Simulink for Virtual Vehicle Development

Chris Fillyaw
Application Engineering Manager
cfillyaw@mathworks.com

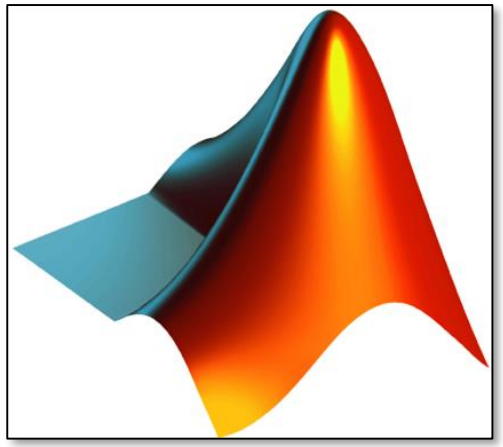
Mike Sasena, PhD
Automotive Product Manager
msasena@mathworks.com

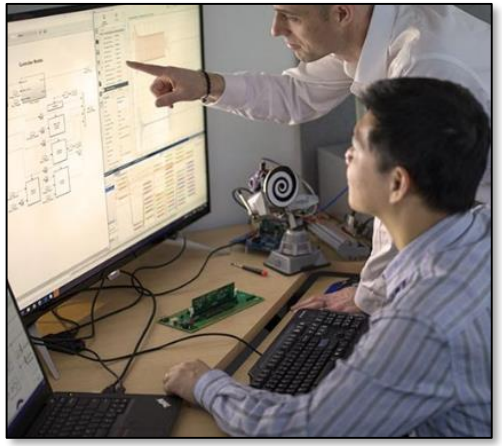
© 2020 The MathWorks, Inc.

Key takeaways

MathWorks provides a **powerful platform** for building your **Virtual Vehicle**

Our platform is very **flexible**, and we can help you **customize** it for your needs

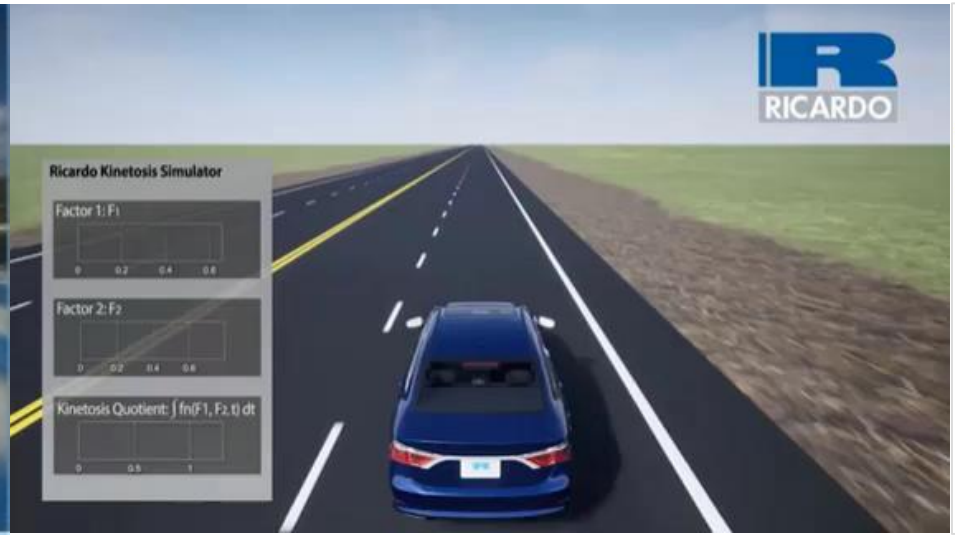


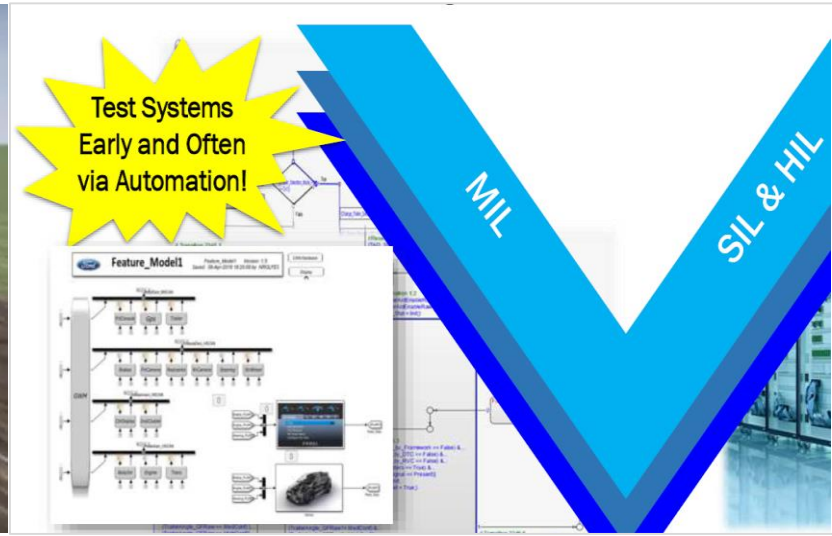


Out-of-the-box capability

Custom virtual vehicle solution

Virtual vehicle: functional simulation of full vehicle behaviors





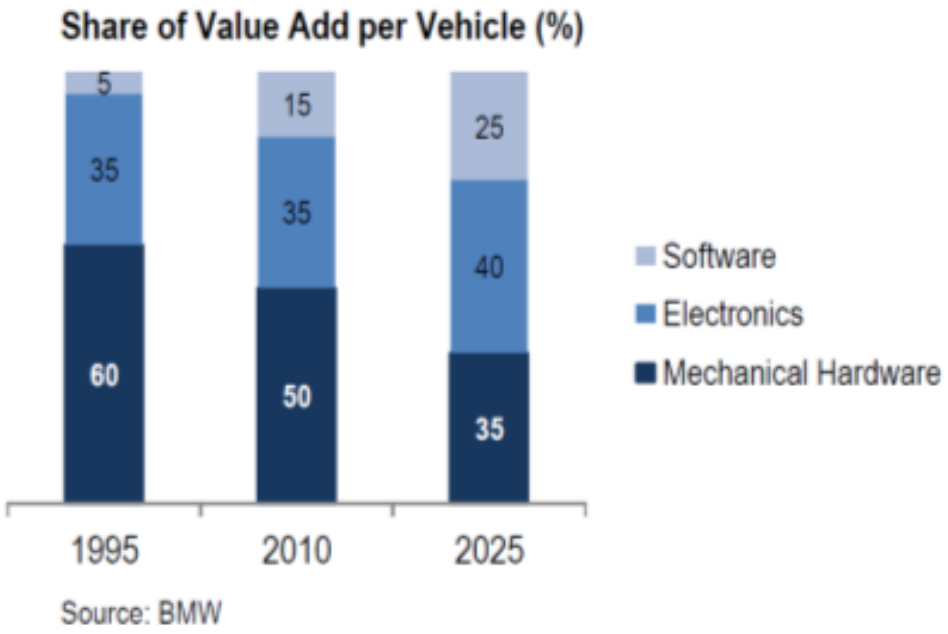
[Tesla: vehicle design tradeoff]

[Ricardo: simulating passenger comfort]

[Ford: software validation]

Reduce physical testing needed before design validation

Embedded software is essential for many virtual vehicle applications

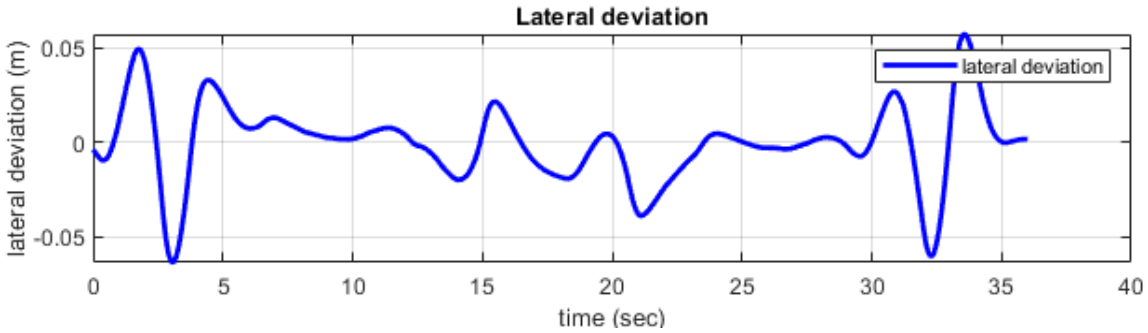


Virtual vehicle applications such as attribute development, software validation, calibration **require simulation of embedded software**.

- Application software behavior fully represented
- Interfaces consistent with software component definitions
- Basic software components included as need for the application

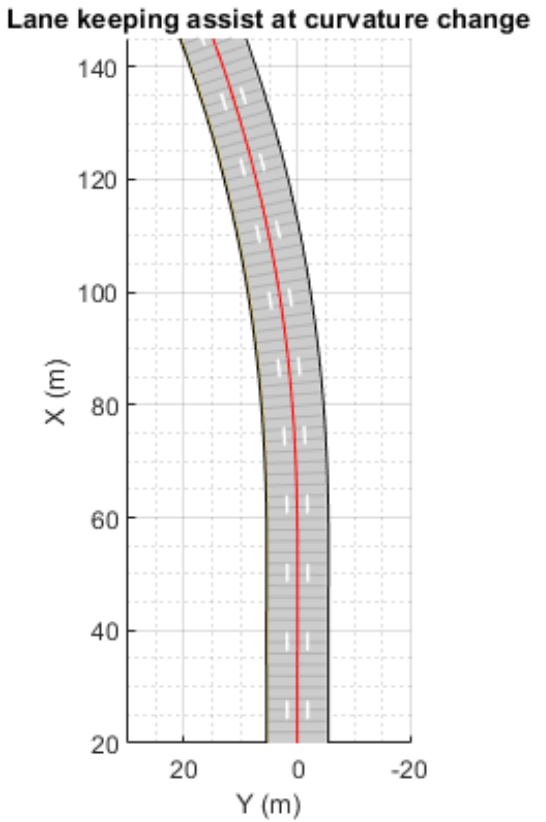
Example: Validating lane following software functional safety requirement (FSR)

FSR: The lane following system lateral error shall be less than 1 meter



Questions to consider:

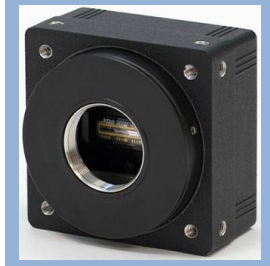
- System performance under normal conditions?
- Impact of environment conditions?
- Impact of a component failure?
- Required processor throughput?



System level interactions need to be considered

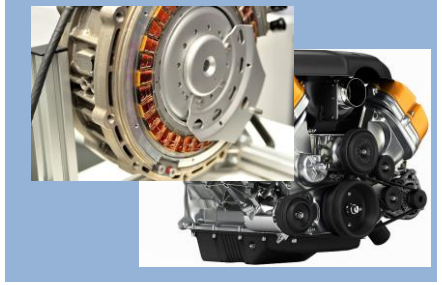
FSR: The lane following system lateral error shall be less than 1 meter

Sensors



Controllers

Powertrain



Environment

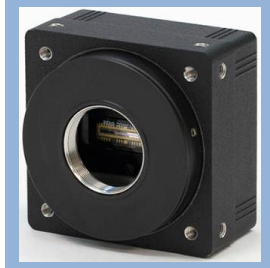
Driver

Vehicle

System level testing typically occurs with hardware integration

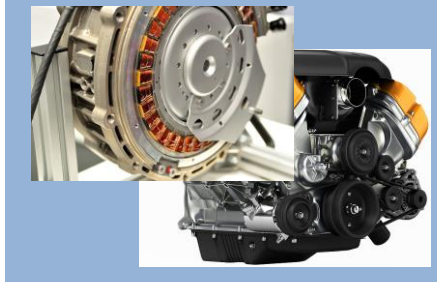
FSR: The lane following system lateral error shall be less than 1 meter

