Software Tools for: Connected Work Zone Mapping and Message Building

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I-35 Connected Work Zone Project

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Reduced Speed Zone Warning / Lane Closure Warning (RSZW/LC)

Introduction

The RSZW/LC application informs the driver of an approaching work zone and warns when,

(i) vehicle speed is higher than the work zone speed limit
(ii) Lane change is required in the case of Lane Closure

The in-vehicle application receives work zone related information from the infrastructure and combines it with vehicle dynamics to warn the driver if appropriate.

Illustration of RSZW/LC Concept
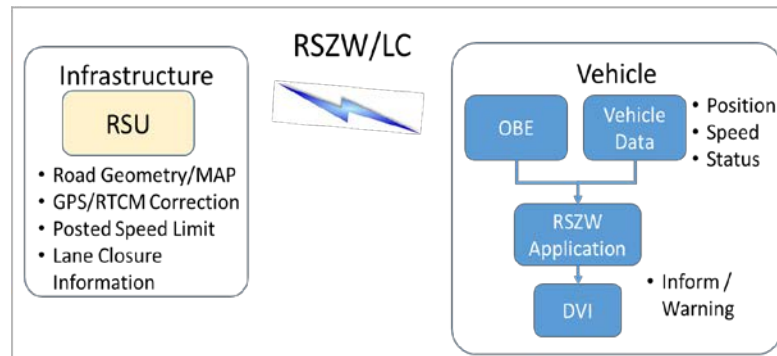
Information Flow for RSZW/LC

System Functionality

Infrastructure:

A Road-Side Unit (RSU) broadcasts every second data elements from the infrastructure in the Roadside Safety Message (RSM):

- Geometry of the work zone
- Lane closures
  - Posted speed limits in the work zone
  - Normal speed limit
  - Work zone speed limit
  - Speed limit when workers are present

Vehicle:

- On-Board Unit (OBU) receives BIM for the work zone from RSU
- The OBU combines work zone information from RSU with vehicle position, speed, turn signal status for determining appropriate warning
- The driver is informed and warned:
  i. when the vehicle speed is higher than posted speed limit in the work zone
  ii. when the vehicle is traveling on the closing lane and the turn signal for lane change is off

