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
Problem statement from initial MAB Meetings

Observation: traditional process is document based

- Concept definition
- Design
- Implementation
- Testing and deployment

MathWorks®
25 Years of MAB

Vision emanating from initial MAB Meetings
Model-Based Design Framework

- Modeling
  - Simulation
  - Analysis

- Automation
  - Coding
  - Verification
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

Process Automation

Modeling
- Simulation
- Analysis

Automation
- Coding
- Verification

New MBD Approaches

Automated: CI/CD
Service Oriented Architectures
Cloud Development
Zonal and Vehicle HPCs
How to measure software operational performance?

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<thead>
<tr>
<th>Metric</th>
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Role of Model-Based Design?

Throughput

Quality
Model-Based Design Workflow
Model-Based Design Workflow

System Models
Component Physical Model
Concept
Design
Code

Throughput
Full automation?

Unit Test
System Test

Quality

Requirement

code generation
Model-Based Design: Integration and Automation

System Models

Component Physical Model

Concept

Design

Code

Requirement

code generation

CI support package

Detailed Testing Workflow

Sub-Process: Test Authoring
Model-Based Design: Integration and Automation
Simulink as a simulation integration platform
Simulink Scales to Complex Systems

Components & test harnesses
Buses, ports, connectors
Architecture
Variant Manager
Virtual Vehicle Composer

>500 organizations have adopted
You successfully target a range of devices with code generation

4700 organizations use automatic code generation

* 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

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)

- Embedded Linux
- Proprietary / homegrown
- FreeRTOS
- Not using an RTOS / baremetal
- Other commercial
- QNX
- OSEK
- VxWorks
- Integrity

237 responses

* MathWorks Advisory Board cross-industry survey
MAB Survey: Which standards-based architecture and middleware does your organization plan on using? (select all that apply)

- In-house/proprietary software stack
- AUTOSAR Classic
- AUTOSAR Adaptive
- Other (e.g., open-source, consortium)
- Robotics Operating System (ROS)
- RTOS + Data Distribution Service (DDS)
- Future Airborne Capability Environment (FACE)

269 responses

* MathWorks Advisory Board cross-industry survey
You have been successful deploying models as individual components and complete applications

codes, logic, physics, array, AI
We continue investing in architecture standards and middleware.
Use System Composer to model middleware more completely

System Composer

Real-Time Operating System

Middleware

Components

Scheduler

Platform Aware Code Generation

Coding
Modeling

- Simulation
- Analysis

Automation

- Coding
- Verification
Find bugs sooner

**Design**
- Simulink Design Verifier
- Simulink Check
- HDL Verifier

**Test**
- Simulink Test
- Simulink Coverage
- MATLAB Test

**Code**
- Polyspace Bug Finder
- Polyspace Code Prover
- Polyspace Access

**Certify**
- DO Qualification Kit
- IEC Certification Kit
- Simulink Code Inspector

Requirements Toolbox
Model-Based Design Framework

Process Automation

Modeling
- Simulation
- Analysis

Automation
- Coding
- Verification

New MBD Approaches

Automated: CI/CD
Service Oriented Architectures
Cloud Development
Zonal and Vehicle HPCs
Cloud solutions roadmap

Access
Scaling
Collaboration
Cloud solutions roadmap

Access
Scaling
Collaboration

Simulink Online
Cloud solutions roadmap

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

Access

Scaling

Collaboration

Massive simulation jobs
Cloud solutions scaling

Access

Scaling

Collaboration

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

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

Access
Scaling
Collaboration

Project dashboard
Design review
Instant search
31% EVs by 2030 – According to OEM Announcements

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

Source: Analyzed top 23 companies, by sales. Weighted target by major market sales.
Electric Vehicles

Electric motors

Battery packs

Full vehicle models
Green Energy

- Solar
- Wind
- Hydroelectric
- Green Hydrogen
Modeling
- Simulation
- Analysis

Automation
- Coding
- Verification

Deep Solutions

Electrification

Connectivity

Autonomous
## Connectivity

### Wireless, RF, and Mixed Signal Product Portfolio

<table>
<thead>
<tr>
<th>Model &amp; Simulate</th>
<th>Digital Baseband</th>
<th>Standards</th>
<th>Implement &amp; Test</th>
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<tbody>
<tr>
<td></td>
<td>Communications Toolbox</td>
<td>5G Toolbox, LTE Toolbox, WLAN Toolbox</td>
<td>Wireless HDL Toolbox, SoC Blockset, Wireless Testbench</td>
</tr>
<tr>
<td>RF &amp; Mixed Signal</td>
<td>RF Toolbox, RF Blockset, Antenna Toolbox, Mixed Signal Blockset, SerDes Toolbox</td>
<td>Signal Integrity Toolbox</td>
<td>RF PCB Toolbox</td>
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Model-Based Design Workflow

System Models

Component Physical Model

Concept → Design → Code

Test Inputs

Requirement

code generation
Model-Based Design Workflow
RoadRunner Scenario
## Autonomous Product Portfolio

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<tr>
<th>Category</th>
<th>Automated Driving Toolbox</th>
<th>Robotics System Toolbox</th>
<th>UAV Toolbox</th>
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<td>Industry-Based</td>
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<td>Middleware</td>
<td>AUTOSAR Blockset</td>
<td>ROS Toolbox</td>
<td>DDS Blockset</td>
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<td>Scene &amp; Scenario</td>
<td>RoadRunner + Asset</td>
<td>RoadRunner Scene Builder</td>
<td><strong>RoadRunner Scenario</strong></td>
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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)

Recorded sensor data

Perception AI models
- Road and lanes
- Actor trajectories
- Roadside objects

Reconstructed RoadRunner Scenario

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

Deep3dbox, CLRNet, PVRCNN, RandLANet, K-lane
Model-Based Design Workflow

- System Models
- Component Physical Model
- Concept
- Design
- Code

- Code generation
- Unit Test

Throughput vs. Quality

System Test

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