Sensors



Controllers

Powertrain

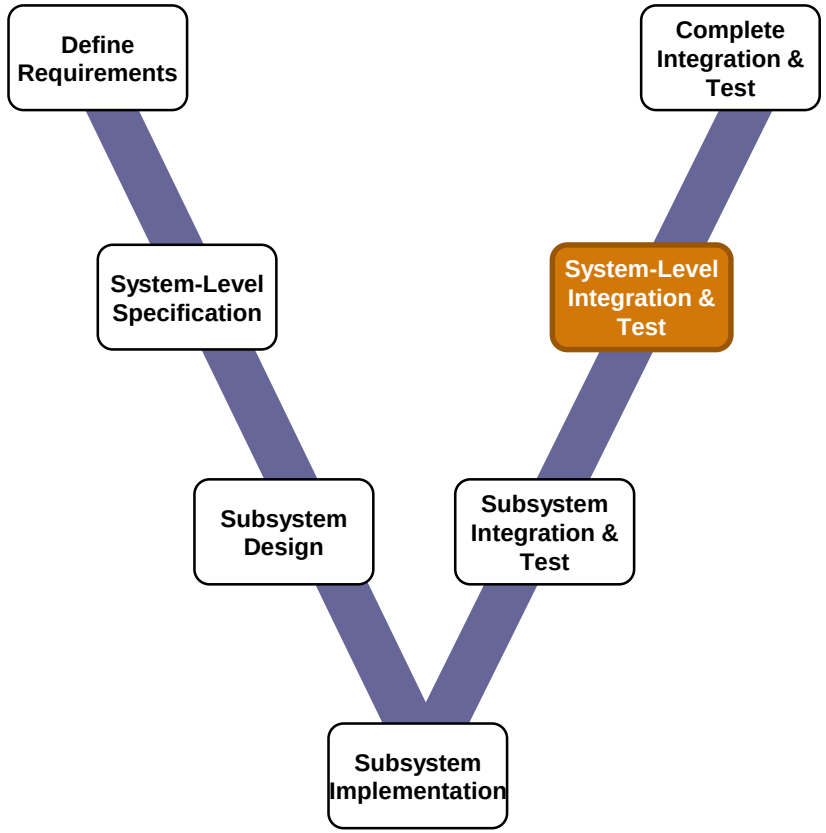


Environment

Driver

Vehicle

Discovering problems during system-level integration is ***expensive***

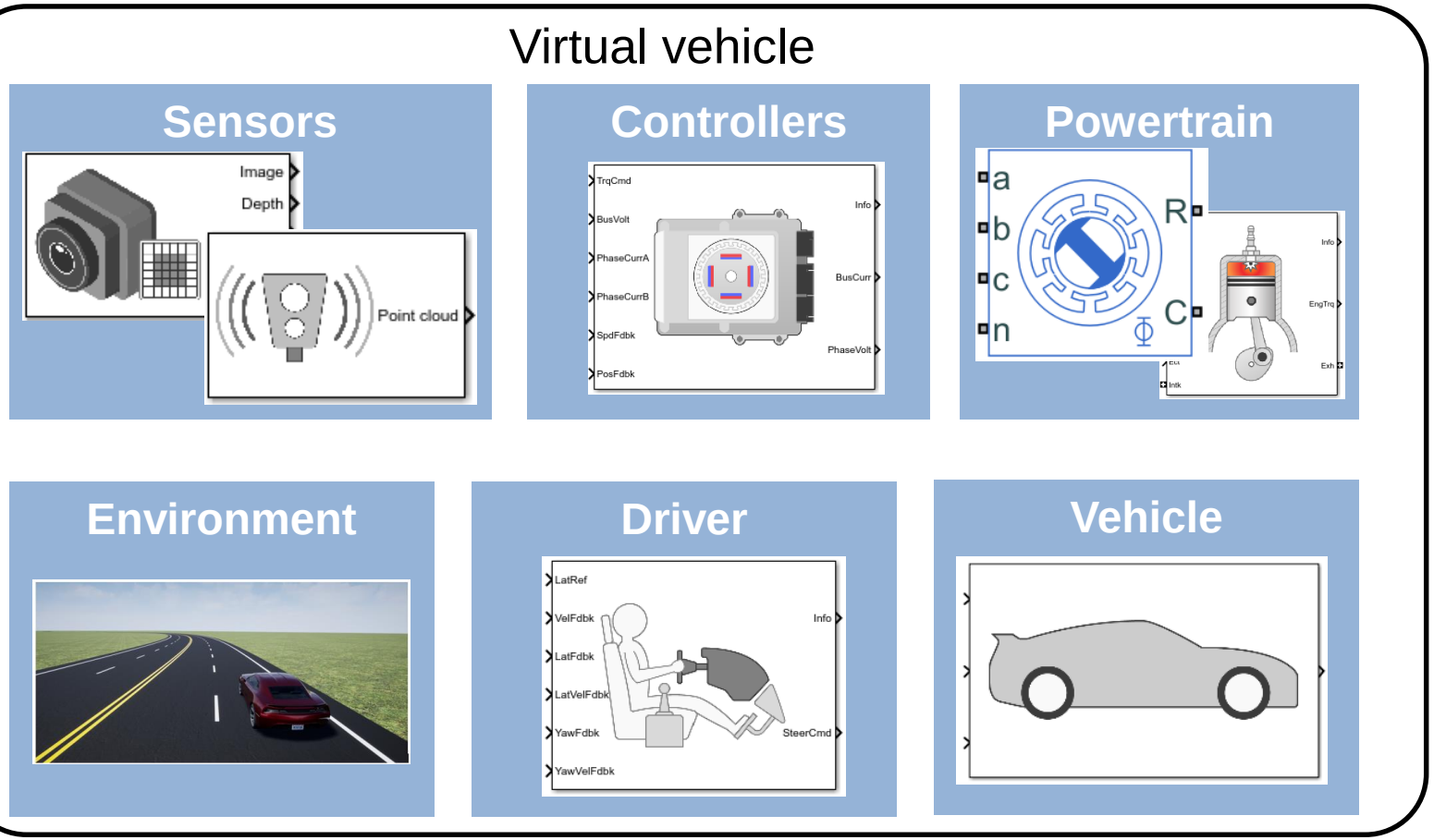


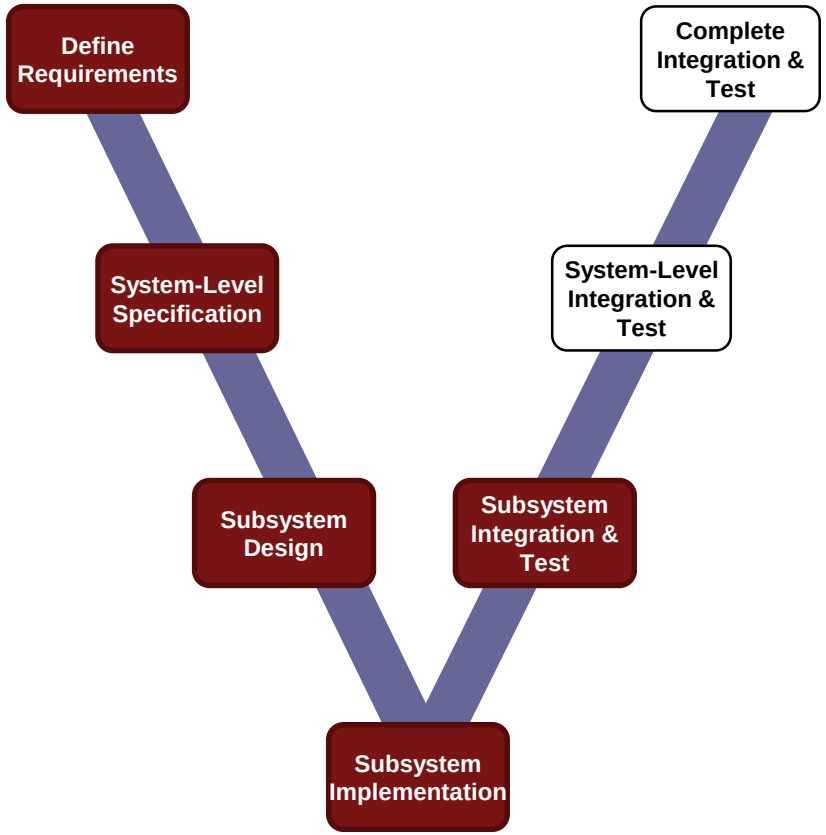
Validate software against function safety requirements early

FSR: The lane following system lateral error shall be less than 1 meter

*Use simulation to do system-level integration testing **early***

Virtual vehicle





Agenda

- Common challenges
- MathWorks solutions
- Case study

Agenda

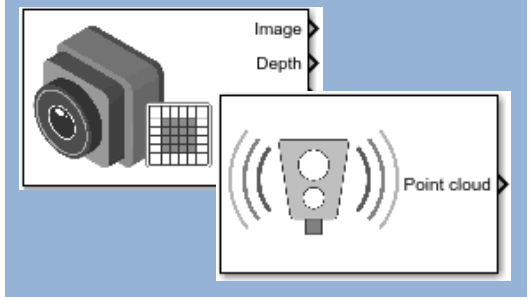
- **Common challenges**
- MathWorks solutions
- Case study

Challenges to early system-level testing

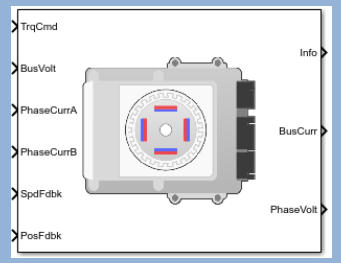
Create Vehicle → Integrate Software → Author Scenarios → Simulate & Analyze → Deploy Simulation

Virtual vehicle

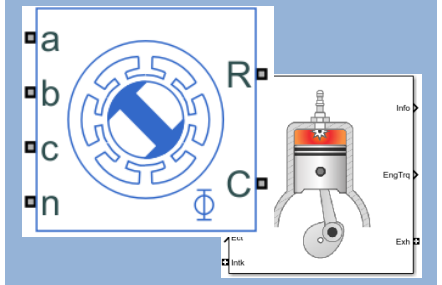
Sensors



Controllers

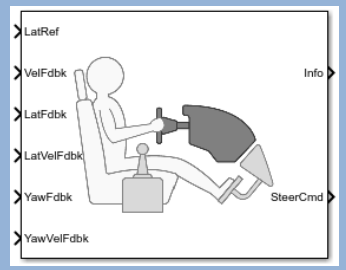


Powertrain

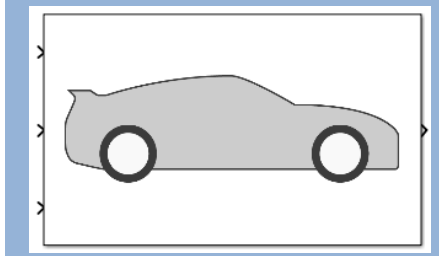


Environment

Driver



Vehicle



Using a virtual vehicle for systems integration testing early in development can **save time / money**

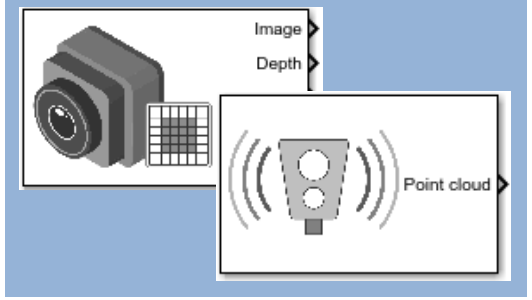
What are the **challenges** to building one?

Challenges to early system-level testing

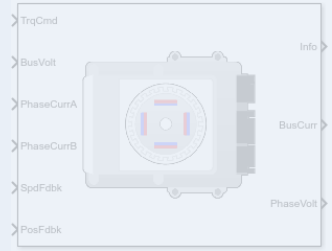
Create Vehicle | Integrate Software | Author Scenarios | Simulate & Analyze | Deploy Simulation

Virtual vehicle

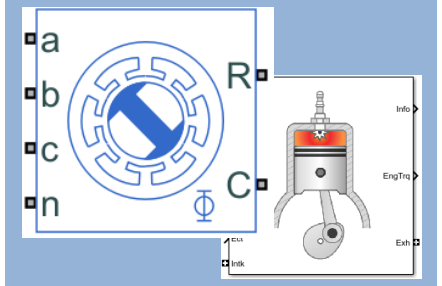
Sensors



Controllers



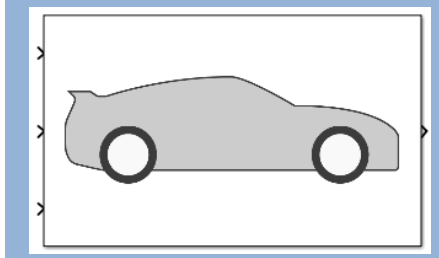
Powertrain



Environment

Driver

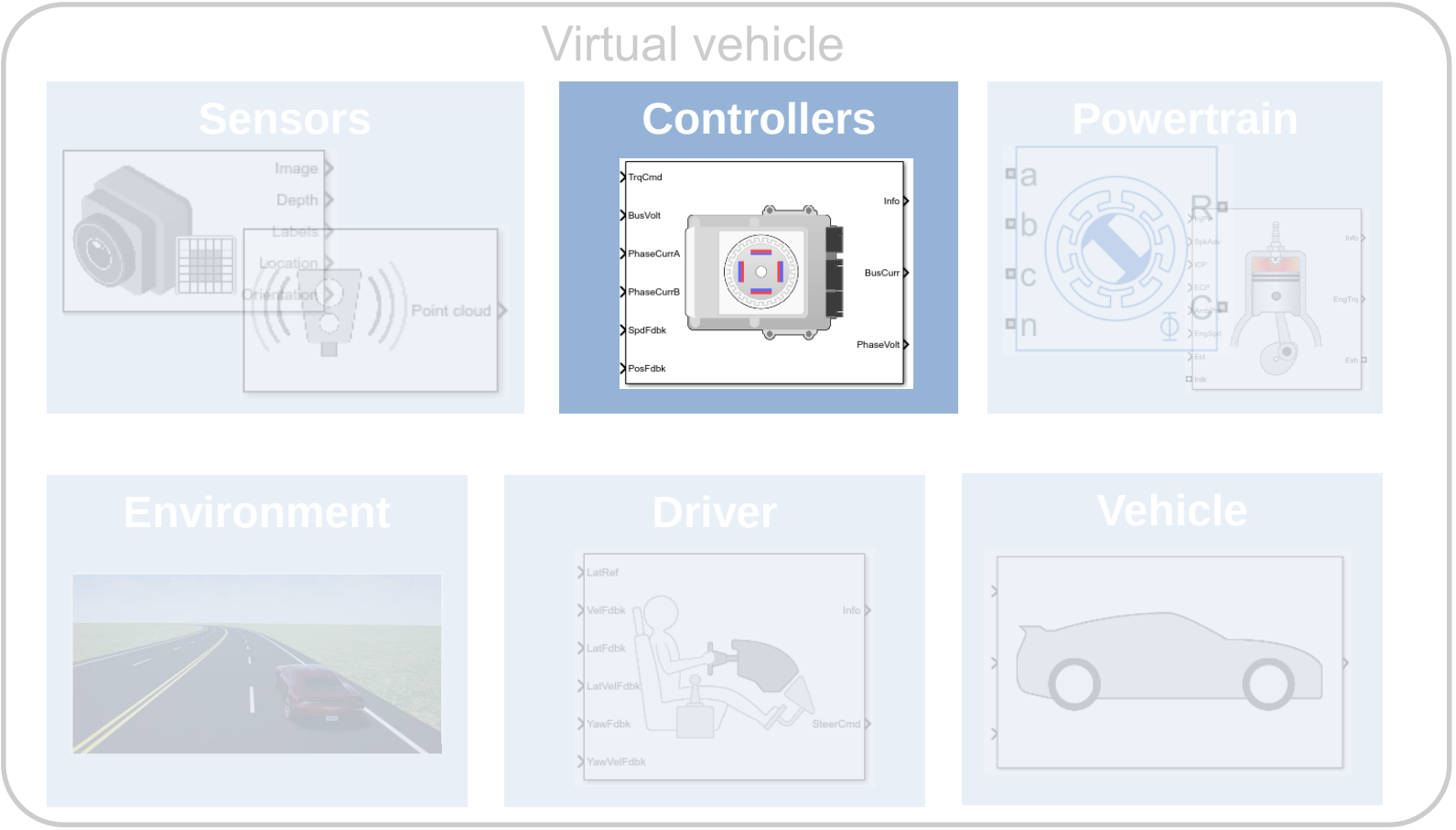
Vehicle



- Availability of appropriate vehicle level model
- Access to plant and sensor models with “right” level of fidelity
- Model calibration

Challenges to early system-level testing

Create Vehicle | **Integrate Software** | Author Scenarios | Simulate & Analyze | Deploy Simulation



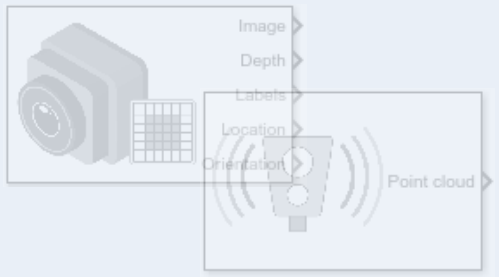
- Standardizing interfaces and data management
- Access to software components across different teams
- Assembly of software components from multiple sources

Challenges to early system-level testing

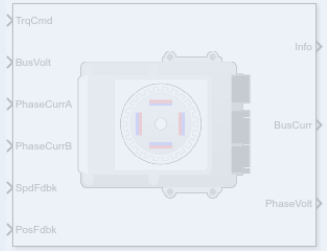
Create Vehicle | Integrate Software | **Author Scenarios** | Simulate & Analyze | Deploy Simulation

