

MathWorks
**AUTOMOTIVE
CONFERENCE 2023**
Europe

Accelerating Development of Clean, Safe, Automated Software-Defined Vehicles

Andy Grace, MathWorks



Application Trends for the Software Defined Vehicle



Electrification



Connectivity



Autonomous

Application Trends for the Software Defined Vehicle



Electrification

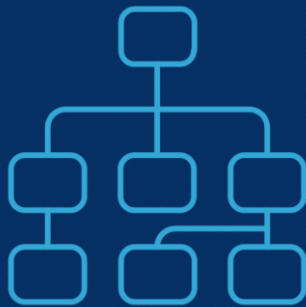


Connectivity



Autonomous

Workflow Trends



**Systems
Engineering**



**Modern
Software Practices**



**AI and Data-Driven
Development**

Application Trends for the Software Defined Vehicle



Electrification
#3 (39%)



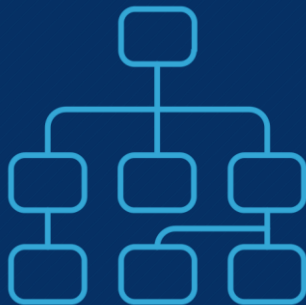
Connectivity
#6 (19%)



Autonomous
#4 (24%)

Top trends?

Workflow Trends



Systems Engineering

#1 (63%)



Modern Software Practices

#2 (58%)



AI and Data-Driven Development

#5 (21%)

* MathWorks Advisory Board cross- industry survey, 274 responses

Historical perspective: First MathWorks Automotive Advisory

Germany, 1998

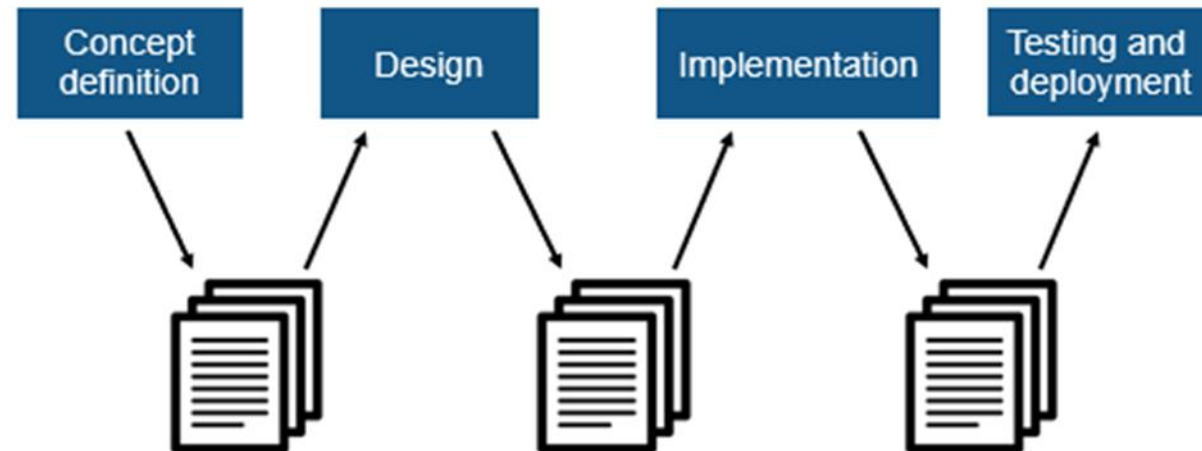


25 Years of MAB

Problem statement from initial MAB Meetings



Observation: traditional process is document based

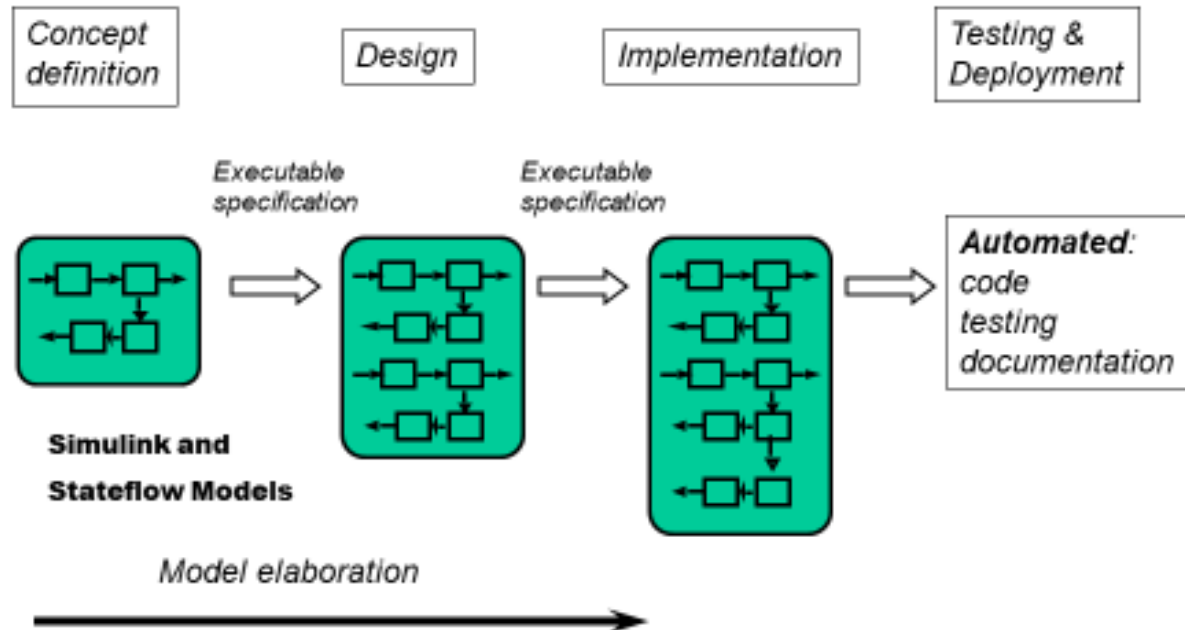


25 Years of MAB

Vision emanating from initial MAB Meetings



Model-Based Design

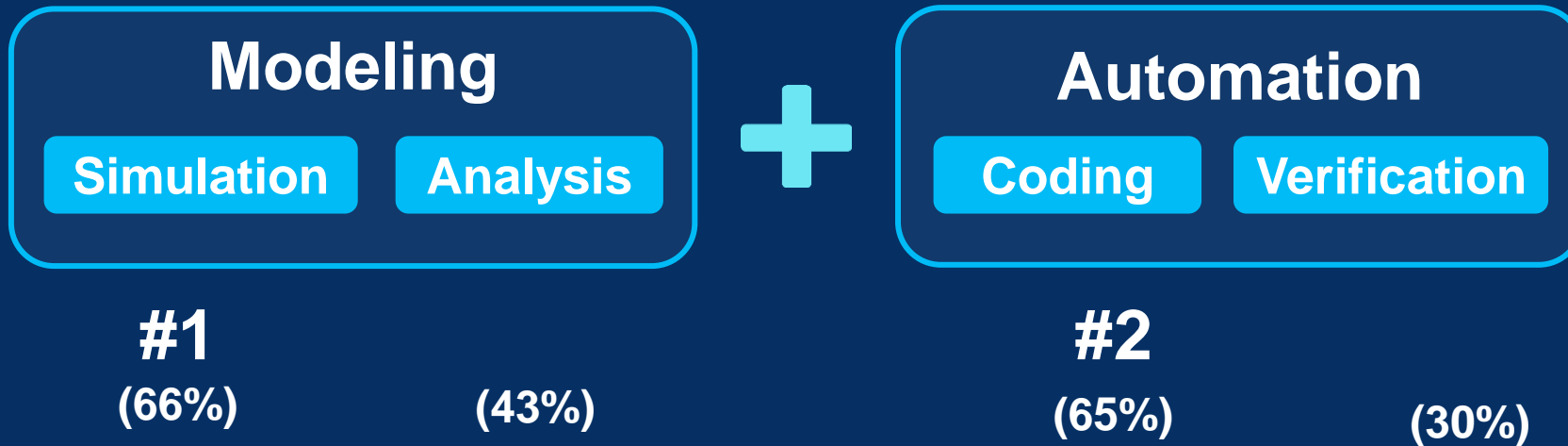


© 2002 The MathWorks, Inc.

Model-Based Design Framework



Model-Based Design Framework



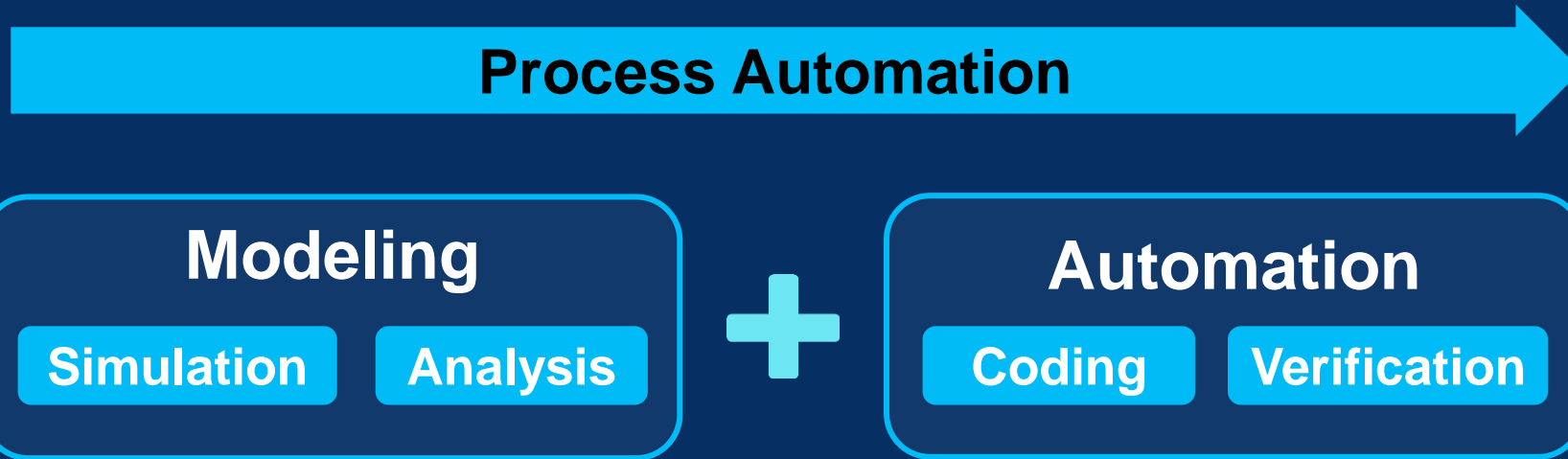
Survey: Which areas is your organization deriving the most value from Model-Based Design?
(pick up to three)

Model-Based Design Framework

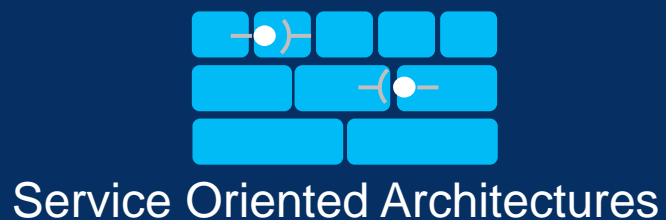


**How should
Model-Based Design adapt?**

Model-Based Design Framework



New MBD Approaches





How to measure software operational performance?



Metric	Description
Lead Time for Changes	The time it takes from code commit to code successfully running in production.
Deployment Frequency	The frequency at which code is deployed to production.
Change Failure Rate	The percentage of deployments causing a failure in production.
Mean Time to Recover (MTTR)	The time it takes to recover from a failure in production.



How to measure software operational performance?



