Meeting ISO26262 using a Robust and Efficient Workflow

Nukul Sehgal
Application Engineer
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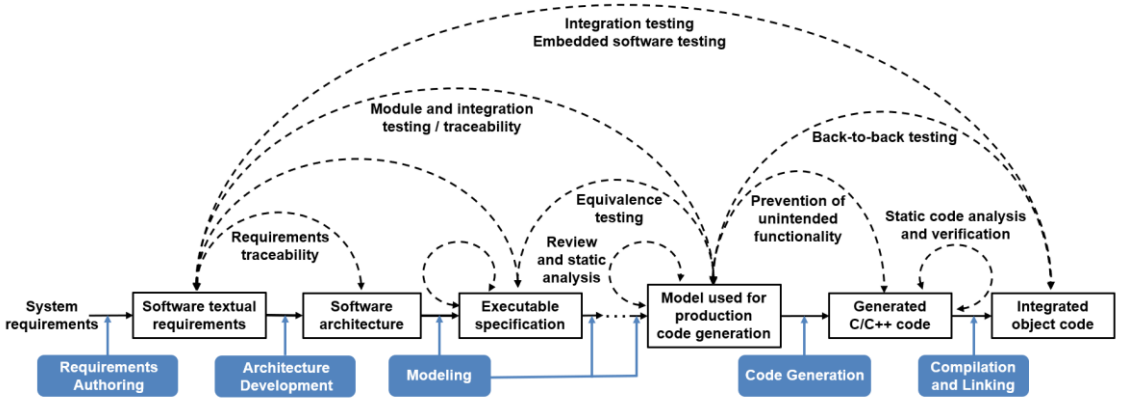
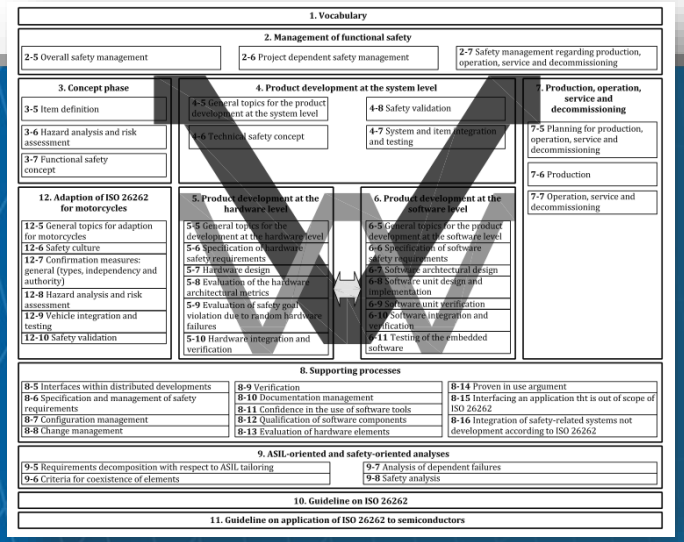
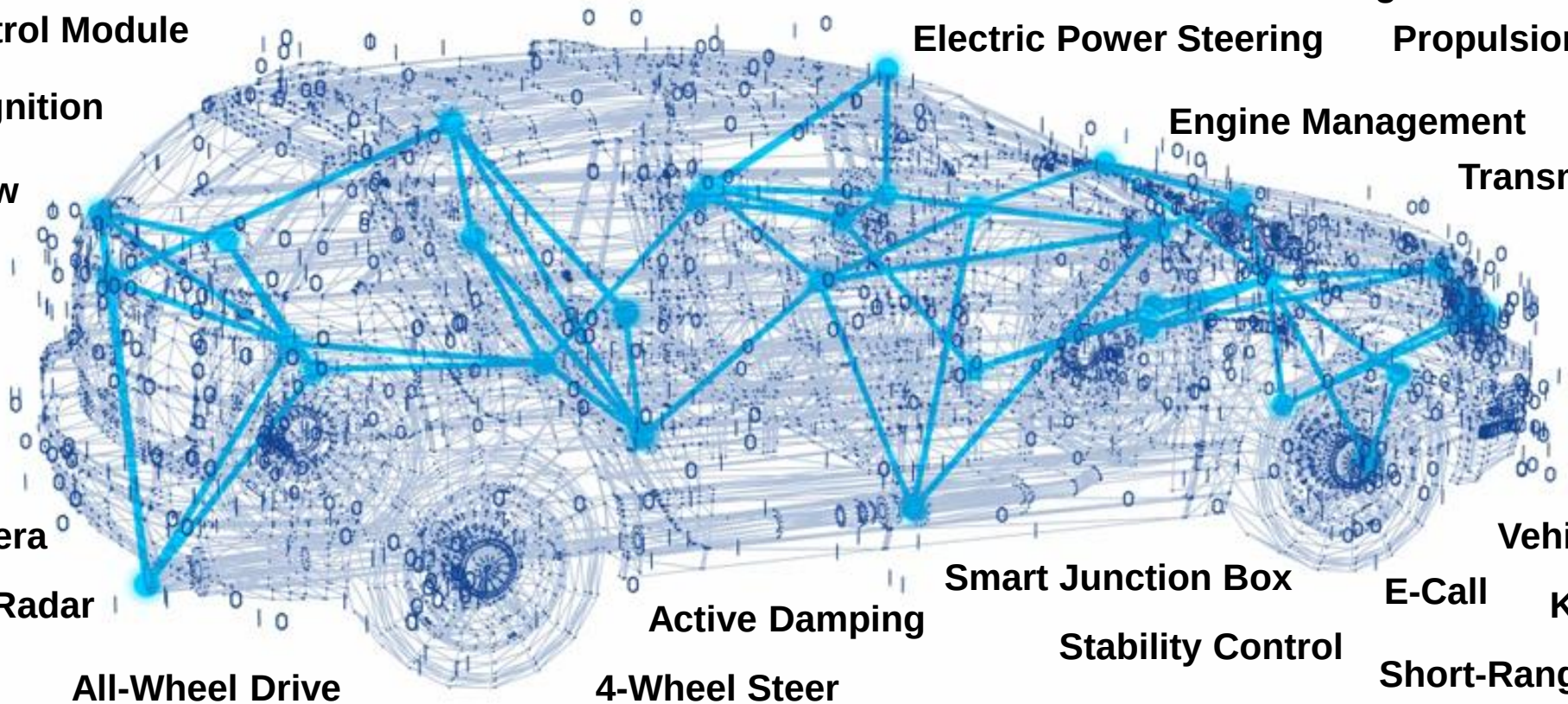


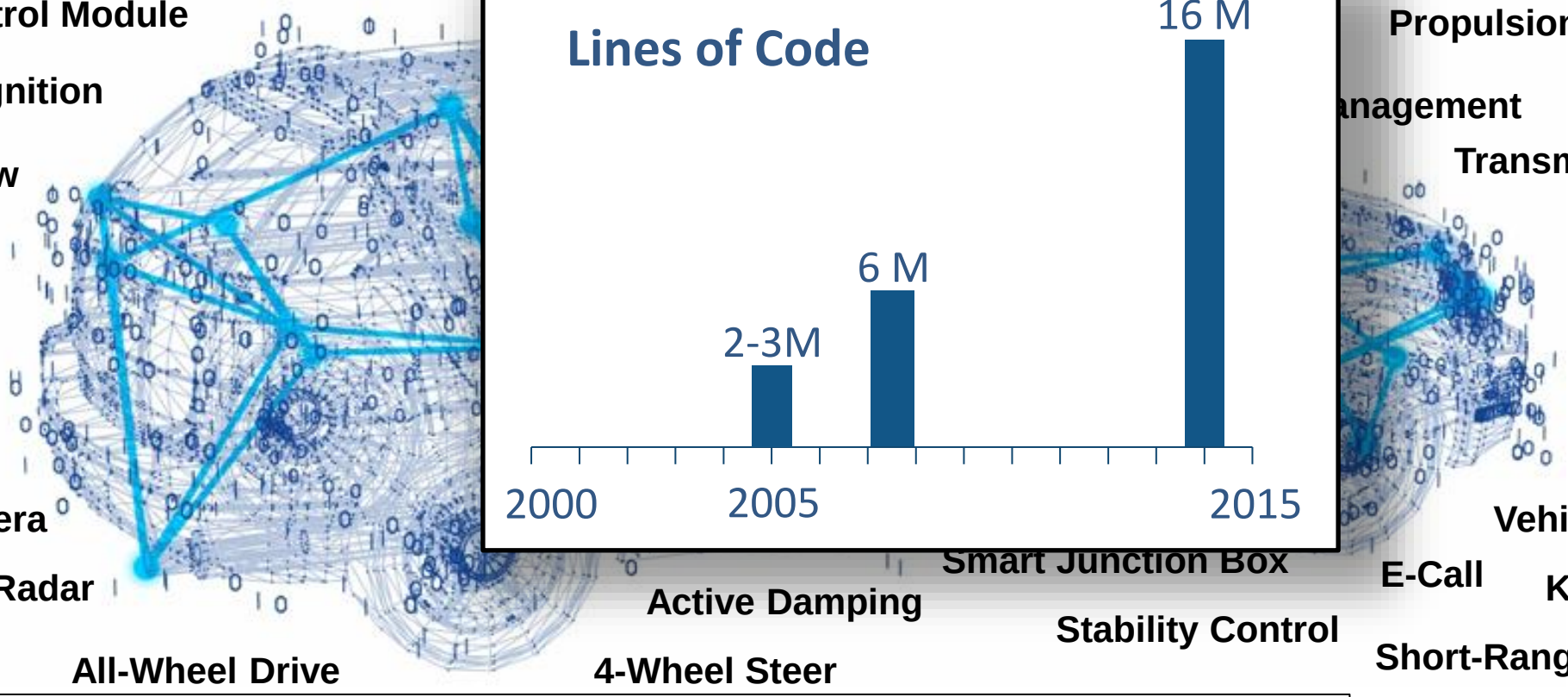


Growing Complexity of Controls in the Automotive industry



Source of graphic: http://360.here.com/2013/11/28/putting-firmly-drivers-seat/

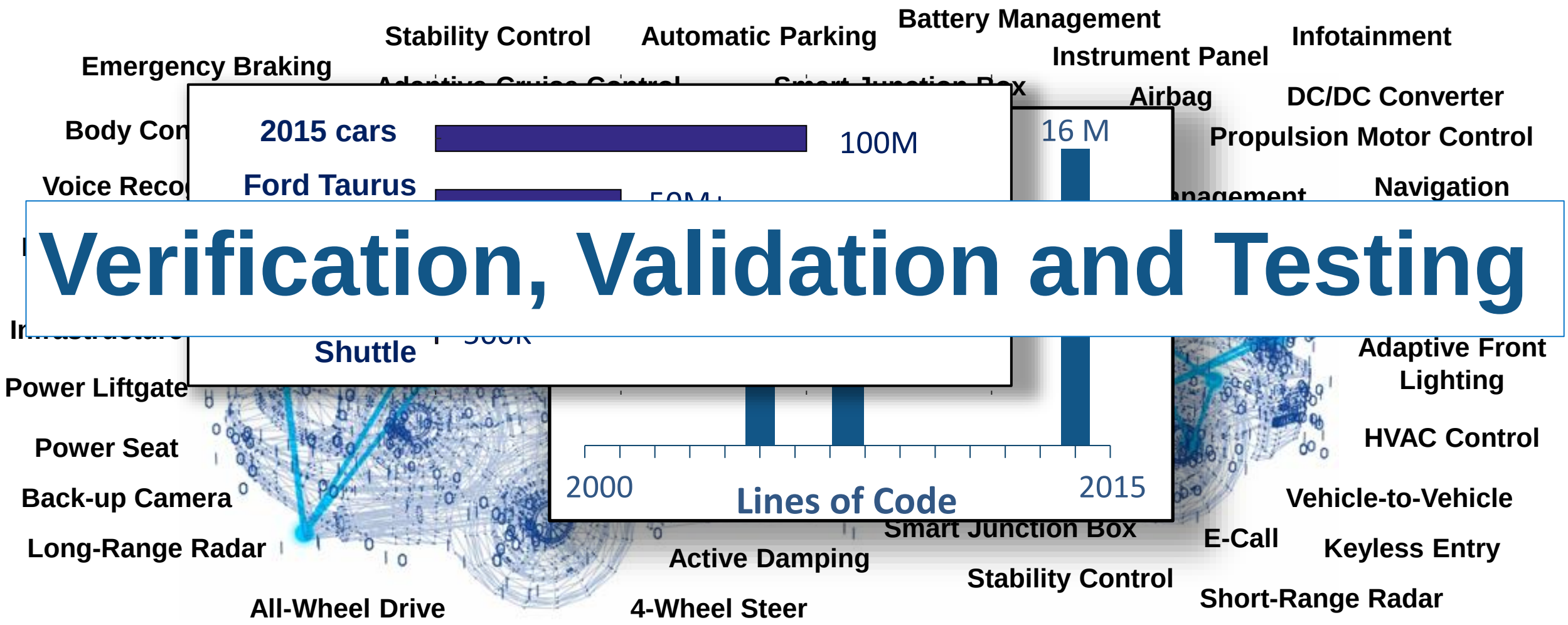
Growing Complexity of Controls in the Automotive industry



Emergency Braking
Stability Control
Automatic Parking
Battery Management
Infotainment
Instrument Panel
Adaptive Cruise Control
Smart Junction Box
Airbag
DC/DC Converter
Body Control Module
Propulsion Motor Control
Voice Recognition
Navigation
Power Window
Transmission Control
Vehicle-to-Infrastructure
Forward Camera
Power Liftgate
Adaptive Front Lighting
Power Seat
HVAC Control
Back-up Camera
Vehicle-to-Vehicle
Long-Range Radar
Smart Junction Box
E-Call
Keyless Entry
Active Damping
Stability Control
Short-Range Radar
All-Wheel Drive
4-Wheel Steer

Siemens, "Ford Motor Company Case Study," Siemens PLM Software, 2014
McKendrick, J. "Cars become 'datacenters on wheels', carmakers become software companies," ZDJNet, 2013

Growing Complexity of Controls in the Automotive industry

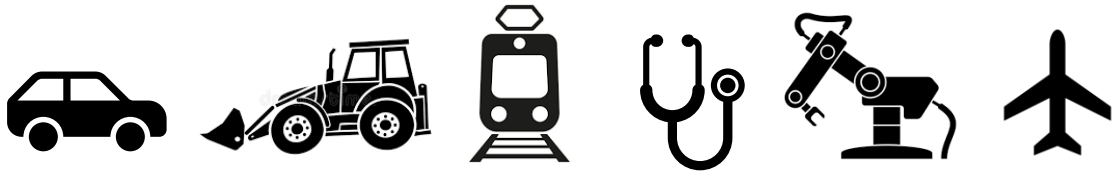


Verification, Validation and Testing

Source:
https://interact.gsa.gov/sites/default/files/J3061%20JP%20presentation.pdf