Virtual vehicle

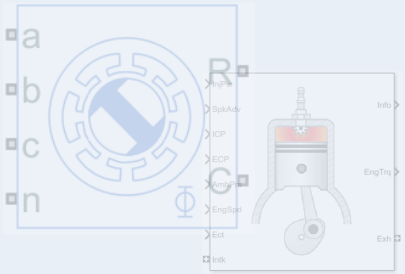
Sensors



Controllers

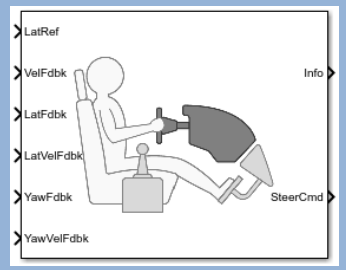


Powertrain

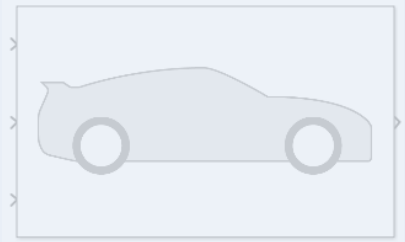


Environment

Driver



Vehicle



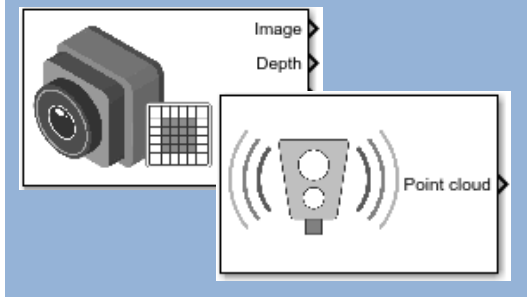
- Creation of virtual 3D environment
- Definition of scenarios to test
- Linking test cases to requirements

Challenges to early system-level testing

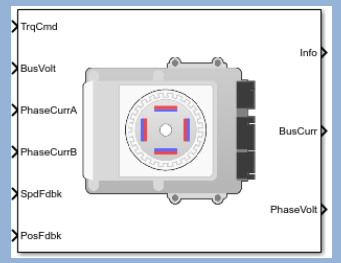
Create Vehicle | Integrate Software | Author Scenarios | **Simulate & Analyze** | Deploy Simulation

Virtual vehicle

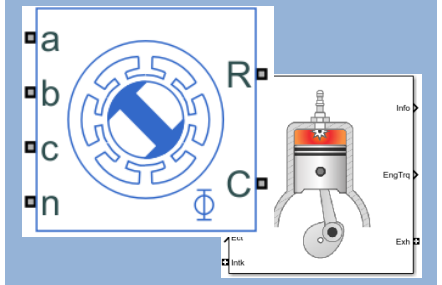
Sensors



Controllers

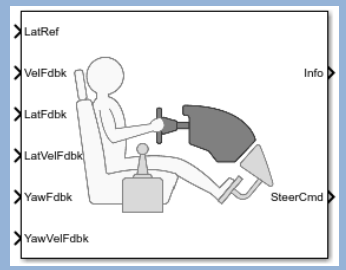


Powertrain

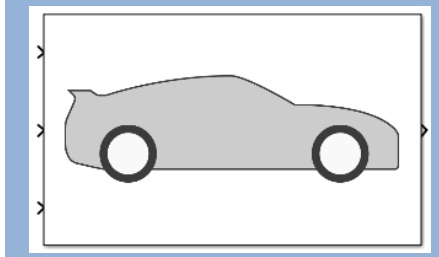


Environment

Driver



Vehicle



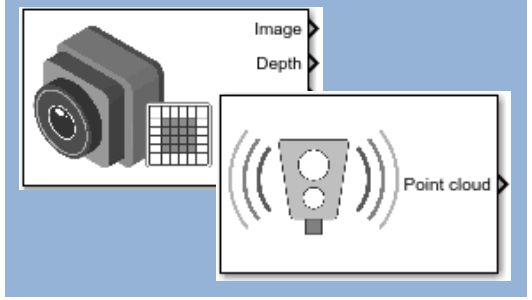
- Post-processing and visualizing results
- Automatically generating reports
- Running large numbers of simulations efficiently

Challenges to early system-level testing

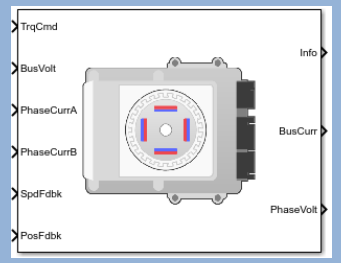
Create Vehicle → Integrate Software → Author Scenarios → Simulate & Analyze → **Deploy Simulation**

Virtual vehicle

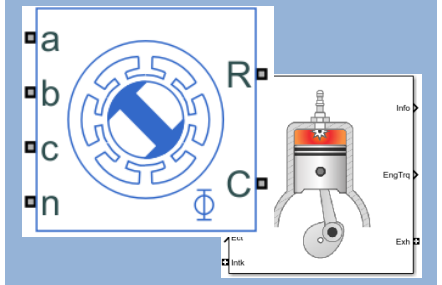
Sensors



Controllers

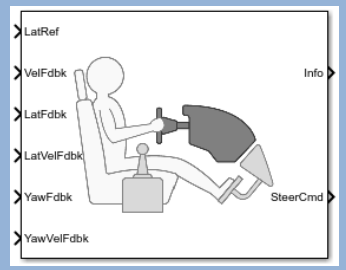


Powertrain

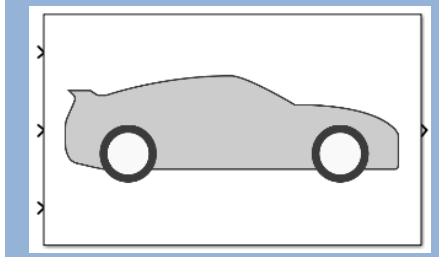


Environment

Driver



Vehicle



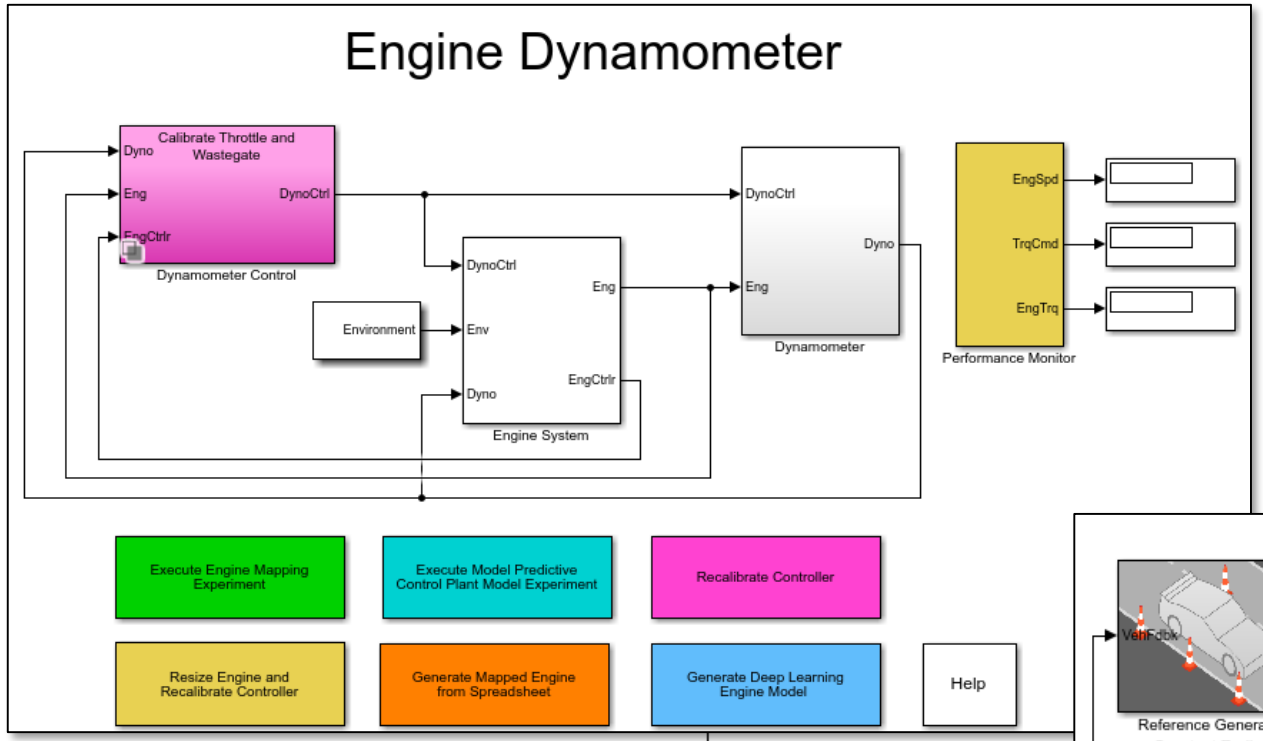
- Sharing models across the organization
- Deploying models to users who aren't tool experts
- Deploying models for SIL, HIL, etc.

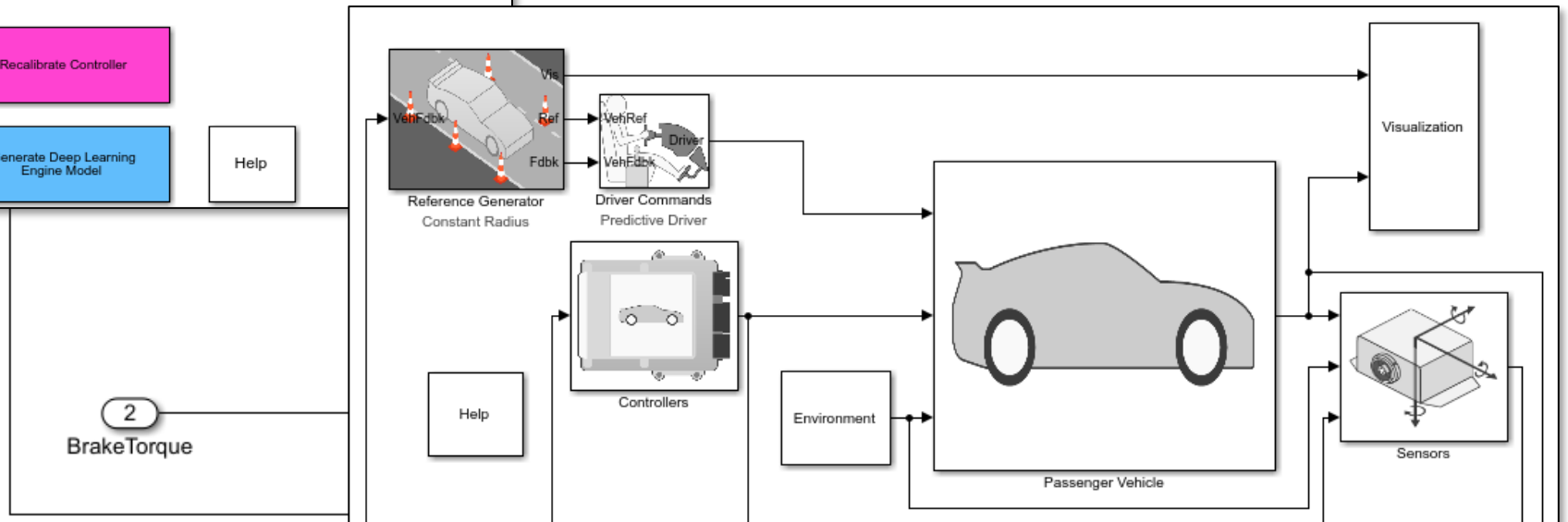
Agenda

- Common challenges
- **MathWorks solutions**
- Case study

MathWorks Virtual Vehicle: reference applications

Create Vehicle | Integrate Software | Author Scenarios | Simulate & Analyze | Deploy Simulation





- Start with in-house vehicle models
  - We can help you customize it and apply best practices for Model-Based Design
- Start with our reference applications
  - Detailed system and vehicle level models for powertrain, vehicle dynamics, ADAS and other applications

Learn more:

[Powertrain Blockset]

[Vehicle Dynamics Blockset]

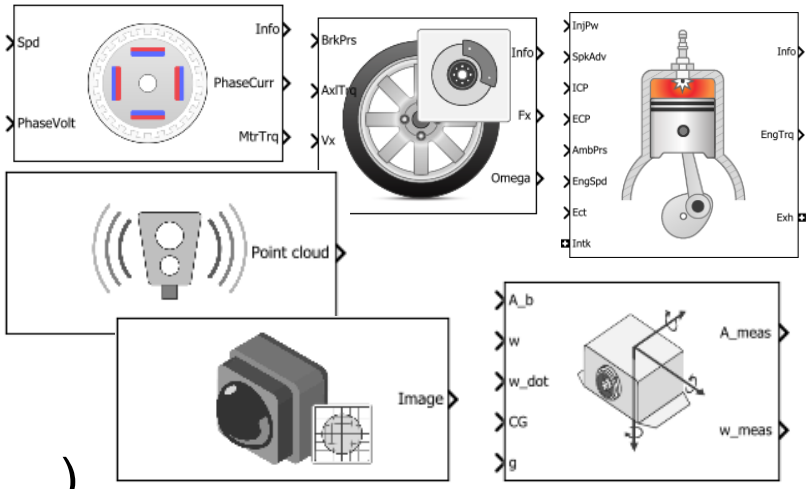
[Automated Driving Toolbox]

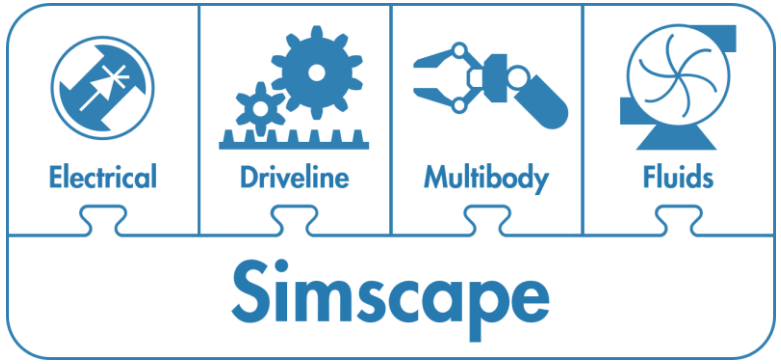
MathWorks Virtual Vehicle: model customization

Create Vehicle | Integrate Software | Author Scenarios | Simulate & Analyze | Deploy Simulation

Add detail where needed using:

- In-house Simulink models
- Simulink and Simscape libraries
- 3rd party tools (S-function, FMU, …)



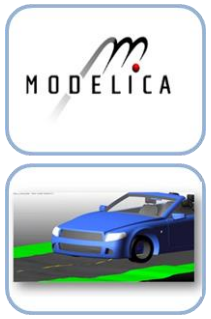


Learn more:

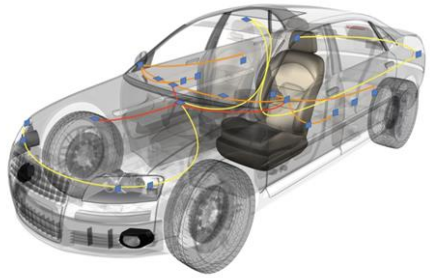
[Simscape]

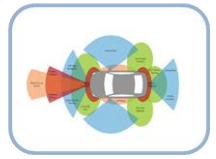
[Multi-core cosim]

[Integrate with existing sims]



