



Accelerating Safe Railway Application Development using Model-Based Design

Daran Smalley
Brakes Subsystem Manager

May 10 2023



Agenda



1. About Us
2. Global Trends
3. Our Traditional Workflow
4. Model-Based Design
Modelling instead of documenting
Failing Fast
5. Future Model-Based Design
Even Earlier modelling
Failing Faster

01

About us

Leading the way to greener and smarter mobility solutions



We are where mobility is needed

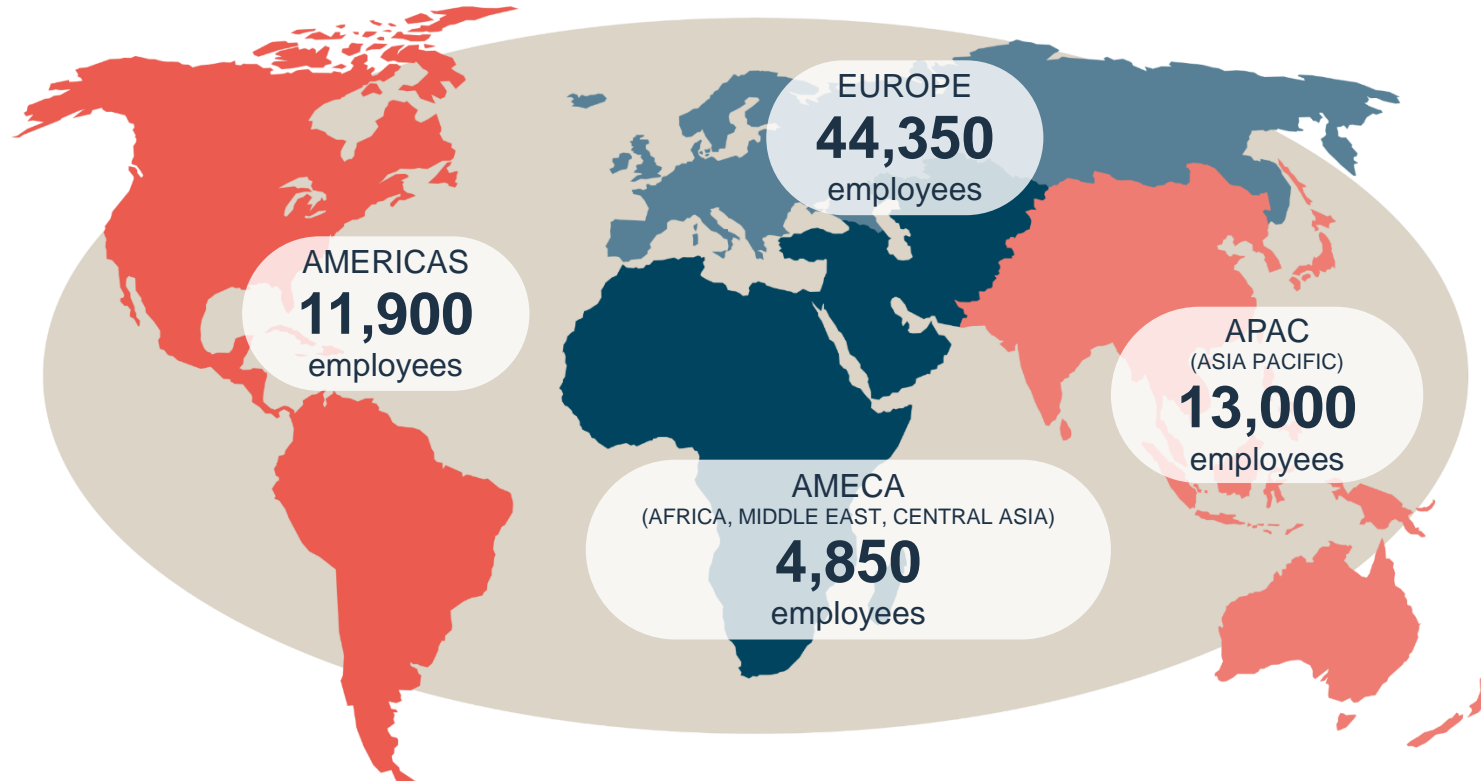
Over
74,000
employees worldwide

From
166
nationalities

70
countries

140 sites

250 depots