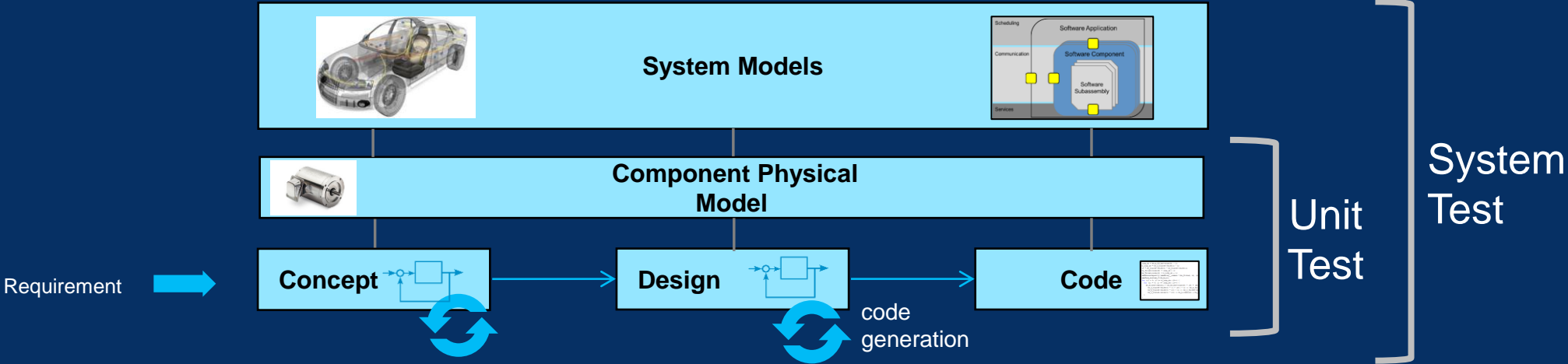
Role of Model-Based Design?

Metric	
Lead Time for Changes	The time it takes from code commit to code successfully running in production.
Deployment Frequency	The frequency at which code is deployed to production.
Change Failure Rate	The percentage of deployments that fail in production.
Mean Time to Recover (MTTR)	The time it takes to recover from a failure in production.

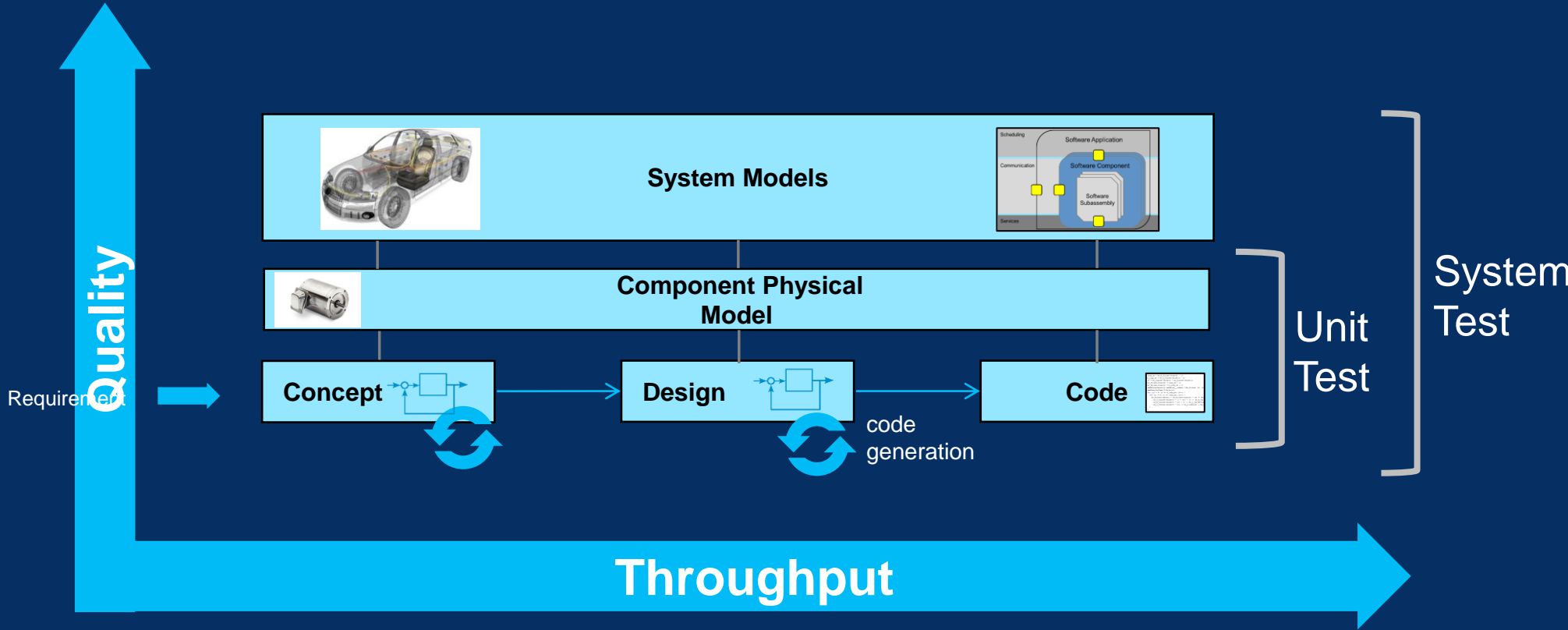
Throughput

Quality

Model-Based Design Workflow

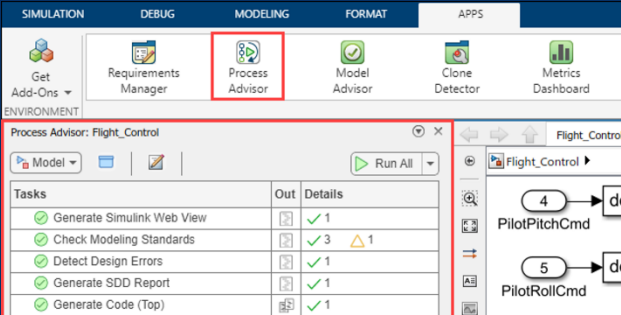
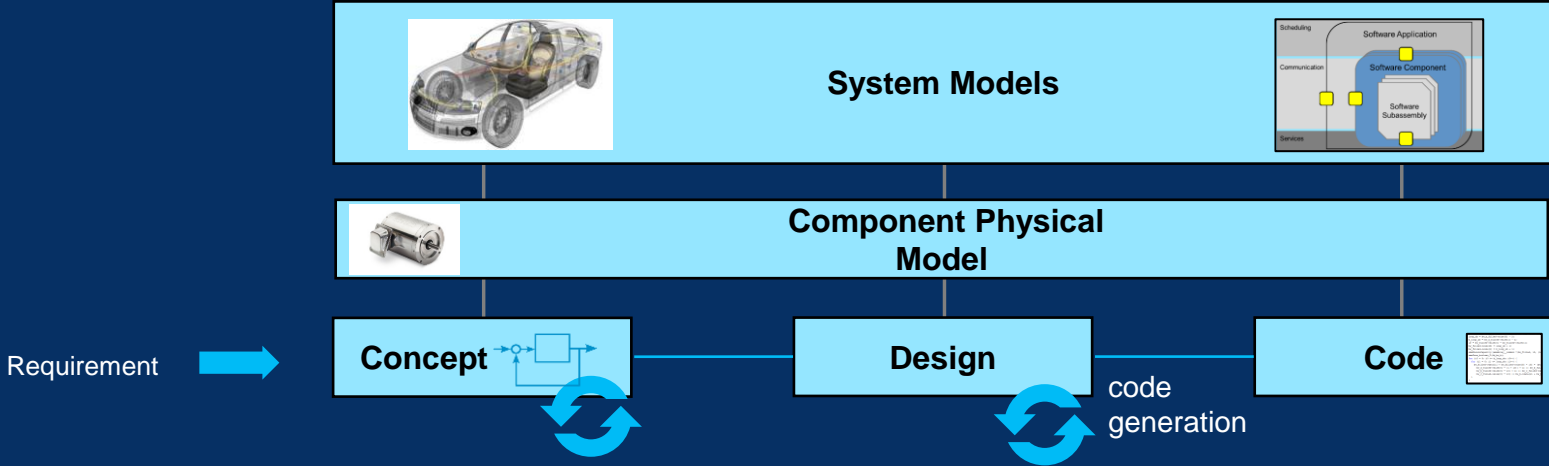


Model-Based Design Workflow

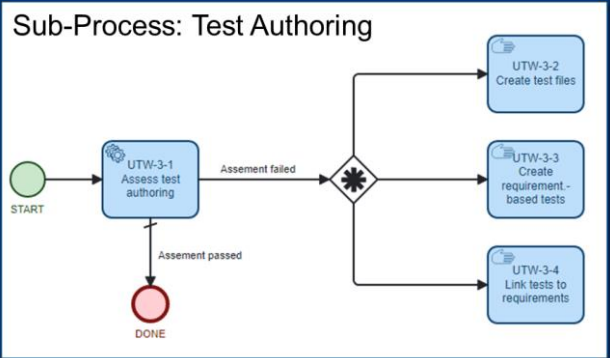


Full automation?

Model-Based Design: Integration and Automation

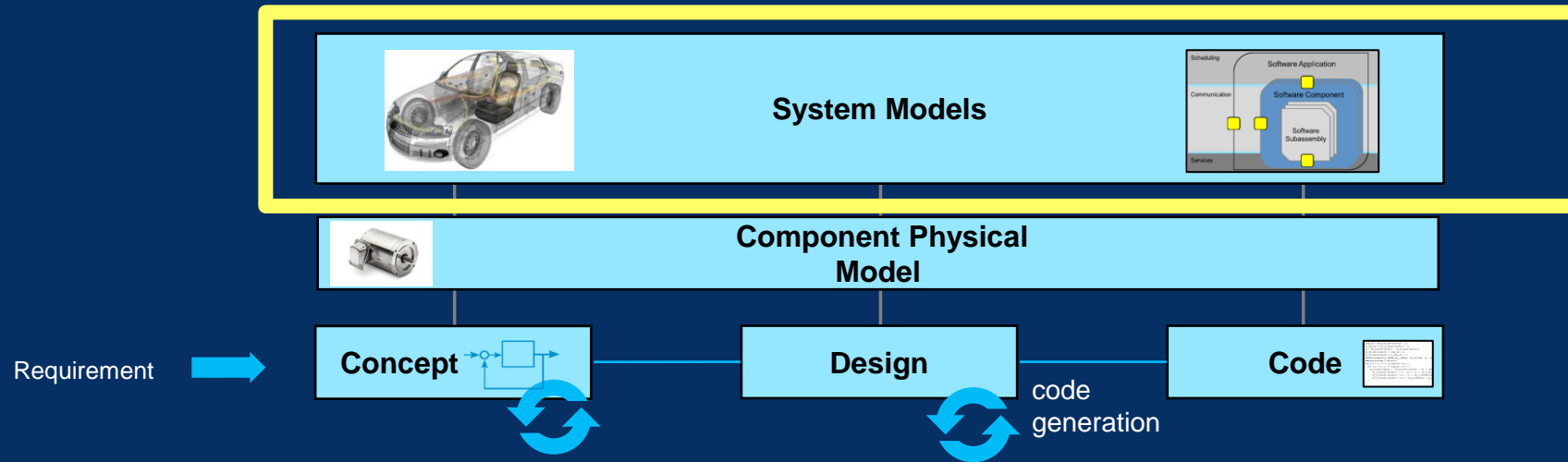


CI support package
R2022a



Detailed Testing Workflow

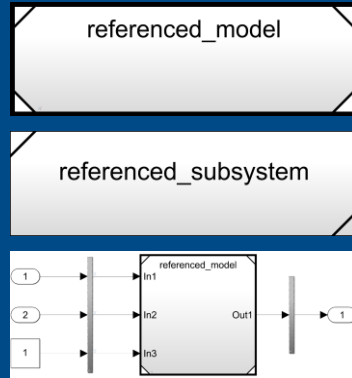
Model-Based Design: Integration and Automation



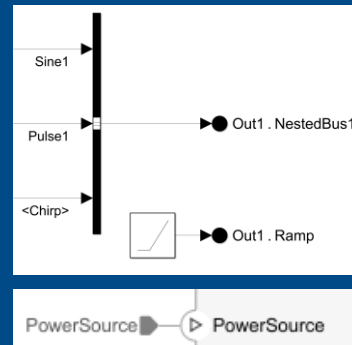
Simulink as a simulation integration platform



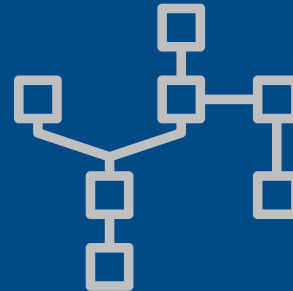
Simulink Scales to Complex Systems



Components & test harnesses



Buses, ports, connectors



Architecture

File Exchange

Variant Manager for Simulink

by MathWorks Variant Manager for Simulink Team **STAFF**

Manage, configure and analyze variants in your system with Variant Manager for Simulink package.

