VIRGINIA TECH TRANSPORTATION INSTITUTE
Advancing Transportation Through Innovation



# 100-series Breakout: FMVSS Nos. 108, 110, 111, and 126 Translation Update

**Moderator:** Michelle Chaka, VTTI

**Presenters –** Loren Stowe, VTTI, Kevin Kefauver, VT and Global Center for Automotive Performance, Luke Neurauter, VTTI

# Translations Update

Not covered in the April Stakeholder Meeting

FMVSS Nos. 110 and 126

Updated based on feedback from the April Stakeholder Meeting

FMVSS No. 108 and 111

## Crash Avoidance

| | | |
|---|---|---|
| 101 Controls and displays | 110 Tire selection and rims and motor home/recreation vehicle trailer load carrying capacity information | 124 Accelerator control systems |
| 102 Transmission shift position sequence, starter interlock, and transmission braking effect | 111 Rear visibility | 125 Warning devices |
| 103 Windshield defrosting and defogging systems | 113 Hood latch system | 126 Electronic stability control systems for light vehicles |
| 104 Windshield wiping and washing systems | 114 Theft protection and rollaway prevention | 138 Tire pressure monitoring systems |
| 108 Lamps, reflective devices, and associated equipment | 118 Power-operated window, partition, and roof panel systems | 141 Minimum Sound Requirements for Hybrid and Electric Vehicles |

# Crosscutting Themes

| Themes | 101 | 102 | 103 | 104 | 108 | 110 | 111 | 113 | 114 | 118 | 124 | 125 | 126 | 138 | 141 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Congressional Mandate | | | | | | | ● | | ● | ● | | | | ● | ● |
| Controls, Telltales, Indicators, & Alerts | ● | ● | | | ● | | | | ● | | | | ● | ● | |
| Driver (Operator) | ● | ● | ● | ● | ● | | ● | | ● | | ● | ● | ● | ● | |
| Driver/Passenger Position/Presence | ● | ● | | | | ● | | ● | ● | ● | | | ● | | |
| Equipment May Not be Applicable | | | | | ● | | ● | | ● | | | | | | |
| Front/Rear of Vehicle | | | ● | | ● | ● | ● | | | | | | | | ● |
| Service Brake Application | | ● | | | ● | ● | | | ● | | | | ● | ● | ● |
| Shift Position (Gear, Selects, Reverse) | | ● | ● | ● | ● | | ● | | ● | | | | | | ● |
| Vehicle Loading Including Test Driver and Instrumentation | | | | | | ● | | | ● | | | | ● | ● | ● |
| Visibility | | | ● | ● | ● | | ● | ● | | | | | | | |

# FMVSS No. 108 Lamps, Reflective Devices, and Associated Equipment

## Scope

This standard specifies requirements for original and replacement lamps, reflective devices, and associated equipment.

## Purpose

The purpose of this standard is to reduce traffic accidents and deaths and injuries resulting from traffic accidents, by providing adequate illumination of the roadway, and by enhancing the conspicuity of motor vehicles on the public roads so that their presence is perceived and their signals understood, both in daylight and in darkness or other conditions of reduced visibility.

# Crosscutting Themes

- Controls, Telltales, Indicators, and Alerts
- Driver (Operator)
- Equipment May Not be Applicable
- Front/Rear of Vehicle
- Service Brake Application
- Shift Position (Gear, Selects, Reverse)
- Visibility

| Option | Driver | Lighting Functions Controlled by ADS | Turn Signal Lamp Failure or Hazard Lamp Activation | Occupant Compartment Telltales | Telltale Location(s) |
|---|---|---|---|---|---|
| 1 | Driver Definition 1 | Communication of status to ADS <u>not required</u> | Communication of status to ADS required | Turn signal lamp failure and hazard lamp activation | All DSPs |
| 2 | Driver Definition 2 | Communication of status to ADS <u>required</u> | Communication of status to ADS required | Turn signal lamp failure and hazard lamp activation | All DSPs |
| 3 | Driver Definition 1 | Communication of status to ADS <u>not required</u> | Communication of status to ADS required | Retains all telltales provided for human drivers | Left, front DSP, maintance panel, and/or manufacturer specified DSP(s) |

# Summary of Updates

- Added an option under which information that is currently provided through a telltale to remind a human driver of his or her prior selection (such as activation of the upper beams or the turn signals) would not need to be provided to the ADS because the ADS would not "forget" that the lamps had been activated.
- Provided additional alternatives for what and where information must be communicated to one or more occupants and/or to the ADS.
- Further clarified translation languages (e.g., removed references to driver).

# Translation Considerations

- FMVSS is an equipment standard and may require limited translations to remove the identified regulatory barriers.
- There may be opportunities to research system performance requirements that are specific to ADS-DV sensor capabilities (e.g., whether upper beam headlamps should be required for ADS-DVs).

# FMVSS No. 110 Tire Selection and Rims and Motor Home/Recreation Vehicle Trailer Load Carrying Capacity Information

# Scope and Purpose

This standard specifies requirements for tire selection to prevent tire overloading and for motor home/recreation vehicle trailer load carrying capacity information.

# Crosscutting Themes

- Driver/Passenger Position/Presence
- Front/Rear of Vehicle
- Service Brake Application
- Vehicle Loading Including Test Driver and Instrumentation

# A couple of the key translation aspects of FMVSS No. 110

- Vehicle Placard, which is generally located on the driver's side B-pillar as shown to the top right of the slide.
- Maximum Tire Loading, which uses the FMVSS No. 110 Table 1 based on seating patterns as shown to the bottom right of the slide.


TABLE I—OCCUPANT LOADING AND DISTRIBUTION FOR VEHICLE NORMAL LOAD FOR VARIOUS DESIGNATED SEATING CAPACITIES

| Designated seating capacity, number of occupants | Vehicle normal load, number of occupants | Occupant distribution in a normally loaded vehicle |
|---|---|---|
| 2 through 4 | 2 | 2 in front. |
| 5 through 10 | 3 | 2 in front, 1 in second seat. |
| 11 through 15 | 5 | 2 in front, 1 in second seat, 1 in third seat, 1 in fourth seat. |
| 16 through 22 | 7 | 2 in front, 2 in second seat, 2 in third seat, 1 in fourth seat. |

https://www.google.com/search?rlz=1C1GCEU_enUS819US819&biw=1280&bih=530&tbm=isch&sa=1&ei=7zbyW8SNKeyxggengb2gCQ&q=car+door+b+pillar+and+placard+label&oq=car+door+b+pillar+and+placard+label&gs_l=img.3...41932.46823..47200...0.0..0.93.1529.18......0....1..gws-wiz-img.......0i30.LO1doo1T0co#imgdii=YxzmUav-fn5RzM:&imgrc=YGuqd6SoVB07qM:

| Option | Driver | Placard Location | Tire Loading | Additionally Research May Be Beneficial |
|---|---|---|---|---|
| 1 | Driver Definition 1 | Translates “driver’s side” B-pillar to “left, front side” B-Pillar” | Retains the current tire loading patterns | n/a |
| 2 | Driver Definition 2 | Applies an alternative frame of reference (e.g., the VIN label) to locate Placard | Applies an alternative frame of reference (e.g., the VIN label) for loading patterns | • |
| 3 | Driver Definition 1 | Replaces the reference to the “driver's side B-pillar” with the “left side B-pillar” | Replaces Table 1 with an occupant loading and distribution procedure [or “table”] that would determine occupant placement for maximum tire loading. | • |

# Translation Considerations

- There are a few areas that may require additional research; for example, the current regulations assume a human driver and typical seating pattern (e.g., front passenger) in determining the normal tire loading requirements.
- A new approach for determining the tire loading may be needed.

# FMVSS No. 111 Rear Visibility

## Scope

This standard specifies requirements for rear visibility devices and systems.

## Purpose

The purpose of this standard is to reduce the number of deaths and injuries that occur when the driver of a motor vehicle does not have a clear and reasonably unobstructed view to the rear.

# Crosscutting Themes

- Driver/Operator
- Front/Rear of Vehicle
- Shift Position
- Visibility

# Summary of Updates

- Initial Translation Approach: Clarified that the standard is intended for vehicles that can be operated by a human driver and would not apply to ADS-DVs
  - SME process – majority (71%) agreed with that approach; some (29%) believed standard should apply to ADS-DVs [see comment in e-mail]
  - During April Stakeholder meeting obtained additional feedback to consider field of view (FOV) translation option.
- FOV translation option included.  Recently, we conducted a second round of SME review.

# Translation Overview

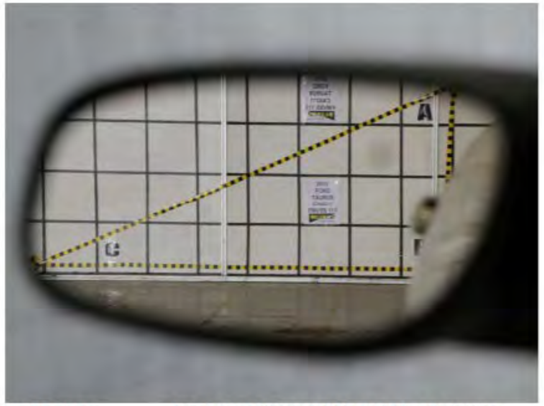
- Option 1: translate to clarify that the requirements apply only to human-driven vehicles

- Option 2: translate to incorporate analogous field of view (FOV) requirements that would apply to ADS-DVs

The backup camera in the all-new 2019 Ram 1500 displays what's behind the truck when the driver shifts into reverse.

2010 FORD TAURUS
NHTSA NO. CA0211
FMVSS NO. 111

FIGURE 18:RIGHT EYE FIELD OF VIEW TEST (INSIDE MIRROR)



2010 FORD TAURUS
NHTSA NO. CA0211
FMVSS NO. 111

FIGURE 20:LEFT EYE FIELD OF VIEW TEST (DRIVER SIDE MIRROR)

# Translation Considerations

- Option 1: translate to clarify applicability
  - Only requires translating S3. “Application”
  - Considerations noted for potential visibility requirements for ADS-DVs
- Option 2: translate to apply FOV requirements to ADS-DVs
  - Possibly apply existing rearward visibility FOV requirements to ADS sensors
  - Several test procedures alternatives are outlined
  - The translation would not address what the ADS-DV should do upon object detection

# FMVSS No. 126 Electronic Stability Control Systems for Light Vehicles

## Scope

This standard establishes performance and equipment requirements for electronic stability control (ESC) systems.

## Purpose

The purpose of this standard is to reduce the number of deaths and injuries that result from crashes in which the driver loses directional control of the vehicle, including those resulting in vehicle rollover.

# Crosscutting Themes

- Controls, Telltales, Indicators, and Alerts
- Driver (Operator)
- Driver/Passenger Position/Presence
- Service Brake Application

# Translation Overview

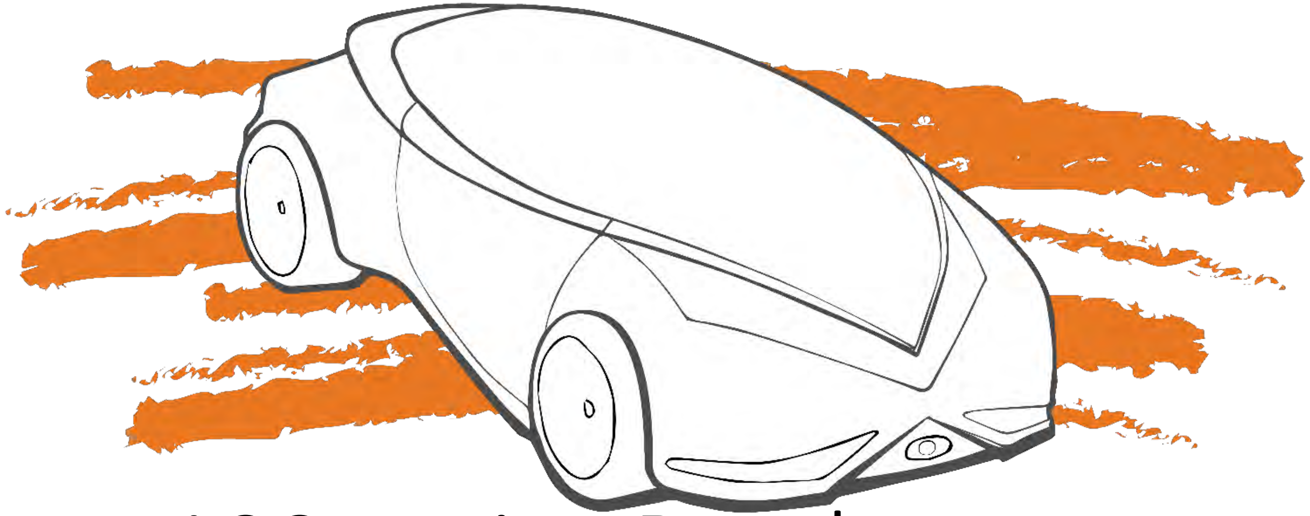
- Option 1
  - Establishes an equivalency between a human driver and an ADS.
  - Current steering wheel inputs are generalized as inputs into the steering system of the ADS-DV.
- Option 2
  - Removes references to the driver or specifies driver as “human driver” or “ADS.”
  - Steering wheel and steering wheel angle are defined generically.
- Option 3
  - Uses the road wheel angle as the reference for the steering inputs.

# Translation Considerations

- Option 1
  - Eliminates reference to steering wheel.
  - Novel steering system configurations may require additional information regarding the steering system to conduct the specified tests.
- Option 2
  - Two new definitions allow references to steering wheel and steering wheel angle to remain.
  - May require additional information regarding steering system
- Option 3

  Measuring road wheel angle could introduce additional technical challenges.

# Questions?



## 100-series Breakout: FMVSS Nos. 108, 110, 111, and 126 Translation Update

# 100-series Breakout: Test Procedure Overview

**Moderator:** Loren Stowe, VTTI

**Presenters:** Loren Stowe, VTTI, Michelle Chaka, VTTI

Kevin Kefauver, Virginia Tech and The Global Center for Automotive Performance Simulation

# Overview

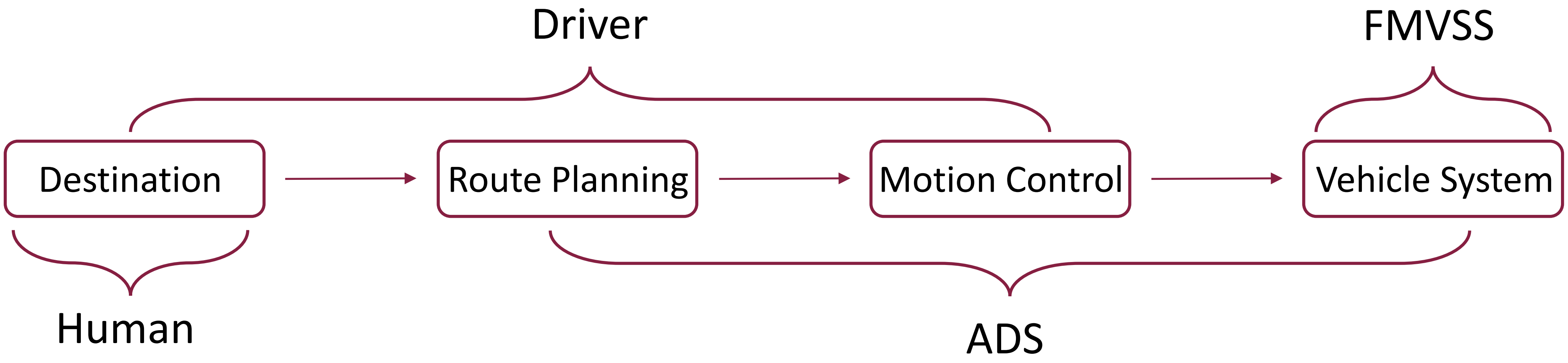
- Review
- Vehicle-based Test Methods
- Non-vehicle-based Test Methods
  - Documentation
  - Simulation
- Discussion

# Test Method Introduction

- Remove barriers associated with compliance verification
- Identify means and the associated considerations that could be utilized to verify compliance to the FMVSS
- Basic premise – there is something associated with the vehicle that may preclude verification of compliance as performed today

# Basic Driving Task

Currently a clear distinction between the system and control of the system




What happens when that line does not exist?

- ODD considerations
- Localization
- Operation during malfunction?

