

I-35 Traveler Information During Construction

Connected Work Zone Applications

- **Work Zone Warning**
- **Queue Warning**

Geza Pesti, Ph.D., P.E.

FHWA Peer Exchange, November 15-16, 2022



Other Key Team Members

TTI:

- Hassan Charara
- Leonard Ruback

SwRI:

- Purser K. Sturgeon
- Lynne Randolph

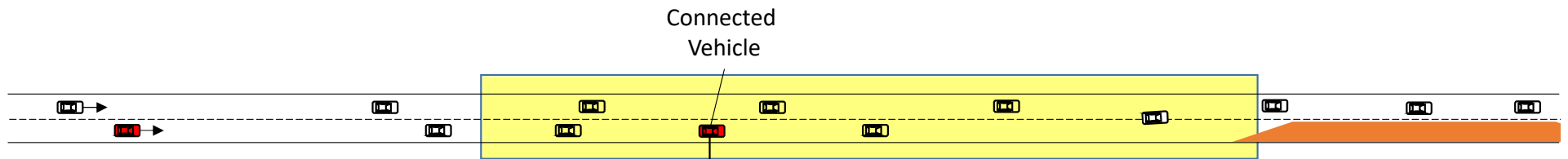
Objective

Testing and verification of the Southwest Research Institute (SwRI) OBU application that provides in-vehicle work zone and queue warning information to drivers in a connected vehicle environment.

Specific Tasks:

- Test Plan Development
- Conduct Tests and Collect Data
- Review results and make recommendations for future refinement needs and/or enhancements.
- Capture information related to Lonestar™ integration and ways to automate this process.

