- RESEARCH SCIENTIST II,
  MICHIGAN TECH RESEARCH INSTITUTE
- “V21 FOR RESEARCH AT SMART CITY TEST CENTERS”

DR. RICHARD A. CHASE

rachase@mtu.edu

V2X for Research at Smart City Test Centers

Richard Chase, Ph.D., P.E.

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Presentation Overview

- Overview
  - Project Description
  - Example Algorithms
  - Testing Facility
- V2X
  - Terminology, Architecture, Challenges
- Mixed Reality Environment
  - Architecture
  - Information flow
  - Constructing simulated environment
- Autonomous Vehicle Example

Project Overview

CAEV Project Description

- Connected and Automated Fuel Efficient Vehicles
- The objective of this project is to provide controlled, reconfigurable physical test environments paired with connected public roadways to the U.S. Department of Energy, National Laboratories, and their partners to safely validate analytical models and simulations.
- Specifically, implement fuel-saving driving algorithms from various national labs onto vehicles and necessary infrastructure and correlate measured results with simulations.

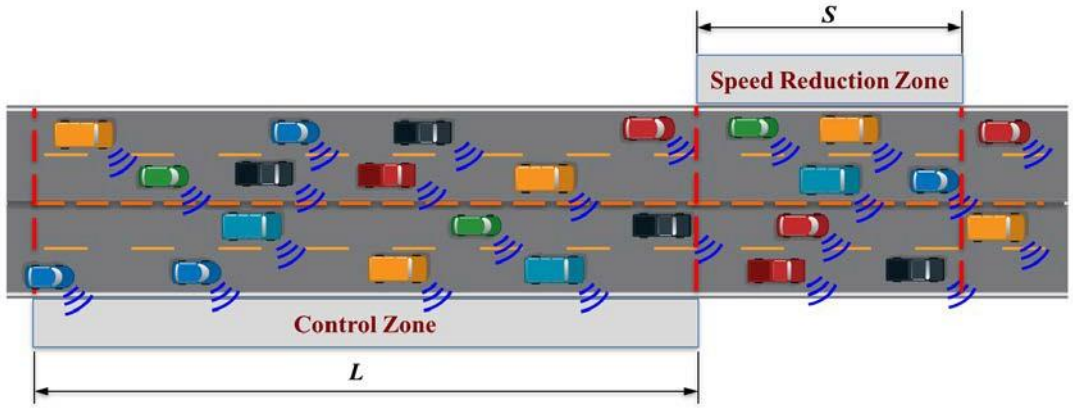
Team Members

- U.S. Department of Energy
- American Center for Mobility
- Michigan Technological University (MTU)
- Michigan Tech Research Institute (MTRI)
- Intertek
- National Labs (ORNL, ANL)