Variant Manager

Virtual Vehicle Composer - ConfiguredVirtualVehicle.m

PassengerCar

Chassis: Vehicle Body 3DOF Longitudinal

Parameter...	Description	Unit	Value
PireVehMass	Vehicle mass	kg	1623
PireVehDist	Longitudinal distance from ...	m	1.09
PireVehDist	Longitudinal distance from ...	m	1.7
PireVehCG	Vertical distance from cent...	m	0.3
PireVehEV	Vehicle initial vertical position	m	-0.3
PireVehVEL	Initial longitudinal velocity	m/s	0
PireVehPIC	Principal inertial compone...	kg	1922.6667
PireVehCar	Longitudinal drag area	m ²	2.27

Virtual Vehicle Composer



>500 organizations have adopted



You successfully target a range of devices with code generation

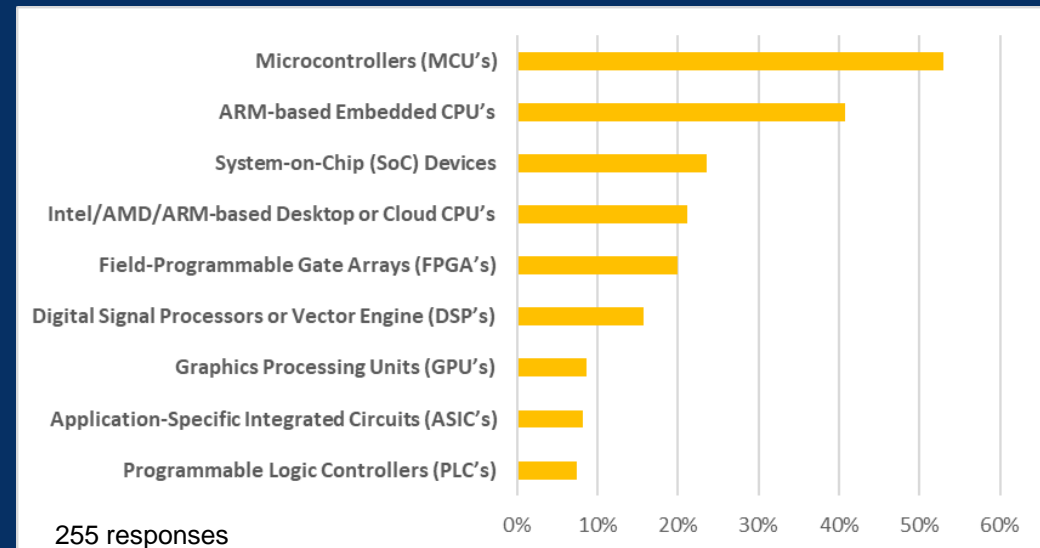


4700 organizations
use automatic code generation

CPU

GPU

FPGA, ASIC, PLC

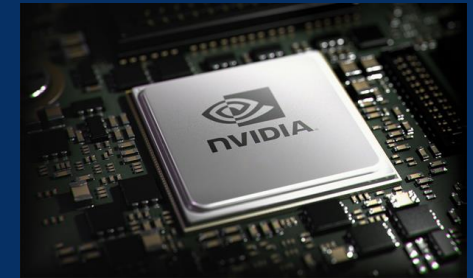


* MathWorks Advisory Board cross- industry survey

Each release we get more out of your hardware



127 FPS, Nvidia GPU



GPU

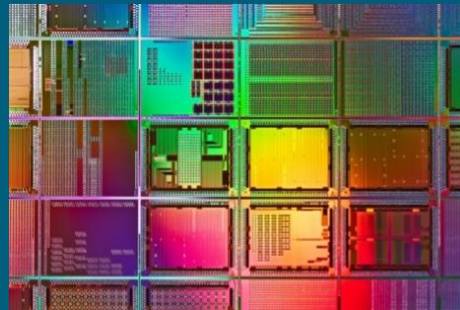


CPU



FPGA/SoC

Each release we get more out of your hardware



Multicore
Cache
Accelerators
SIMD

Parallelization

Neighborhood Processing
Subsystem in Simulink
R2022b

Improved SIMD for ARM,
Intel and AMD
R2023a

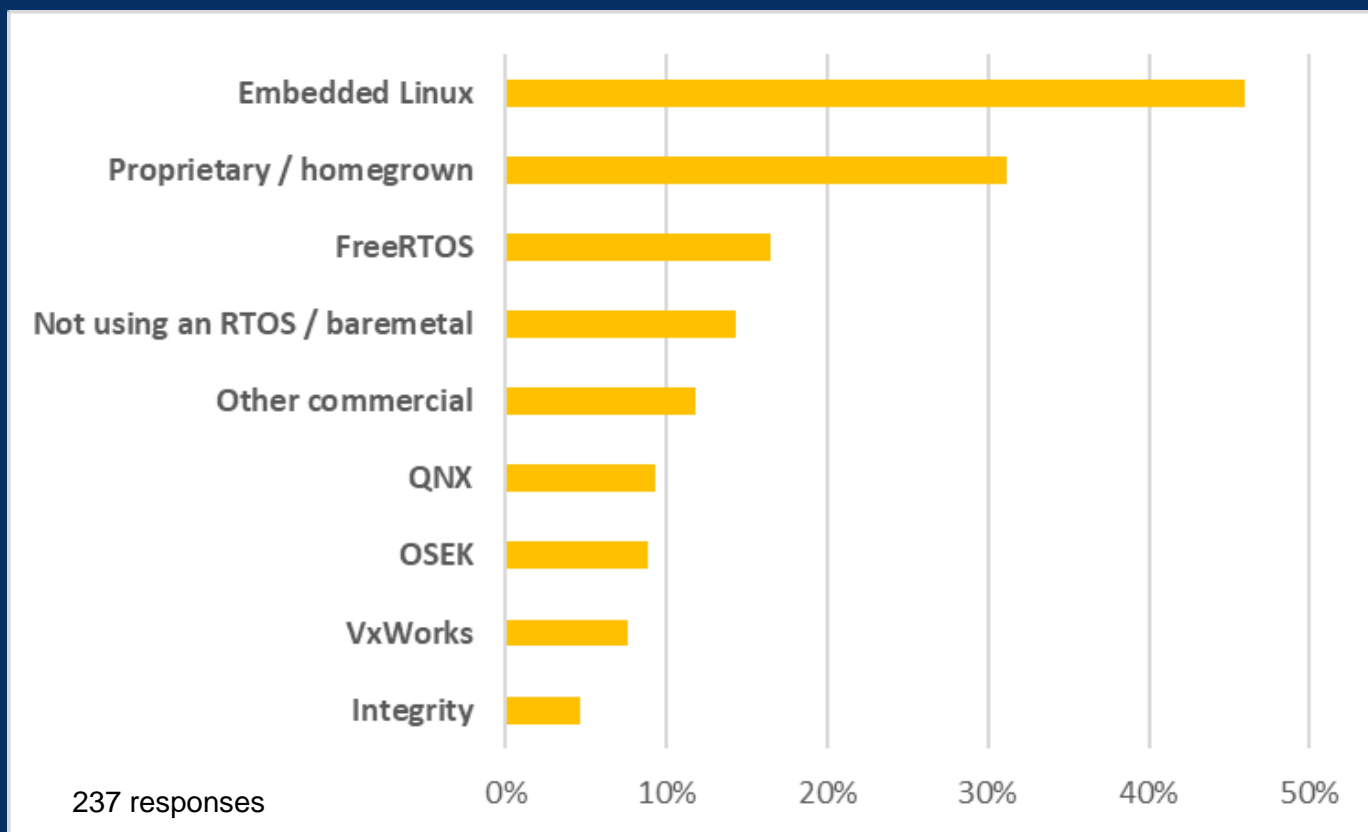
Hardware Aware

Xilinx Versal
R2022a

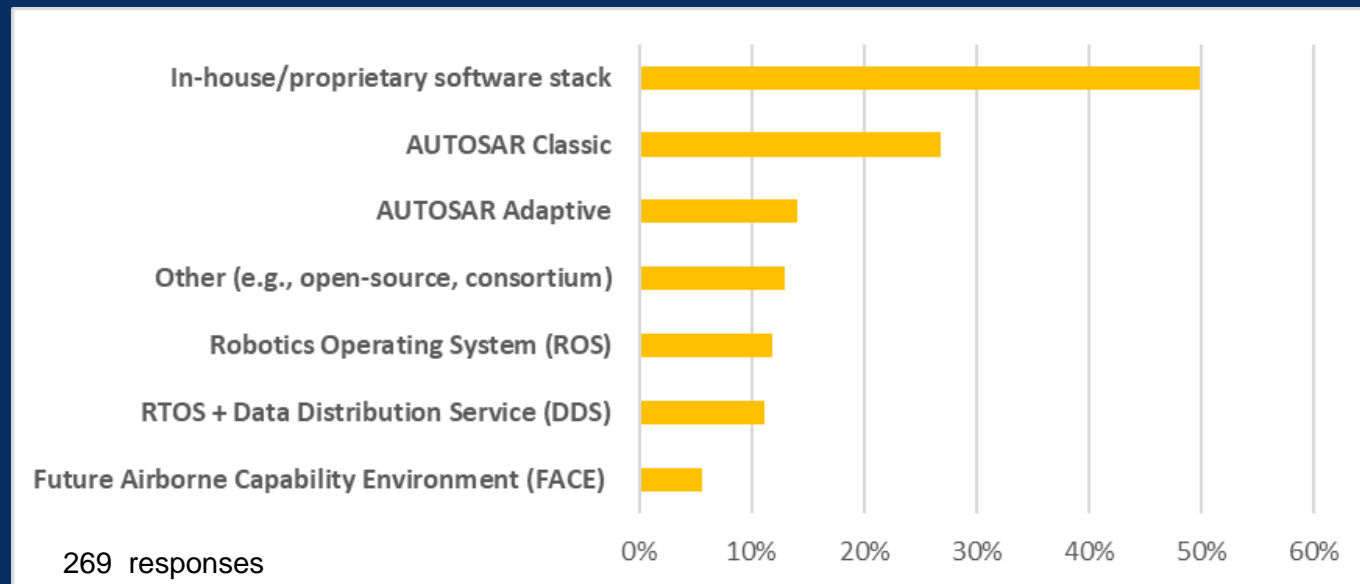
Infineon AURIX TC4x
R2022b

GPU Performance
Analyzer
R2023a

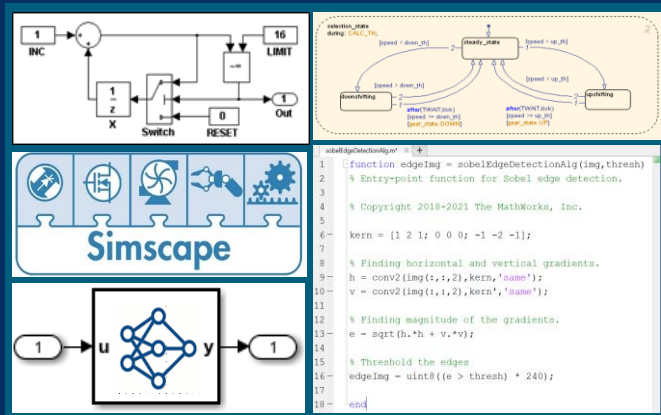
MAB Survey: Which Real-Time Operating System (RTOS) is likely to be in your next generation of systems? (select all that apply)