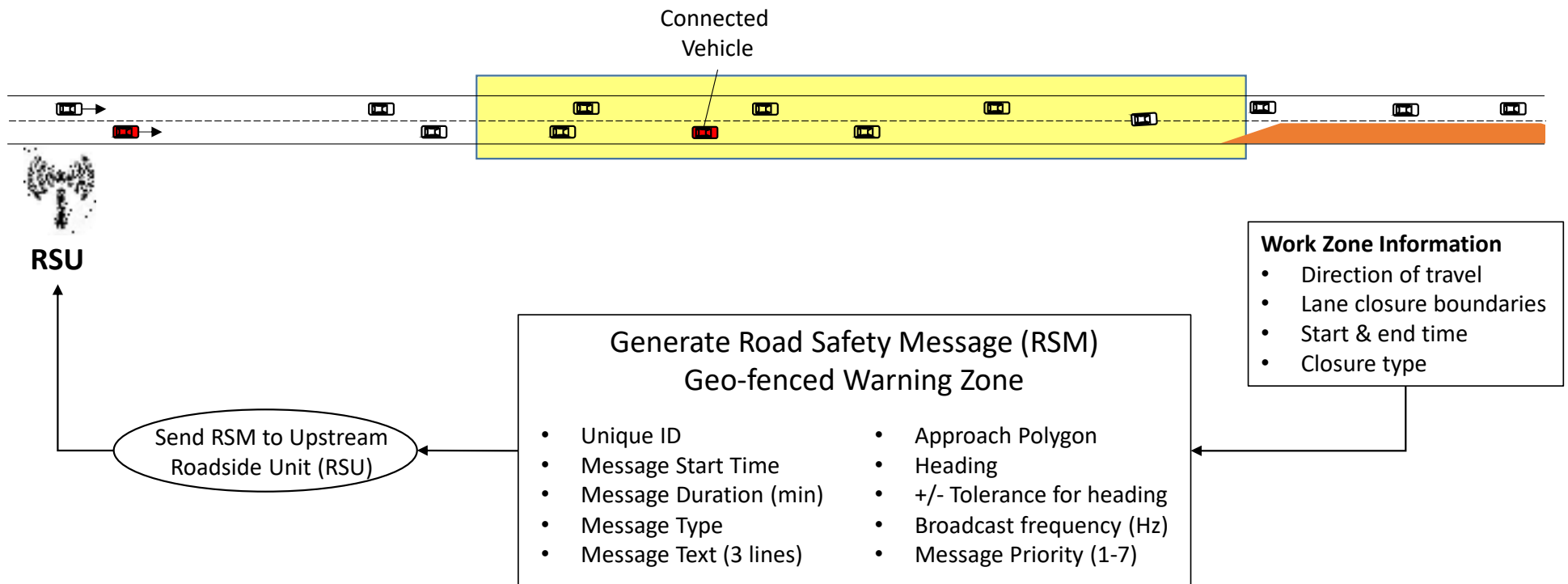
Work Zone Warning



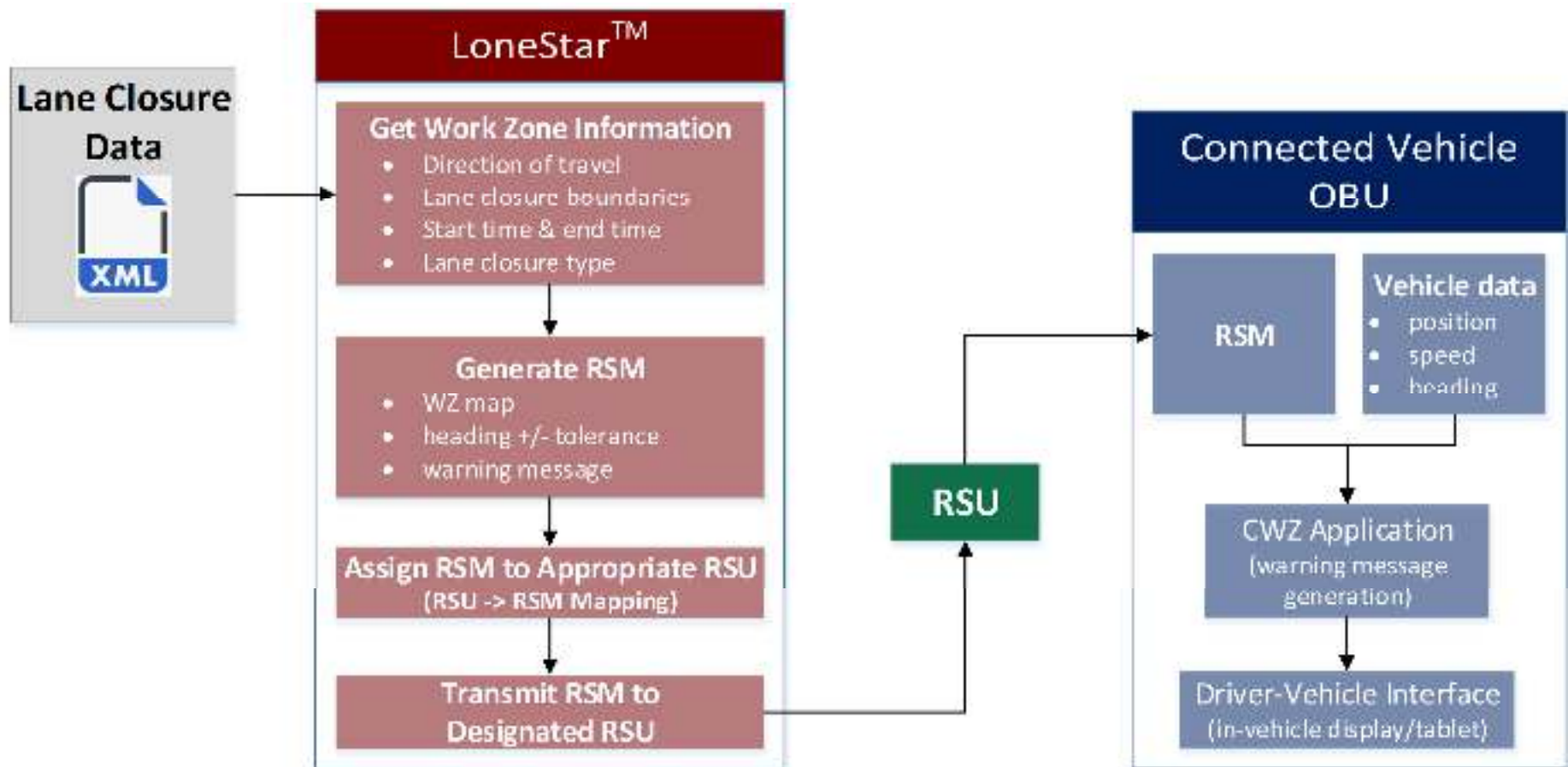
Queue Warning