Verification, Validation and Testing

Safety Critical System



Best Practices and Guidelines

Functional Safety Standard

Functional Safety Certification

IEC 61508 - ISO 26262

IEC 61508 is a functional safety standard for Industrial Automation

Umbrella for industry-specific adaptions:

- ISO 26262 - Automotive / Motorcycle  
- ISO 25119 - Agriculture and Forestry 
- EN 50128 - Rail 
- IEC 62304 - Medical 
- IEC 61511 - Process Control 

Supported by
IEC Certification Kit

ISO 26262: 2018 Structure

ISO 26262-1	Vocabulary
ISO 26262-2	Management of functional safety
ISO 26262-3	Concept phase
ISO 26262-4	Product development: system level
ISO 26262-5	Product development: hardware level
ISO 26262-6	Product development: software level
ISO 26262-7	Production, operation, service and decommissioning
ISO 26262-8	Supporting processes
ISO 26262-9	ASIL-oriented and safety-oriented analyses
ISO 26262-10	Guidelines on ISO 26262
ISO 26262-11	Guidelines on application of ISO 26262 to semiconductors
ISO 26262-12	Adaptation of ISO 26262 for motorcycles

ISO 26262: Model-Based Design in Part 6 and Part 8

ISO 26262-1	Vocabulary
ISO 26262-2	Management of functional safety
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Model-Based Design
- Development
- Verification & Validation
- Code generation

Tool classification and qualification

ISO 26262: Model-Based Design in Part 4

ISO 26262-1	Vocabulary
ISO 26262-2	Management of functional safety
ISO 26262-3	Concept phase
ISO 26262-4	Product development: system level
ISO 26262-5	Product development: hardware level
ISO 26262-6	Product development: software level
ISO 26262-7	Production, operation, service and decommissioning
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ISO 26262-10	Guidelines on ISO 26262
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ISO 26262-12	Adaptation of ISO 26262 for motorcycles

Model-Based Systems Engineering

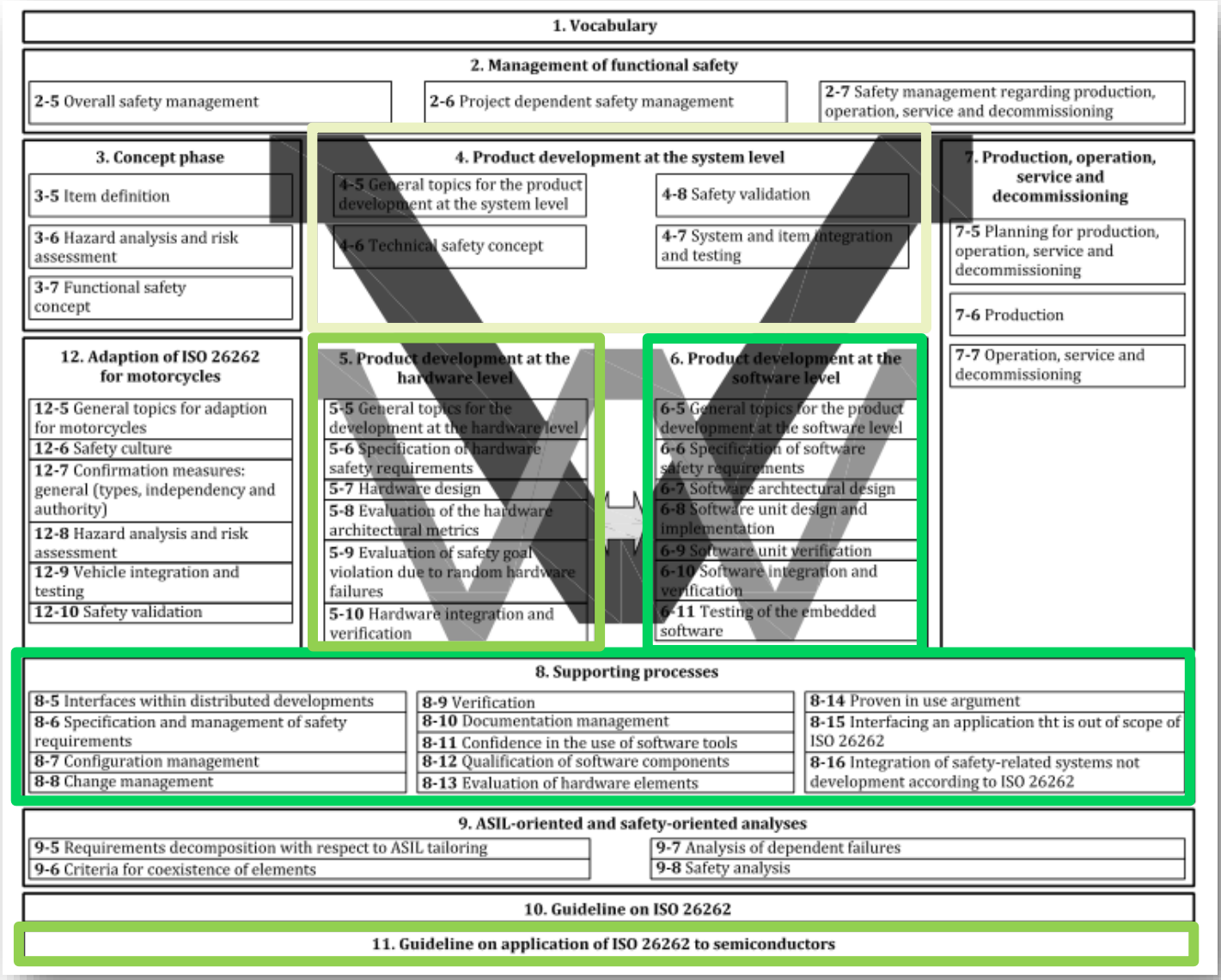
Model-Based Design
- Development
- Verification & Validation
- Code generation

Tool classification and qualification

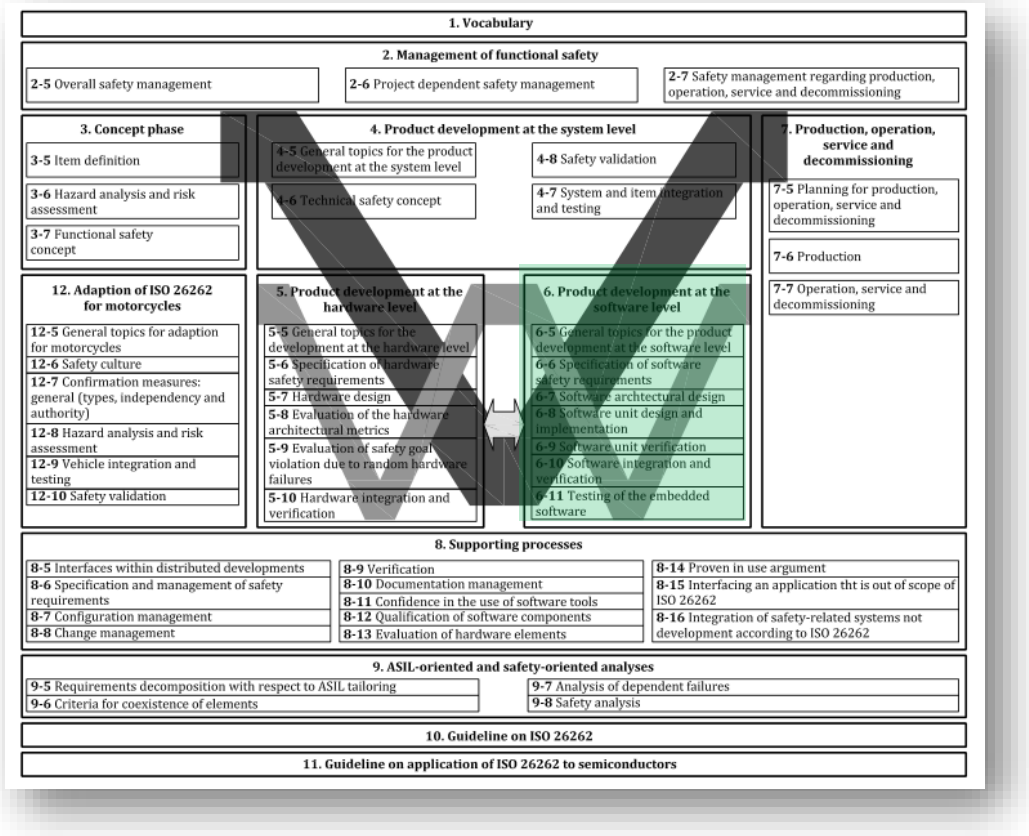
ISO 26262: Model-Based Design in Part 5 and Part 11

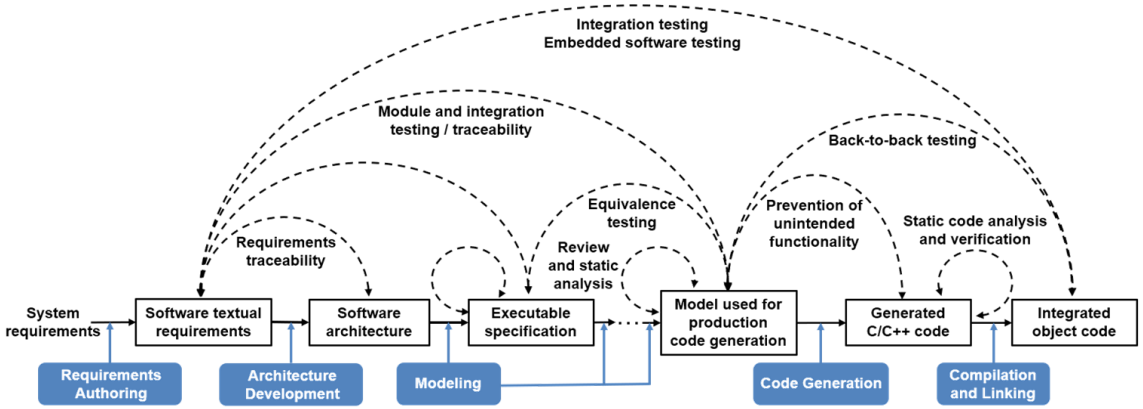
ISO 26262-1	Vocabulary	
ISO 26262-2	Management of functional safety	
ISO 26262-3	Concept phase	
ISO 26262-4	Product development: system level	Model-Based Systems Engineering
ISO 26262-5	Product development: hardware level	Design of hardware system
ISO 26262-6	Product development: software level	Model-Based Design ❖ Development ❖ Verification & Validation ❖ Code generation
ISO 26262-7	Production, operation, service and decommissioning	
ISO 26262-8	Supporting processes	Tool classification and qualification
ISO 26262-9	ASIL-oriented and safety-oriented analyses	
ISO 26262-10	Guidelines on ISO 26262	
ISO 26262-11	Guidelines on application of ISO 26262 to semiconductors	HDL Code generation
ISO 26262-12	Adaptation of ISO 26262 for motorcycles	

ISO 26262 Overview



ISO 26262 Part 6 – IEC Certification Kit and Reference Workflow



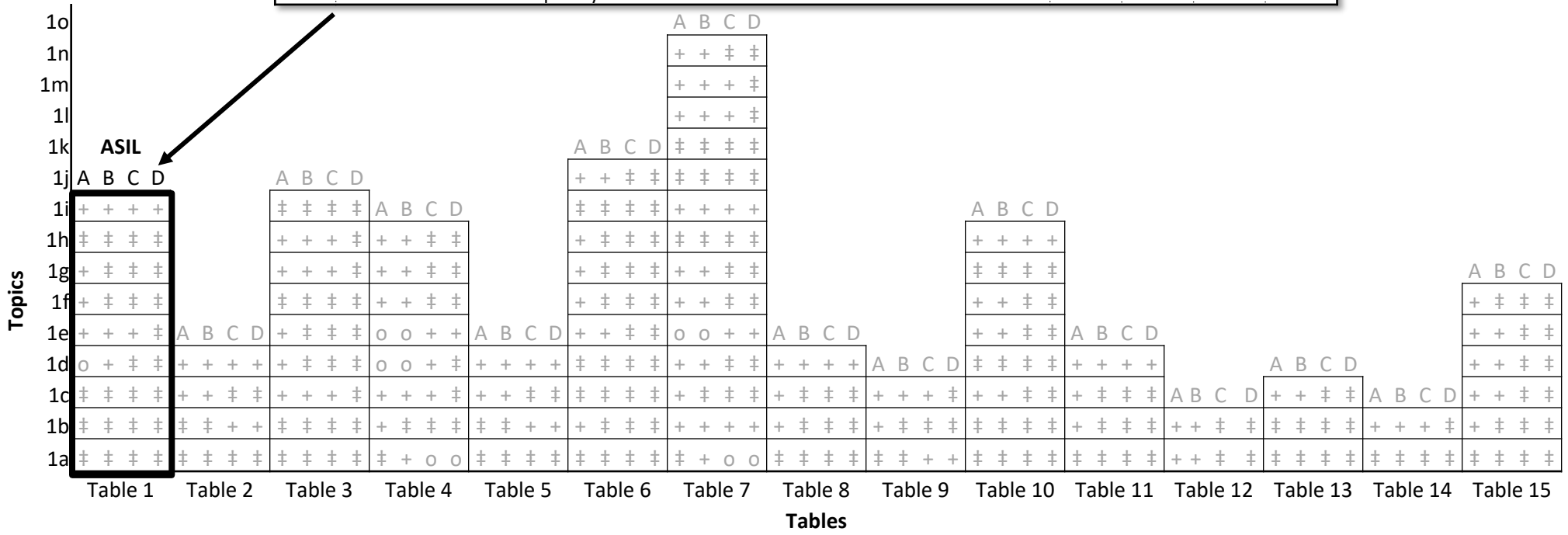


ISO 26262 Part 6

‡ Highly recommended
\+ Recommended
o No recommendation

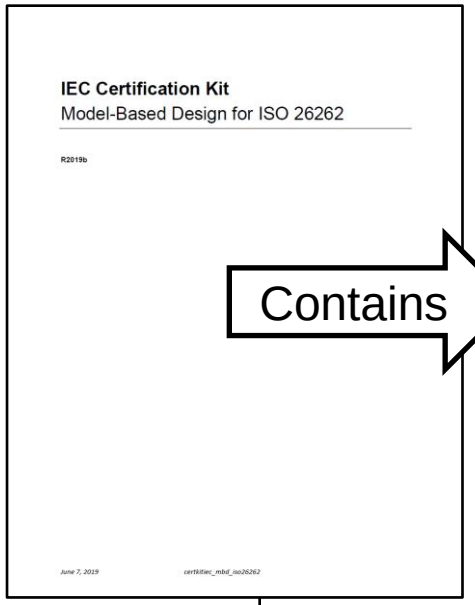
Table 1 – Topics To Be Covered By Modeling and Coding Guidelines