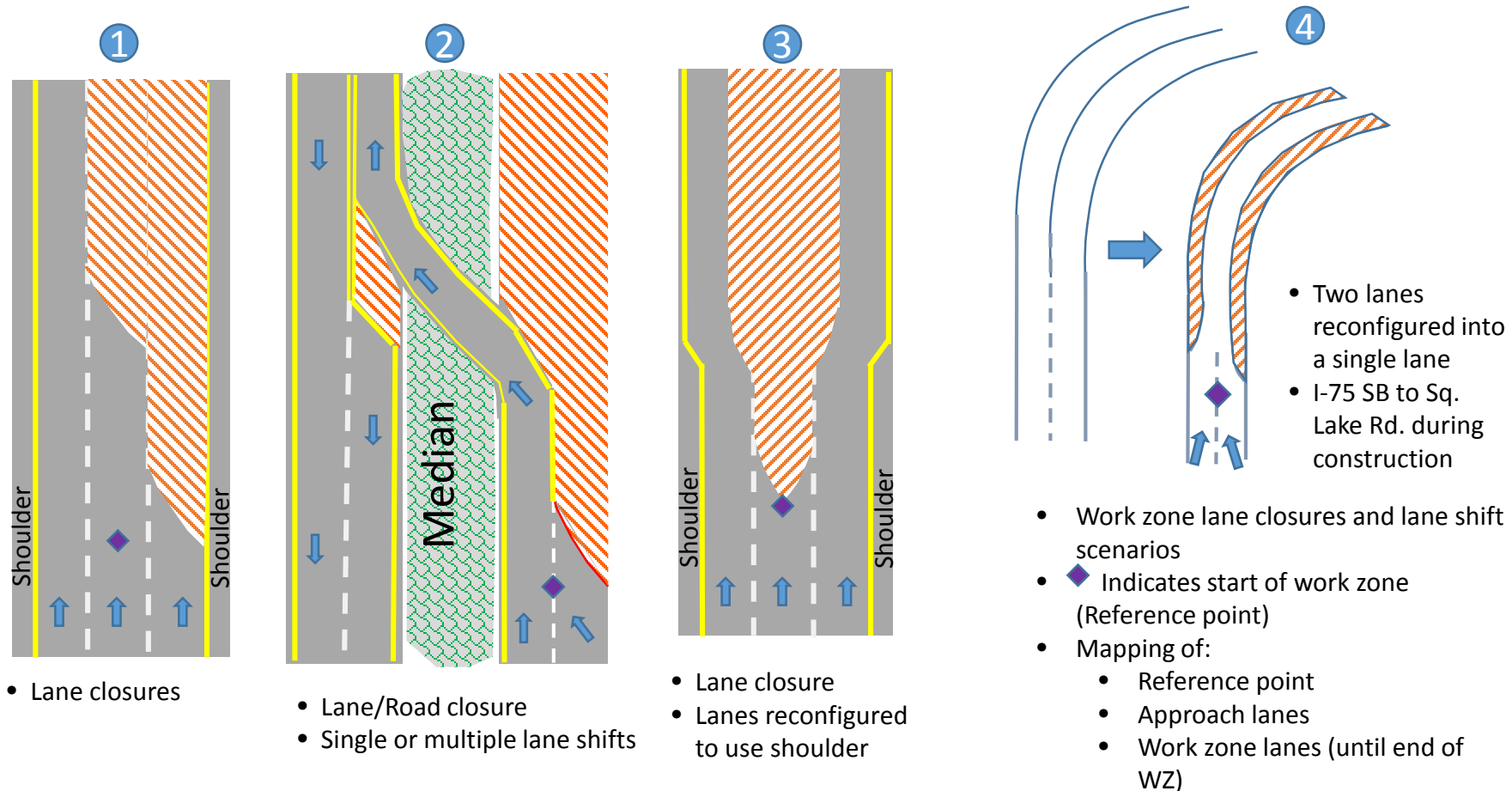# Mapping of Connected Work Zone

Connected Work Zone Application:

- Informs the driver of an approaching work zone and warns when,
    I. Vehicle speed is higher than the work zone speed limit
    II. Lane change is required in the case of Lane Closure

Need:

- Ability to easily generate, validate and transmit accurate and efficient lane level digital maps for V2I applications

- Implementation of consistent mapping technology to easily produce map in standard format for over-the-air transmission

…Currently implementing and testing the application

Example Work Zone Configurations

① ② ③ ④

Shoulder · Shoulder

- Lane closures

Median

- Lane/Road closure
- Single or multiple lane shifts

Shoulder · Shoulder

- Lane closure
- Lanes reconfigured to use shoulder

- Two lanes reconfigured into a single lane
- I-75 SB to Sq. Lake Rd. during construction

- Work zone lane closures and lane shift scenarios
- ◆ Indicates start of work zone (Reference point)
- Mapping of:
  - Reference point
  - Approach lanes
  - Work zone lanes (until end of WZ)

Elements of WZ Map Message

- Map Elements
  - Reference point – Location to identify start of WZ
  - Approach Lanes – Map of lanes leading to the WZ event
  - Work Zone Lanes – Map of lanes in the work zone
  - Lane Closures/Opens – Location where the lane closure/open starts (taper begins / ends)
  - Workers presence zone – Location where the start/end of workers presence
- Speed limits
  - Normal speed limits
  - Speed limit in active work zone
  - Speed limit where workers are present