MAB Survey: Which standards-based architecture and middleware does your organization plan on using? (select all that apply)



You have been successful deploying models as individual components and complete applications

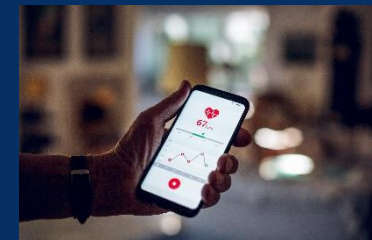
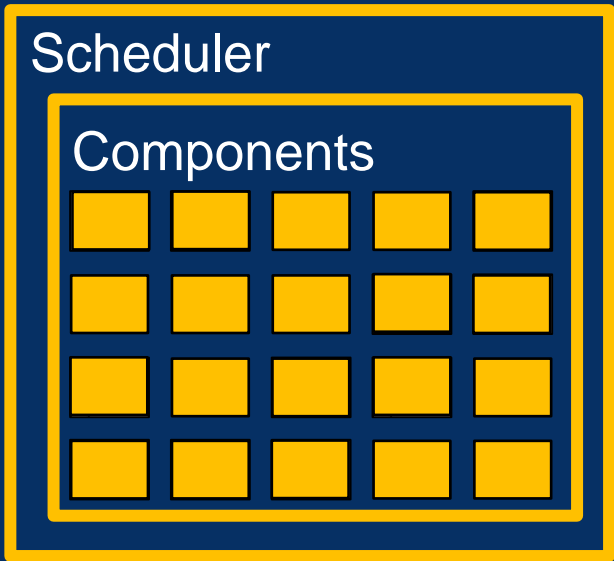


The image shows two parts of a Simscape model. On the left is a control block diagram with inputs 'INC', 'LIMIT', 'Switch', and 'RESET', and an output 'Out'. On the right is a MATLAB function for Sobel edge detection:

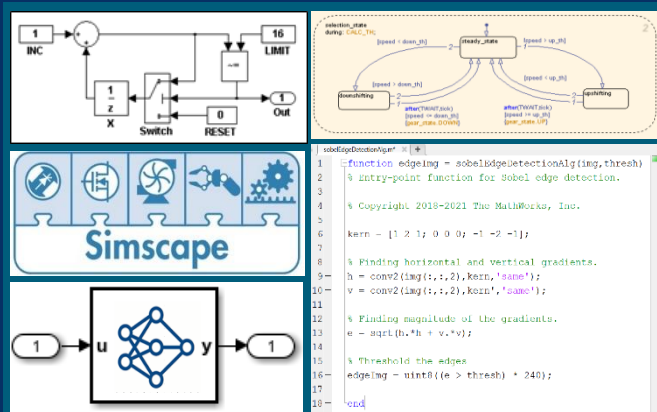
```
function edgeImg = sobelEdgeDetectionAlg(img,thresh)
% Entry-point function for Sobel edge detection.
% Copyright 2018-2021 The MathWorks, Inc.
kern = [1 2 1; 0 0 0; -1 -2 -1];
% Finding horizontal and vertical gradients.
h = conv2(img(:,:,2), kern, 'same');
v = conv2(img(:,:,3), kern, 'same');
% Finding magnitude of the gradients.
e = sqrt(h.*h + v.*v);
% Threshold the edges
edgeImg = uint8(e > thresh) * 240;
end
```

controls, logic, physics, array, AI

Code Generation



We continue investing in architecture standards and middleware



The image shows a Simscape block diagram on the left and MATLAB code on the right. The block diagram includes an input 'u', a summing junction, a gain block '1/X', a switch, a 'RESET' block, a 'LIMIT' block, and an output 'y'. The MATLAB code defines a function 'edgeing' for Sobel edge detection, including comments and a kernel matrix.

Platform Aware Code Generation

Real-Time Operating System

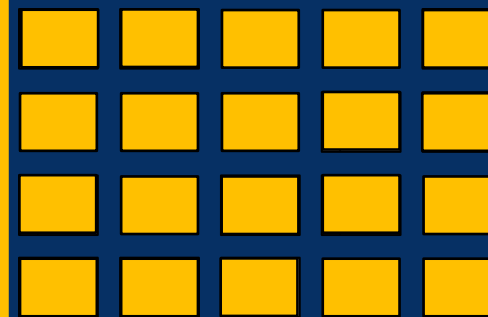


Middleware

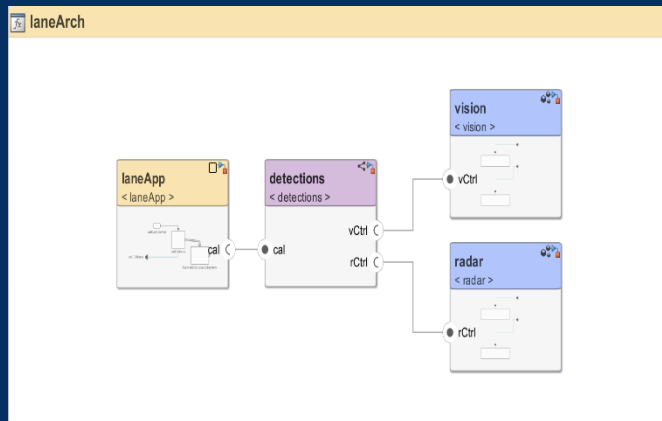


Scheduler

Components



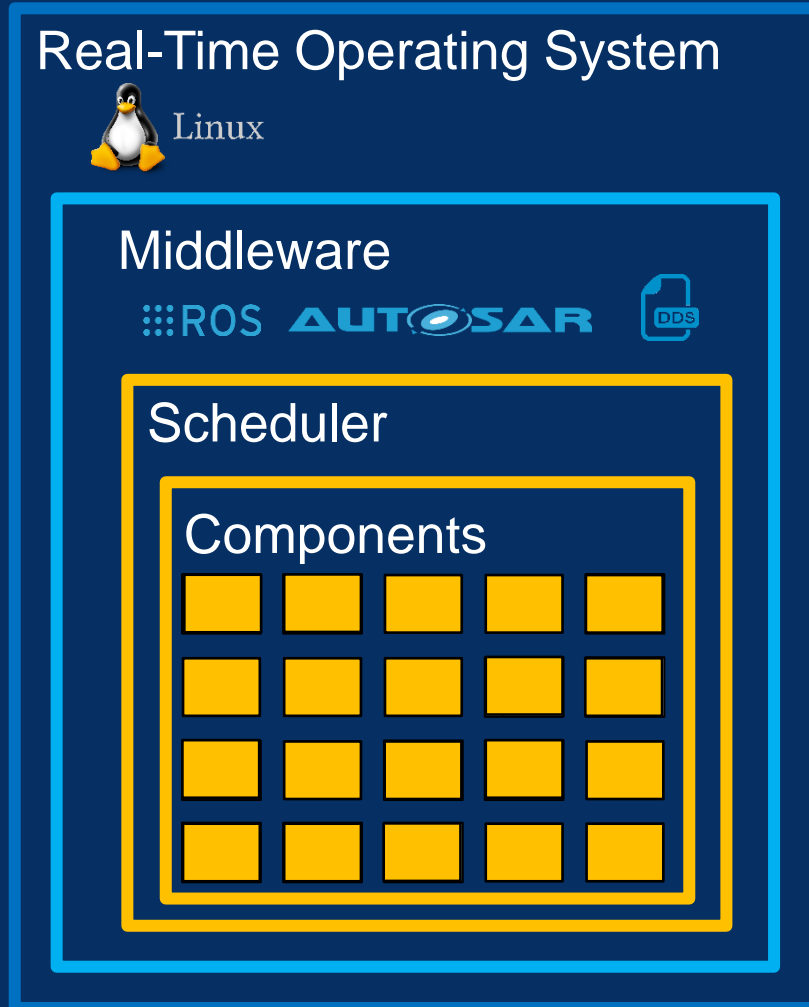
Use System Composer to model middleware more completely



