

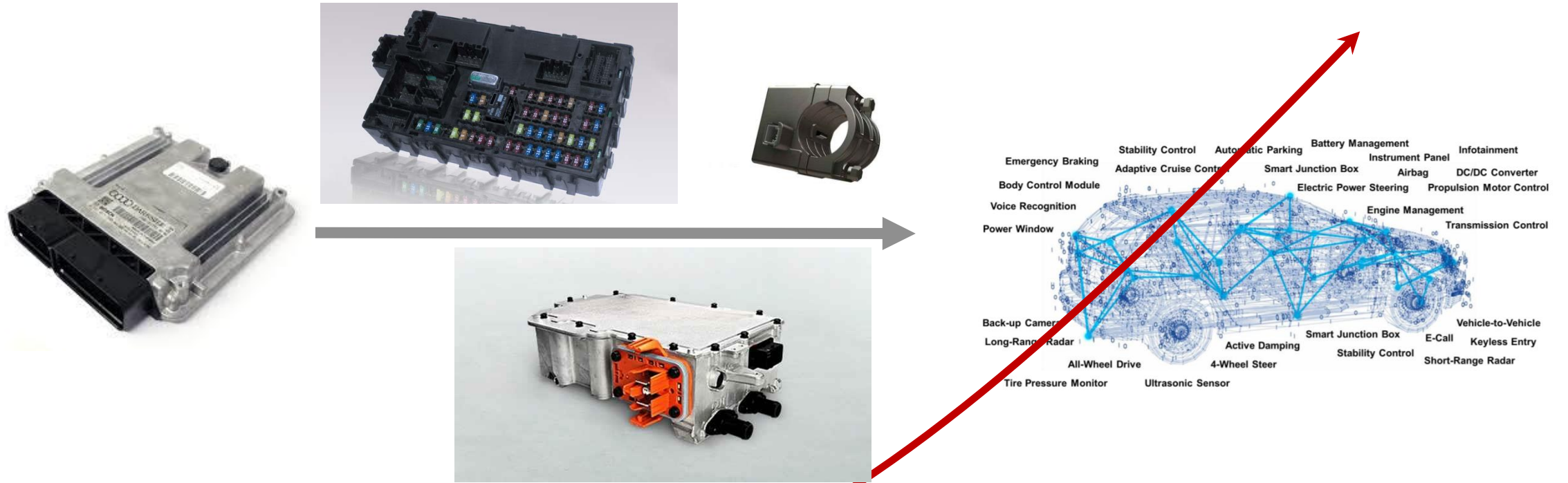
# Learnings from Process Assessments

## Model-Based Design Maturity Framework™



Govind Malleichervu – Industry Marketing  
John Lee – Consulting Services  
June 23, 2020

# First Digital Transformation: Adding Embedded Software to Everything



Design complexity

1980

1990

2000

2010

2020

2030

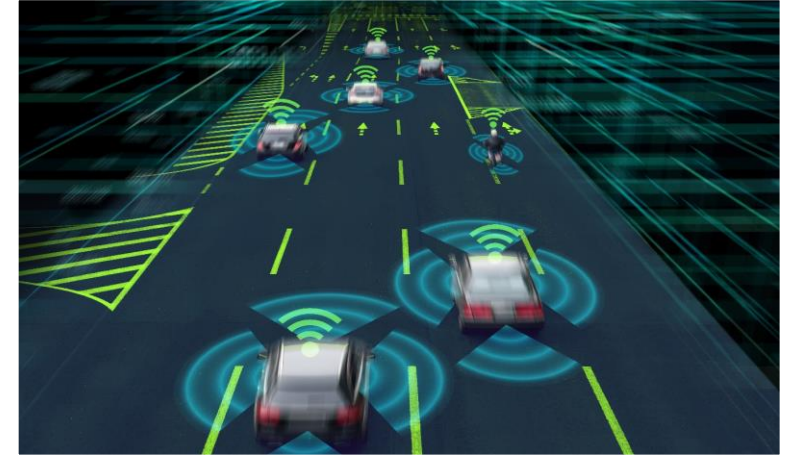
# Second Digital Transformation in Automotive



Vehicle Electrification



Automated Driving



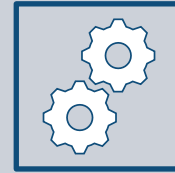
Connected Vehicles

- Digital transformation is raising new questions about tools and processes

# Questions to Answer



How well is your verification and validation process capable of meeting **ISO 26262**?



Why is **integration level testing** not being leveraged?



Are models leveraged for **validation** and **analysis** beyond code generation? How are they being maintained?



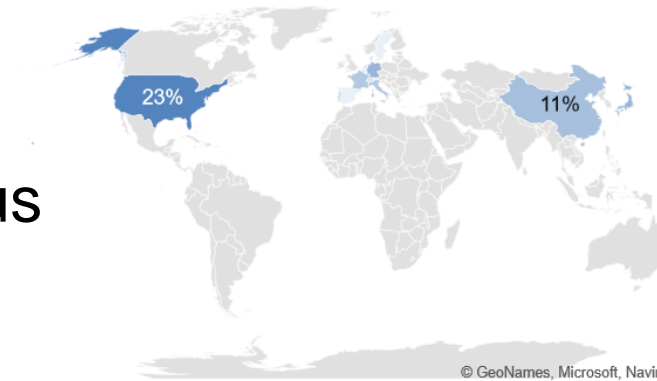
Are processes and tools being **evolved** to meet the application needs?

# Objective for Today

- Over the years, MathWorks have conducted numerous Process Assessments across various industries around the world.

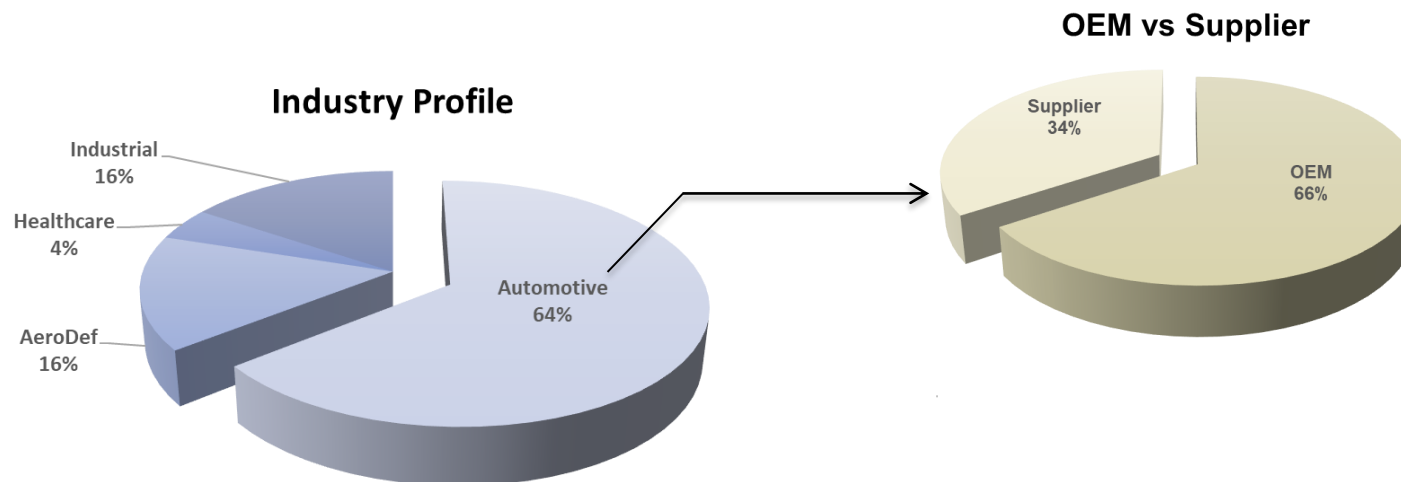
Process Assessment Locations

% of total assessments 2% 23%

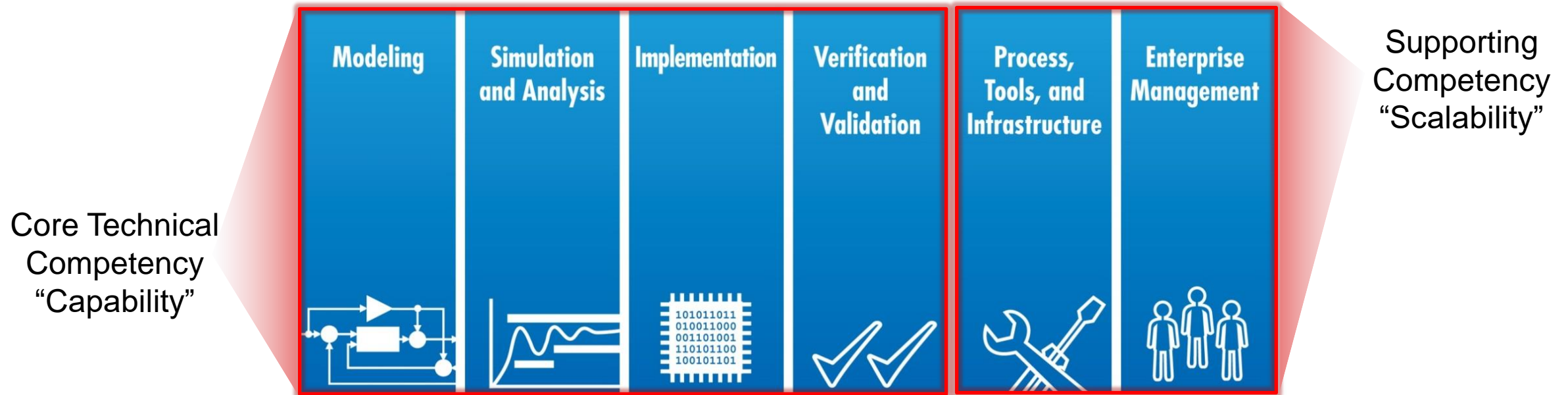


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- Share findings including general trends and correlation with opportunities for tool and process improvements with a focus on Automotive Industry.



