INTEGRATION OF REAL STEERING AND BRAKING SYSTEMS INTO VI-GRADE DRIVING SIMULATORS OF MERCEDES-AMG BY USING HARDWARE-IN-THE-LOOP TESTBENCHES FROM MDYNAMIX

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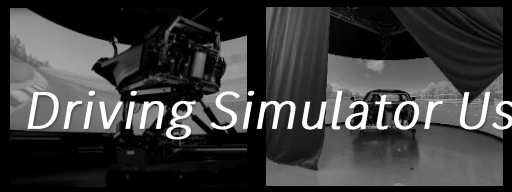
Agenda

1 

Driving Simulator Usage @ Mercedes-AMG

Digital Vehicle Development: DiM & HiL @ Mercedes-AMG 2

3 *HIL Motivation and Requirements*

Technical Details brake & steerHIL 4

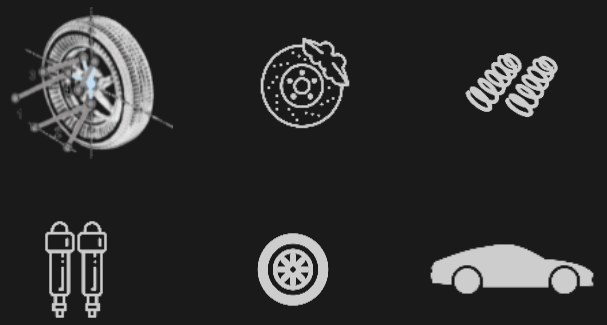
5 *Summary*

Driving Simulator Usage @ Mercedes-AMG

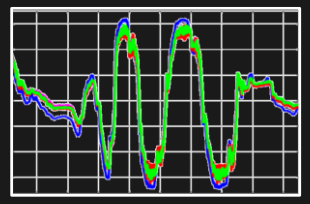
Concept

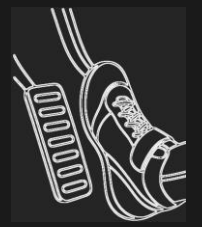
Digital Development

Functional Chassis Design



Objective and subjective Development





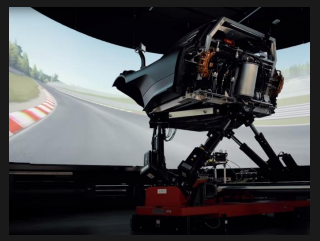
Real Vehicle

FOCUS DIM: Early Driver-in-the-Loop. Real Insight.

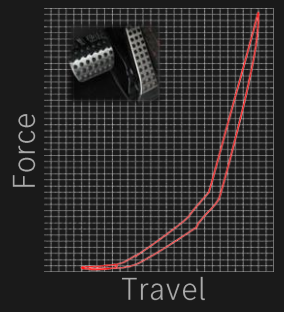
- Perception of chassis, kinematics, elastokinematics, tyre, concept, track pace
- Driver involved from early development phases
- Real-Driver for Subjective assessment: ride, handling and comfort
- Risk-free testing

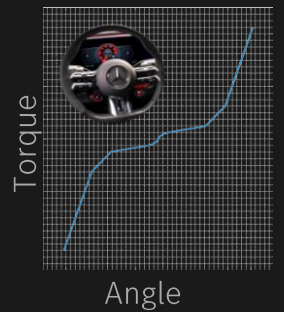
Digital Vehicle Development: DiM & HiL

Functional Substitutions



Driver in Motion (DiM) & Static Simulator

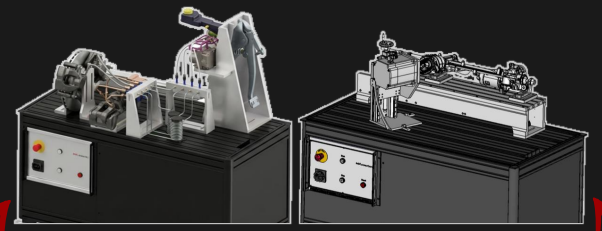




Hardware-in-the-Loop ★

Cockpit HiL-Mode (Real Driver)
Real ECU behavior for driving performance evaluation

Standalone HiL-Mode (Virtual Driver)
Software development of the ECUs by using virtual driver and driving maneuver catalog



MX brakeHiL + MX steerHiL

Virtual Driver | Real Driver

Basic Simulation

Vi-Grade model & extensions (MiL & SiL)

Real Vehicle

OUR FOCUS: Early Driver-in-the-Loop. Real Insight.