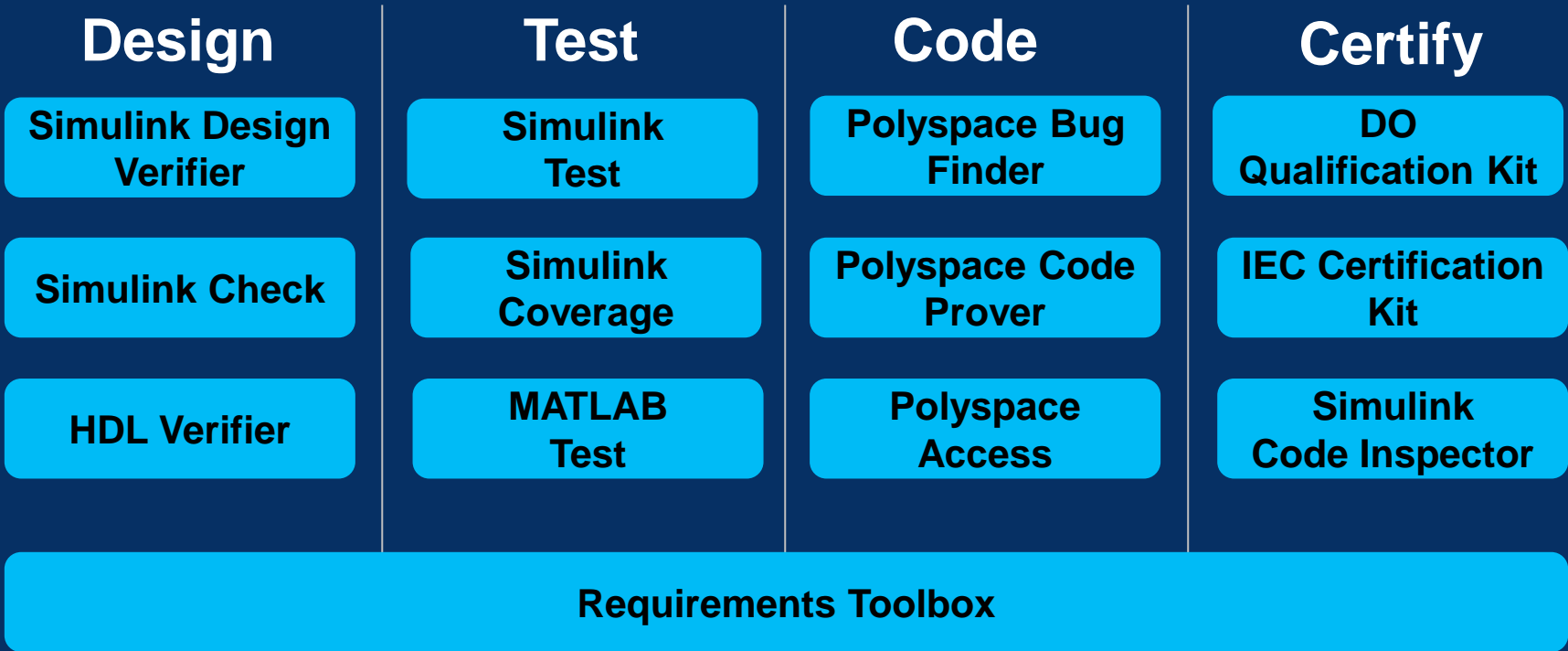
System Composer



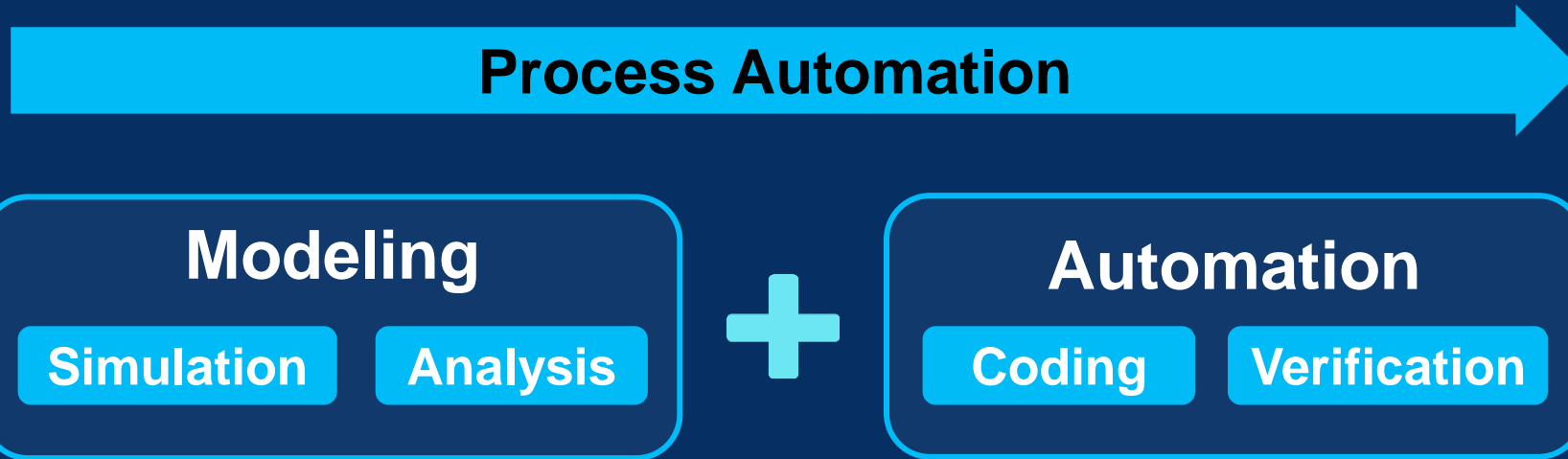
Platform Aware
Code Generation



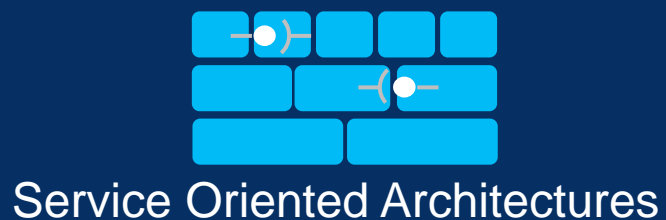




Model-Based Design Framework



New MBD Approaches



Cloud solutions roadmap

Access

Scaling

Collaboration

Cloud solutions roadmap

Access

Scaling

Collaboration

The screenshot displays the Simulink Online web interface. The main workspace shows a Simulink model for a cruise control system. The model includes a 'reference' input, a 'Cruise Control' block (containing a PI controller), a gain block of $-K$, an integrator block $1/s$, and a feedback path with a gain of $-b$. The equations $\Sigma F = ma$ and $u - bv = ma$ are shown above the model. The output is labeled 'velocity' and is connected to a 'Signal Assessment' block.

On the left, the 'Training - Tasks' panel shows '2.2 Identifying Blocks and Signals: (1/2) P'. The text explains that the model is missing an input: the desired speed of the car. A unit step (a function whose value goes from 0 to 1 at a specified time) is a common test input for such a system. It also states that in Simulink, the Step block provides a unit step at $t=1$ by default. A small graph shows a step function from $t=0$ to $t=10$.

A 'TASK' box instructs the user to add a Step block from the Simulink > Sources library and connect it to the unconnected signal labeled 'reference'. It also instructs to connect the model output, 'velocity', to the Signal Assessment block. Buttons for 'Submit', 'Next task', 'Hint', 'See Solution', and 'Reset' are visible.

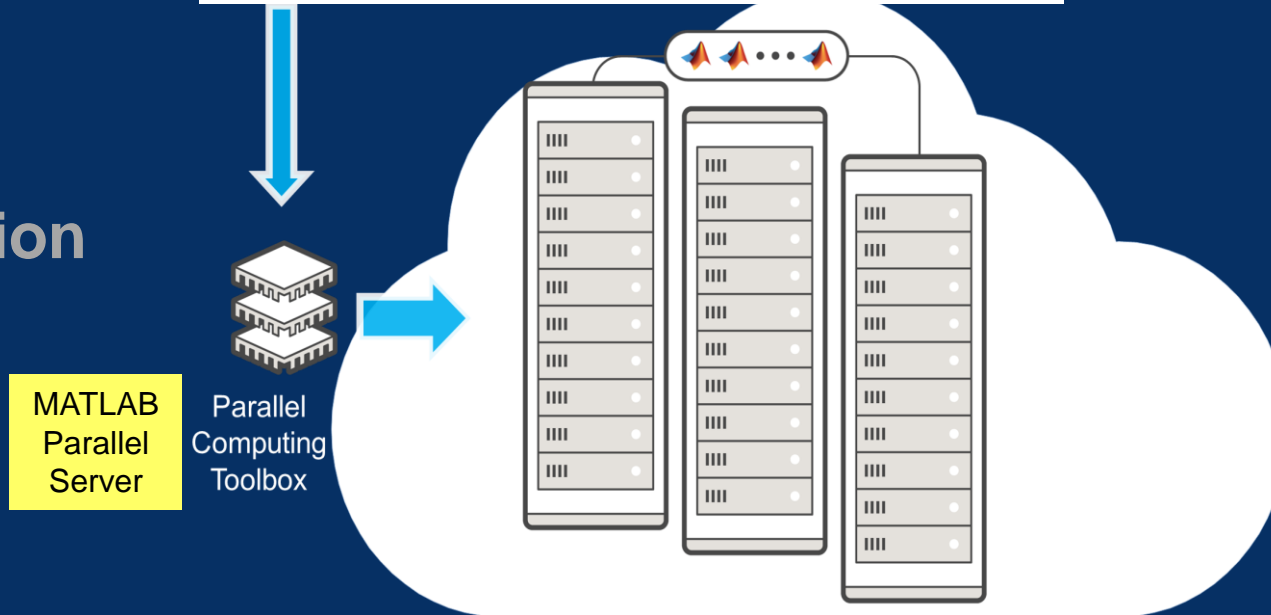
On the right, the 'Training - Assessment' panel shows 'Task 1 Signal'. A graph plots 'Value' (from -1 to 2) against 'Time' (from 0 to 10). The 'Signal requirement' is shown as a red line that steps up at $t=1$ and remains constant at 1. The 'My signal' is shown as a blue line that smoothly rises from 0 to 1 and then remains constant. A 'Requirements' section below the graph asks 'Does the connected signal meet the requirement?' and shows a green checkmark.

Simulink Online

Cloud solutions roadmap

Access
Scaling
Collaboration

```
for i = 1:10000  
    in(i) = Simulink.SimulationInput(my_model)  
    in(i) = setVariable(my_var, i);  
end  
out = parsim(in);
```



Massive
simulation
jobs

Cloud solutions scaling

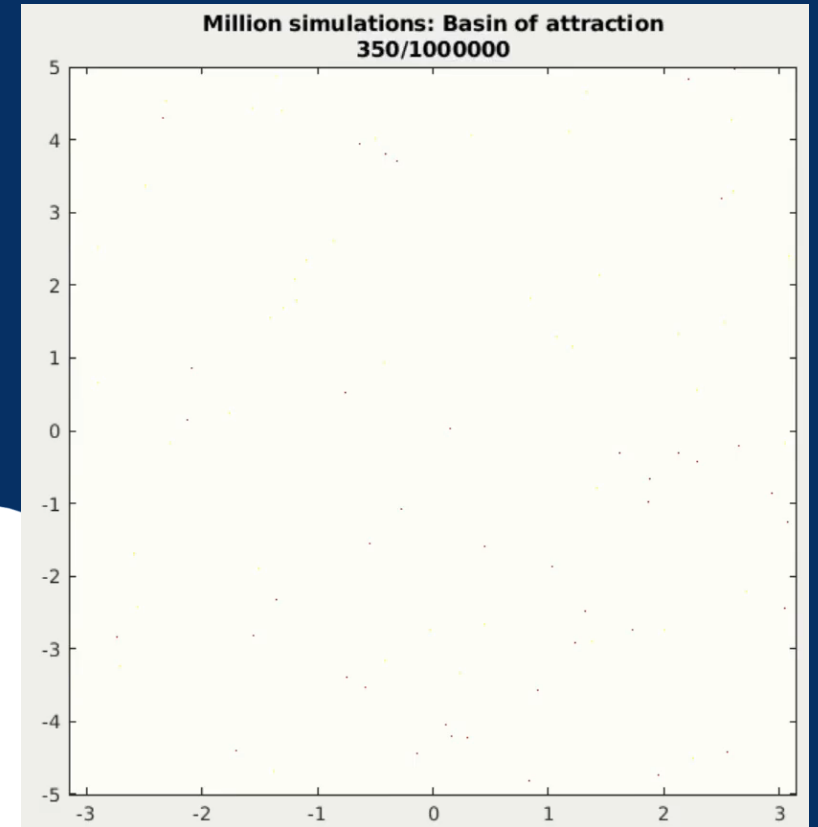
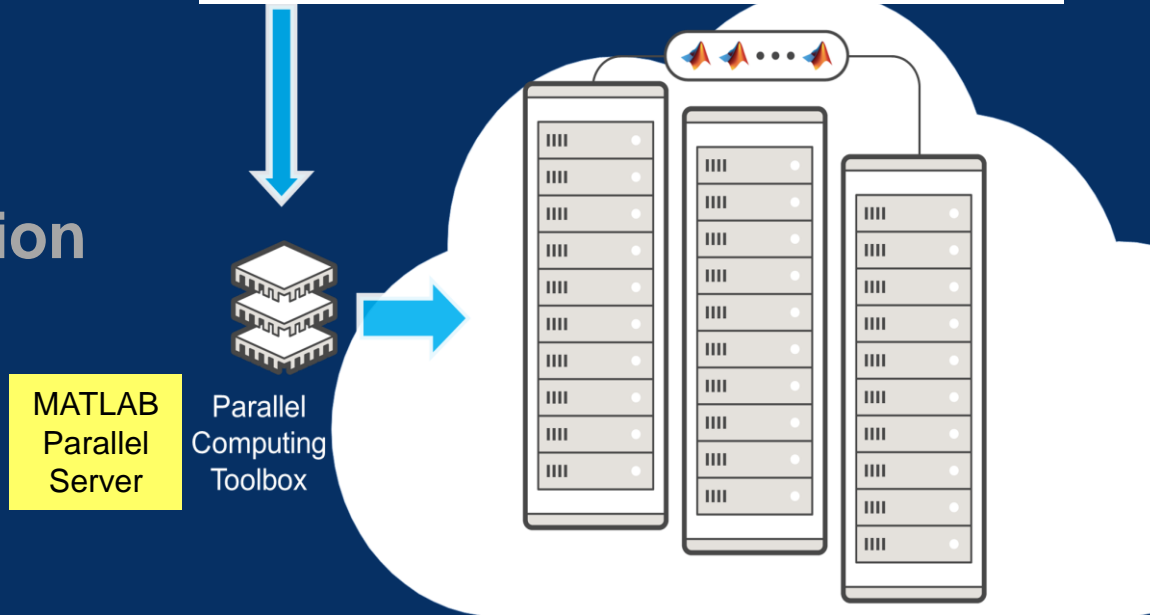
One million simulations finished in
2.5 minutes!
Over 1 day if ran serially

Access

Scaling

Collaboration

```
for i = 1:10000  
    in(i) = Simulink.SimulationInput(my_model)  
    in(i) = setVariable(my_var, i);  
end  
out = parsim(in);
```



Cloud solutions roadmap

Access

Scaling

Collaboration

The screenshot displays a project dashboard with the following sections:

- Alerts:** A notification dated December 1st, 2022, stating: "New dashboard has been added. The content is currently a placeholder and is not interactive. Fully responsive design is still being implemented. Updates will be communicated in this space." It includes a crane icon and three dots below the text.
- Status:** Two summary cards: "10 Active Design Reviews" and "26 Total Projects".
- New Comments:** Two entries: "landscapeMission" by JSmith (6 hrs ago) and "asesmentBuilder" by SHamil (15 hrs ago), each with a "View >>" link.
- Awaiting Reviews:** Two entries: "matlab_airframe" by JSmith (2 hrs ago) and "tunnelProject_inMotion" by JSmith (3 hrs ago), each with a "View >>" link.
- Recently Opened Projects:** A section header with a "landscapeMission" link below it.