Topics		ASIL A	ASIL B	ASIL C	ASIL D
1i	Concurrency aspects	+	+	+	+
1h	Use of naming conventions	‡	‡	‡	‡
1g	Use of style guides	+	‡	‡	‡
1f	Use of unambiguous graphical representation	+	‡	‡	‡
1e	Use of well-trusted design principles	+	+	+	‡
1d	Use of defensive implementation techniques	+	+	‡	‡
1c	Enforcement of strong typing	‡	‡	‡	‡
1b	Use of language subsets	‡	‡	‡	‡
1a	Enforcement of low complexity	‡	‡	‡	‡



ISO 26262 Part 6 – IEC Certification Kit Documentation

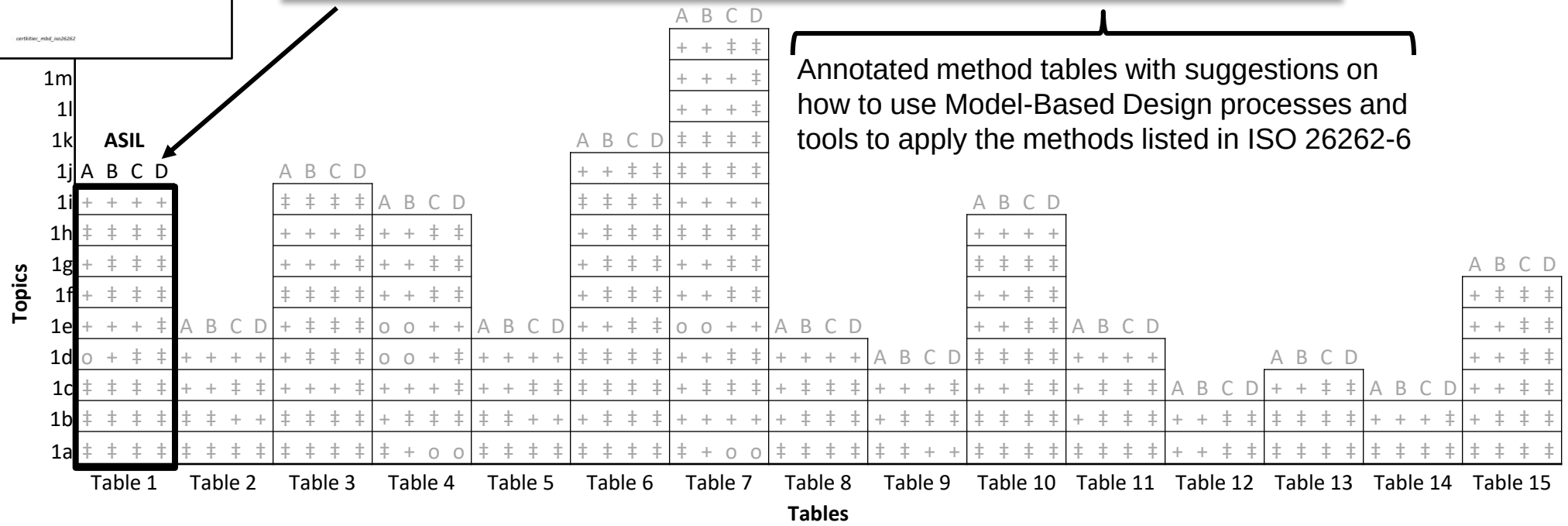
‡ Highly recommended
\+ Recommended
o No recommendation



Contains

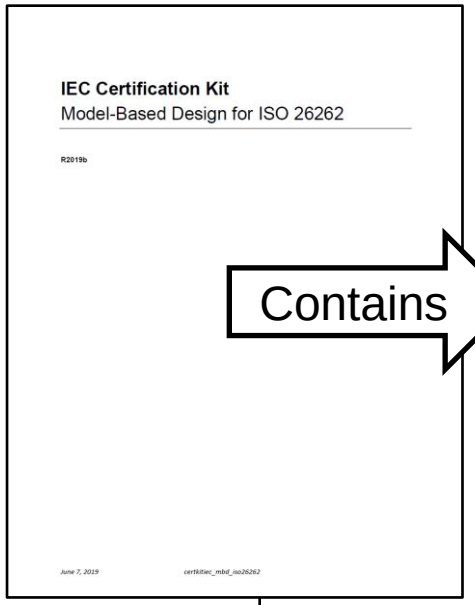
Table 1 – Topics to be Covered by Modelling and Coding Guidelines

Topics		ASIL A	ASIL B	ASIL C	ASIL D	Applicable Model-Based Design Tools and Processes	Comments
1a	Enforcement of low complexity	++	++	++	++	Simulink® – Modeling Guidelines Simulink Check Polyspace® Bug Finder™ and Polyspace® Bug Finder™ Server™ – Coding Rules Checks	The High Integrity System Modeling Guidelines and the MathWorks® Automotive Advisory Board — Control Algorithm Modeling Guidelines as well as applicable coding standards (MISRA C®:2004, MISRA C:2012, MISRA C:2012 (Amendment 1:2016) MISRA® C++, or JSF®++) can be used to address topics listed in this table. The guideline subset used for a project should address a combination of topics applicable for the ASIL under
1b	Use of language subsets	++	++	++	++		
1c	Enforcement of strong typing	++	++	++	++		
1d	Use of defensive implementation techniques	+	+	++	++		



Annotated method tables with suggestions on how to use Model-Based Design processes and tools to apply the methods listed in ISO 26262-6

ISO 26262 Part 6 – IEC Certification Kit Documentation



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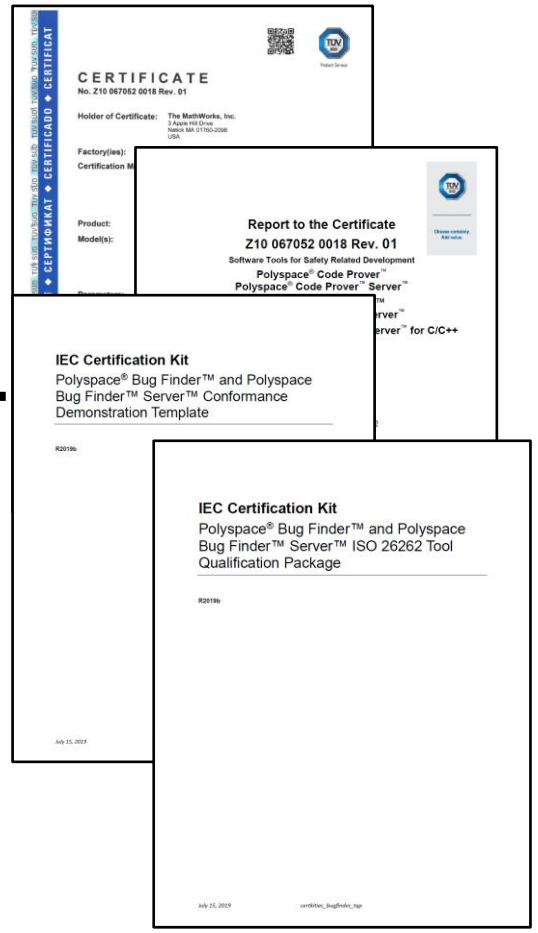
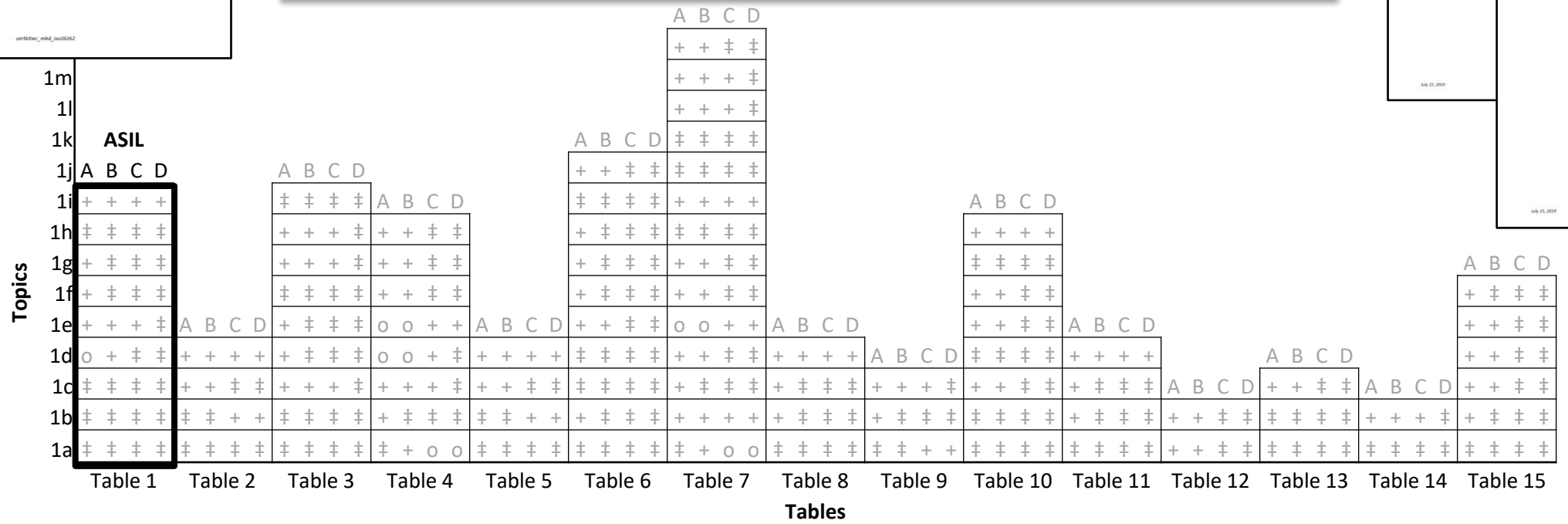
1b	Use of language subsets	++	++	++	++		
1c	Enforcement of strong typing	++	++	++	++		
1d	Use of defensive implementation techniques	+	+	++	++		

+





ISO 26262 - Reference Workflow

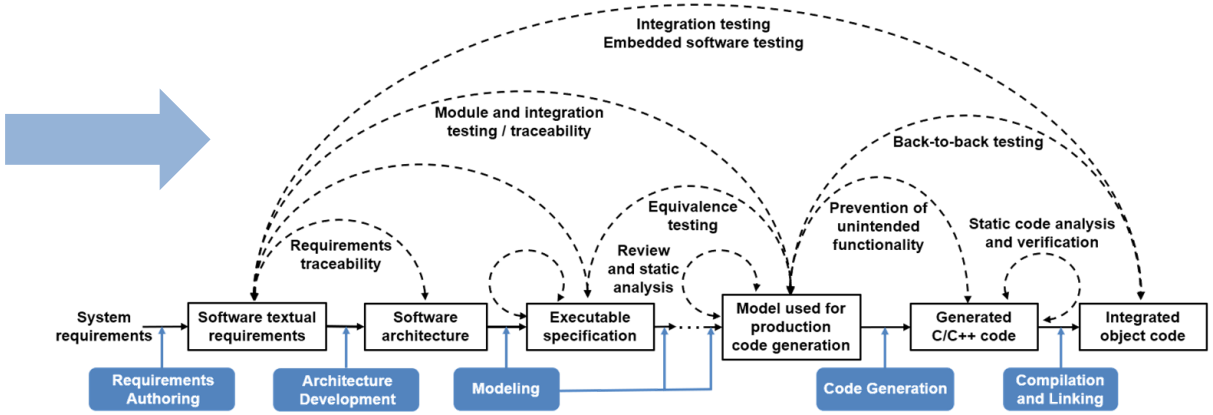
Table 1 — Topics to be Covered by Modelling and Coding Guidelines

Table 8 — Methods for Deriving Test Cases for Software Unit Testing

Table 9 — Structural Coverage Metrics at the Software Unit Level

Table 11 — Methods for Deriving Test Cases for Software Integration Testing

Methods		ASIL A	ASIL B	ASIL C	ASIL D	Applicable Model-Based Design Tools and Processes	Comments
1a	Analysis of requirements	++	++	++	++	Simulink Test	Simulink Test can be used to establish bidirectional links between textual requirements and test cases.
						Simulink Requirements	Simulink Requirements can be used to analyze the coverage or requirements by tests.
						Simulink Signal Builder block	The Signal Builder block can be used to create requirements-based model tests. Requirements pane in the Signal Builder block can be used to link tests with textual requirements.
1b	Generation and analysis of equivalence classes	+	++	++	++	Simulink Design Verifier – Test case generation	The analysis of equivalence classes can be based on the interfaces of the model. Automatic test case generation in combination with Test Objective blocks can be used to generate test cases and test sequences for given equivalence classes.
1c	Analysis of boundary values	+	++	++	++	Simulink Design Verifier – Test case generation	The analysis of boundary values can be based on the interfaces of the model. Automatic test case generation in combination with Test Objective blocks can be used to generate test cases and test sequences for given boundary values.
1d	Error guessing based on knowledge or experience	+	+	+	+		



ISO 26262 Part 6: 2018

Simulink and Stateflow as Suitable for Software Architecture, Design and as basis for Code Generation

Table 5 — Notations for software unit design

Notations		ASIL			
		A	B	C	D
1a	Natural language[a]	++	++	++	++
1b	Informal notations	++	++	+	+
1c	Semi-formal notations[b]	+	+	++	++
1d	Formal notations	+	+	+	+

[a] Natural language can complement the use of notations for example where some topics are more readily expressed in natural language or provide an explanation and rationale for decisions captured in the notations.

EXAMPLE To avoid possible ambiguity of natural language when designing complex elements, a combination of an activity diagram with natural language can be used.

[b] Semi-formal notations can include pseudocode or modelling with UML®, SysML®, Simulink® or Stateflow®.