Simulink



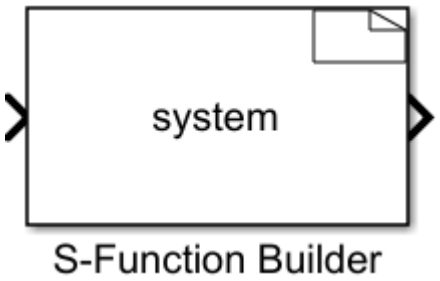


MathWorks Virtual Vehicle: C code integration

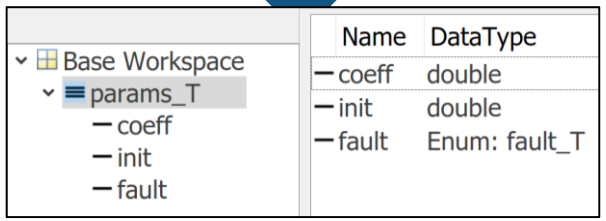
Create Vehicle | **Integrate Software** | Author Scenarios | Simulate & Analyze | Deploy Simulation

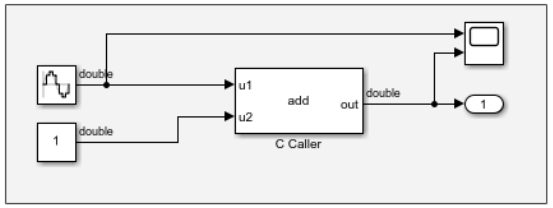
Integrate controller algorithms:

- Native Simulink models
- 3rd party tools (S-function, FMU, …)
- C / C++ code




```
typedef struct {
    double  coeff;
    double  init;
    fault_T fault;
} params_T;
```

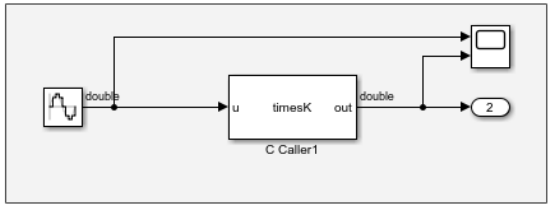


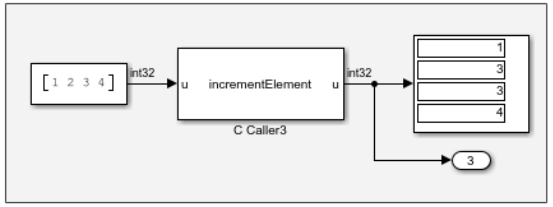


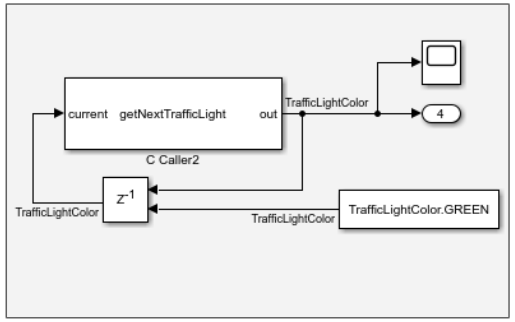
Call C Functions Using C Caller Block

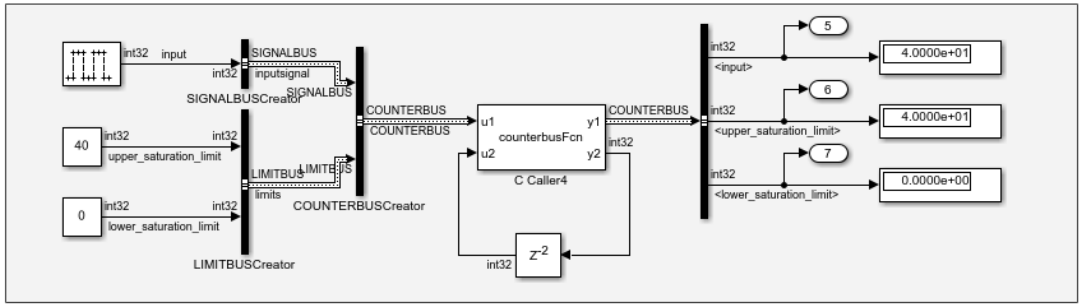
matlabroot\toolbox\simulink\simdemos\simfeatures\include\my_func.h

matlabroot\toolbox\simulink\simdemos\simfeatures\src\my_func.c









Learn more:

[C / C++ code integration]

[C Caller block]

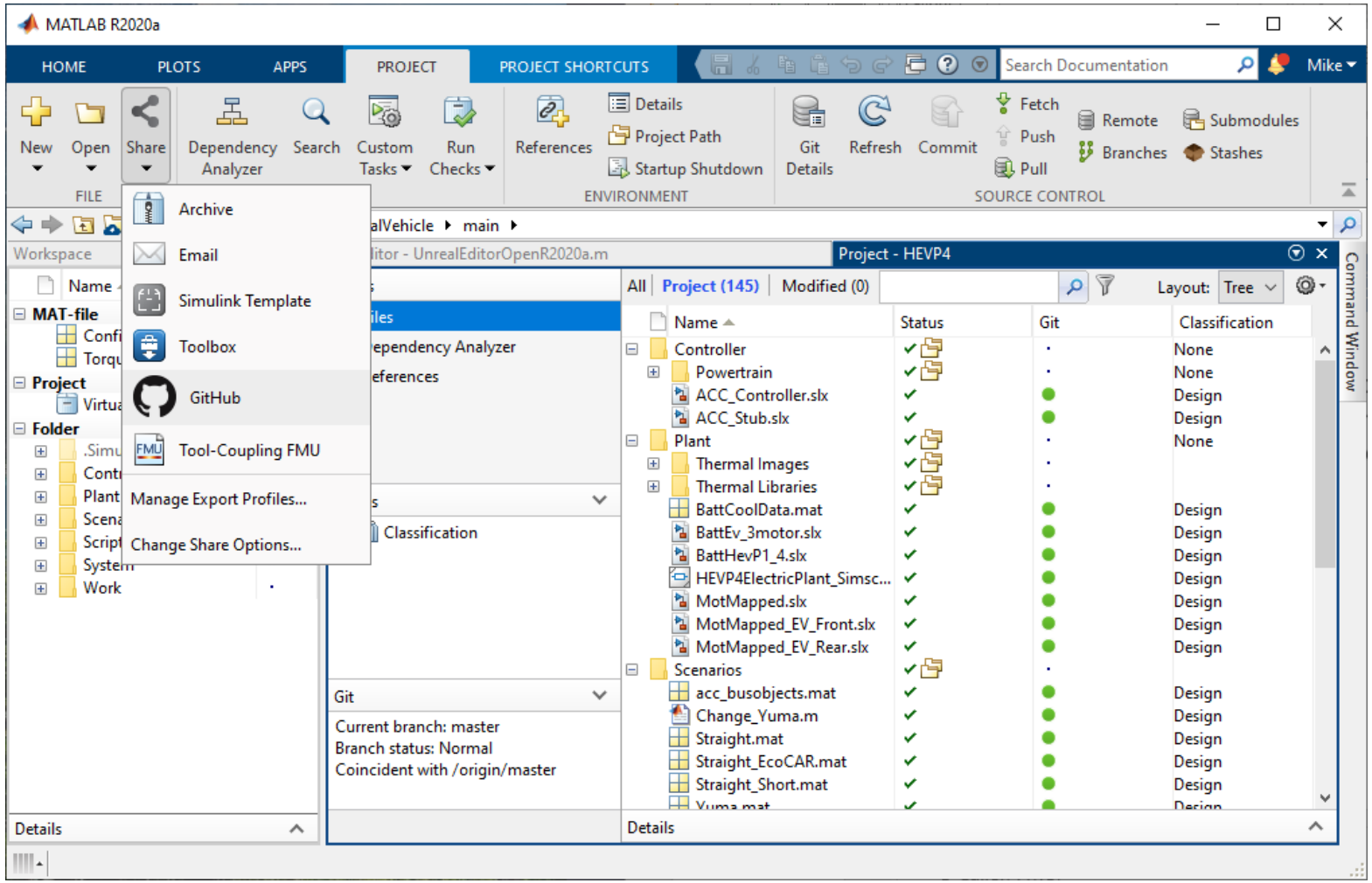
Copyright 2019 The MathWorks, Inc.

MathWorks Virtual Vehicle: complex project management

Create Vehicle | **Integrate Software** | Author Scenarios | Simulate & Analyze | Deploy Simulation

Use MathWorks platform to:

- Collaborate across teams
- Reference related project files
- Manage version control



Learn more:

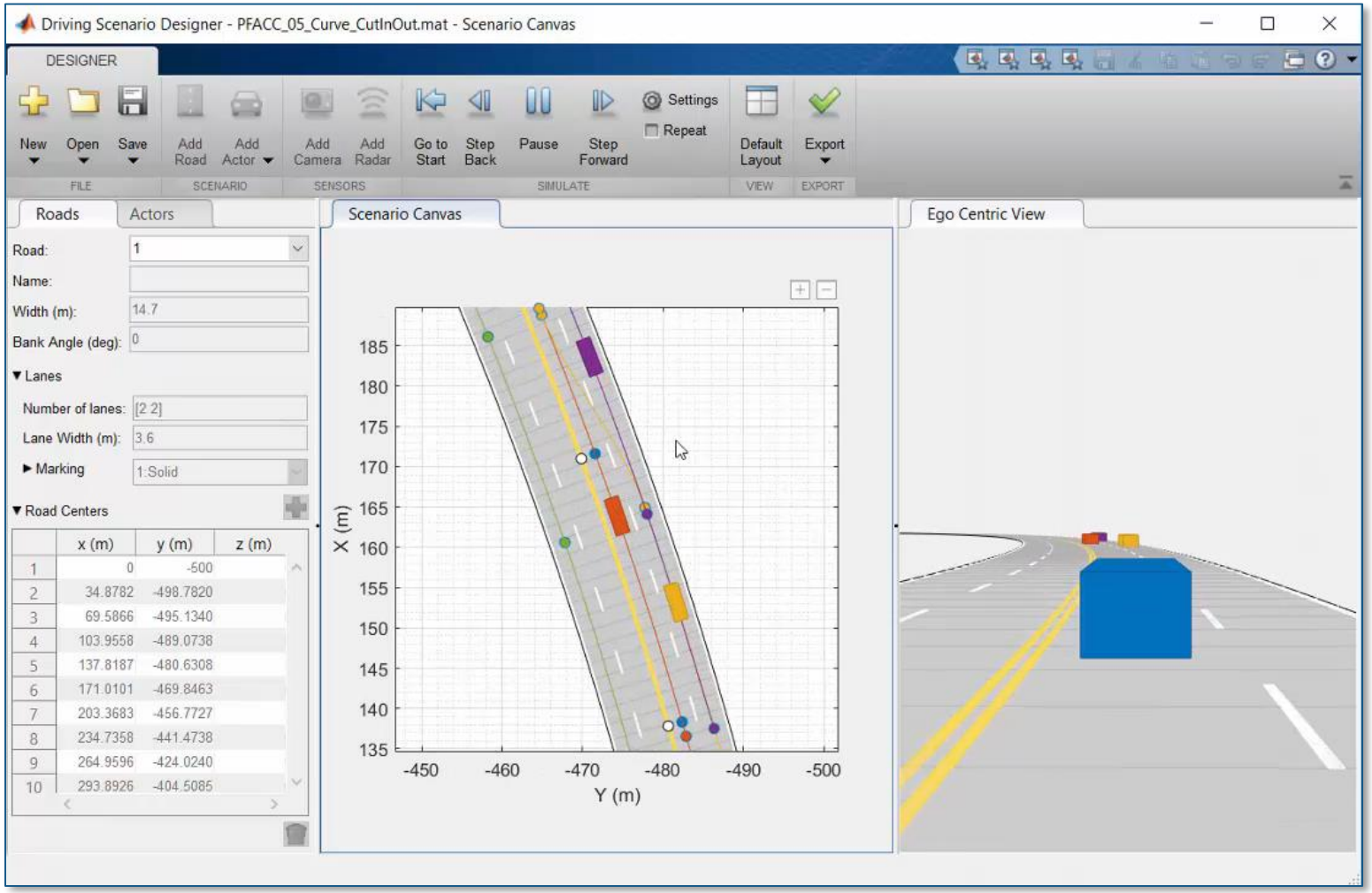
[MATLAB Projects]

MathWorks Virtual Vehicle: graphical scenario authoring

Create Vehicle | Integrate Software | **Author Scenarios** | Simulate & Analyze | Deploy Simulation

Use Driving Scenario Designer to:

- Create roads and lane markings
- Add actors and trajectories
- Specify actor size and radar cross-section (RCS)
- Explore pre-built scenarios
- Import OpenDRIVE and HERE HD Live Map roads
- Export MATLAB code
- Export Simulink model



Learn more:

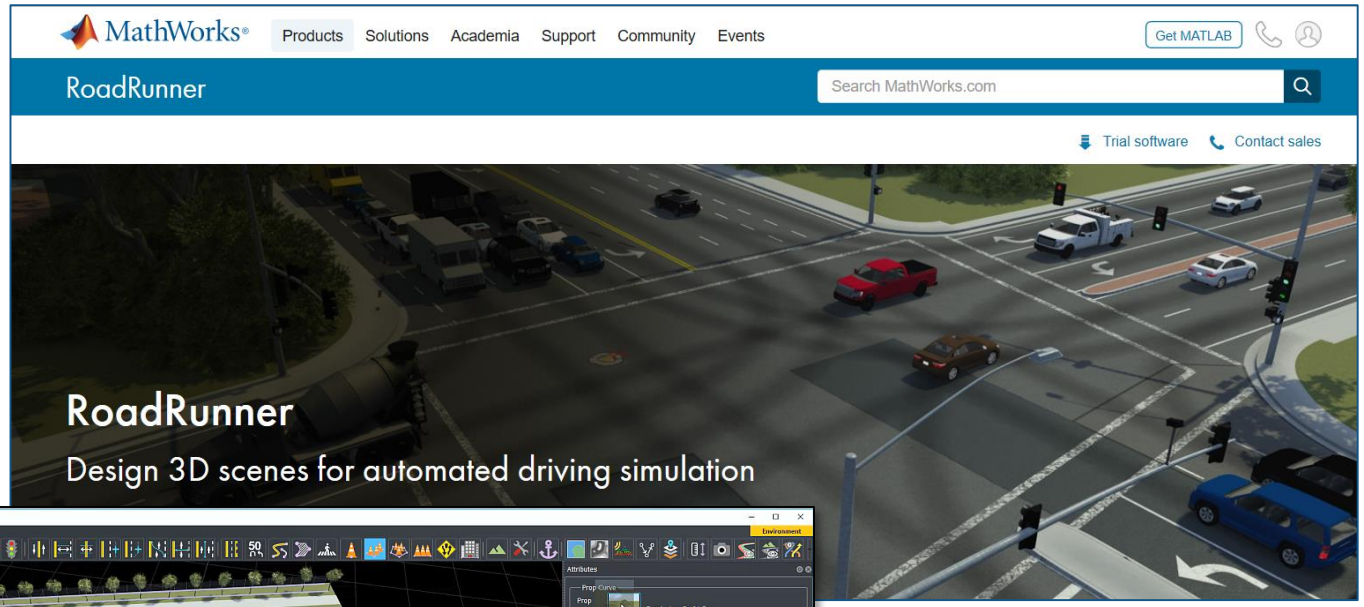
[Automated Driving Toolbox]

