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Making Vehicles Intelligent

Steve Dellenback, Ph.D., PMP
Director, R&D

Intelligent Transportation Systems Department

Automation and Data Systems Division

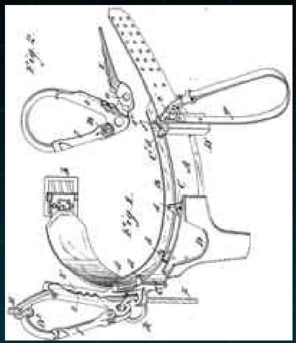
Why: Safety

- **US-6.3M crashes per year; 43K fatalities; 2.9M injuries**
- **Accident Costs-US-$231B (2000); $36.5K per (GDP derived)**
- **90% of crashes are due to driver error**
- **44% of all crashes occur at intersections with 23% fatality rate**
- **What is being done to address safety?**
  - **US Government has several programs under development to help improve safety.**
  - **European Commission has invested in excess of 100M€ in various projects to address safety.**
  - **Auto OEMs are developing several vehicle safety systems to make vehicles more intelligent.**

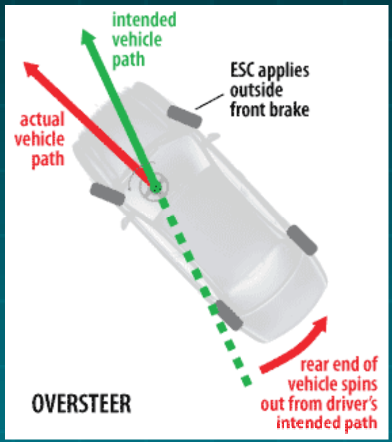
Source: TRG Telematics Research Group Incorporated

In-Vehicle Safety Technology

- 1849 Volvo credited with invention of first seat belts
- 1885 Claghorn obtains first US patent
- 1959 Nils Bohlin develops fist 3 point lap-and-shoulder belt for Volvo
- 1961 SAE issues standards for seatbelts
- 1964 50% of US States require seatbelts in front seats
- 1967 Rear lap belts available in passenger vehicles
- 1971 Ford builds air bag experimental fleet
- 1974 GM becomes first manufacturer to develop and offer airbags in production vehicles
- 1997 Tractors Required to have ABS.
- 2003 The C.E. White Co. introduces the Student Safety Seat, an integrate 3-point lap/shoulder belt seats for use in school buses.
- 2011 All passenger vehicles must have ESC.



"E. J. Claghorn United States Patent #312,085 for a Safety-Belt"



http://www.iihs.org/ratings/esc/esc_explained.html

Source: http://inventors.about.com/gi/dynamic/offsite.htm?site=http://www.stnonline.com/stn/occupantrestraint/seatbelthistory/

Potential Roadmap for European Product Introductions

	NOW	2006	2007	2008	2009	2010	2012	2015	2020+
Electronic Stability Control	X								
Adaptive Cruise Control	X								
Lane Departure Warning	X								
Low Speed Following		X							
Short Range Obstacle Detection / Blind Spot		X	X						
Collision Mitigation Braking			X						
Lane Keeping Assist			X	X					
Curve Speed Warning			X	X					
Drowsy Driver Detection				X	X				
Pedestrian Detection						X			
V-V Communications						X	X		
V-R Communications							X		
Extensive Information based on Floating Car Data						X	X		
Cooperative Intersection Collision Avoidance							X		
Cooperative Adaptive Cruise Control							X	X	
Low Speed Automation (congested traffic)								X	
Automated Vehicles									X

Source: Richard Bishop, Bishop Consulting

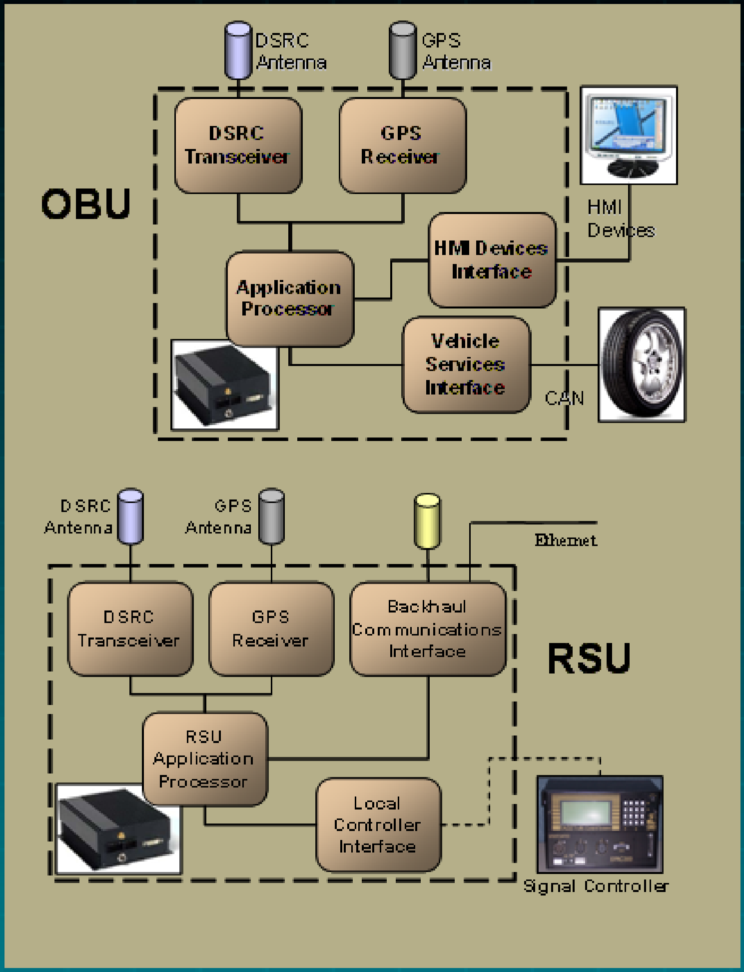
Approaches to Intelligence

- Vehicle Infrastructure Integration (VII):
  - Vehicle to Vehicle (V2V)
  - Vehicle to Infrastructure (V2I)

- Autonomous Vehicles

What is VII?

