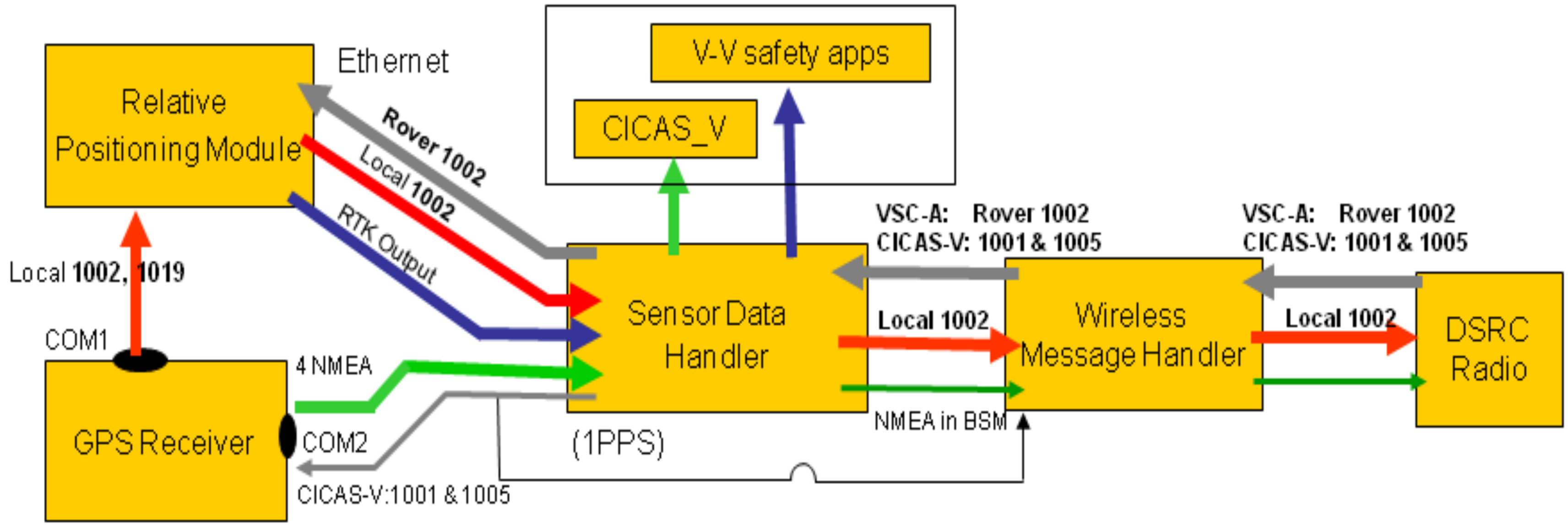
a. Event Notifications
b. Vehicle Trail
c. Vehicle Path Prediction
d. Raw GPS

(III): Proprietary (optional)

| | |
|---|---|
| Message Type | |
| Millisecond stamp | |
| Temp ID (MAC addr) | |
| Latitude | **POSITION** |
| Longitude | **POSITION** |
| Elevation | **POSITION** |
| Speed | **MOTION** |
| Heading | **MOTION** |
| Accel. Frame (4way) | **MOTION** |
| Brake Status | **CONTROL** |
| Steering Angle | **CONTROL** |
| Throttle Position | **CONTROL** |
| Exterior Lights | **CONTROL** |
| Vehicle Size | |