# Test Methods Being Evaluated

## Vehicle-based

- Human control
- Programmed control of the ADS
- ADS normal operation

## Non-vehicle-based

- Technical Design Documentation
- Simulation

# Test Procedure Approach

- Classification of standards
- Selection of standards for inclusion
  - Development of generic test procedures
- Implementation and execution
- Evaluation of test methods
- Iteration of testing and evaluation of results as necessary
- Validation

# Identified Vehicle Functionalities

| Theme | Functionality |
|---|---|
| Driving Task | Steering control |
| | Speed control (veh/eng) |
| | Service brake application |
| | Parking brake |
| | Gear selection |
| Vehicle Comm. | Telltales/warnings/ indicators |

| Theme | Functionality |
|---|---|
| Key/Ignition Function | Key insertion/removal |
| | Ignition start/stop |
| | Accessory mode |
| Non-driving Tasks | Door open/close |
| | Non-driving controls |
| Environment Awareness | Visibility |

# FMVSS Vehicle Functionalities Distribution

| Category | Functionality | 101 | 102 | 103 | 104 | 108 | 110 | 111 | 113 | 114 | 118 | 124 | 125 | 126 | 138 | 141 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Driving Tasks | Steering control | | | | | | ● | ● | | ● | | | | ● | ● | ● |
| | Speed control (vehicle/engine) | | | ● | ● | | ● | ● | | ● | | ● | | ● | ● | ● |
| | Service brake application | | | | | | ● | ● | | ● | | | | ● | ● | ● |
| | Parking brake | | | | | | | ● | | ● | | | | | | ● |
| | Gear selection | | ● | ● | ● | | ● | ● | | ● | | | | ● | ● | ● |
| Vehicle Communications | Telltales/warnings/indicators | ● | ● | | | ● | | | | ● | | ● | | ● | ● | |
| Key/Ignition Function | Key insertion/removal | | | | | | | | | ● | | | | | | |
| | Iginition start/stop | | ● | ● | ● | | ● | ● | | ● | ● | ● | | ● | ● | |
| | Accessory mode | | | | | | | | | ● | ● | | | | | |
| | Door open/close | | | | | | | | | ● | ● | | | | | |
| Non-driving Tasks | Non-driving controls | | | ● | ● | ● | | ● | | | ● | | | | | |
| Environment Awareness | Visibility | ● | | ● | ● | | | ● | ● | | | | | | | |

# Classification Analysis for Standards

| FMVSS No. | Test Procedure | Specific Sequence | Driving Task | Method* |
|---|---|---|---|---|
| 101 | No | No | No | n/a |
| 102 | No | No | No | HC, D |
| 103 | Yes | No | Yes | HC, P, D |
| 104 | Yes | No | Yes | HC, P, D |
| 108 | Yes | No | No | n/a |
| 110 | Yes | No | Yes | HC, P, ADS(?) |
| 111 | Yes | No | Yes | HC, P, ADS, D |
| 113 | No | n/a | n/a | n/a |

| FMVSS No. | Test Procedure | Specific Sequence | Driving Task | Method* |
|---|---|---|---|---|
| 114 | Yes | Yes | Yes | HC, P, D |
| 118 | Yes | Yes | No | HC, D, ADS(?) |
| 124 | No | n/a | n/a | HC, P |
| 125 | Yes | No | No | n/a |
| 126 | Yes | Yes | Yes | HC(?), P, ADS(?), S |
| 138 | Yes | No | Yes | HC, P, ADS, D |
| 141 | Yes | Yes | Yes | HC, P, ADS, D |

** HC = human control; P = programmed; ADS = normal ADS operation; S = simulation; D = documentation; n/a = current verification method may be adequate; (?) = may be possible*

# Test Functionalities for Purposes of Compliance Verification

| Category | Functionality |
|---|---|
| Basic Driving | Steering control |
| | Speed control |
| | Service brake application |
| | Parking brake |
| | Gear selection |
| Vehicle State | Telltales/ warnings/ indicators/non-driving controls |

| Category | Functionality |
|---|---|
| Accurate and Precise Control | Steering |
| | Speed |
| | Brake |
| Engine Idle | Engine speed |
| Visibility | Mirrors/camera |

# Functionality-Based Test Matrix (Example)

| | Description | Comment | Output Record/display | Steering control general | Steering control specific | Speed control (veh./eng.) general | Speed control (veh./eng.) specific | Service brake general | Service brake specific | Parking brake | Gear state | Ignition on/off |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Theme Driving Task | Position vehicle at starting location | Manual control | | | | | | | | | | |
| | Apply service brake | Assumes key in system | | | | | | ● | | | | |
| | Start engine | Undefined sequence | | | | | | ● | | | ● | ● |
| | Shift transmission to drive | | Transmission state | | | | | | | | ● | |
| | Release service brake | | Brake state | | | | | ● | | | | |
| | Navigate to specified location and stop | Requires steering and braking control | Position tolerance x/y=1.5m | ● | opt. | ● | opt. | ● | | | ● | |
| | Apply parking brake | | Parking brake state | | | | | | | ● | | |
| | Shift transmission to park | | Transmission state | | | | | | | | ● | |
| | Release service brake | | Brake state | | | | | ● | | | | |
| | Disengage parking brake | Shows control of service brake independent of ADS normal control | Parking brake state | | | | | | | ● | | |
| | Turn off engine | | Parking brake state | | | | | | | | | ● |

*See "FMVSS_Generic functionality testing - Phase 1_v1.xlsx"*

# Test Methods Being Evaluated

## Vehicle-based

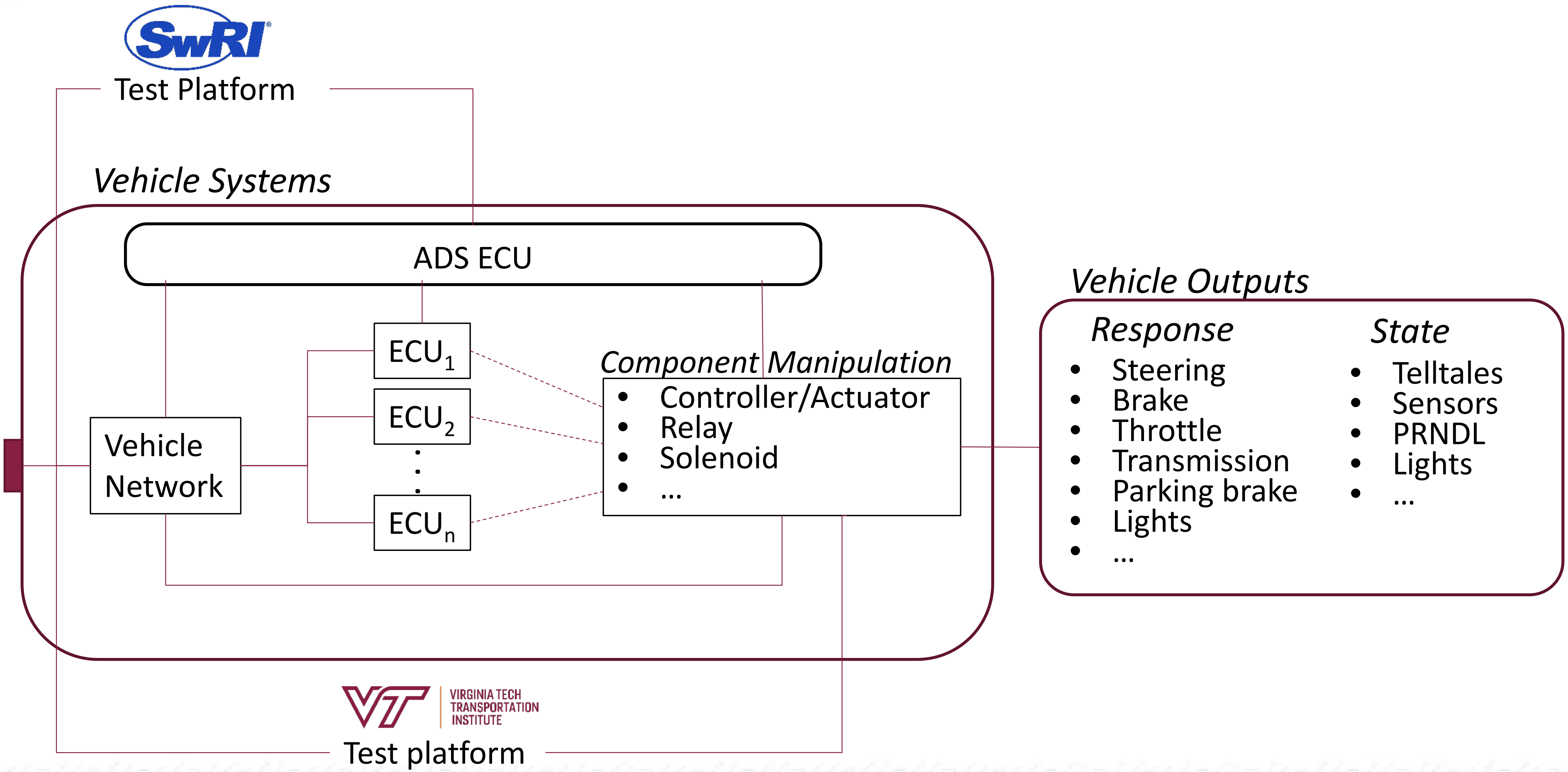
- Human control
- Programmed control of the ADS
- ADS normal operation

## Non-vehicle-based

- Technical Design Documentation
- Simulation

# Approach

- Develop test platform for proof of concept
- Implement and execute test procedures identified in during classification exercise
- Implement and execute test procedures on additional ADS vehicles or test platforms


SwRI
Test Platform
Vehicle Systems
ADS ECU
ECU$_1$
ECU$_2$
ECU$_n$
Vehicle Network
Component Manipulation
• Controller/Actuator
• Relay
• Solenoid
• …
Vehicle Outputs
Response
• Steering
• Brake
• Throttle
• Transmission
• Parking brake
• Lights
• …
State
• Telltales
• Sensors
• PRNDL
• Lights
• …
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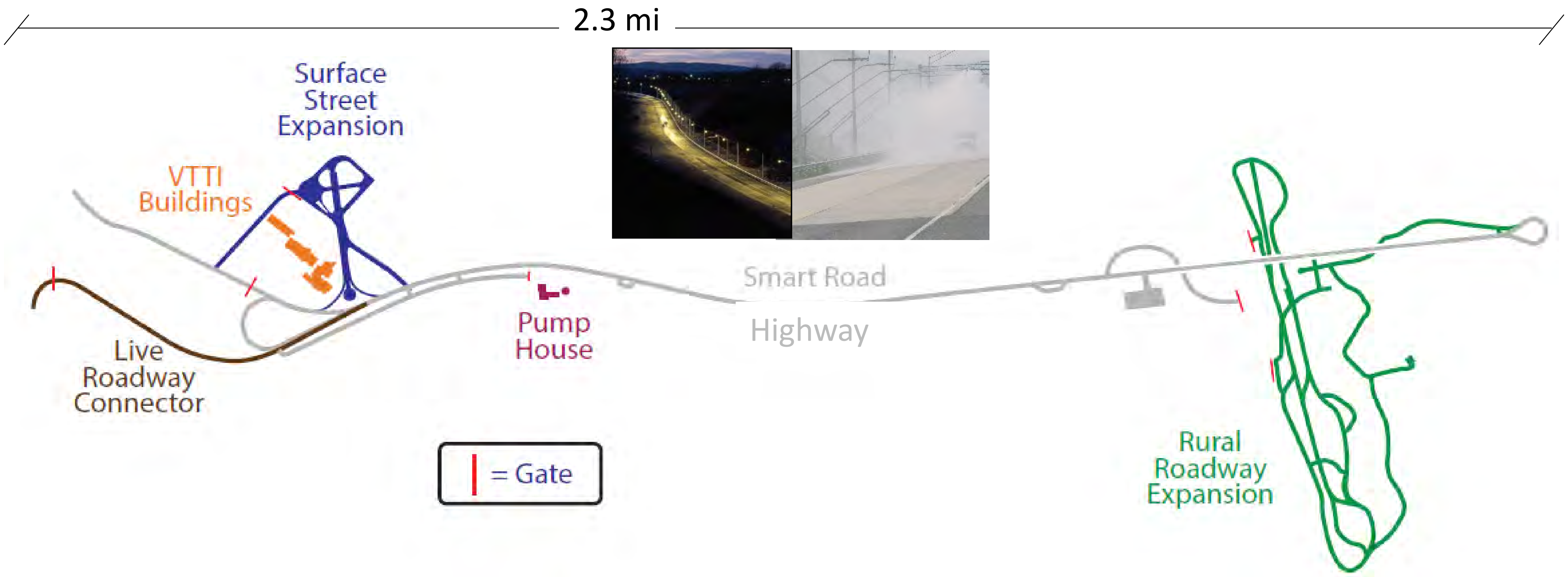
Test platform

# VTTI Test Platform

Cadillac SRX modified to include ADS functionality

| Function | Control |
|---|---|
| Steering | Motor attached to steering shaft between steering wheel and steering gear |
| Accelerator | Tap into sensor signals |
| Service brake | Motor attached to brake pedal |
| Transmission | Linear actuator attached to shift mechanism |
| Parking brake | Tap into electrical signal |
| Ignition | Tap into electrical signal |

# VTTI Track Facilities in Blacksburg, VA

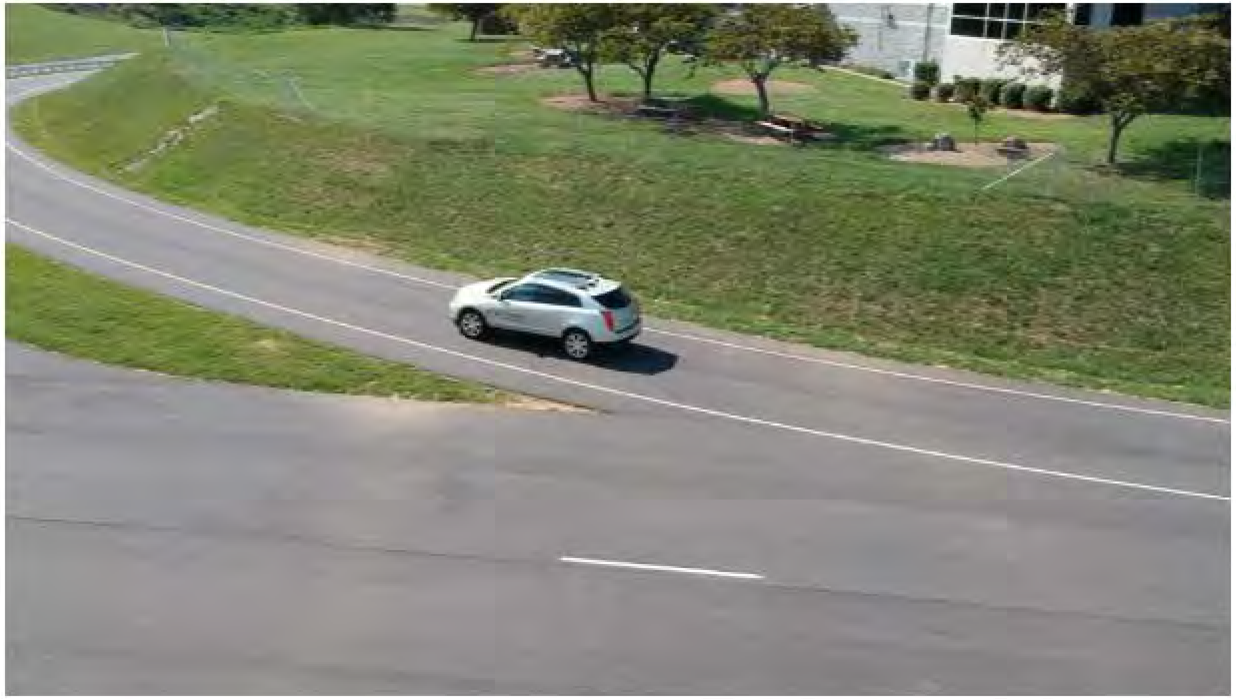


# Tests Executed or in Development

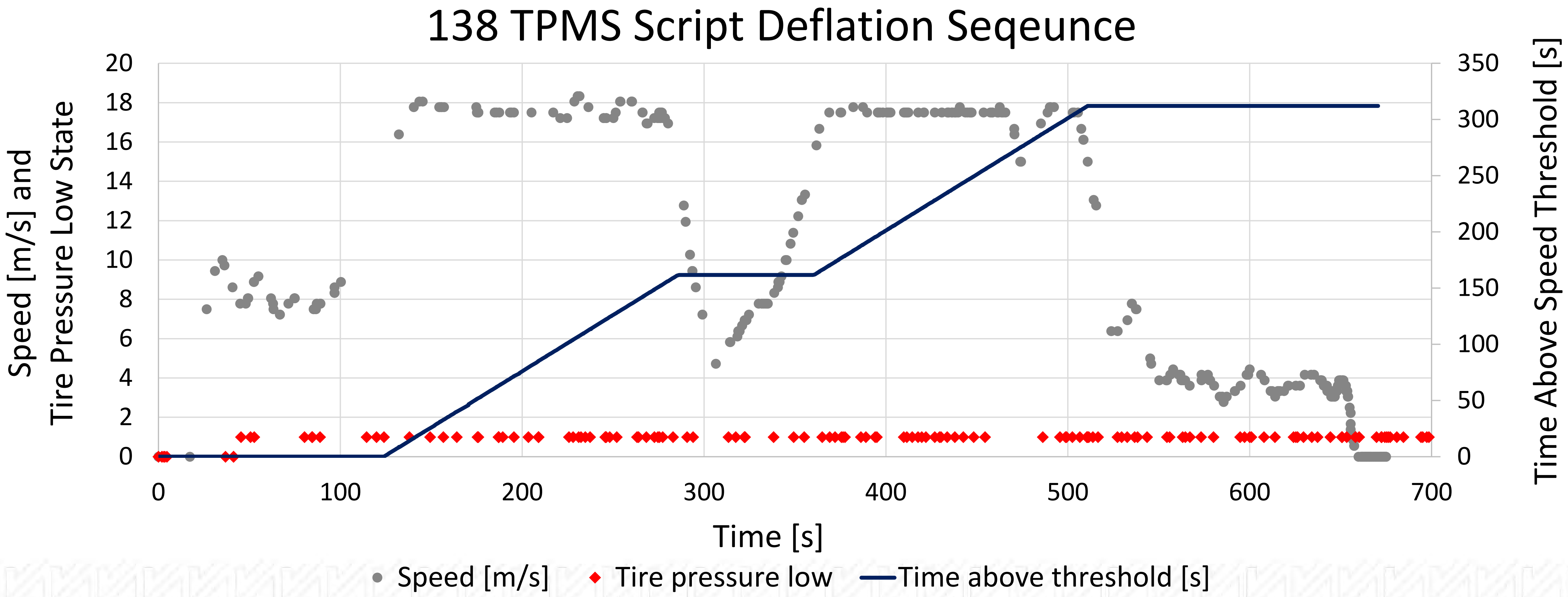
- Basic Driving (based on FMVSS Nos. 114 and 138)
  - Accurate and precise steering and speed
  - Nominal route following based on destination selection
  - Specific control over vehicle functions (brake, service brake)
- Vehicle State Monitoring
  - Tire pressure
  - Transmission state
- Specific Steering Control
  - FMVSS No. 126 sine-with-dwell

