Ford's Use Of Driving Simulator Technology For Automated Driving Feature Development

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DRIVING SIMULATION & VIRTUAL REALITY CONFERENCE & EXHIBITION

Agenda

- Driving Simulators at Ford
- Driver Research Methods, Levels of Autonomy
- L2, L4 Studies Conducted in VIRTTEX
  - Overview
  - Simulating Automated Driving Features
  - Motion Scaling and Motion Drive Algorithms
  - Examples

Driving Simulators at Ford

Early 1990s → Today

VIRTTEX (2001)

Driving Simulators at Ford

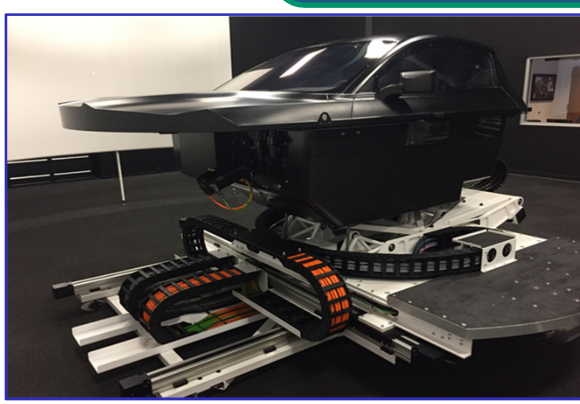
Static HMI Simulators

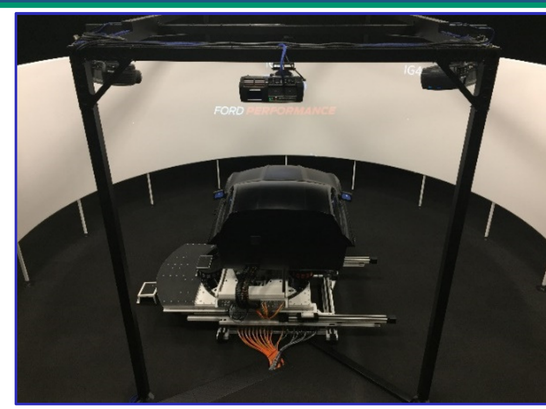
Static NVH Simulator

SQ & P/T NVH design/evaluation

Dynamic Driving Simulator (2013)

- Vehicle Dynamics technology exploration and tuning
- Basic ADAS feature reviews
- Suspension studies





Driving Simulators at Ford

VIRTTEX

VIRtual Test Track EXperiment

Displays

- 360° Field-of-View

Inside VIRTTEX

- Realistic sound cues
- Steering feedback

	Acceleration	Velocity	Displacement
Longitudinal/ Lateral	> 0.6g	> 1.2m/s	± 1.6m
Vertical	1.0g	1.0m/s	± 1.0m
Pitch/ Roll	> 200deg/s^2	> 20deg/s	± 20deg
Yaw	> 200deg/s^2	> 20deg/s	± 40deg

Go Further

Driver Research Methods

Higher **Behavior**

Certainty

Knowledge

- **Naturalistic Data Collection**
  - Sampled People, Real Cars, Real Roads (Focus on *Today*)
- **Field Operational Tests**
  - Sampled People, Modified Cars, Real Roads (Focus on *Tomorrow*)
- **Driving Simulation**
  - Sampled People, Virtual Cars, Virtual Roads (Focus on *Today*, *Tomorrow* and *Beyond*)

Lower **Performance**

SAE Level	Name	Narrative Definition	Execution of Steering and Accel	Monitoring	Fallback	Driving Modes
Human driver monitors the driving environment						
0	No Automation	• The full-time performance by the human driver	Human driver	Human driver	Human driver	n/a
1	Drive Assistance	• Driving mode-specific execution by a driver assistance system of *either steering **or** acceleration/deceleration* • Human driver performs all remaining aspects of the dynamic driving task	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	• Driving mode-specific execution by a driver assistance system of *steering **and** accel/decel* • Human driver performs all remaining aspects of the dynamic driving task	System	Human driver	Human driver	Some driving modes
Automated driving system monitors the driving environment						
3	Conditional Automation	• Driving mode-specific performance by an automated driving system of all aspects of the driving task • *Human driver will respond appropriately to a request to intervene*	System	System	Human driver	Some driving modes
4	High Automation	• Driving mode-specific performance by an automated driving system of all aspects of the driving task • *Even if a human driver does not respond appropriately to a request to intervene*	System	System	System	Many driving modes
5	Full Automation	• Full-time performance by an automated driving system of all aspects of the dynamic driving task *under all roadway and environmental conditions* that can be managed by a human driver	System	System	System	All driving modes

