Vehicle Dynamics Models for Driving Simulators

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Agenda

- **Introduction to Mechanical Simulation**
- **Vehicle dynamics simulation software**
- **Engineering driving simulators**
  - Wide range of vehicles, features, capabilities and prices
- **Advantages of high-fidelity vehicle model**
- **New automotive technologies**
  - ADAS – compatibility with road systems
  - CAMP – Vehicle to vehicle and vehicle to infrastructure
- **Questions**

Mechanical Simulation Corporation

Founded in 1996 in Ann Arbor

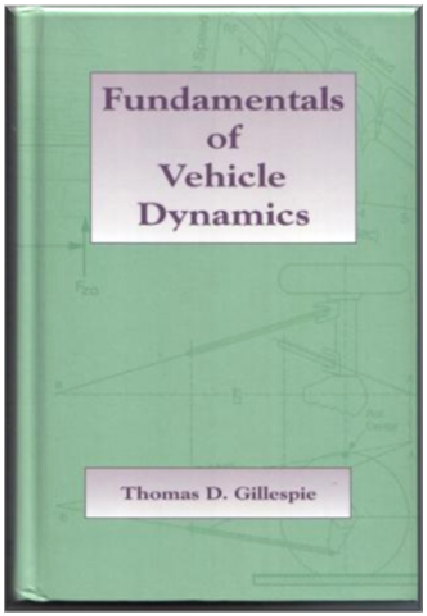
- Dr. Thomas Gillespie
- Dr. Michaels Sayers
- University of Michigan Transportation Research Institute (UMTRI)
- 40+ years experience in vehicle dynamics and testing

PhDs specializing

- vehicle dynamics
- control theory
- real-time systems

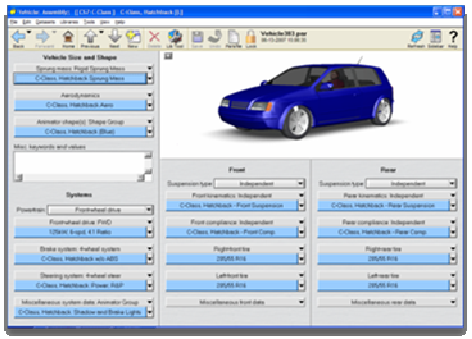
Technical expertise

- vehicle dynamics
- test engineering
- automotive R & D
- racing



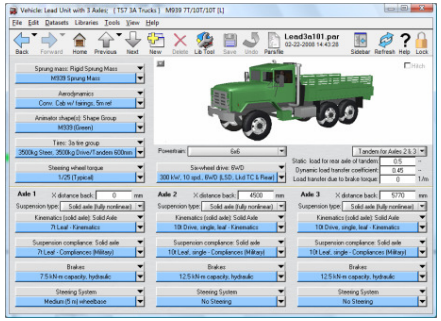
CarSim

- Cars, light trucks, SUVs, race cars
- Trailer option
- 15 sample vehicles
- 150+ test examples



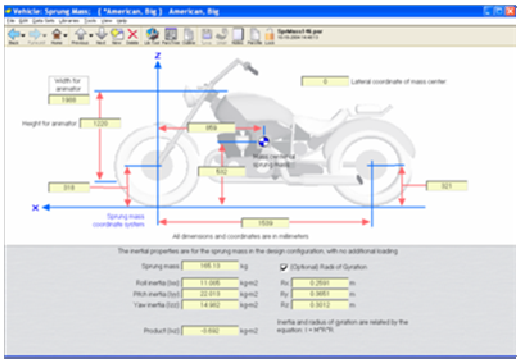
TruckSim

- Combination vehicles (trucks and trailers)
- Dual tires, multiple axles
- 12 sample truck-trailer-axle configurations
- 100+ test examples
- Custom configurations