HIL Benefits and Requirements

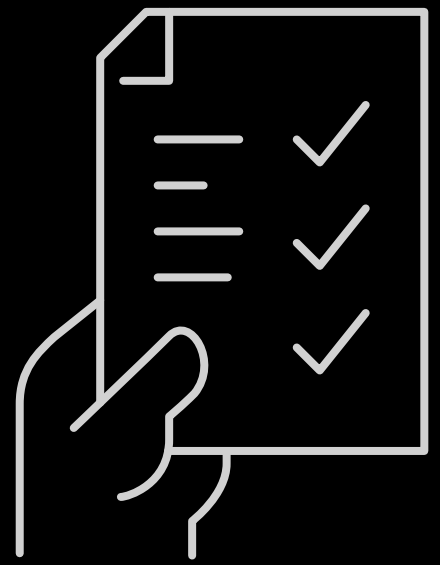
BENEFITS

Subjective Benefits (DiM)
- Realistic steering and braking behavior
- Authentic driver feedback through real vehicle characteristics

Objective Benefits
- Software Development of ECU with virtual driver & driving maneuver catalog
- Network testing (FlexRay, Ethernet, CAN, LIN)
- Validation and Plausibility of Simulation against Real-Car

Development & Testing
- Real ECUs for application development and measurements
- Early-stage testing under vehicle-like conditions

Flexibility & Reusability
- Same HiL platform for different brake & steering systems



Proof of Concept with MdynamiX: Requirements for Brake and Steering fully met.

HIL Benefits and Requirements

BENEFITS

Subjective Benefits (DiM)

Objective Benefits

Development & Testing

Flexibility & Reusability

REQUIREMENTS

Control Performance & Stability
- Fast closed-loop control
- High stability and robustness
- Low latency without signal phase shift

Driver–ECU Interaction
- Real ECU feedback
- Driver input to controller

I/O, Interfaces & Communication
- Robust I/O with adequate sampling
- Network communication (FlexRay, CAN, LIN)
- Restbus simulation and sensor stimulation

Safety & Compliance
- Switching of steering and braking systems
- Safety mechanisms with CE conformity

Proof of Concept with MdynamiX: Requirements for Brake and Steering fully met.

MXbrakeLink: DIL-accessed Hardware-in-the-Loop testbench

MXbrakeHiL – HiL Powerhouse
- Real hydraulic brake system with full ESC ECU logic
- Quick-swap setup for different brake systems
- Optimized for advanced ECU function development
- Compact footprint, standalone capable

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MXbrakePedal – Simulator-Ready Braking
- Standalone force-feedback pedal unit
- Up to 7 kN pedal force
- Fully tunable curves incl. ABS effects
- Real-time capable feedback unit