https://en.wikipedia.org/wiki/Autonomous_car

Go Further

L0-L1 Safety Studies in VIRTTEX

- **Types of studies**
  - Driver distraction
  - Alerts for
    - Lane Departure Warning (LDW)
    - Forward Collision Warning (FCW)
  - Drowsy driver
- **Study Results**
  - Quantitative/Objective data
    - E.g., brake/steer reaction times
  - Subjective data

L2, L4 Studies in VIRTTEX

- **Driver Performance**
  - Driver take-over / re-engagement and Driver Controllability to safety relevant event
    - External event (example: surprise forward collision event)
    - AV system event (example: sub-system fault)
  - Distraction Mitigation – Keeping drivers in the loop
- **Comprehension**
  - Driver take-over / re-engagement for L2 strategy
  - Situational Awareness – How much information should be presented to the driver…
    - … about the driving environment?
    - … about what the vehicle senses?

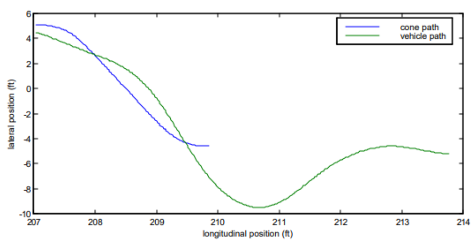
Simulating Automated Driving Features

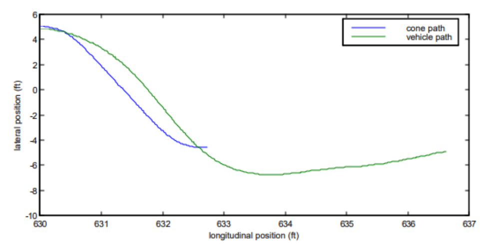
Various techniques to simulate Automated Driving Features

Method	Advantages	Disadvantages
Ford-specific models (MIL)	• Use (Simulink) model that is planned for the Feature	• Model often not fully developed/debugged
"Autonomous mode" in scenario simulation software	• Use when general AV/ADAS capability is needed	• Can require "tuning", particularly with motion-based simulators
Playback of a recorded drive	• Use when existing simulation technology doesn't exist, or • When a simulator driver can create a drive that will feel realistic and stay within the motion system capabilities.	• Can require many recording to get the one that is "just right"

Motion Scale

- **Motion scale must match the scenario under test**
  - Lateral motion generally scaled above 50%
    - Driver can feel <u>Feature Lateral Control</u> (e.g., lane-keeping)
    - <u>Driver Lateral Control</u> is more realistic [e.g., DSC-NA 2001 “The Effect of Lateral Motion Cues During Simulated Driving”, Greenberg, Artz, Cathey]

