Agenda

- What is a Virtual Vehicle?

- Building a Virtual Vehicle

- Performing desktop studies

- Preparing for large scale studies

Agenda

- **What is a Virtual Vehicle?**

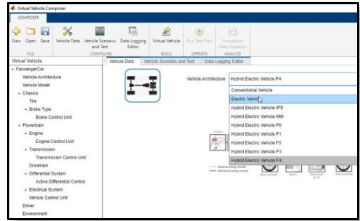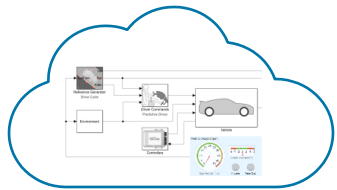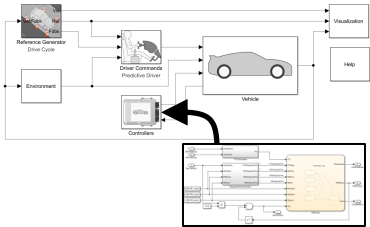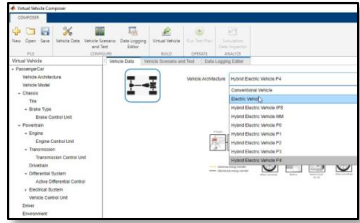- Building a Virtual Vehicle

- Performing desktop studies

- Preparing for large scale studies

What is a Virtual Vehicle?

- Companies are deepening virtual development
  - Increasing reliance on system-level simulation for development
  - Using physical prototypes for confirmation and final validation
  - Focus on powertrain, vehicle dynamics and ADAS / AD

- Common challenges
  - Integration of both **physics** and **software** models
  - Access to "right level" **fidelity** models across organization
  - Deploying models to users who **aren't tool experts**

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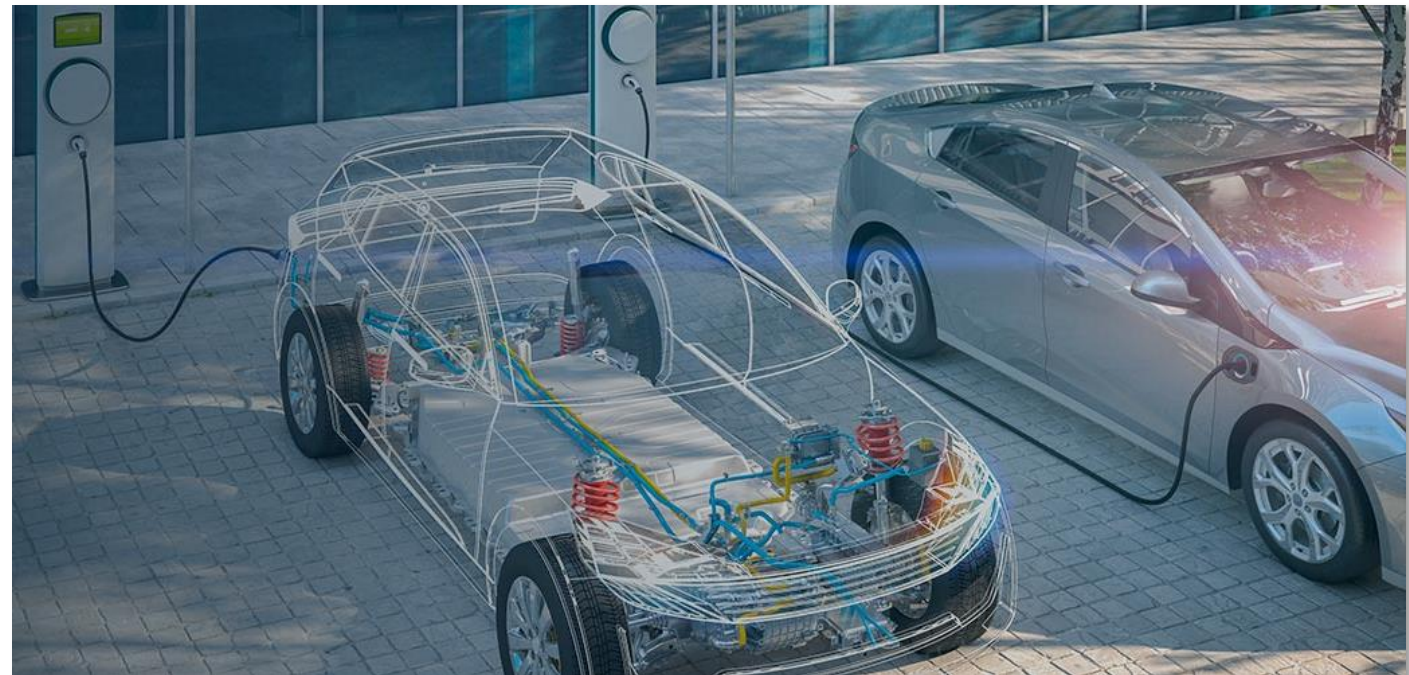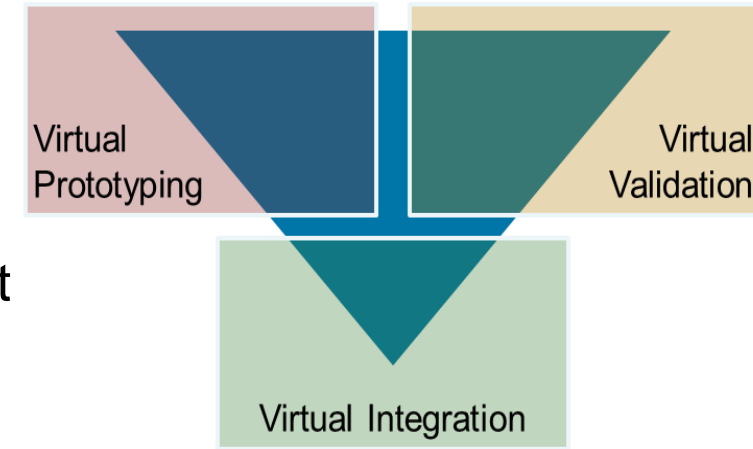
MathWorks Offering for Virtual Vehicle Simulation

Engineering Tools + Application Expertise

Create Vehicle	Integrate Software	Author Scenarios	Simulate & Analyze	Deploy Simulation
Vehicle Templates Subsystem Libraries Modeling Guidelines	C/C++ Interface Reduced Order Models FMU Integration	Scene & Scenarios Open Standards Drive Cycles	Visualization Data Analysis Report Generation	Cloud Integration Datalake Integration HIL Deployment

Value proposition:
- Proven tools for modeling of physics and software
- Reference applications for reduced time-to-simulation
- Common platform for model reuse
- Solutions for large-scale modeling and simulation
- Flexible platform for growth / new use cases

How Are Companies Building Virtual Vehicles with MathWorks?

Ford: Build Virtual Vehicle in minutes

- Different virtual vehicles are built for different use cases
- Common themes are the automation of model creation, simulation and analysis

GM: Autonomous parking development

Bosch: Autonomous truck development

Agenda
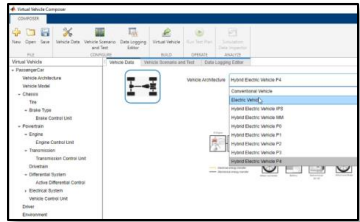
- What is a Virtual Vehicle?