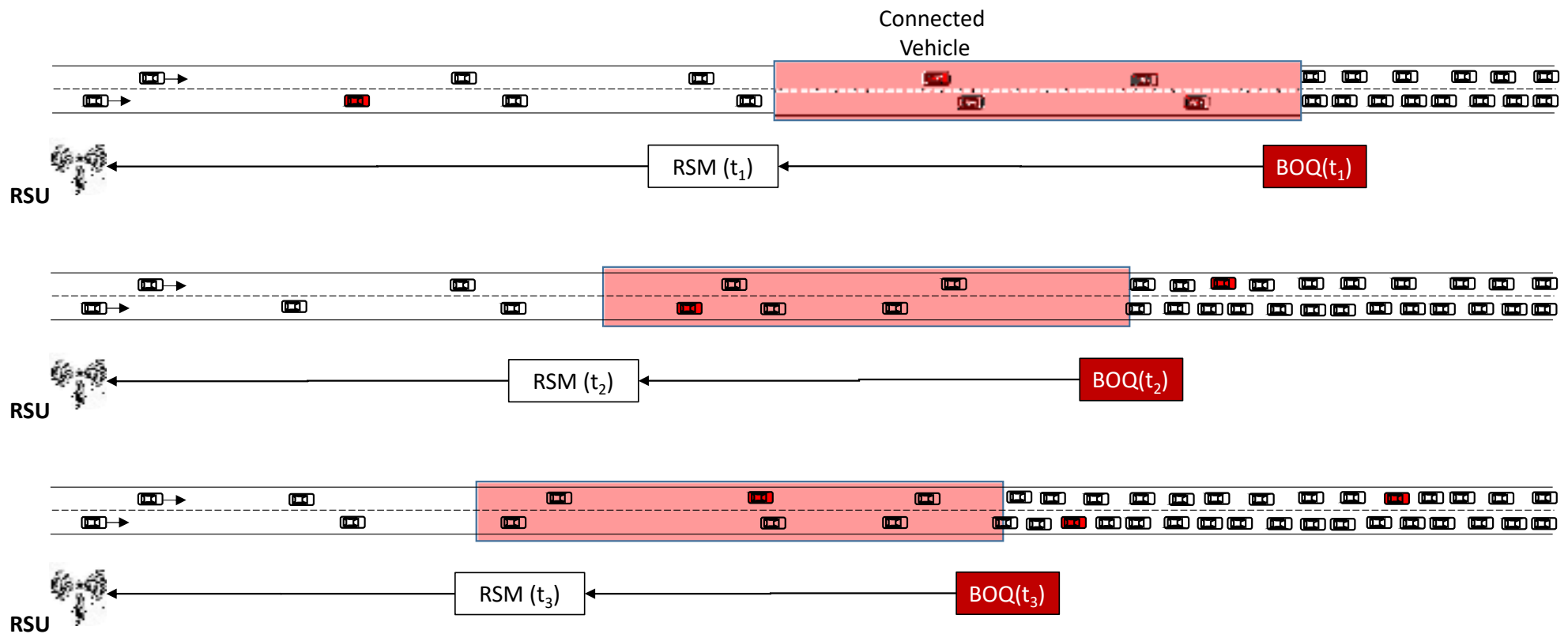
Work Zone Warning



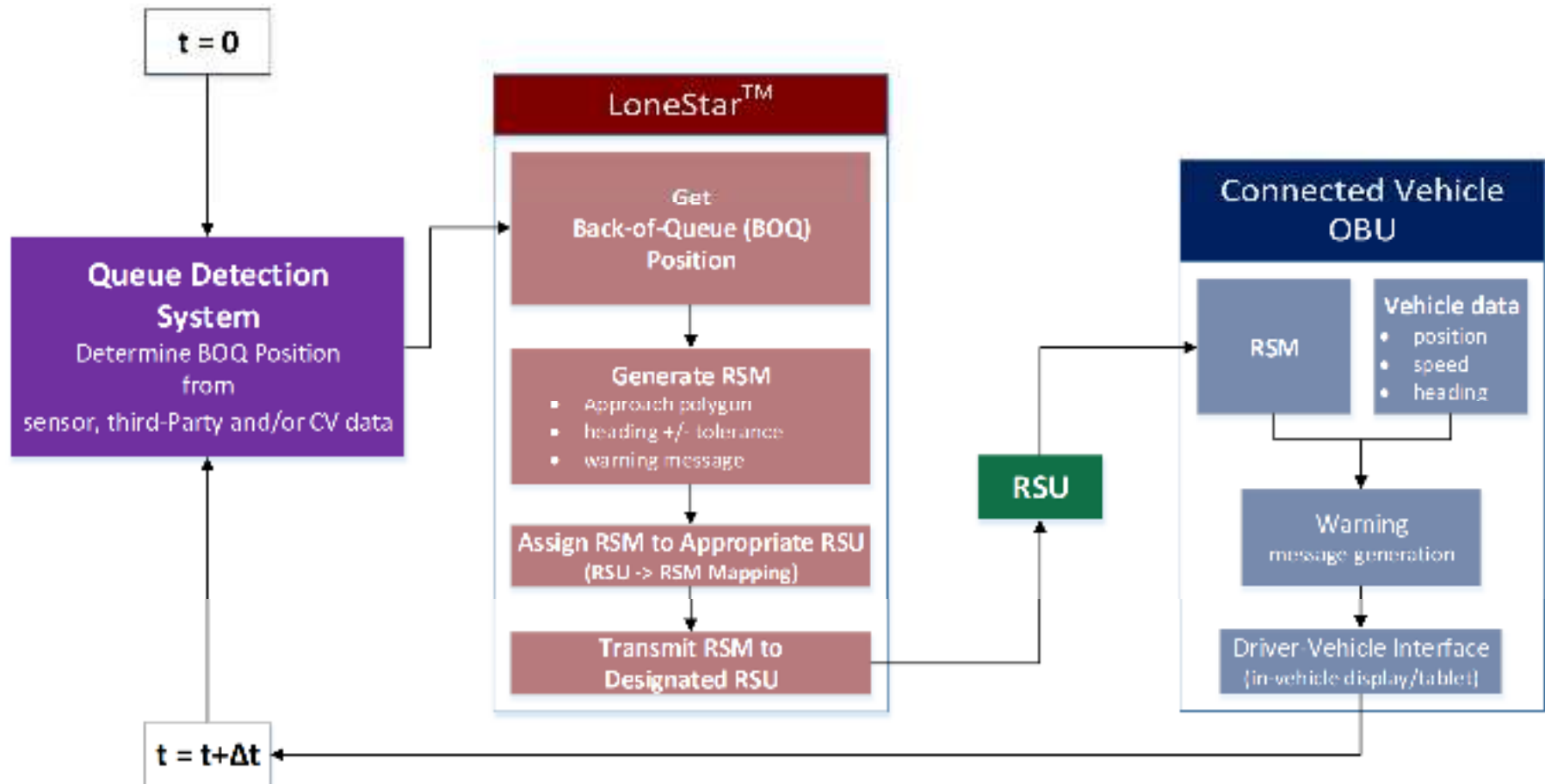
Work Zone Warning with LoneStar™ Integration