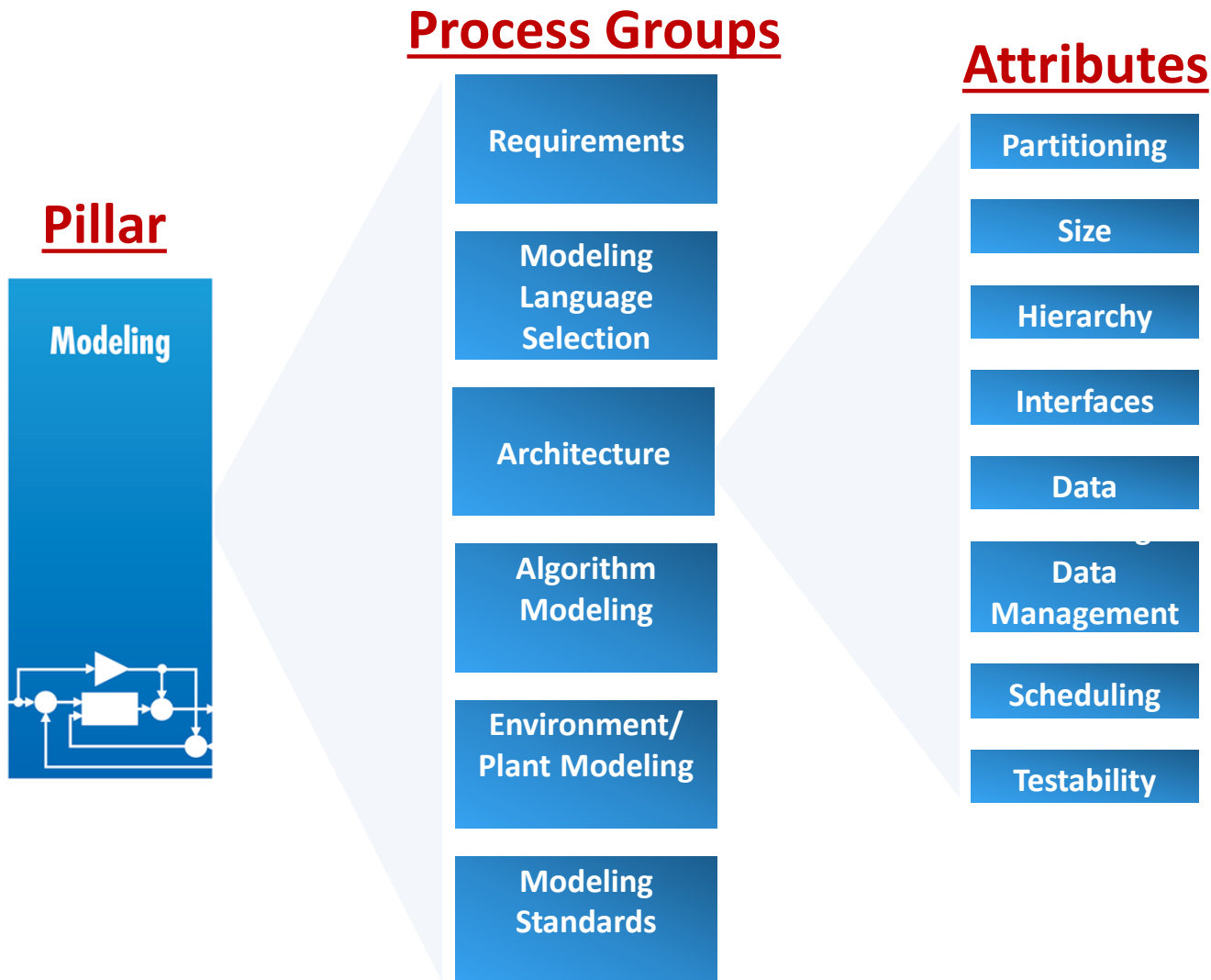
# Assessment is based on Model-Based Design Maturity Framework™



- Key Features
  - **Comprehensive measurement** of capabilities
  - Independently **measures each capability**
  - Applies to **any level of expertise**

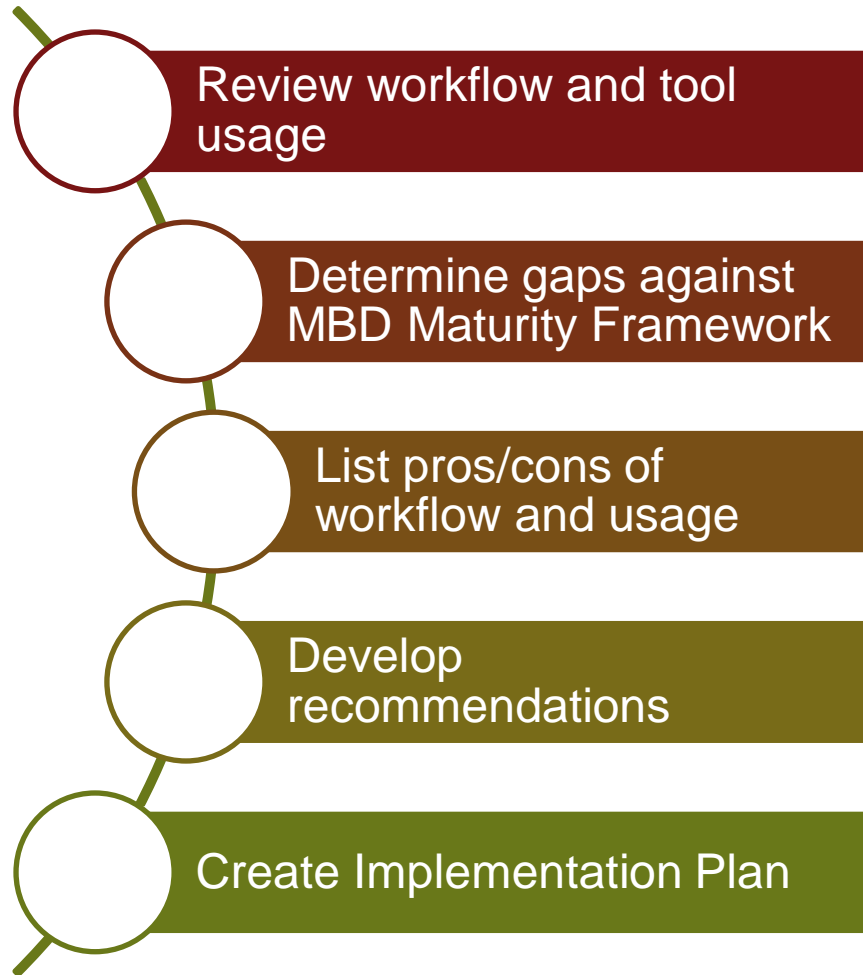
# Model-Based Design Maturity Framework™

## Modeling Pillar Example

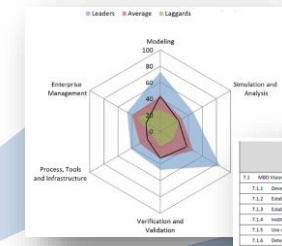
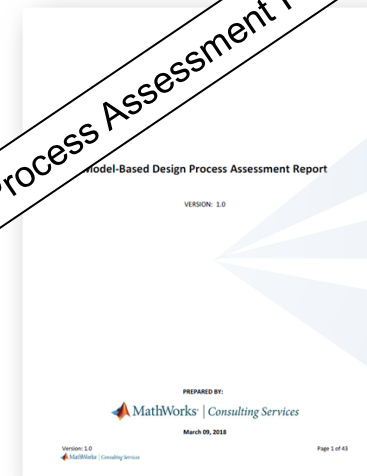


- Maturity determined by rating:
  - 6 Pillars
  - 28 Key Process Groups
  - 200+ Attributes