- **Building a Virtual Vehicle**

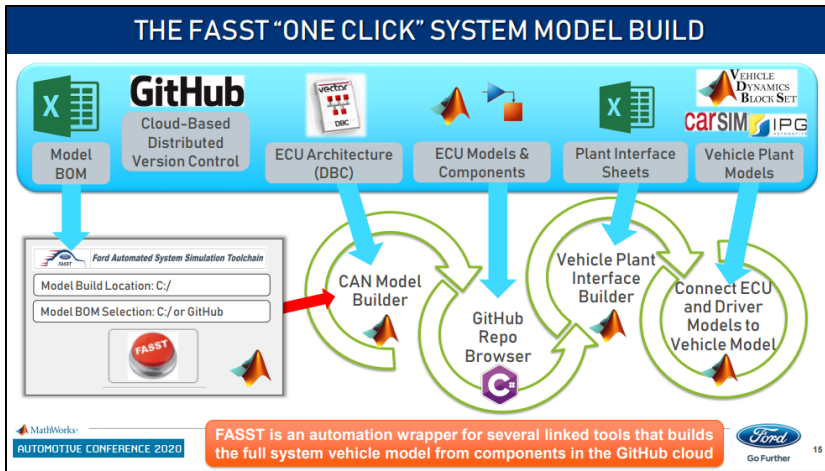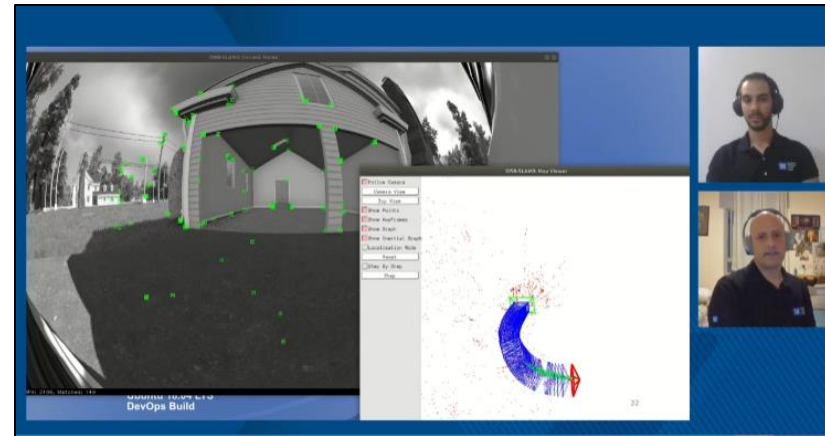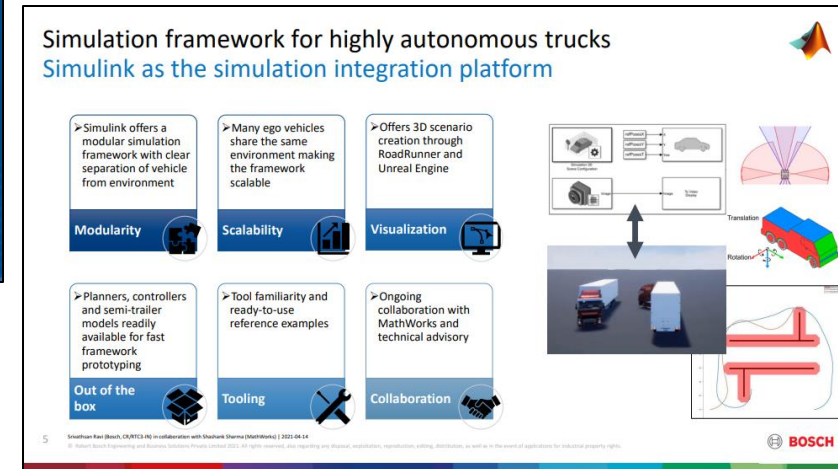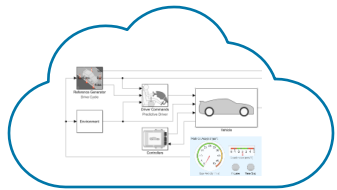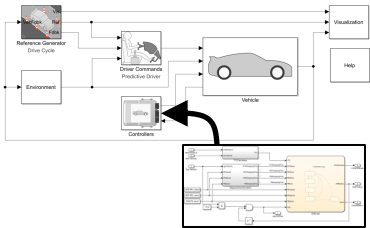- Performing desktop studies

- Preparing for large scale studies

Building a Virtual Vehicle with MathWorks

- Start with one of our reference applications
- Customize as needed
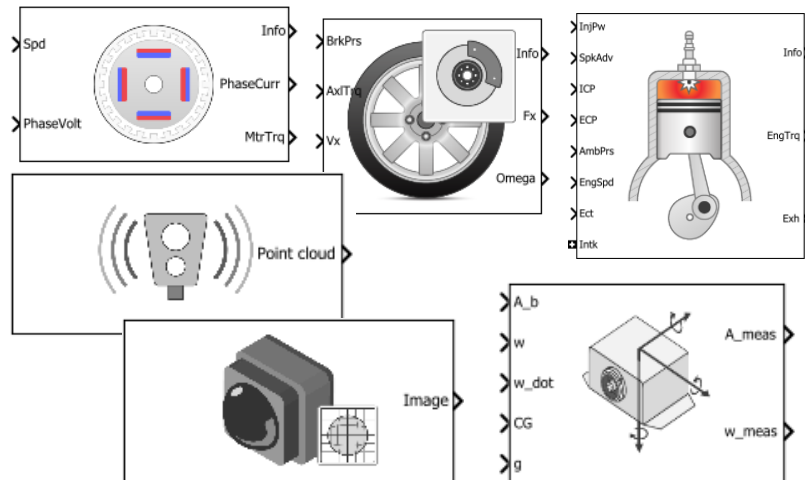
Learn more:

[Powertrain Blockset](#)

[Vehicle Dynamics Blockset](#)

[Simscape](#)