BikeSim

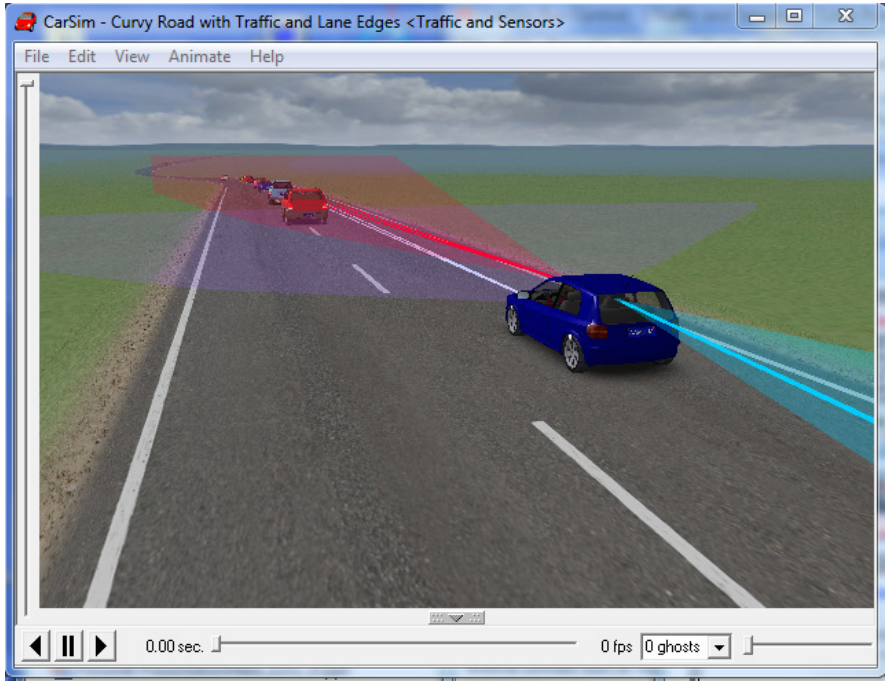
- Motorcycle dynamics
- Touring, racing, motocross, and scooters
- 10 sample bikes
- 40+ test examples



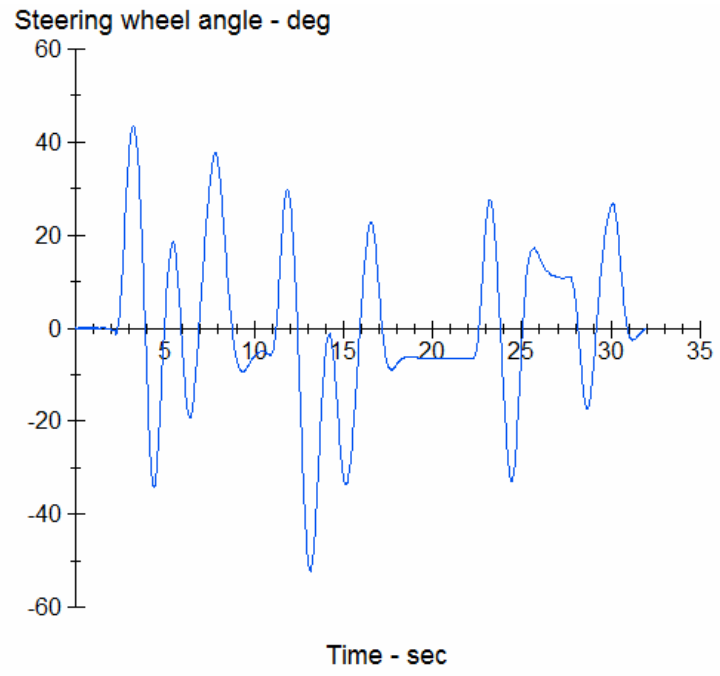
Used in over 750 driving simulators worldwide

Engineering Testing Results

- Example Animation



- Example Plots



Worldwide Customers

- 45+ Car and Truck OEMs
- 60+ Tier 1 and Tier 2 Suppliers
- 200+ Universities, Testing and Research Organizations

70% of Licenses are outside of U.S.

Global Sales and Technical Support

10 Agent companies, worldwide

Human Factors Driving Simulators

- Research into:
  - Driving behavior
  - Driver performance
  - Drug interactions
  - Design of vehicle controls

University of Michigan

Ford VIRTTEX

FORUM 8 simulator at 2008 ITS WC in NYC

Human Factors Research with city-driving scenarios

Marketing Simulators

- Teach customers about new product features
- ESC – electronic stability control
- ACC – adaptive cruise control
- LDW – lane departure warning
- LKA – lane keeping assist (steering intervention)
- CWS – collision warning and collision mitigation systems
- BSD – blind spot detection
- ….