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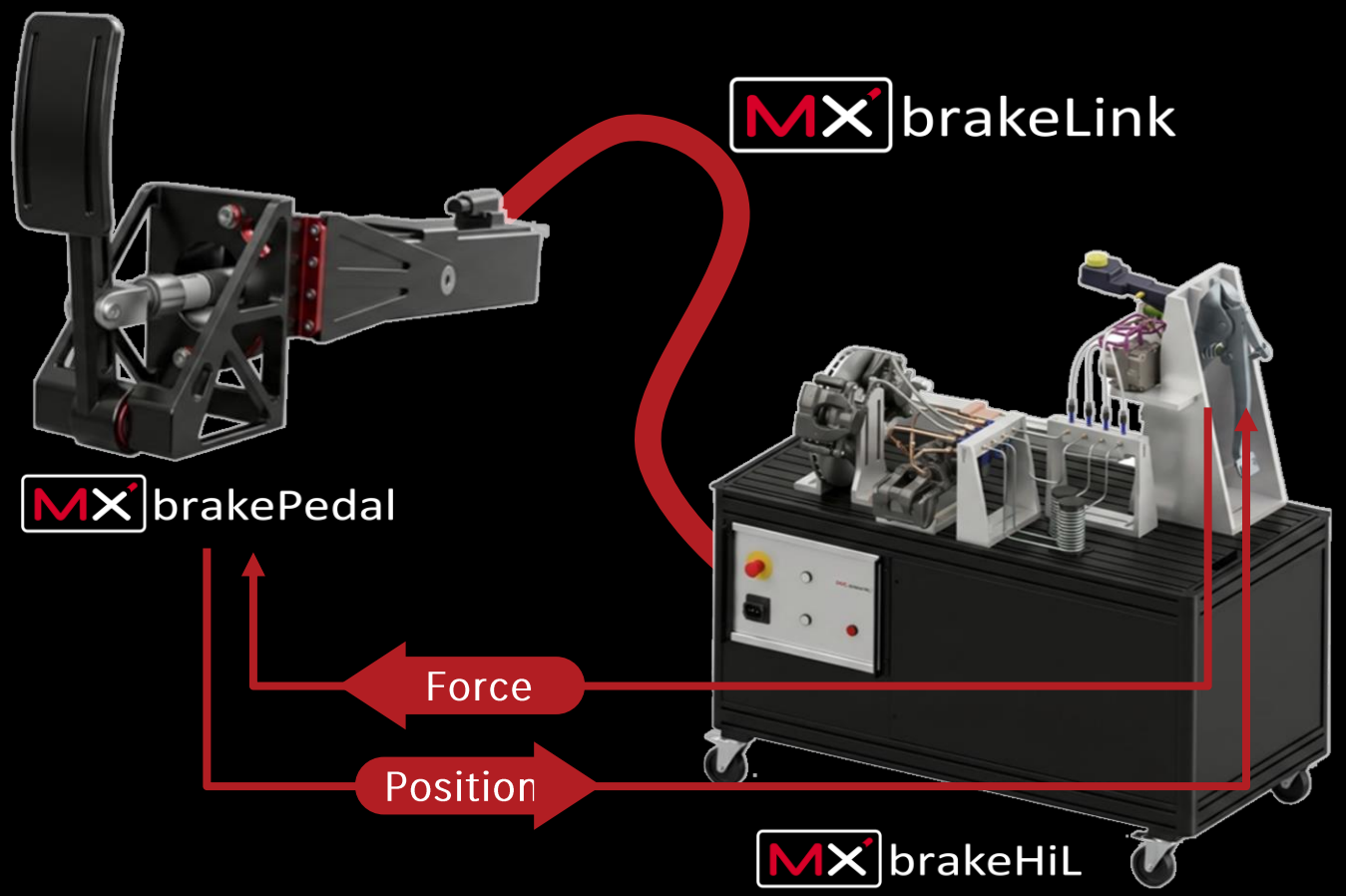
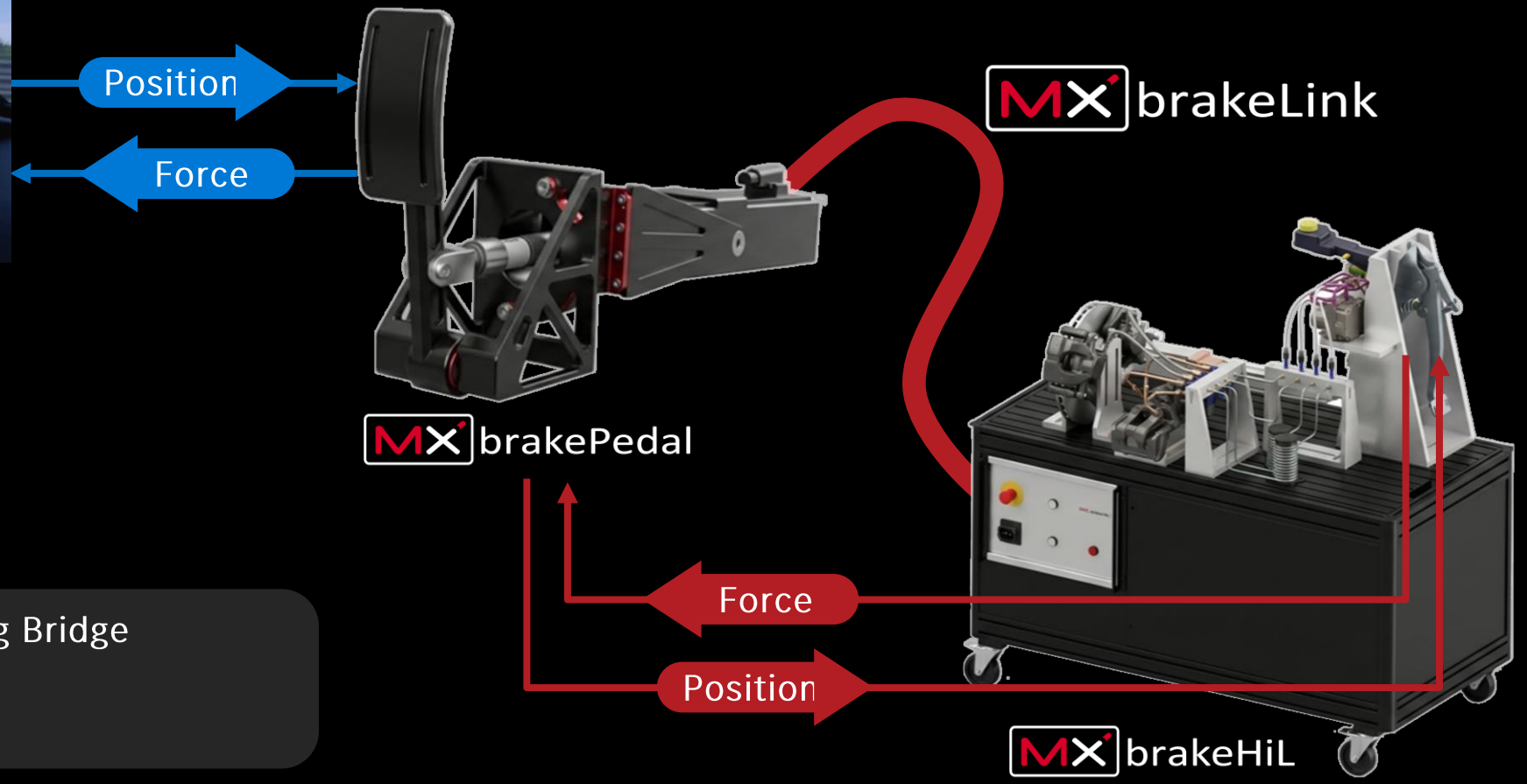
MXbrakeLink – Unified Testing Bridge
- Bidirectional DiL-to-HiL coupling
- Single source of truth for brake system data
- 1:1 comparability between virtual and hardware tests