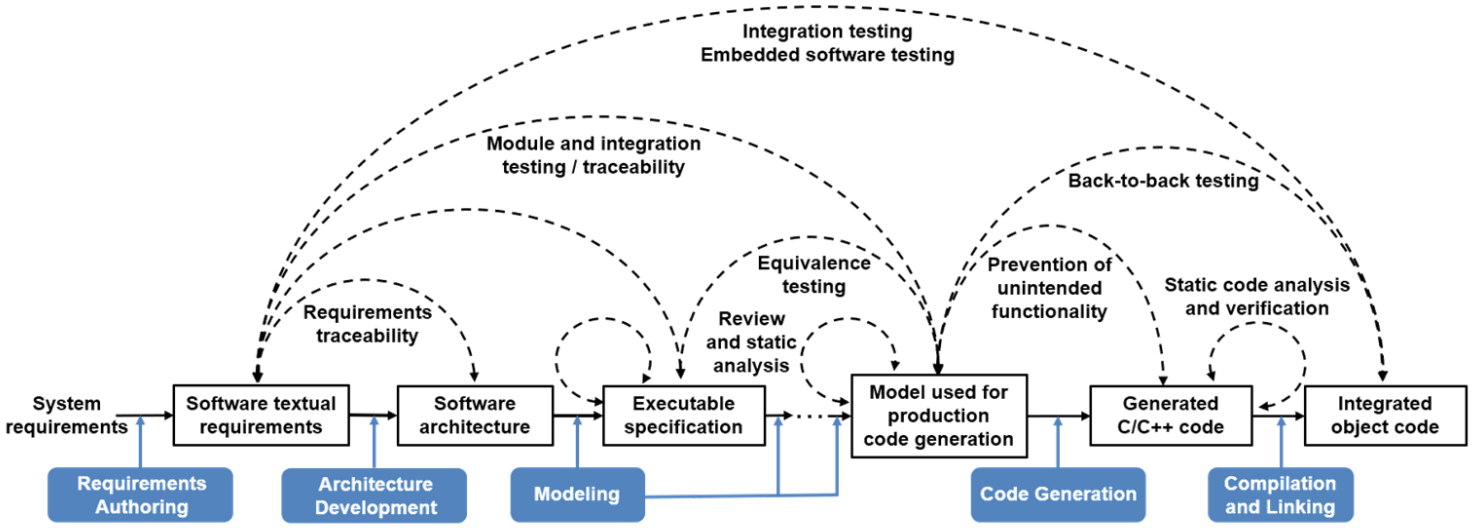
NOTE UML®, SysML®, Simulink® and Stateflow® are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of these products.

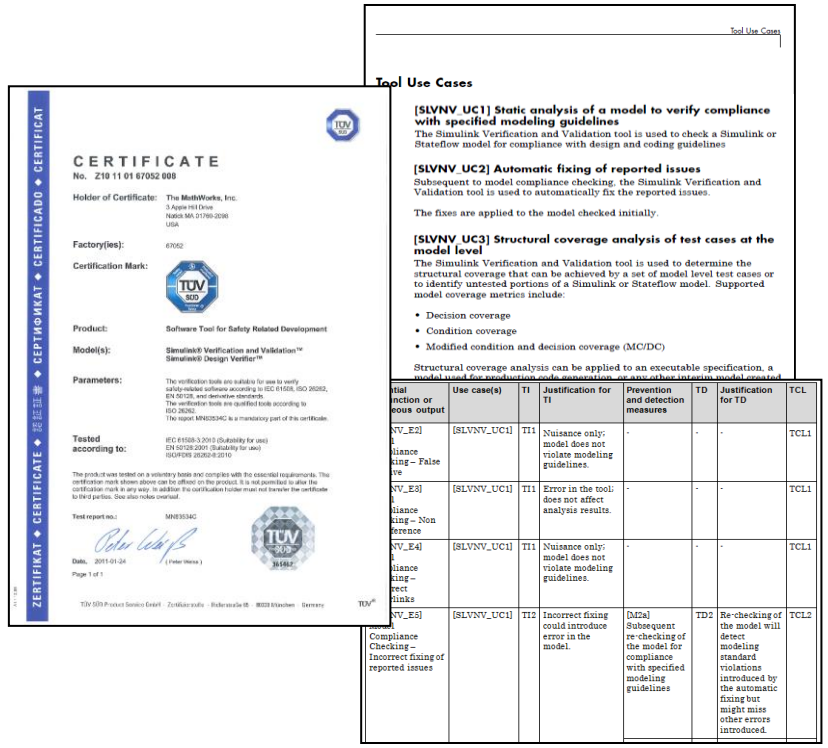
NOTE In the case of model-based development with automatic code generation, the methods for representing the software unit design are applied to the model which serves as the basis for the code generation.

Table 2 Software Architecture Design Notations has similar suitability wording for use of Simulink and Stateflow

Structure of the IEC Certification Kit

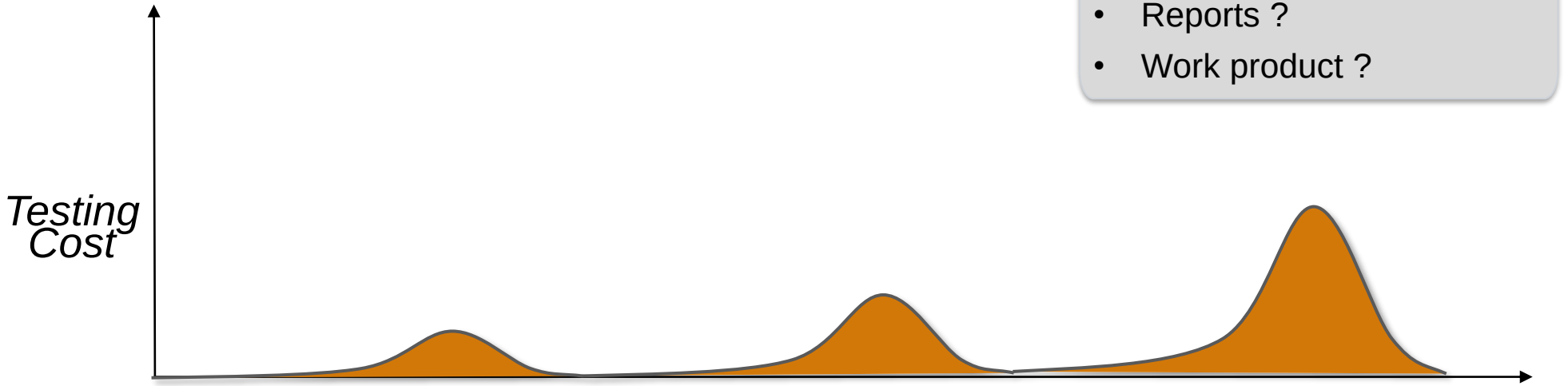
1. **Reference Workflow** for systematic **Verification and Validation (V&V)** of models and generated code
2. **Tool certification/qualification** accomplished by tool test suites, vendor audits, and reference workflow

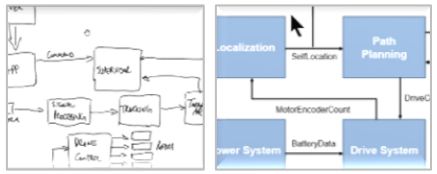




Traditional Development Process

- Formal documentation ?
- Reports ?
- Work product ?





System requirements → Software textual requirements → Software architecture → Design specification → C/C++ Hand Coding → Integrated object code

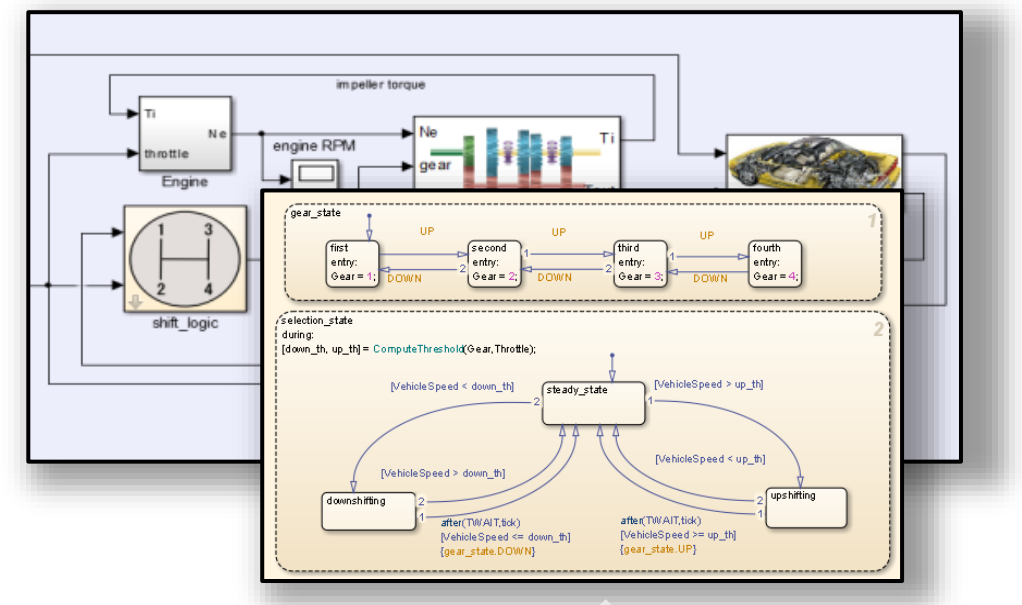
Requirements Authoring

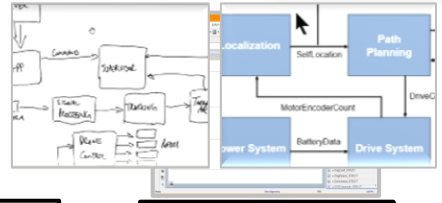
Architecture Development

Manual Coding

Compilation and Linking

Model-Based Design Workflow





System requirements → Software textual requirements → Software architecture → Executable specification → Model used for production code generation → Generated C/C++ code → Integrated object code

Requirements Authoring

Architecture Development

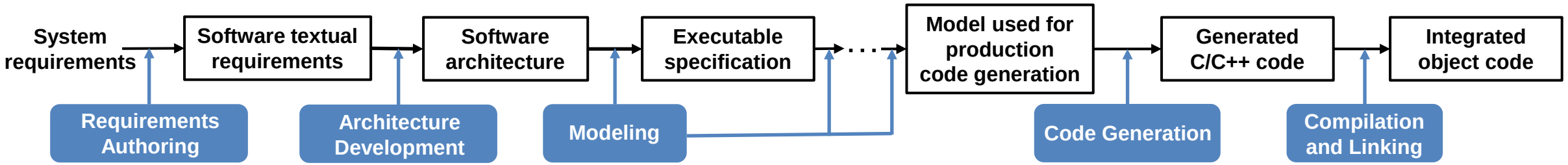
Modeling

Code Generation

Compilation and Linking

Model-Based Design Workflow

get the complete confidence in your design



Complete Model-Based Design Workflow

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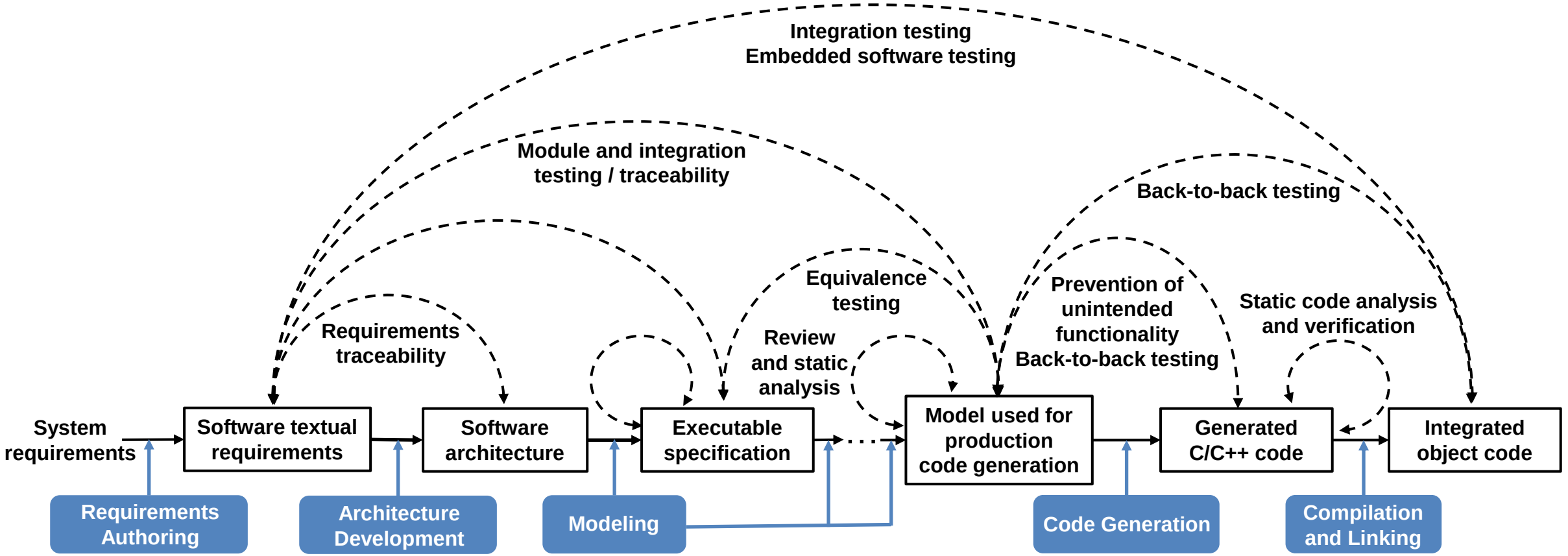
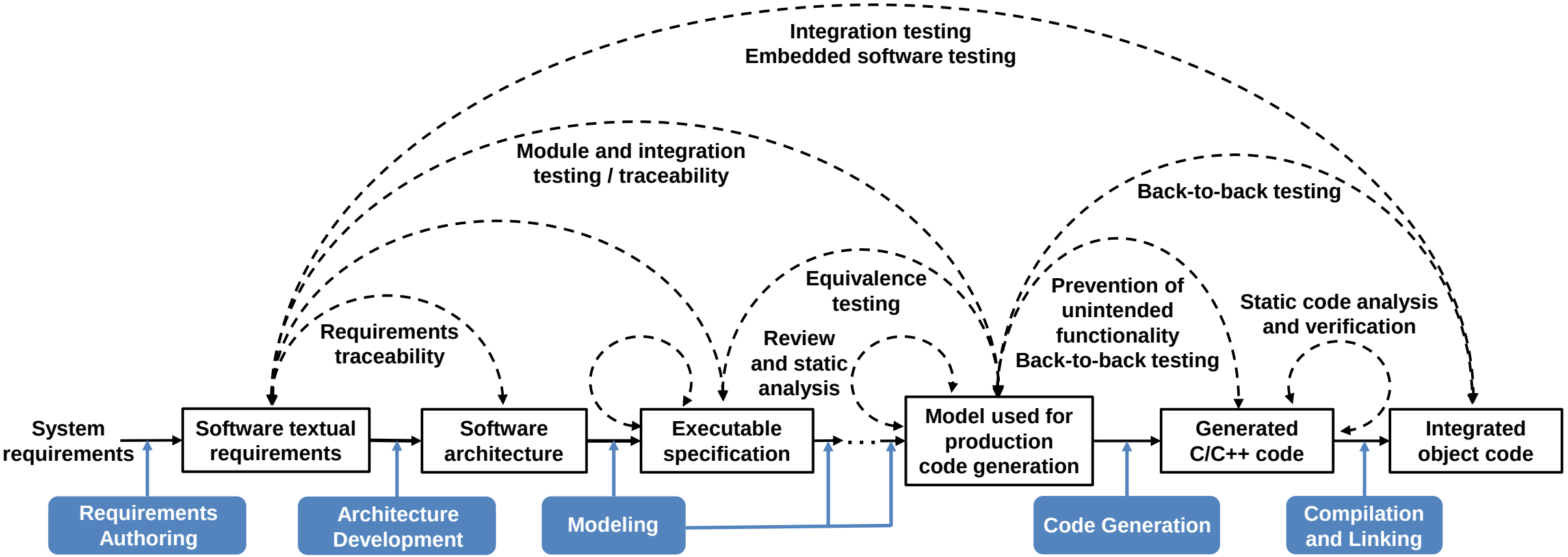