Simscape
Electrical | Driveline | Multibody | Fluids

Virtual Vehicle Composer App
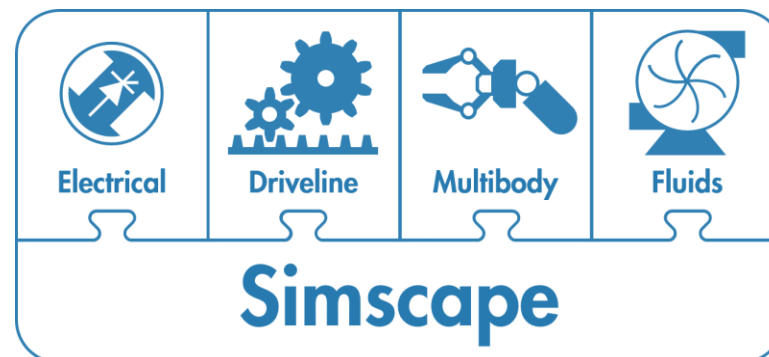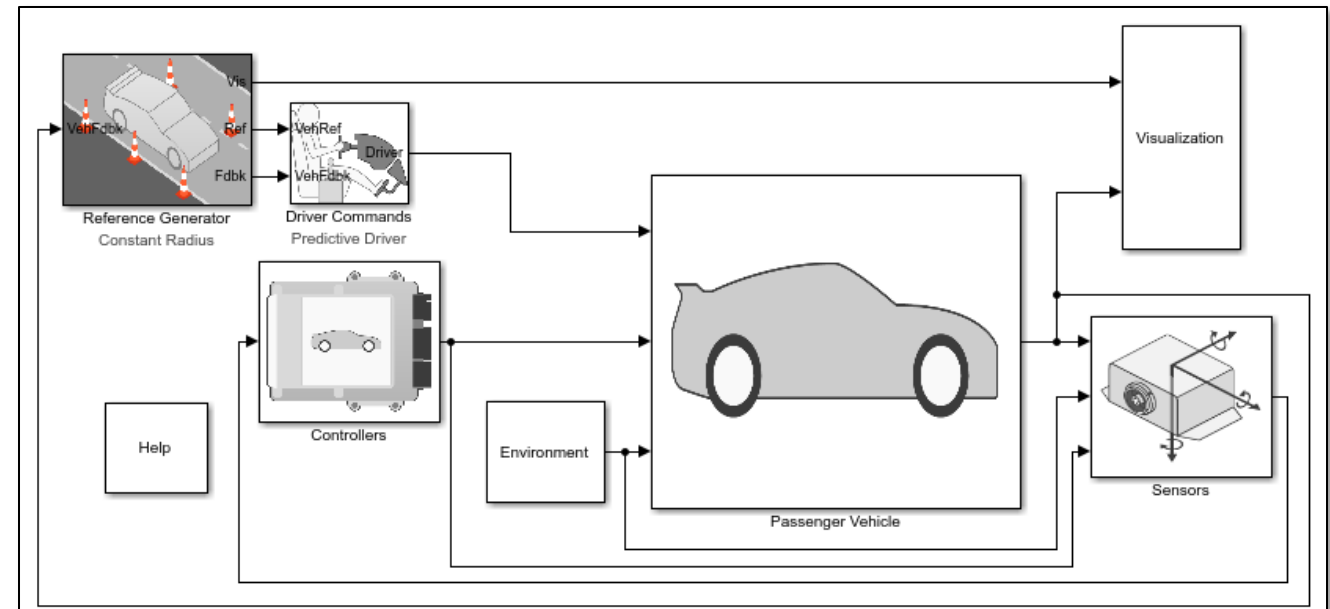
- Unified interface to quickly configure a virtual vehicle model, select test cases and review results

- Available with **Powertrain Blockset** and / or **Vehicle Dynamics Blockset**

- Includes detailed powertrain models, vehicle dynamics and closed-loop controls
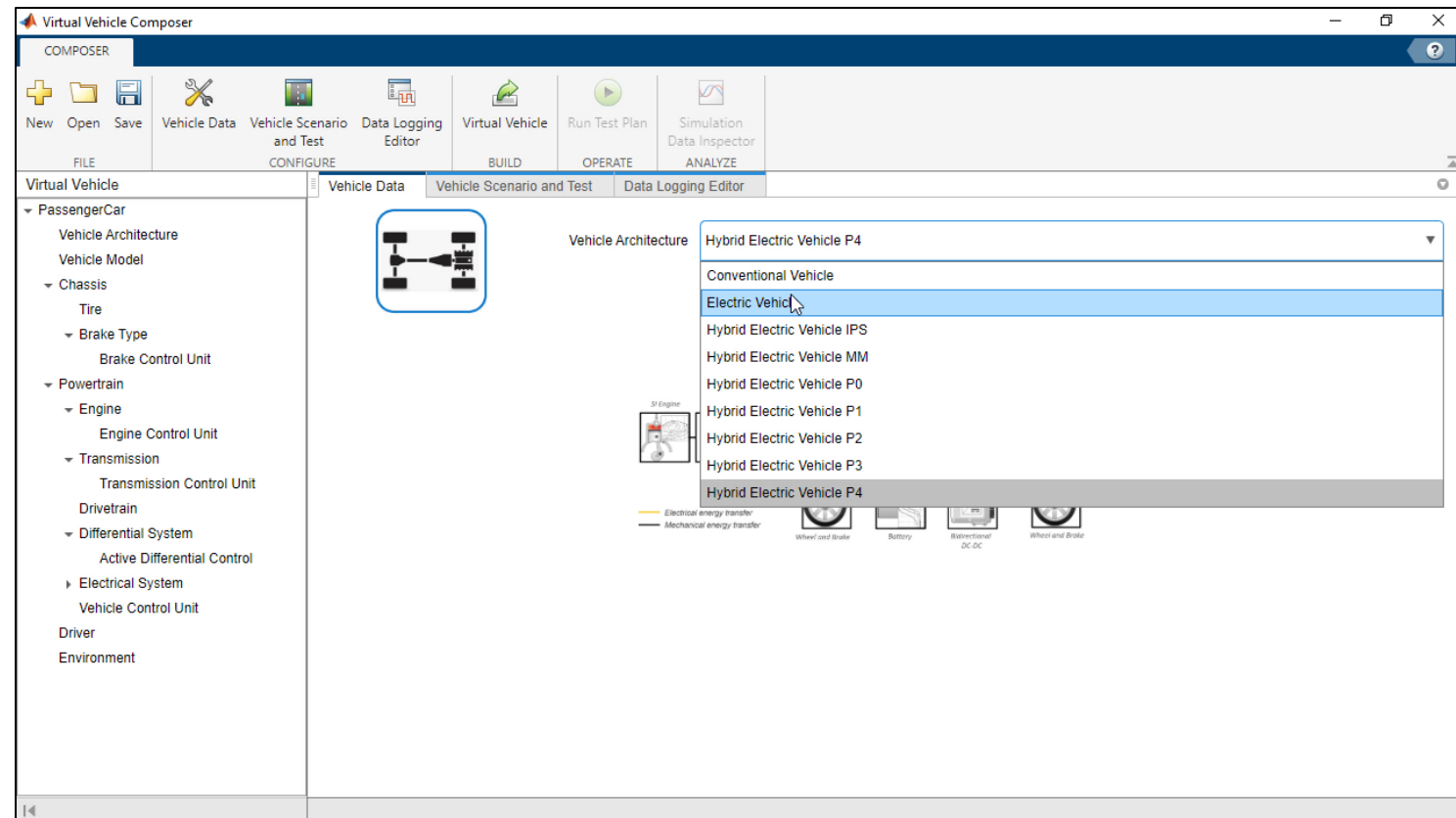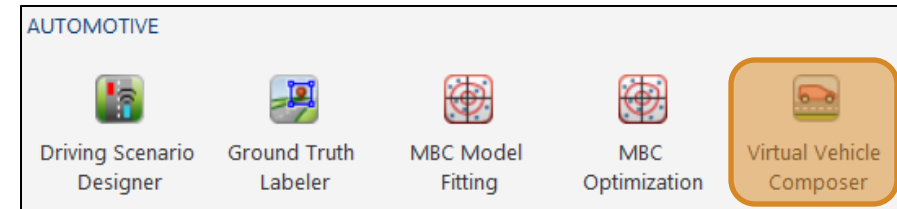
Learn more:

Virtual Vehicle Composer

Virtual Vehicle Composer App
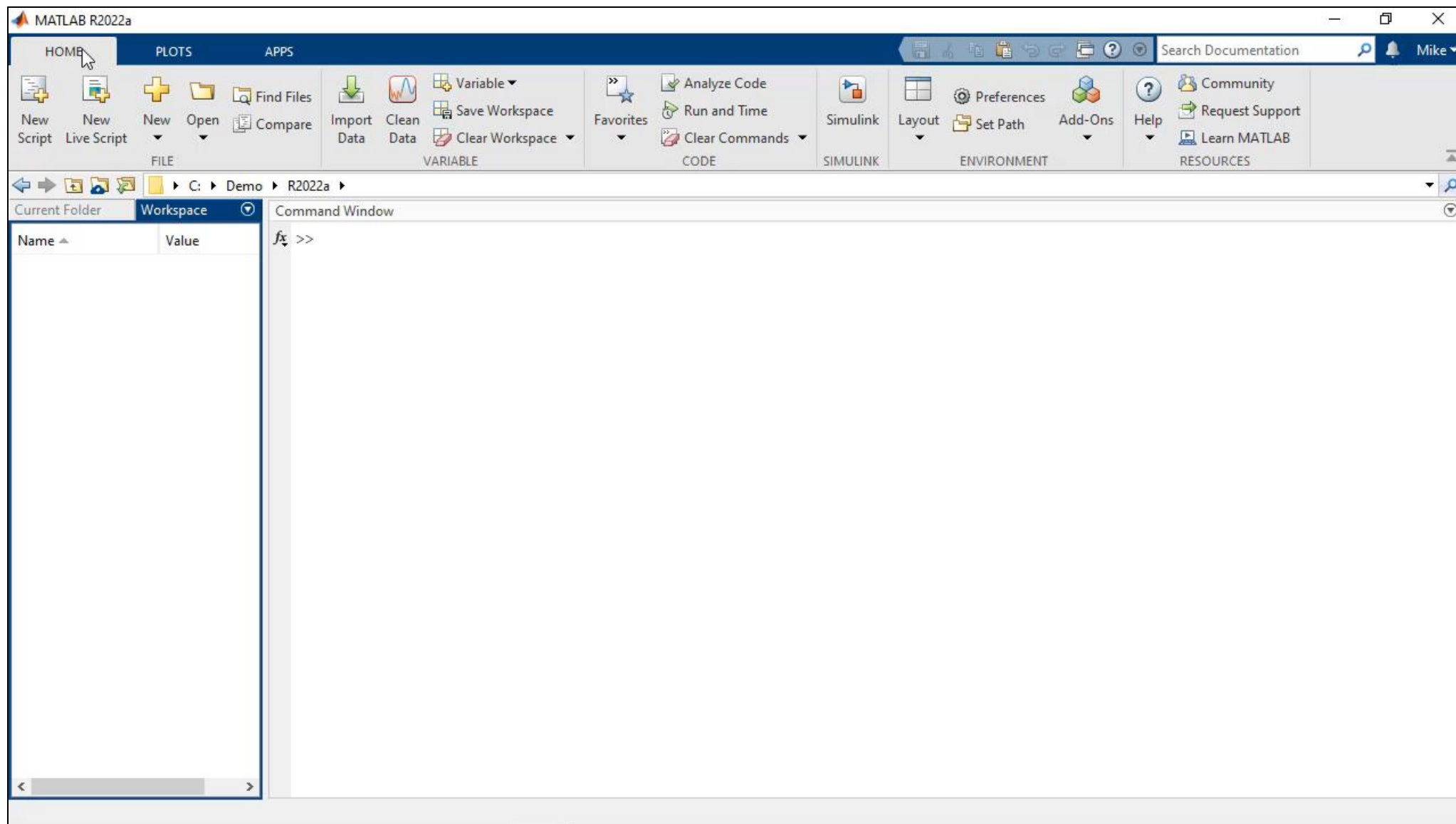
Workflow steps:
1. Start new session
2. Select powertrain
3. Select data
4. Select scenarios
5. Select signals to log
6. Generate model
7. Run test suite
8. Review results

Model Customization

- Virtual Vehicle Composer app gets you a <u>good starting point quickly</u>

- Generated models are open, so you can <u>customize it</u>
  - Add new plant, controller or sensor model features
  - Create custom test scenarios

- Leverage <u>Simulink platform</u>
  - Integrate C code, S-functions, FMU, etc.
  - Perform large scale studies
  - Deploy model (HIL, cloud, etc.)
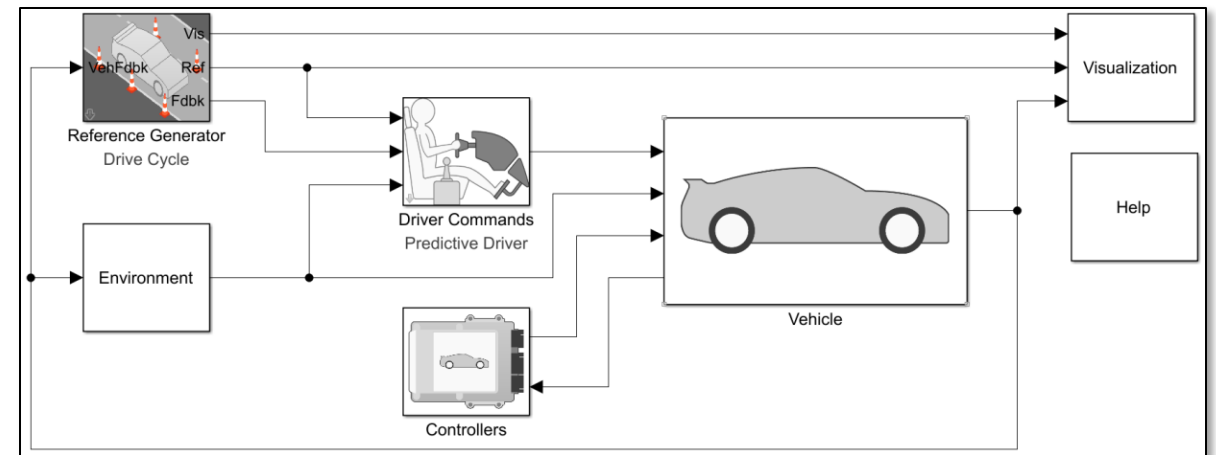
Autonomous Emergency Braking (AEB)