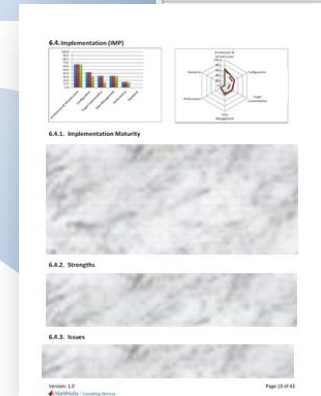
# Process Assessment Execution



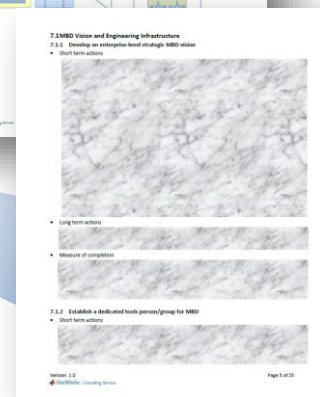
MBD Process Assessment Report



Recommendations	Impact	Level of Difficulty
7.1 MBD Vision and Engineering Infrastructure		
7.1.1 Develop an enterprise level strategic MBD vision	High	High
7.1.2 Establish a dedicated tool group for MBD	High	High
7.1.3 Establish a capable software development process	High	Medium
7.1.4 Institute knowledge sharing and management	Medium	Medium
7.1.5 Use of metrics for forecasting project status, process improvement, and workload	High	Medium
7.1.6 Determine tool upgrade strategy	Medium	Medium
7.2 Verification Strategy and Improvements		
7.2.1 Establish verification strategy	High	Medium
7.2.2 Select VIL strategy for MBD based on tool requirement testing	Medium	Medium
7.3 Plant model Strategy and Improvements		
7.3.1 Establish strategy for plant modeling	High	High
7.3.2 Assess if current the plant model for integration tool testing	Medium	Medium
7.4 Available modeling organization with separate functional specialist and integration engineer (IE)	Medium	Medium
7.5 Establish the use of simulation for system optimization and performance analysis for the requirement's phase	High	Medium
7.6 Test Capabilities Enhancement		
	Low	Low
	Medium	Low
	Medium	Medium
	Medium	Medium
	Medium	Medium
	Low	Low
	Medium	Low
	Medium	Medium

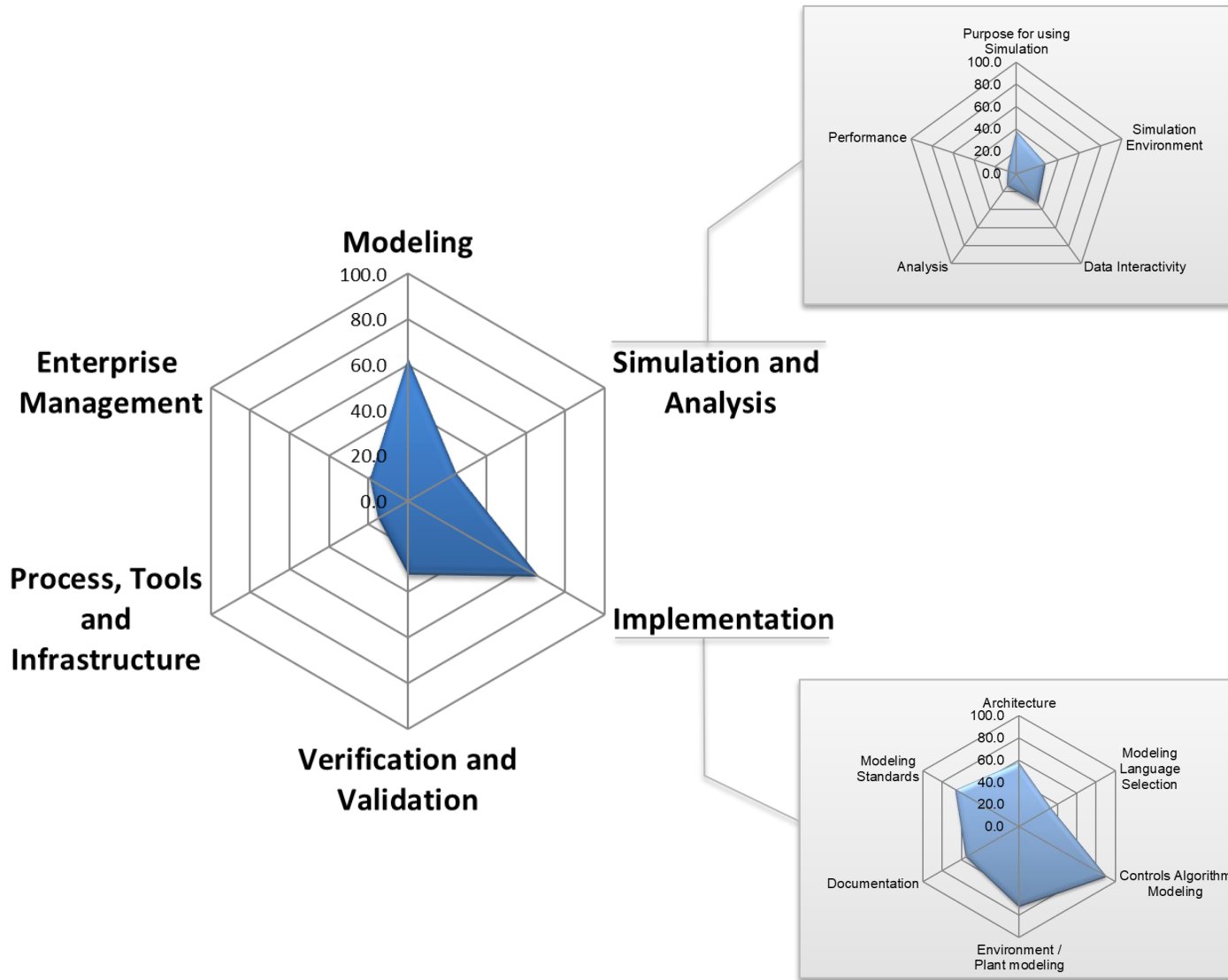


MBD Process Assessment Implementation Plan





# How Did We Review the Data?...Simple Example



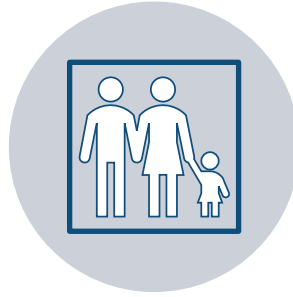
- **Observation**

- Strong in Implementation (code generation)
- Verification and Validation, and Simulation and Analysis not fully leverage
- Model-Based Design focuses on software creation

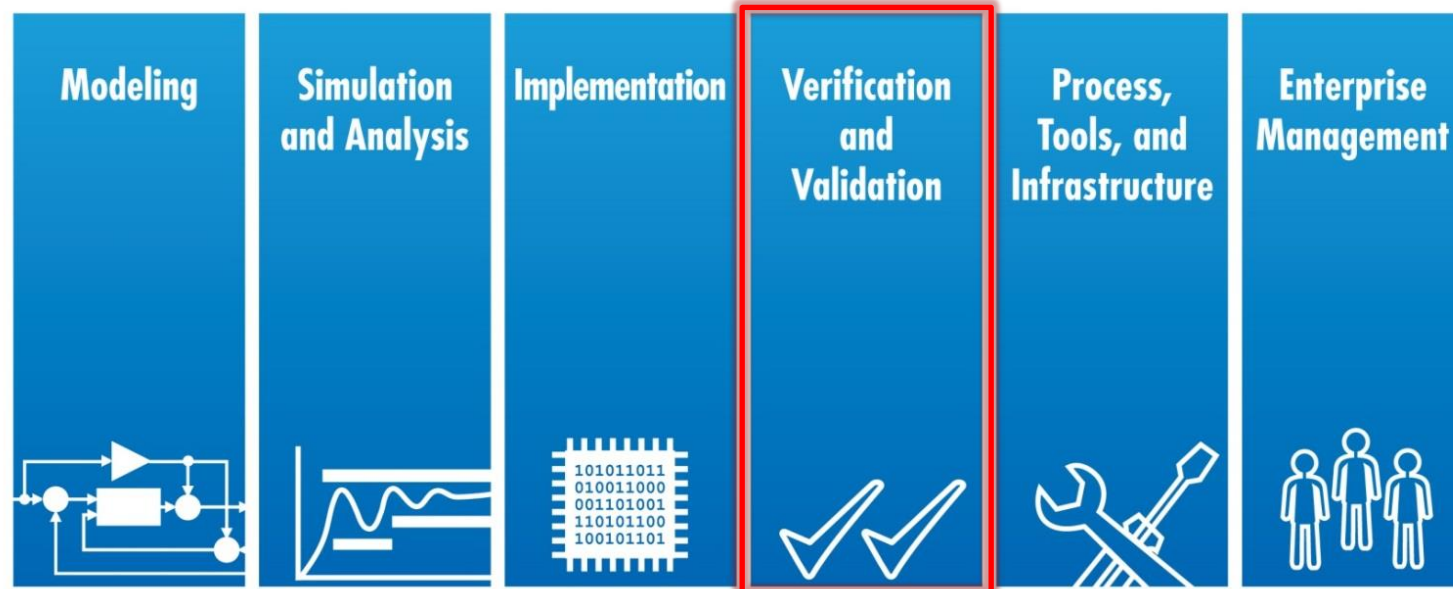
# Process Assessment – Data Analysis

- Quantitative analysis
  - Plots of Process Assessment data
- Qualitative analysis
  - Analysis of detail report



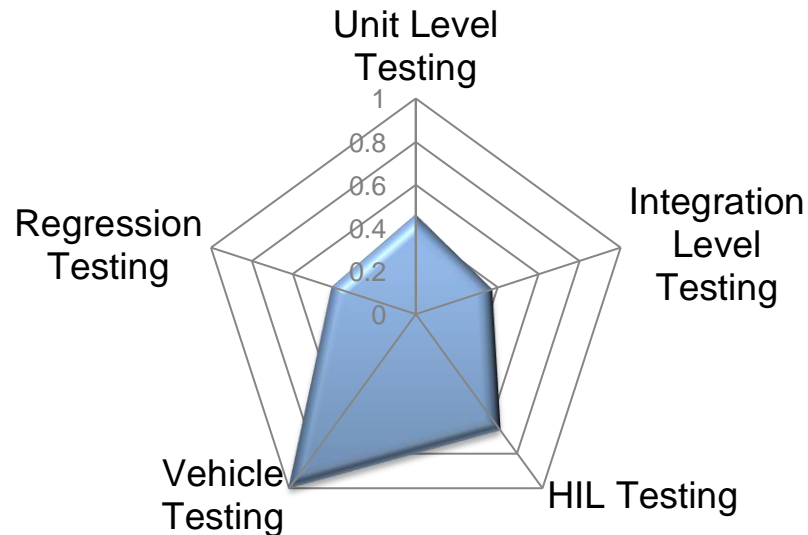


How well is your  
verification and validation  
process capable of  
meeting **ISO 26262**?