Location – latitude, longitude and altitude

Map – Series of node points (lat, lon, alt) that define lane geometry

Constructing WZ Map Using Google Earth

Grass

Approach lane geometry points ← ← Work zone lane geometry points →

Lane 1	5	4	3	2	1	1 (Reference Point)	2	3	4	5
Lane 2	5	4	3	2	1	1	2	3	Lane Closure 2
Lane 3	5	4	3	2	1	1	Lane Closure 1
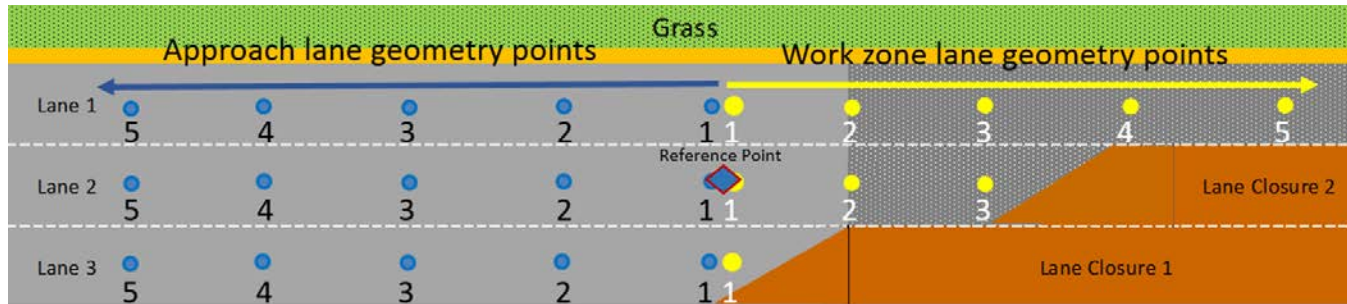
◆ Indicates Reference Point (start of work zone)
● Indicates map node points of approach lanes leading to work zone
● Indicates map node points of work zone lanes
   ○ Node points are not required to be equidistant
- Lane #3 closure – 0m from the Reference Point
- Lane #2 closure – 250m from the Reference Pint

Work Zone Lanes ← ReferencePoint → Approach Lanes
Closed Lane
Closed Lane
Map Node Points
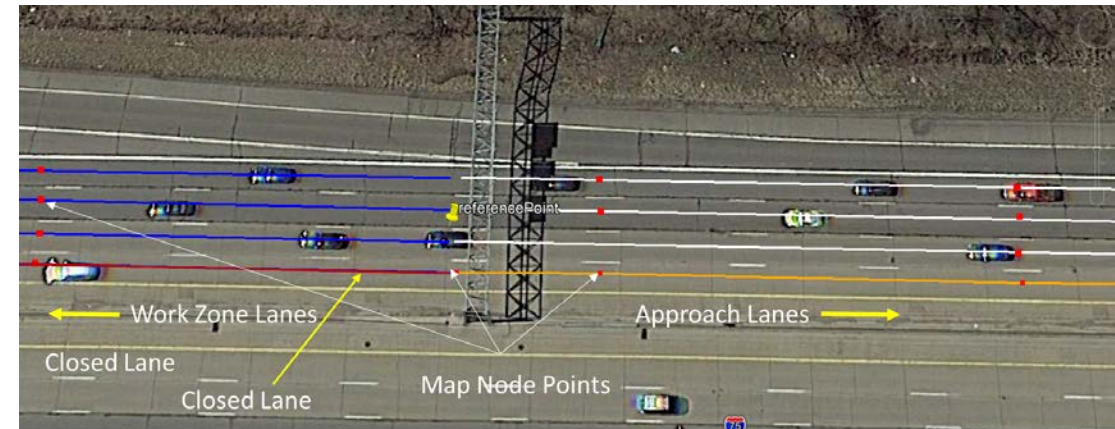
— Approach lanes
— Approach lane closed at the reference point
— Work zone lanes
— Closed lane in work zone
▪ Map node points