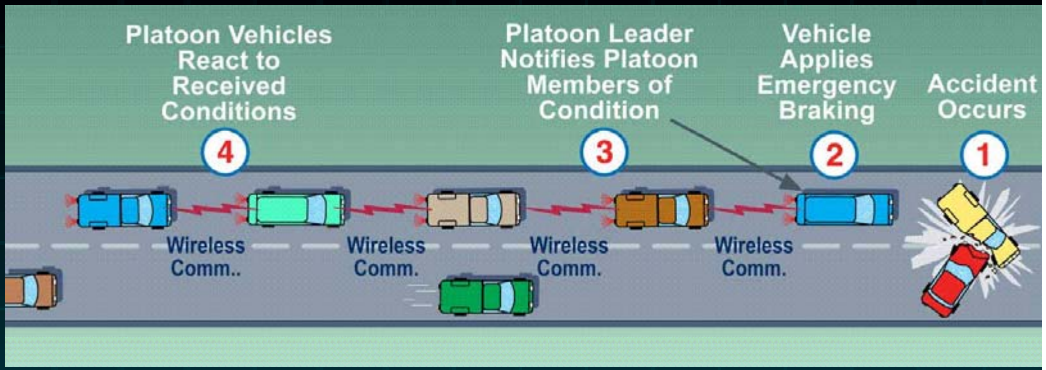
- Vehicle Infrastructure Integration (VII) Initiative
- RITA Definition: Creating an "Enabling Communication Infrastructure" to support vehicle-to-vehicle And Vehicle-to-Infrastructure Communications
- Primary Focus: Support of Safety and Mobility Applications
- To be deployed as "A Nationwide Network of Hot Spots" along the nation's vehicle-based transportation infrastructure. ~100,000 to 400,000 RSE envisioned
- Will utilize Dedicated Short Range Communications (DSRC) protocols.

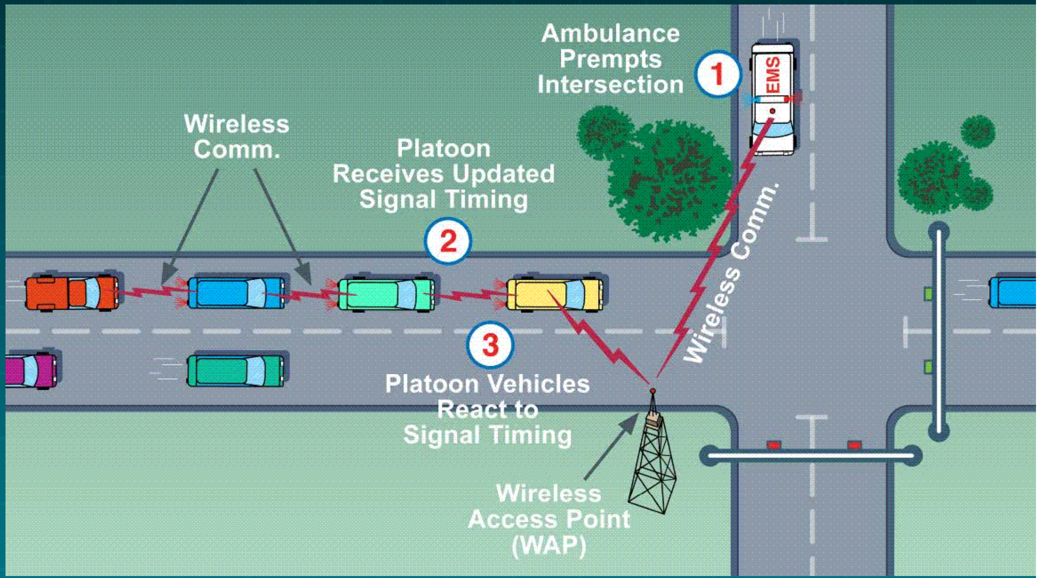


Source: OmniAir briefing IBTTA September 2006

Top VII Use Cases (source Motorola)

1. **Emergency Braking**
2. **Signal Violation Warning**
3. **Stop Sign Violation Warning**
4. **Curve Speed Warning**
5. **Roadway Conditions (Work Zone, Icy Bridge, Potholes, Road Debris)**
6. **Electronic Payment**
7. **Signal Timing & Adjustment**
8. **Ramp Metering**
9. **Traffic Information (Weather, In Route Alerts, Emergency Alerts,)**
10. **Public Vehicle Alert (EMS, etc)**
11. **In Vehicle Signage (School Zone, Deaf Child, Railroad Crossing Dynamic Turn Rest.)**
12. **Parking (Availy, Restrictions – Fire Hydrant)**
13. **Traveler Information (Parking, Route Guidance, Location Assistance…)**





What is the plan for realizing VII?