MXbrakeLink: DIL-accessed Hardware-in-the-Loop testbench



MXbrakeLink – Unified Testing Bridge

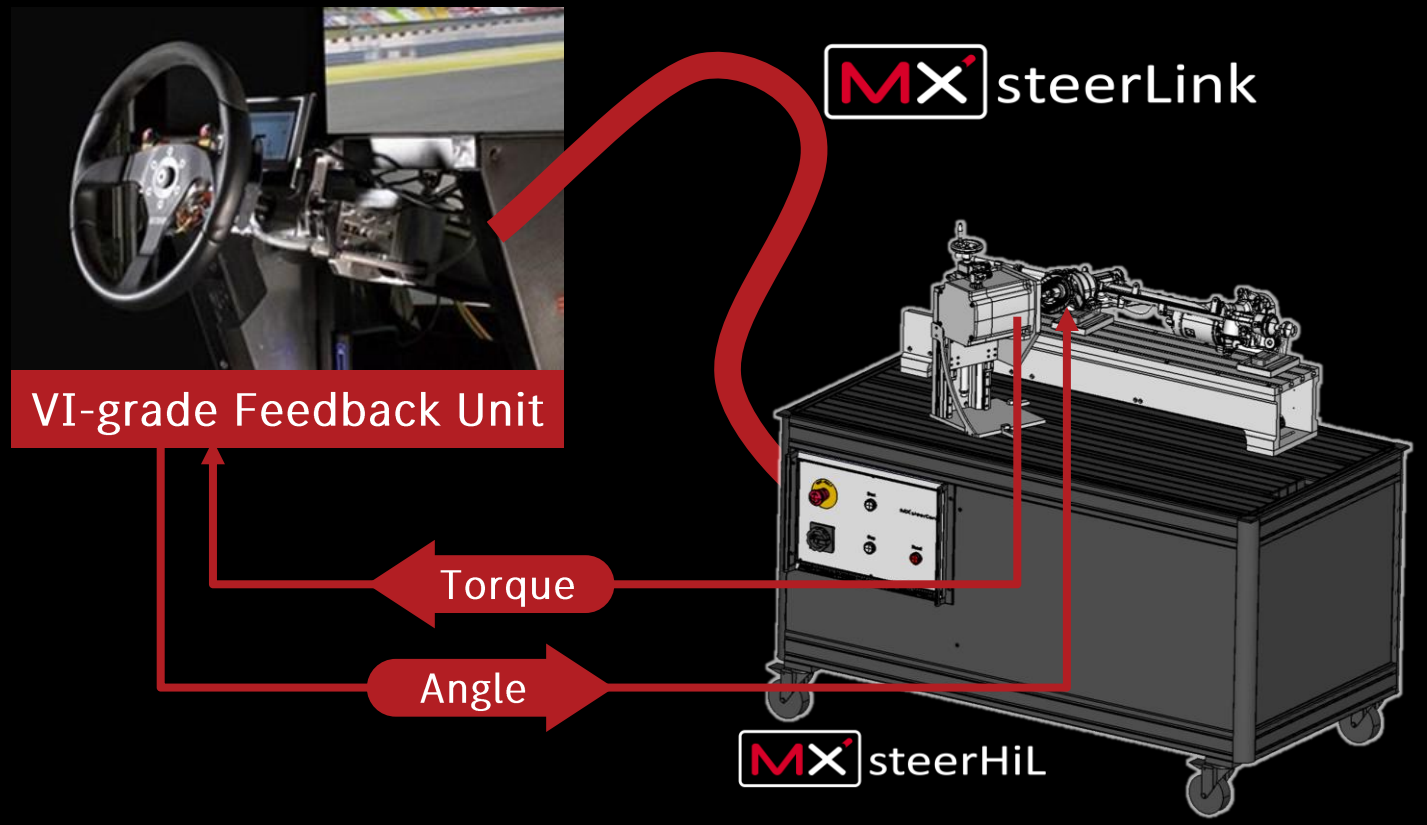
- Position: ~ 1 ms latency
- Force: ~ 10 ms latency

MXsteerLink: DIL-accessed Hardware-in-the-Loop testbench

MXsteerHiL – HiL Powerhouse
- Real EPS — column or rack configuration
- Authentic steering feel incl. mechanical effects and ECU logic
- Compact footprint, standalone capable

VI-grade Feedback Unit
- Standalone force-feedback steering unit
- Up to 15 Nm steering torque
- Native CarRealTime integration
- Real-time feedback with low latency

MXsteerLink – Unified Testing Bridge
- Bidirectional DiL-to-HiL coupling
- Single source of truth for steering system data
- 1:1 comparability of steering feel — virtual vs. hardware