High-fidelity vehicle model is important in this application

Geely Automotive – "BMBS"
Blowout Monitoring Braking System

CarSim Graphics for Marketing

Engineering Simulators

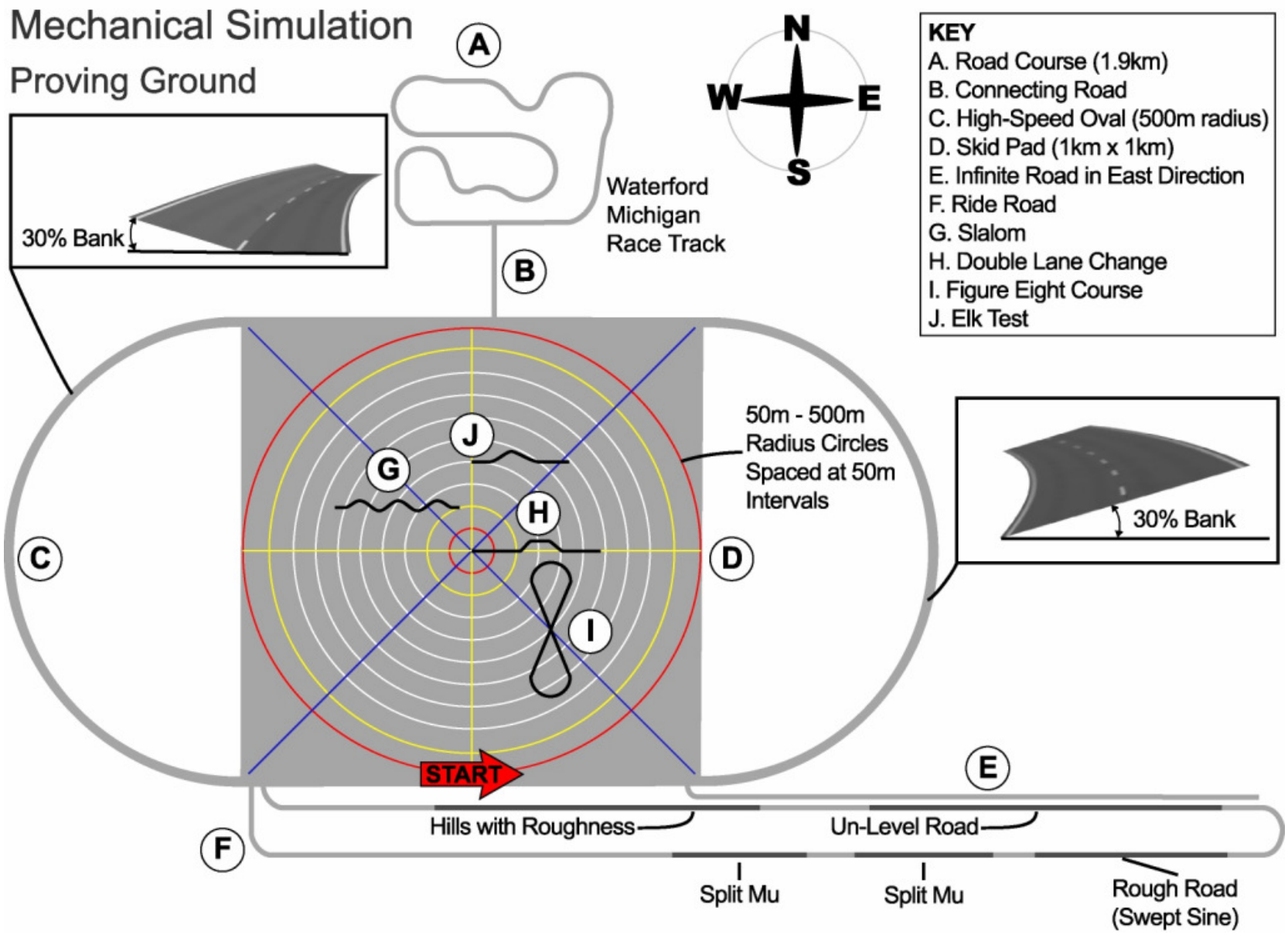
- Designed and built by Mechanical Simulation
  - Used for SIL testing, HIL and ADAS (new safety systems)