- If driver fails to apply brakes in time, AEB system engages automatically to avoid or mitigate collision
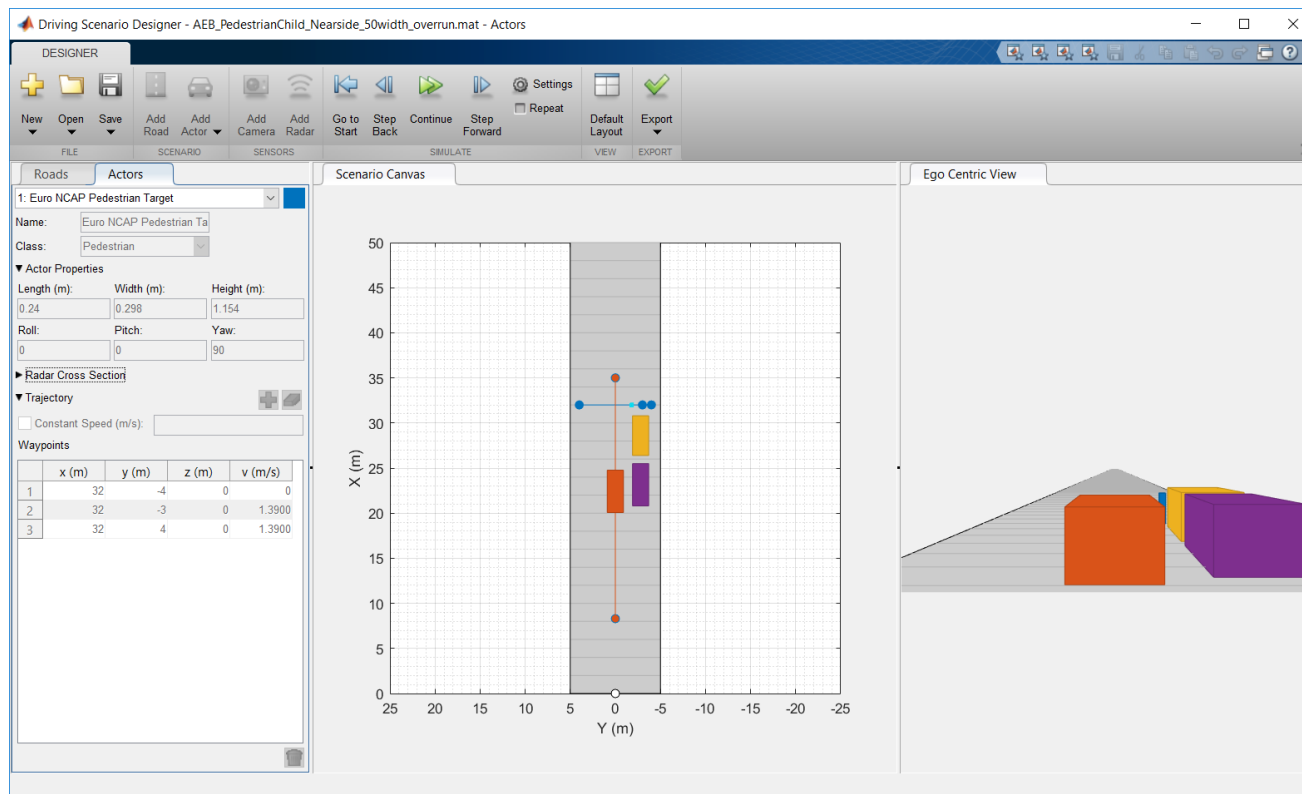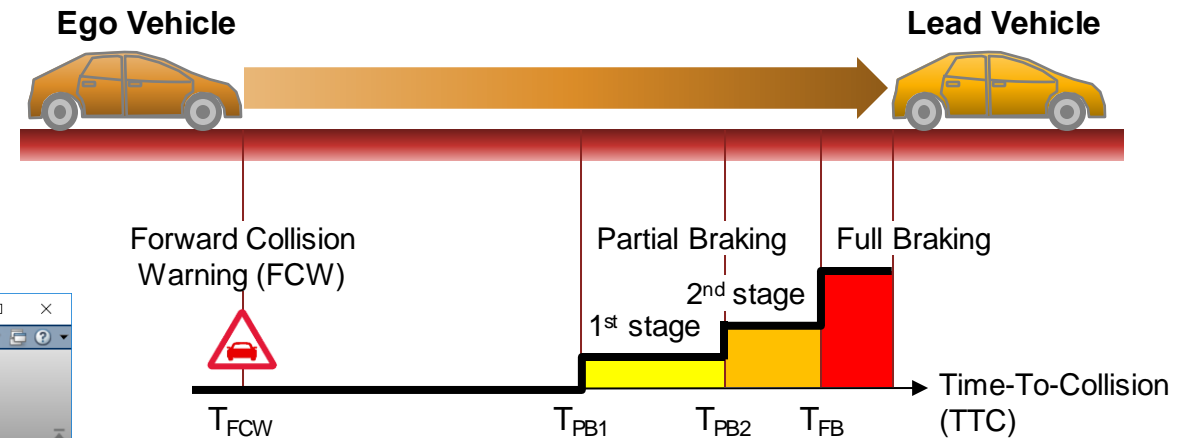

- Driving Scenario Designer can graphically author test scenarios
- Automated Driving Toolbox includes AEB demos for different use cases

Learn more:

Automated Driving Toolbox

AEB with Vehicle Variants

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Customizing for AEB
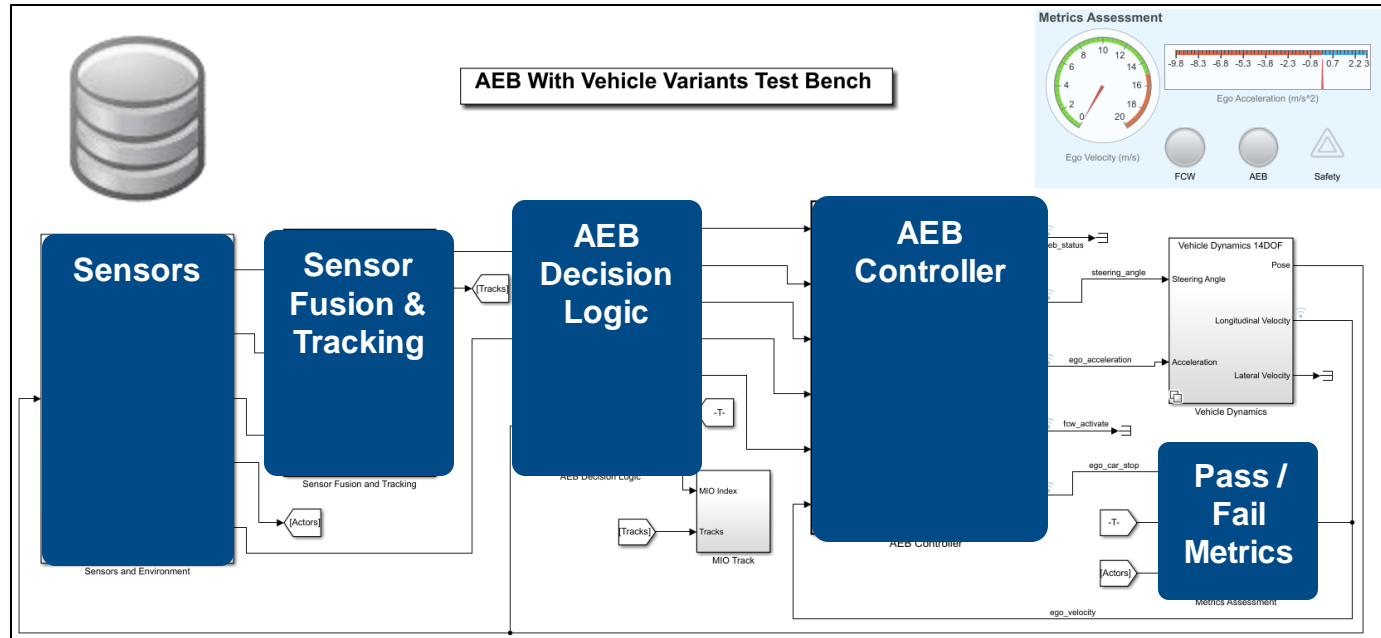
- Start with EV model generated from app
- Incorporate required features from AEB demo:
  - Sensor models
  - AEB control algorithm with brake input override
  - Test scenarios / metrics
- Import data developed for AEB application
  - Vehicle parameters
  - Controller calibrations
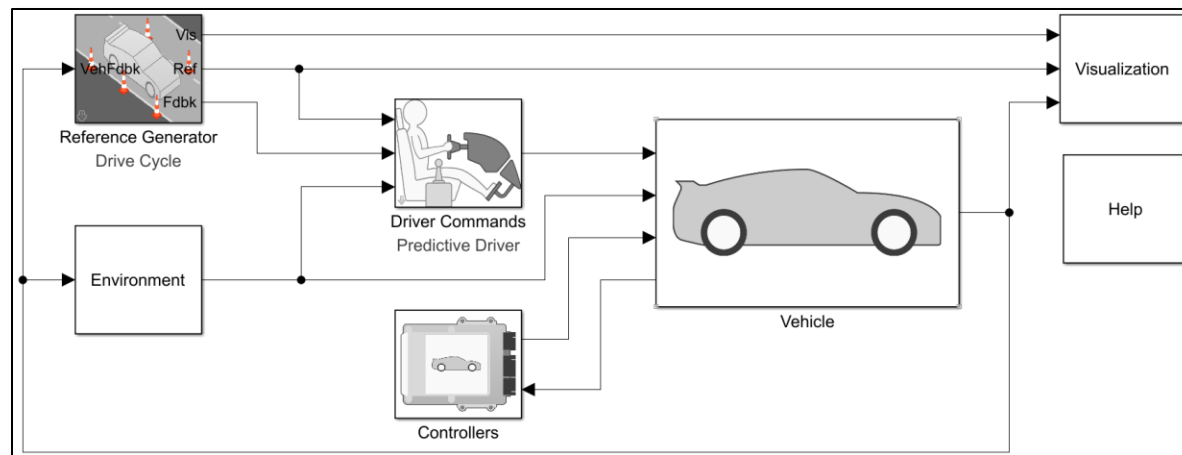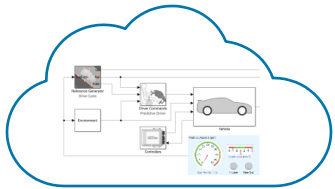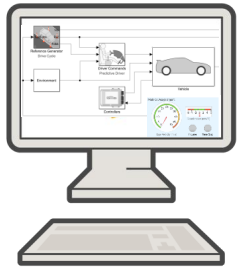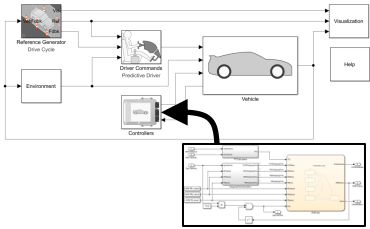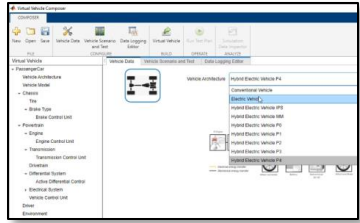
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Setting Up AEB Study