MXsteerLink: DIL-accessed Hardware-in-the-Loop testbench

Angle

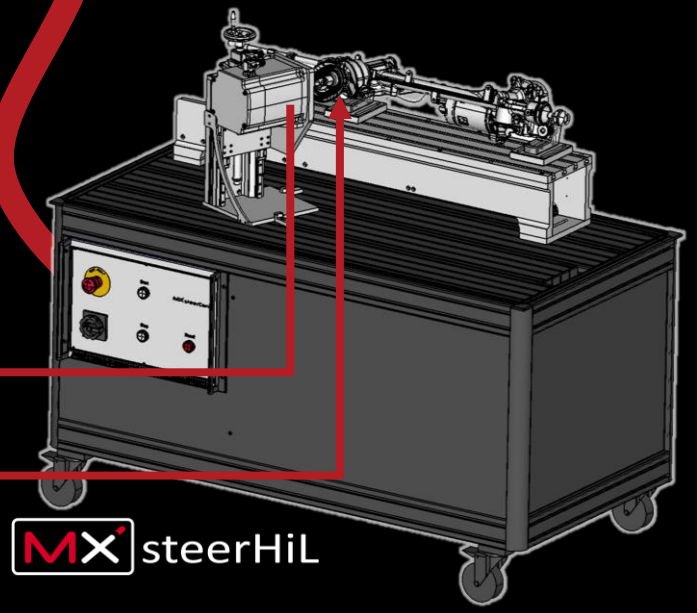
Torque

VI-grade Feedback Unit

MXsteerLink

Torque

Angle



MXsteerHiL

MXsteerLink – Unified Testing Bridge

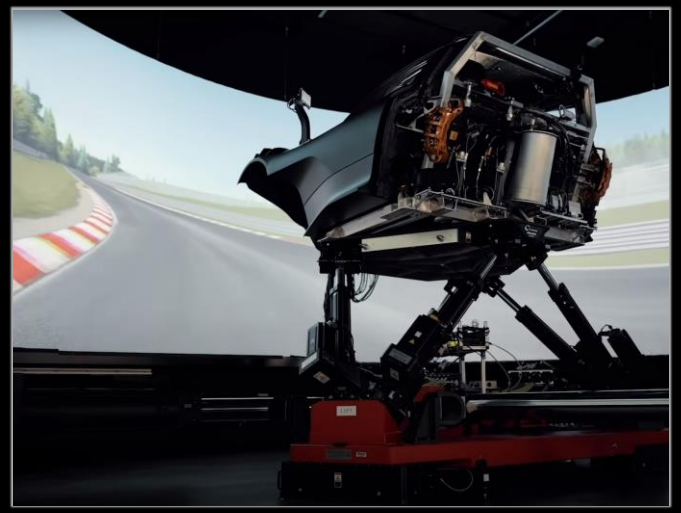
- Angle: ~ 1.5 ms latency
- Torque: ~ 2 ms latency

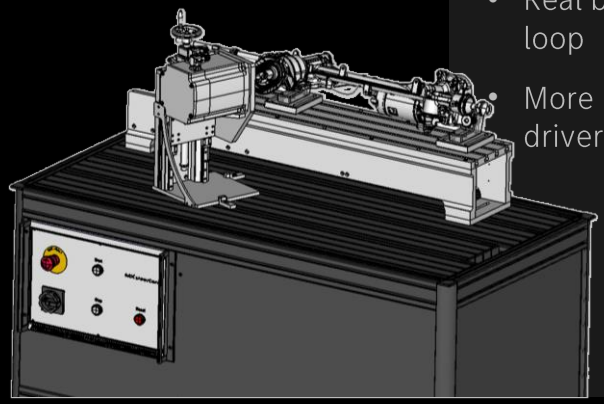
Summary

Accelerated Development
- Very early evaluation without physical prototypes
- Higher development maturity

Early Driver Integration
- Driver involved from early development phases
- Subjective assessment of ride, handling, and comfort

Safe Testing
- Risk-free evaluation of limit and critical maneuvers
- Repeatable and consistent test conditions





MX brakeHiL

MX steerHiL

Fast Iteration
- Rapid parameter changes and variant comparisons
- Immediate feedback from driver

Cost-Efficient Development
- Simulator bridges development gap with fewer prototypes
- Digital development plays a key role in achieving vehicle maturity

Realism with HiL
- Real brake and steering hardware in the loop
- More realistic vehicle feeling and higher driver confidence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