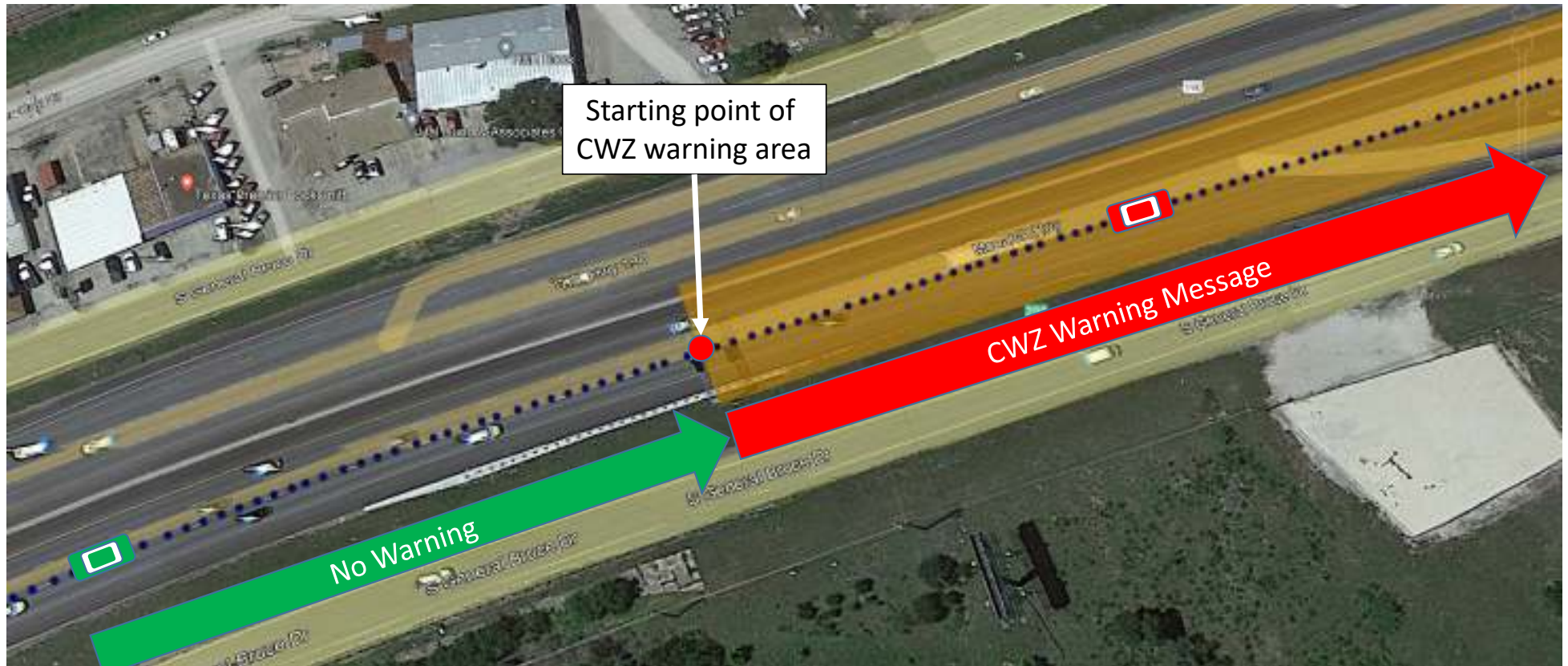




Queue Warning



Work Zone Warning with LoneStar™ Integration





- Connected vehicle (CV) trajectory
-  OBU of CV does not generate warning
-  OBU of CV generates CWZ warning



Geo-fenced region of CWZ warning area defined by RSM

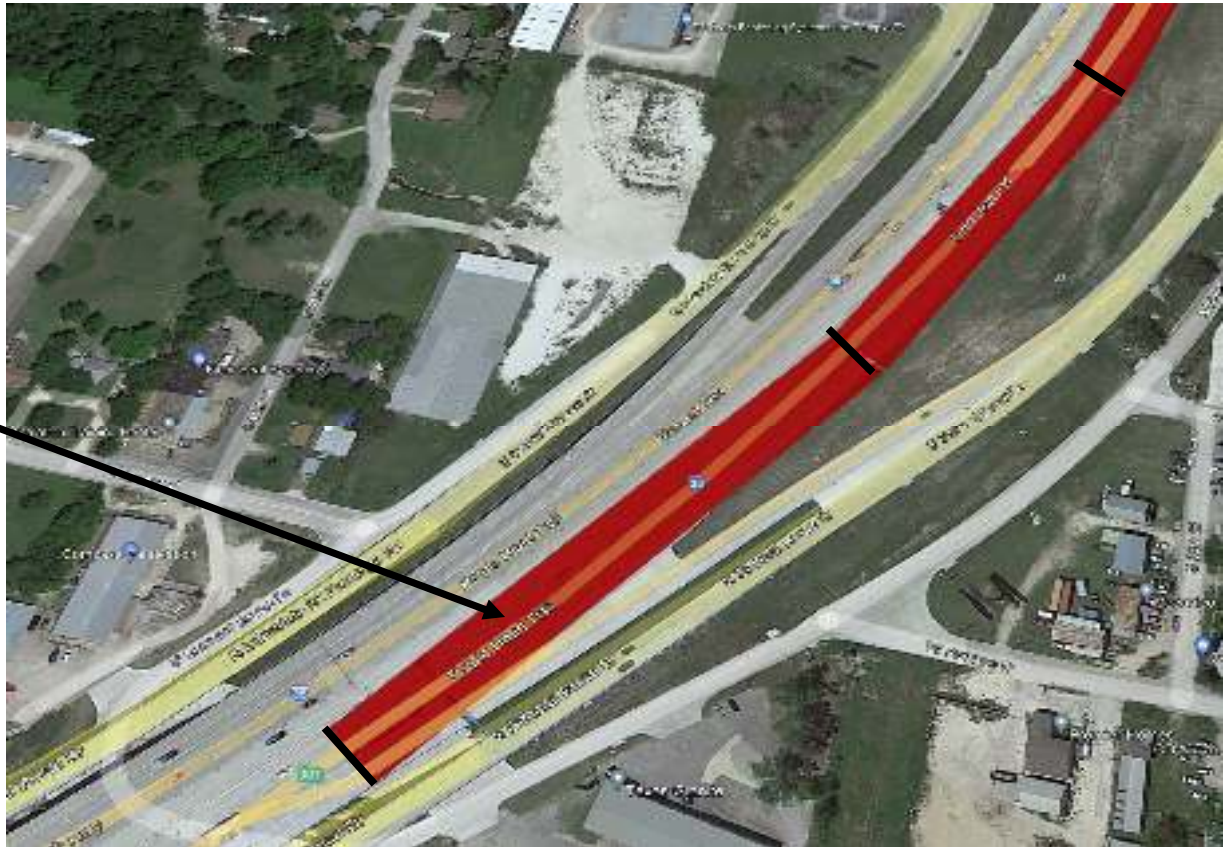
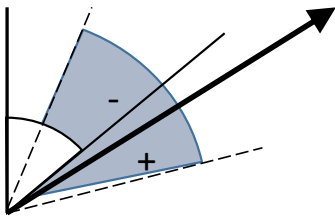
Approach Polygon for Work Zone Warning