# Precise Driving (114): Preprogrammed Control

# Basic Driving (138): Preprogrammed Control

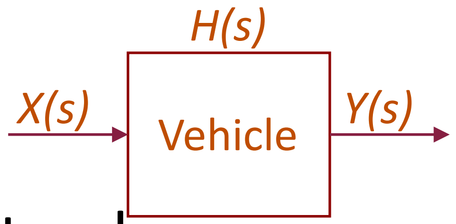


# Sample Test Data – Basic Driving/State Monitoring



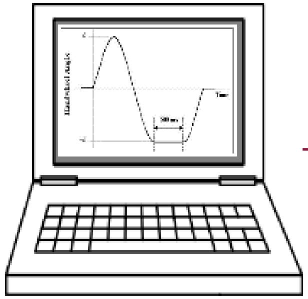
# Current Activity

# FMVSS No. 126 Vehicle Test Overview




- Vehicle conditioning
- Vehicle characterization: Slowly increasing steer (SIS) test
  - Purpose: establish relationship between steered input and lateral acceleration of vehicle for the linear range of the vehicle using controlled input
  - Output: initial conditions for ESC test
- ESC test: Sine-with-Dwell (SWD) test
  - Purpose: methodically increase magnitude for double lane change type maneuver at fixed speed to cause ESC to activate
  - Output: vehicle response (yaw rate) during ESC operation

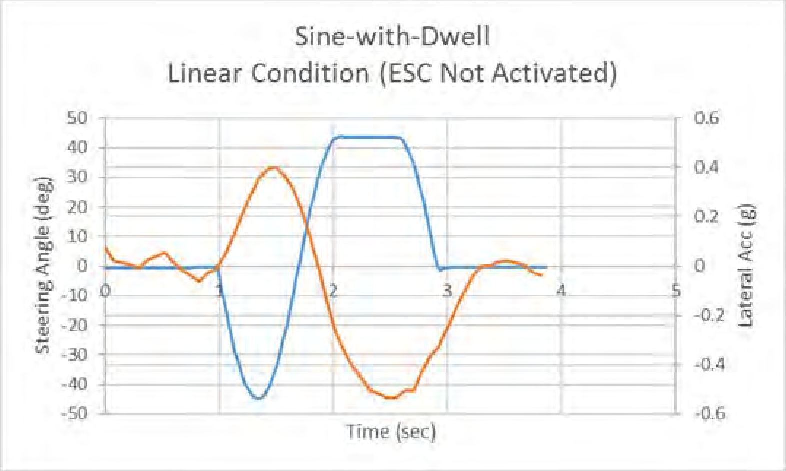
# FMVSS No. 126 Test: Conventional Controls



**d**

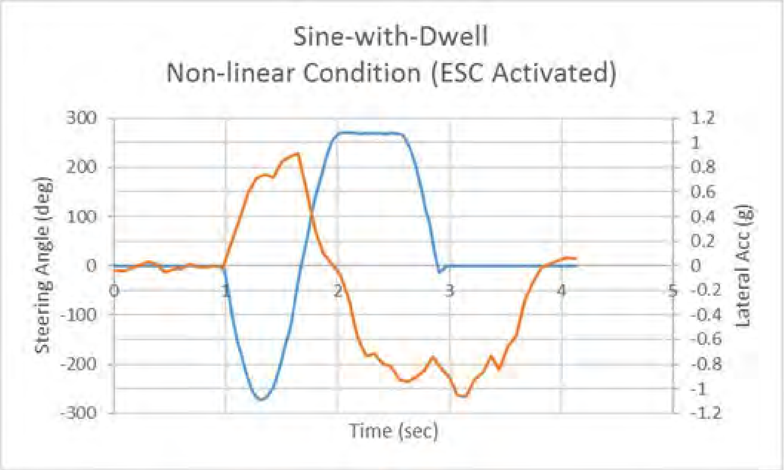
Automatic steering controller

$\mathbf{d_0}$




$\mathbf{d_0}$ = 42 deg.

⋮



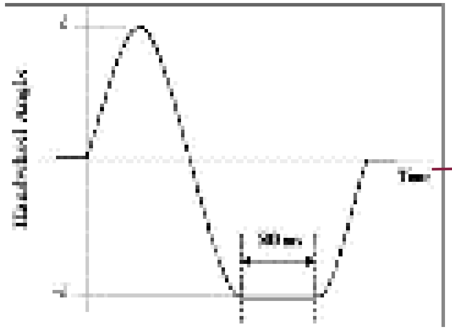

$\mathbf{d_f}$ = 270 deg.

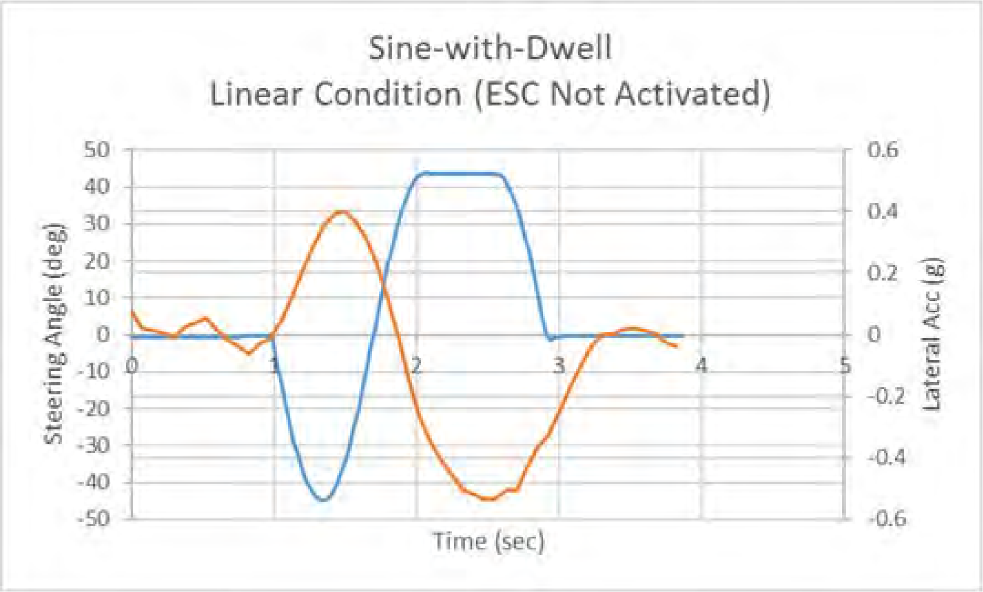
Where
  **d**= steering amplitude
With
  $\mathbf{d_0} = 1.5*d_{0.3g}$
And
  $\mathbf{d_i} = \mathbf{d_{i-1}} + 0.5*\mathbf{d_0}$
Up to $6.5*\mathbf{d_0}$ or 270 deg.

# FMVSS No. 126 Test: Vehicle-based Methods

**Pre-programmed control**

- Resides on vehicle
- Resides on plug-in module

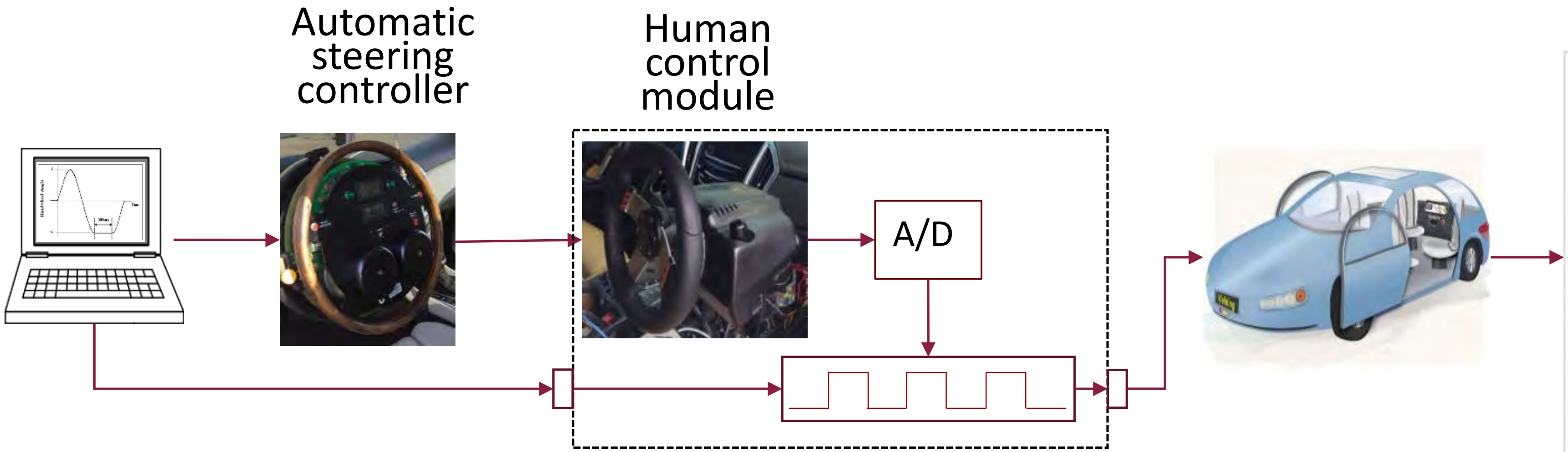


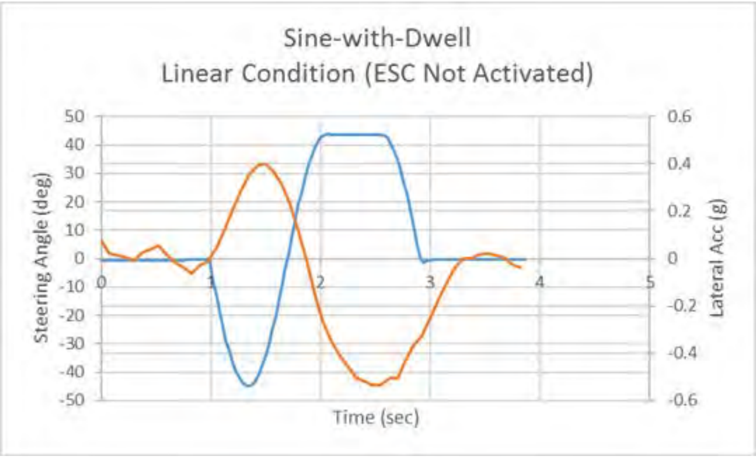


# FMVSS No. 126 Test: Vehicle-based Methods

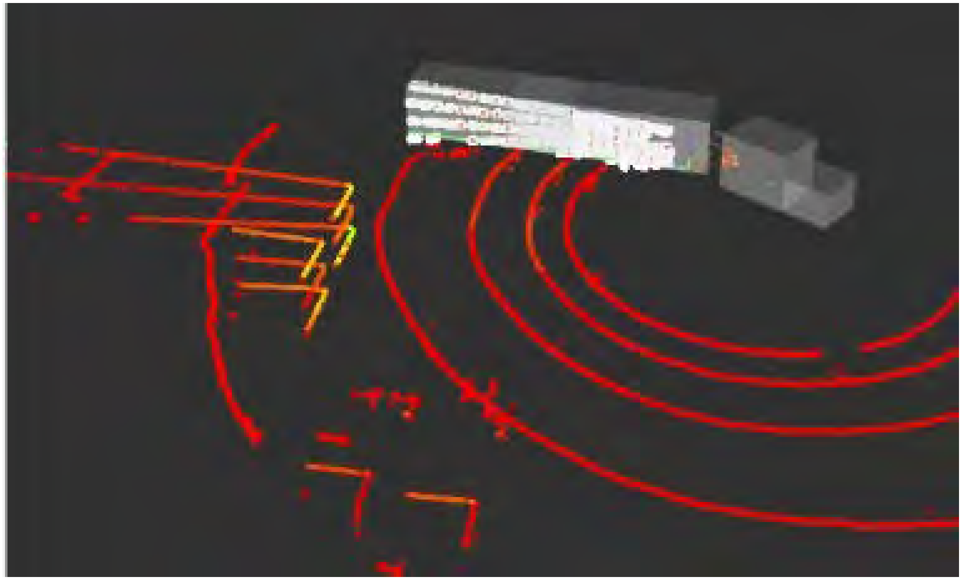
**Human control**

- Surrogate steering wheel
- Steering wheel not required



# Sample Test Data – Visibility

# Independent Implementation and Assessment of Vehicle-based Test Method

# SwRI Independent ADS-Equipped Research Vehicle Testing

- Alternate execution of generic tests
  - ADS-equipped research vehicle with different architecture and capabilities
- Note special considerations
  - Design/implementation differences that may impact testing
  - Availability (or lack thereof) of required data
  - Required procedural differences

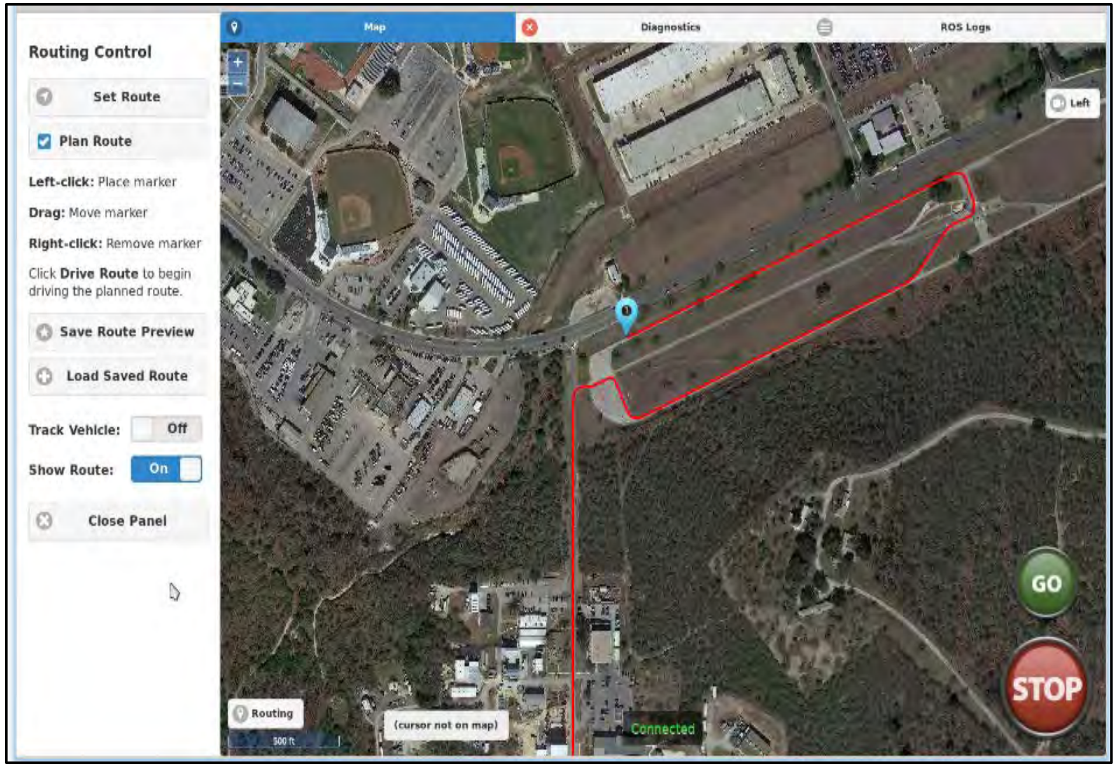
# SwRI ADS-Equipped Research Vehicle

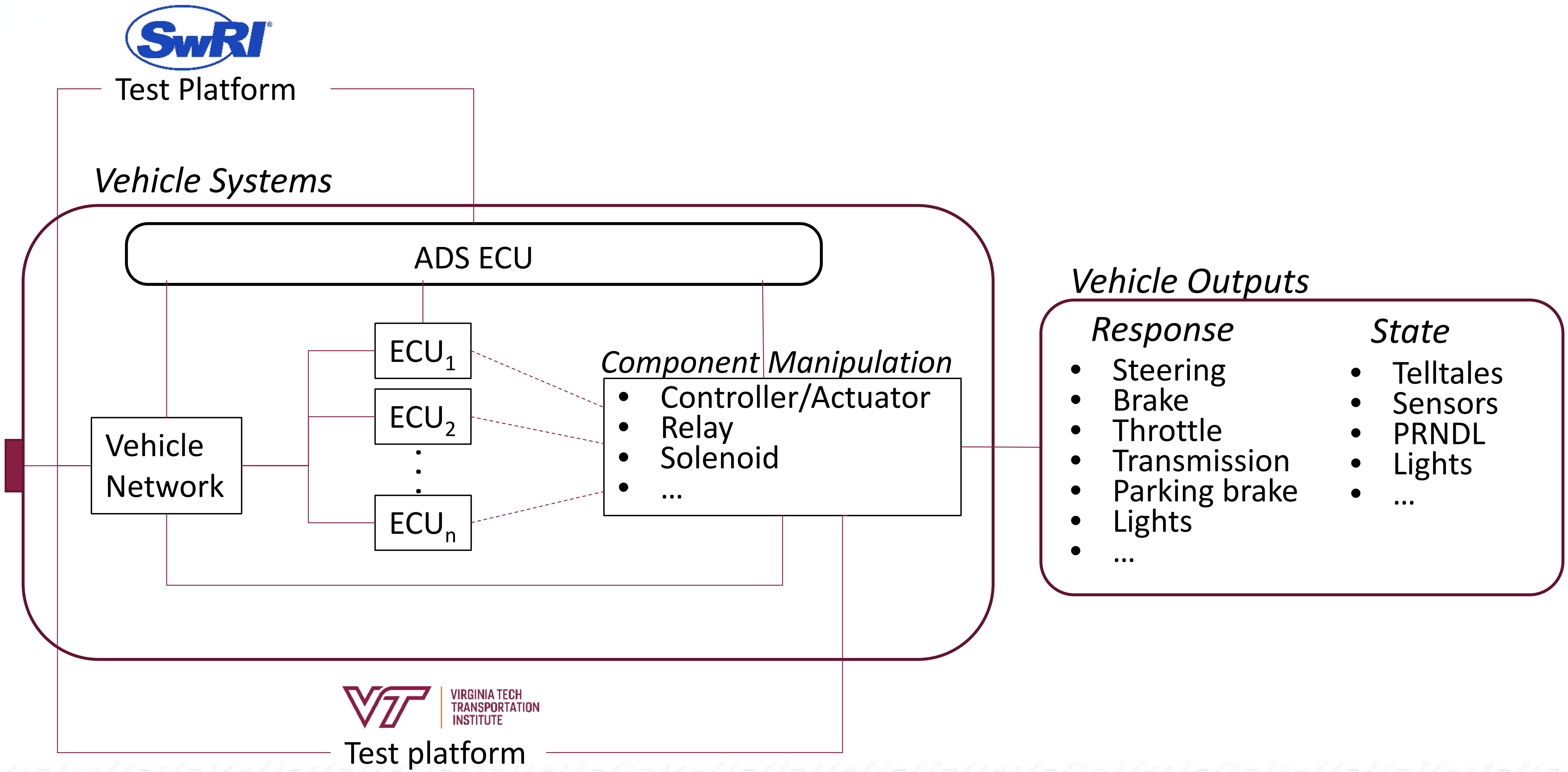
- AutonomouStuff Lincoln MKZ
  - Velodyne VLP-16, Delphi ESR, Stereovision
  - SwRI Ranger system, GPS, IMU
  - SwRI Tablet UI