19,700
engineers

More than
9,400
patents

Over
150,000
vehicles in commercial
service

Partner to over
300
cities

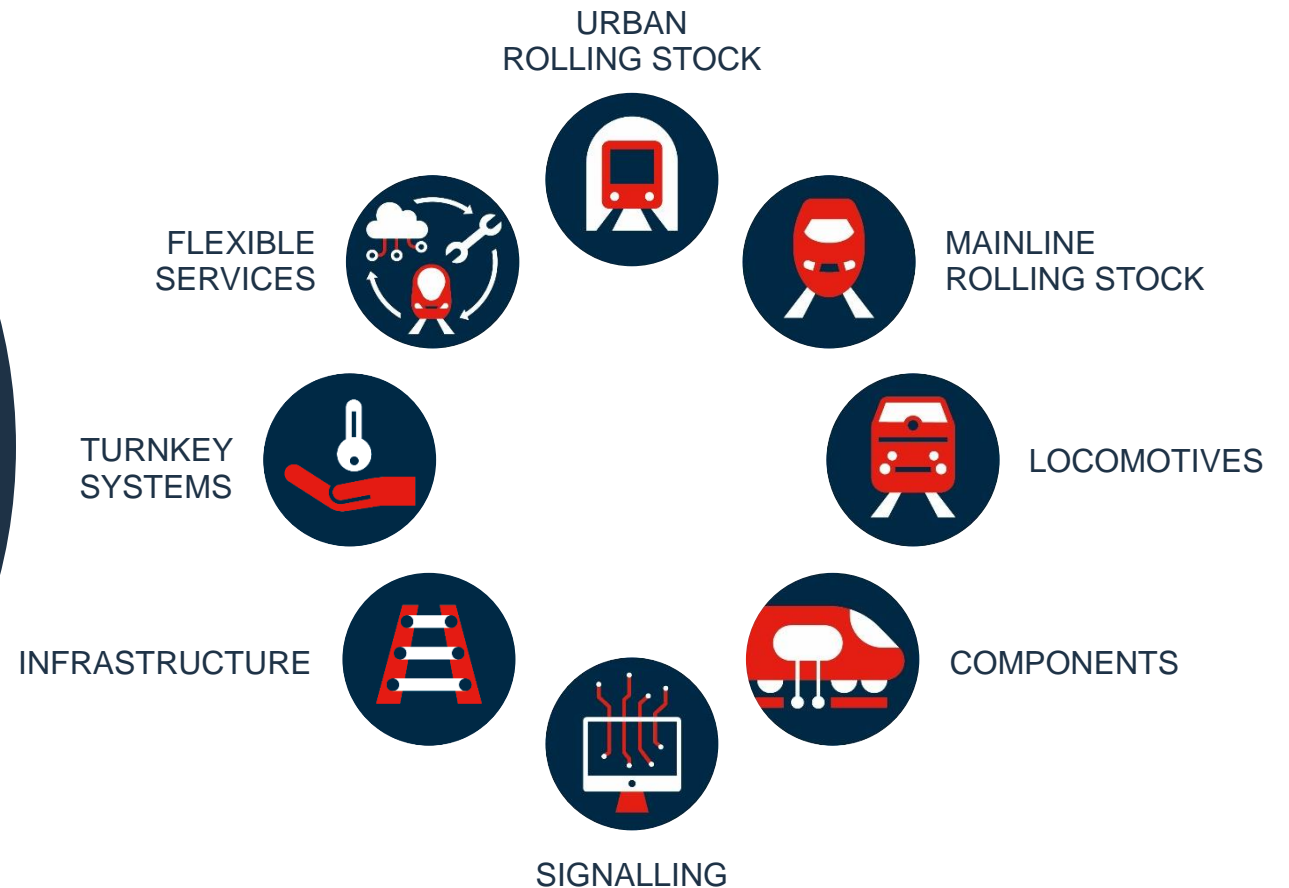
As of 31 March 2022

A global leader in the transportation sector in the digital age

Leading societies to a low carbon future

Alstom develops and markets mobility solutions that provide sustainable foundations for the future of transportation.

Our comprehensive product portfolio ranges from high-speed trains, metros, monorail and trams, to turnkey systems, services, infrastructure, signalling and digital mobility solutions.