Complete Model-Based Design Workflow for ISO 26262

- Certifiable Model-Based Design Workflow to develop critical embedded software
- Reviewed and approved by TÜV SÜD certification authority
- Detailed workflow documented in MathWorks *IEC Certification Kit*



Reference Workflow

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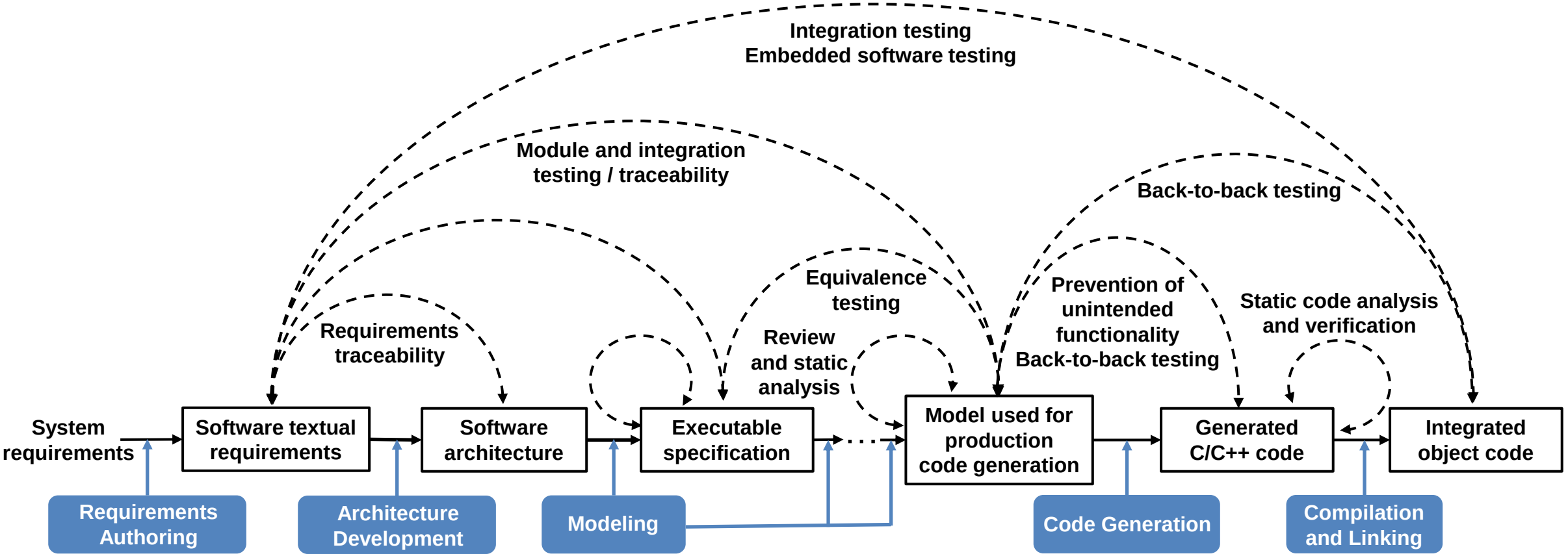


KOSTAL Achieves ISO 26262 ASIL D Certification using Embedded Coder

Challenge

Develop automotive electronic steering column lock software and certify it to the highest-level functional safety standard

Solution

Use Model-Based Design to design, implement, and verify the application software via back-to-back PIL testing required for ISO 26262 ASIL D certification

Results

- Development and certification time cut by 30%
- 80% of errors identified in modeling phase
- PIL test framework for ISO 26262 established

Kostal's electronic steering column lock module

"Using Model-Based Design to design, implement, and verify our software for the highest functional safety standard enabled our team to save costs, increase efficiency, and ensure software quality. Without Model-Based Design, more engineers would be needed to complete the project in the same time frame."

– Cheng Hui, KOSTAL

Link to user story

LG Chem Develops AUTOSAR - and ISO 26262 - Compliant Software of a Battery Management System (BMS) for a Hybrid Vehicle

Challenge

Design and implement production battery management system (BMS) software for the Volvo XC90 plug-in hybrid

Solution

Use Model-Based Design with MATLAB and Simulink to model, simulate, verify, and generate production code for AUTOSAR application layer software components

Results

- Existing library of core components reused
- Software issues reduced by more than 50%
- ISO 26262 ASIL C certification achieved

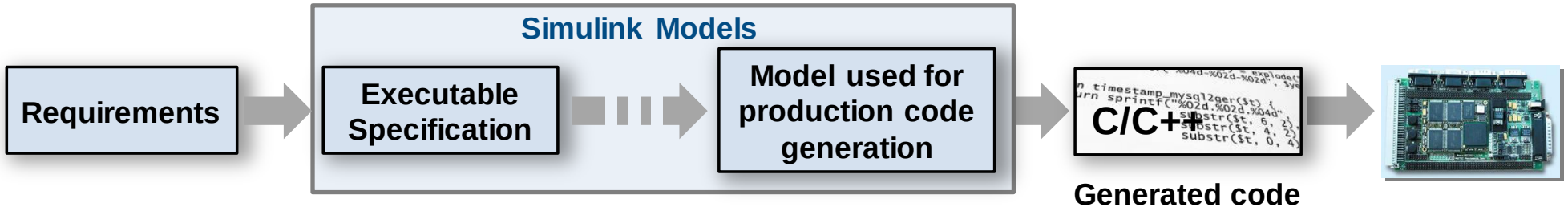
The LG Chem battery management system.

"Model-Based Design with MATLAB and Simulink enables us to increase component reuse, reduce manual coding, improve communication with our customers, and ultimately deliver higher-quality BMS in less time."

- Won Tae Joe, LG Chem

Link to user story

Verification & Validation



- Author, manage requirements in Simulink
- Early verification to find defects sooner
- Automate manual verification tasks
- Workflow that conforms to safety standards

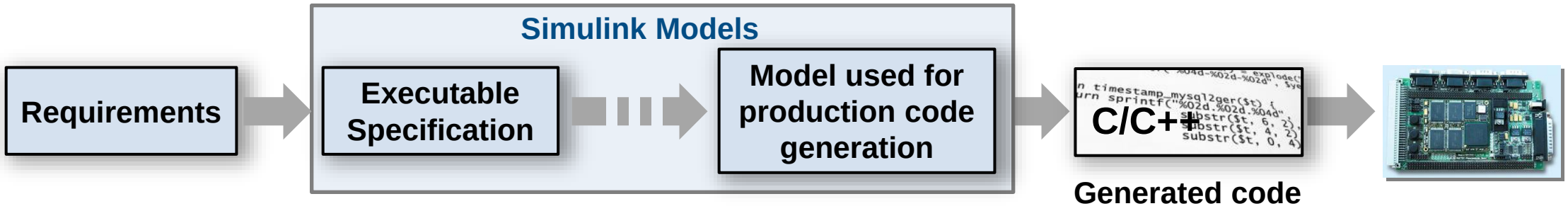
"Reduce costs and project risk through early verification, shorten time to market on a certified system, and deliver high-quality production code that was first-time right"
Michael Schwarz, ITK Engineering

High Integrity Verification Workflow

Modeling: Simulation, Analysis

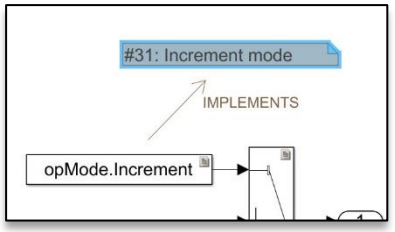
+

Automation: Coding, Verification

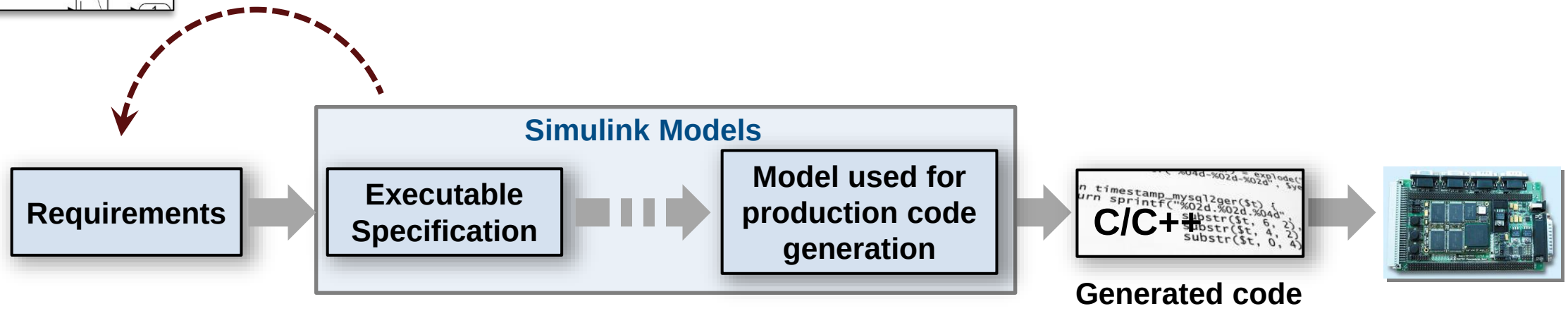


High Integrity Verification Workflow

Modeling: Simulation, Analysis + Automation: Coding, Verification



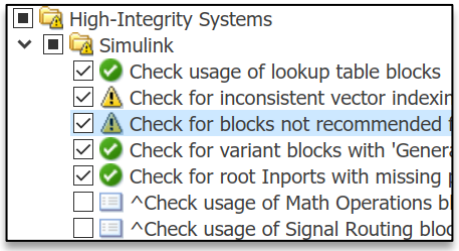
Requirements Traceability
Prevent unintended design behavior



Product Name: Simulink Requirements

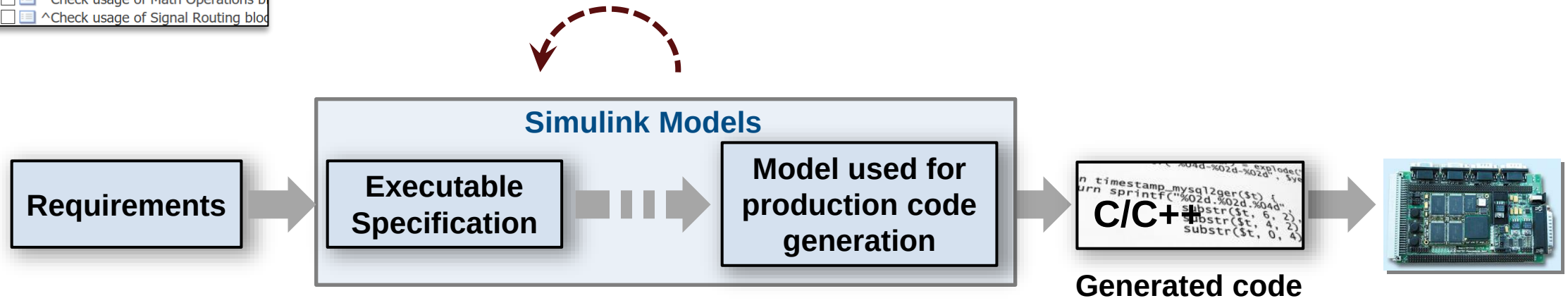
High Integrity Verification Workflow

Modeling: Simulation, Analysis + Automation: Coding, Verification



Standards Compliance with Review and Static Analysis

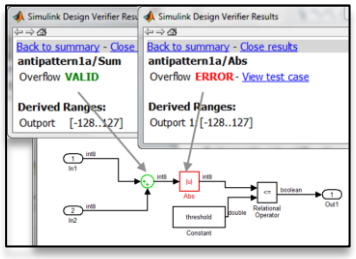
Confirm design meets standard guidelines



Product Name: Simulink Check

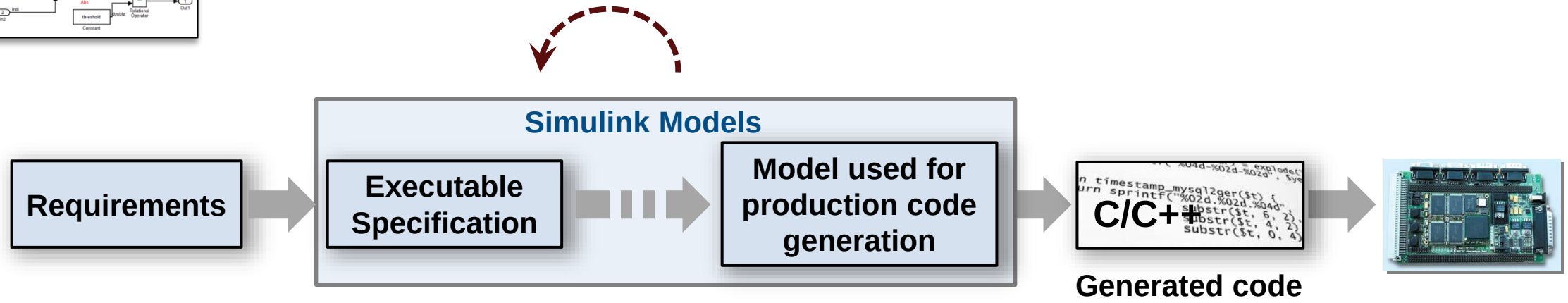
High Integrity Verification Workflow

Modeling: Simulation, Analysis + Automation: Coding, Verification



Formal Verification

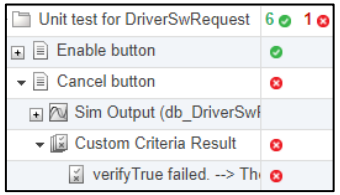
Prove that the design is robust and meets requirements