OBU application generates a warning if a connected vehicle's

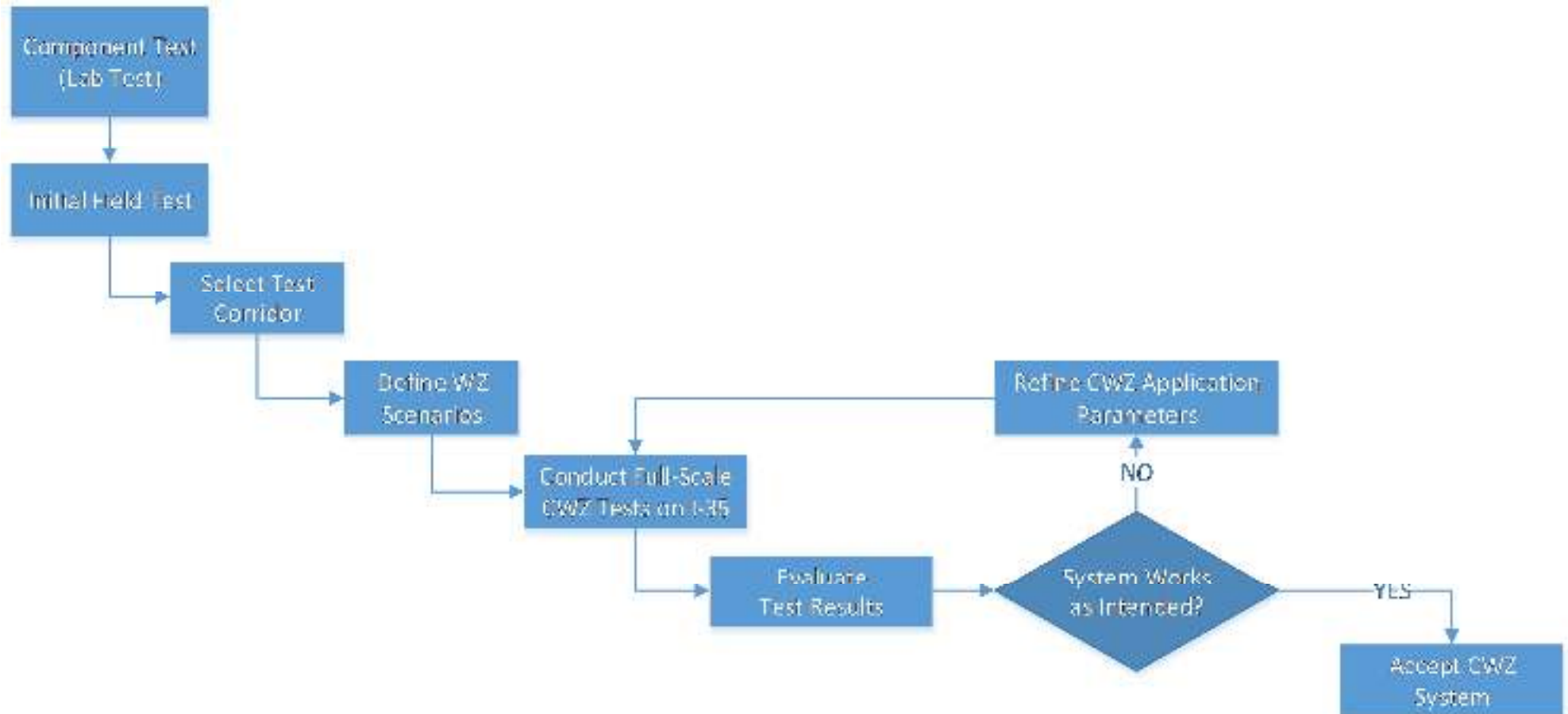
[position coordinates are within approach polygon]

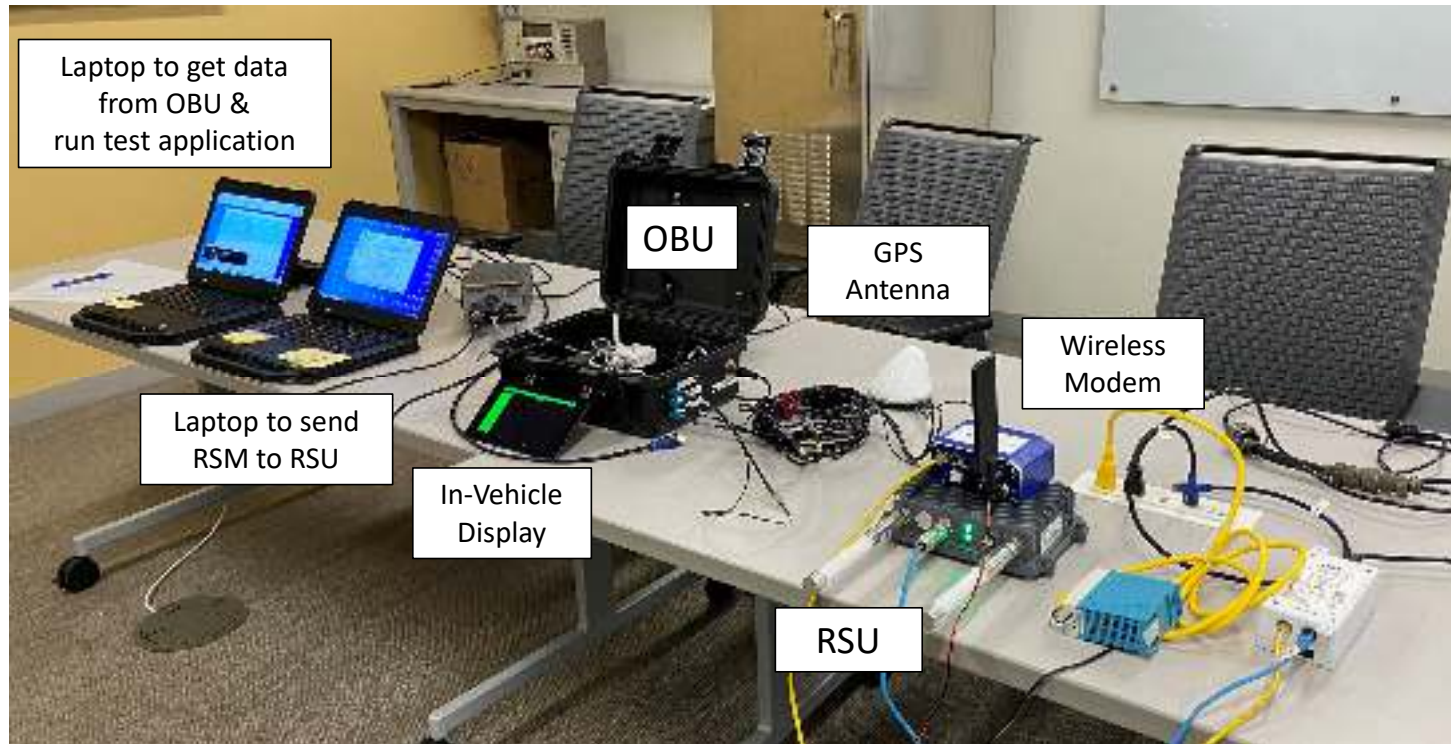
AND

[heading is within a specified value for heading +/- tolerance]