- SwRI-developed ADS software for perception, localization, situational awareness, navigation, and control
  - Leverages open-source Robot Operating System (ROS) framework
  - Driverless operation with occupant waypoint/destination selection

# SwRI ADS-Equipped Research Vehicle

- Digital map loaded via tablet UI
  - User selects desired destination
  - Research ADS plans route
  - User approves route and initiates ADS operation
- Pure pursuit steering control
- Gas/Brake PID control

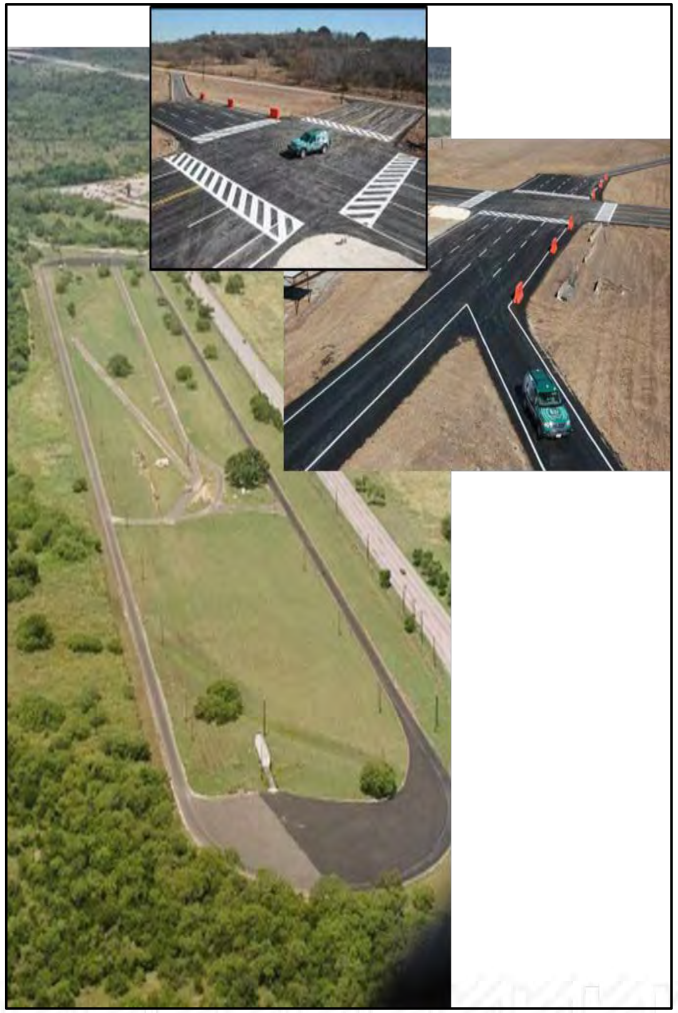



Test Platform
Vehicle Systems
ADS ECU
ECU$_1$
ECU$_2$
ECU$_n$
Vehicle Network
Component Manipulation
• Controller/Actuator
• Relay
• Solenoid
• …
Vehicle Outputs
Response
• Steering
• Brake
• Throttle
• Transmission
• Parking brake
• Lights
• …
State
• Telltales
• Sensors
• PRNDL
• Lights
• …
VIRGINIA TECH TRANSPORTATION INSTITUTE
Test platform

# SwRI Testing Facilities

- SwRI Test Track
  - 1.93km single-lane outer loop
  - Multi-lane signalized intersection
  - Controlled access

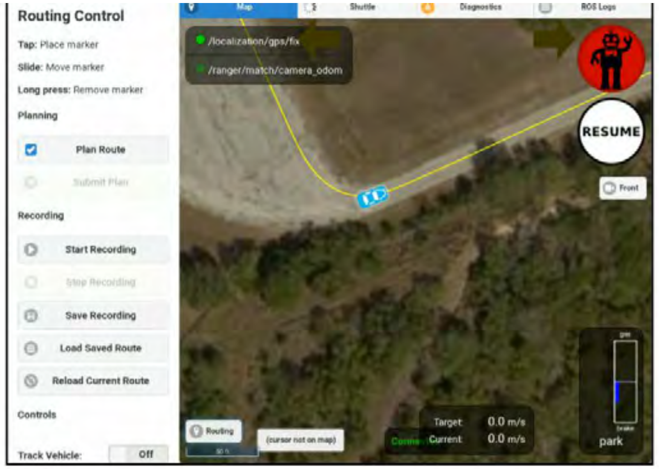
- Full SwRI Ranger map coverage with defined lanes, directionality, stop points, entry/exit points, etc.



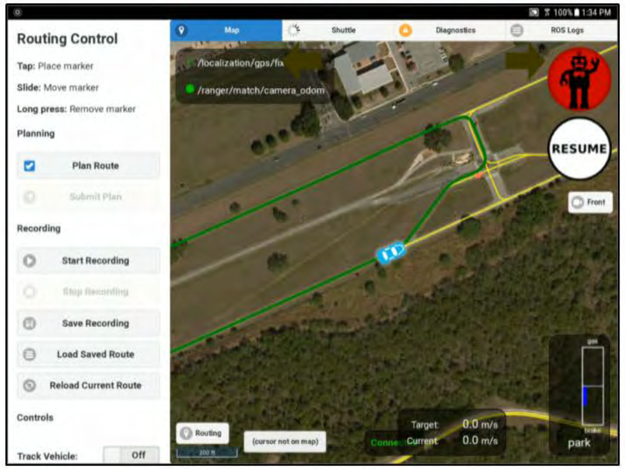
# Generic Testing

- Basic Driving
  - Accurate and Precise Steering and Speed
  - Nominal route following based on destination selection
- Vehicle State Monitoring
  - e.g., tire pressures, door state
  - Test activation/deactivation of safety telltales, etc.
- Visibility
  - Test onboard sensing system(s)

# Basic Driving

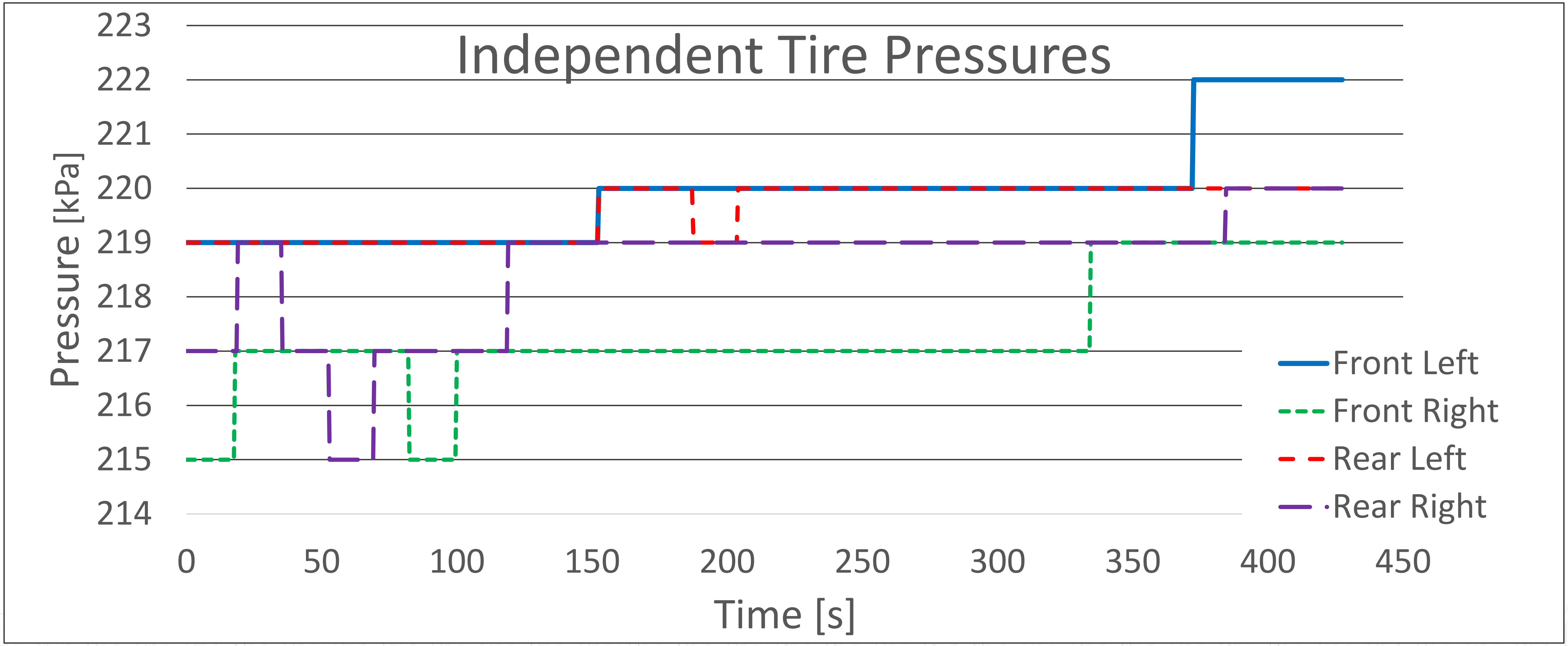



# Accurate and Precise Steering and Speed

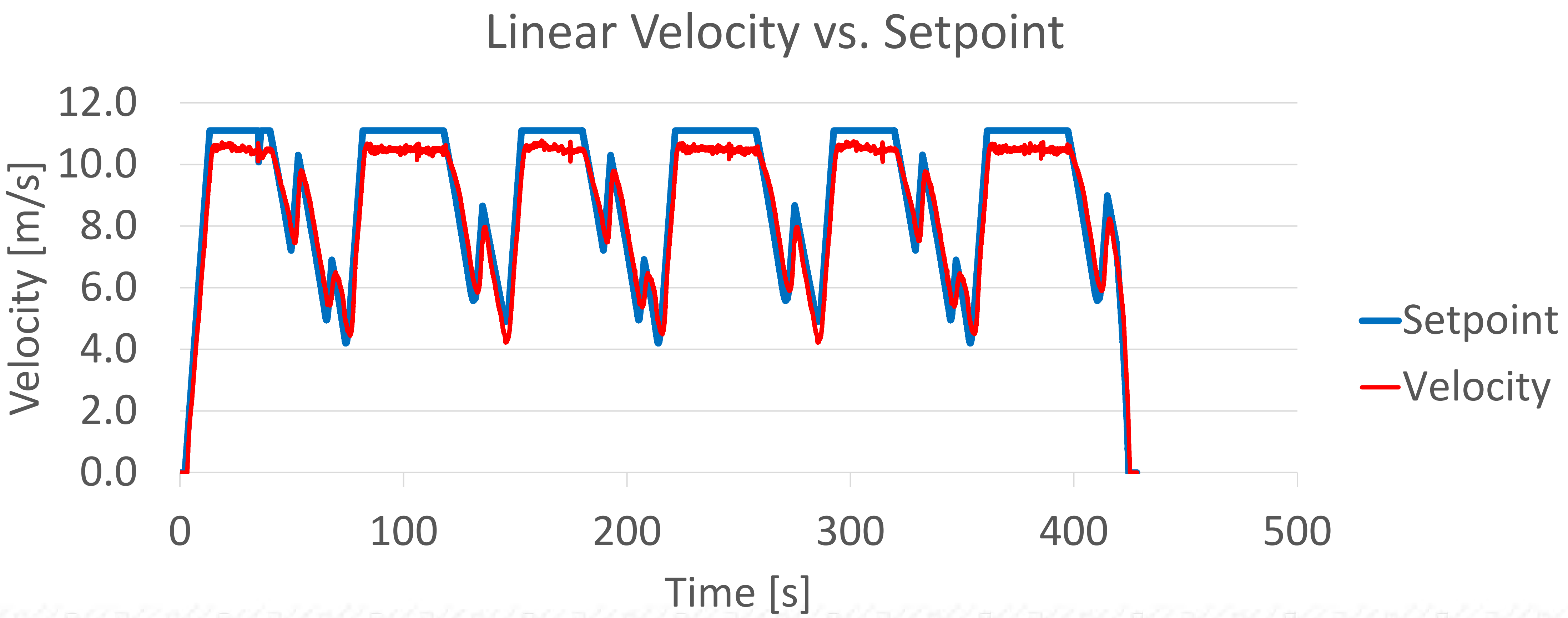



– Draft

# Sample Test Data – Vehicle State Monitoring



# Sample Test Data – Vehicle Control: Speed



# Sample Test Data – Visibility

- Object detection: LiDAR obstacle list


```
▼ header
    seq: 21280
  ▼ stamp
      secs: 1541693808
      nsecs: 863854000
    frame_id: odom
▼ obstacles
  ▼ [0]
      id: 243
    ▶ pose
    ▼ polygon
      ▼ [0]
          x: 572.769043
          y: 310.632324
          z: -614.737732
      ▼ [1]
          x: 573.008362
          y: 310.854553
          z: -614.722961
      ▼ [2]
          x: 572.813538
          y: 310.066284
          z: -614.829285
```

# Observations From Implementation and Test Execution

# Observations

- Traditional production vehicle adapted for ADS
- Research vs. production
- Discrepancies between standardized test steps and actual procedures
- ADS configuration changes required for some tests
- Digital mapping requirements (SwRI Ranger system)

# Adapted Production Vehicle

- Current production vehicles have interfaces and features that may not be present or available on future ADS-DV
- Examples:
  - Existing manual control interfaces used
    - Steering wheel, brake pedal, gas pedal, gear shift, parking brake
  - Vehicle state telltales and indicators present
    - TPMS, fuel level, turn signals, etc.

# Research vs. Production

- ADS-equipped research vehicle affords accessibility that may not be true in production ADS-DV
- Examples:
  - Ability to inject control signals directly
  - Ability to modify ADS source code, if necessary
  - Ability to modify ADS configurations, if necessary
  - Access to data interfaces to record required data

# Procedural Differences

- For vehicle without direct input control, not all FMVSS or generic test procedures could be exactly followed as result of ADS design or implementation
- Examples:
  - SwRI research vehicle does not manage parking brake or engine start/stop
  - SwRI research vehicle leverages key fob which does not require physical insertion

# Configuration Changes

- Some configuration changes may be necessary to enable some testing

- Examples:
  - Maximum speeds associated with digital maps may need changed
  - SwRI steering control constrained by speed (among other things)
  - Physical hardware may be incapable of executing tests (e.g., 126 force and rate requirements)

# Localization

- Some testing facilities may not be included in digital maps, roadway features or sufficient GPS coverage required by some ADS-equipped vehicles

- Examples:
  - SwRI ADS-equipped research vehicle requires SwRI Ranger maps for localization and routing
  - VTTI GPS occlusion by geographic features
  - Lack of lane markings

# Non-vehicle-based Test methods

# Test Methods Being Evaluated

## Vehicle based

- Human control
- Programmed control of the ADS
- ADS normal operation

## Non-vehicle based

- Technical Design Documentation
- Simulation

# Introduction

Non-vehicle based approaches to verify compliance with the FMVSS are not used today.

- One exception to this is a small portion of FMVSS No. 126 (e.g., over/understeer migration requirements).
- Production vehicles are tested to ensure that the vehicle, as manufactured, meets the FMVSS requirements.
- This may allow NHTSA to verify the adequacy of the manufacturer's quality control systems, manufacturing processes, and materials.
- One concern with using non-vehicle based test methods is whether they will allow verification of the compliance of actual production vehicles, and not just the theoretical design of a vehicle or system.