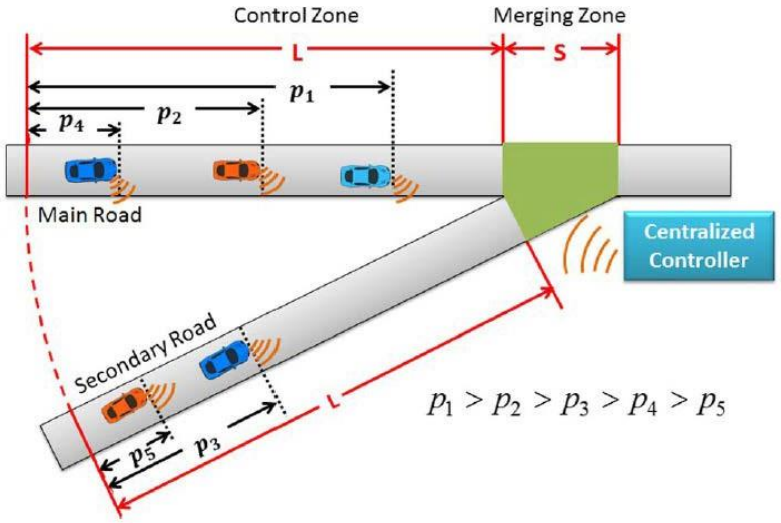
Vendors

- AutonomouStuff
- Pilot Systems
- New Eagle
- Chargepoint

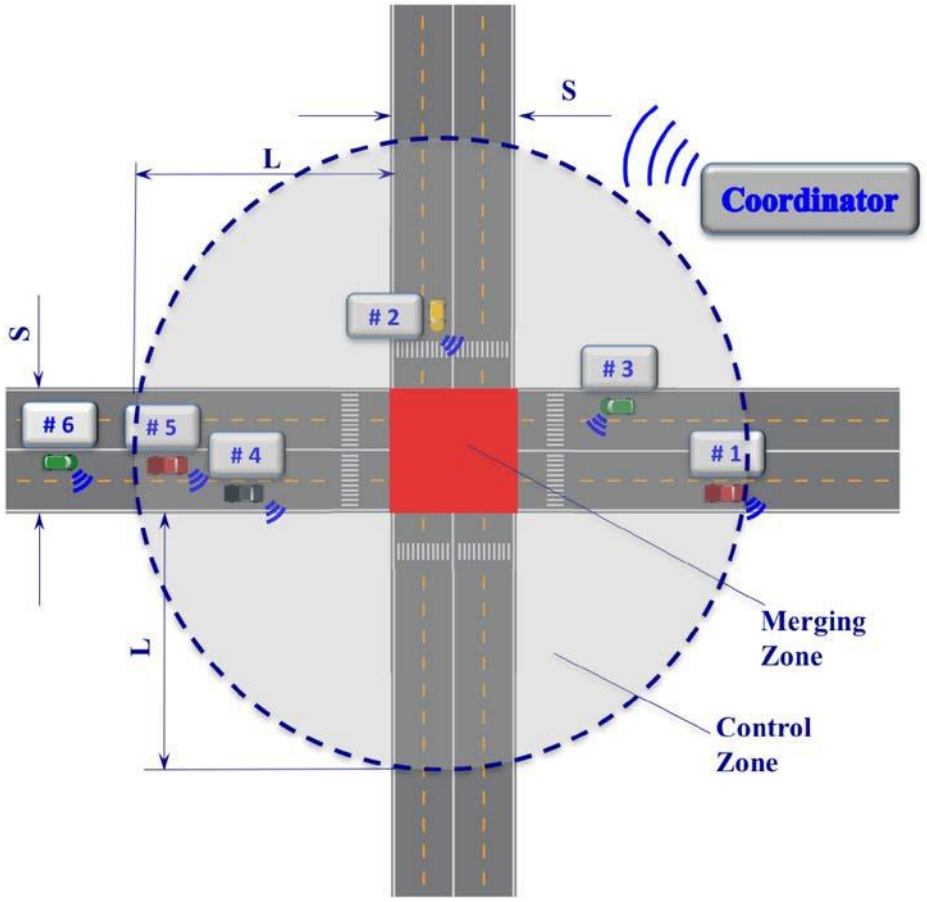
Example Algorithms



Speed Harmonization



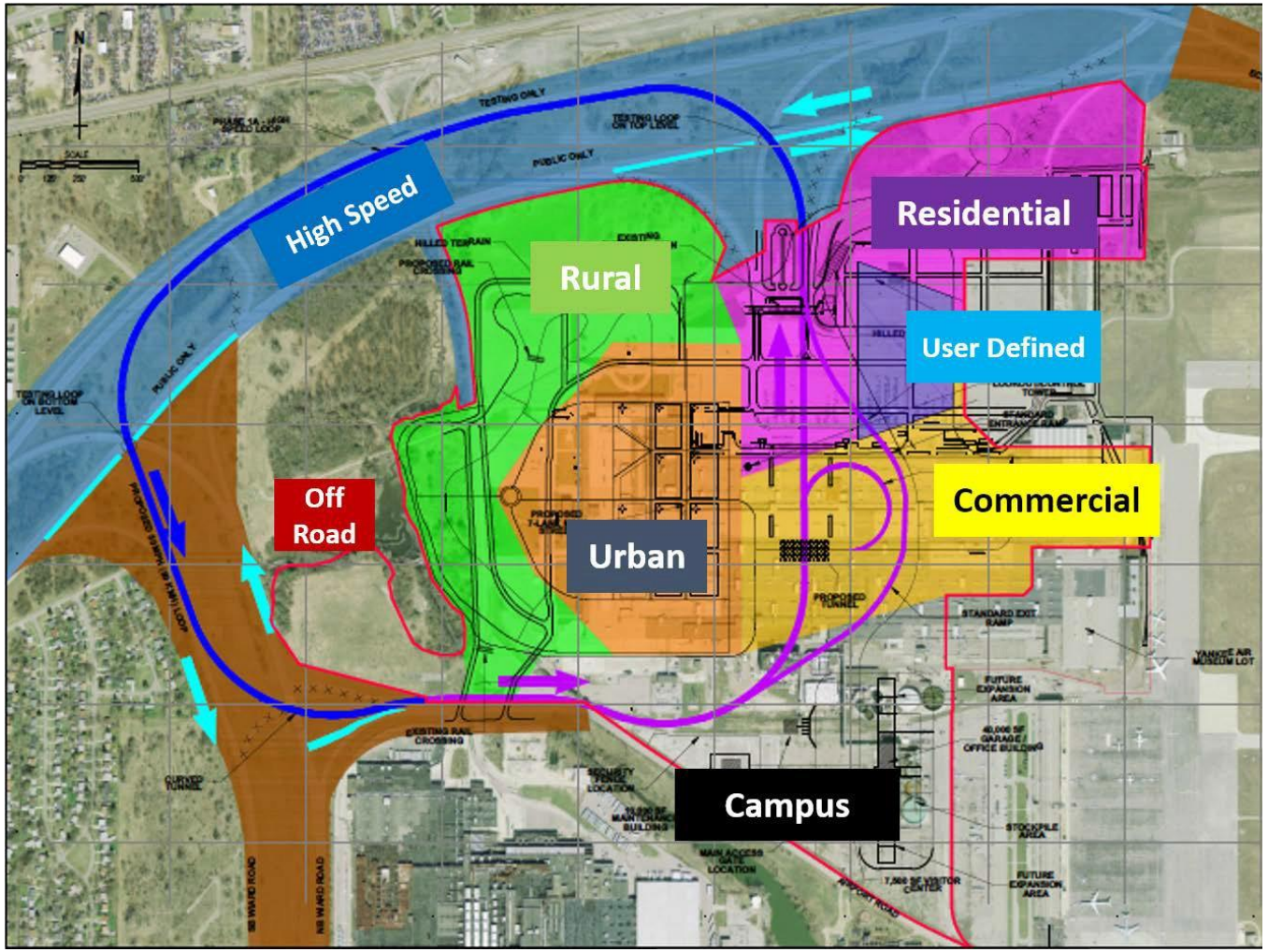
High Speed Coordinated Merging



Traffic Light-less intersections

Testing Facility

- American Center for Mobility
- Reconfigurable driving environments
  - Highway
  - Intersection
  - Off-road
  - Rural
  - Residential