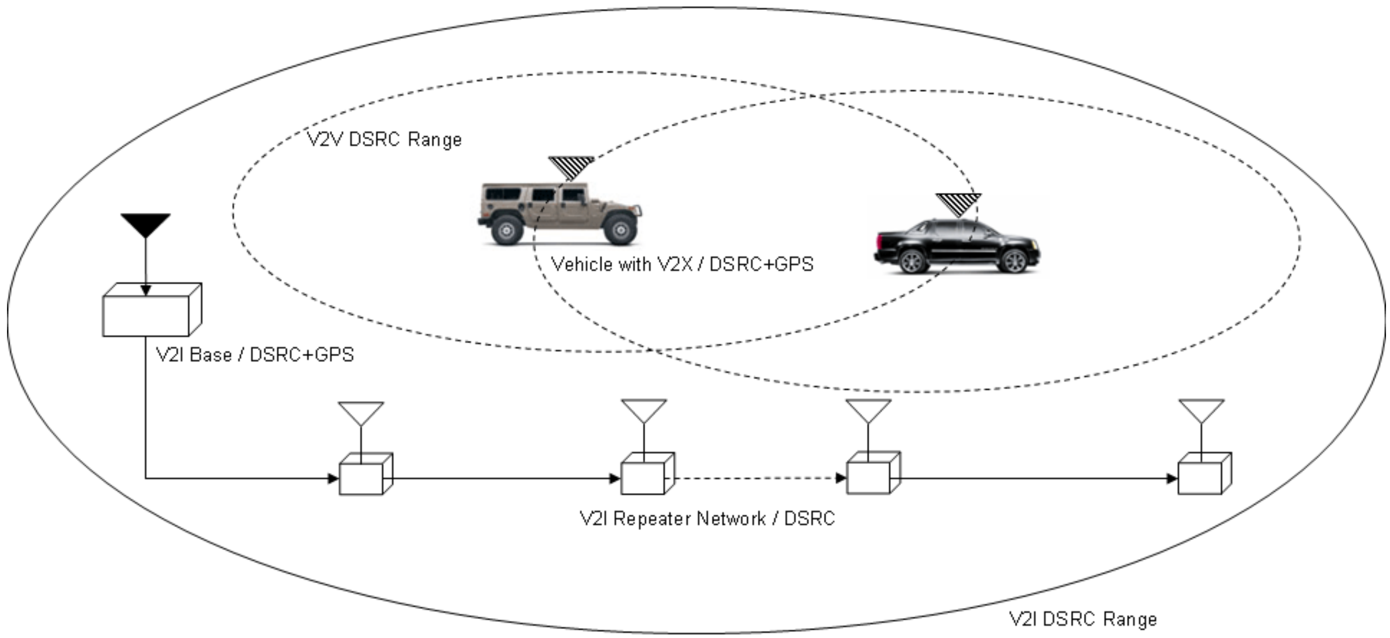
- VSC-A actively involved in standard development regularly attend SAE meetings
- VSC-A is working with SAE DSRC Committee members to:
  - Ballot the next revision
  - Improve standard for trial testing

# VSC-A & CICAS-V Positioning System Implementation




- RTK (Real-Time Kinematic) engines are included in:
  - GPS Receiver (1)
  - Relative Positioning Module (20)
- All 10XX messages shown are RTCM V3.0 messages

# A Common Positioning Architecture for V2V and V2I




- **Equipped vehicles *talk* to each other when they are within DSRC range (i.e., 300 m):**
  - share positioning and other V2V data

- **V2I intersections broadcast intersection dependent data:**
  - A *master GPS station* may be used by a cluster of intersections
  - Each intersection may add own signal timing and map information to master GPS data

# DSRC Transceiver Devices

**Standalone** – GPS-based device
**Integrated** – GPS-based device with vehicle network interface

**Passive** – Standalone or Integrated device that broadcasts vehicle position data to other network users

**Active** – Standalone or Integrated device that executes V2V features

**Personal** – Small device that provides visibility enhancement to pedestrians, cyclists, etc

# GM V2X Transponder Demo Video

(2 min)

# Ongoing Research and Development

- Further development of relative positioning
- Defining future enhancements
  - New GPS signals, L2, L5 and GPSIII
- Hardware dependency of performance
  - Tests with multiple receiver types
- Tests with applications and other algorithms
- Enhancement possibilities for challenging GPS environments