Product Name: Simulink Design Verifier

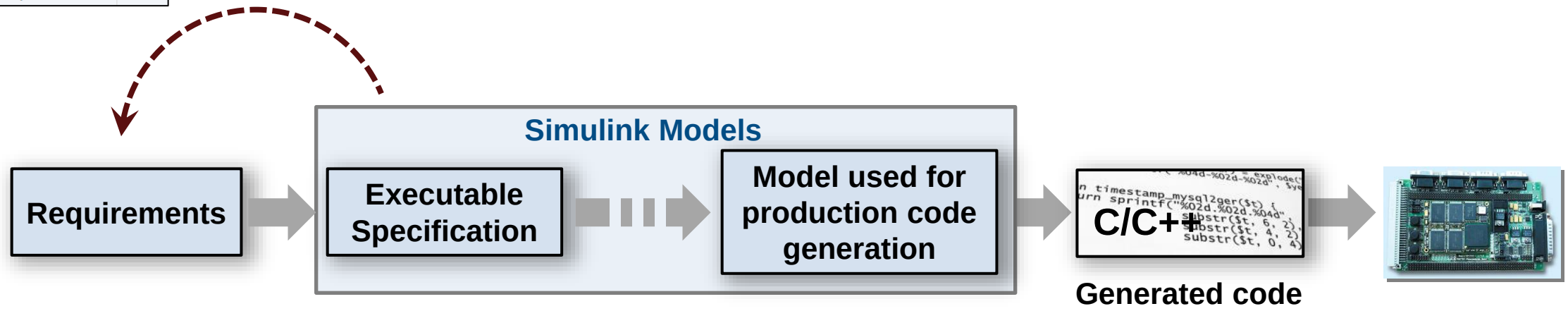
High Integrity Verification Workflow

Modeling: Simulation, Analysis + Automation: Coding, Verification



Component and System Testing

Confirm with testing in simulation (MIL) that design meets requirements

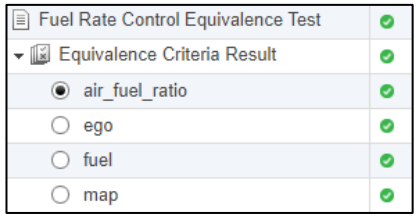


Product Name: Simulink Test

MIL, Model in the Loop, simulate on host PC

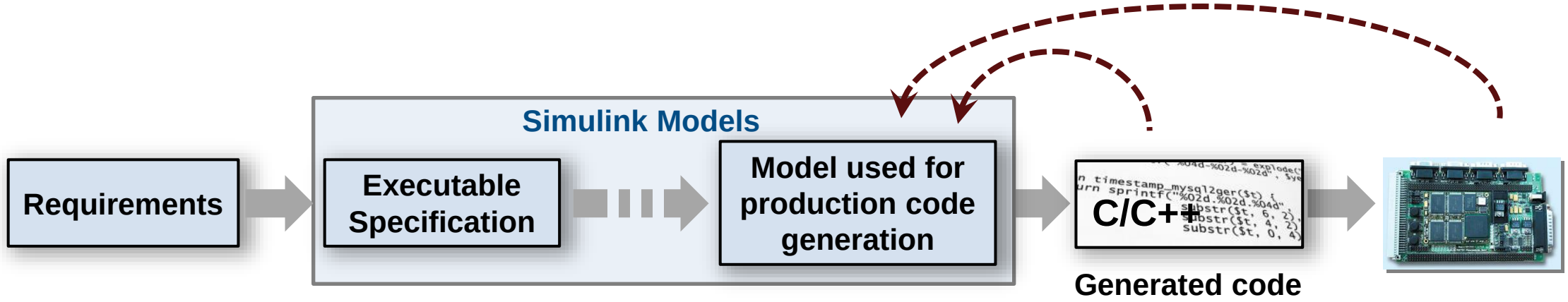
High Integrity Verification Workflow

Modeling: Simulation, Analysis + Automation: Coding, Verification



Back to Back Testing

Equivalence checking and testing for SIL and PIL

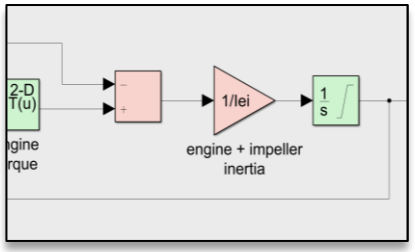


SIL, Software in the Loop, execute on host PC
PIL, Processor in the Loop, execute on target processor, or instruction set simulator

Product Name: Simulink Test

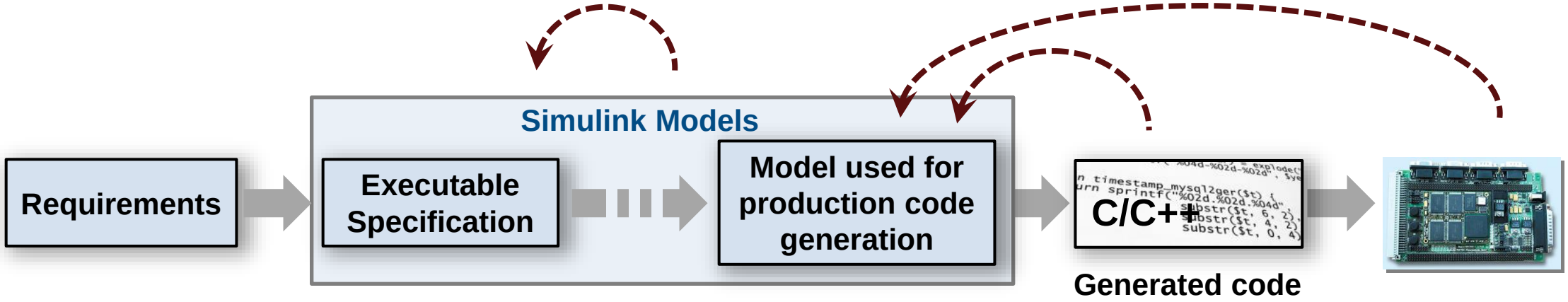
High Integrity Verification Workflow

Modeling: Simulation, Analysis + Automation: Coding, Verification



Coverage Analysis

Verify that design has been completely tested in MIL, SIL, PIL

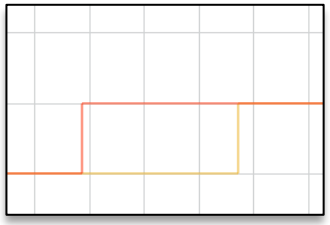


MIL, Model in the Loop, simulate on host PC
SIL, Software in the Loop, execute on host PC
PIL, Processor in the Loop, execute on target processor, or instruction set simulator

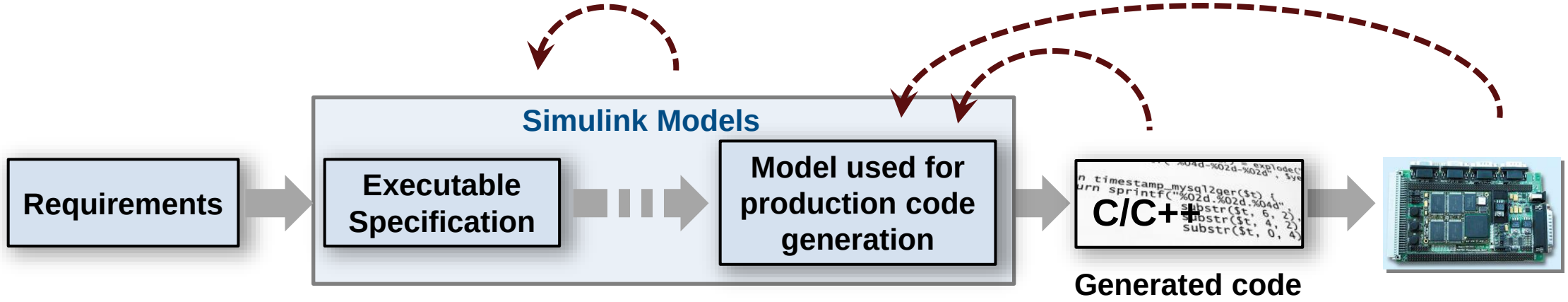
Product Name: Simulink Coverage

High Integrity Verification Workflow

Modeling: Simulation, Analysis + Automation: Coding, Verification



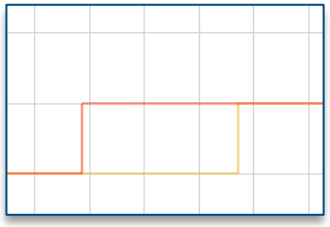
Automatic Test Generation
Generate tests for back-to-back testing, coverage analysis, etc.



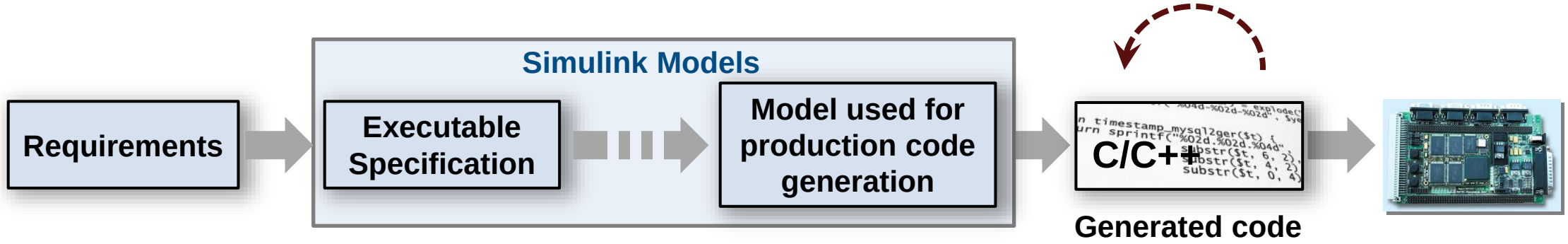
Product Name: Simulink Design Verifier

High Integrity Verification Workflow

Modeling: Simulation, Analysis + Automation: Coding, Verification



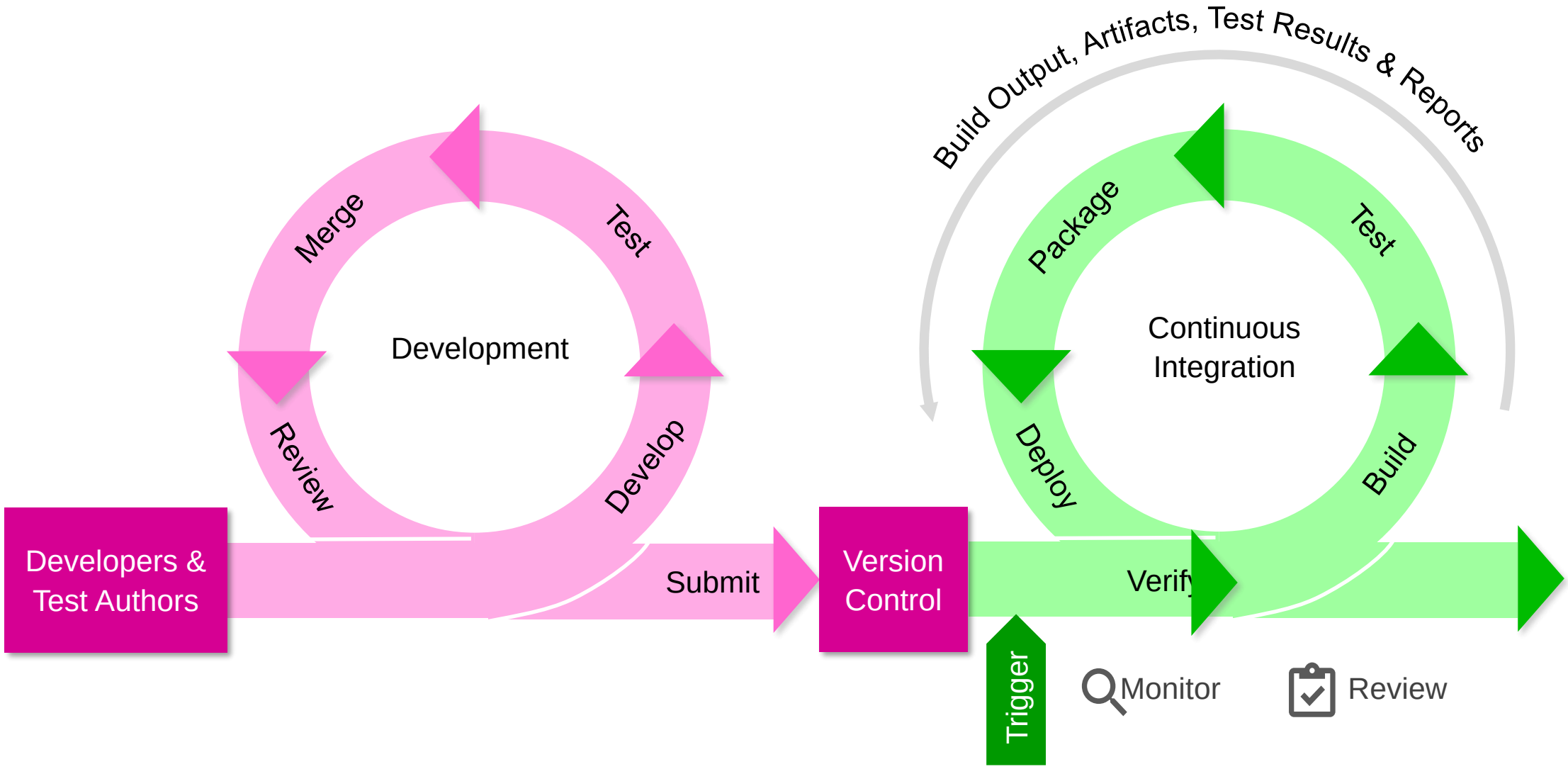
Static Code Analysis
Check that code meets standards (MISRA) and free of run-time errors