# Non-Vehicle Based Test Methods Introduction

NHTSA's Automated Vehicle 3.0 states the following:

*"Other approaches, such as computer simulation and requirements expressed in terms of mathematical functions could be considered, as Federal law does not require that NHTSA's safety standards rely on physical tests and measurements, only that they be objective, repeatable, and transparent."*

# Non-Vehicle Based Test Methods Introduction

Development and evaluation of non-vehicle based test methods that identify potential options that may be suitable for FMVSS compliance verification

- The project is evaluating the potential use of
  - simulation for FMVSS No. 126 and
  - technical design documentation for FMVSS No. 138
- It is important to note that a determination that a non-vehicle based test method is appropriate for one standard does not mean that it would be appropriate or suitable for other standards.

# Test Methods Being Evaluated

## Vehicle based

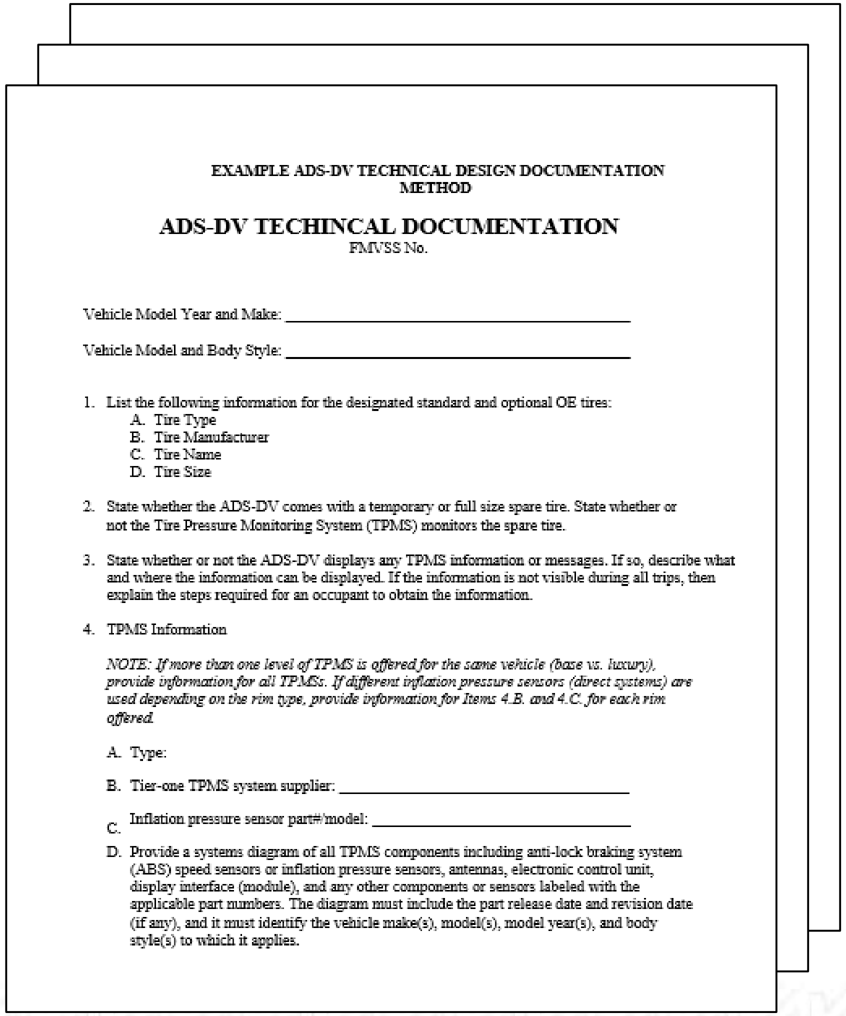
- Human control
- Programmed control of the ADS
- ADS normal operation

## Non-vehicle based

- Technical Design Documentation
- Simulation

# Technical Design Documentation Introduction

- The approach taken is to expand upon the Test Specification Forms currently used by OVSC.
- Manufacturers complete these Forms and submit them to OVSC after a vehicle is selected for potential testing.
- The Forms vary, but they generally request some, but not all, of the information needed to verify that a vehicle complies with an FMVSS.
- The following example is a subset of the type of information that may be required using this method. The presentation does not walk-through the entire standard.



EXAMPLE ADS-DV TECHNICAL DESIGN DOCUMENTATION METHOD

**ADS-DV TECHINCAL DOCUMENTATION**

FMVSS No.

Vehicle Model Year and Make: ____________________

Vehicle Model and Body Style: ____________________

1. List the following information for the designated standard and optional OE tires:
   A. Tire Type
   B. Tire Manufacturer
   C. Tire Name
   D. Tire Size
2. State whether the ADS-DV comes with a temporary or full size spare tire. State whether or not the Tire Pressure Monitoring System (TPMS) monitors the spare tire.
3. State whether or not the ADS-DV displays any TPMS information or messages. If so, describe what and where the information can be displayed. If the information is not visible during all trips, then explain the steps required for an occupant to obtain the information.
4. TPMS Information

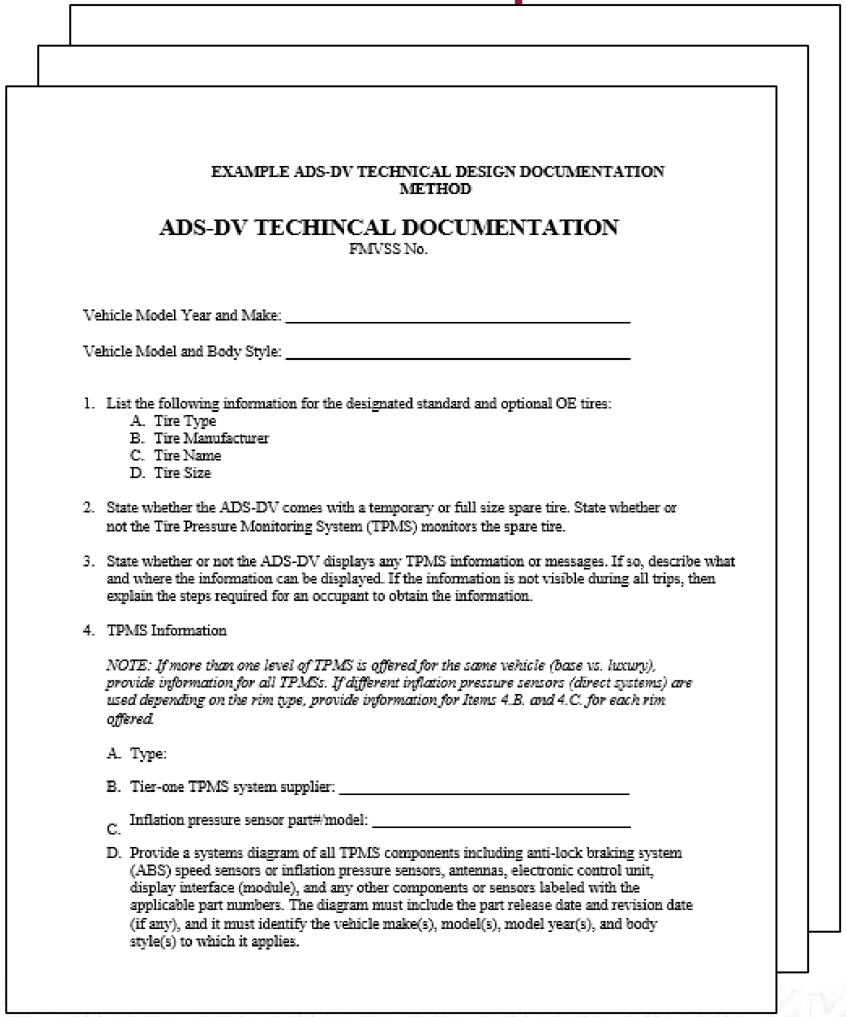
   *NOTE: If more than one level of TPMS is offered for the same vehicle (base vs. luxury), provide information for all TPMSs. If different inflation pressure sensors (direct systems) are used depending on the rim type, provide information for Items 4.B. and 4.C. for each rim offered.*

   A. Type:
   B. Tier-one TPMS system supplier: ____________________
   C. Inflation pressure sensor part#/model: ____________________
   D. Provide a systems diagram of all TPMS components including anti-lock braking system (ABS) speed sensors or inflation pressure sensors, antennas, electronic control unit, display interface (module), and any other components or sensors labeled with the applicable part numbers. The diagram must include the part release date and revision date (if any), and it must identify the vehicle make(s), model(s), model year(s), and body style(s) to which it applies.

Office of Vehicle Safety and Compliance (OVSC)
NHTSA Test Specification Forms (Forms)

# Technical Design Documentation Example

- Provide a systems diagram of all TPMS components (e.g., anti-lock braking system (ABS) speed sensors or inflation pressure sensors, antennas, electronic control unit), with the applicable part numbers.
- For each component, provide the release date and revision date(s) (if any), and identify the vehicle make, model, model year, and body style(s) to which it applies.



EXAMPLE ADS-DV TECHNICAL DESIGN DOCUMENTATION METHOD

ADS-DV TECHINCAL DOCUMENTATION
FMVSS No.

Vehicle Model Year and Make: ____________________

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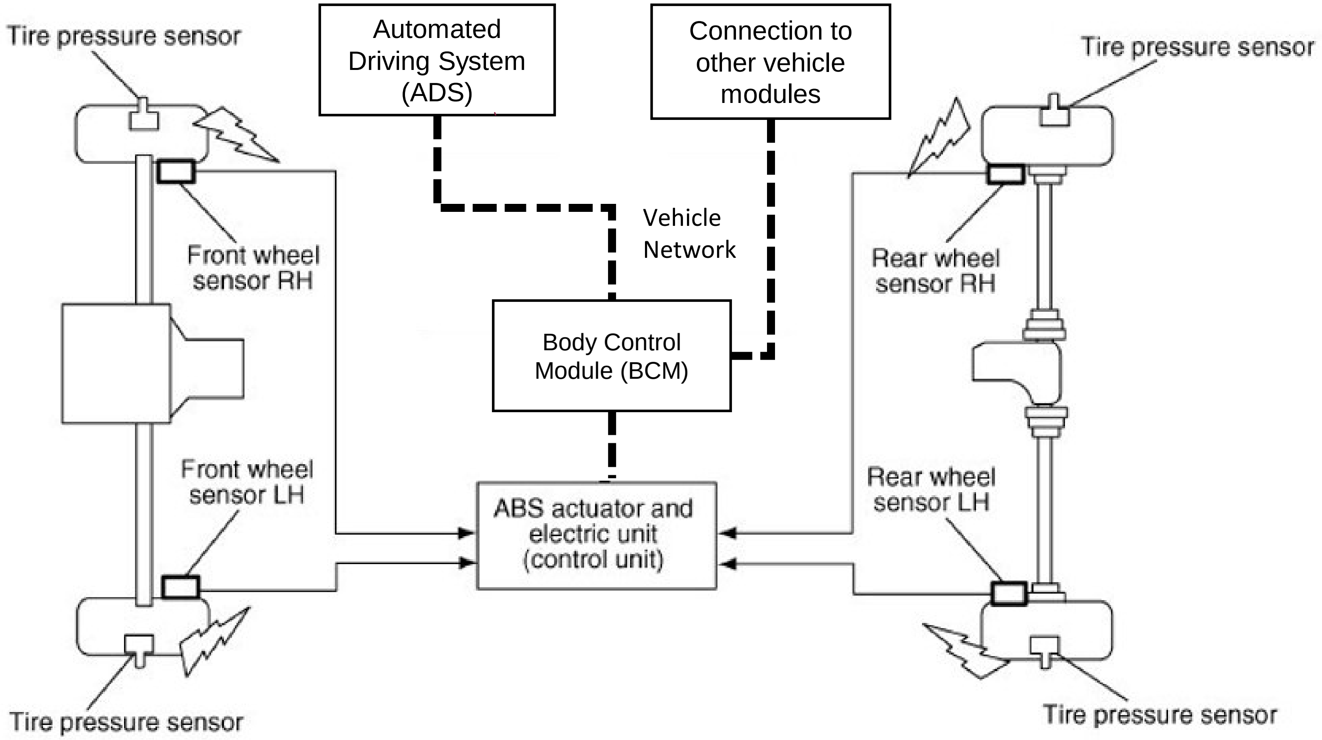
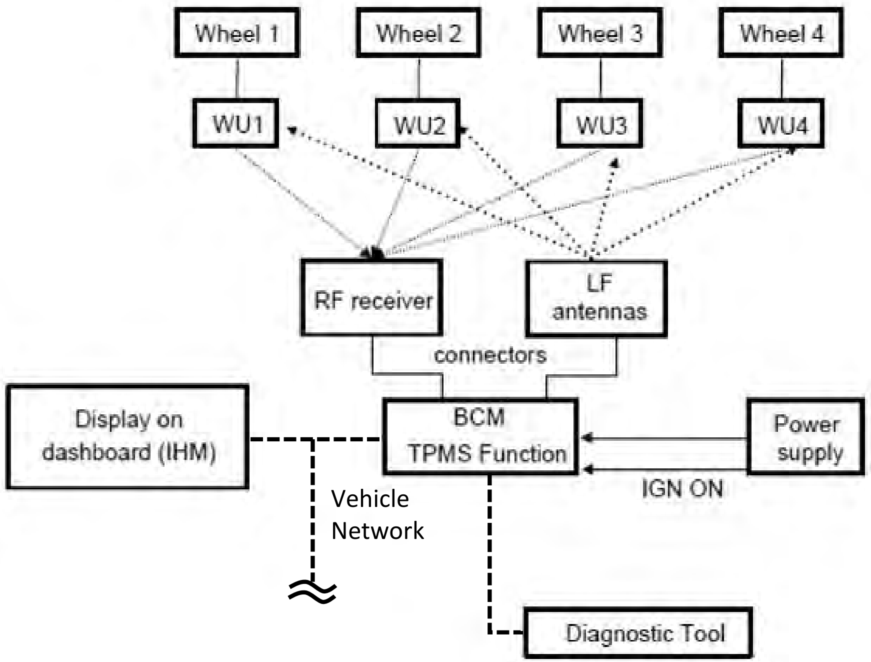
# Example Systems Diagram of all TPMS Components




The following information should be provided separately.

- Applicable part numbers, release date(s) and revision date(s) (if any)
- Identification of the vehicle make, model, model year, and body style(s) to which the diagram applies

# Technical Design Documentation Example

- Describe how a low tire pressure state is communicated to the ADS.
- Provide a schematic diagram showing the electrical connection that transmits information about a low tire state to the ADS.
- Provide the release date and revision level(s) (if any), and identify the vehicle make, model, model year, and body style(s) to which it applies on the diagram.

EXAMPLE ADS-DV TECHNICAL DESIGN DOCUMENTATION METHOD

**ADS-DV TECHINCAL DOCUMENTATION**

FMVSS No.

Vehicle Model Year and Make: ____________________

Vehicle Model and Body Style: ____________________

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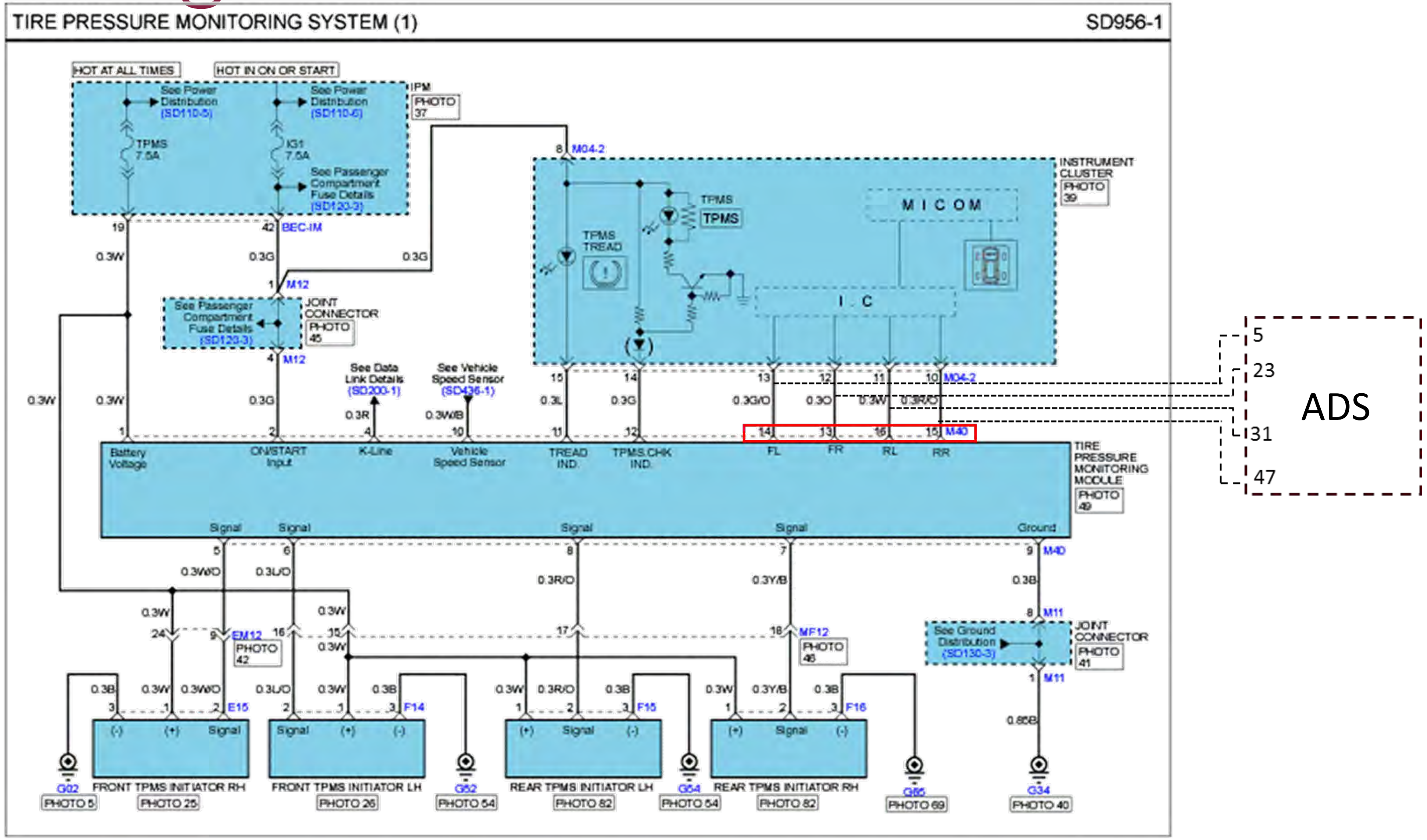
# Schematic Diagram TPMS and ADS Connection Ex.