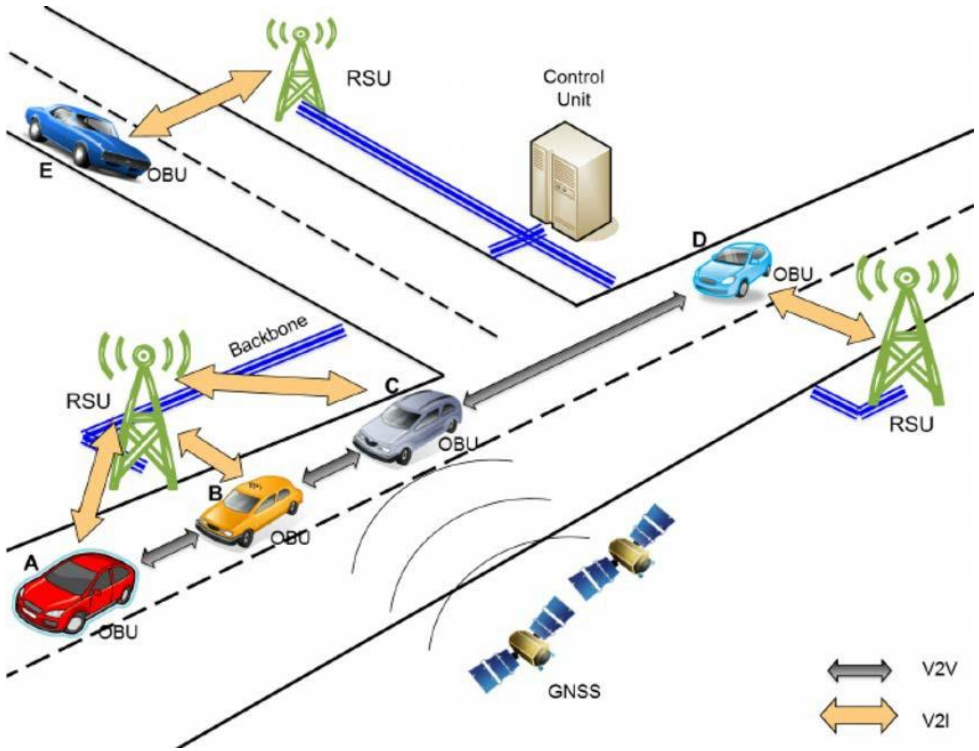


American Center for Mobility
CONNECTED. AUTOMATED. VALIDATED.