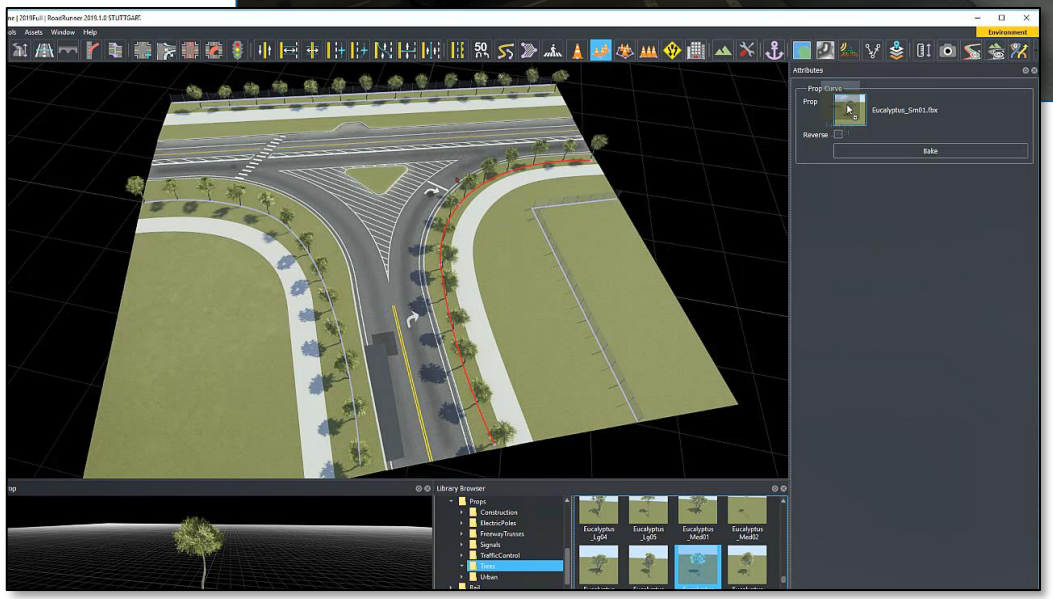
MathWorks Virtual Vehicle: automotive scene creation

Create Vehicle | Integrate Software | **Author Scenarios** | Simulate & Analyze | Deploy Simulation

Use RoadRunner to:

- Design 3D scenes for AD simulation
- Customize with region-specific road signs and markings
- Configure traffic signal timing
- Import from OpenDRIVE
- Export to OpenDRIVE, FBX, …
- Use scenes in Unreal, Unity, CARLA, …





Learn more:

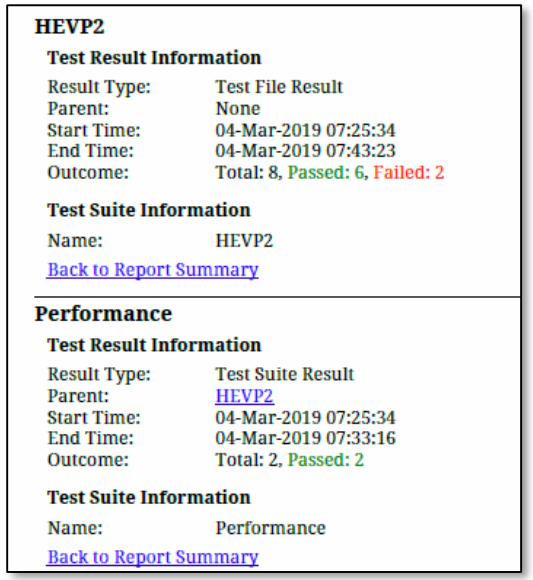
[RoadRunner]

MathWorks Virtual Vehicle: requirements definition

Create Vehicle | Integrate Software | **Author Scenarios** | Simulate & Analyze | Deploy Simulation

Use V&V tools to:

- Define sequence of simulations to run
- Define requirements for these tests
- Define custom report template



HEVP2

Test Result Information

Result Type:	Test File Result
Parent:	None
Start Time:	04-Mar-2019 07:25:34
End Time:	04-Mar-2019 07:43:23
Outcome:	Total: 8, Passed: 6, Failed: 2

Test Suite Information

Name: HEVP2

Back to Report Summary

Performance

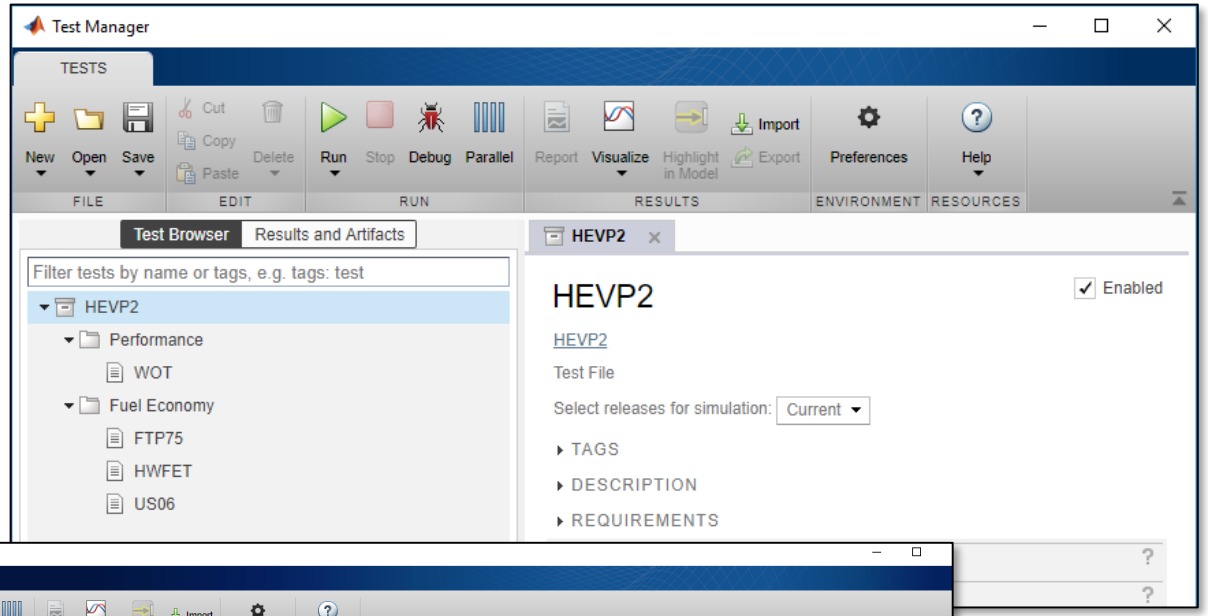
Test Result Information

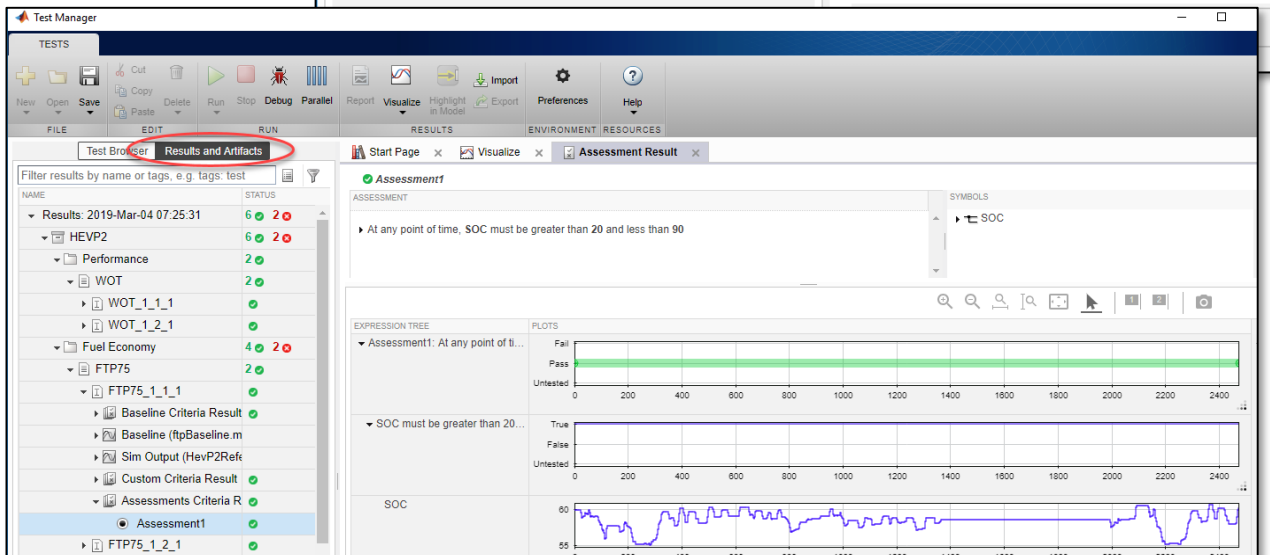
Result Type:	Test Suite Result
Parent:	HEVP2
Start Time:	04-Mar-2019 07:25:34
End Time:	04-Mar-2019 07:33:16
Outcome:	Total: 2, Passed: 2

Test Suite Information

Name: Performance

Back to Report Summary





Learn more:

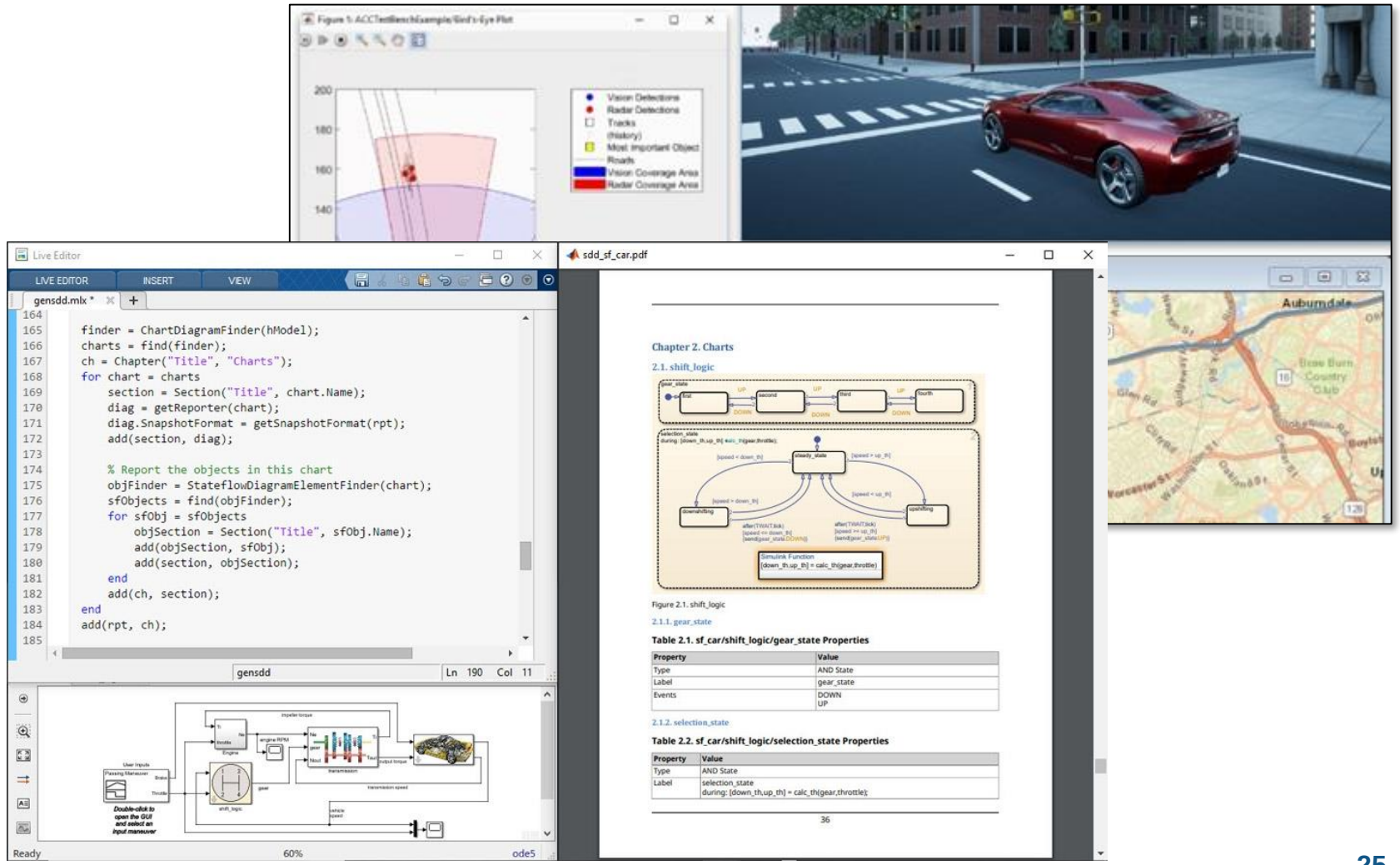
[Verification & Validation]

MathWorks Virtual Vehicle: results analysis

Create Vehicle | Integrate Software | Author Scenarios | **Simulate & Analyze** | Deploy Simulation

Use post-processing tools to:

- Review results with flexible MATLAB platform and visualization tools
- Interact with user-friendly Live Scripts
- Automate report generation



Learn more:

[MATLAB Live Editor]

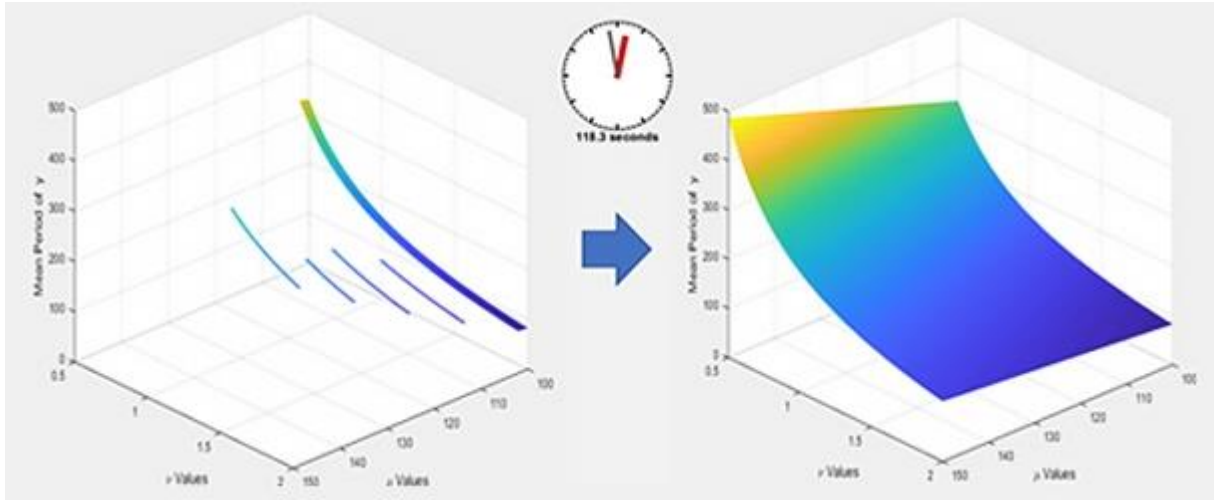
[Simulink Report Generator]

MathWorks Virtual Vehicle: scalability

Create Vehicle | Integrate Software | Author Scenarios | **Simulate & Analyze** | Deploy Simulation

Use MATLAB and Simulink to:

- Distribute simulations to local multi-core, GPU, clusters, or the cloud
- Scale up computation power as needed without needing to rewrite code