# Verification and Validation Pillar Mapping with ISO 26262-6

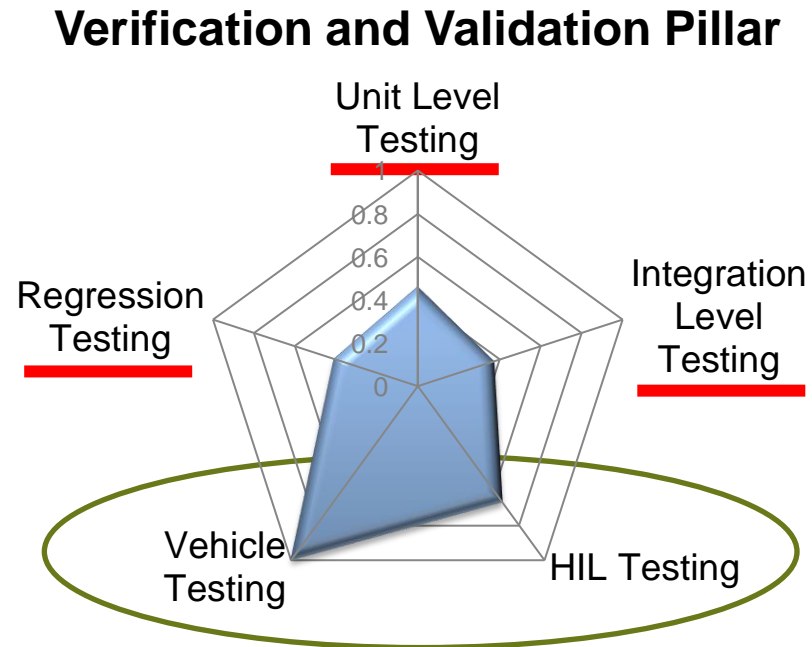
## Verification and Validation Pillar



VV Pillar	ISO 26262
Unit Level Testing	ISO 26262-6 Clause 9 Software Unit Verification
Integration Level Testing	ISO 26262-6 Clause 10 Software Integration and Verification
Vehicle and HIL Testing	ISO 26262-6 Clause 11 Testing of Embedded Software
Regression Testing	ISO 26262-8 Clause 9 Verification

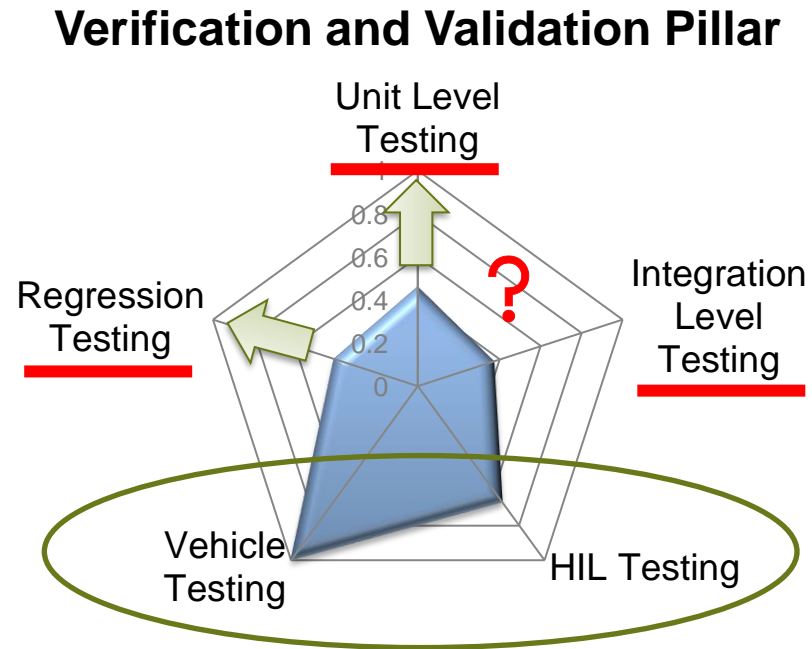
\*Average maturity rating V&V pillar normalized against Vehicle Testing

# Verification and Validation Pillar Status and Trends



- Vehicle and HIL Testing are strong due to legacy reasons
- Low maturity in the other 3 process groups shows difficulty for meeting safety standards such ISO 26262

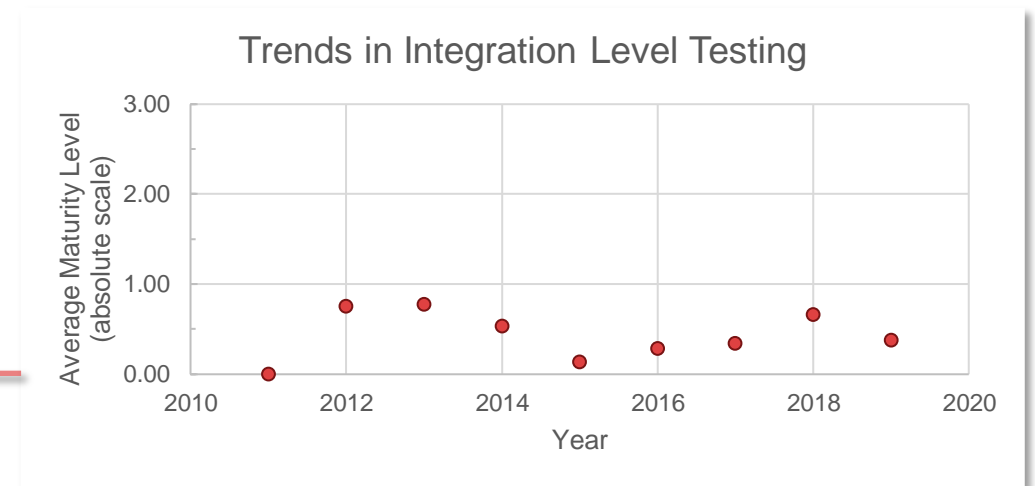
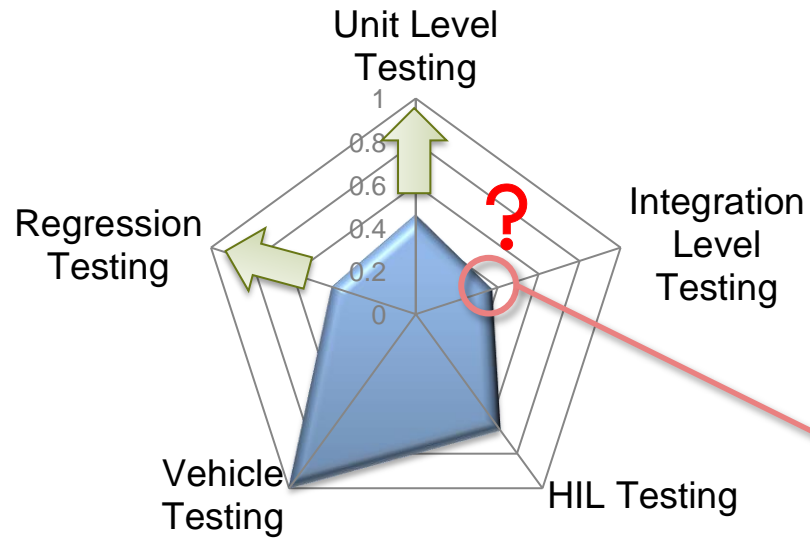
# Verification and Validation Pillar Status and Trends



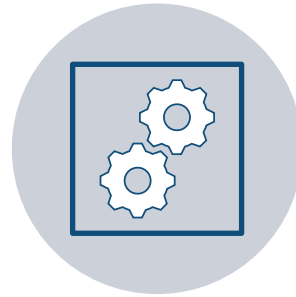
- Positive trend:
  - Increasing rigor for Unit Testing and Regression Testing
  - Cause:
    - Increase system complexity
    - Standards such as ISO 26262 and ASPICE
  - Expectation is a maturity increase due to complex application – AV/ADAS/AD
- Puzzle: What about Integration Level Testing?

# Verification and Validation Pillar Status and Trends

## Verification and Validation Pillar



\*Average maturity rating V&V pillar normalized against Vehicle Testing



Why is **integration level testing** not being leveraged?