Project dashboard

Design review

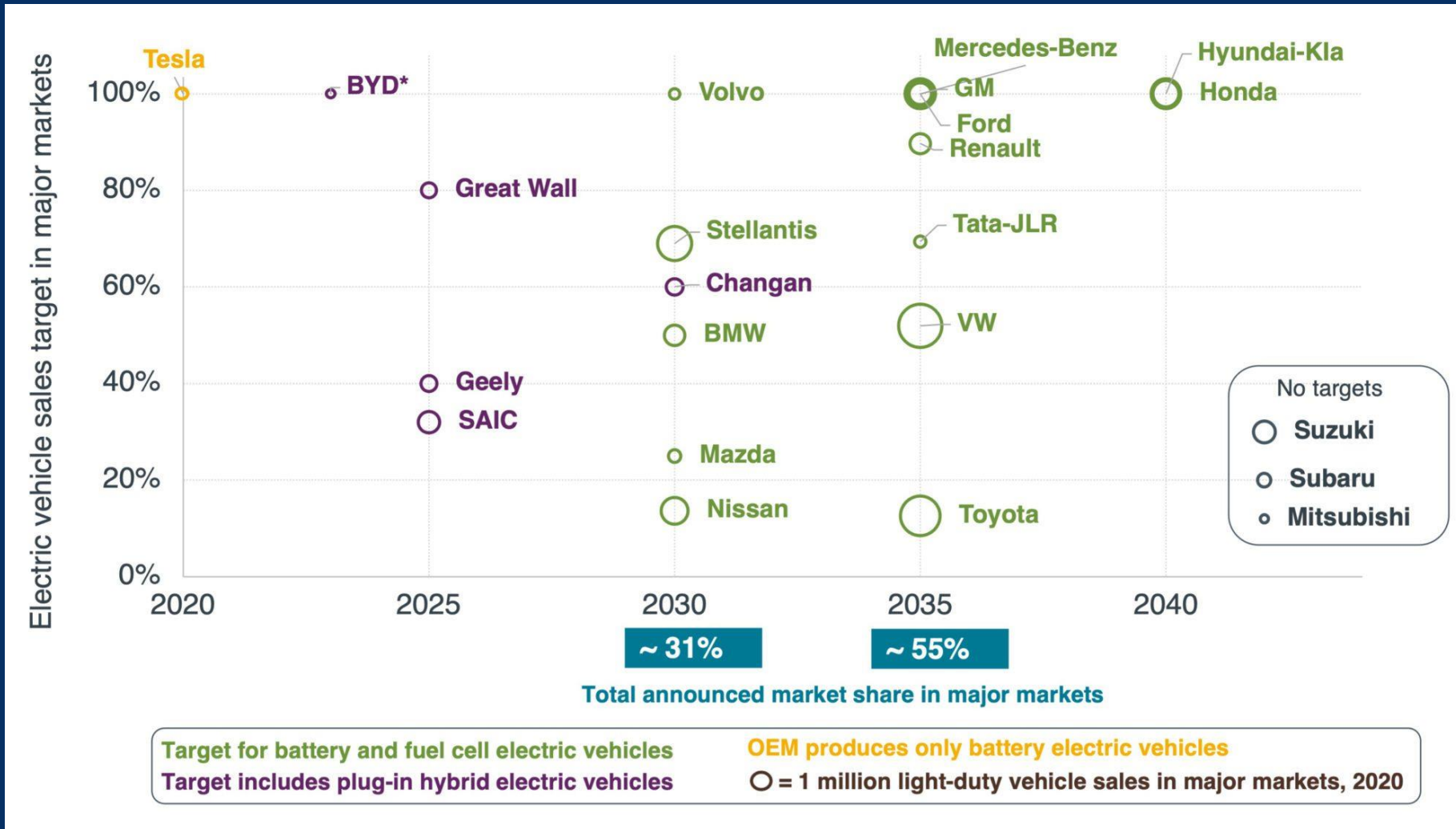
Instant search



Deep Solutions

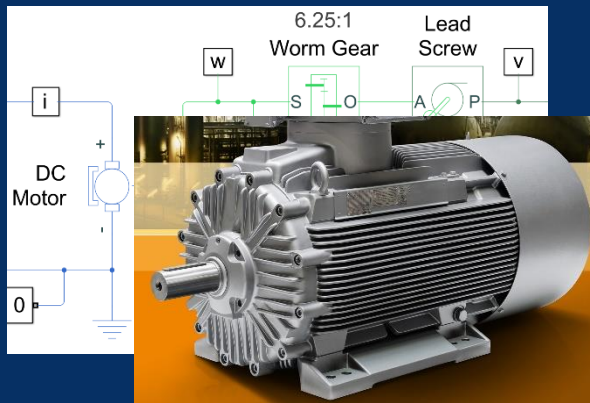


31% EVs by 2030 – According to OEM Announcements

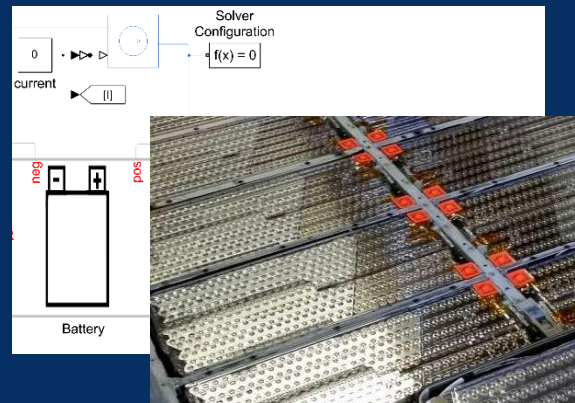


- EV announcements made for about 55% of the total automotive market.