V2X Overview

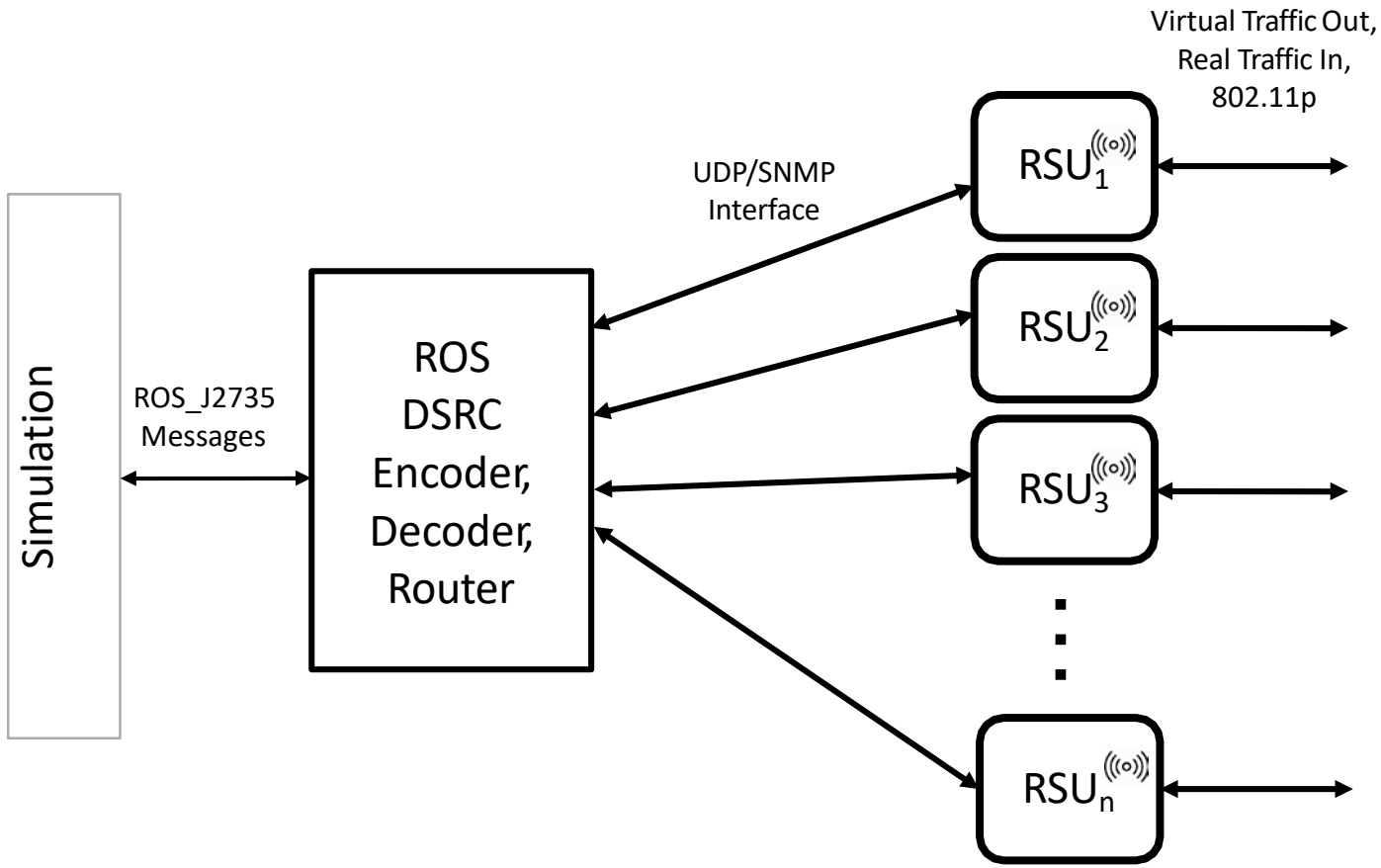
Communication Terminology

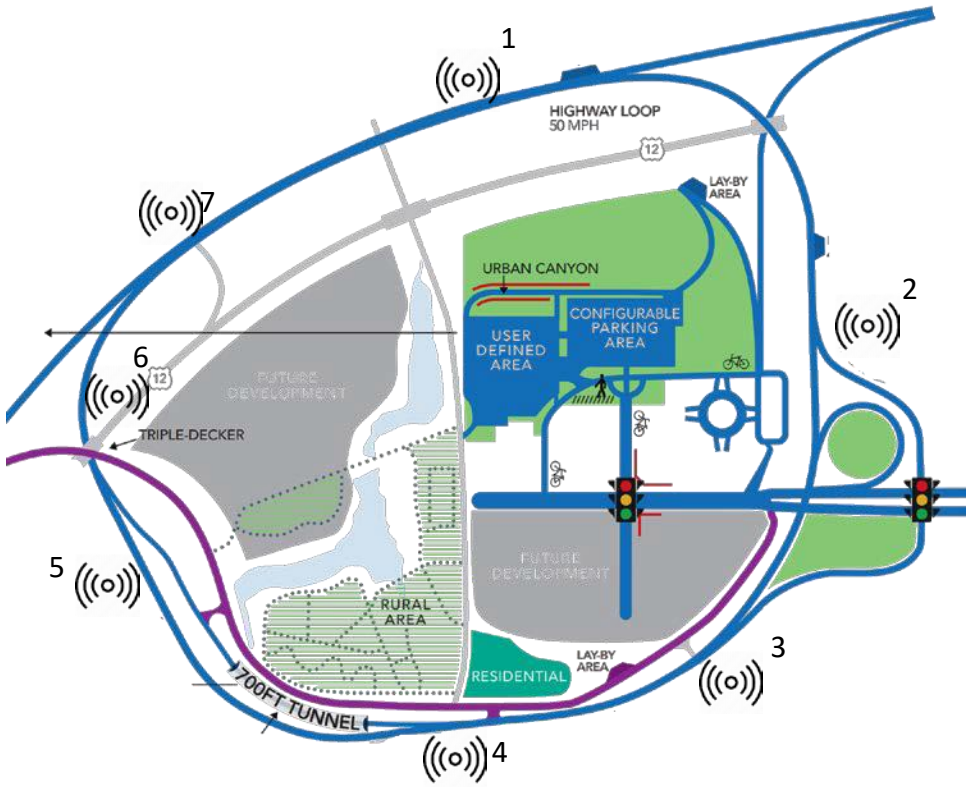
- Communications are done through a V2X architecture, which is a combination of V2I and V2V
  - (V2I) Vehicle to Infrastructure
  - (V2V) Vehicle to Vehicle
- Road-side Units (RSUs)
  - radios permanently placed in the infrastructure.
- On-board Units (OBUs)
  - radios that are placed inside the vehicle
- Each type of radio unit is capable of transmitting and receiving messages.
- Radios are place throughout ACMs infrastructure, as well as on all physical cars.
- Various custom software modules allow information to flow through these radios in real time with low latency
- V2X is sometimes referred to as DSRC (dedicated short range communications)



Sanguesa, J. A., Barrachina, J., Fogue, M., Garrido, P., Martinez, F. J., Cano, J. C., ... & Manzoni, P. (2015). Sensing traffic density combining V2V and V2I wireless communications. *Sensors*, *15*(12), 31794-31810.

ACM Communication Architecture





Types of V2X messages

- mapData
  - Provides roadway geometry
- signalPhaseAndTiming
  - Link to map messages and provide status of lights
- basicSafteyMessage
  - Vehicle information
- travelerInformation
  - Traffic conditions
- And many more…

BSM Fields

- messageId
- msgCnt
- id
- secMark
- **latitude**
- **longitude**
- **elevation**
- positionalaccuracy_semiMajor
- positionalaccuracy_semiMinor
- positionalaccuracy_orientation
- transmission
- **speed**
- **heading**
- **steering_angle**
- accelSet_long
- accelSet_lat
- accelSet_vert
- accelSet_yaw
- wheelBrakes
- brake_traction
- brake_abst
- brake_scs
- brake_brakeBoost
- brake_auxBrakes
- size_width
- size_length

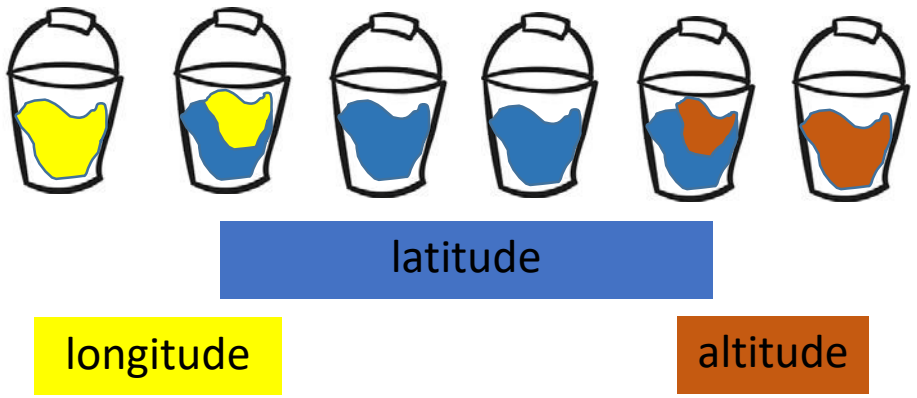
V2X Challenges

- Vendor specific radios
  - Each radio vendors interface is different; lots of nuances to debug
- Latency
  - Virtual traffic is not a use case for radio vendors, so how messages are transmitted from the central controller is key
- Strict definition and encoding
  - V2X is a commercial standard, not designed for research purposes. Modifying data for a purpose not designed into the standard is challenging due to UPER encoding
- Duplicate messages
  - When an OBU transmits within range of 2 or more RSUs