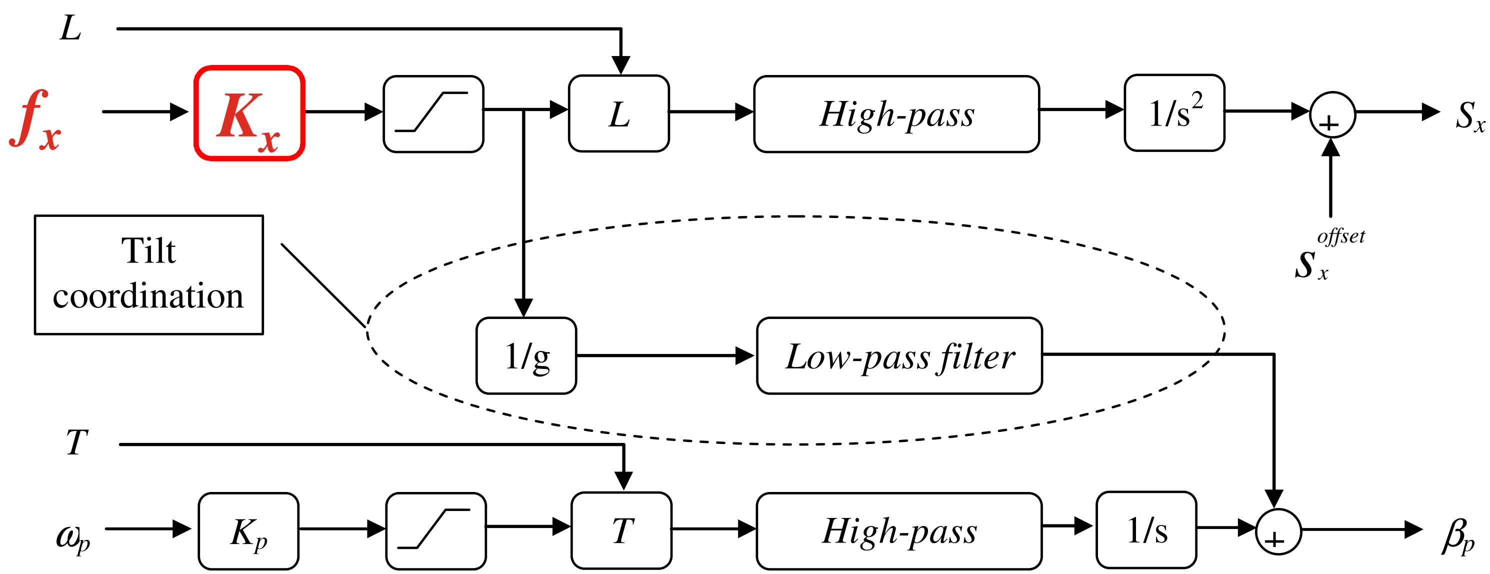




  - Longitude motion generally scaled above 40%
    - Driver can feel <u>Feature Longitude Control</u> (e.g., headway maintenance)
    - <u>Driver Longitude Control</u> is challenging (next slide)

Motion Scale: Mixed Longitudinal Scaling

- **Classical Motion Drive Algorithm for longitude**
- **K_x = scale factor applied to specific force**
  - Typically reduced to contain expected worst-case longitudinal motion