# Why Is Integration Level Testing Important?

- Safety standard
  - Detail unit level verification
  - Ensure unit working together through integration testing
  
- Requirement validation
  - Top-down design approach
  - Ensuring requirement is correct

## The “digital” car

Fighter planes	:	20 M lines of code
High end cars	:	100 M lines of code
Electronics SW	:	< 20% of car cost in 2005
Electronics SW	:	Almost 40% today
Innovation Spend	:	90% in Electronic Systems
Spend on innovation	:	US\$ 105 B in 2014, 4% of revenue
SOC market	:	USD 31B, 7.5% growth



OEMs increasing Model choices but decreasing number of Vehicle Architectures

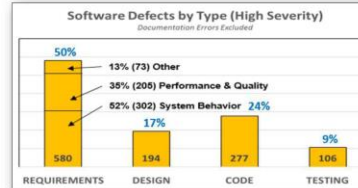
TATA ELXSI

A “digital” car contains **100 M** lines of code in car

## THE SOURCE OF SOFTWARE ISSUES



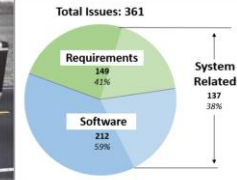
“The IV&V Program documented 10,677 software artifact defects on 22 NASA projects in 2007...The IV&V Program analyzed the defects sorting them by severity and type of defect.”



**50%** of defects are from requirement

## THE SOURCE OF SOFTWARE ISSUES

### 2016MY Pro Trailer Backup Assist



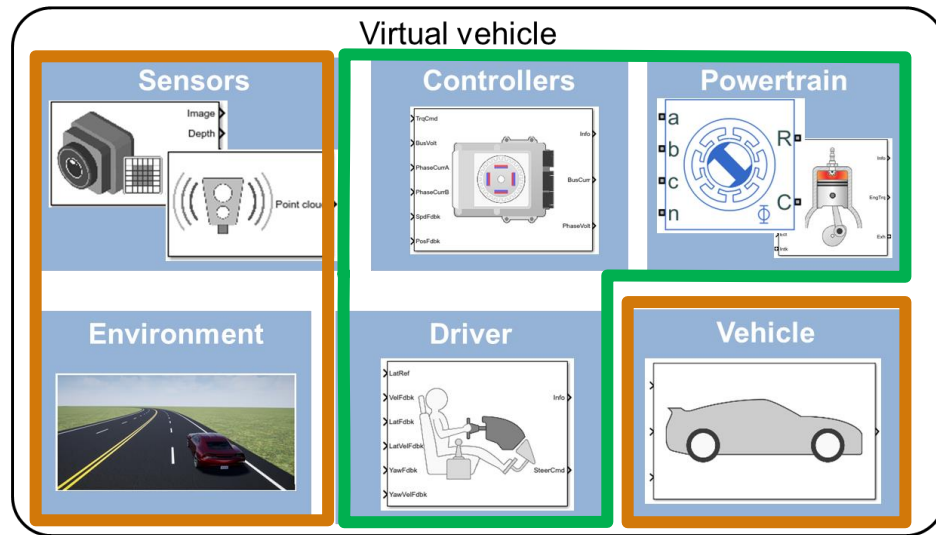
41% of Software issues found during development of the 2016MY F-150 Pro Trailer Backup Assist Feature were related to the requirements, and 38% of all software issues were system-related.

**38%** of software issues were system-related

## Key Components for Building Integration Level Model

- Automatic integration of unit level models
- Stronger integration with Software/Model repository
- Out of box solution for Plant Model
- Simulation in scalability
- Matching software construct such as scheduler
- ....etc.

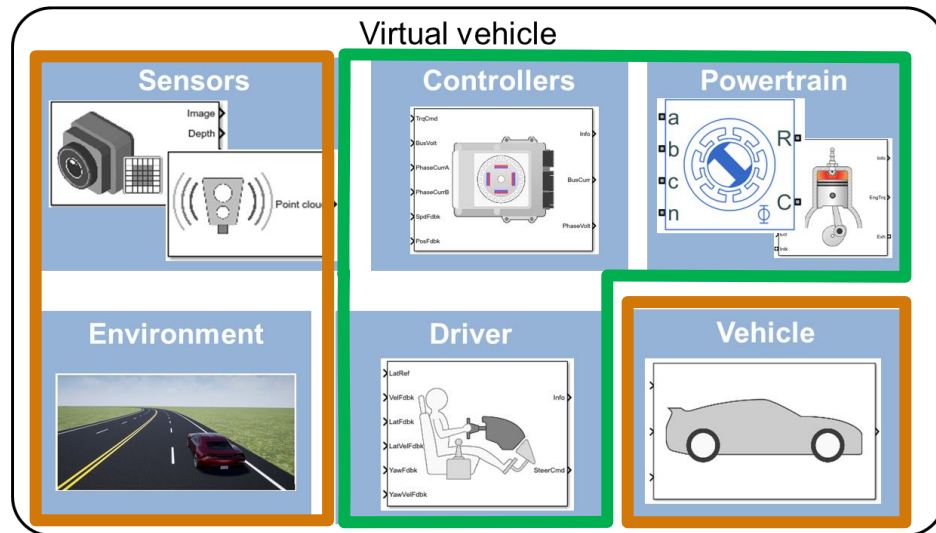
# Development for Integration Level Testing



R2016b release – Powertrain Blockset

R2018a release – Vehicle Dynamic Blockset

# Enable Integration Level Testing



## MathWorks Consulting Services

- 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  
 ...



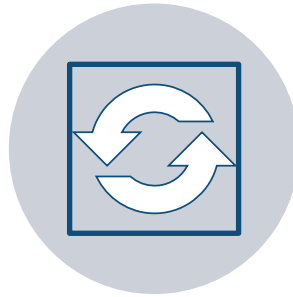
- Provide expert-level guidance
- Automate workflows
- Develop custom UI's