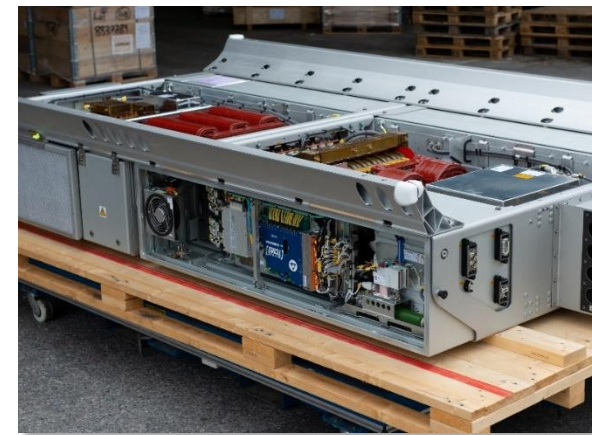
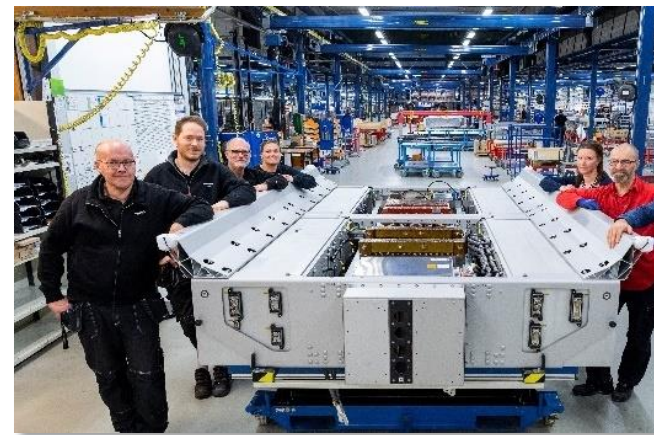


Alstom in Västerås - Rolling Stock & Components

- One out of three Global Component Development Sites for Traction equipment
- A Global Test and Technology Centre for Powertrain Systems
- Product responsibility for Mitrac control electronics

Site scope:

- Development of Powertrain Systems including converter- and traction-motor design with validation & verification at in-house, large scale, PowerLab
- Traction equipment manufacturing, from prototyping to after market
- Train Control and Communication electronics
- TCMS Applications including Control, I/O and visualization products