Encoding ex: Latitude

31 bits, unaligned in memory

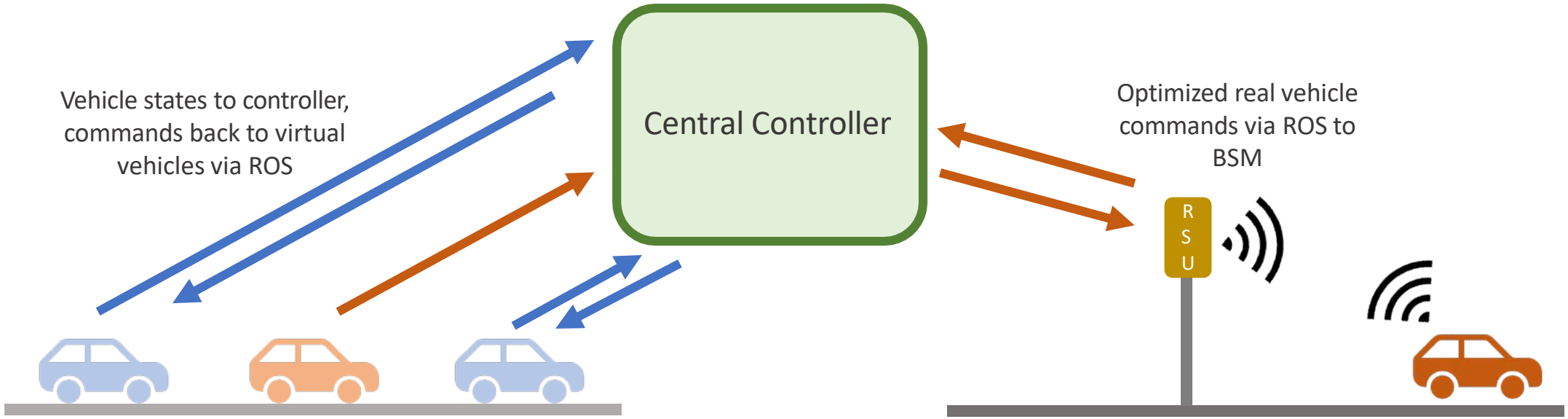
```
Latitude ::= INTEGER (-900000000..900000001)
    -- LSB = 1/10 micro degree
    -- Providing a range of plus-minus 90 degrees
```



Problem: Extract just the blue liquid, change it to green and put it back without disturbing the other liquids

Mixed Reality Environment

Mixed Reality Environment



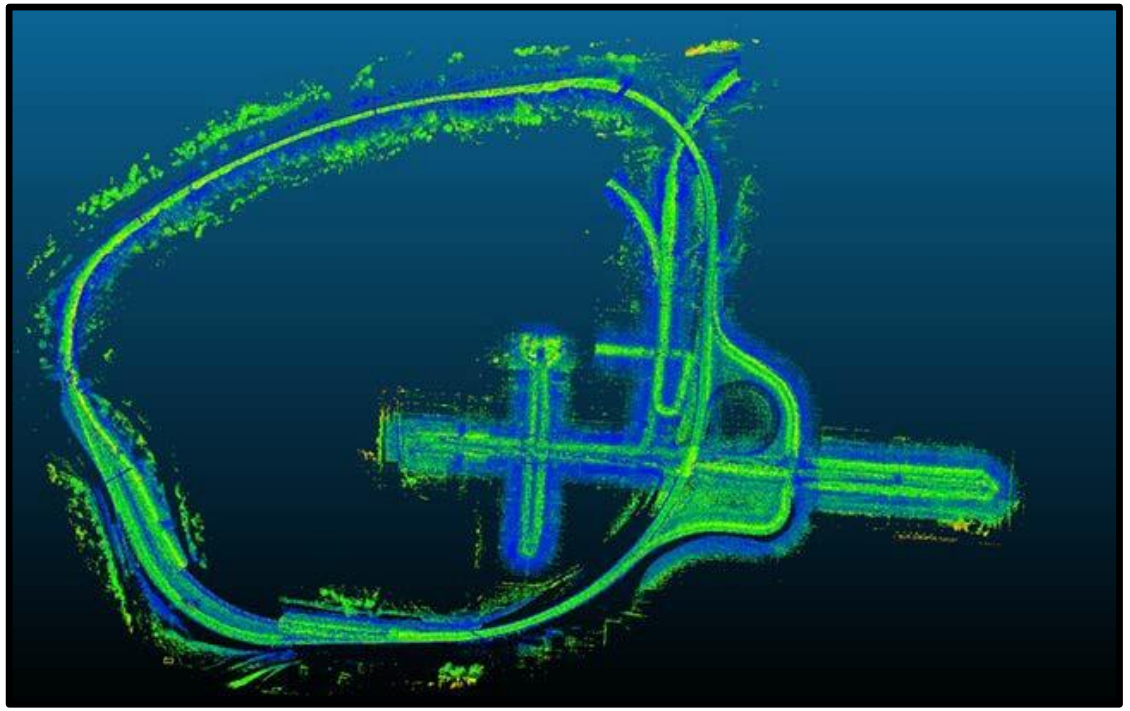
VTD Simulation (Virtual World)