**Out-of-the-box capability**

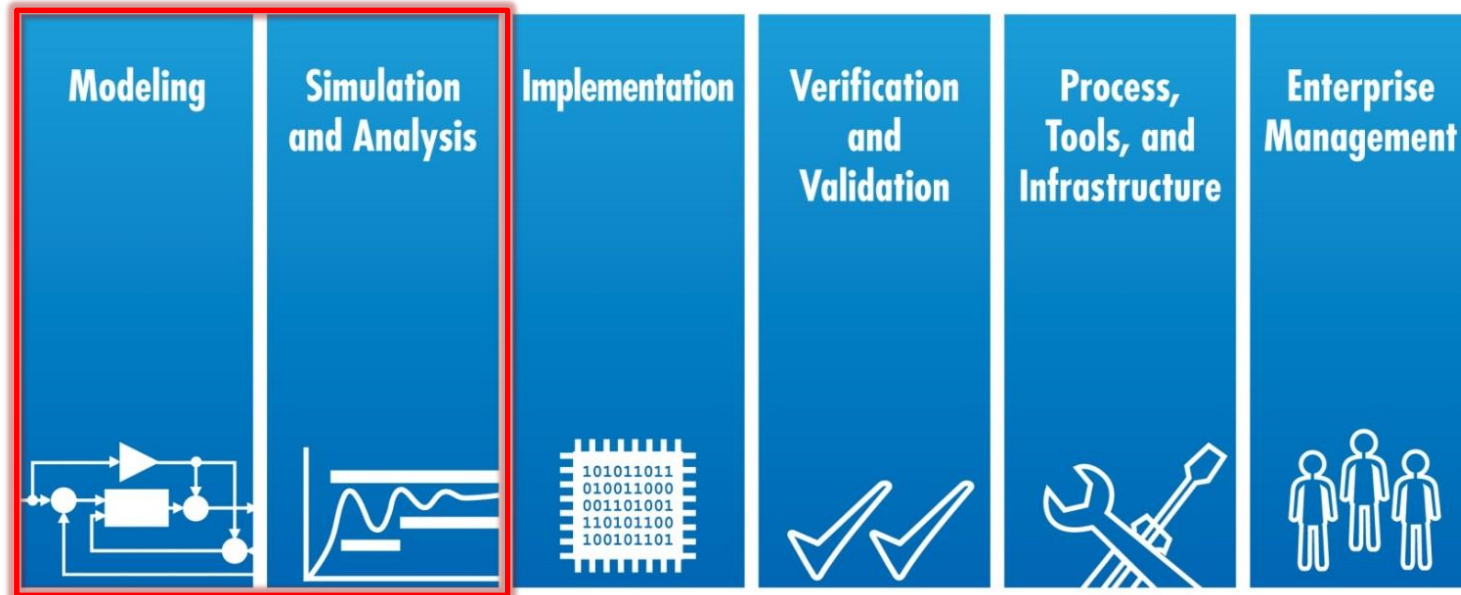
**Custom virtual vehicle solution**

R2016b release – Powertrain Blockset

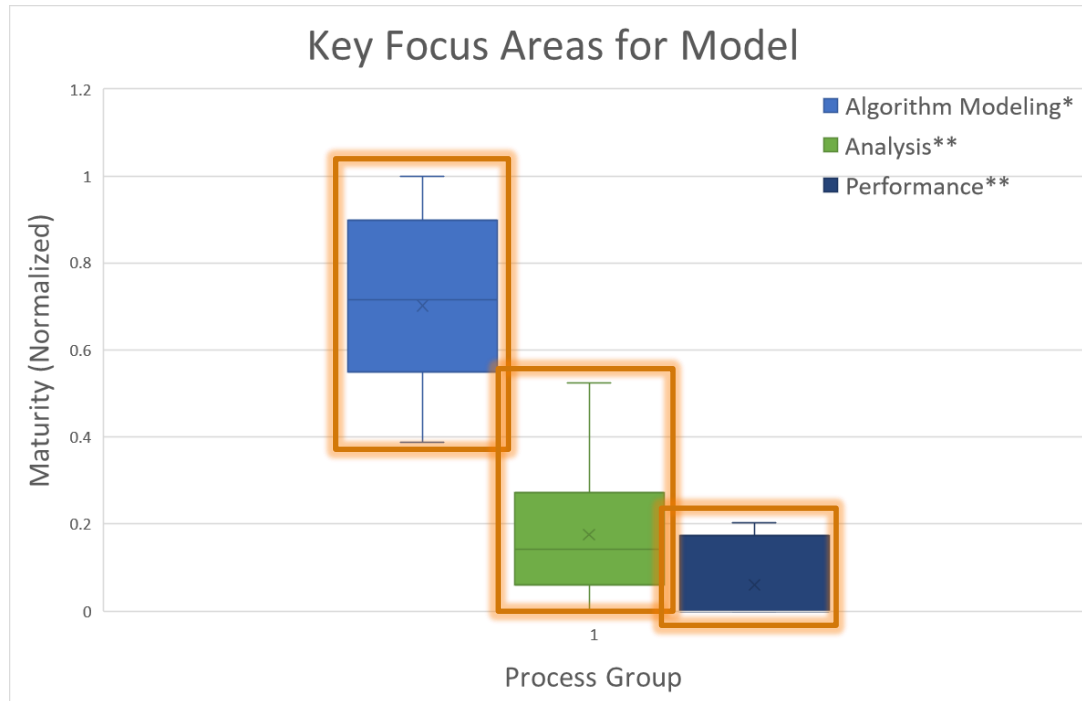
R2018a release – Vehicle Dynamic Blockset



Are models leveraged for **validation** and **analysis** beyond code generation? How are they being maintained?



# Model Usage



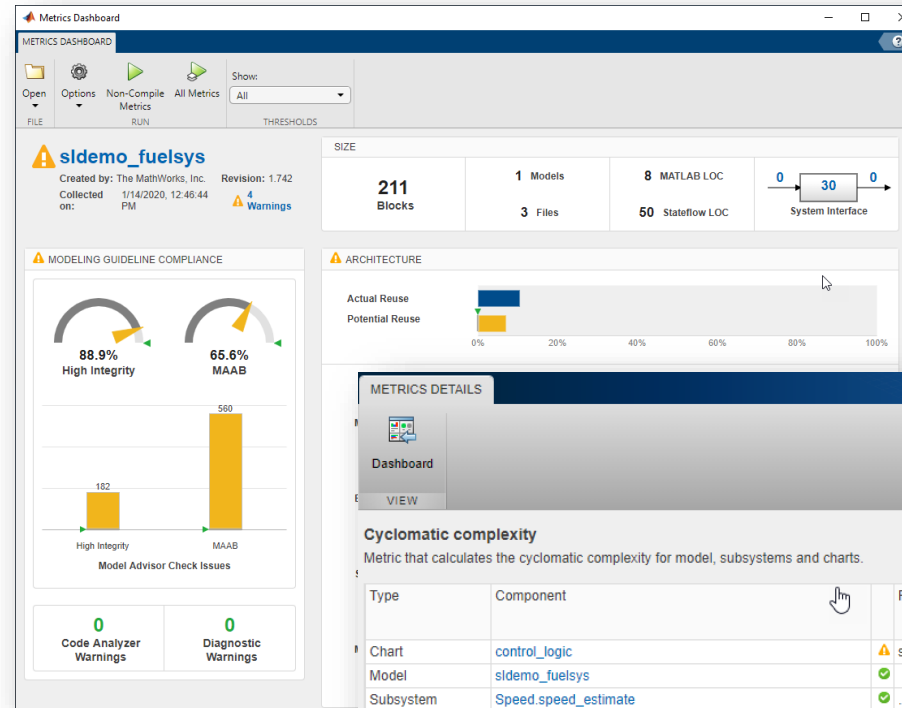
\* Part of the Model Pillar

\*\* Part of the Simulation Pillar

- Most companies develop model for algorithm development.
- Leading companies also develop models for
  - Requirement validation
  - Performance optimization
- Leading companies maintain models and
  - Gather metrics and reports
  - Optimize simulation speed
- Usage of models is an area that exhibits wide differences between leaders and laggards

# Model Lifecycle Management Through Metrics

- Out-of-the-Box
  - Model Metric Dashboard



**METRICS DETAILS**

Dashboard

**Cyclomatic complexity**

Metric that calculates the cyclomatic complexity for model, subsystems and charts.

Type	Component	Path	Qty	Model Complexity	Model Complexity (incl. Descendants)
Chart	control_logic	sldemo_fuelsys/fuel_rate_control/control_logic	1	51	56
Model	sldemo_fuelsys		1	5	80
Subsystem	Speed speed_estimate	.../s/fuel_rate_control/control_logic/Speed speed_estimate	1	3	3
MATLAB function	f(theta)	.../Engine Gas Dynamics/Throttle & Manifold/Throttle/f(theta)	1	2	2
Subsystem	Throttle	..._fuelsys/Engine Gas Dynamics/Throttle & Manifold/Throttle	1	2	6
Subsystem	Throttle & Manifold	sldemo_fuelsys/Engine Gas Dynamics/Throttle & Manifold	1	2	10
Subsystem	switchable_compensation	...elsys/fuel_rate_control/fuel_calc/switchable_compensation	1	2	2
MATLAB function	EGO Sensor	.../Engine Gas Dynamics/Mixing & Combustion/EGO Sensor	1	2	2
MATLAB function	MATLAB Function	...mics/Throttle & Manifold/Intake Manifold/MATLAB Function	1	2	2
MATLAB function	g(pratio)	.../Engine Gas Dynamics/Throttle & Manifold/Throttle/g(pratio)	1	2	2
Subsystem	feedforward_fuel_rate	...o_fuelsys/fuel_rate_control/fuel_calc/feedforward_fuel_rate	1	2	2
Subsystem	airflow_calc	sldemo_fuelsys/fuel_rate_control/airflow_calc	1	1	1
Subsystem	Throttle throttle_estimate	...ys/fuel_rate_control/control_logic/Throttle throttle_estimate	1	1	1
Subsystem	Pressure map_estimate	.../s/fuel_rate_control/control_logic/Pressure map_estimate	1	1	1
Subsystem	Mixing & Combustion	sldemo_fuelsys/Engine Gas Dynamics/Mixing & Combustion	1	1	3
Subsystem	fuel_rate_control	sldemo_fuelsys/fuel_rate_control	1	1	62
Chart	Fueling_Mode.Running.Low_Emissions.Normal	...ntrol_logic/Fueling_Mode.Running.Low_Emissions.Normal	1	0	0
Subsystem	rich_mode	...rate_control/fuel_calc/switchable_compensation/rich_mode	1	0	0

# Model Lifecycle Management Through Metrics

- Out-of-the-Box
  - Model Metric Dashboard
- Industry partnership
  - Model Quality Objectives



**1.10 Authors**

This document was prepared by the MQO working group, representing various OEMs and suppliers.

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Patrick Munier	MathWorks
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Alain Spiewek	Delphi
Yves Touzeau	Renault

Table 2 below provides the list of Model Quality Requirement (MQR) applicable to achieve the quality objective of each type of design models. The details of each MQR are specified in section 3.2.

MQR ID	MQR Title	MQO-1	MQO-2	MQO-3	MQO-4
MQR-01	Model layout	M	M	M	M
MQR-02	Model comments	M	M	M	M
MQR-03	Model links to requirements	M	M	M	M
MQR-04	Model testing against requirements	M	R	M	M
MQR-05	Model compliance with modeling standard		M	M	M
MQR-06	Model data		M	M	M
MQR-07	Model size			M	M
MQR-08	Model complexity			M	M
MQR-09	Model coverage			M	M
MQR-10	Model robustness			M	M
MQR-11	Generated code testing against requirements			R	M
MQR-12	Generated code compliance with coding standard			R	M
MQR-13	Generated code coverage			R	M
MQR-14	Generated code robustness			R	M
MQR-15	Generated code execution time				M

**3.2.7 Model size**

**MQR-07** Model size

**Description**

- The model shall have less than 500 elements including:
  - The number of Simulink blocks
  - The number of MATLAB executable lines of codes
  - The number of Stateflow transition, states, and connections
  - The number of truth tables decision

**Recommendation level**

MQO-1	MQO-2	MQO-3	MQO-4
		Mandatory	Mandatory

**Notes**

The model reference block only counts as one element.  
The company standard utility function (e.g. Simulink library block, MATLAB function file) only counts as one element.  
Please refer to MathWorks guidance on large-scale modeling in Simulink documentation.

**References /Examples of techniques**

**Rationale**

Very large models are more difficult to merge and are more likely to be modified by several users at the same time.  
Smaller models are more likely to be reusable and easily configurable.  
Generated code of very large models cannot be incrementally tested.