- Current VII Work Plan
  – Proof-of-Concept testing in 2007
  – Field operational tests in 2008
  – Viability decision Nov 2008
  – Initial deployment (Day 1) by 2011

- Anticipate 27% of passenger car fleet equipped with VII technology by 2015

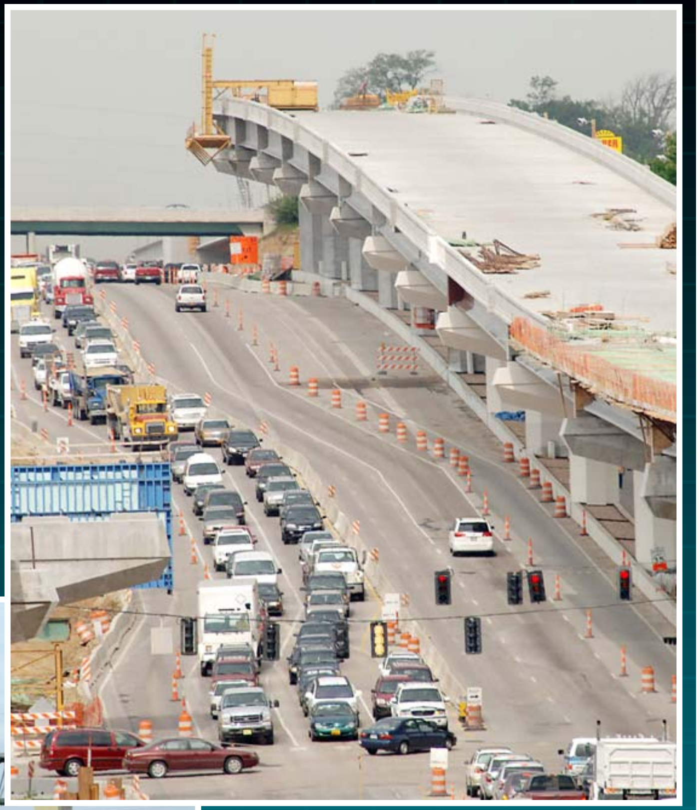
Source: Bob Ferlis briefing at ITFVHA in London October 2006

What is an Autonomous Vehicle?

- Navigates Using GPS Information
- Uses Sensors to Identify Obstacles
- Plans its Path
- Uses “Behaviors” that Mimic a Human Driver

Why Autonomous Vehicles?

- Cannot "Build Out of Congestion"
  - Use Existing Roads More Efficiently
  - Limited Expansion Space
  - Lack of Funds
- Safety Aspects
  - Intersection Safety
  - Driver Fatigue
  - Vehicle Platooning



Why Autonomous Vehicles? Transit Perspective

- Operator Transit Vehicles in a "Platoon"
- Densely Pack Roadway
- More Efficiently Utilize Existing Capacity
- "Electronic" Tow Bar

European CyberCar and CityMobil Programs

- Targeted at City Centers
- “To the curb” mobility.
- Fully Autonomous Solutions for dense urban environments with pedestrian interactions.


Rome, Italy


Heathrow Airport, UK

Government Efforts: DARPA “Challenges”

- 2004 Challenge
  - 142-Mile Desert Course
  - 0 of 15 Participants Finished
- 2005 Challenge
  - 132-Mile Desert Course (10-Hour Time Limit)
  - 4 Finished (Stanford Won)
  - $2 Million Prize

Source: DARPA

Government Efforts: DARPA “Challenges”

- **DARPA Urban Challenge**
  - 60-Mile “Urban” Course
  - 6-Hour Time Limit
  - 6 of 22 Teams Finished (Carnegie Mellon Won)

Source: DARPA

How Do You “Create” An Autonomous Vehicle

- Advance the State-of-the-Art in Autonomous Ground Vehicles
- Create Enabling Technologies by Developing an Autonomous Ground Vehicle
- Advance Technologies
  - Vehicle Behaviors
  - Intelligence and Knowledge Representation
  - Cooperative Vehicle Maneuvers and Interactions
  - Advanced Situational Awareness