Node Selection for WZ Lane Mapping Equidistant vs. Non-equidistant Nodes

Rectangular bounding box for map matching

Determination of Vehicle lane position
False positive
False negative

Waypoints that define lane geometry

Equidistant Nodes

Chrysler Fwy
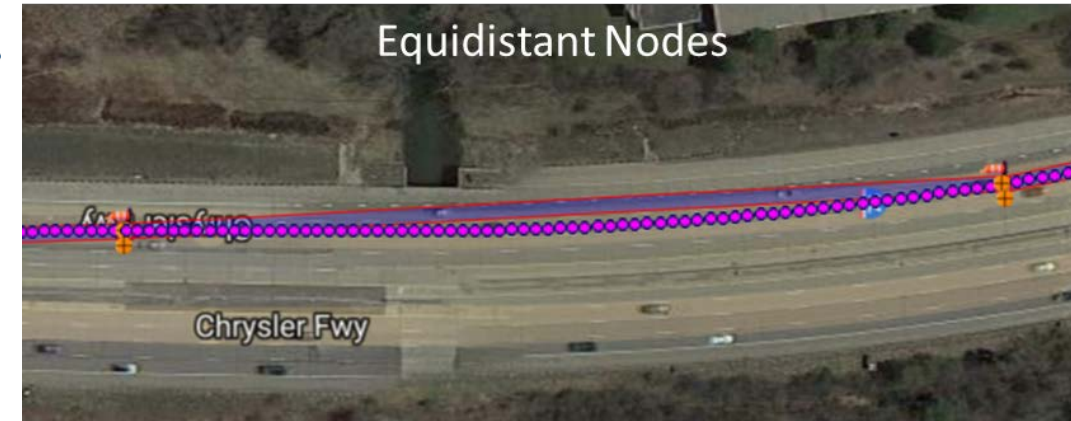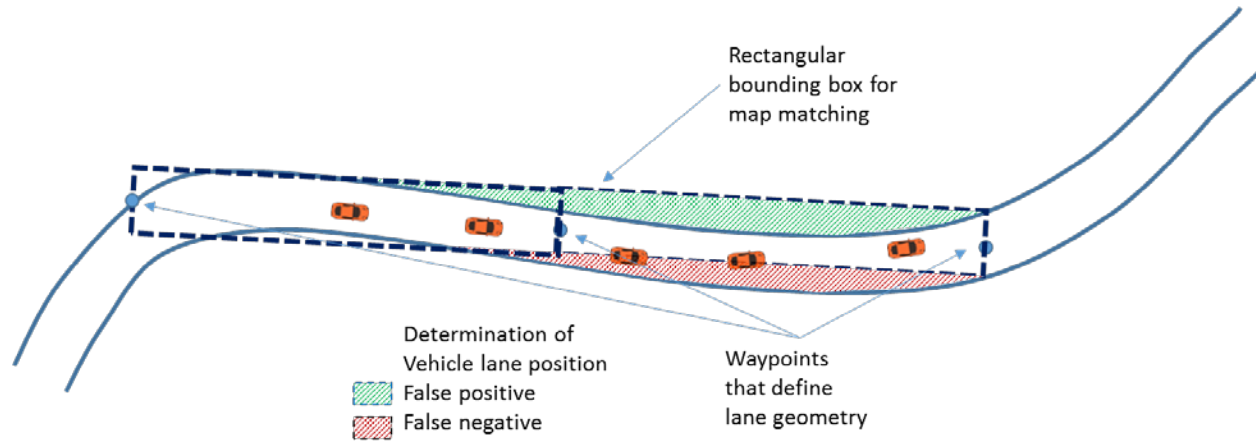
● Indicates vehicle path points

Non-equidistant Nodes

Building WZ Map & Roadside Safety Message (RSM)