# Thank You !

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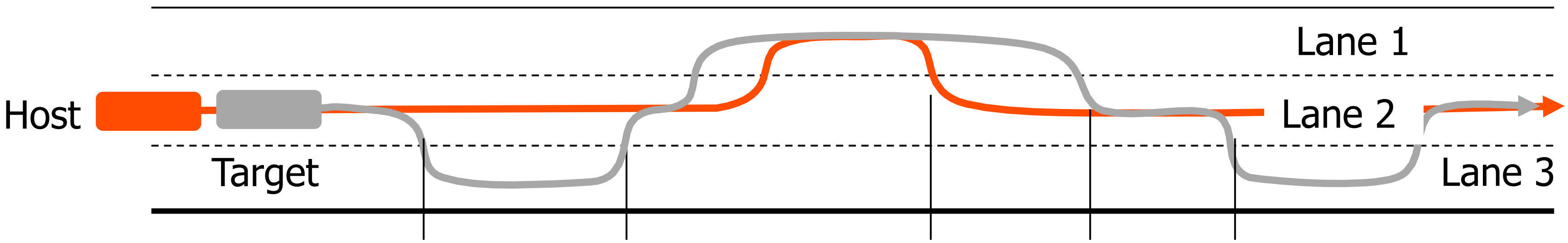
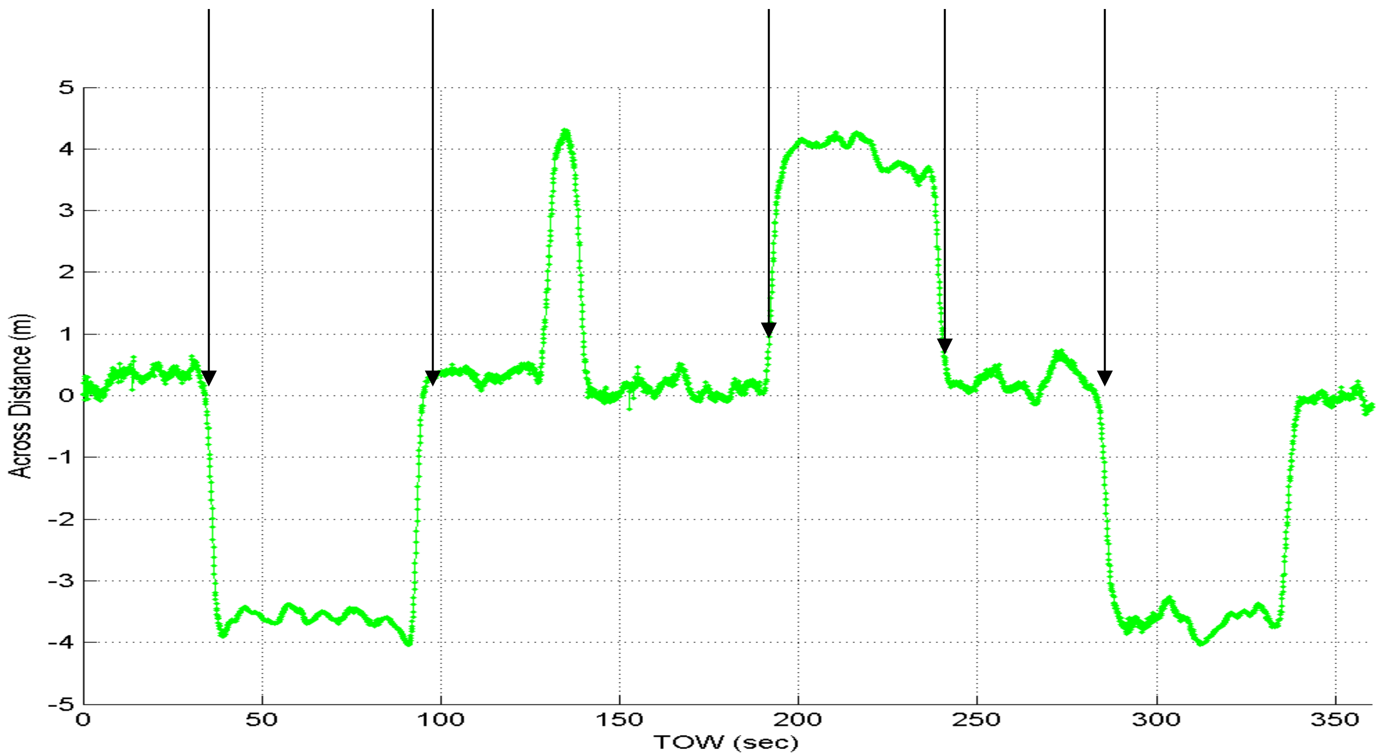
# Backup Slides