Test Plan for CWZ Application



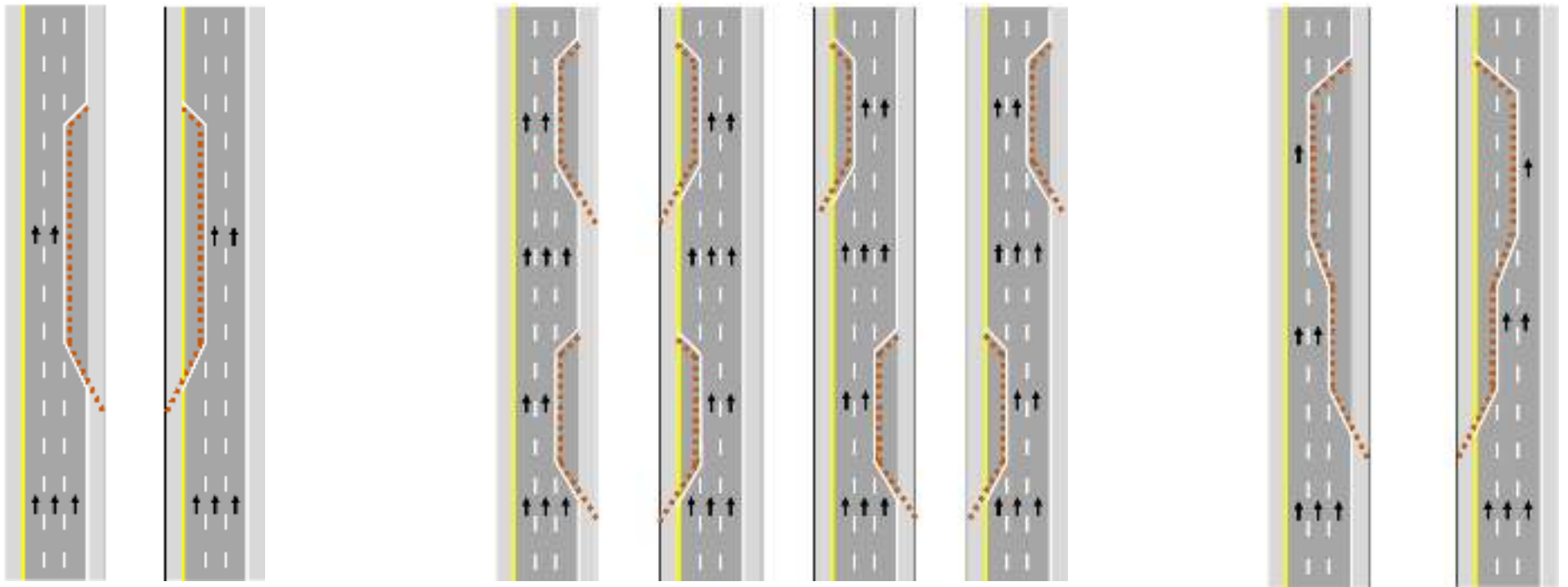




RSUs on I-35 in Temple, TX

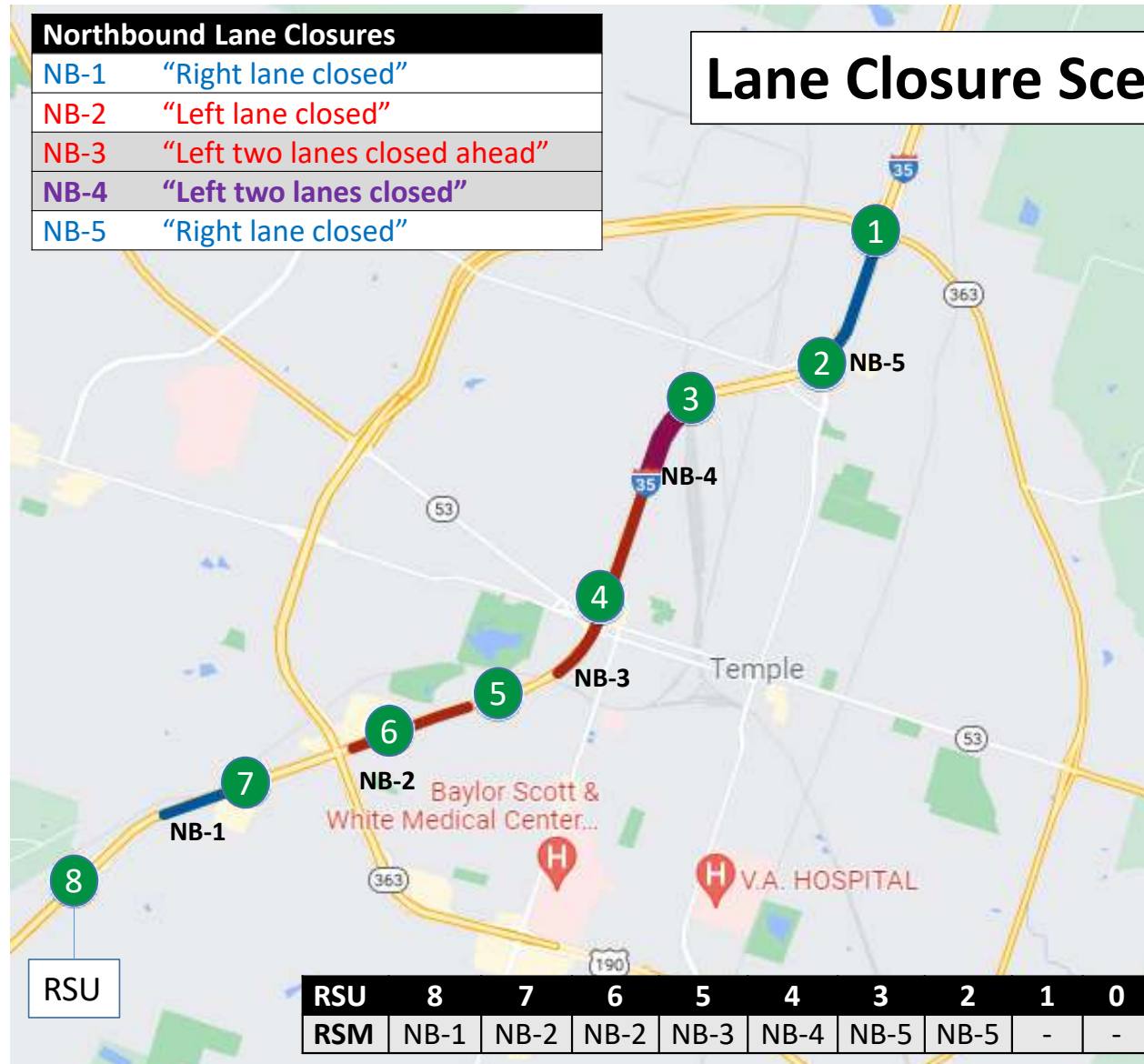


Work Zone Lane Closure Scenarios



Lane Closure Scenarios Tested

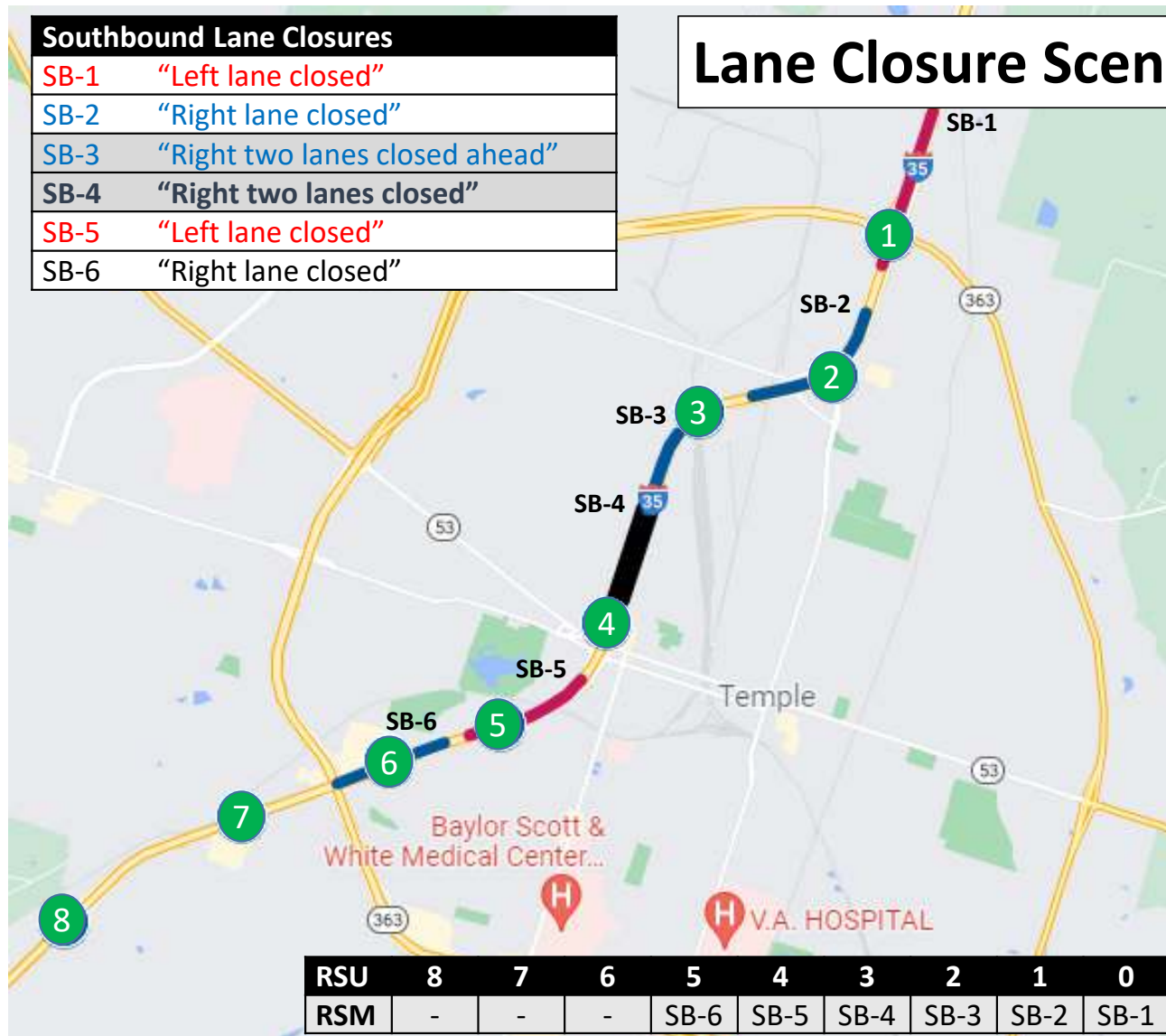
Northbound Lane Closures	
NB-1	"Right lane closed"
NB-2	"Left lane closed"
NB-3	"Left two lanes closed ahead"
NB-4	"Left two lanes closed"
NB-5	"Right lane closed"



RSU	8	7	6	5	4	3	2	1	0
RSM	NB-1	NB-2	NB-2	NB-3	NB-4	NB-5	NB-5	-	-

Lane Closure Scenarios Tested

Southbound Lane Closures	
SB-1	"Left lane closed"
SB-2	"Right lane closed"
SB-3	"Right two lanes closed ahead"
SB-4	"Right two lanes closed"
SB-5	"Left lane closed"
SB-6	"Right lane closed"