https://www.autozone.com/repairguides/Hyundai-Cars-2006-2008/G-3-8-DOHC-2008/Tire-Pressure-Monitoering-System-TPMS/_/P-0996b43f80e64585

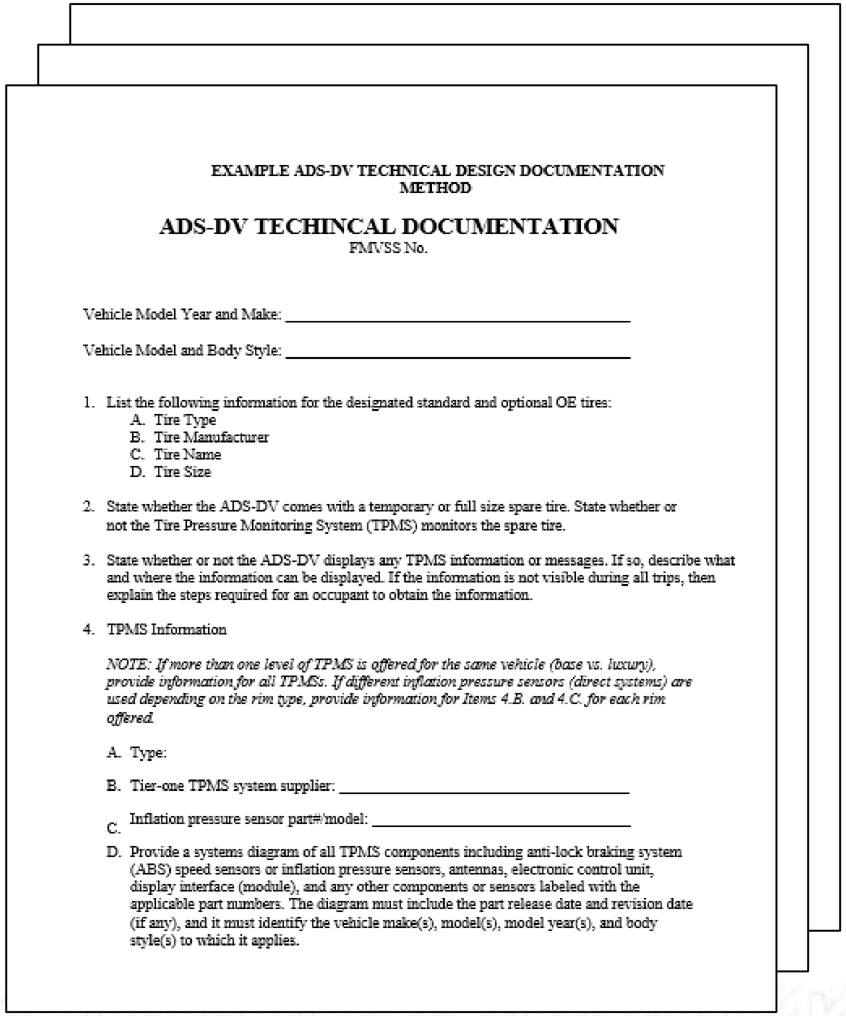
# Technical Design Documentation Example

The diagram and schematic are not sufficient to verify compliance.

- Additional information is needed, such as a demonstration that the low tire pressure state is actually communicated to the ADS and, if applicable, whether a telltale illuminates. For example,
    - Providing the software code used to define what is a "low tire pressure" within the meaning of S4.2(a)

  Or

    - Providing the network data log recorded during a FMVSS No. 138 physical test of the vehicle using the procedures set out in S5 and S6



EXAMPLE ADS-DV TECHNICAL DESIGN DOCUMENTATION METHOD

ADS-DV TECHINCAL DOCUMENTATION
FMVSS No.

Vehicle Model Year and Make: ____________________

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# Test Methods Being Evaluated

## Vehicle based

- Human control
- Programmed control of the ADS
- ADS normal operation

## Non-vehicle based

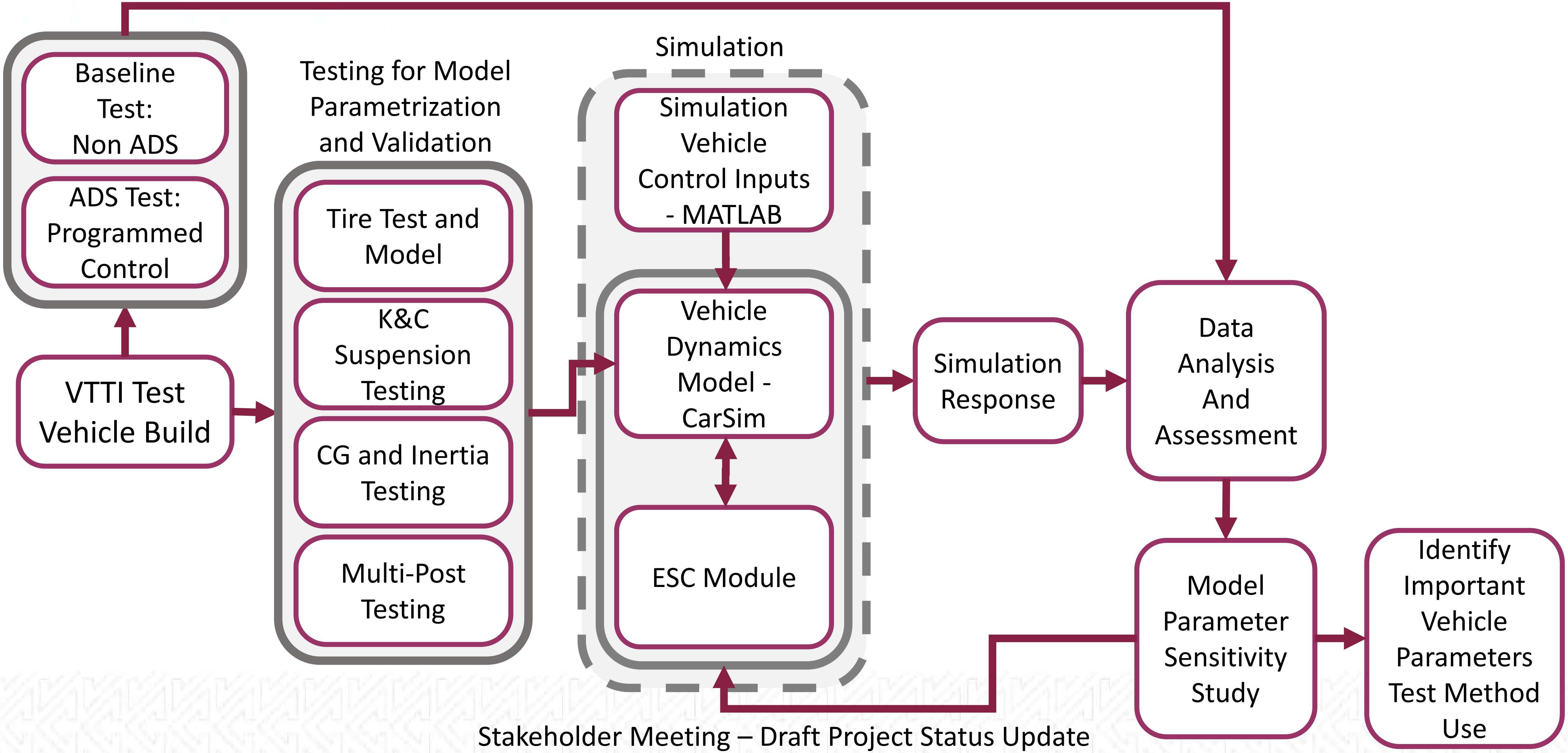
- Technical Design Documentation
- Simulation

# Simulation Introduction

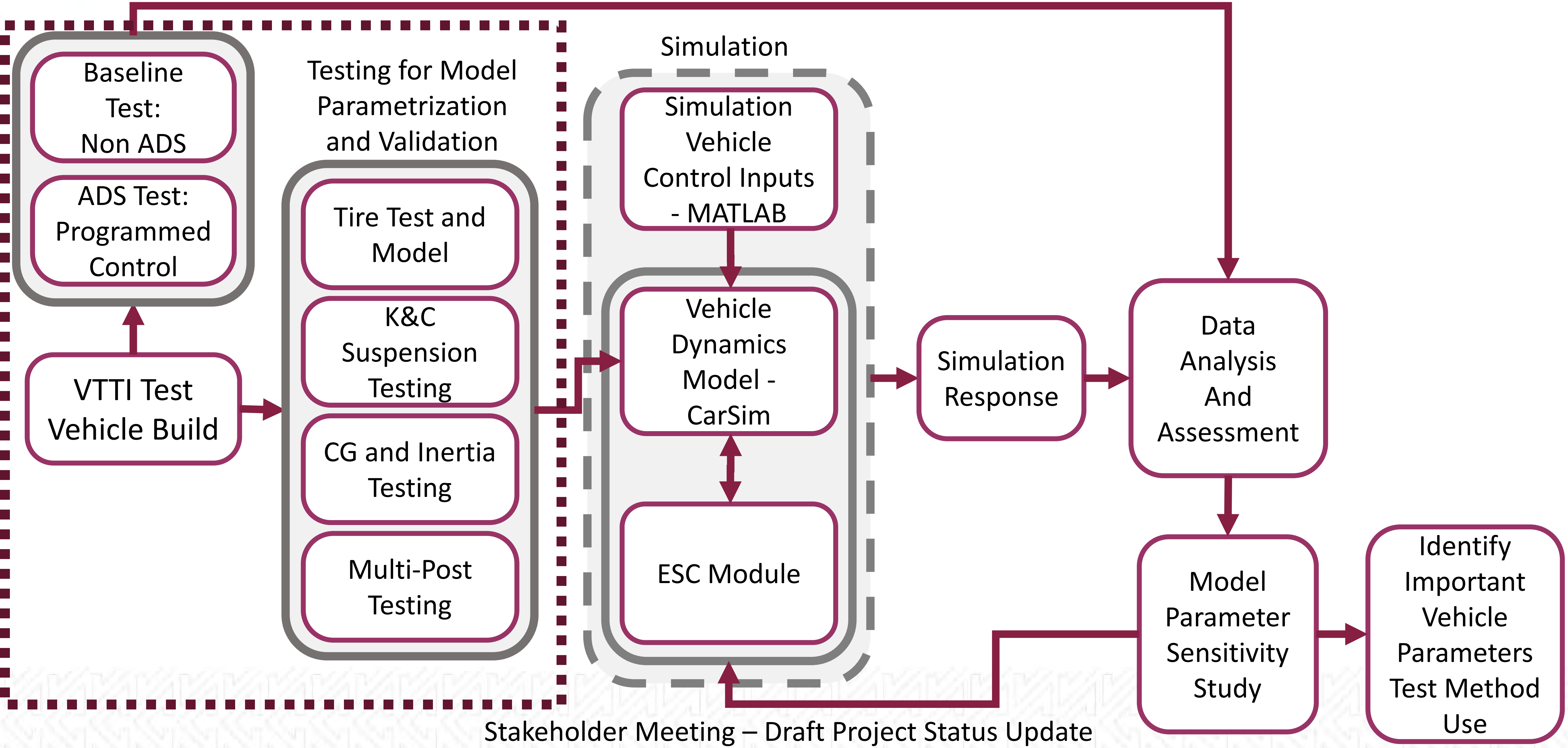
For simulation to be a viable test method, there must be trust in the model and its simulation output:

- The first step in developing “trust” is to understand the important model parameters directly related the systems being tested.
  - One method to identify these parameters is through a sensitivity study.
- Additionally, there must be test processes that include methods for validating the model and the associated simulation.
  - Perform actual vehicle measurements that directly relate to the parameters of the model that are being verified
  - Compare actual vehicle test output to simulation output

# VTTI Simulation Workflow



# VTTI Simulation Workflow




Stakeholder Meeting – Draft Project Status Update

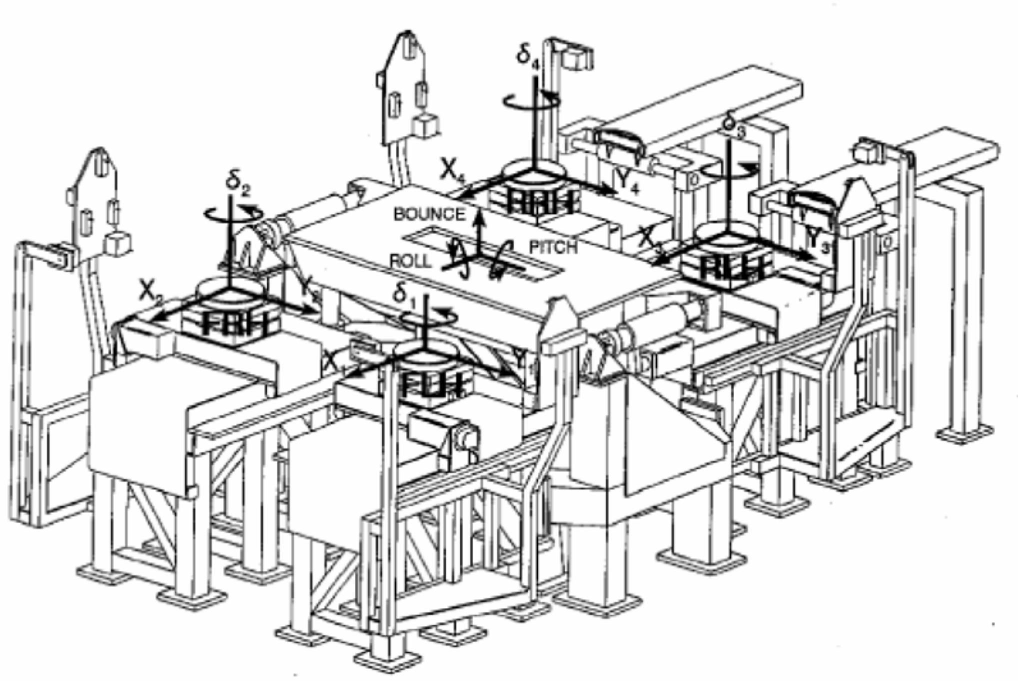
# Physical Vehicle Measurements: Specific to FMVSS No. 126

- Exercise an actual vehicle (e.g., operating and/or component testing) within its design capability associated to the speeds and maneuvers contained defined in the standard.
- Measure the parameters required for verification, for example:
  - Mass Properties
  - Suspension Properties
  - Powertrain Properties
  - Vehicle Control Electronics

# Suspension Properties Example

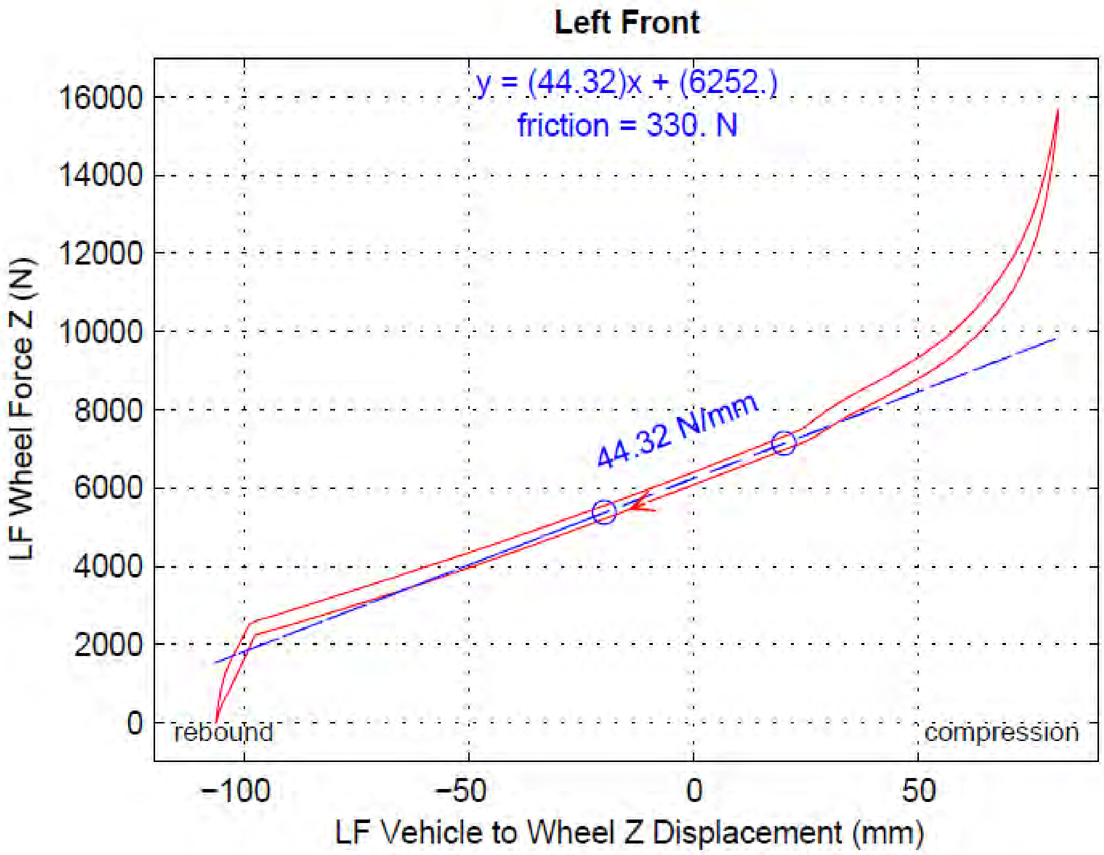
## Kinematics and Compliance

- Provides the basic suspension properties
- Table data can be imported into CarSim