RSU Independent Software Toolchain

Instrumented Vehicle – Vehicle Path Data

WZ Map and Other Data

XML

ASN.1

Compile and UPER encode

Data Array for Visualizer

Road Side Unit

Road Side Unit

IEEE Protocols

Work Zone RSM Broadcast
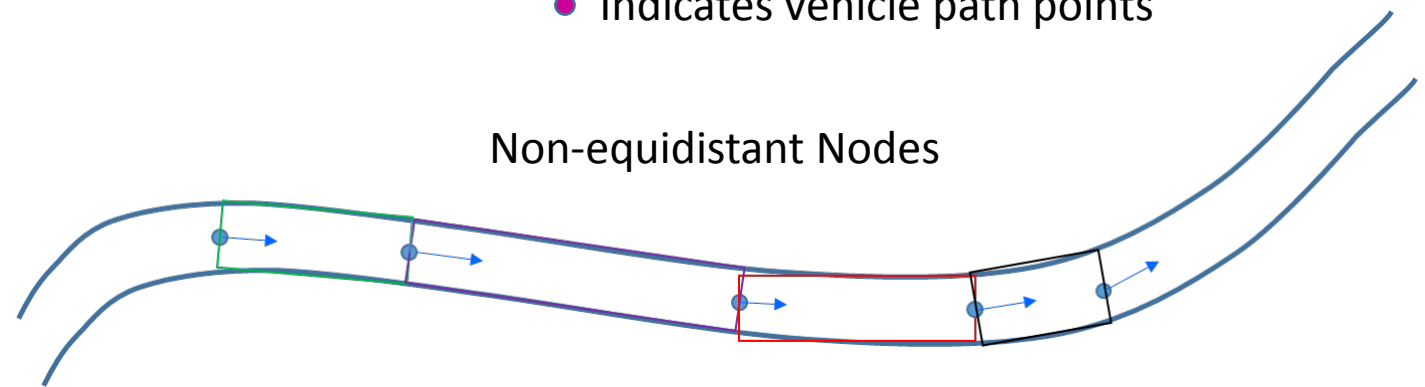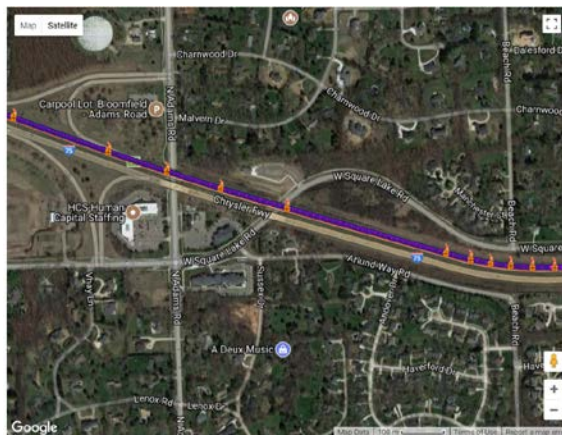
CAMP V2I Consortium Proprietary.

Steps for Mapping Work Zone
and
Building Message

Work Zone Configuration Input

- File names:
  - Configuration file name
  - Vehicle path data file name
  - Work zone description

- WZ lane information
  - # of lanes in WZ
  - Average Lane width
  - Lane used for collecting vehicle path data

- Speed limits
  - Normal
  - In construction zone
  - When workers are present

- Work zone type code
  - Static, moving, short-term, long-term, etc.

- Work zone schedule
  - Start and end dates and time
  - Days in week

Driving Through WZ and Vehicle Path Data Collection

- Select a lane that is open throughout the work zone

- Drive the work zone
  - Stay on the selected lane
  - Maintain the vehicle in the center of the lane as much as possible
  - Maintain constant speed as much as possible

- Use following keys to mark:

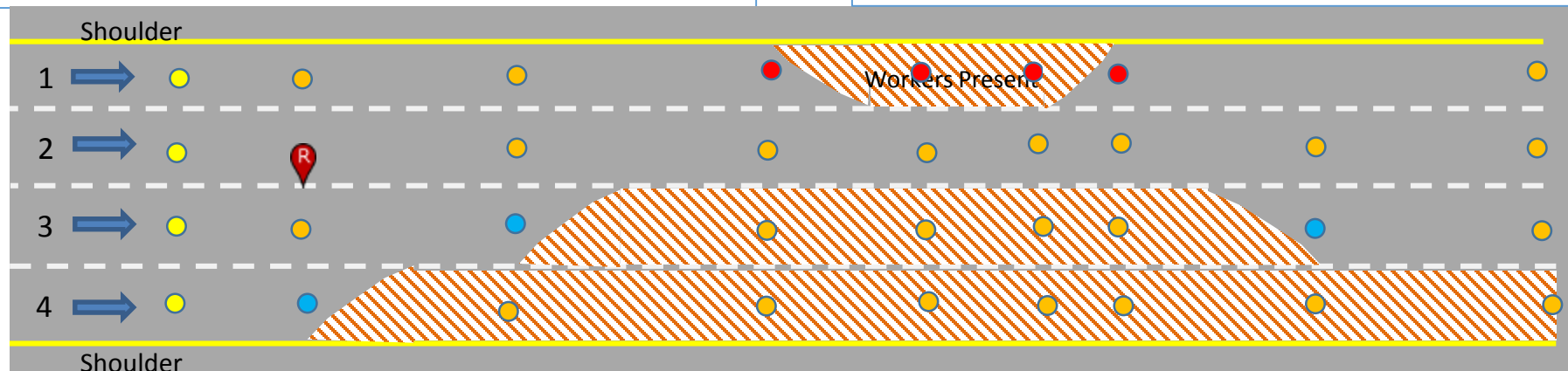 | | |
  |---|---|
  | r | – Reference point (indicate start of work zone) |
  | 1/2/3… | – Toggle lane closed/open marker |
  | w | – Toggle workers present/not present marker |
  | s | – Toggle start/stop data logging |
  | Esc | – End data logging and quit the application |