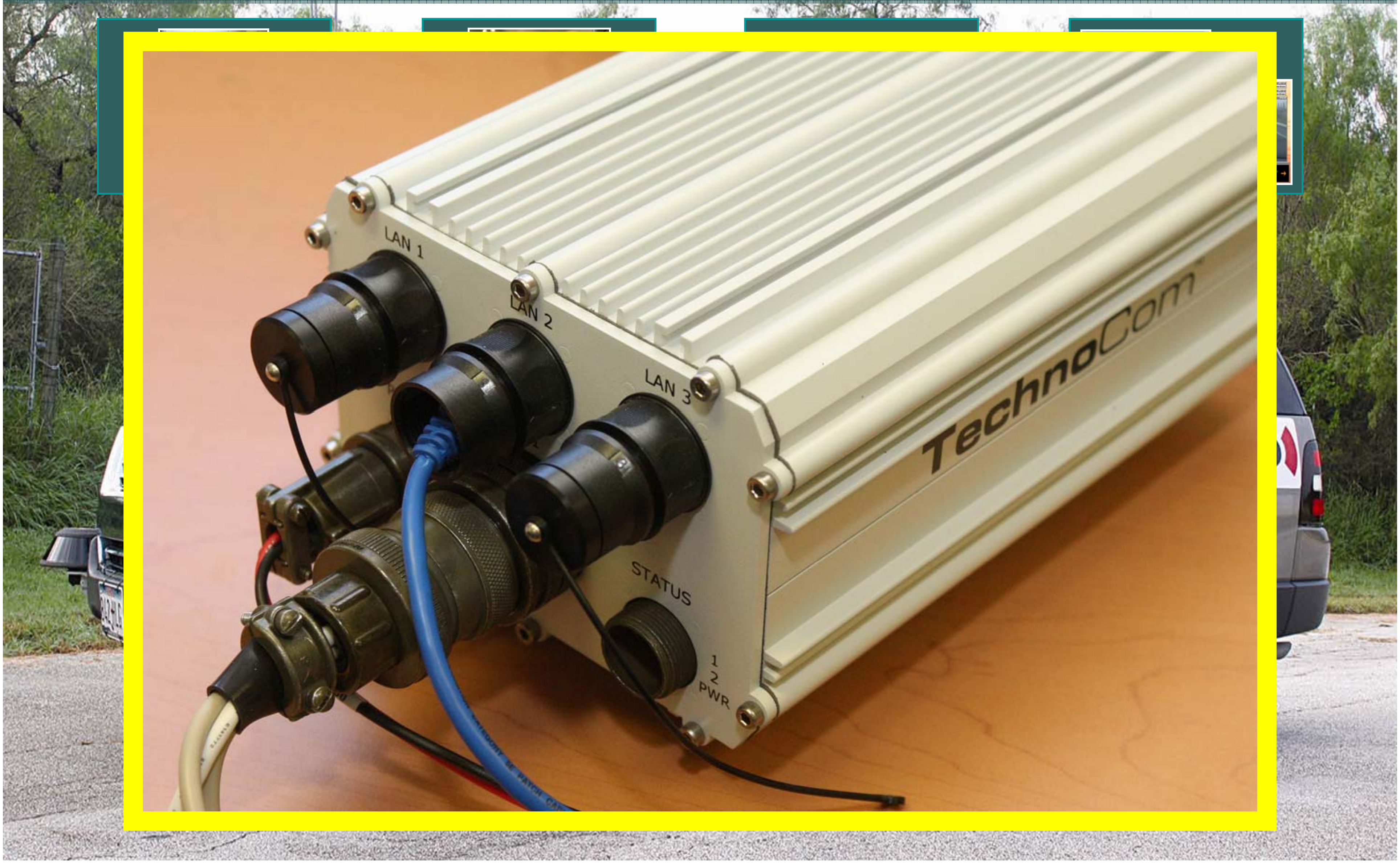
System Components: Drive-by-Wire System

System Components: High-Resolution Camera

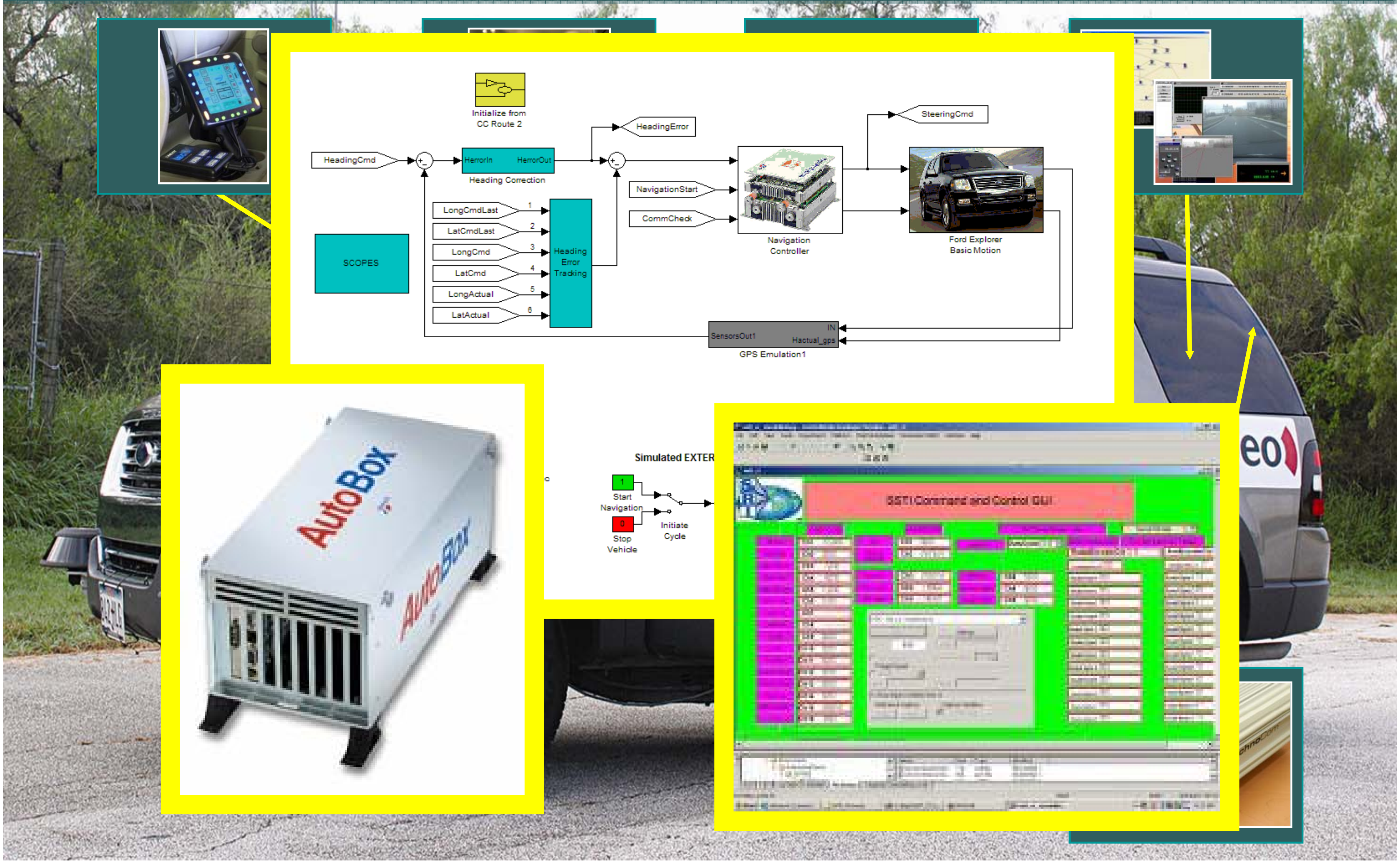
System Components: Global Positioning System/Inertial Navigation System