# Suspension Properties Example

## Kinematics and Compliance - Wheel Rates Results (Left Front Example)

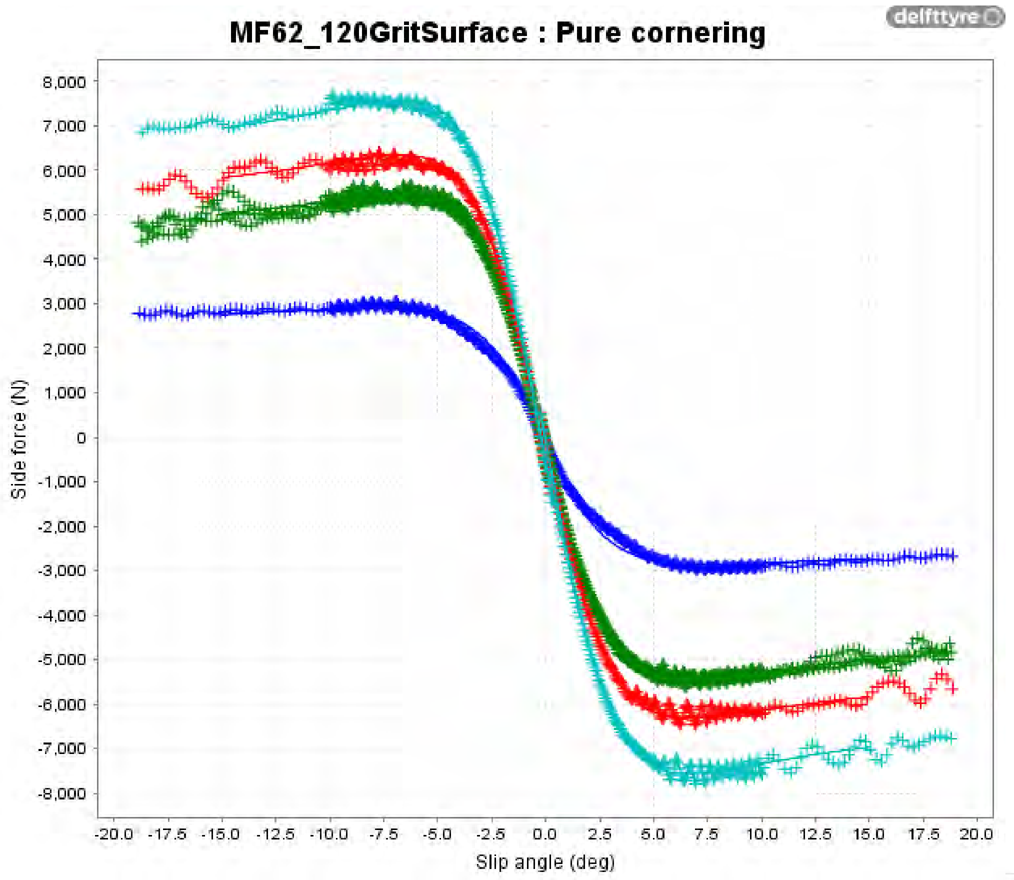


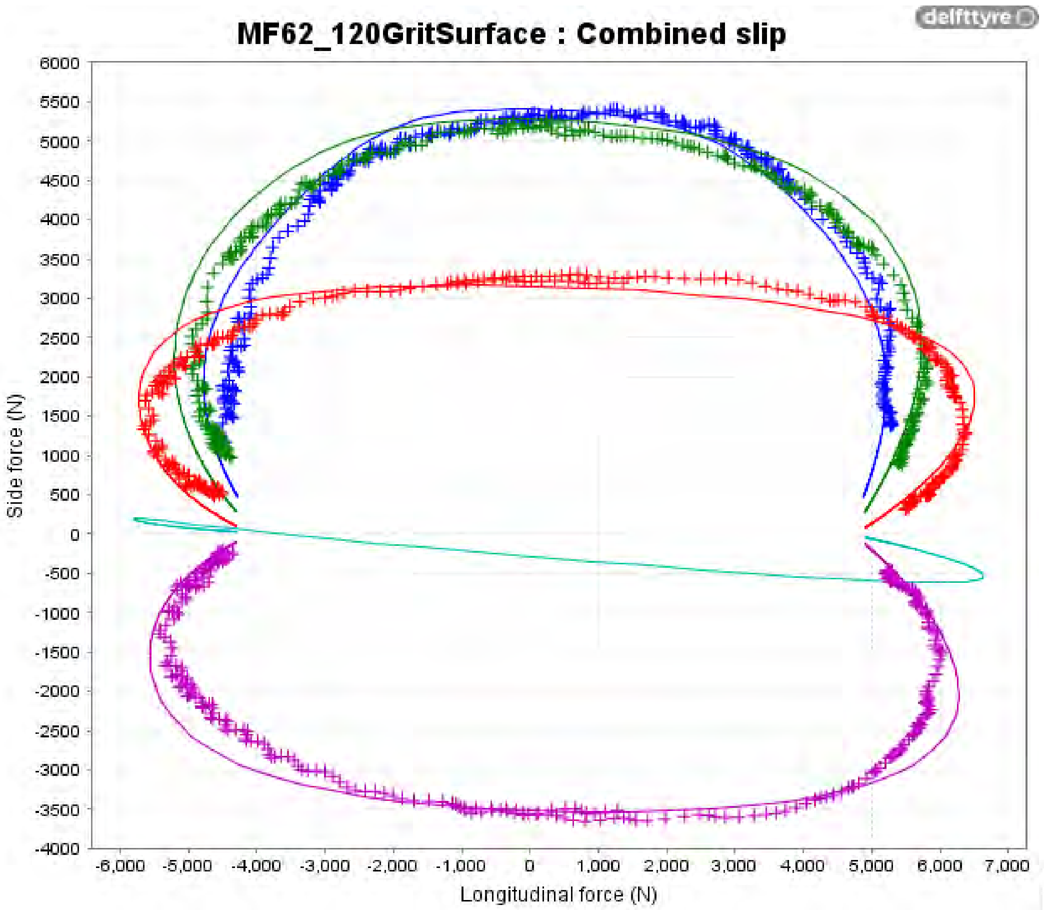
# Suspension Properties Example

## Force and Moment Tire Testing

# Suspension Properties Example

## Force and Moment Tire Testing



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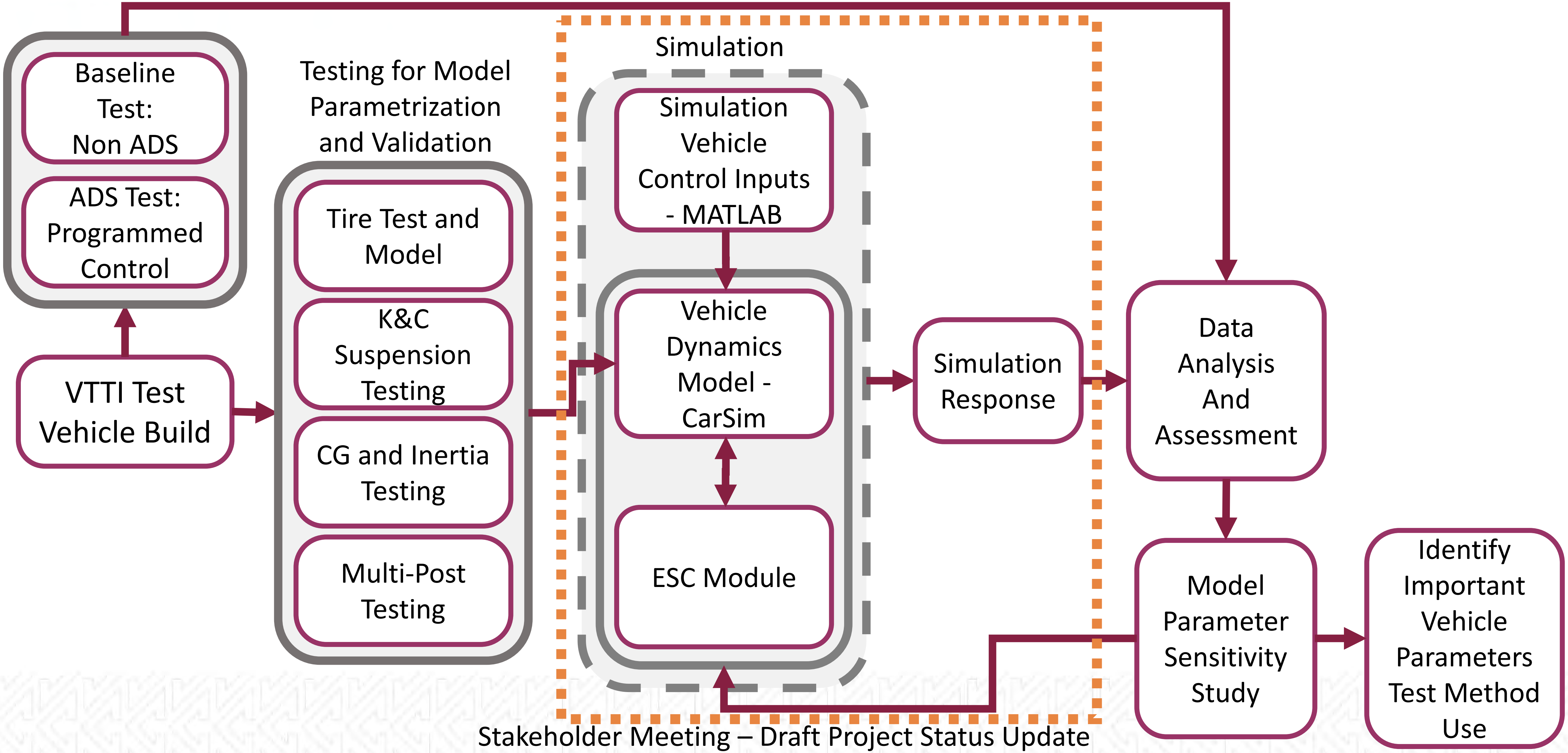
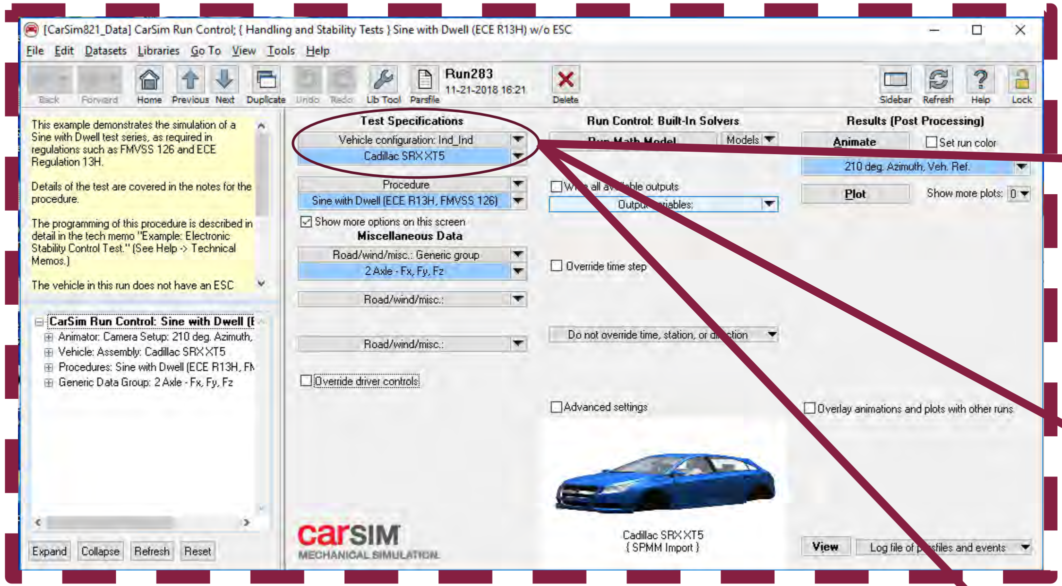
# VTTI Simulation Workflow

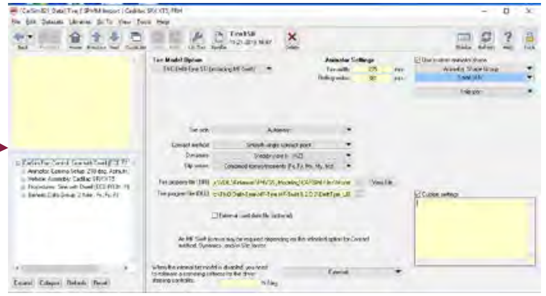


# Model and Simulation

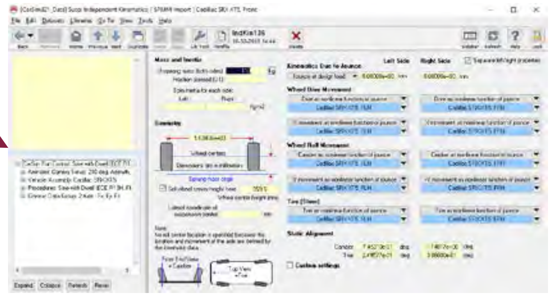
## CarSIM Simulation and Model – Sine with Dwell Test