Learn more:

[Parallel Computing Toolbox]

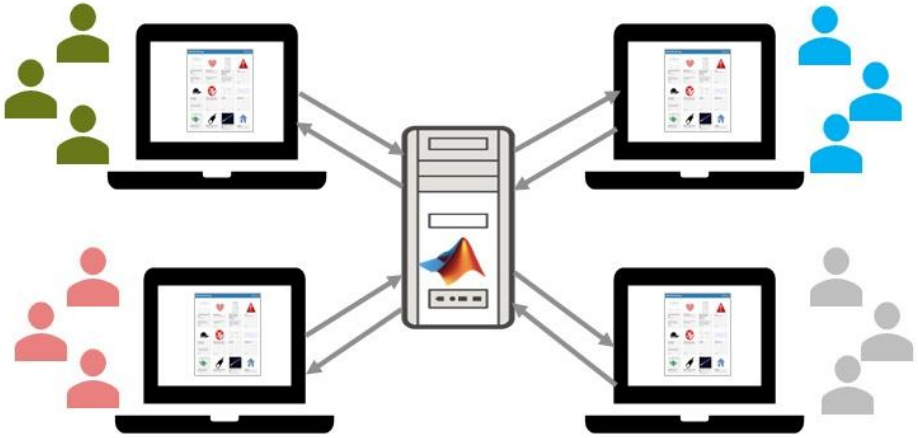
[MATLAB Parallel Server]

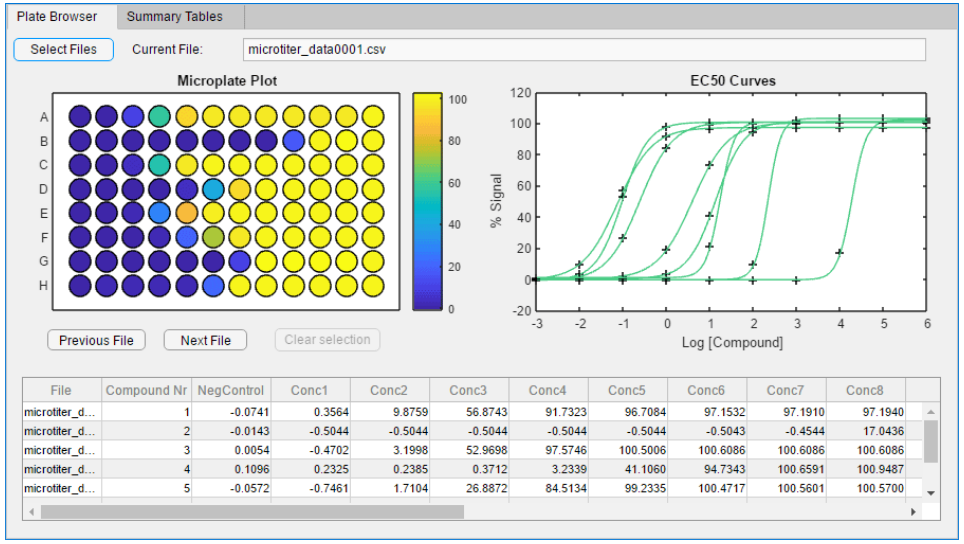
MathWorks Virtual Vehicle: model deployment

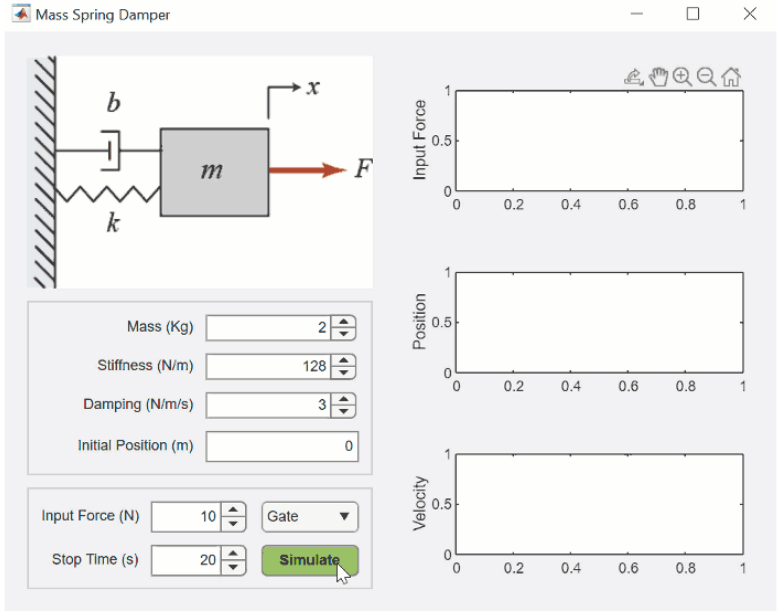
Create Vehicle | Integrate Software | Author Scenarios | Simulate & Analyze | **Deploy Simulation**

Use MATLAB and Simulink to take applications farther:

- Create custom UI's
- Create installers for distribution
- Deploy models as executables, FMU's or web apps
- Generate code for SIL, HIL testing







Learn more:

[MATLAB Web App Server]

[MATLAB App Designer]

[Simulink Compiler]

[Embedded Systems]

MathWorks Consulting Services can support you

Model Architecture

Model assessment
Simulation performance
Interface standardization
…

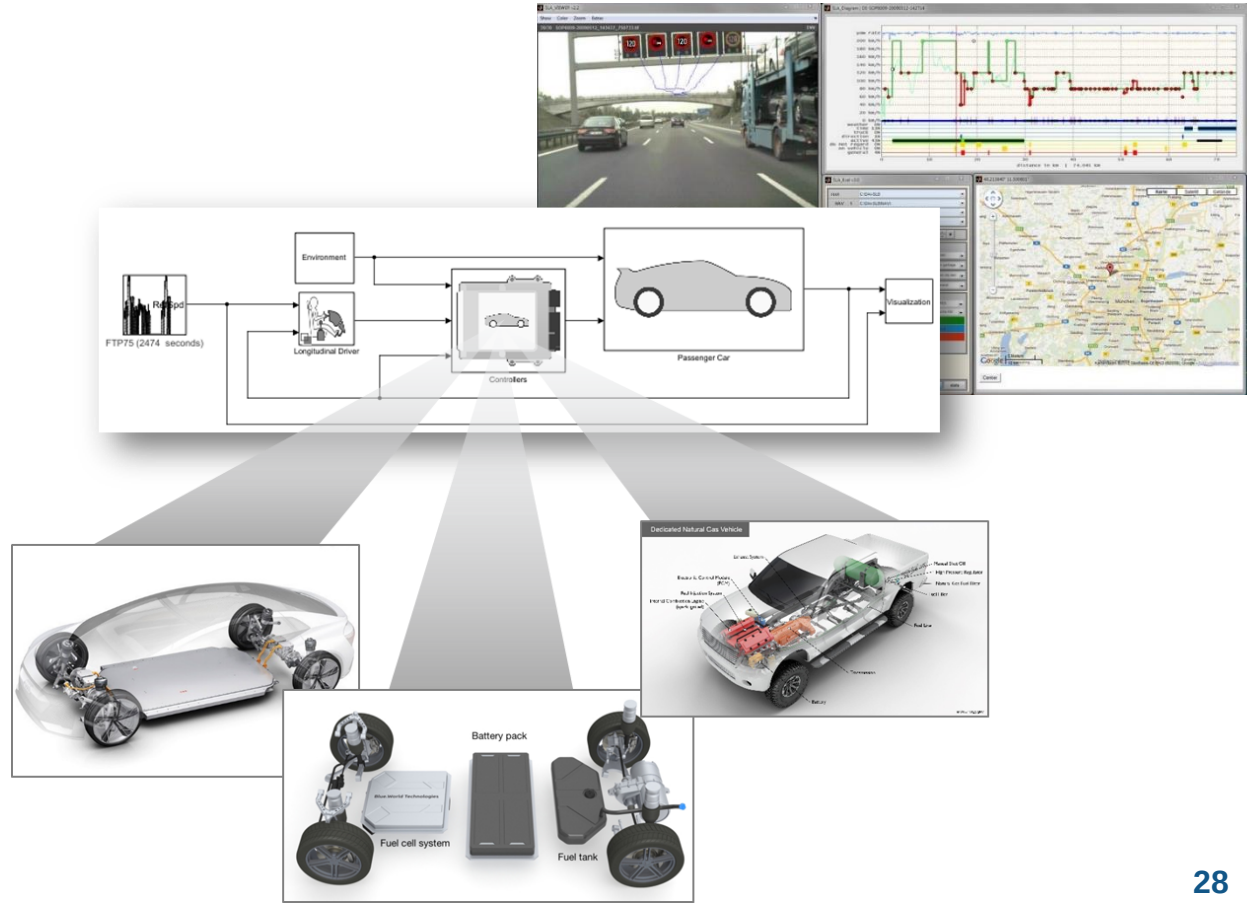
Construction

Build process automation
Database/Repo interface
Model-Building know-how
…

User Experience

GUI driven workflow
Tool compatibility support
Artifact creation
…

- Provide expert-level guidance
- Automate workflows
- Develop custom UI’s

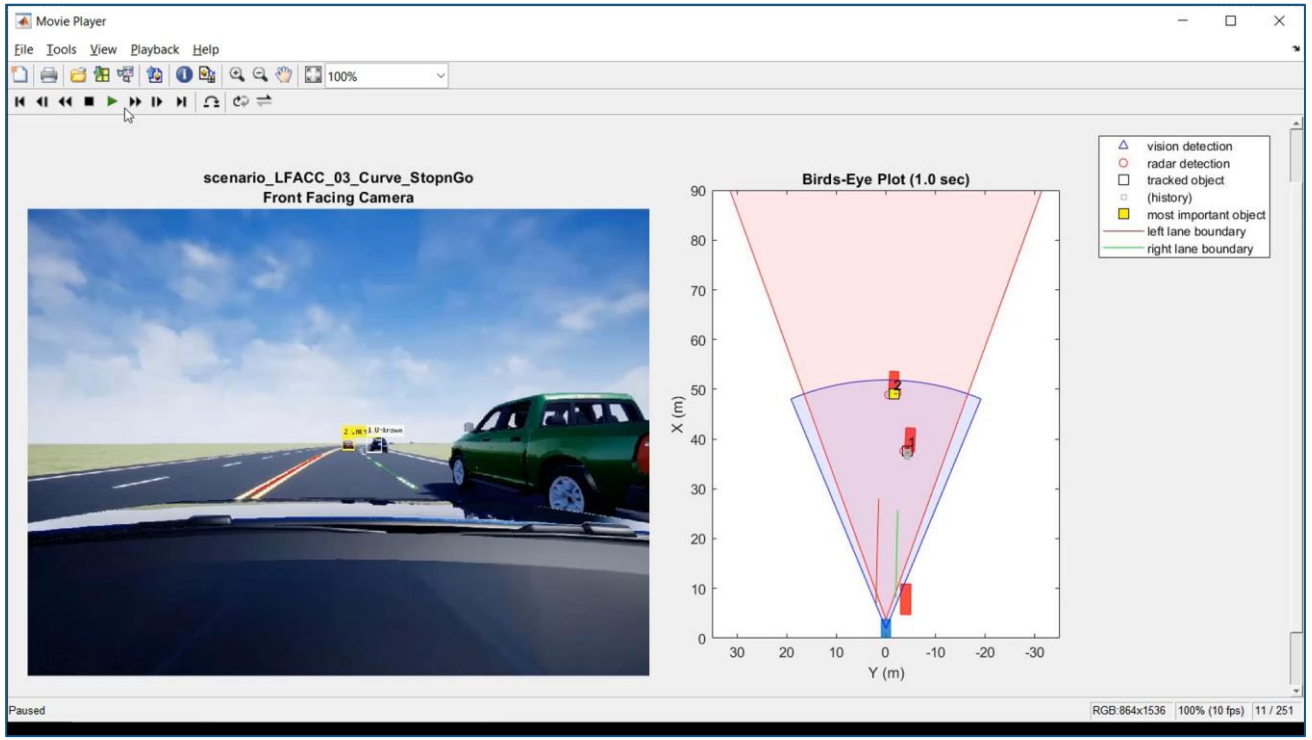


Agenda

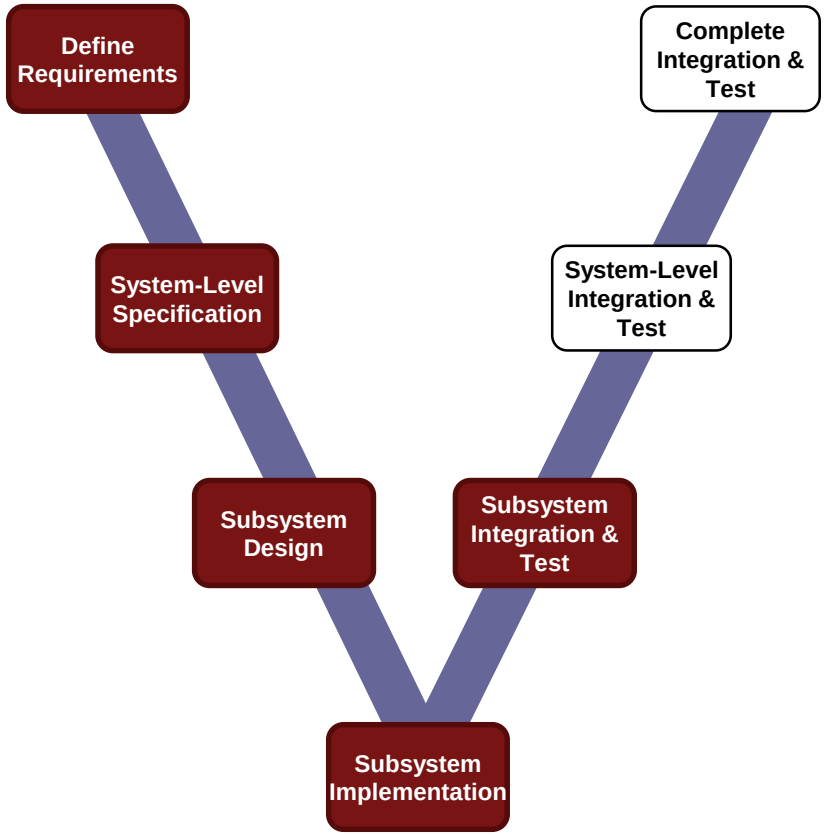
- Common challenges
- MathWorks solutions
- **Case study**