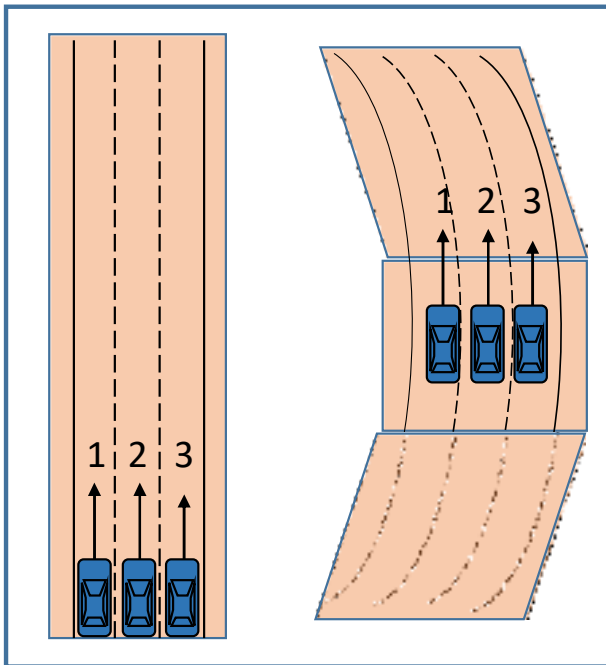


RSU	8	7	6	5	4	3	2	1	0
RSM	-	-	-	SB-6	SB-5	SB-4	SB-3	SB-2	SB-1

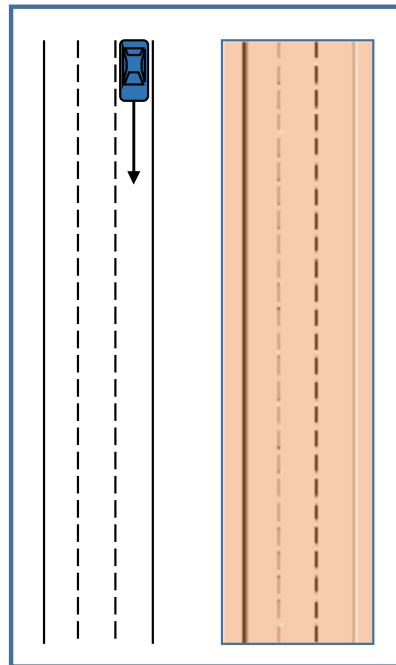
Work Zone Warning CV Application Field Tests

Drove Connected Vehicle in Various Test Scenarios

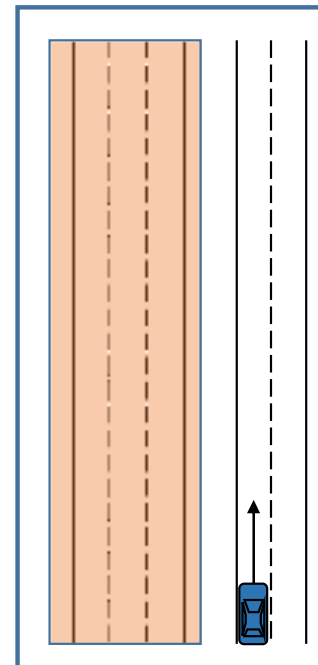
In different lanes



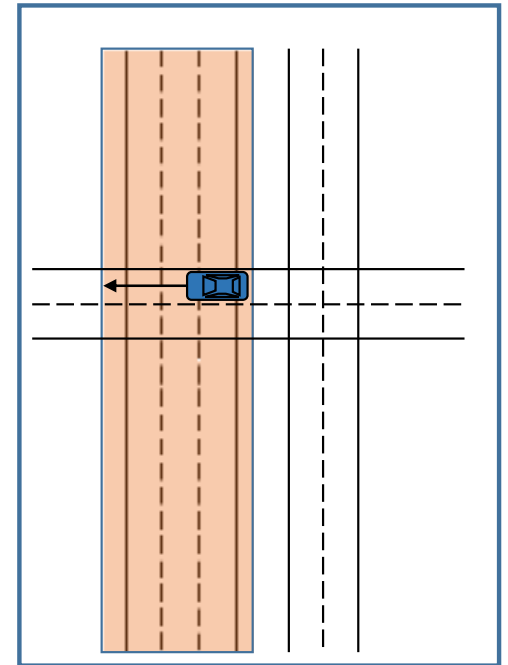
In opposite direction



On frontage road



On cross-road



Field Tests

Multiple test-runs

- Drove the connecting vehicle in different lanes.
- Stayed in selected lane & avoided lane change.

Test Dates	Number of Test-Runs	
	Northbound	Southbound
December 2, 2021	3	3
December 20, 2021	4	4
January 25, 2022	4	4
February 8, 2022	4	4
February 17, 2022	7	7
February 22, 2022	5	5

Field Observations

- Messages displayed were continuously monitored
- Observation recorded using a CWZ Data collection Form.

- Warning was displayed correctly
- Warning was displayed incorrectly
 - appeared correctly but did not stay on
 - appeared late
 - was on-and off

Connected Work Zone Test on I-35 in Temple, TX					
Direction:		Closure No:			
Date:					
Test run #:	Time:	Lane 1 2 3 4 :			
Expected					
Message:	"Right lane closed"	Appears at		Stays on until	
		I 35_MidwayOn_Scdl	I 35_OfflineStation_Scdl	I 35_OfflineStation_Scdl	I 35_OfflineStation_Scdl
		SL08052	07/01/88	SL08060	07/01/88
Observed					
Expected message displayed?		Yes			
		No	Nothing displayed		
			Another message displayed:		
Message first appeared at expected location?		Yes			
		No	Before	Where?	
			Seconds before:		
		After	Where?		
			Seconds after:		
Comments:					

Data Collection and Results

Data Collected:

- Vehicle trajectory data
- Message logs
- Locations and times when RSM was received from RSU

Findings :

- OBU received the appropriate RSM at the right location upstream of the lane closure.
- The generated warning message was occasionally lost. It typically occurred on curves when the connected vehicle got outside of the geo-fenced warning polygon.
- After making the following changes system worked as intended:
 - increased from 20 m to 25 m, and
 - revised the degree of +/- tolerance for headings

Test-vehicle receives
WZ warning message

WZ warning message disappears when
test-vehicle gets outside of the geo-fenced region

..... Connected vehicle (CV) trajectory



Geo-fenced region of
work zone warning area

Lessons Learned

- The performance of CWZ Applications depends on the
 - Accuracy of the roadway map used to define the warning zone.
 - Expected positioning accuracy of connected vehicles that are driving in that area.
- Roadway map accuracy in construction areas is often questionable due to significant changes in roadway geometry.
- The width used for creating of the geofenced warning zone should be guided by the actual physical width of the roadway.
- Guidance needed on how many points should be used to define a warning zone/approach polygon based on the curvature of the roadway to ensure OBUs correctly match to the region along the entire path.

For further information contact:

Geza Pesti, Ph.D., PE
g-pesti@tti.tamu.edu