# VSC-A Performance




**Driving Scenario: Host and Target Driving in Same and Adjacent Lane**




**Host System Output: Across Distance to Target**

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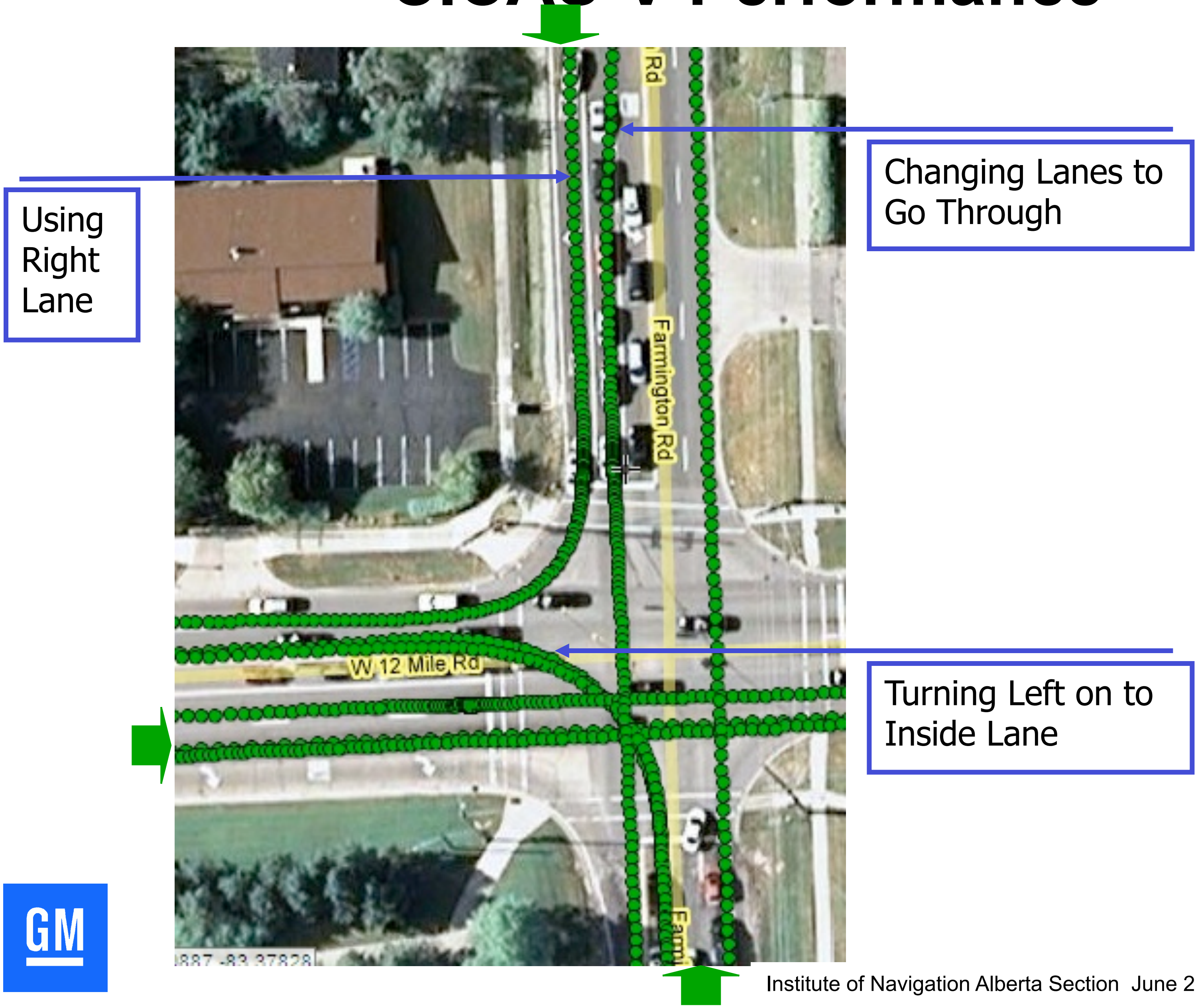
# CICAS-V Performance