Simulation

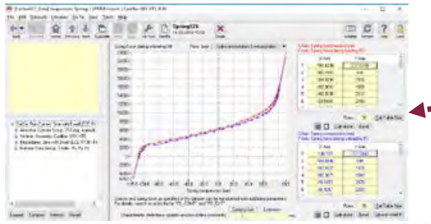


Model – Tire



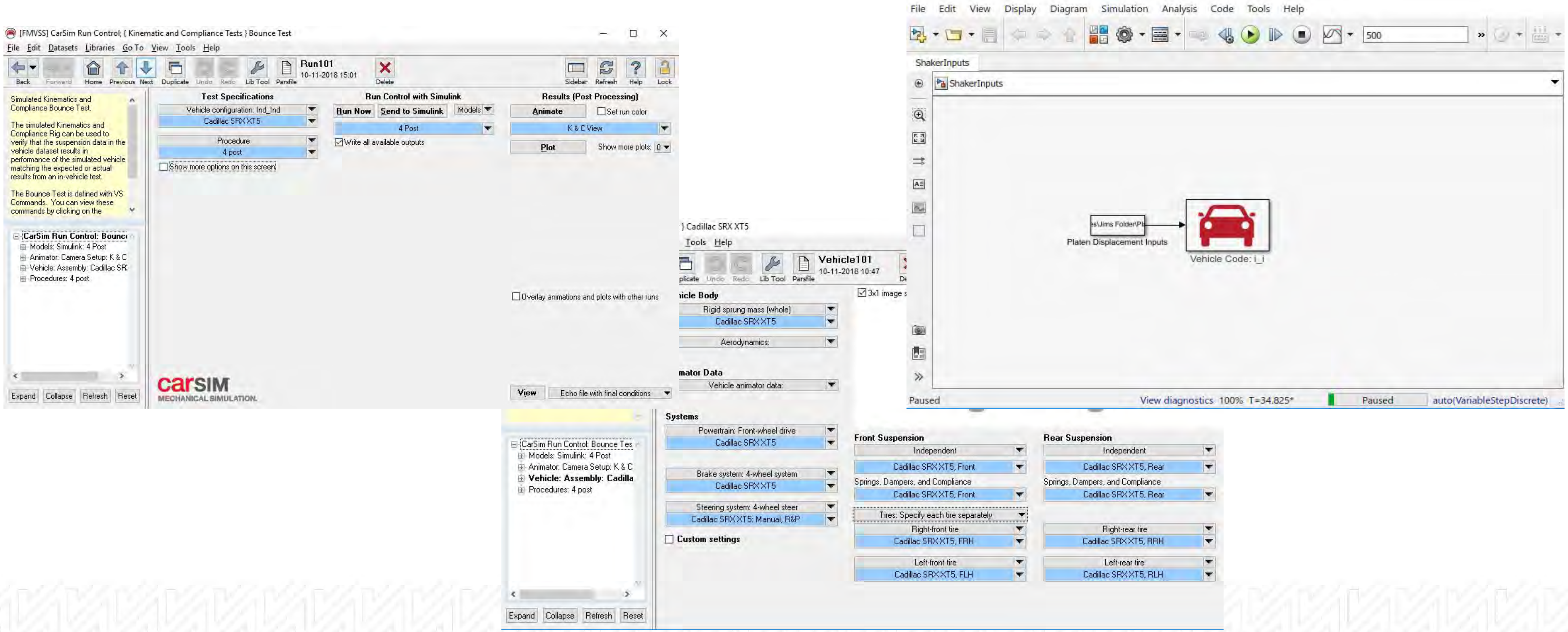
Model – Suspension

Model – Spring



# Model and Simulation

## Carsim/MATLAB Co-Simulation and Model for Data Comparison



# Simulation Example

# Simulation Status

**Model Validation**

Development in-process which includes vehicle level testing

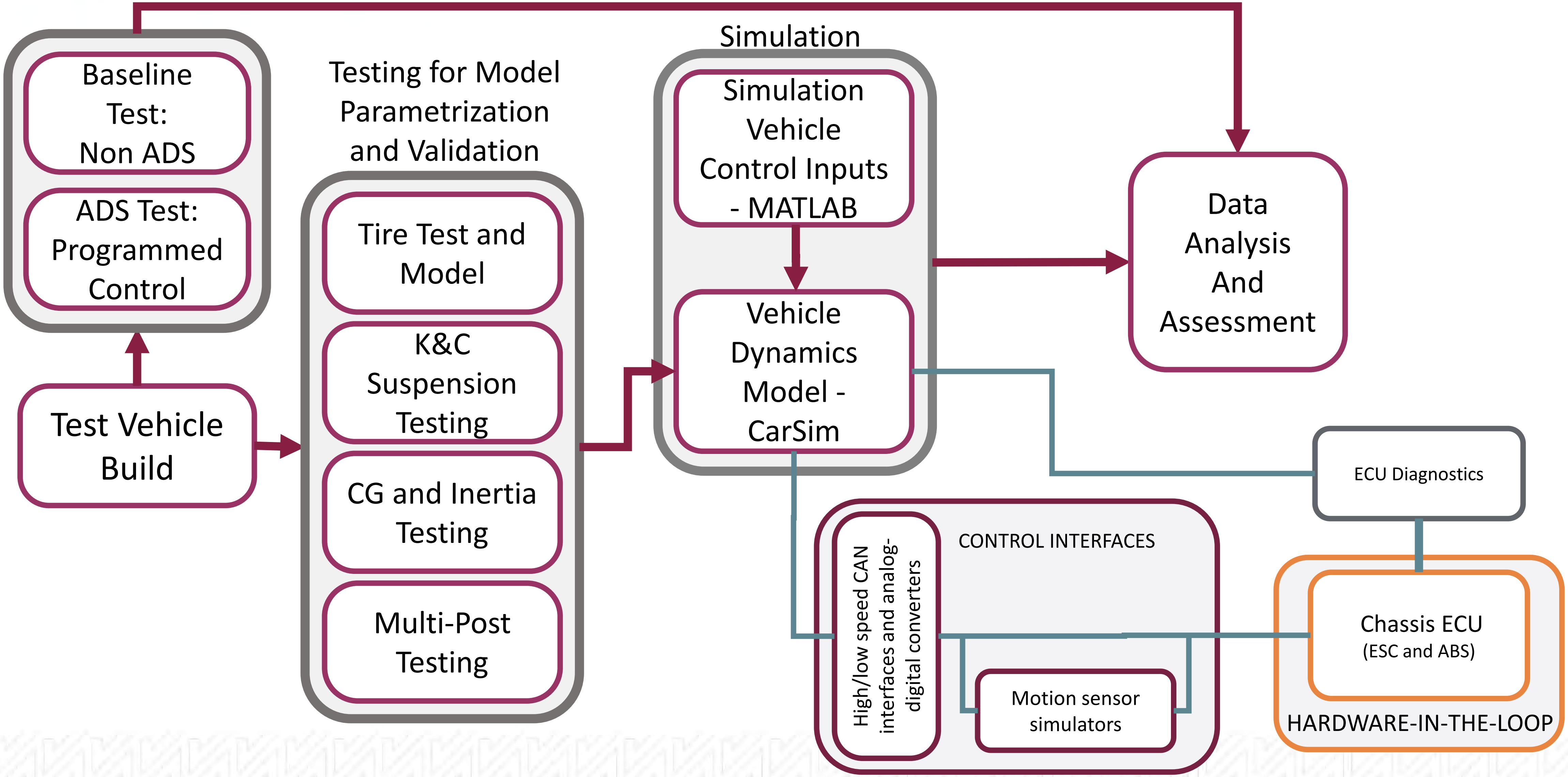
- Multi-Post Shaker Rig – 4 Post Mode
- FMVSS No. 126 with manually operated driving controls
- FMVSS No. 126 with programmed control of the ADS

Completion of the model parameter sensitivity study

- Establishes the potential fidelity for the input parameters to provide trust in the model outputs

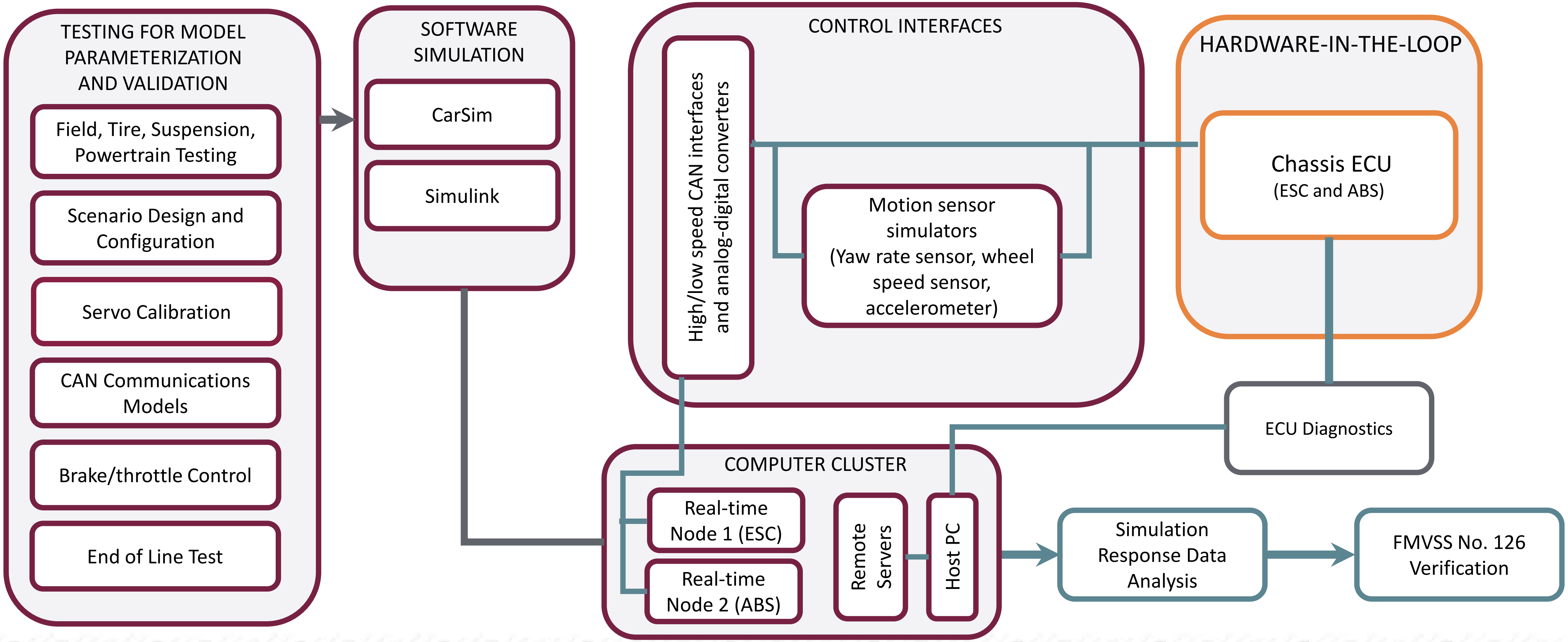
Assessment of simulation capability based on each step of the process

# HIL Simulation Workflow



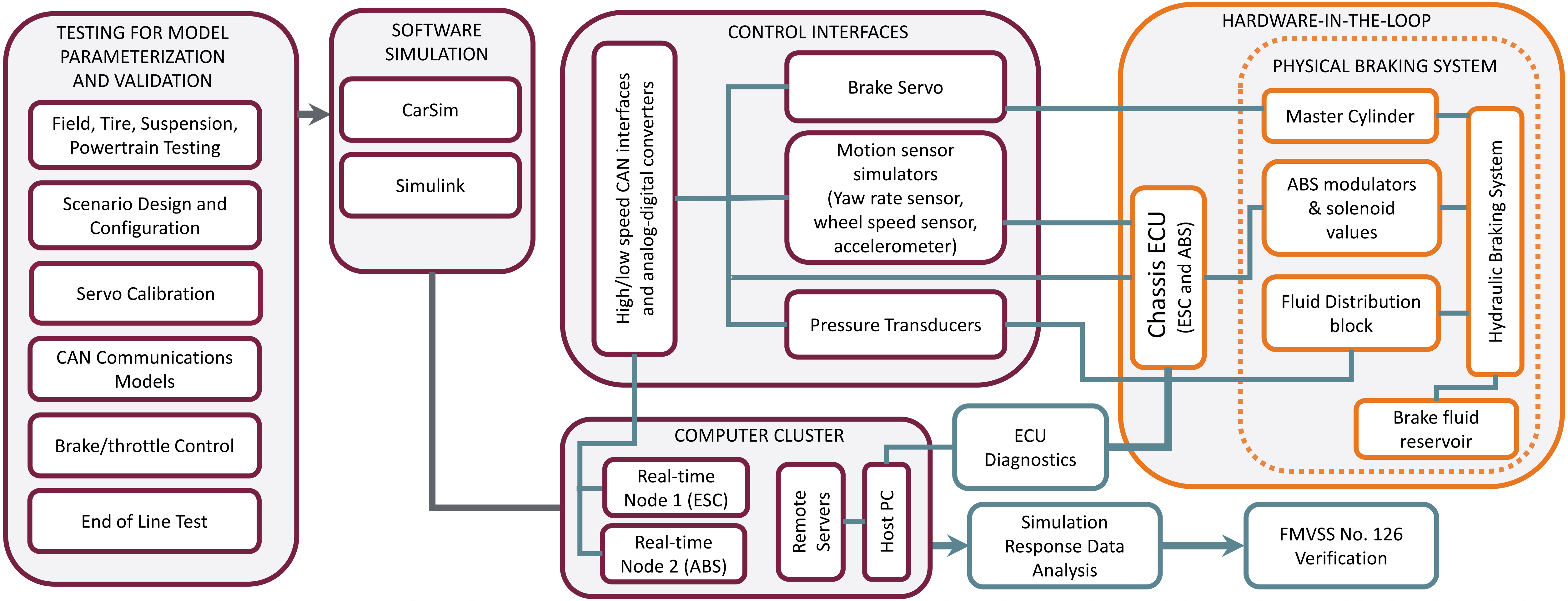
# Hardware-in-the-Loop (HIL)

## HIL Use Case 1: Generic ECU



# Hardware-in-the-Loop (HIL)

## HIL Use Case 2: ECU + Brake System



# HIL Considerations

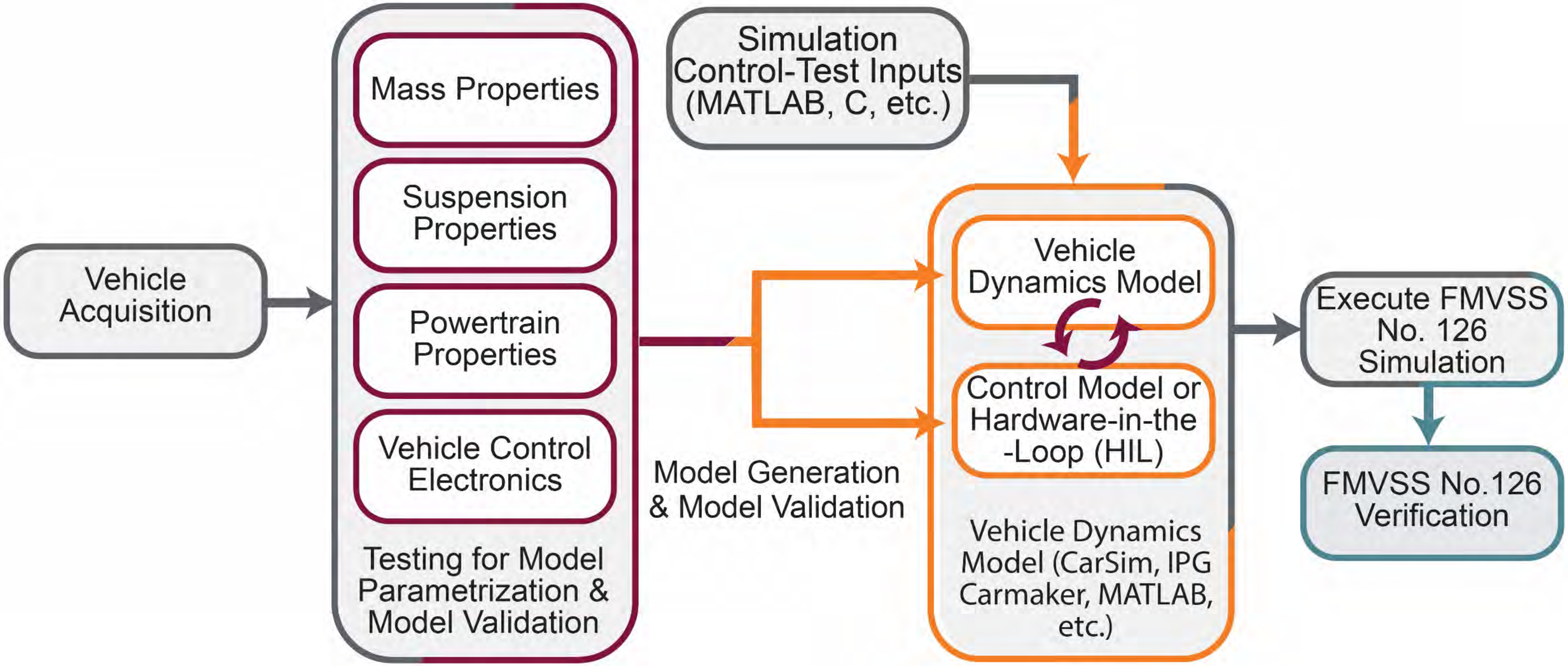
- Provides a means to include components of the system that may be difficult to create simulation models for
- Includes physical testing of components as part of verification
- May be difficult to procure individual components
- May require knowledge of proprietary information to interface to physical component
- If HIL components become numerous, would require interfacing software simulation to vehicle

# Simulation Implementation Process Consideration

Considerations for using simulation as a compliance verification method:

- Vehicle Acquisition
- Model Development:
  - Developed by NHTSA, developed by an independent test laboratory, or developed by individual vehicle manufacturers
  - Establishment of a standardized model may help to ensure repeatability and reproducibility
- Perform testing of the vehicle and associated systems (e.g., electrical control system)
- Assess model to validate simulation
- Execute the standard’s test procedure

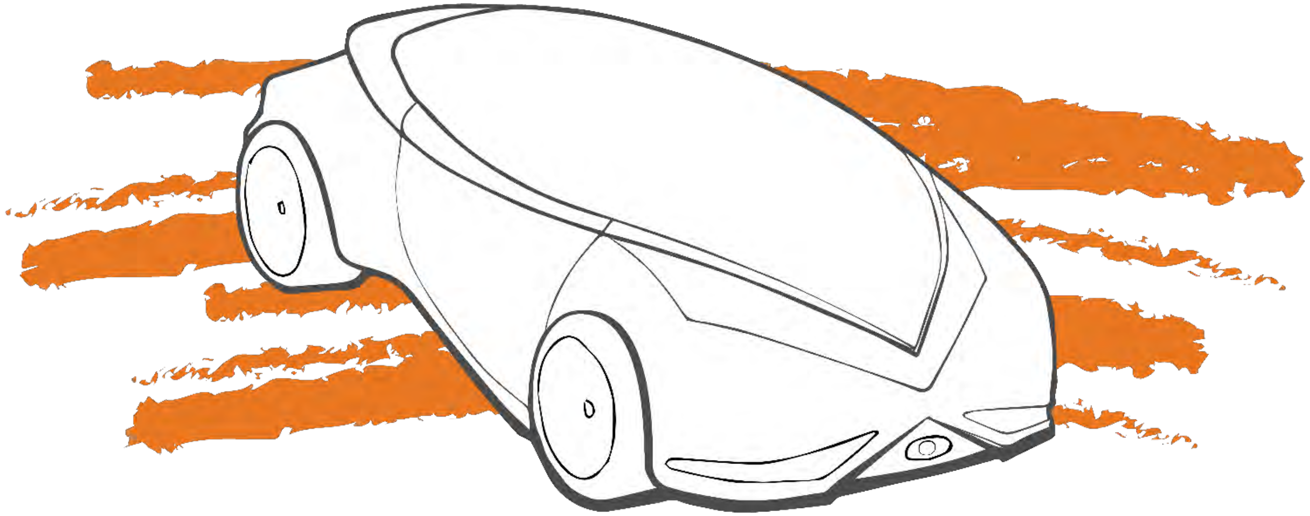
# Simulation Implementation Process Consideration



# Non-vehicle Based Test Method Summary

- The standards do vary, the potential suitability of a test method for one standard does not necessarily imply suitability across all standards
- Developing approaches that include actual vehicle component testing and/or complementary physical testing may help to build trust in non-vehicle based test methods
- Applying a combination of non-vehicle based and vehicle based testing may help provide the ability to verify the manufacturer's quality control, manufacturing processes, and materials used to produce the vehicle comply with the standards
- Research is on-going to further develop and evaluate the non-vehicle based test methods

# Thank You



# Test Procedure Overview

# Test Method Evaluation Discussion

**Moderators:** Loren Stowe, VTTI

**Panelists:**

- **Gurunath Vemulakonda**, Ford Motor Company
- **David Liu,** Honda
- **Michael Plotzke,** General Motors
- **Barbara Wendling,** Mercedes-Benz
- **Andrew Christensen,** Nissan