System Components: Automotive Prototyping System

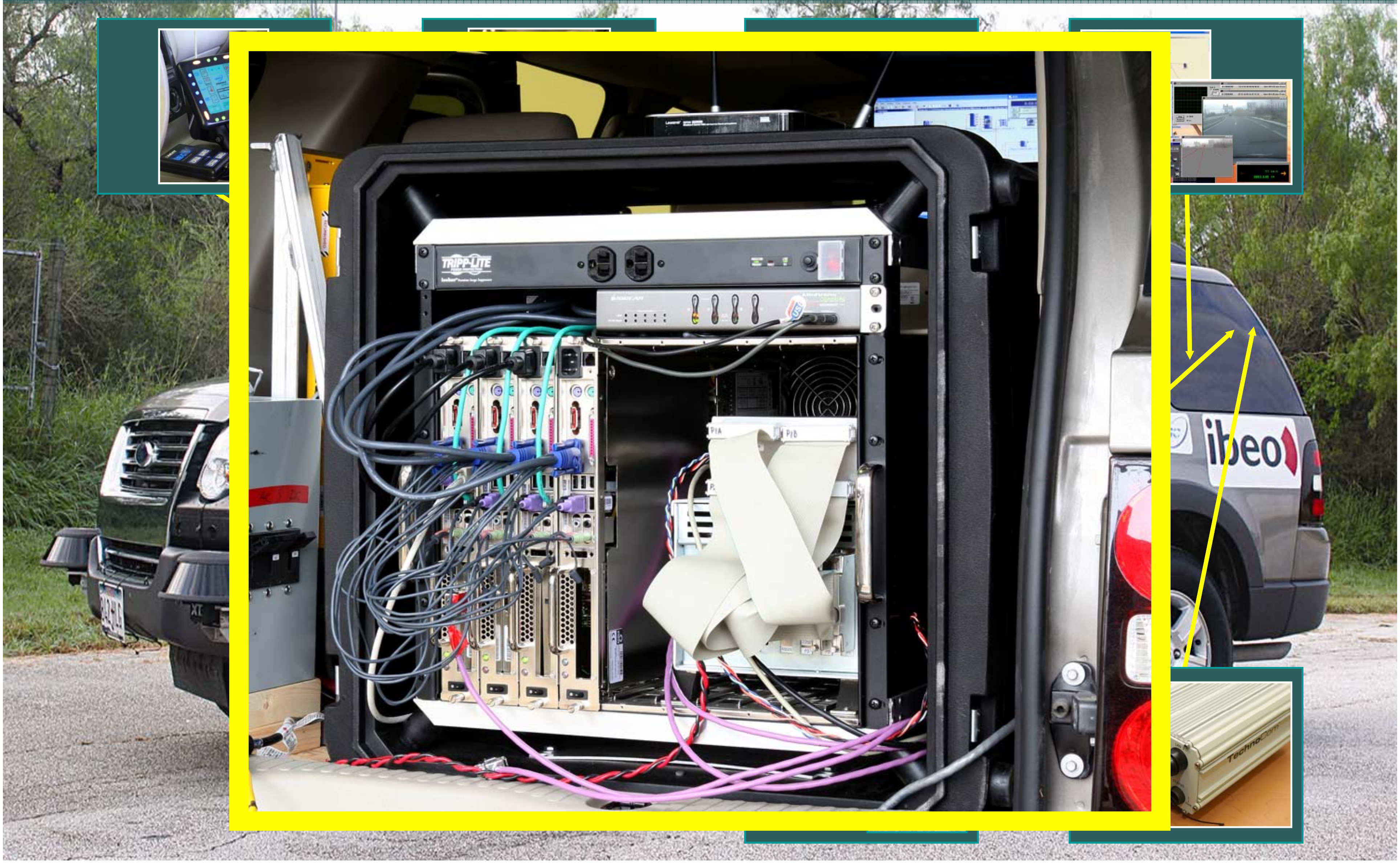
System Components: Short-Range Communications Radio



System Components: Vehicle Simulation Software



System Components: High Performance Computers

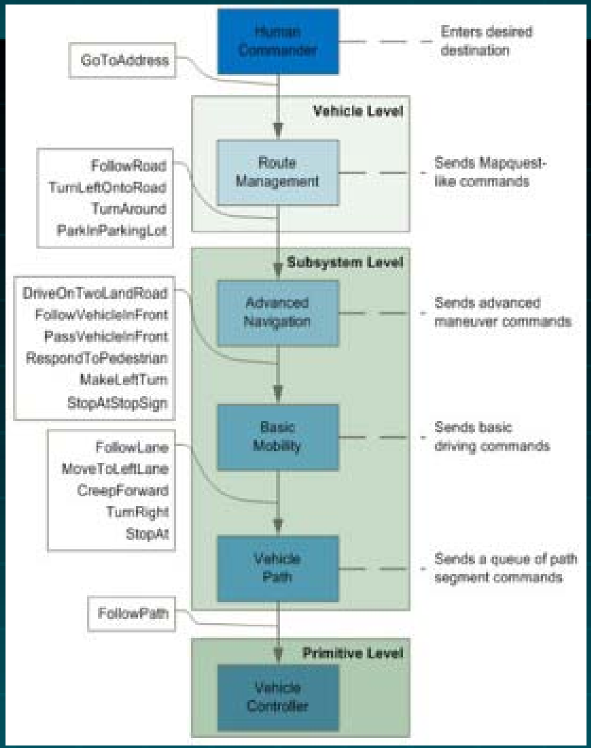


System Components:
Laser-Scanners (2 in Front, 1 in Back)