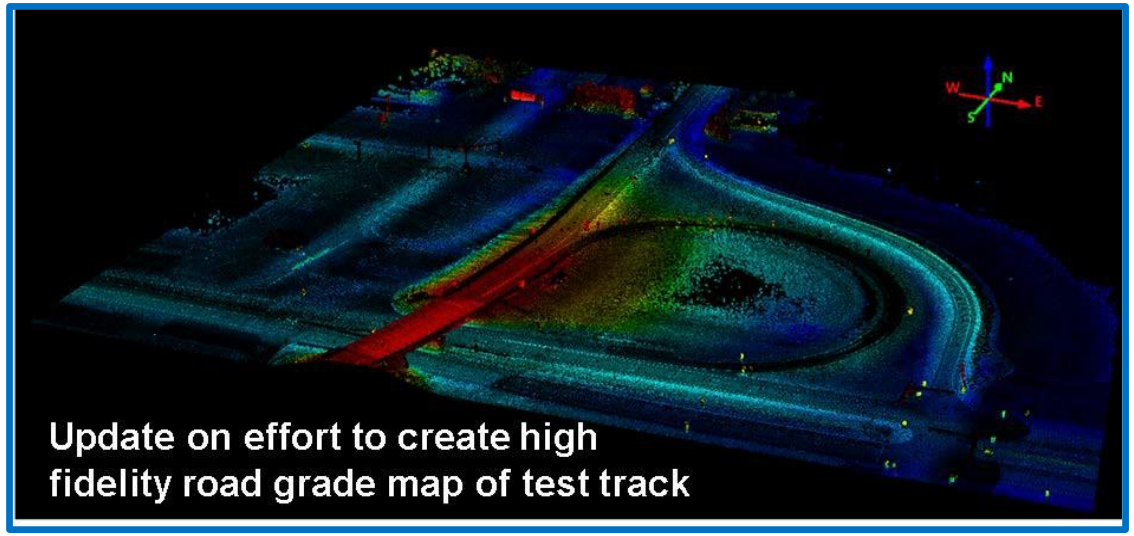
- Virtual ACM test track
- Fully simulated cars (blue)
- Virtual representation of real vehicle (orange)

ACM Test Track (Real World)

- Real autonomous vehicles
- Communication with controller via RSU / BSM messages

Virtual ACM Map

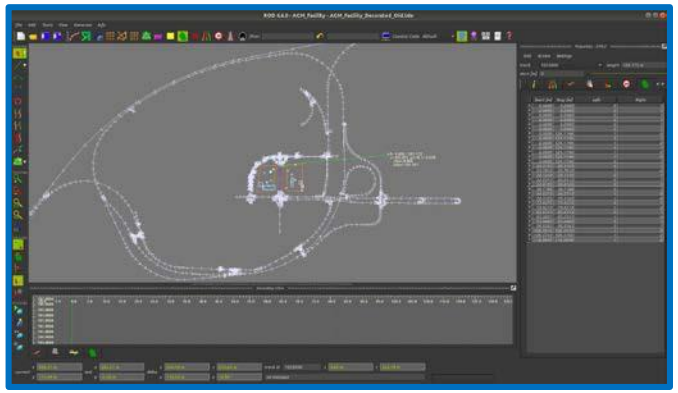


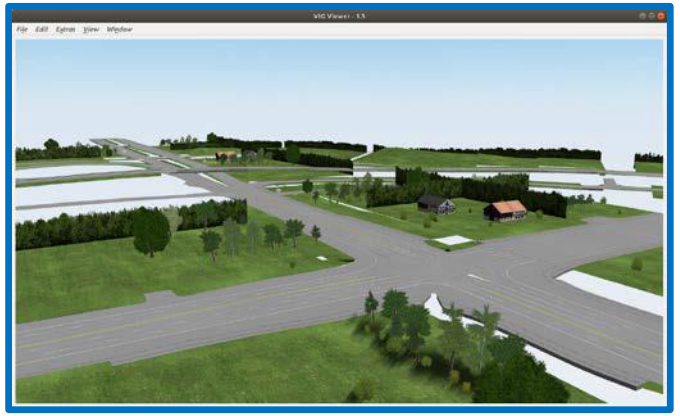


- 20 tiles of 3D lidar point cloud data from Mandli
- PCD file size 7.2 GB
- MTRI is processing this data for high-fidelity road grade information

Virtual ACM Simulation

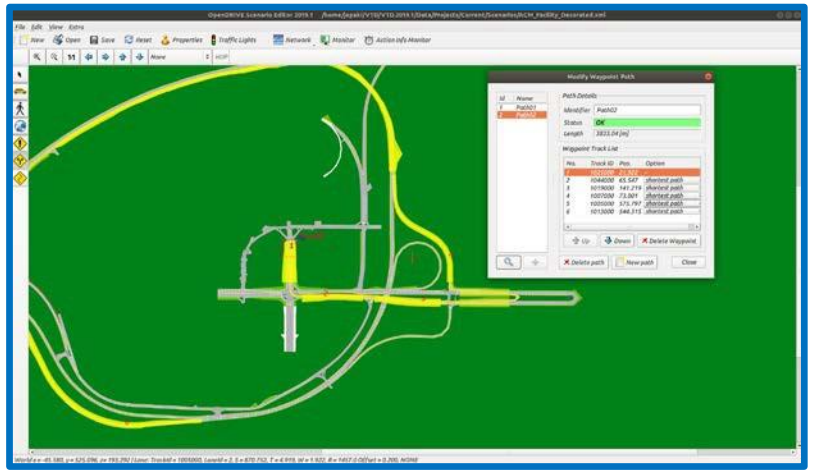
Map: What does it look like?
ACM OpenDrive maps turned into 3D worlds via VIRES Road Designer