**Last update**

1.0

---

**3.2.8 Model complexity**

**MQR-08** Model complexity

**Description**

The model and its subsystems, Stateflow charts, and MATLAB functions shall have a local cyclomatic complexity lower or equal to '30'.

**Recommendation level**

MQO-1	MQO-2	MQO-3	MQO-4
		Mandatory	Mandatory

**Notes**

Local complexity is the cyclomatic complexity for objects at their hierarchical level. Aggregated cyclomatic complexity is the cyclomatic complexity of an object and its descendants.  
The threshold of 30 for local cyclomatic complexity is a recommendation and can be adapted on a project basis. The number 30 for cyclomatic complexity has been derived from the MIS [7] code metric and adapted to Model-Based Design.

**Examples of techniques**

Cyclomatic complexity is a measure of the structural complexity of a model. It approximates the McCabe complexity measure for code generated from the model. The McCabe complexity measure is slightly higher on the generated code due to error checks that the model coverage analysis does not consider.  
To compute the cyclomatic complexity of an object, such as a block, chart, or state, model coverage uses the following formula:

$$c = \sum_i (n_i - 1)$$

*N* is the number of decision points that the object represents and *n* is the number of outcomes for the only decision point. The tool adds one to the complexity number for atomic subsystems and Stateflow charts.

**Rationale**

Cyclomatic complexity is a leading testability metric. Test harness can be created for simulation at model, subsystem, chart, and MATLAB function level.

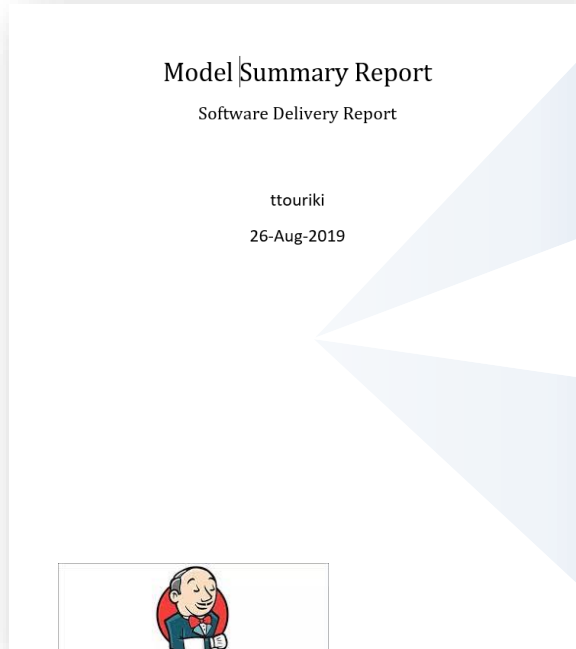
**Last update**

1.0



# Model Lifecycle Management Through Metrics

- Out-of-the-Box
  - Model Metric Dashboard
- Partnering with industry
  - Model Quality Objectives
- Customized solution - Consulting
  - Custom report with integration to Jenkins
  - Embedded pass/fail thresholds



Model:	XXXX
Version:	1.223
Date:	26-Aug-2019
Page:	2

**1 Contents**

- 1. Model Dependency View ..... 4
- 1.1 Model Dependency View Detail ..... 4
- 2. Integration Test Metrics ..... 5
- 2.1 Integration Test Metrics Info ..... 5
- 2.1.1 Integration Test Metrics Table ..... 5
- 3. Unit Test Metrics ..... 6
- 3.1 Unit Test Metrics Info ..... 6
- 3.1.1 Unit Test Metrics Table ..... 6
- 3.1.2 Unit Test Coverage Metrics Table ..... 6
- 4. Code Metrics ..... 7
- 4.1 Code Metrics Info ..... 7
- 4.1.1 Code Metrics Info Table ..... 7
- 4.2 MISRA:C 2012 ..... 7
- 5. Model Metrics ..... 8
- 5.1 Model Metrics Info ..... 8
- 6. Model Specific Metrics ..... 10
- 6.1 Model Specific Metrics Info ..... 10

**2 Figures**  
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**3 Tables**  
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Version:	1.223
Date:	26-Aug-2019
Page:	7

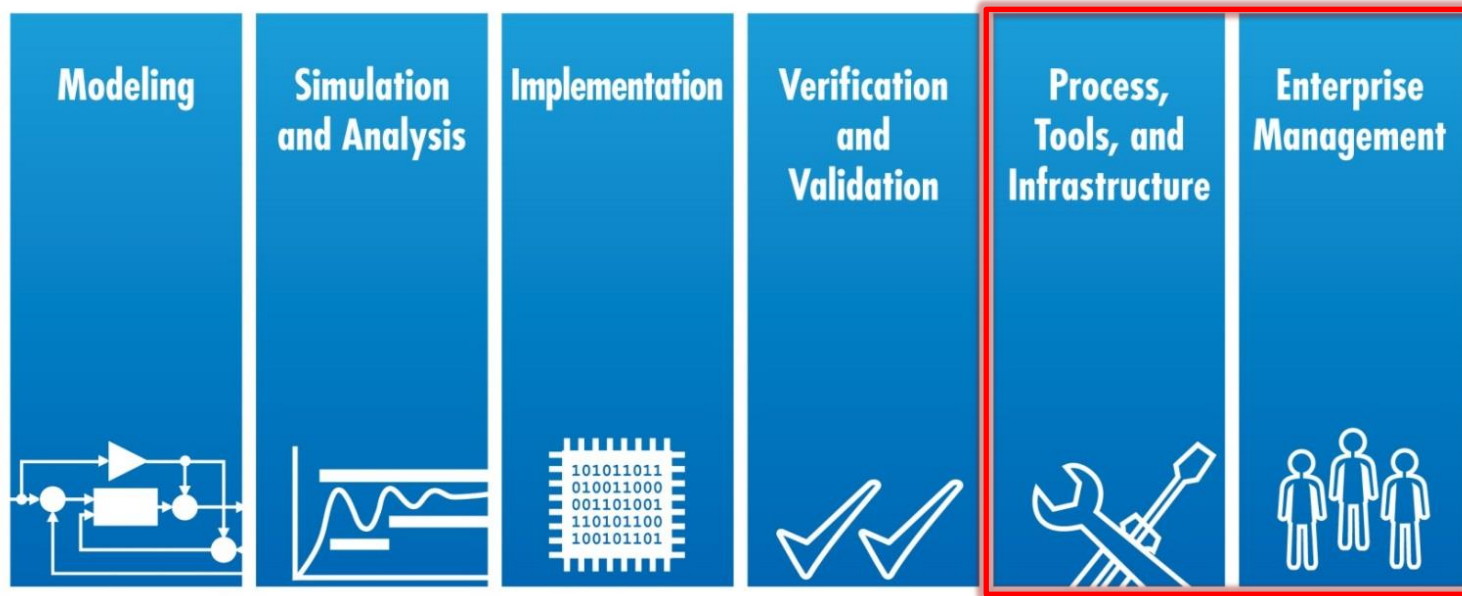
**5. Model Metrics**

**5.1 Model Metrics Info**

Metric	Details	Value
CloneDetection	AAAI_XDXFun_CasFun1	1
CloneDetection	AAAI_XDXFun_CasFun3	1
CloneDetection	XXXX/DummyOSTask/Triggered Subsystem1 XXXX/DummyOSTask/Triggered Subsystem4 XXXX/DummyOSTask/Triggered Subsystem9 XXXX/DummyOSTask/Triggered Subsystem3 XXXX/DummyOSTask/Triggered Subsystem7 XXXX/DummyOSTask/Triggered Subsystem6 XXXX/DummyOSTask/Triggered Subsystem8 XXXX/DummyOSTask/Triggered Subsystem14 XXXX/DummyOSTask/Triggered Subsystem13 XXXX/DummyOSTask/Triggered Subsystem5 XXXX/DummyOSTask/Triggered Subsystem12 XXXX/DummyOSTask/Triggered Subsystem2 XXXX/DummyOSTask/Triggered Subsystem11 XXXX/DummyOSTask/Triggered Subsystem10 XXXX/DummyOSTask/Triggered Subsystem4	15
CyclomaticComplexity	XXXX	47
DescriptiveBlockNames	XXXX	38
DiagnosticWarningsCount	XXXX	2
Inputs	-	5
Outputs	-	5
FileCount	XXXX	8
IOCount	XXXX	10

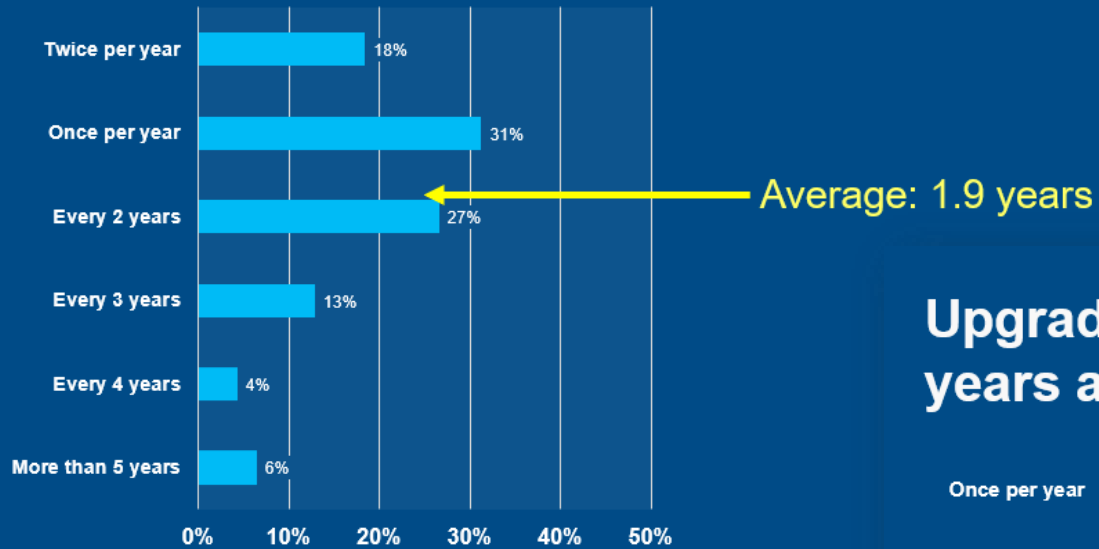


Are processes and tools being **evolved** to meet the application needs?