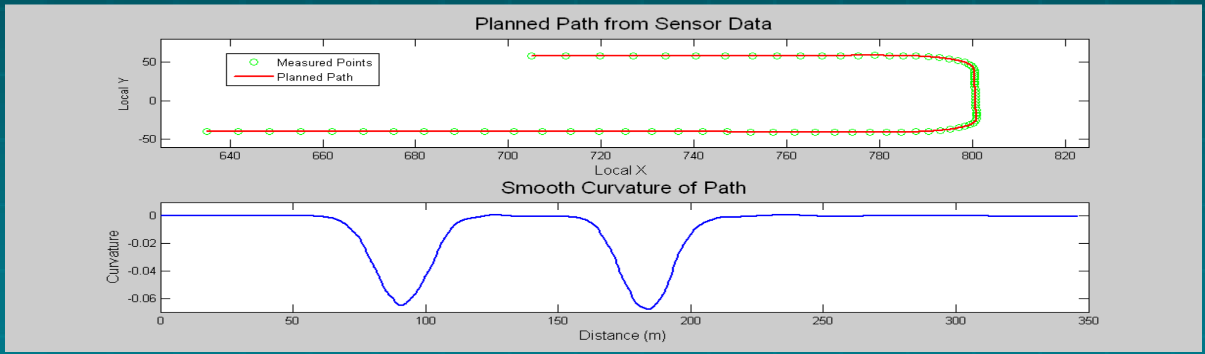
System Components: Core Vehicle – Research Base

Navigation and Path Planning

- ***Vehicle Path Agent*** **generates smooth paths to send to the vehicle controller -- Implemented two different path generation approaches:**
  - **Cubic curvature polynomial method to achieve a goal posture**
  - **Curvature-spline separation method to track curves**
- ***Basic Mobility Agent*** **commands the vehicle path agent to follow lanes, change lanes, make turns, stop, etc.**

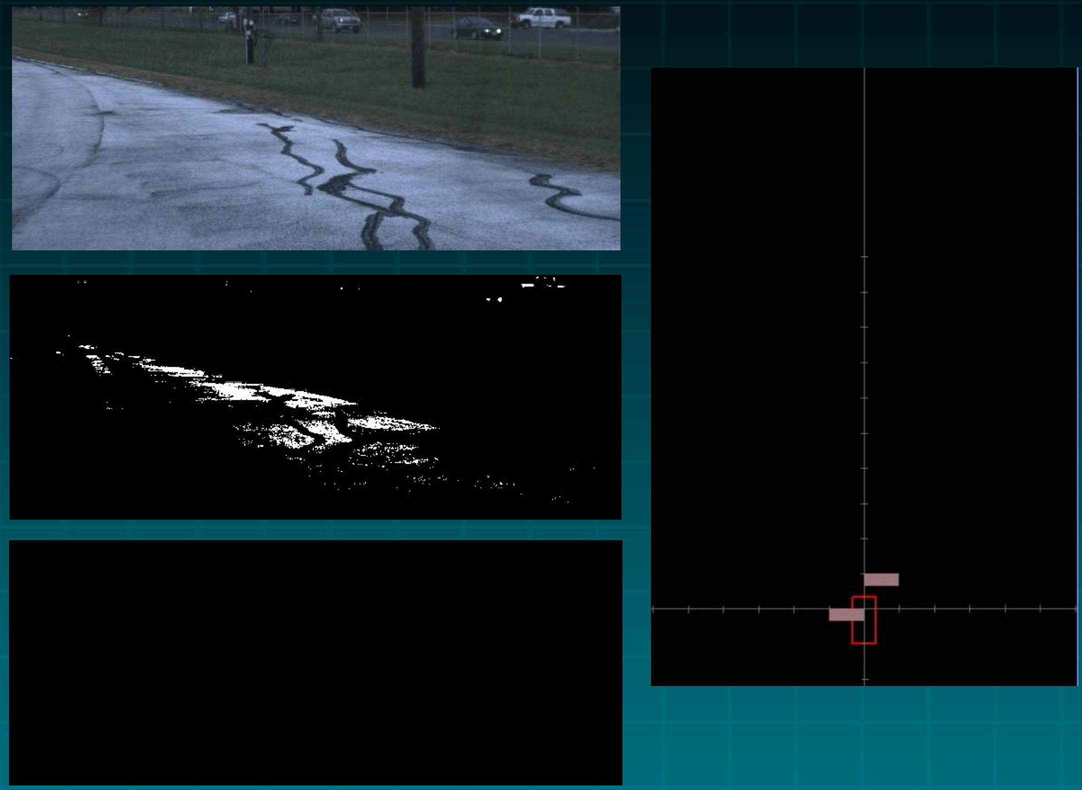


- ***Advanced Navigation Agent*** **commands the basic mobility agent to pass other vehicles, respond to pedestrians, turn around, etc.**
- ***Route Management Agent*** **provides Mapquest-like routes to send to the advanced navigation agent**



Lane Detection Using Image Processing

- Camera Images Provide “Environmental” Insight
- Vision Determines
  - Stripes when Available
  - Pavement Edges
  - Intersections
  - Obstructions
- Weather Conditions (Light, Moisture) Affect Image Processing