Fixed Base

Motion Base

High-fidelity vehicle models are required in these applications

CarSim DS Proving Ground Facility



Forum8 simulator at 2009 SEMA Show

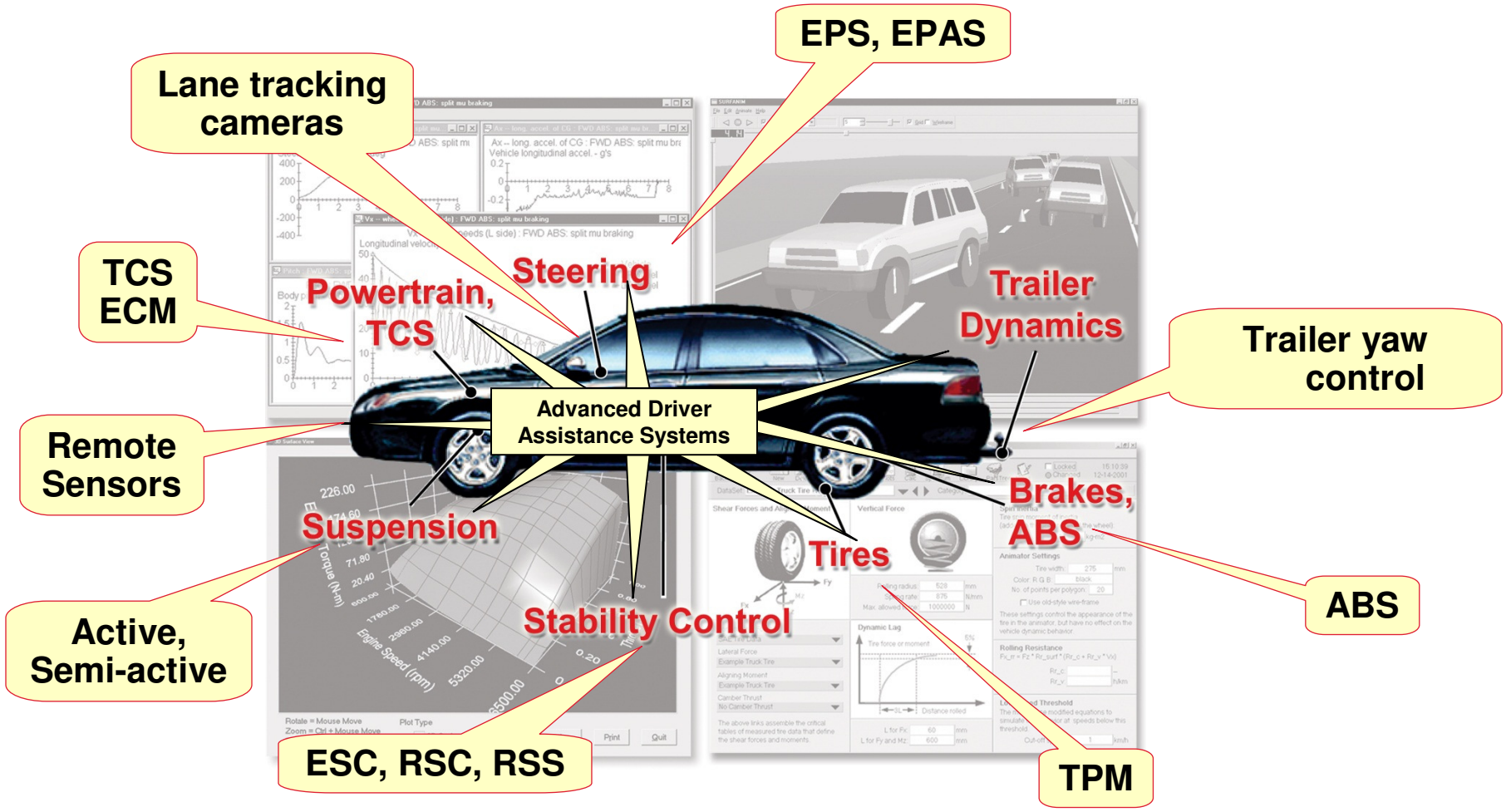
- CarSim on a proving ground made with UC-win/Road scenario software

Tire Manufacturer R&D Example

- Evaluate handling and steering feel of different tire designs

A high-fidelity vehicle model is required in this application

Electronics Influence All Vehicle Dynamics



Advanced Driver Assistance Systems (ADAS)

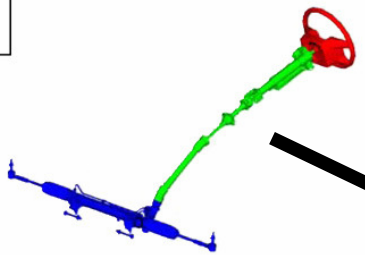
Any Chassis System can be "Driven"

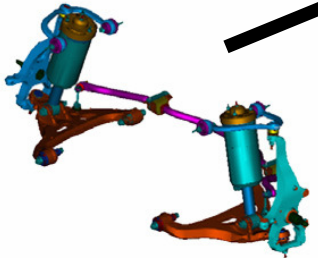
ECU controller

Real-time HIL system

Chassis System

- Steering Hardware
- Brake Hardware
- Suspension Hardware





A high-fidelity vehicle model is required

ADAS Safety Development and Testing

78-ton motion platform
15’ x 23’ enclosed dome
65’ x 135’ range of motion
360 deg. visual system
CarSim vehicle dynamics

Driving Simulator System Considerations

Driver environment

- Desktop, Cockpit, Partial Vehicle, Full Vehicle
- Open or closed driver compartment
- Type of steering system, pedals, and shifter
- Number of screens – 1, 3, 5, 8+
- Type of visual display – monitors or projection system
- Scenario software requirements