# V2X Safety Applications

## Communications Between Vehicle and Infrastructure

- Blind Merge Warning
- Curve Speed Warning
- Emergency Vehicle Signal Preemption
- Highway/Rail Collision Warning
- Intersection Collision Warning
- Intersection Crossing Assistance (Electronic Button)
- In-Vehicle Signage
- Left Turn Assistant
- Low Bridge Warning
- Low Parking Structure Warning
- Pedestrian Crossing Information at Intersection
- Road Condition Warning
- Stop Sign Movement Assistance
- Stop Sign Violation Warning
- Traffic Signal Violation Warning
- Work Zone Warning

## Communications Between Vehicles

- Approaching Emergency Vehicle Warning
- Blind Spot Warning
- Cooperative Adaptive Cruise Control
- Cooperative Collision Warning
- Emergency Electronic Brake Lights
- Highway Merge Assistant
- Lane Change Warning
- Post-Crash Warning
- Pre-Crash Sensing
- Vehicle-Based Road Condition Warning
- Vehicle-to-Vehicle Road Feature Notification
- Visibility Enhancer
- Wrong Way Driver Warning

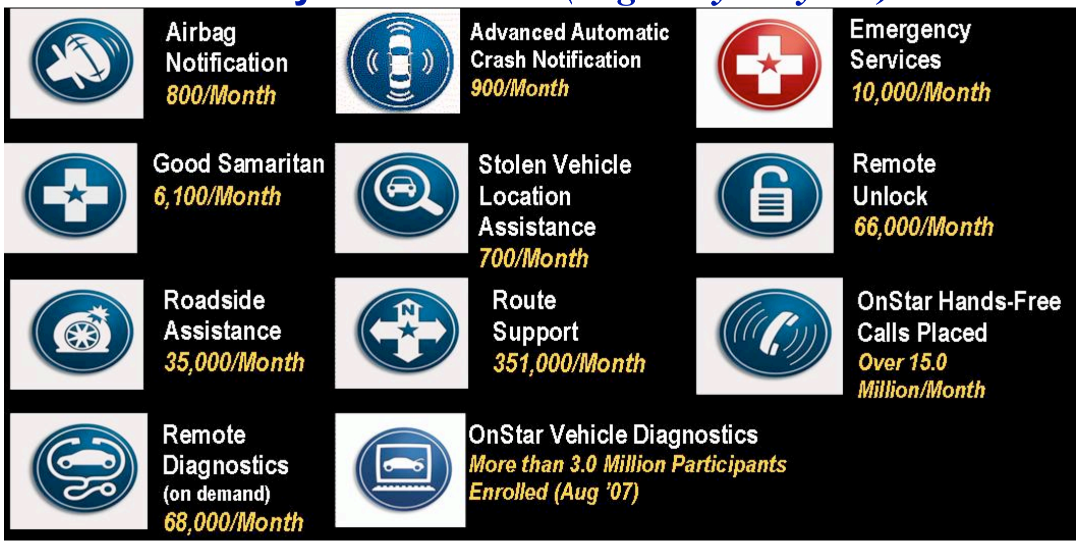
**NOTE: Highest ranking applications based on safety benefit estimates are highlighted in yellow**

**Source: Task 3 CAMP VSC1 Projec**

# GM OnStar

- **GPS location & clock are critical enablers for all OnStar services**

**OnStar Monthly interactions** ***(Avg. May-July '07)***




- **In addition, OnStar uses GPS to be an effective advocate against crime**
  - *Targeted Amber alert with the National Center For Missing Children*
  - *Stolen Vehicle location*
  - *GM and Red Cross partner to provide information to those in crisis*
- **OnStar currently has over 5 million active subscribers**
- **OnStar will be standard across all General Motors retail vehicles in the U.S. & Canada *(~4 Million per year)***