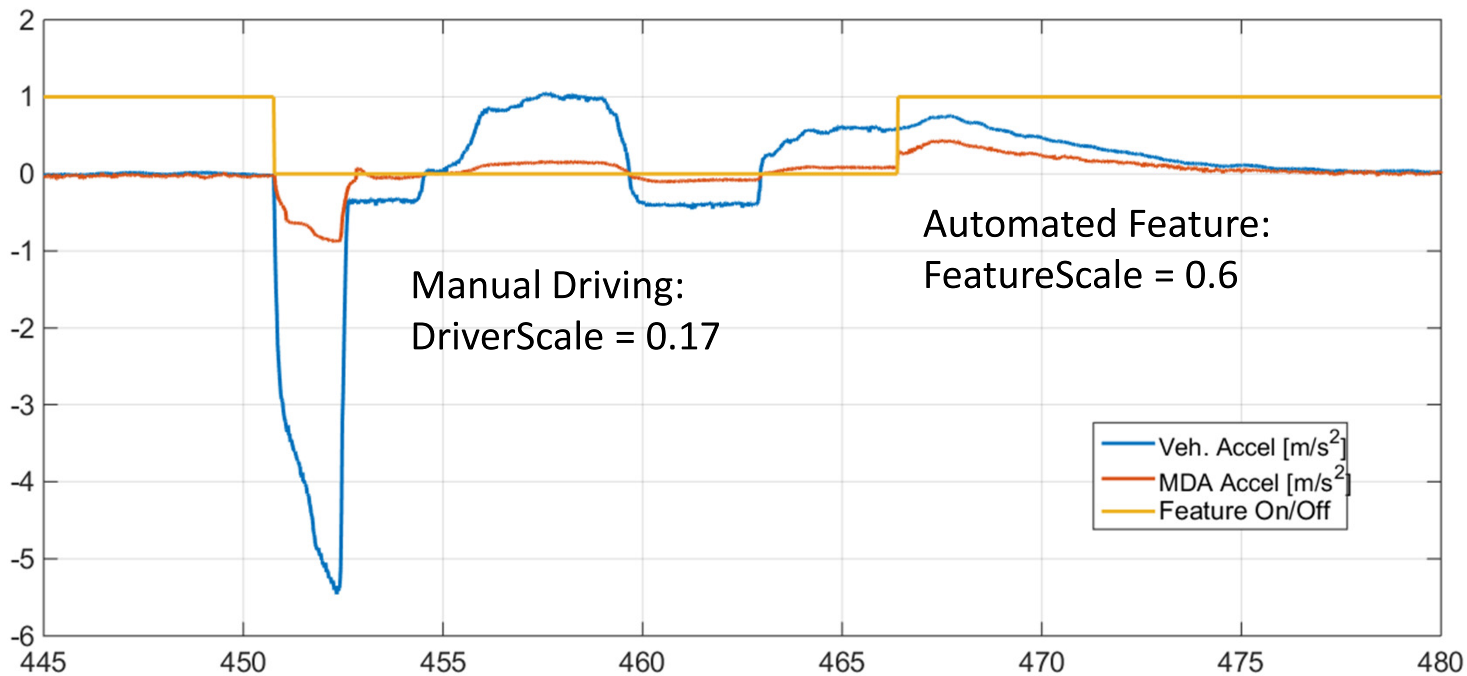


Motion Scale: Mixed Longitudinal Scaling

- **Example: Automated Driver Feature and Driver Mixed With Driver Braking**
  - Automated Feature typically < 0.1 g
  - Driver braking typically > 0.3 g for 1-2 seconds
- **Conflicting Goals:**
  1. Minimize motion scaling for Driver braking (Minimize motion limiting)
  2. Maximize motion scaling for Feature (Feel headway maintenance)
- **Typical global longitudinal scaling in VIRTTEX is < 0.2 for sustained, hard braking**
  - Goal (1) is met; no motion limiting.
  - Goal (2) is not met. Driver experiences < 0.02 g

Motion Scale: Mixed Longitudinal Scaling

- **Solutions: Different Scales for Driver and Feature**
  1. [E.g., DSC 2008 "Motion control techniques for subjective testing in motion-based driving simulators," Blommer, Greenberg]
  2. Scale = FeatureScale * [FeatureOn] + DriverScale * [1 – FeatureOn]
- **Example:**



Common Characteristics Across Studies

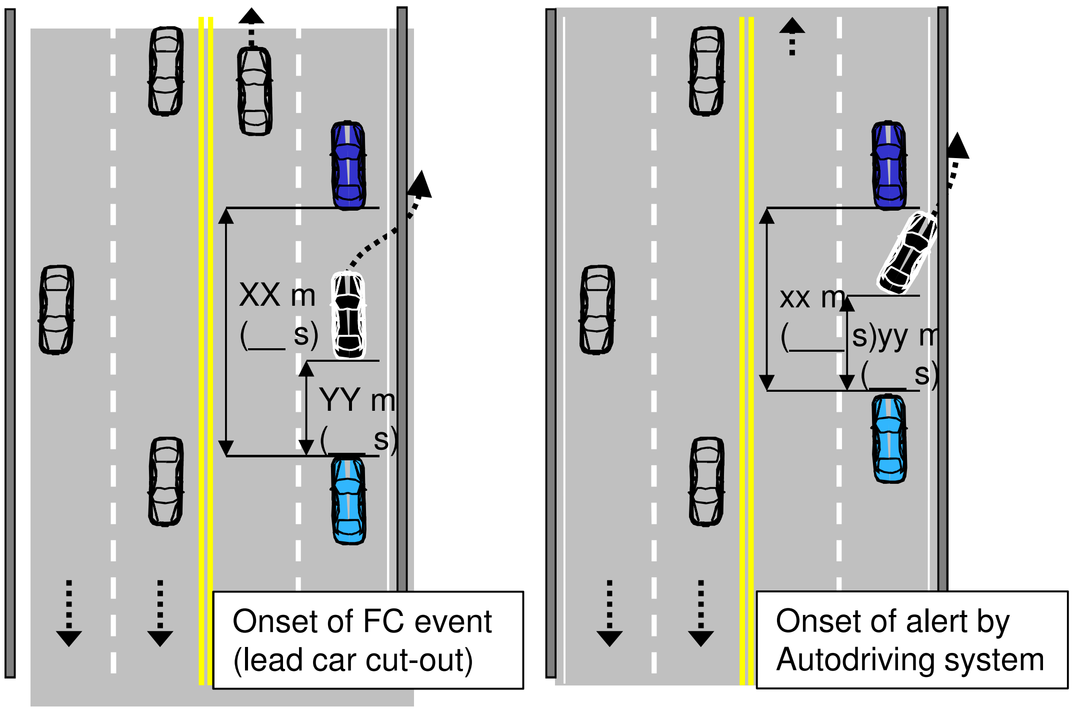
- **Representative driving conditions**
  - Interstate driving, 60-70mph
  - Suburban/Rural driving, 35/55 mph
- **For Driver Performance Studies: Use alternate reason for study purpose.**
  - Don't tell participant about safety-critical event
- **Secondary Task (Distraction Task):**
  - Visual distractions
  - Manual-visual distractions (e.g., tablet games)