- Collected data is saved in csv format

Work Zone Map Builder

- WZ Map Builder Builds:
  - Approach lane geometry node points
  - Work zone lane geometry node points
    - Assign attributes to nodes where:
      - Lane closing/opening is occurring
      - Speed change is occurring
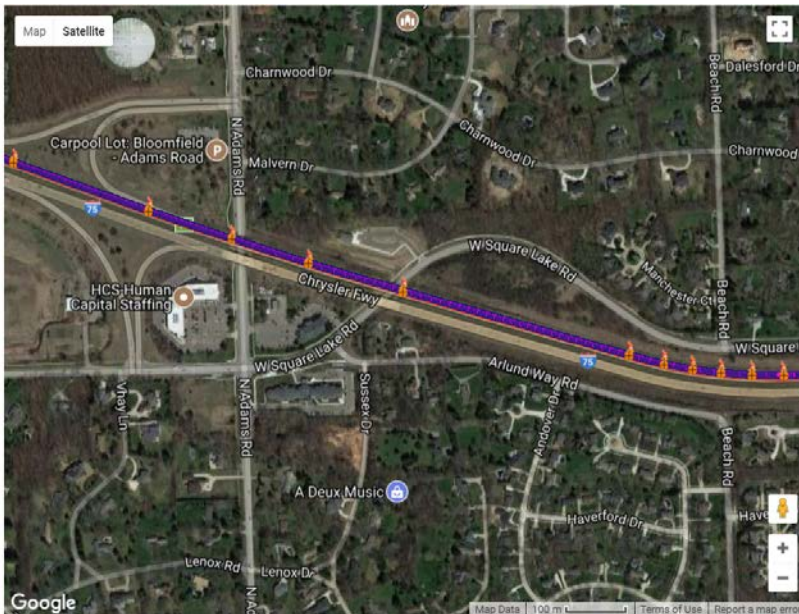   - Workers' presence/absence and associated speed change is occurring