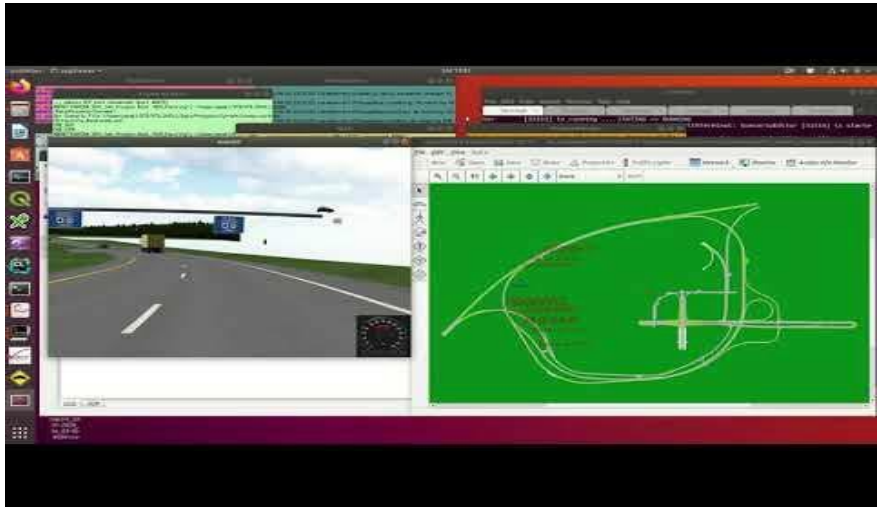
Scenario: What's Going to Happen?
Create scenarios to simulate

- Predefined routes to follow
- Driver models
- Pulk traffic
- Number of vehicles



Simulation

- Communicate / monitor simulation in real time via RDB / TCP
- log data for future processing
- Tune parameters based on behavior



Information Flow

Real CAEV

DSRC

VTD Simulation

Runtime Data Bus (RDB)
Unified network interface that exposes all simulation information to external components during runtime

TCP

ROS / VTD Gateway
TCP client that connects RDB to ROS. Republishes simulation data as ROS topics, allows ROS to nodes to control simulation. Developed in collaboration with VIRES.

ROS

Visualization
Real time monitoring of vehicle and network states via RVIZ

ROS / DSRC Gateway
- Connects the ROS network to the DSRC communications infrastructure
- Ex. Translates between ROS messages and compliant BSMs

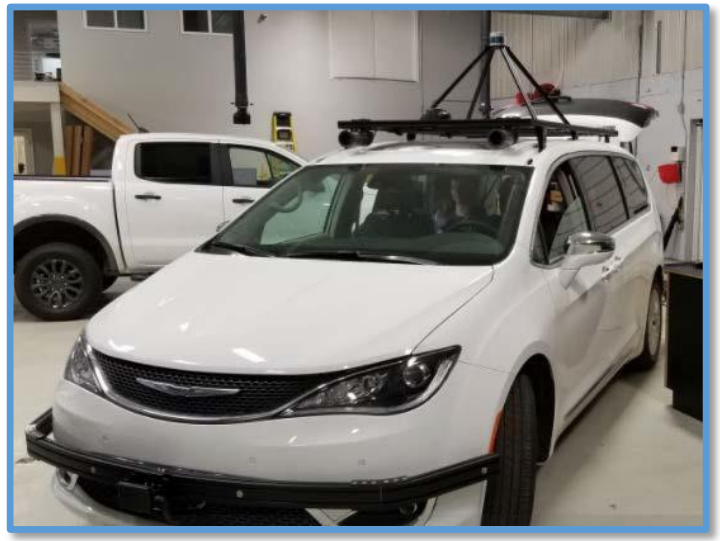
ROS

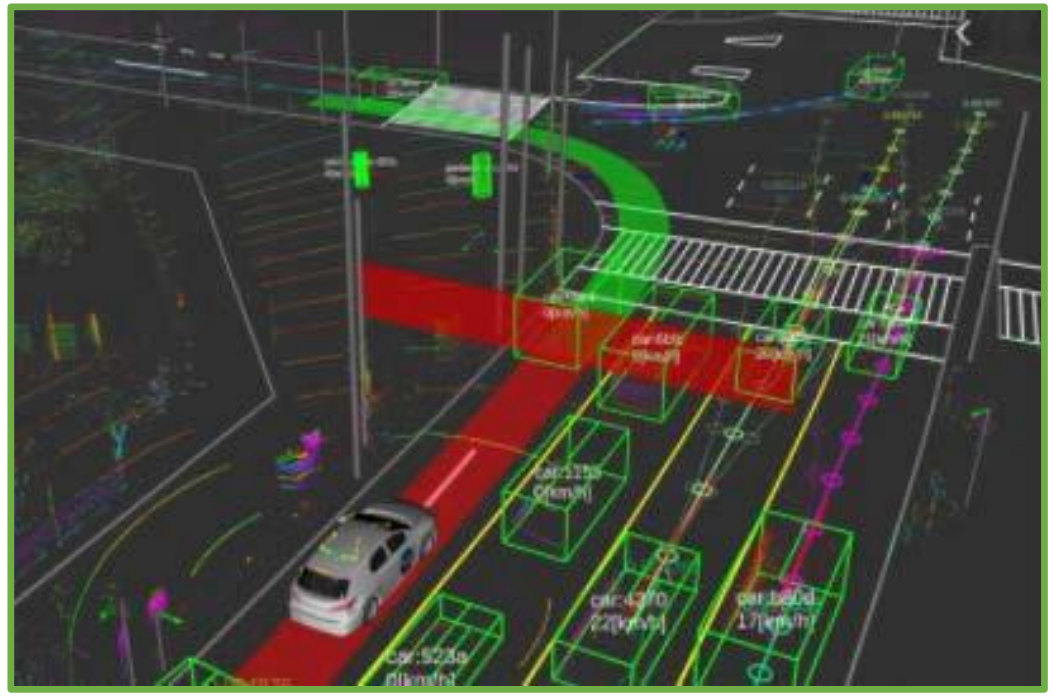
ROS Control Algorithm Implementation
- Collects vehicle data from simulation and computes optimal drive commands according to national lab algorithms.
- Sends commands to virtual vehicles via VTD gateway, commands to real car via DSCR network
- Data logging and system health monitor
- Information available in real time to all computers on the ROS network