Product Name: Polyspace Bug Finder, Polyspace Code Prover

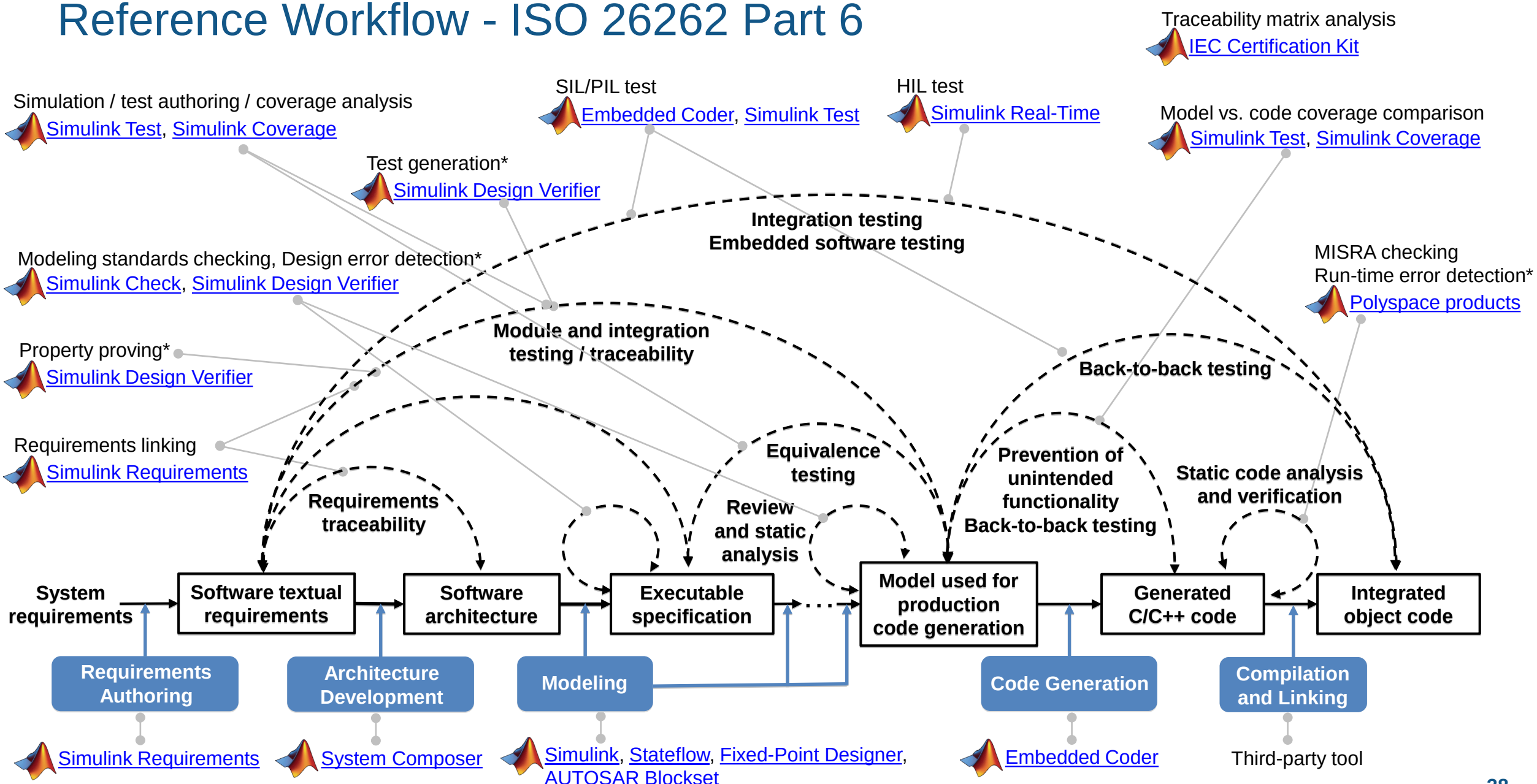
Automate Workflow with Continuous Integration

Modeling: Simulation, Analysis + Automation: Coding, Verification

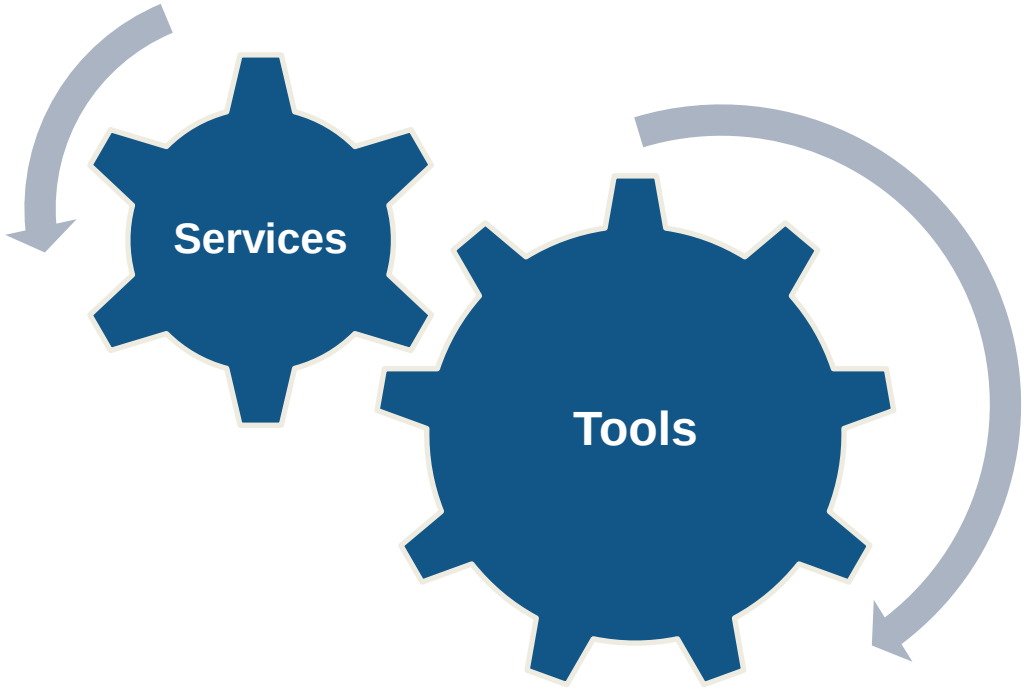


Learn more: [Continuous Integration for Verification of Simulink Models]

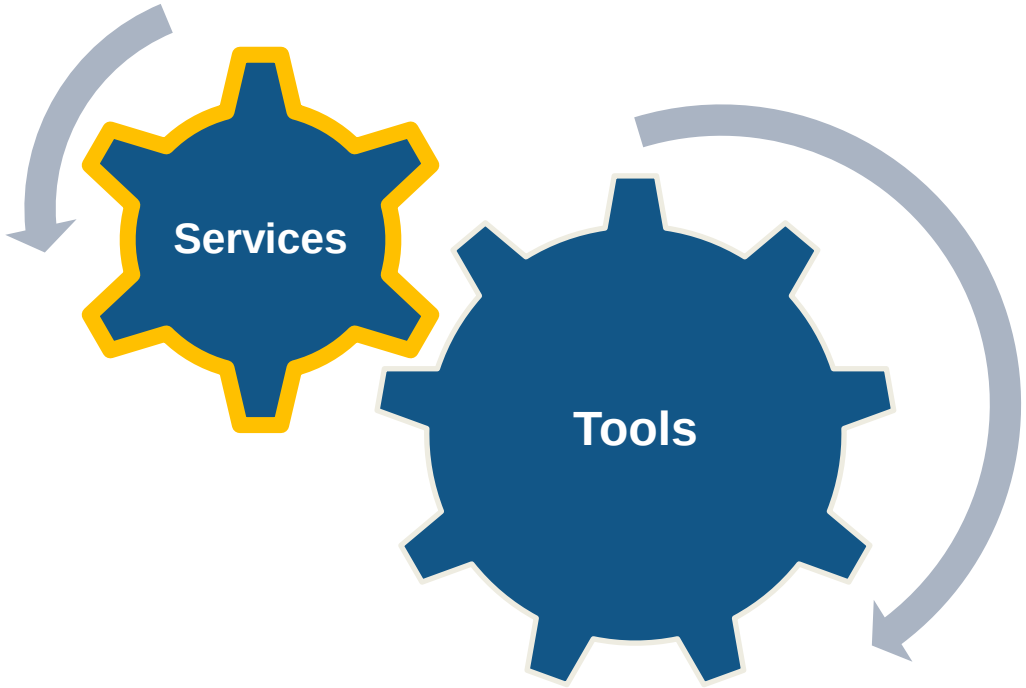
Reference Workflow - ISO 26262 Part 6



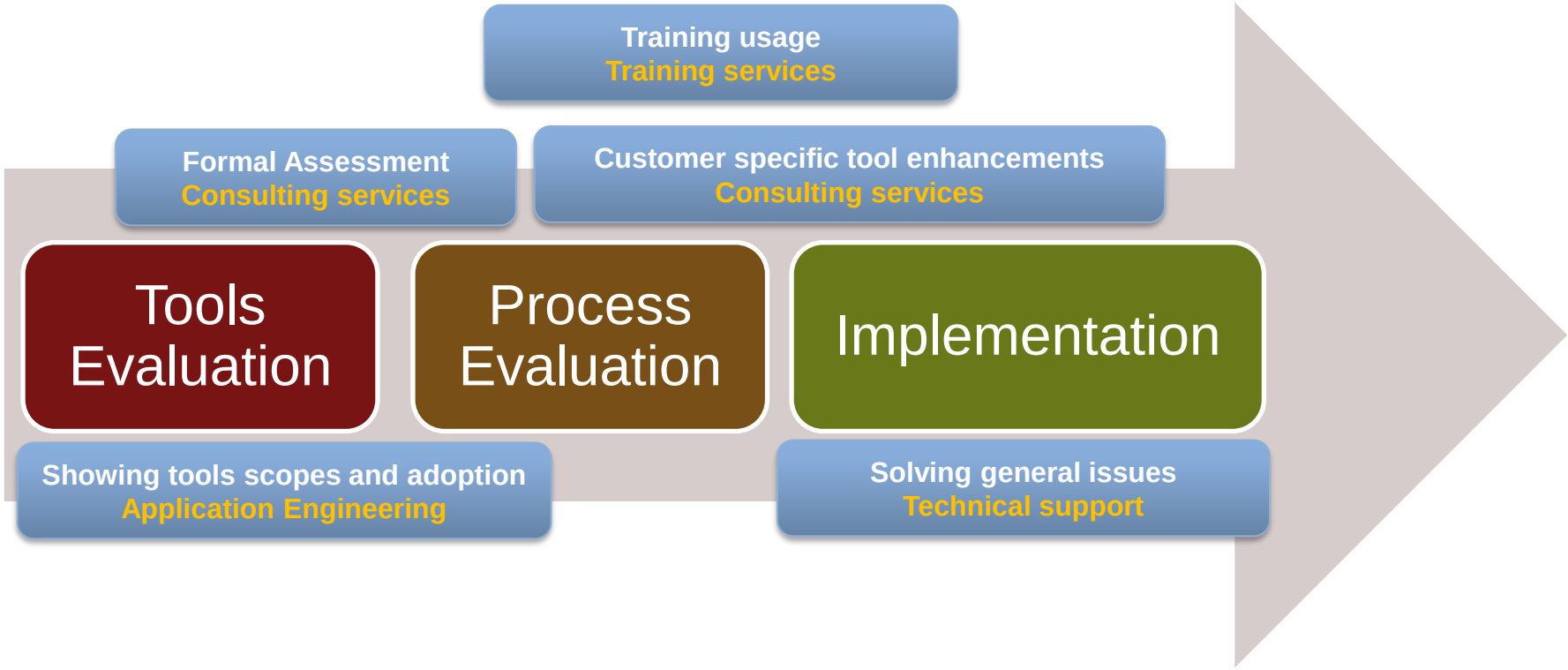
How MathWorks helps you to achieve your goals?



How MathWorks helps you to achieve your goals?



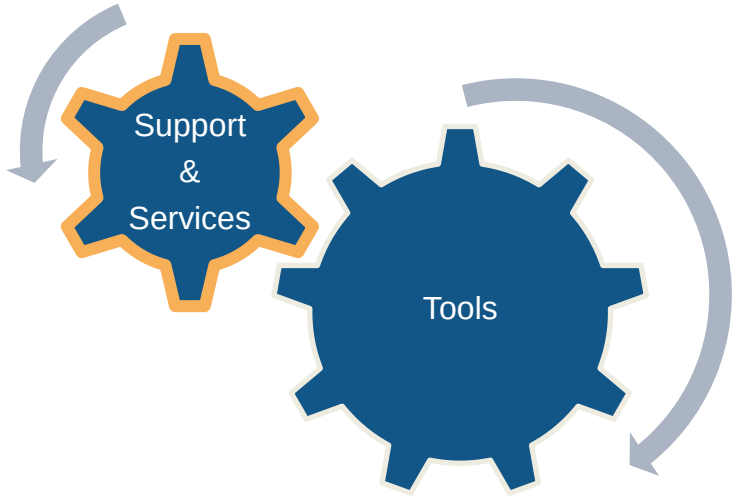
Tools Adoption - MathWorks support and services



How MathWorks helps you to achieve your goals?

Different groups for different aspects:

- Application Engineering
- Training Services
- Consulting Services
- Technical Support



Application Engineering

- Show tools potential and how to adopt them
- Support directly with technical coaching
- Methodology support
- Suggestions on how adopt new features

Examples:

- Specific Seminars/Workshops (Code generation – V&V – System Engineering)
- Generic Seminars (What's new – New products)
- Advisory on specific topics
- Help on map MW workflow to customer needs
- Coordination of technical activities between MW and customers

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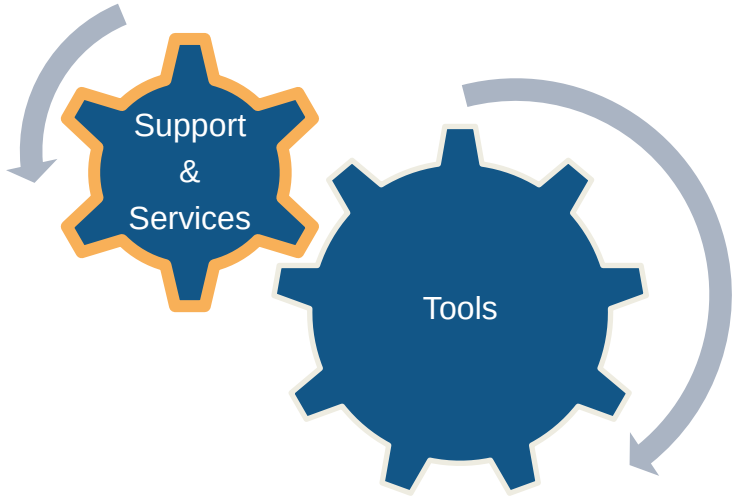