Validate software against function safety requirements early

FSR: The lane following system lateral error shall be less than 1 meter



*Use simulation to do system-level integration testing **early***



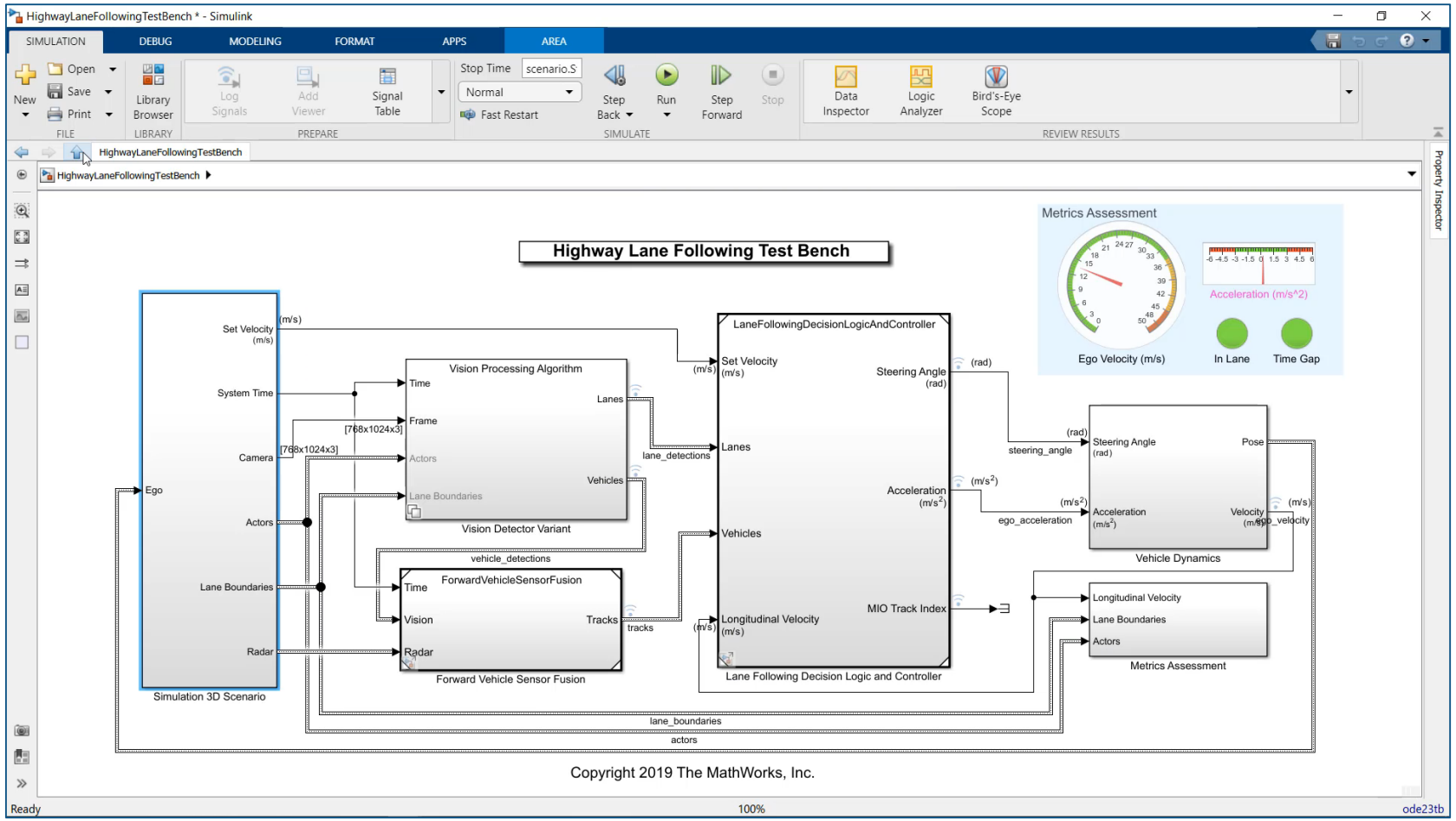
Learn more:

[Highway Lane Following]

[Automate Testing for Highway Lane Following]

Case study: highway lane following algorithm

Create Vehicle → Integrate Software → Author Scenarios → Simulate & Analyze → Deploy Simulation



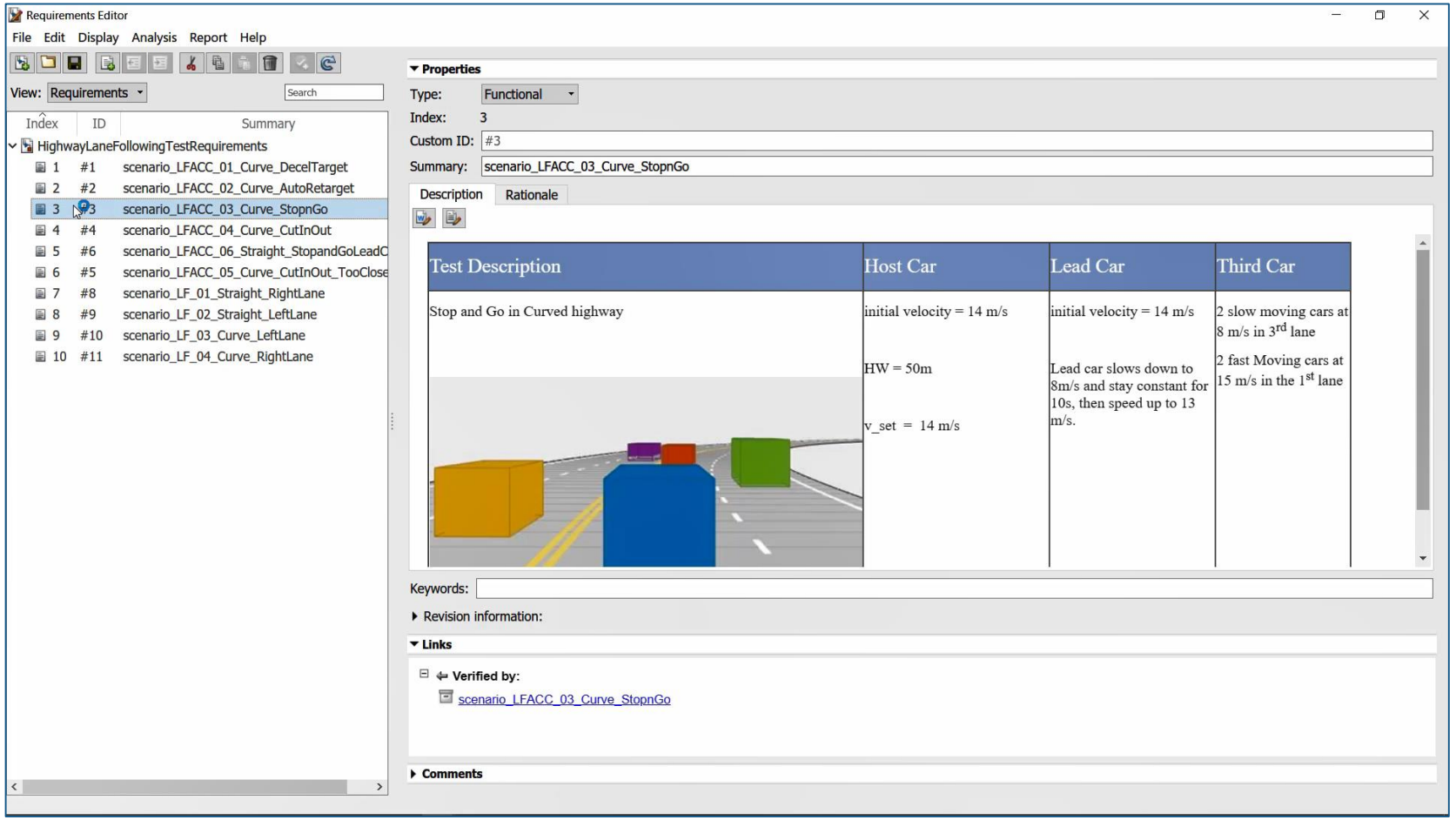
- Create Unreal Engine scene
- Specify target trajectories
- Model camera and radar sensors
- Model ego vehicle dynamics
- Specify system metrics

Learn more:

[Highway Lane Following]

Case study: highway lane following algorithm

Create Vehicle | Integrate Software | **Author Scenarios** | Simulate & Analyze | Deploy Simulation



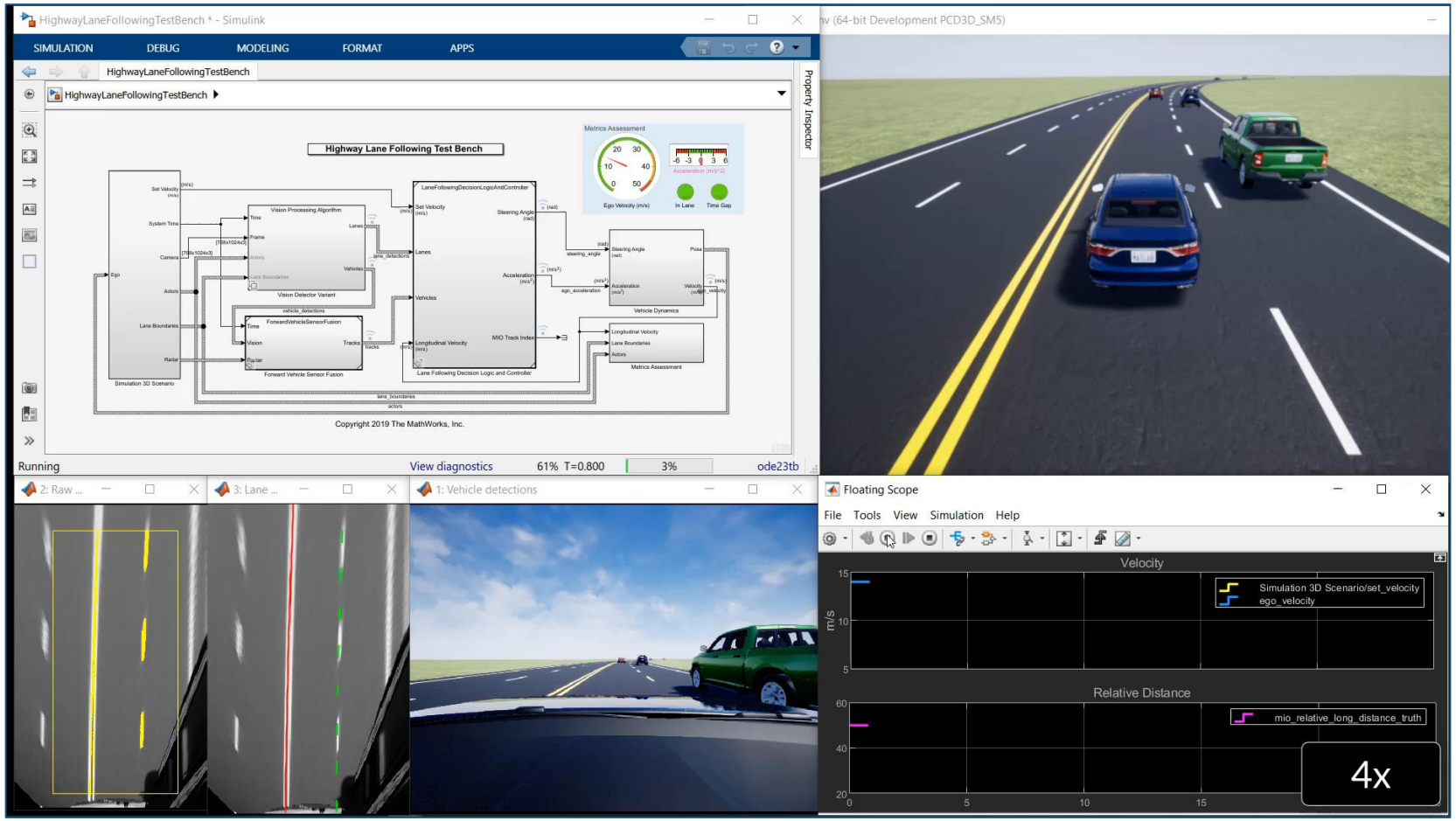
- Author and associate requirements and scenarios

Learn more:

[Automate Testing for Highway Lane Following]

Case study: highway lane following algorithm

Create Vehicle | Integrate Software | Author Scenarios | **Simulate & Analyze** | Deploy Simulation

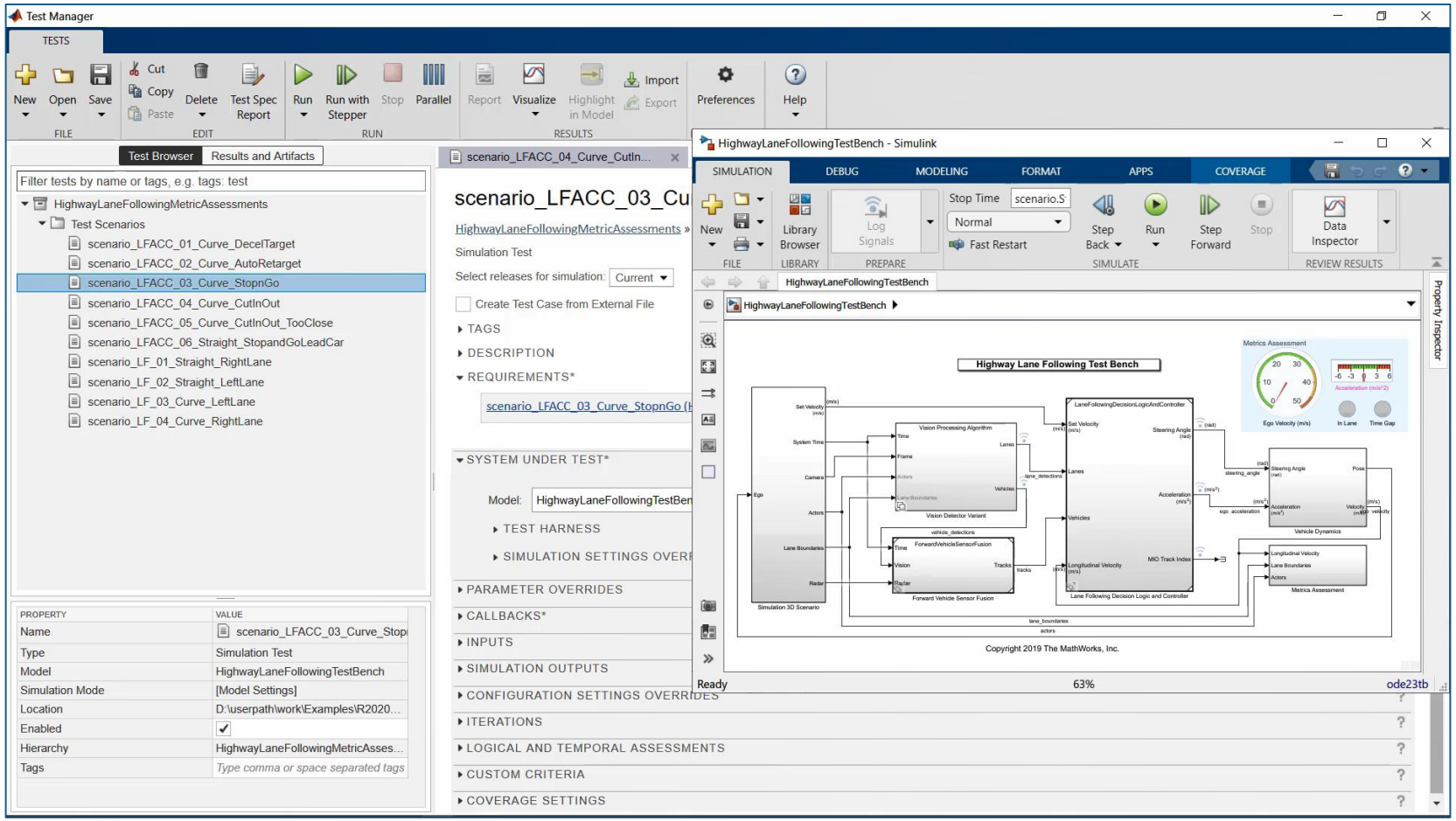


- Visualize system behavior with Unreal Engine
- Visualize lane detections
- Visualize vehicle detections
- Visualize control signals
- Log simulation data