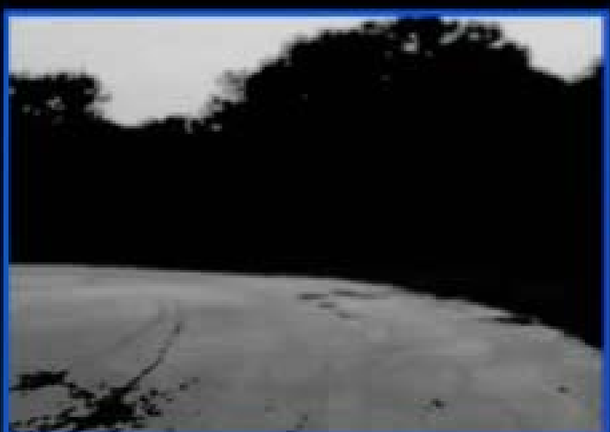


Drivable Path Detection

- "Picture" Environment
  - Vision (Closed-Circuit Cameras)
  - Light Detection and Ranging (LIDAR) Technology
  - Limited Field of View
- Determine Where Vehicle can Navigate
- Couple Path with Known Navigation Database

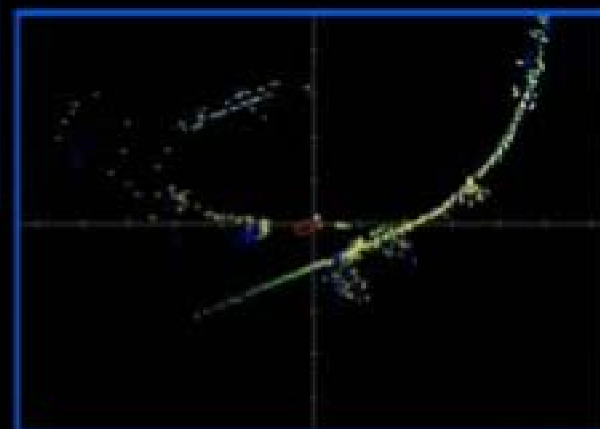
Putting It All Together: Sensor Fusion

Out the Window View (CCTV)



Out the Backseat View (CCTV)