Training Services

SIMULINK

FONDAMENTI

10 Fondamenti Simulink per la Modellazione di Algoritmi e Sistemi

10 Fondamenti Simulink per la Progettazione di Sistemi Aerospaziali

10 Fondamenti Simulink per la Progettazione di Sistemi Automobilistici

11 Elaborazione dei Segnali in Simulink

INTERMEDIO

11 Integrazione di Codice in Simulink

11 Progetto di Sistemi di Controllo in MATLAB e Simulink

11 SimEvents per la Modellazione di Sistemi a Eventi Discreti NUOVO

11 Test Real-Time con Simulink Real-Time e Hardware Speedgoat NUOVO

AVANZATO

11 Verifica e Validazione di Modelli Simulink

12 Architettura e Gestione di Modelli Simulink

12 Modellazione dei Sistemi di Comunicazione in Simulink

GENERAZIONE DI CODICE

FONDAMENTI

13 Test del Codice Generato in Simulink

INTERMEDIO

13 Da MATLAB a C con MATLAB Coder

AVANZATO

13 Embedded Coder per Generazione di Codice di Produzione

14 Generazione di Codice per Componenti Software AUTOSAR

14 Generazione di Codice HDL da Simulink

14 DSP per FPGA

14 Programmazione dei Dispositivi SoC Zynq di Xilinx in MATLAB e Simulink

15 Sistemi SDR (Software-Defined Radio) in Zynq con Simulink

PRODOTTI POLYSPACE

AVANZATO

15 Polyspace per Verifica di Codice C/C++

15 Polyspace Bug Finder per l'Analisi del Codice C/C++

Link

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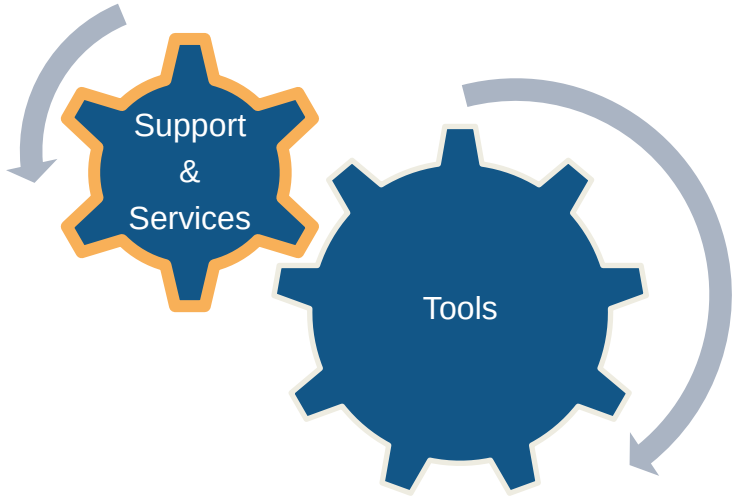
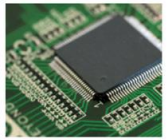


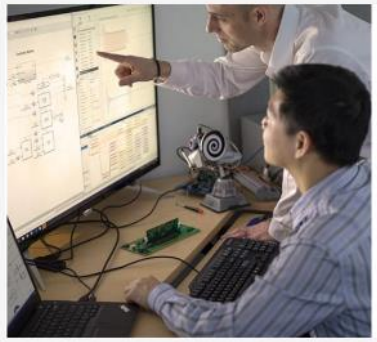
Consulting Services



Developing Embedded Software

Developing embedded controllers is an essential activity in bringing the power of digital electronics to automotive, aerospace, medical devices, robotics, industrial automation, and other computer controlled applications. A Model-Based Design methodology enables the realization of complex algorithms for embedded systems, from concept to validated implementation. Automatic generation of optimized, compact, and readable software code speeds up implementation for a variety of applications ranging from control to signal processing.

Leverage the Expertise of the MathWorks Organization



Having deep product knowledge and broad technical experience, we guide your team to apply best practices to your development projects. We offer "from the source" insights into our products and exclusive access to our in-house subject matter experts. Our worldwide presence means that we live and work where you do, speak your language, and understand local customs and business practices. Wherever you are, we're there to help.

MathWorks Consulting Services brings a broad industry background and technical expertise gained from working with hundreds of companies to help you build workflows to generate code customized to your requirements.

Generating efficient software code to meet size and speed constraints

MathWorks Consulting Services teaches you techniques to optimize the generated code for size and speed by leveraging our detailed and advanced knowledge of the tool and its configuration options. We can also build custom tool extensions when additional size and speed efficiency is required for a specific resource-constrained hardware environment.

Controlling the generated code's functions, files, data and interfaces

We help you use built-in product features, functions, or APIs so your software code meets specified programming standards for function prototypes, file formats, file partitioning, data structures, and interfaces. If the functionality you need is not built-in, MathWorks Consultants can construct customized capabilities as needed and transfer the knowledge to you so you can evolve and maintain the new capabilities.

Meeting certification and safety standards

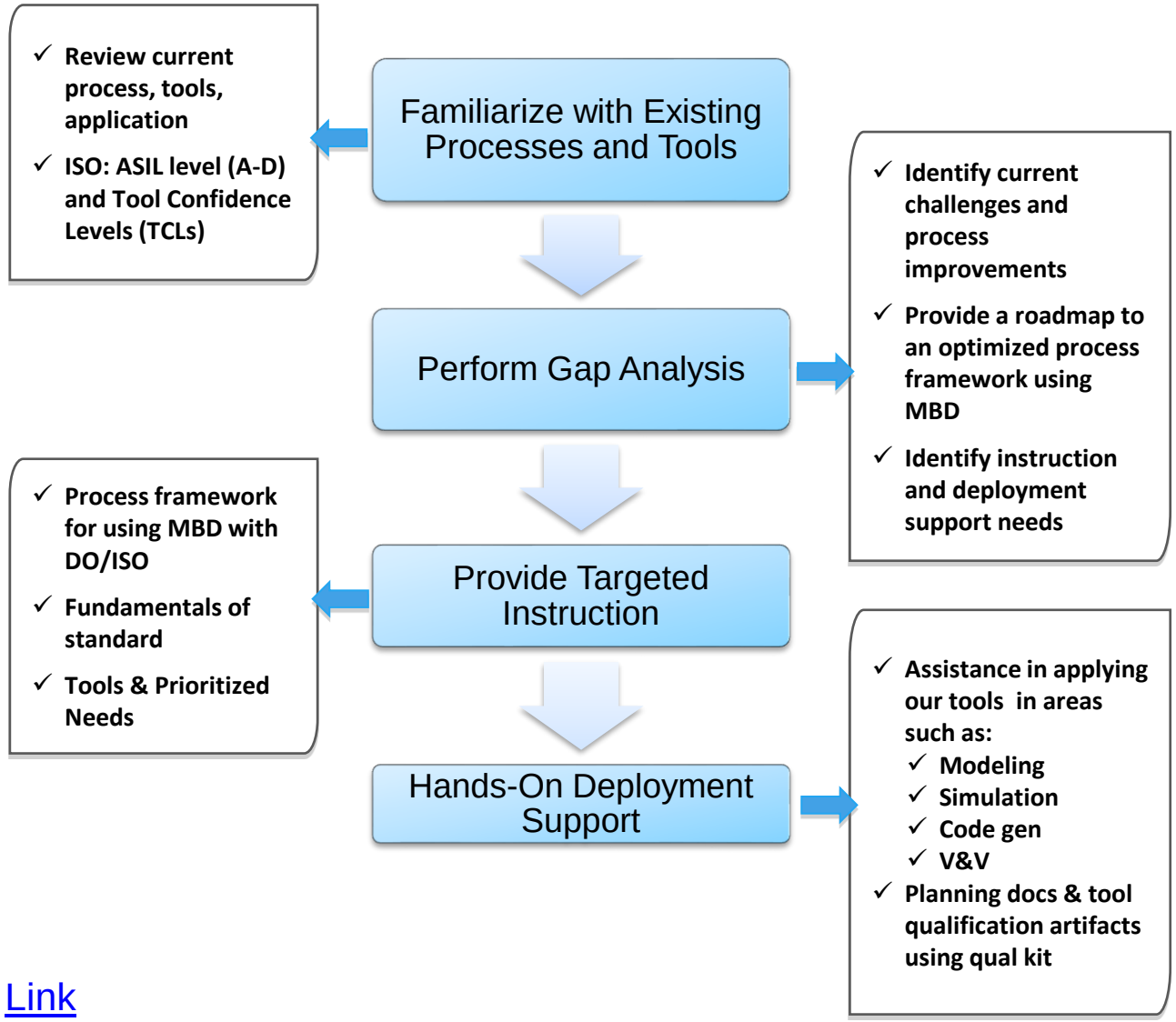
MathWorks Consultants have worked with engineers to implement algorithms and development processes that comply with certification standards such as DO-178, ISO 26262, and IEC 61508. We can help establish or fine-tune your development process around certification standards, ensuring that you achieve the best possible value from MATLAB and Simulink, as well as a significant reduction in development effort.

Proven Solutions

- Battery Simulation and Controls
- Developing Embedded Software
- Developing Embedded Targets Advisory Service
- DO-178 Certification Advisory Service
- Early Verification and Validation with Model-Based Design
- Electrical Power Systems Simulation
- Financial Analysis and Trading
- Image Processing and Computer Vision
- ISO 26262 Process Deployment Advisory Service
- Load Forecasting
- MATLAB in Business Critical Applications
- MATLAB with Hadoop and Spark
- Model-Based Design for Production Real-Time Embedded Systems
- Model-Based Design Process Assessment and Maturity Framework
- Model-Based Design Process Establishment
- Motor Control Development
- Operations, Logistics, and Supply Chain Management
- Optimal Engine Calibration
- Predictive Maintenance
- Signal Processing and Communications
- Software Development with MATLAB
- Software Upgrade Service
- Thermal Systems Modeling
- Tools Integration

Link

ISO 26262 Process Deployment Advisory Service



…helps to:

- educate engineers on the standard
- identify gaps in current design processes,
- provide a road map to an optimized process framework using Model-Based Design, and
- assist with deployment of that road map.

"We leveraged MathWorks consultants to apply Model-Based Design for ISO 26262 on our new Integrated Restraints and Braking Controller (IRBC) developed with Simulink, Stateflow, Simulink Design Verifier, and Embedded Coder for production code generation and verification."

Rich Rakes, Lead Engineer, Autoliv

Link

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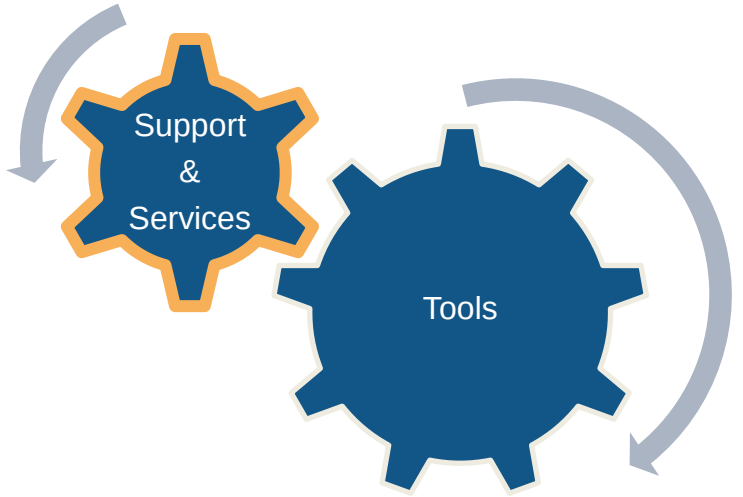

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Eligibility: Access to technical support requires a valid license number and a **Software Maintenance Service** subscription.

Students: Technical support from MathWorks is available for activation, installation and bug-related issues. For additional help visit our **student resource page** or contact your instructor.

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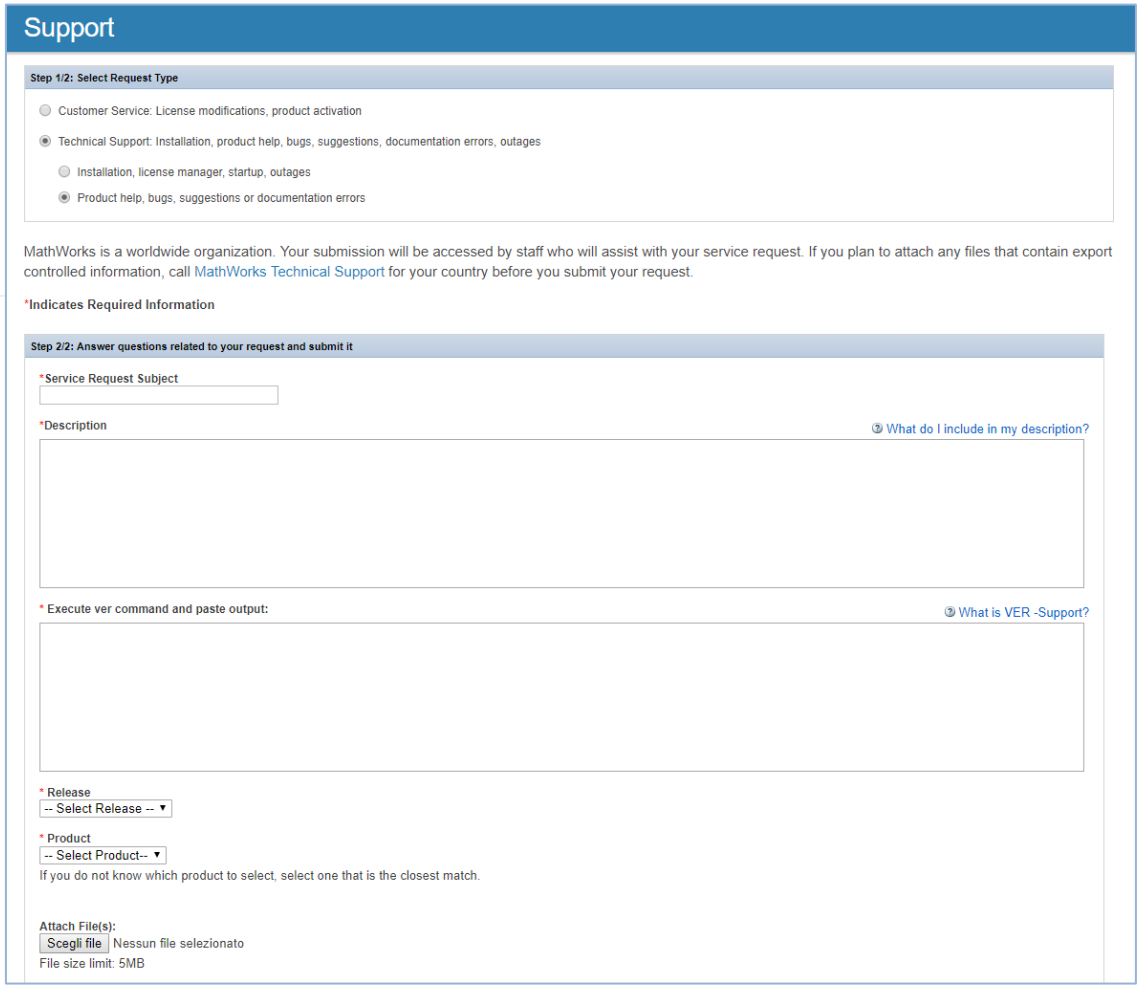
Explore resources for installation, activation, and startup

Documentation
Explore MathWorks Documentation

MATLAB Answers
Ask questions and get answers



Link

Q&A

More information:

Nukul Sehgal
Application Engineer
nsehgal@mathworks.com