Autonomous Vehicle Example

(Cool Stuff)

Autonomous Vehicle (Pacifica)



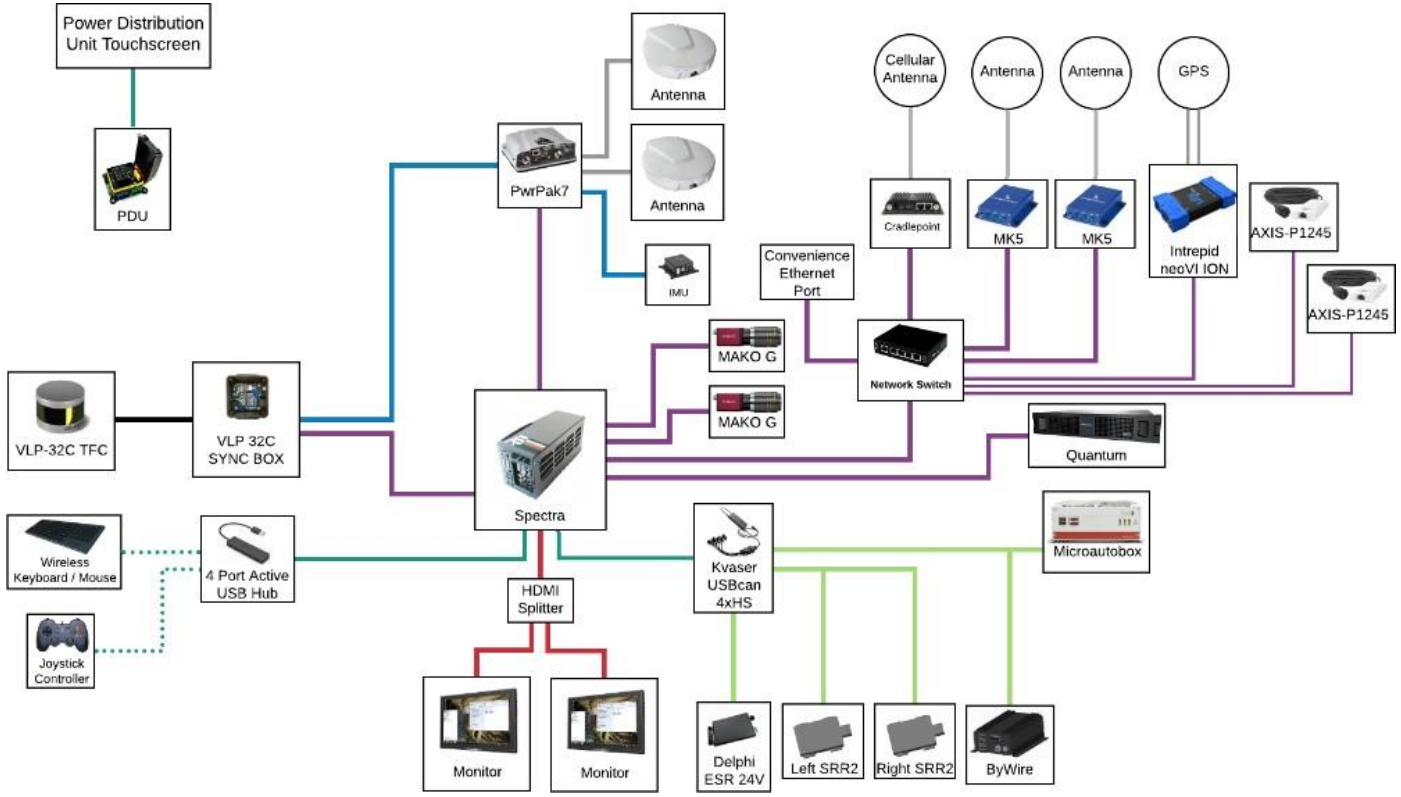


- HD mapping collection and integration
- Sensor fusion to support localization
- Perception and path planning functions
- Object detection module
- Control module (velocity/angle of vehicle)

Autonomous Vehicle (Pacifica)

Primary Components:

- Spectra ECU
- Velodyne VLP-32C Lidar
- Delphi 2.5 ESR Radar
- Delphi SRR2 Radar (2)
- Mako-G 319C (2) 12mm/16mm
- NovAtel GPS/GNSS Solution Pkg
- Quantum Data Storage System
- Cradlepoint Cellular System
- 600W-12VDC Inverter
- Dual Deep Cycle Battery Upgrade
- Intrepid Data Logger/Cameras
- Shore Power, HDMI, Network Ports
- DSPACE MABX



Vehicle Build (Pacifica)

Micro Auto Box

Feeds for Cameras

Intrepid Data logger

Cradle point Modem

R3000 Quantum Gen2 In vehicle solution

Twin Cohda Units CARMA Third for dSPACE

Q&A