Fixed-base or Motion-base

- Space allocation for driving simulator
- Motion platform weight requirements
- Range of motion requirements - x, y, z, roll, pitch, yaw
- Type of motion system - electric, hydraulic
- Motion hardware – 3 DOF, 6 DOF hexapod, 7-8-9 DOF (sliding tracks and rotation)

Budget

Future Intelligent Transportation Systems

Vehicle communication and safety control systems

V2V – “vehicle to vehicle”

- Severe braking by a vehicle several cars ahead
- Slippery road conditions - another vehicle spins out ahead
- Severe curve and speed too fast
- Cross-traffic vehicle is going to intersect your car

V2I - vehicle to infrastructure

- Weather conditions indicate icy road ahead
- Your vehicle is going too fast to stop at a traffic signal
- Cross-road vehicle is going to run a red light

Future vehicle controls

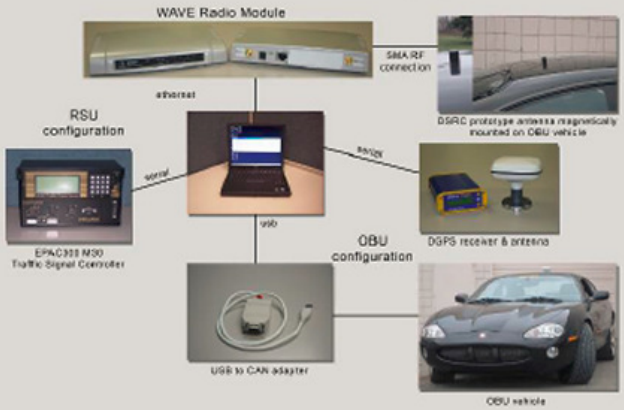
- Many vehicles with V2V, V2I and ADAS systems for “zero” accidents
- Platooning - control speed of all vehicles for best traffic flow with minimum fuel usage and emissions

CAMP – crash avoidance metrics partnership

VSC I
2002 - 2004

CAMP
Vehicle Safety Communications Consortium
DaimlerChrysler Research, Engineering and Design North America Inc. · GM · Toyota · Nissan · VW · Ford · BMW
IVI Light Vehicle Enabling Research Program

DSRC/WAVE Testing System



Potential Safety Applications

Vehicles - Vehicle

- Approaching Emergency Vehicle Warning
- Blind Spot Warning
- Cooperative Adaptive Cruise Control
- Cooperative Collision Warning
- **Cooperative Forward Collision Warning**
- Cooperative Vehicle Highway Automation System
- **Emergency Electronic Brake Lights**
- Highway Merge Assistant
- Highway/Rail Collision Warning
- **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

Vehicle - Infrastructure

- Blind Merge Warning
- **Curve Speed Warning - Rollover Warning**
- Emergency Vehicle Signal Preemption
- Highway/Rail Collision Warning
- Intersection Collision Warning
- In Vehicle Amber Alert
- In-Vehicle Signage
- Just-In-Time Repair Notification
- **Left Turn Assistant**
- Low Bridge Warning
- Low Parking Structure Warning
- Pedestrian Crossing Information at Intersection
- Road Condition Warning
- Safety Recall Notice
- SOS Services
- **Stop Sign Movement Assistance**
- Stop Sign Violation Warning
- **Traffic Signal Violation Warning**
- Work Zone Warning

Draft SAE Message Set

- **Longitude**
- **Latitude**
- **Height**
- **Time**
- **Heading Angle**
- **Speed**
- **Lateral Acceleration**
- **Longitudinal Acceleration**
- **Yaw Rate**
- **Throttle Position**
- **Brake Applied Status**
- **Brake Applied Pressure**
- **Steering Wheel Angle**
- **Headlight Status**
- **Turn Signal Status**
- **Traction Control State**
- **Anti-Lock Brake State**
- **Vehicle Length**
- **Vehicle Width**

Real World V-V Communication Performance

Publications at: http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/060419-0843/

VSC Message Composition

- One common message supports all safety applications.
- Exchange with neighboring vehicles.
- Send periodically (heartbeat) or event-triggered.

SAE J2735 Basic Safety Message (BSM)	
Part I	**Basic Vehicle State Message Part I** (Veh. ID, Seq. #, time, position, motion, control, veh. size) *Part I is mandatory in BSM*
Part II	**Vehicle Event Object** (hard braking, control loss, etc.)
	Vehicle Path History Object
	Vehicle Path Prediction Object
	Relative Positioning RTCM 1002 data

Thank You