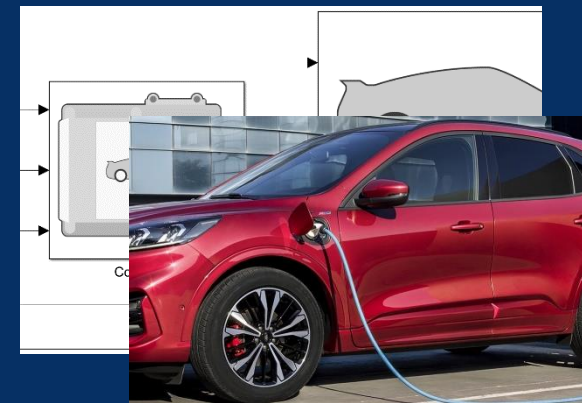
Electric Vehicles



**Electric
motors**

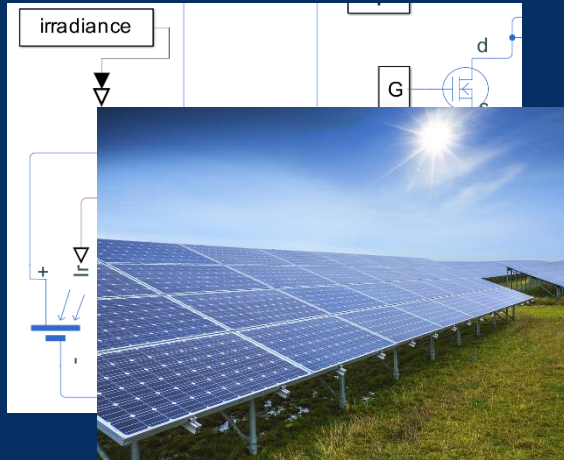


**Battery
packs**

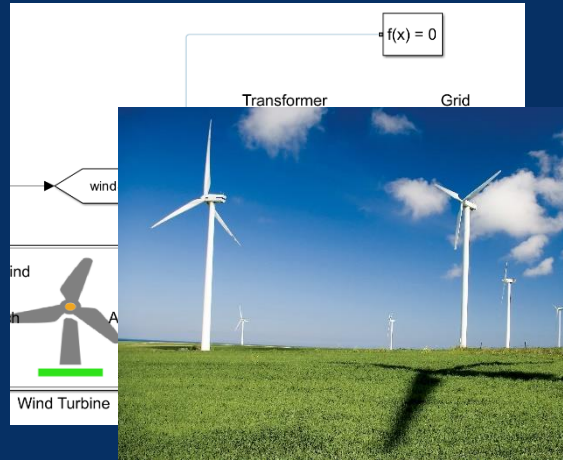


**Full vehicle
models**

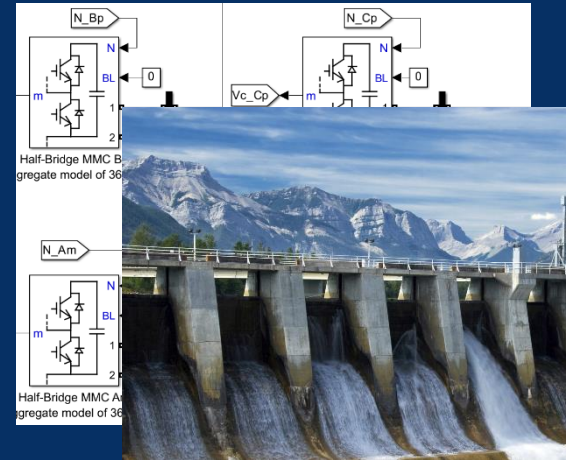
Green Energy



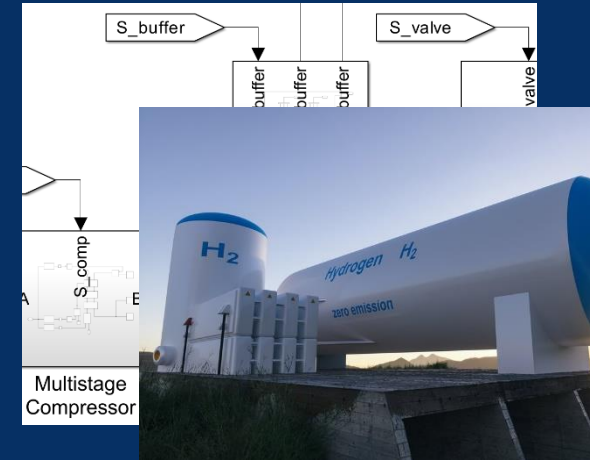
Solar



Wind



Hydroelectric



Green Hydrogen



Deep Solutions



Electrification

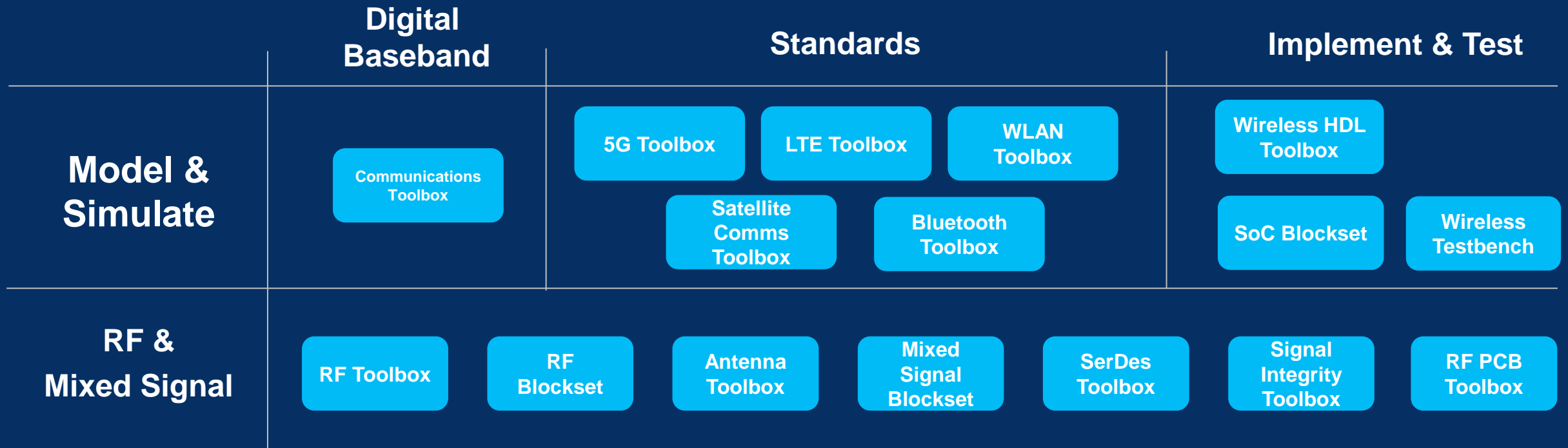


Connectivity



Autonomous

Wireless, RF, and Mixed Signal Product Portfolio

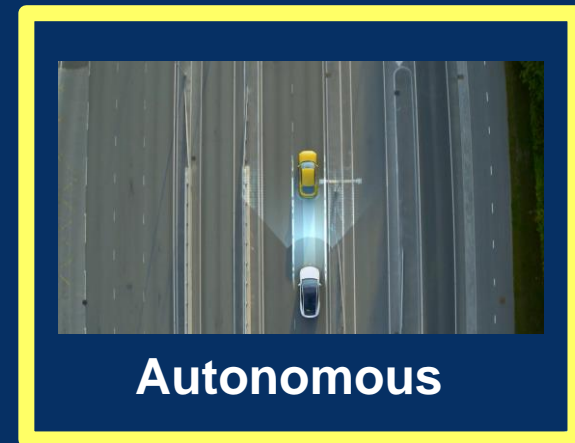




Electrification

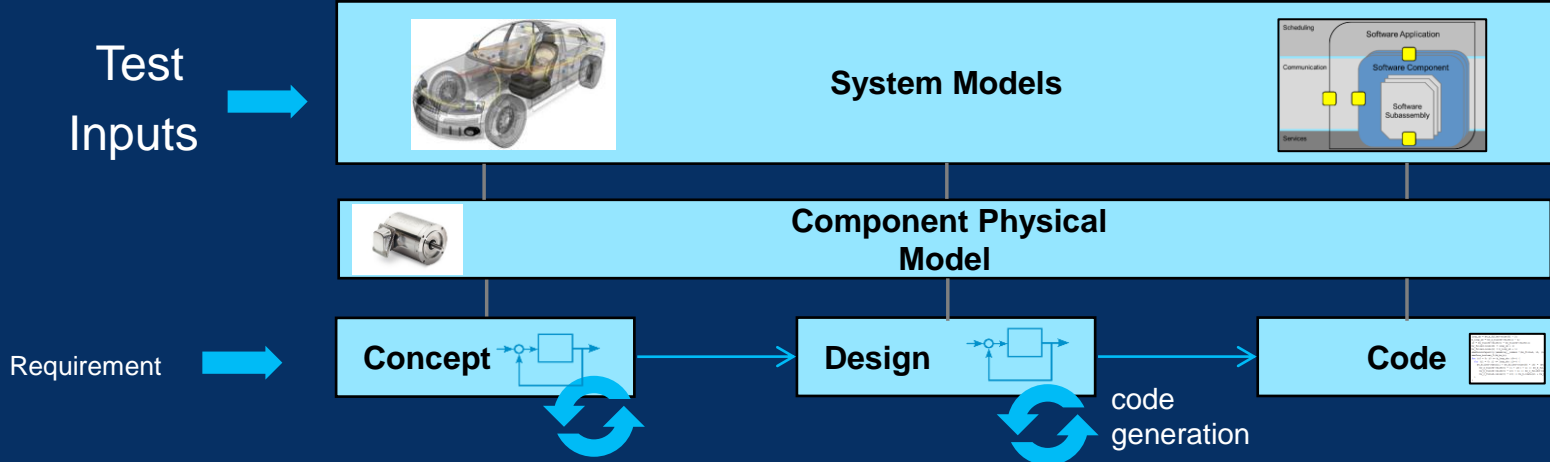


Connectivity

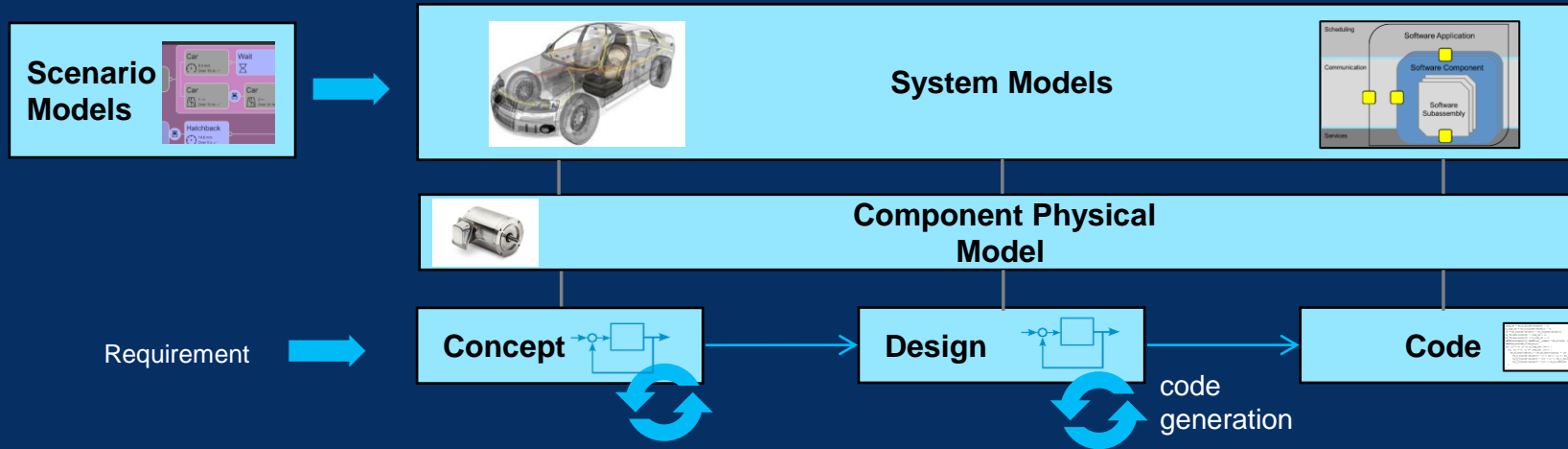


Autonomous

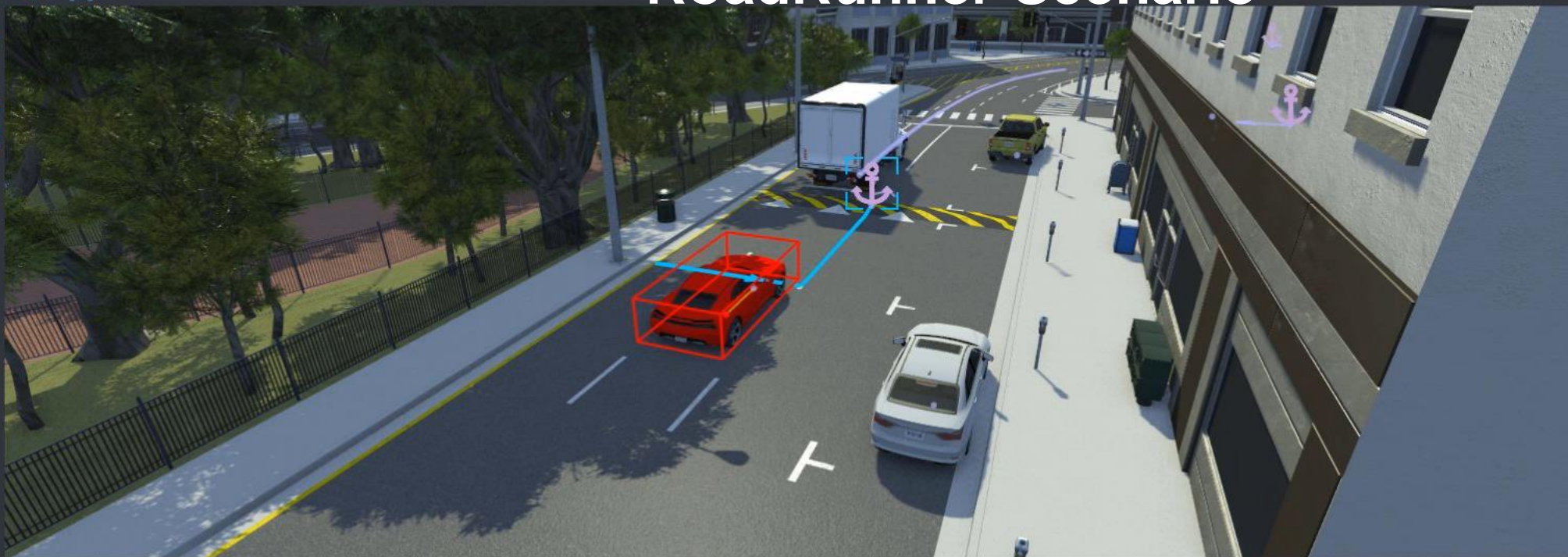
Model-Based Design Workflow



Model-Based Design Workflow



RoadRunner Scenario




Attributes


Vehicle

Name: Car

Actor Id: 2


Color:

Vehicle Type:  SK_MuscleCar.fbx_rr

Behavior: 

Point Offsets

Enable Anchoring:

Anchor: SpeedBump 

Lock To Anchor:

Forward Offset:

Reference Line: Front Origin Back

Lane Offset

Relative To: Road Edge

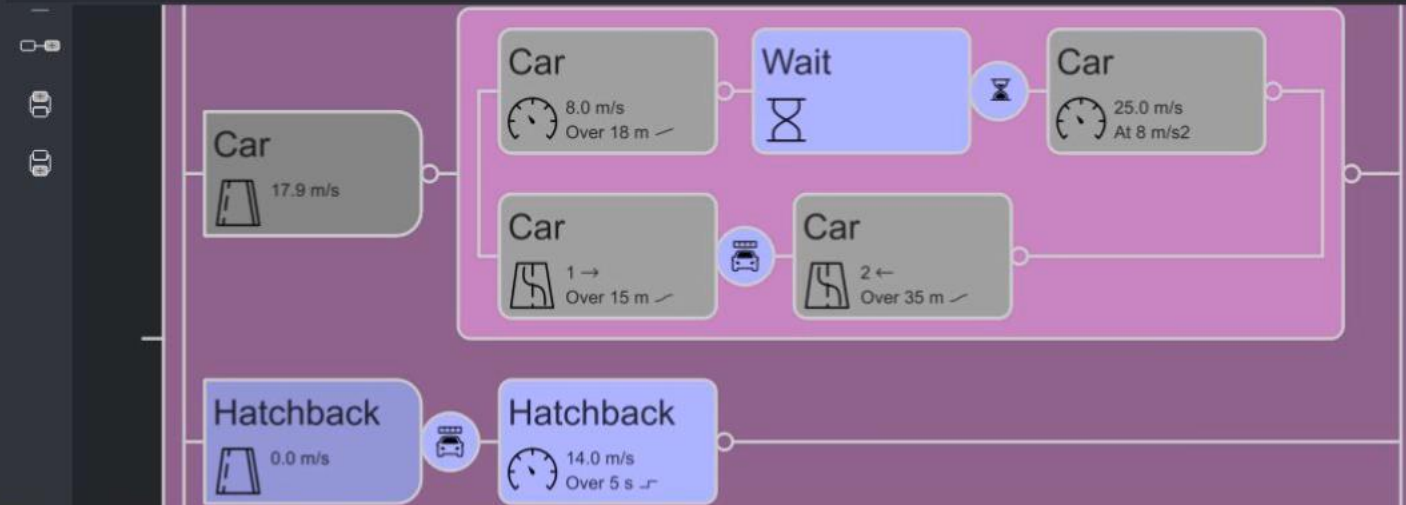
Offset From: Left Lane Right Lane

Lane Offset:

2D Editor | Logic

Variables

	Name	
1	Hatchback_InitialSpeed	14
2	Car_NumLanesToChange	2
3	Car_LaneChangeDirection	LeftOf
4	Car_DistanceBehindSpeedBump	-8



Autonomous Product Portfolio

Industry-Based	Automated Driving Toolbox	Robotics System Toolbox	UAV Toolbox
Navigation, Tracking & Perception	Sensor Fusion Toolbox	Navigation Toolbox	Lidar Toolbox
Middleware	AUTOSAR Blockset	ROS Toolbox	DDS Blockset
Scene & Scenario	RoadRunner + Asset	RoadRunner Scene Builder	RoadRunner Scenario

Application Trends for the Software Defined Vehicle



Electrification

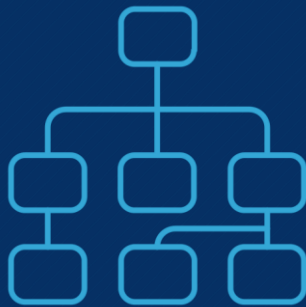


Connectivity



Autonomous

Workflow Trends



**Systems
Engineering**

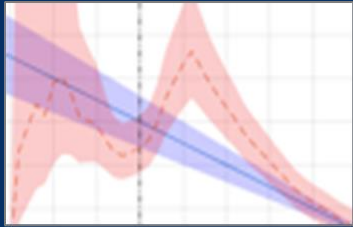


**Modern
Software Practices**



**Data-Driven
Development and AI**

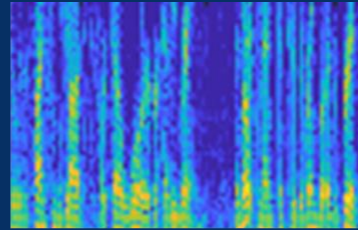
AI Reference Examples



Predictive Maintenance



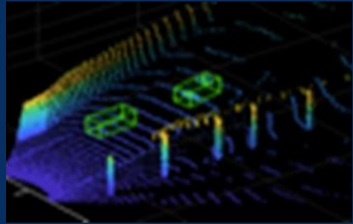
Hyperspectral Imaging



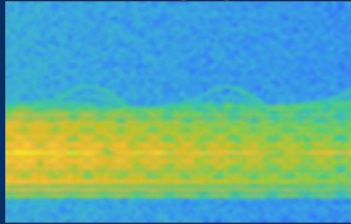
Signal Processing



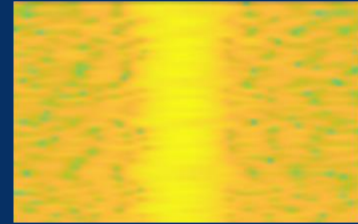
Robotic Control



Lidar Processing



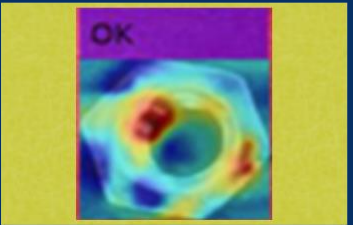
Radar Processing



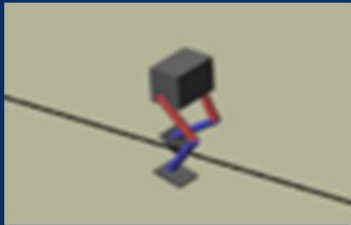
Wireless Communications



Automated Driving



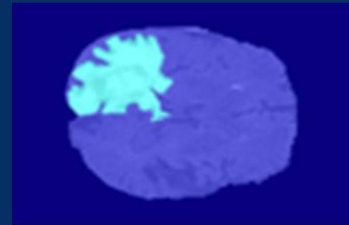
Visual Inspection



Reinforcement Learning

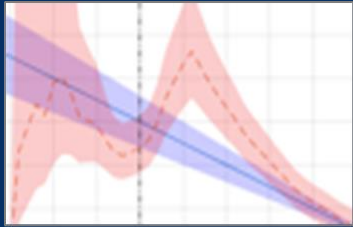


Audio



Medical Imaging

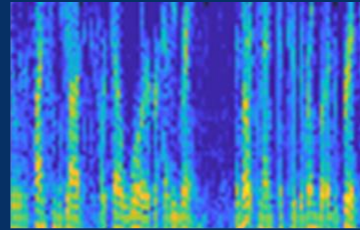
AI Reference Examples



Predictive Maintenance



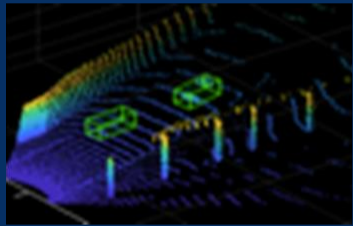
Hyperspectral Imaging



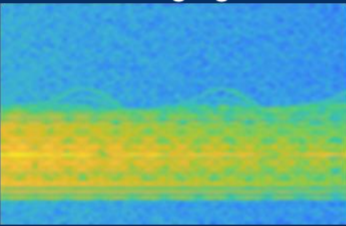
Signal Processing



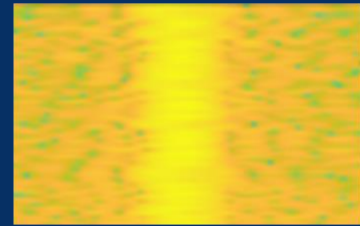
Robotic Control



Lidar Processing



Radar Processing



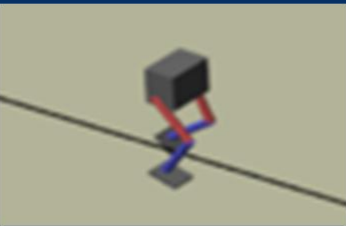
Wireless Communications



Automated Driving



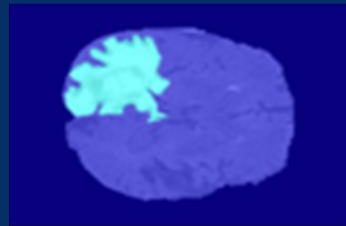
Visual Inspection



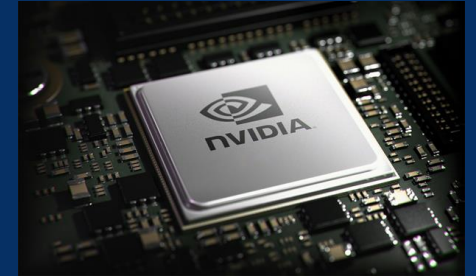
Reinforcement Learning



Audio



Medical Imaging



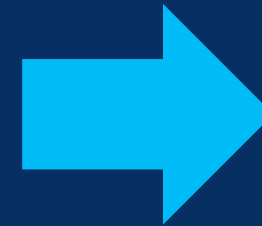
GPU



CPU



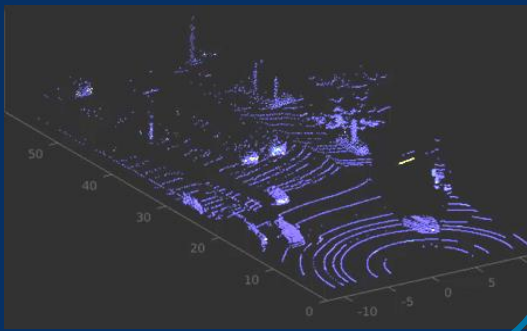
FPGA/SoC



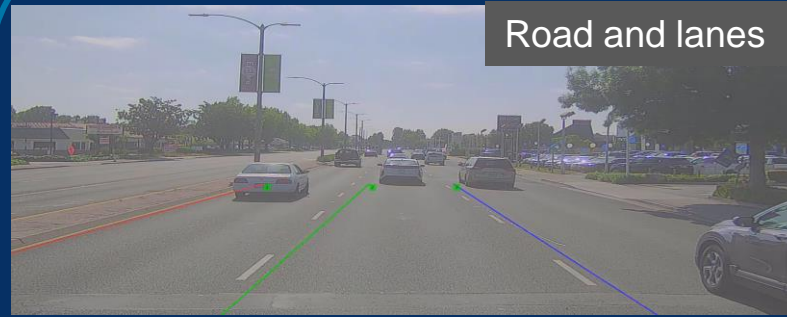
Applying AI to Real-World Sensor Data (Virtual Scenario Generation)

*Scenario Builder Add-on for
Automated Driving Toolbox*

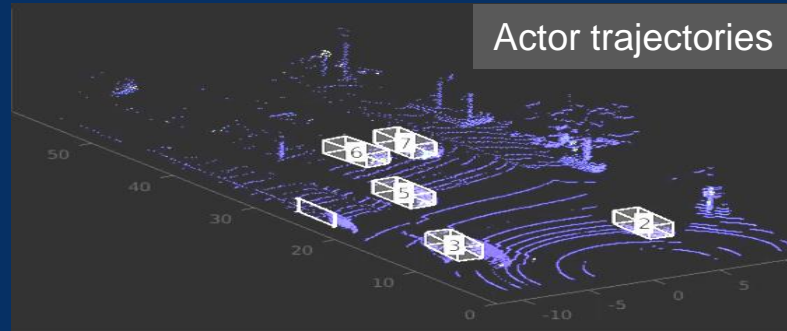
Recorded sensor data



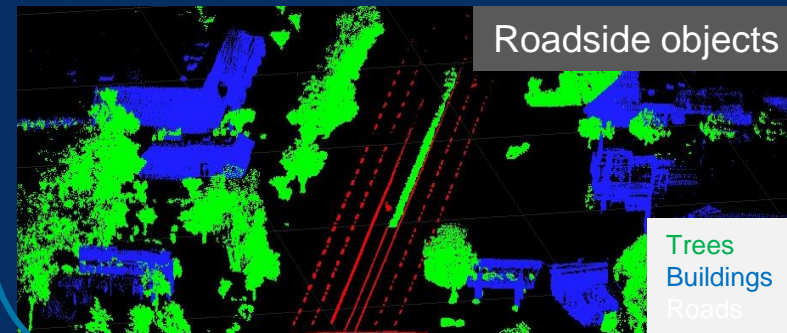
Perception AI models



Road and lanes



Actor trajectories



Roadside objects

Trees
Buildings
Roads

Reconstructed RoadRunner Scenario



~10x faster than a human in
creating scenarios from data



Deep3dbox, CLRNet
PVRcnn, RandLANet, K-lane



Electrification



Connectivity



Autonomous

Model-Based Design Workflow