Distraction display

Common Characteristics Across AV Studies

- **Scenario is designed to expose drivers to representative motion, visuals, sounds, etc**
  - Example: Motion deceleration/acceleration as adapting to lead vehicle speeds
  - Driver Performance Studies: Scenario of safety-critical event looks similar to earlier parts of the drive
- **Study minimally-trained drivers**
  - Trained on general operation of system both before drive, and first part of the drive.
  - No training or description of critical take-over / re-engagement systems
  - Driver’s typically experience one safety-critical event at end of the drive. Can only surprise drivers once!!

L2 Driver re-engagement to a surprise, safety-critical event

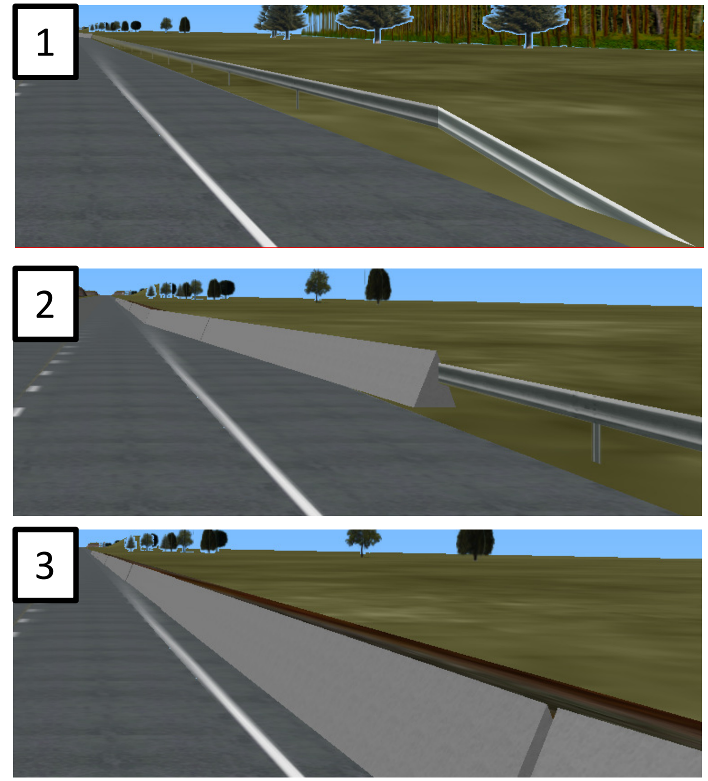


- **Study Factors**
  - Automated Driving Feature strategy
  - Secondary tasks
- **Measurements**
  - Eyes-off-road times
  - Driver response time

- **Key simulation methods**
  - Automation simulated by combination of Ford-specific and Scenario software
  - Mixed longitudinal scaling
    - Automated Driving Feature provides initial deceleration cue at onset of safety-critical event
    - Driver response likely to have large deceleration

L2 Driver Performance For System Fault

- **Host vehicle in right lane, approaches guardrail and Jersey barriers (1-3)**
- **System fault triggered while vehicle has Jersey barriers near the shoulder line (3).**



NOTE: Guardrail and Jersey barrier appear earlier in the drive with no system fault.

- **Key simulation methods**
  - Automation simulated by combination of Ford-specific and Scenario software
  - Key Simulator motions === Key Vehicle motions
    - lateral kinematics, steering wheel angle, etc

L4 Trust

- **Example: Trust in Automation as function of Situational Awareness Displays in L4**

- **Key simulation methods**
  - Automation simulated by playback of recorded drive
    - Multiple starts/stops, lane changes
  - Scenario was deterministic

Thank You