Learn more:
[Highway Lane Following]

Case study: highway lane following algorithm

Create Vehicle | Integrate Software | Author Scenarios | **Simulate & Analyze** | Deploy Simulation



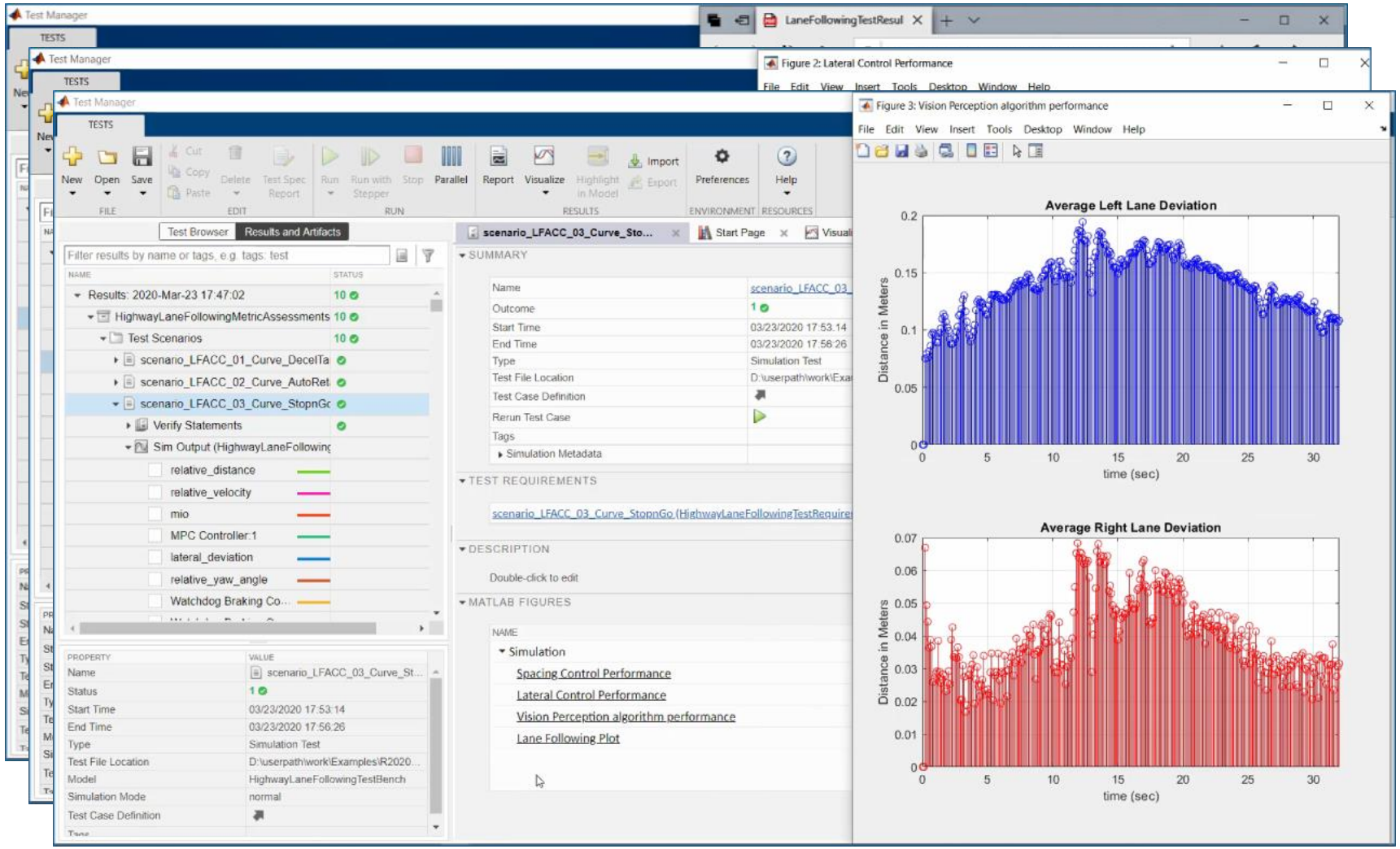
- Automate test execution and reporting
- Execute simulations in parallel

Learn more:

[Automate Testing for Highway Lane Following]

Case study: highway lane following algorithm

Create Vehicle | Integrate Software | Author Scenarios | **Simulate & Analyze** | Deploy Simulation



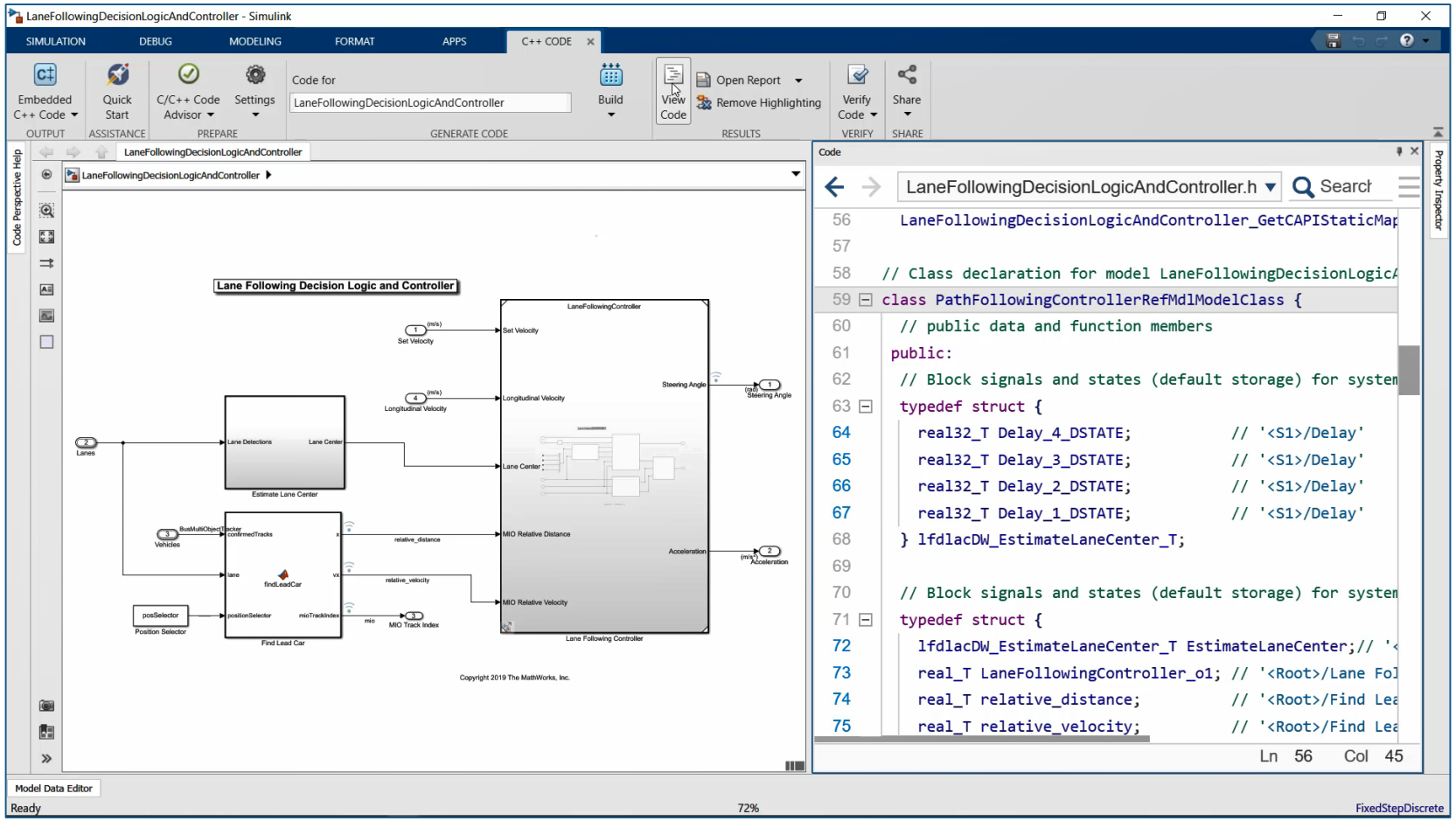
- Assess system metrics
- Assess lane detection metrics

Learn more:

[Automate Testing for Highway Lane Following]

Case study: highway lane following algorithm

Create Vehicle | Integrate Software | Author Scenarios | Simulate & Analyze | Deploy Simulation



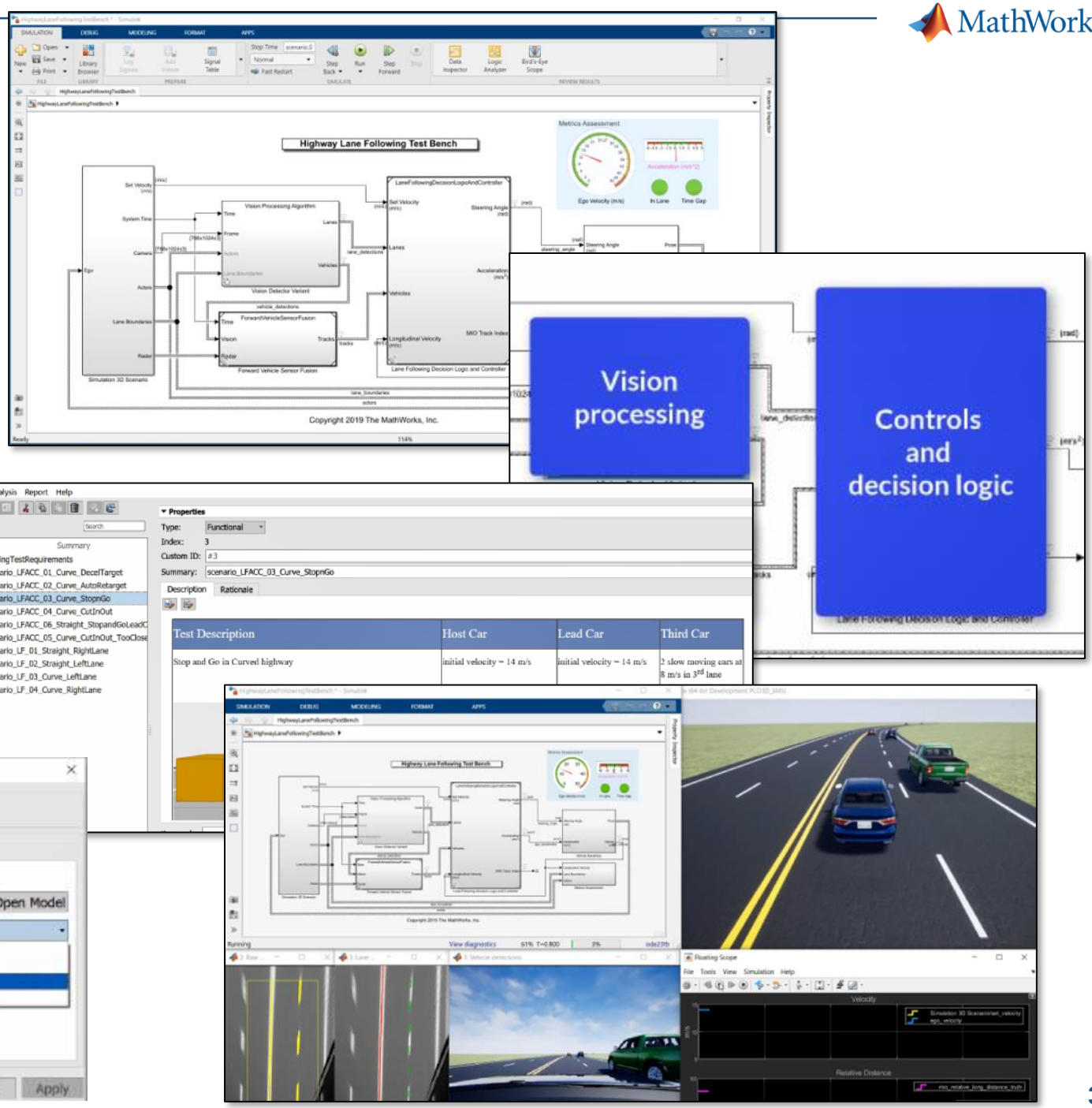
- Generate algorithm code
- Test with Software-in-the-Loop (SIL) simulation
- Workflow could be extended to test hand coded algorithms

Learn more:

[Automate Testing for Highway Lane Following]

Summary

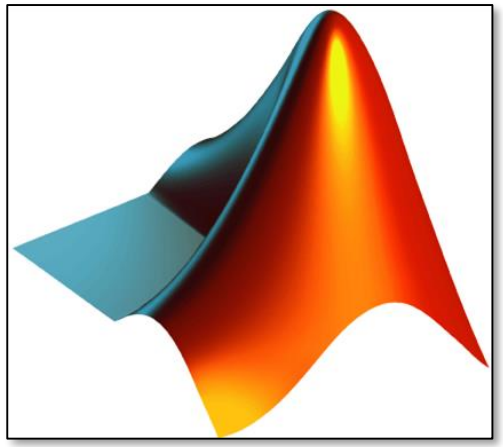
1. Started with reference application, then customized
2. Integrated software
3. Defined scenarios to test
4. Simulated model and analyzed results
5. Deployed model

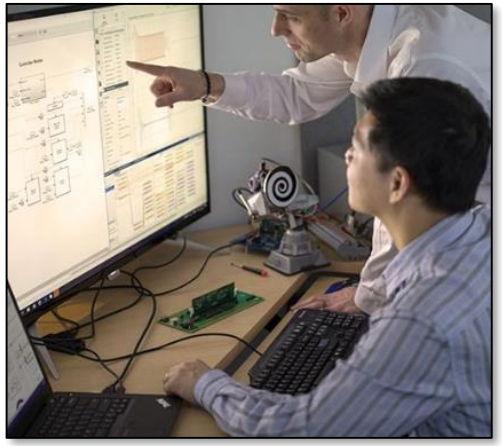


Key takeaways

MathWorks provides a **powerful platform** for building your **Virtual Vehicle**

Our platform is very **flexible**, and we can help you **customize** it for your needs





Out-of-the-box capability

Custom virtual vehicle solution

Presenter contact info and poll questions

Please contact us with questions

Chris Fillyaw
Application Engineering Manager
cfillyaw@mathworks.com

Mike Sasena, PhD
Automotive Product Manager
msasena@mathworks.com

- On a scale of 1 - 4, how challenging is it for your department to:
  - Create the vehicle model
  - Integrate software
  - Author scenarios
  - Simulate and analyze results
  - Deploy simulations

A. 1 (easy)
B. 2 (moderate)
C. 3 (difficult)
D. 4 (major challenge)

- Are you interested in a follow-up conversation with MathWorks?

A. Yes
B. No

- Additional comments

Thank You

Chris Fillyaw
Application Engineering Manager
cfillyaw@mathworks.com

Mike Sasena, PhD
Automotive Product Manager
msasena@mathworks.com

© 2020 The MathWorks, Inc.