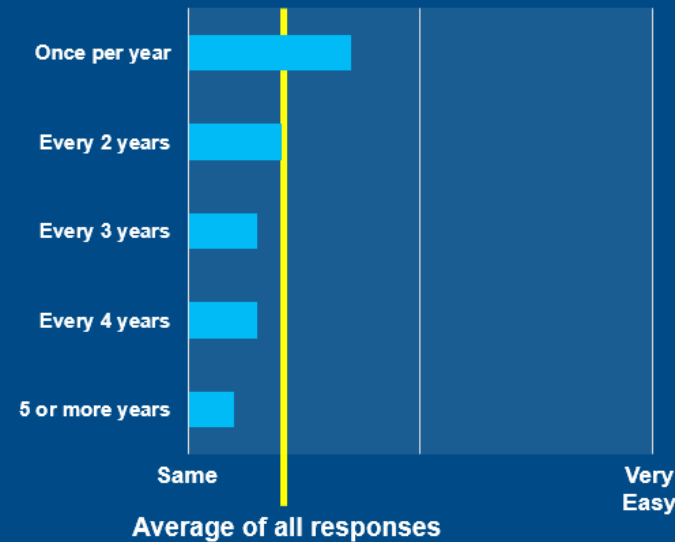


# Version Upgrade – MathWorks Advisory Board (MAB) Survey

## MATLAB Upgrade frequency

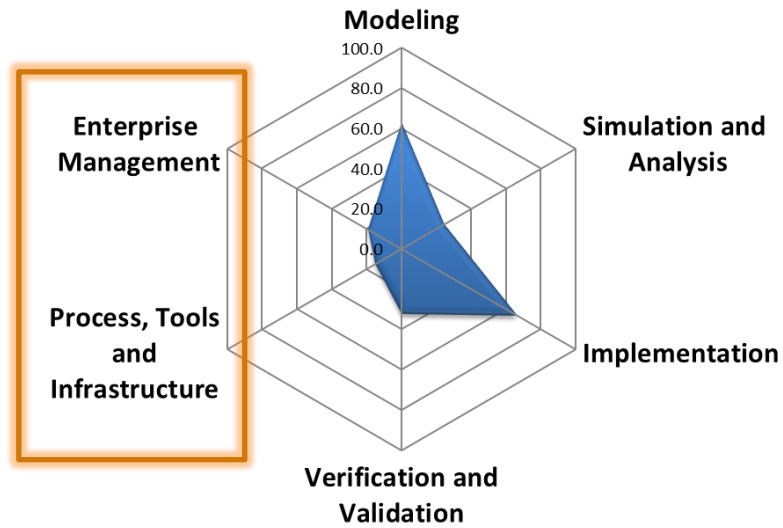


## Upgrade process compared to five years ago



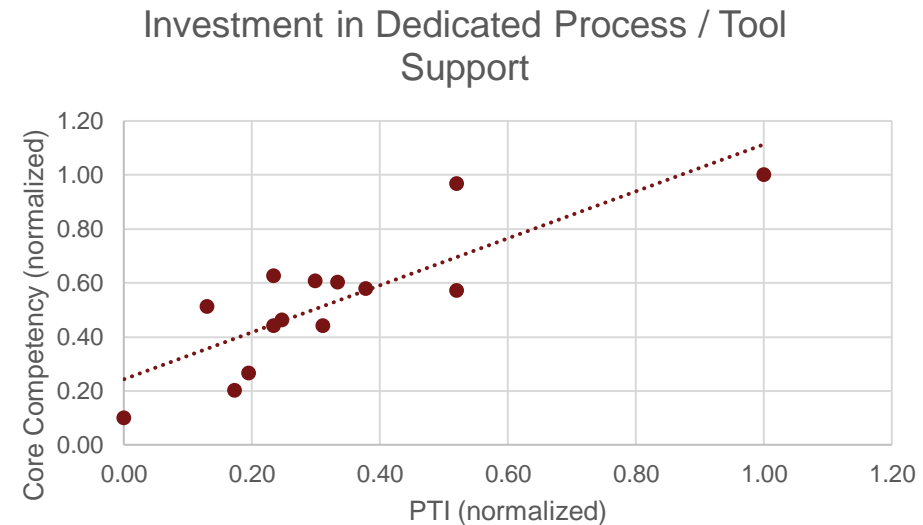
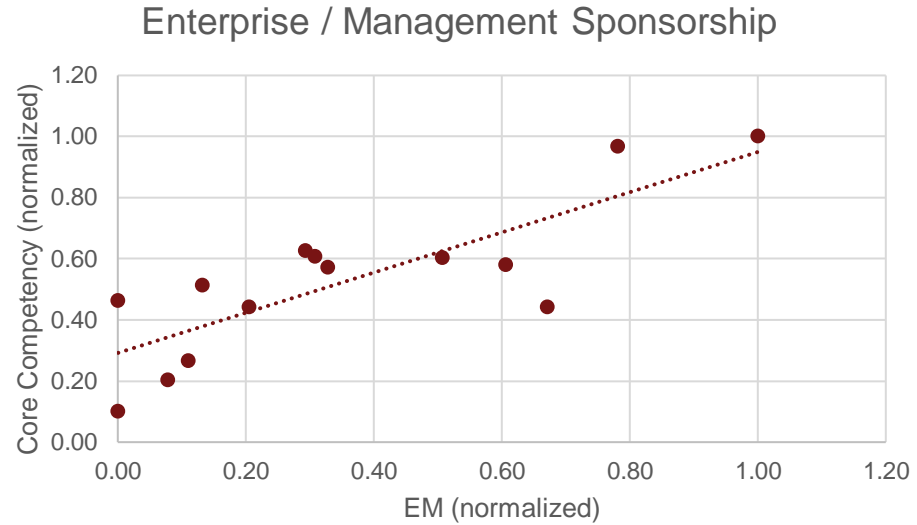
Gets **harder** the longer you wait

# Effect of Supporting Competency



EM → Management Sponsorship

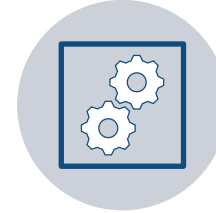
PTI → Process/Tool Investment



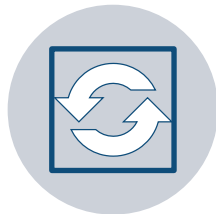
# Summary



Improve Verification and Validation process to meet safety standards



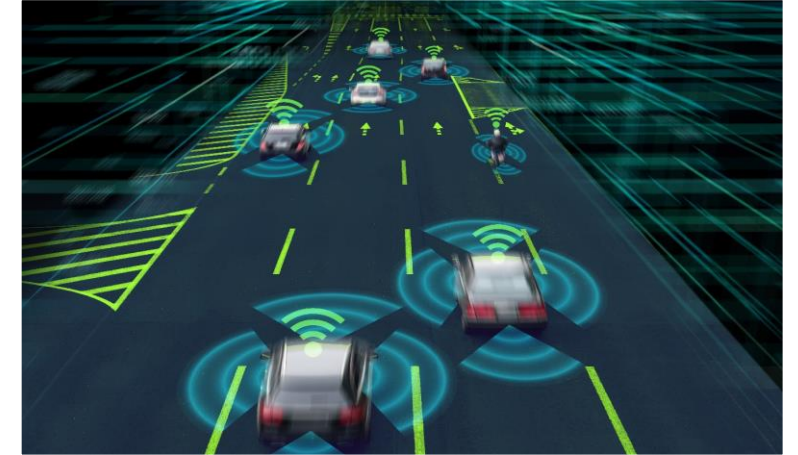
Leverage Integration Level Model for requirement validation



Ensure models are used for analysis and are maintained using leading indicator metrics



Invest in processes and tools



# Thank You for Your Attention!



## ■ Poll Questions

- Are you interested in learning more about Process Assessment?
  - Yes
  - No
- I am interested in Process Assessment for this reason
  - Gap analysis against standard such ISO 26262, ASPICE, ...etc.
  - Optimize existing process
  - Establish a new process
  - None

Please contact Govind Malleichervu / John Lee for questions:



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