LIDAR Image

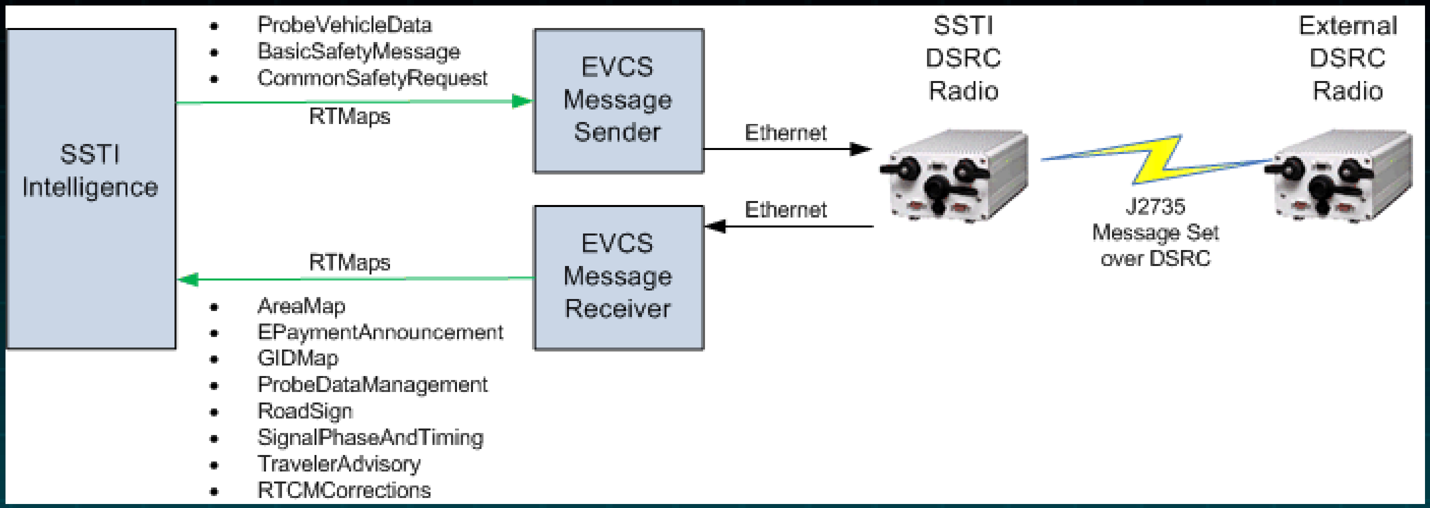


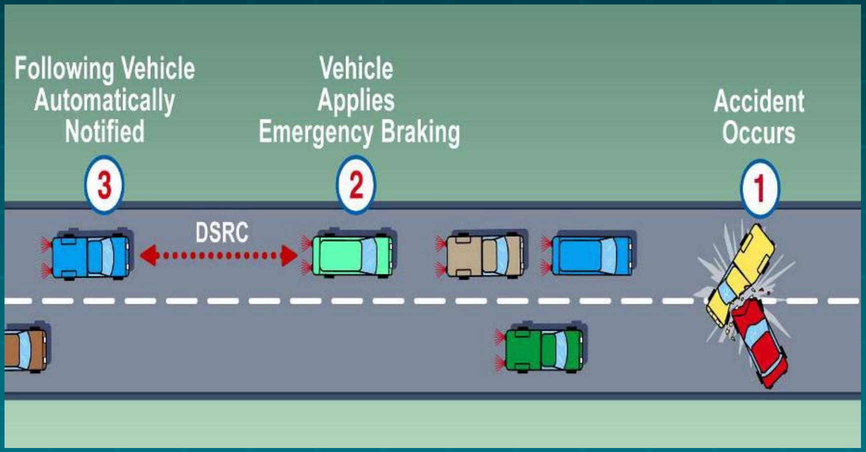
Processed CCTV Image

Processed LIDAR Image

Putting It All Together: Driverless Vehicle

Looking Forward:
DSRC-Enabled Cooperative Autonomy

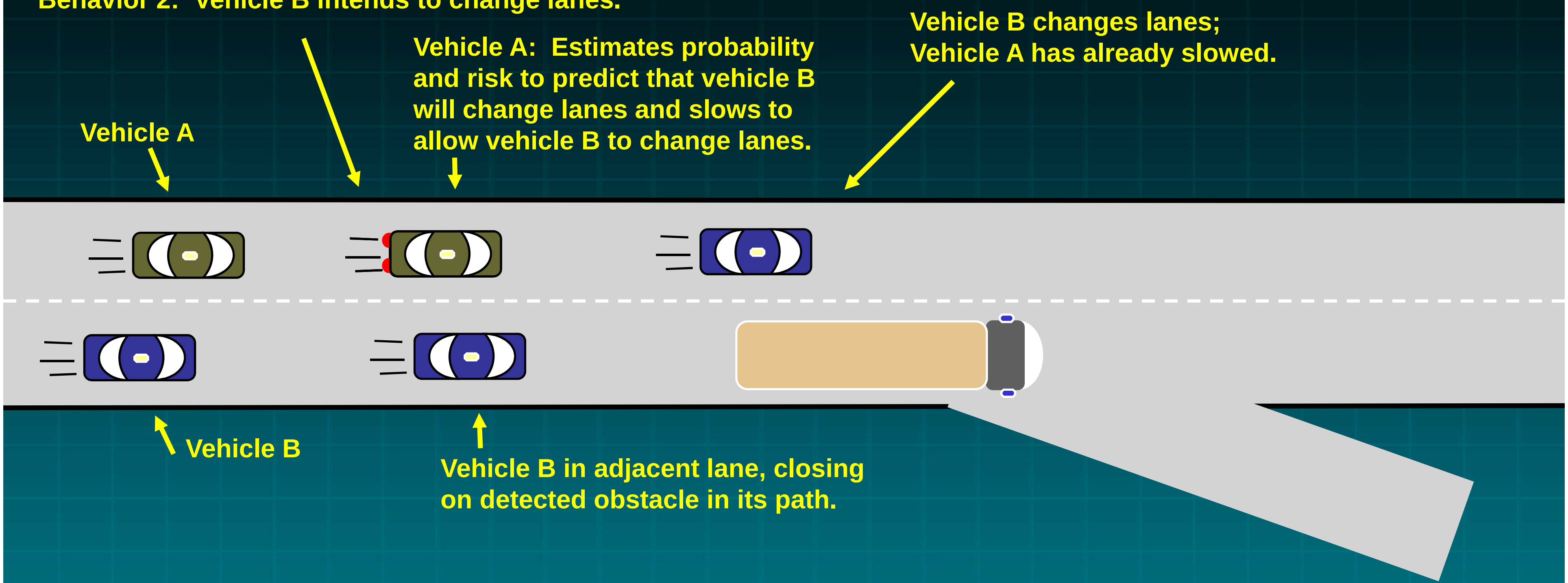




- **Possible Applications:**
  - **Vehicle Platooning (Convoy / Drafting)**
  - **Vehicle – Infrastructure multi-agent system**
  - **Interactions between autonomous and non-autonomous vehicles**
  - **Autonomous action based upon infrastructure provided information.**

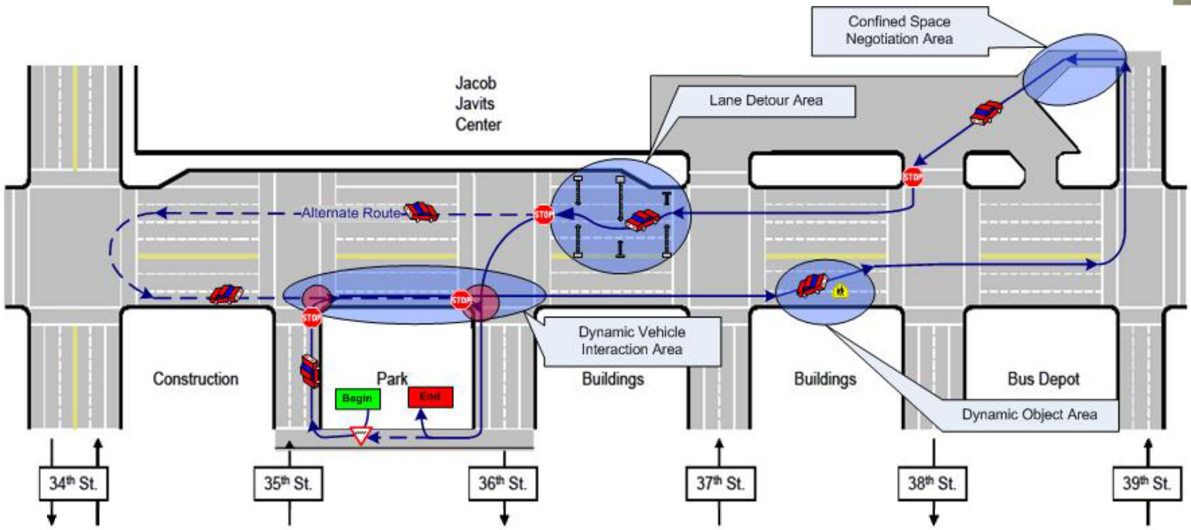
Looking Forward: Vehicles Interacting on Highway

Behavior 0: Vehicle B stays in same lane.
Behavior 1: Vehicle B intends to exit.
Behavior 2: Vehicle B intends to change lanes.



Autonomous vehicle demonstrations on 11th avenue:

- **Several DARPA Urban Challenge Teams**
- **SwRI's SSTI UGV will be demonstrated**



Questions?

Steve Dellenback, Ph.D., PMP
sdellenback@swri.org

210.522.3914

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