- Constructs WZ Map:
  - representation in XML for building map message in binary
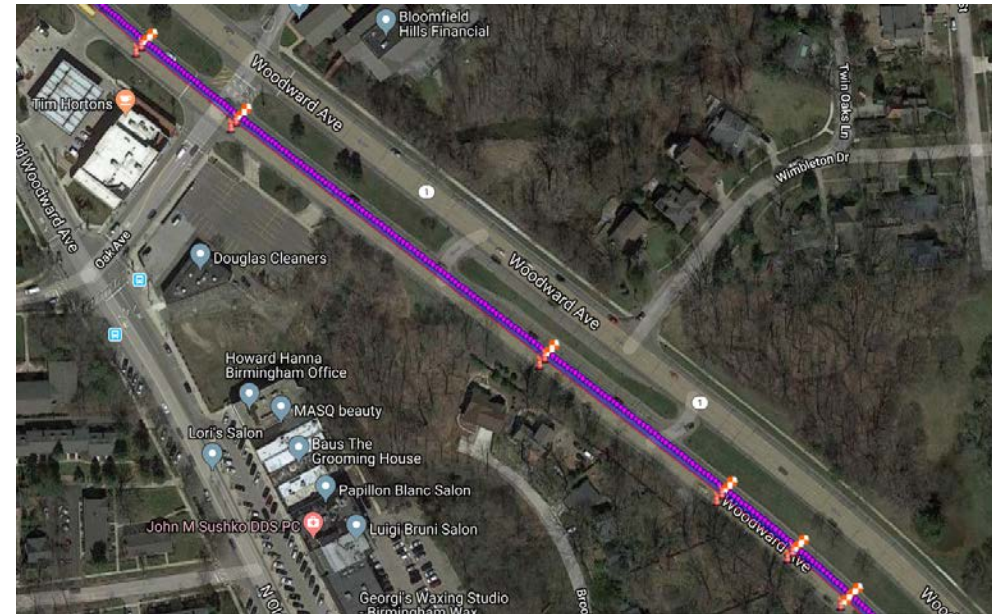 - map data arrays for visualizer in JavaScript

Work Zone Map Visualizer

- Map Visualizer Overlays on Google Satellite Map View:
  - Collected vehicle path data,
  - Constructed map node points

- Marks lane closures and opening for each lane
- Marks presence or absence of workers
- Virtual bounding box to verify generated node points

Message Builder for RSM

Roadside Safety Message (RSM - aka BIM) Development

- Revised the RSM draft design from May 2017 submitted to SAE DSRC TC (J2945/4)
  - Significantly improved and simplified for flexibility in generating maps and lane attributes
- Several new data frames and elements created to support more application-specific requirements for future J2735 incorporation
- Updated ASN.1 representation based on needs and requirements presented in
- Ongoing collaboration with SwRI (AASHTO CVPFS) to finalize the ASN.1 design
- Currently revising needs and requirements based on learnings from implementation and testing
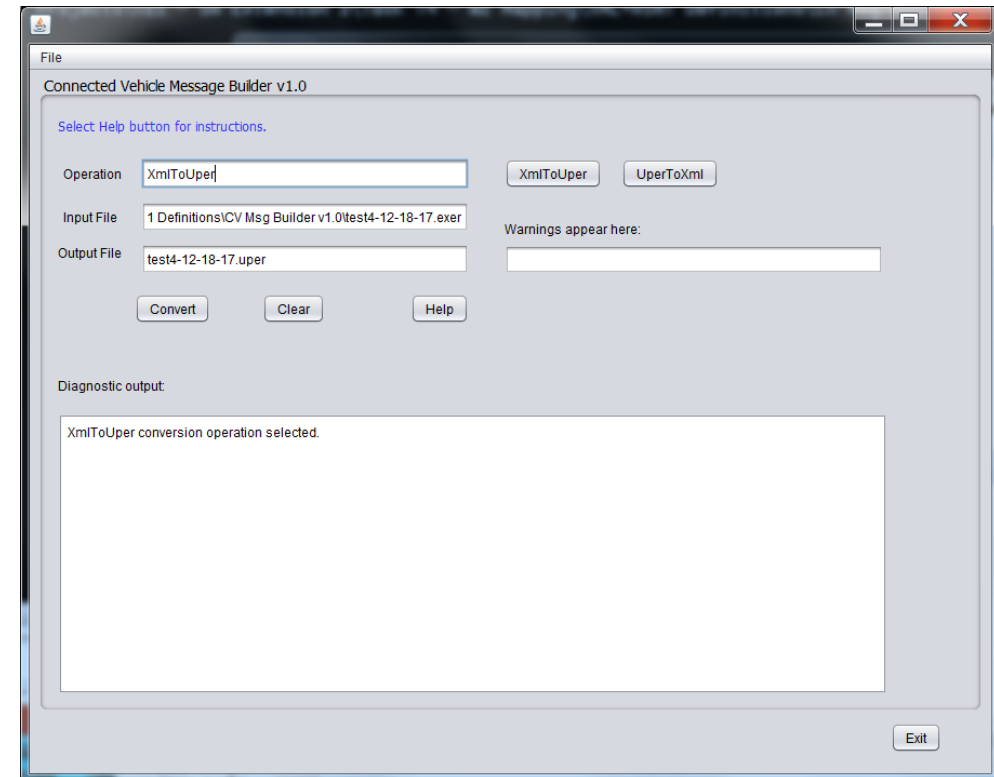
Message Builder Software Architecture