- How robust / optimal is AEB controller?
  - Tests → different scenarios
  - Plant → additional payload
  - Controller → brake application time
    → 2nd stage brake level

- Pail / fail criterion
  - Did AEB bring vehicle to stop before collision?

- Simulink Test can be used to manage test suite

Learn more:
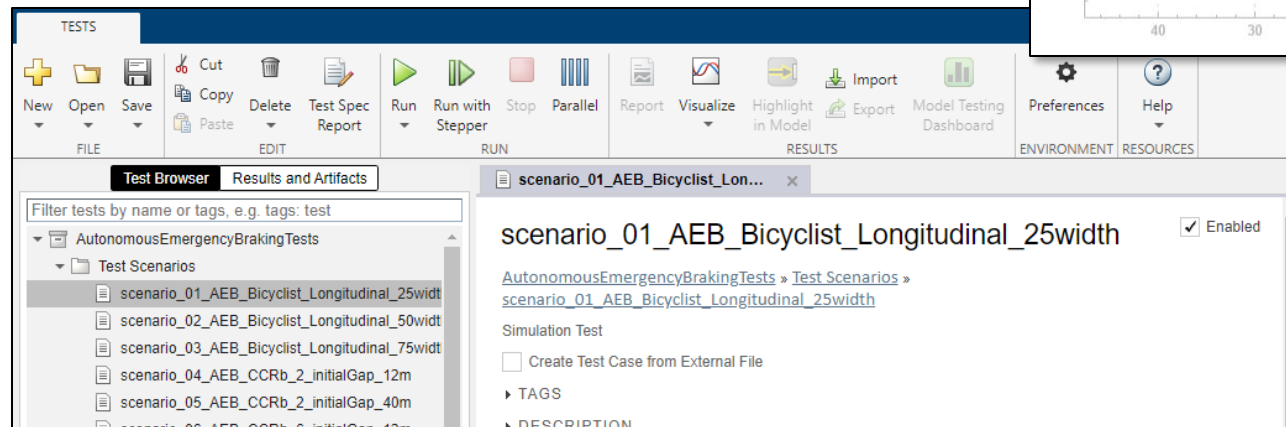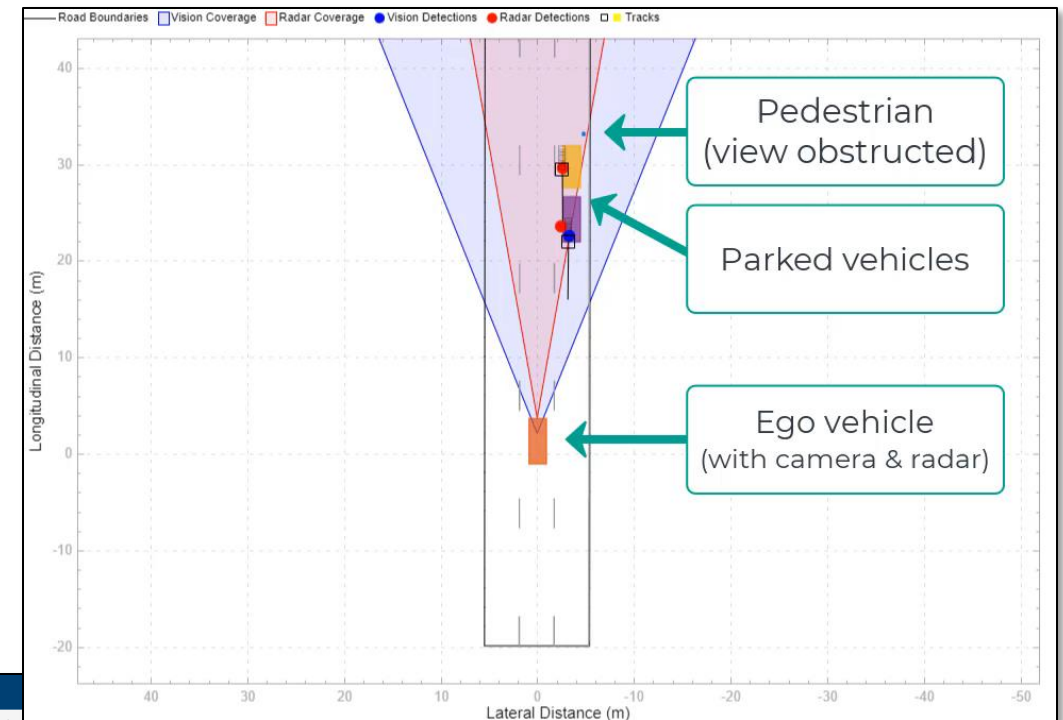
Desktop Study Results