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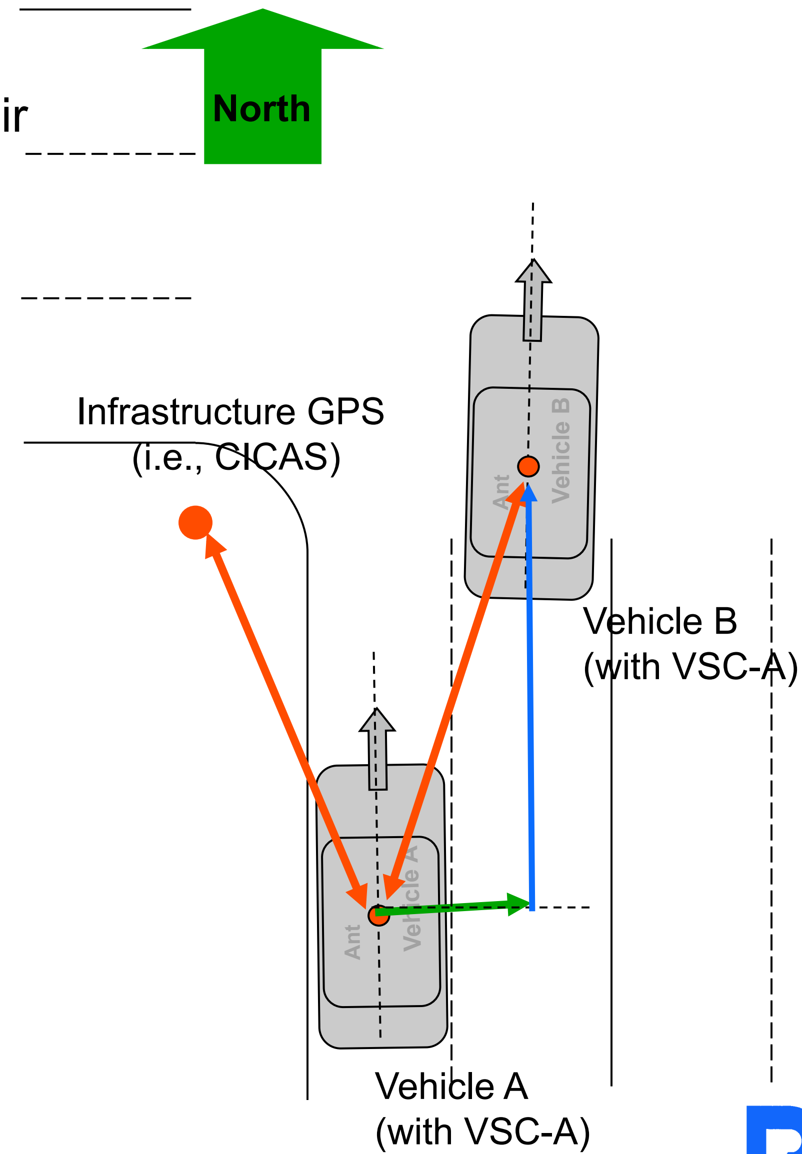
# Concept of Operation

**Sequence of Operation**

- ❑ Vehicles broadcast VSC-A over-the-air (OTA) message
  - ❑ GPS measurement data
- ❑ Infrastructure broadcast CICAS OTA messages
  - ❑ GPS measurement data
  - ❑ Map & timing information
- ❑ Vehicle software
  - ❑ Receives GPS data from others
  - ❑ Generates RTK vectors to others
  - ❑ Performs positioning functions
  - ❑ Output:
    - ❑ Across/Along other vehicles
    - ❑ Precise absolute position



# Research & Development Challenges

- **Strict relative (V2V) and absolute (V2I) positioning requirements**
- **A *common language* for Over-The-Air data: SAE J2735**
- **Technology penetration, particularly for V2V**

- Infrastructure support for V2I
- Reliability of communications and positioning
- Ensuring privacy, security, and scalability