- Created using Google Earth, OSS Nokalva and Java development tools
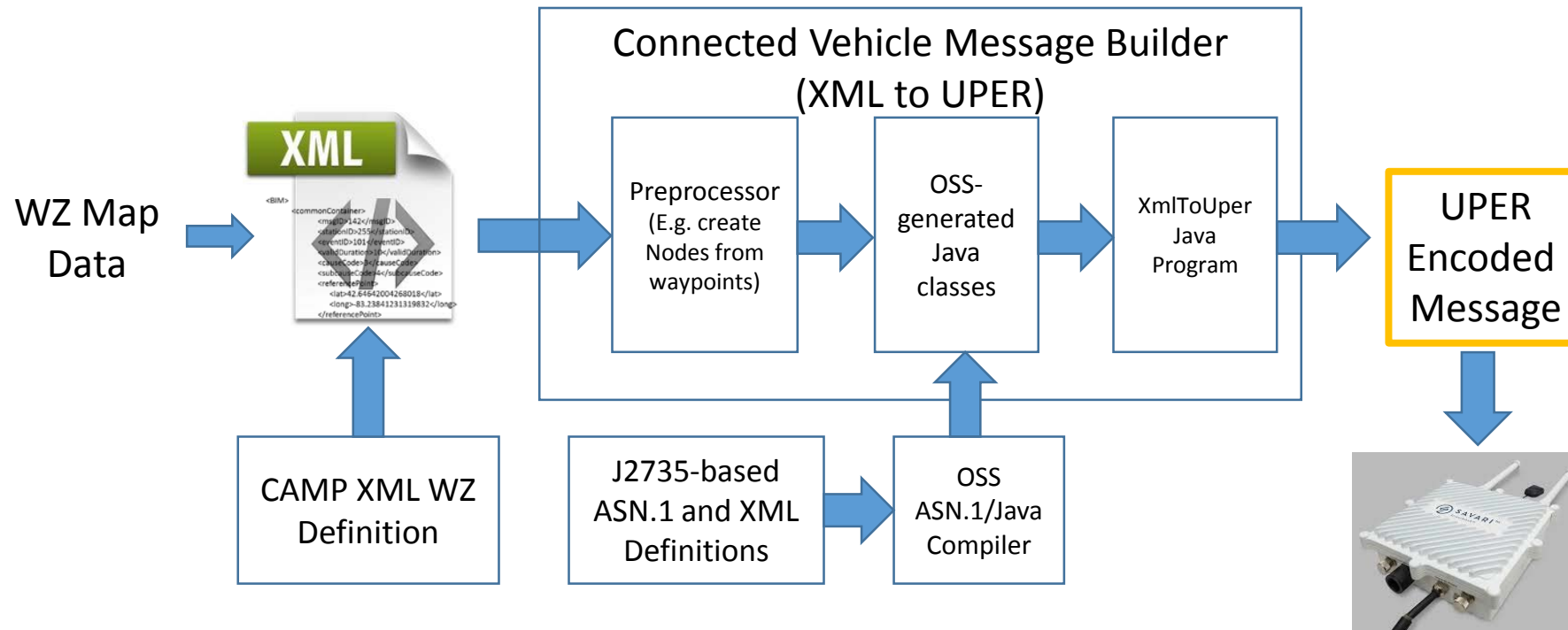
Connected Vehicle Message Builder

- **Completed V 1.0**
  - Input: XML file for RSM
    - Extended XML based on the ASN.1
  - Pre-processor:
    - Converts absolute values of lat/lon/elev of waypoints into offsets
    - Reduces message size
  - Output: UPER-encoded J2735-style RSM ready for over-the-air transmission

Questions / Open Discussion