- ## Desktop as a debugging platform
  - Full study requires >> 1000 runs
  - Desktop is good for small studies, but won't scale well
  - Perform reduced 16-run study before scaling to cloud
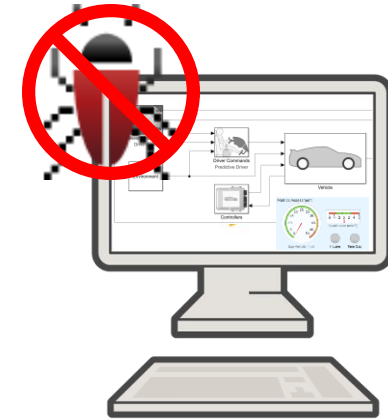
Scenario	TestResults	VehicleMass	BrakingTime	MediumBrakeLevel
{'scenario_24_AEB_PedestrianTurning_Farside_10kph' }	Pass	1575	0.064	4.24
{'scenario_24_AEB_PedestrianTurning_Farside_10kph' }	Pass	1575	0.064	6.36
{'scenario_24_AEB_PedestrianTurning_Farside_10kph' }	Pass	1575	0.096	4.24
{'scenario_24_AEB_PedestrianTurning_Farside_10kph' }	Pass	1575	0.096	6.36
{'scenario_24_AEB_PedestrianTurning_Farside_10kph' }	Pass	2175	0.064	4.24
{'scenario_24_AEB_PedestrianTurning_Farside_10kph' }	Pass	2175	0.064	6.36
{'scenario_24_AEB_PedestrianTurning_Farsio_10kph' }	Pass	2175	0.096	4.24
{'scenario_24_AEB_PedestrianTurning_Farside_10kph' }	Pass	2175	0.096	6.36
{'scenario_25_AEB_PedestrianTurning_Nearside_10kph'}	Fail	1575	0.064	4.24
{'scenario_25_AEB_PedestrianTurning_Nearside_10kph'}	Fail	1575	0.064	6.36
{'scenario_25_AEB_PedestrianTurning_Nearside_10kph'}	Fail	1575	0.096	4.24
{'scenario_25_AEB_PedestrianTurning_Nearside_10kph'}	Fail	1575	0.096	6.36
{'scenario_25_AEB_PedestrianTurning_Nearside_10kph'}	Fail	2175	0.064	4.24
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{'scenario_25_AEB_PedestrianTurning_Nearside_10kph'}	Fail	2175	0.096	6.36

- ## Desktop study confirmed that:
  - Custom EV model performed AEB test and returned desired metrics
  - Script to sweep test scenario and parameters worked properly
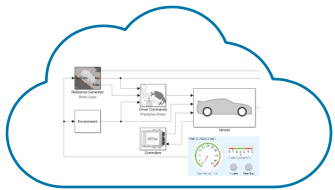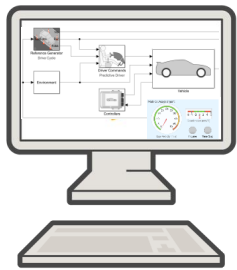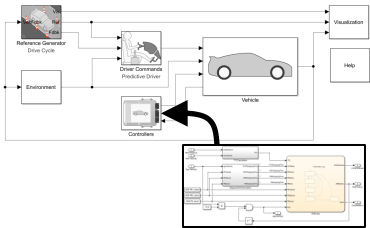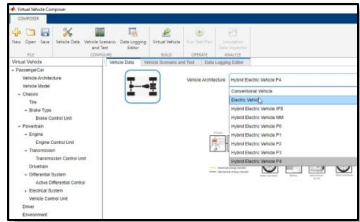 - Sample test scenarios passed / failed as expected

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Transitioning from Desktop to Cloud

- Why would you want to use the cloud?
  - Offload computational load from your working machine
  - Scale up computing power (RAM, GPU, multi-core CPU, etc.)
  - On-demand access ("elastic computing")
  - Proximity to cloud-based data repository

- It's easy to port your code from desktop to cloud-based workflows
  - No need to rewrite your algorithm
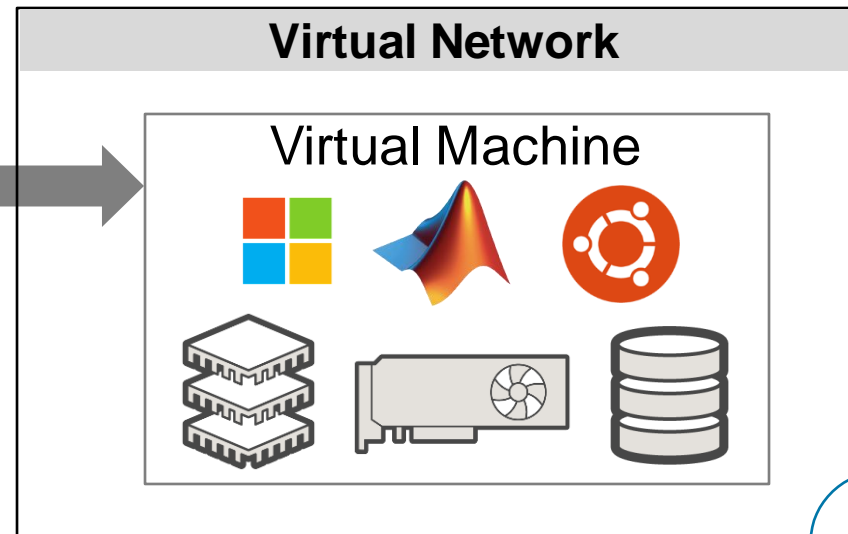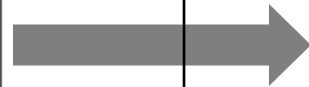 - Supports both Windows and Linux

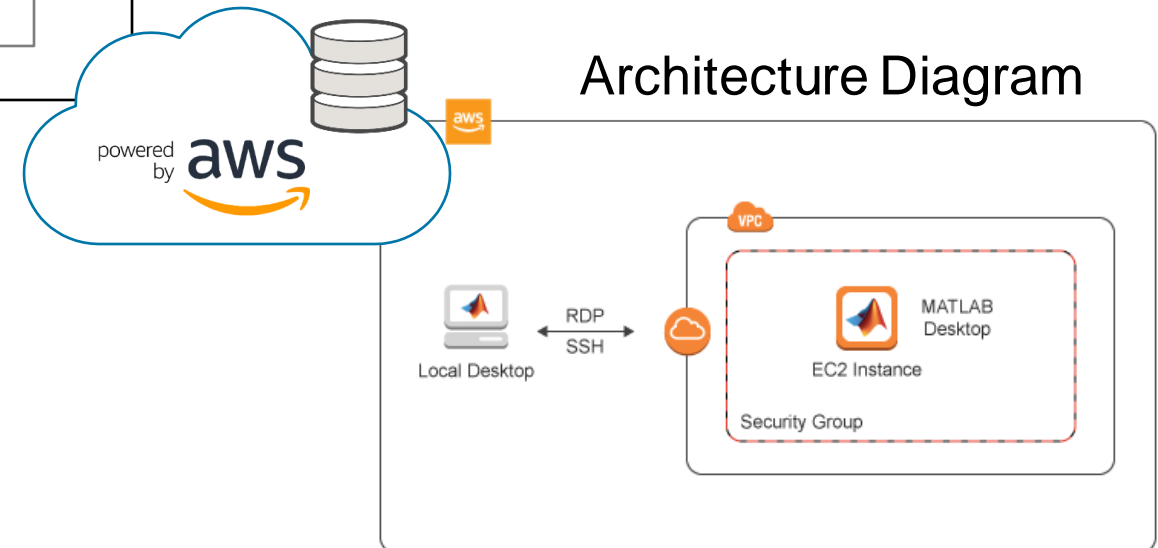Learn more:

Parallel Computing Toolbox

MATLAB Parallel Server

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Prebuilt Cloud Configuration - Reference Architecture

Remote Desktop

Virtual Network

Virtual Machine

- MathWorks provides Reference Architectures for specific OS and software stacks on Virtual Machines (VM) in the cloud

powered by aws

Architecture Diagram

RDP
SSH

Local Desktop

VPC

MATLAB Desktop

EC2 Instance

Security Group

- Select VM with desired hardware setup, then apply Reference Architecture

Learn more:

MATLAB on Amazon Web Services (AWS)

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Cloud Study Results

- **Selected Reference Architecture**
  - Linux VM with 128 cores

- **Executed 11,200 run test suite**
  - ~1.5 hours vs. ~2 days on quad core laptop

- **Insights**
  - Controller appears robust to payload and braking parameter changes
  - Review failed tests (3.6% of sims) in detail
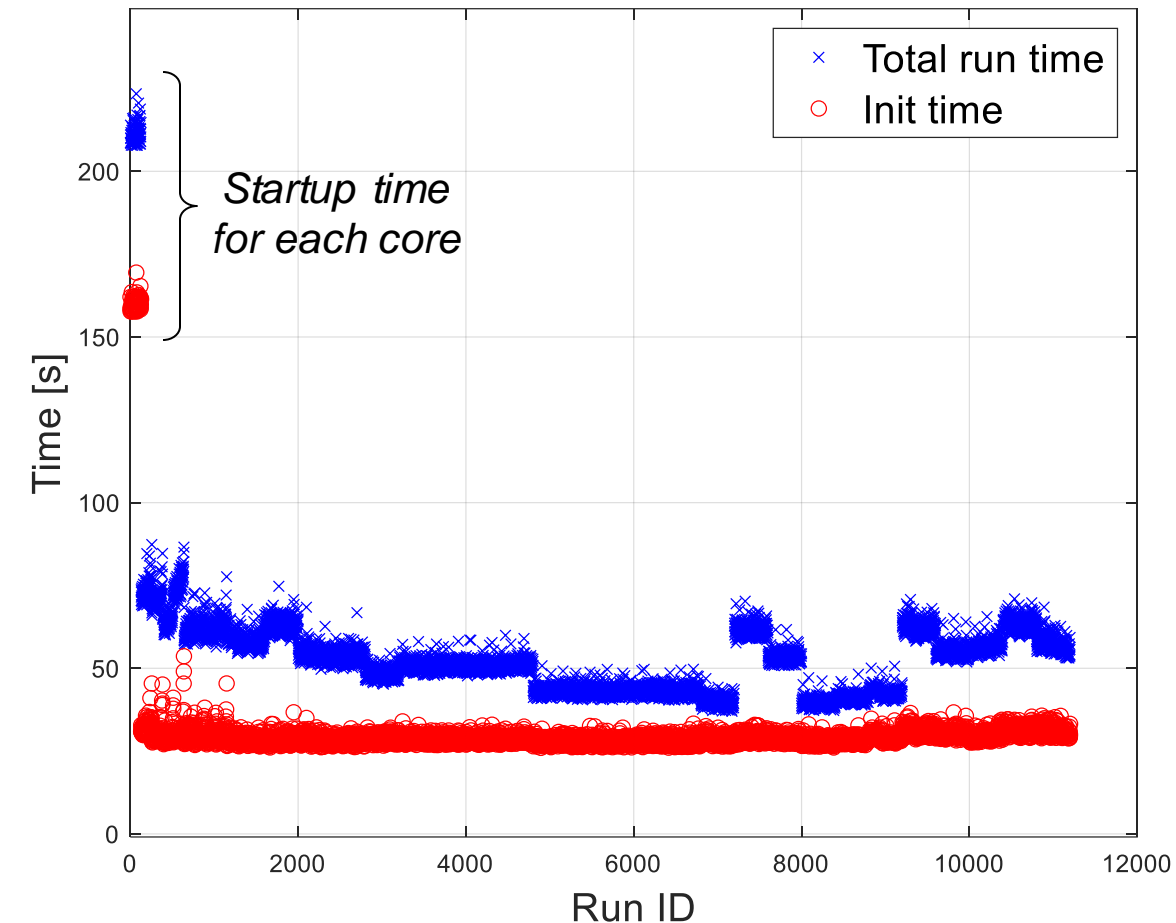
| Scenario	TestResults	VehicleMass	BrakingTime	MediumBrakeLevel
{'scenario_01_AEB_Bicyclist_Longitudinal_25width'}	Pass	1575	0.072	4.77
{'scenario_01_AEB_Bicyclist_Longitudinal_25width'}	Pass	1575	0.072	5.035
{'scenario_01_AEB_Bicyclist_Longitudinal_25width'}	Pass	1575	0.072	5.3
{'scenario_01_AEB_Bicyclist_Longitudinal_25width'}	Pass	1575	0.072	5.565
{'scenario_01_AEB_Bicyclist_Longitudinal_25width'}	Pass	1575	0.072	5.83
:	:	:	:	:

Key Takeaways

- New **Virtual Vehicle Composer app** makes it easy to build a Virtual Vehicle

- Generated models can be **customized**

- Studies can be performed on **desktop**

- Work can easily be deployed to the **cloud** for large-scale studies
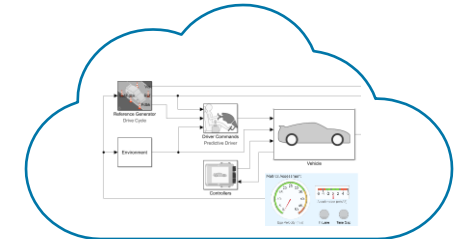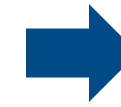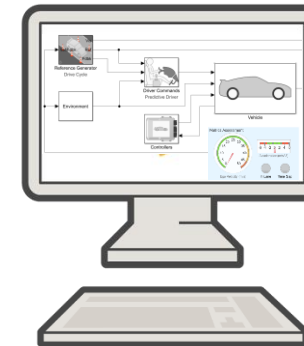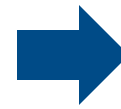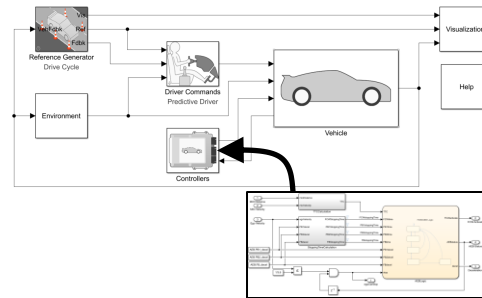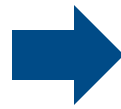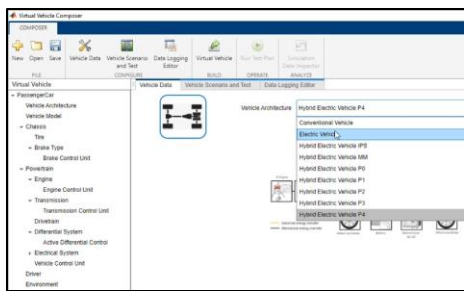
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Germany

Thank you

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Dr. Jan Janse van Rensburg: jjansev@mathworks.com

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