About Me



Daran Smalley

Daran.Smalley@alstromgroup.com

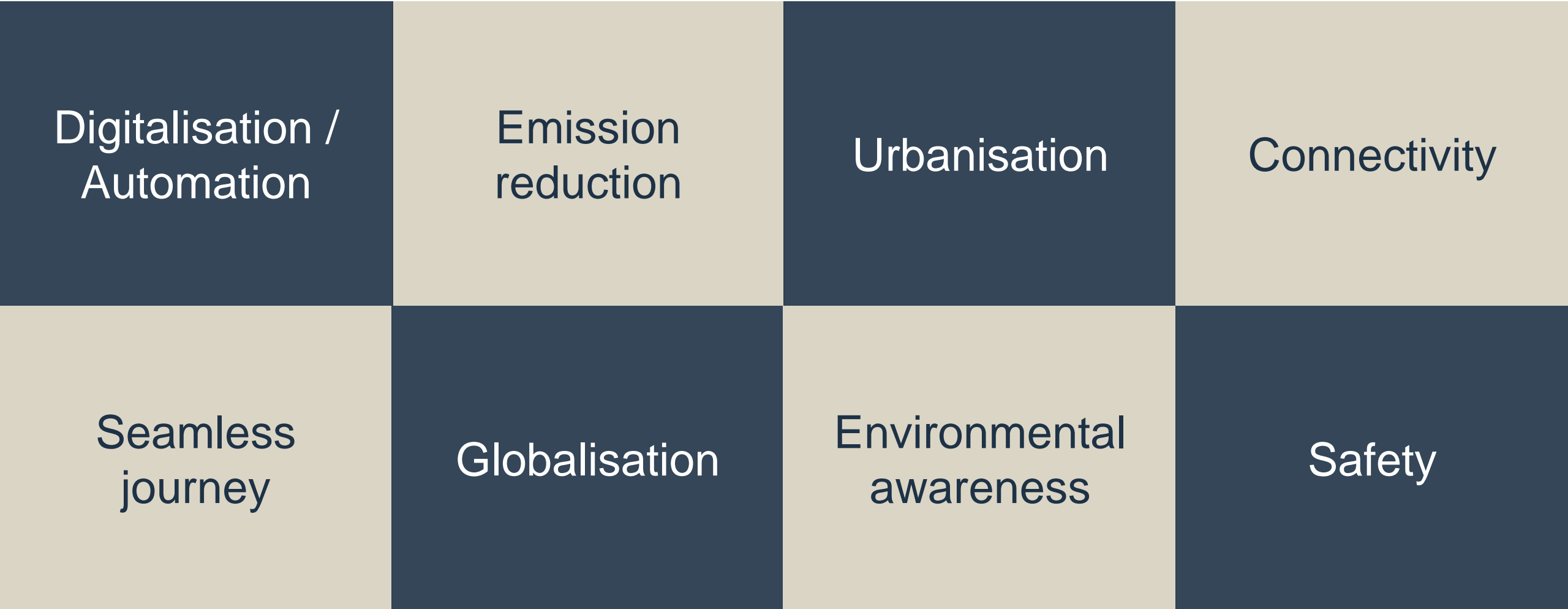
Brakes Subsystem Manager

- Mechatronics Engineer from Monash University in Melbourne, Australia. Now enjoying the freezing cold in Sweden.
- 3 years Electrical Engineer at Rio Tinto aluminium smelter.
- Gap Year travelling Europe
- 7 years Control Software Engineer working in Bombardier/Alstom Traction Control for Traction.
 - Software control engineer transforming Traction Control to a Model Based Design development approach
 - Train performance simulations for Bids and Tenders
 - Customer interface verifying and closing requirements

02

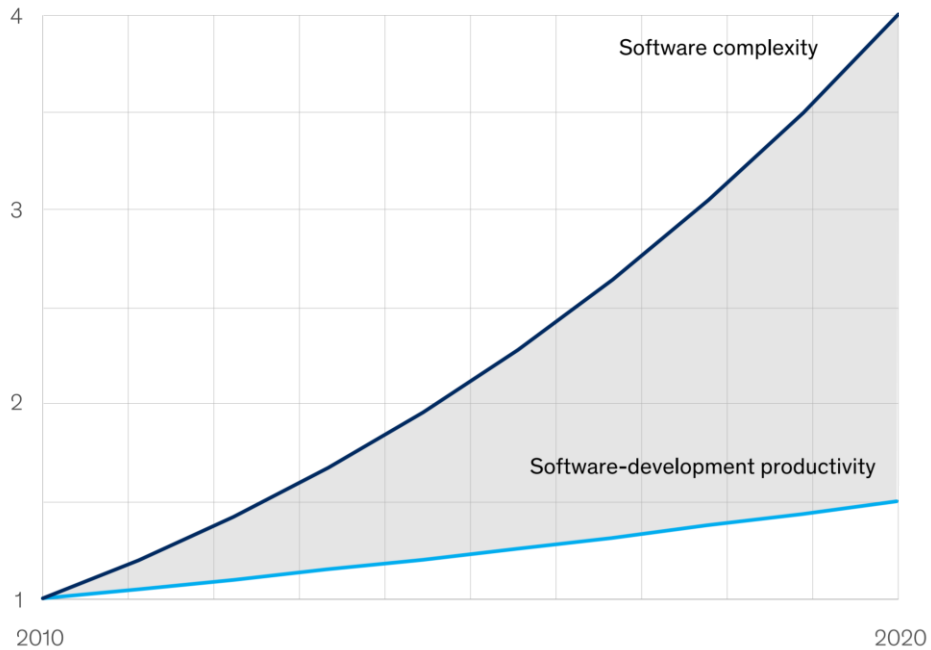
Global Trends

Megatrends affecting the global rail market



Source: UNIFE, Roland Berger

Growing system and software complexity



Source: [McKinsey & Company](#)

NEWS Home / News

Driverless cars will require one billion lines of code, says JLR

Jaguar Land Rover says autonomous vehicles will need ~~1,000~~ times more computer code than Apollo 11



by: [Tristan Shale-Hester](#) 16 Apr 2019

10,000

Source: [Auto Express](#)

The changing face of test: testing advanced aerospace systems

Aerospace electronics and avionics continue to advance at a rapid pace, with few signs of slowing. As aerospace systems grow in complexity, engineers face myriad challenges in the test, validation, and verification of these modern devices. This trend is changing the face of test, and accelerating the need for flexible, scalable test solutions.

Author — [Courtney E. Howard](#)

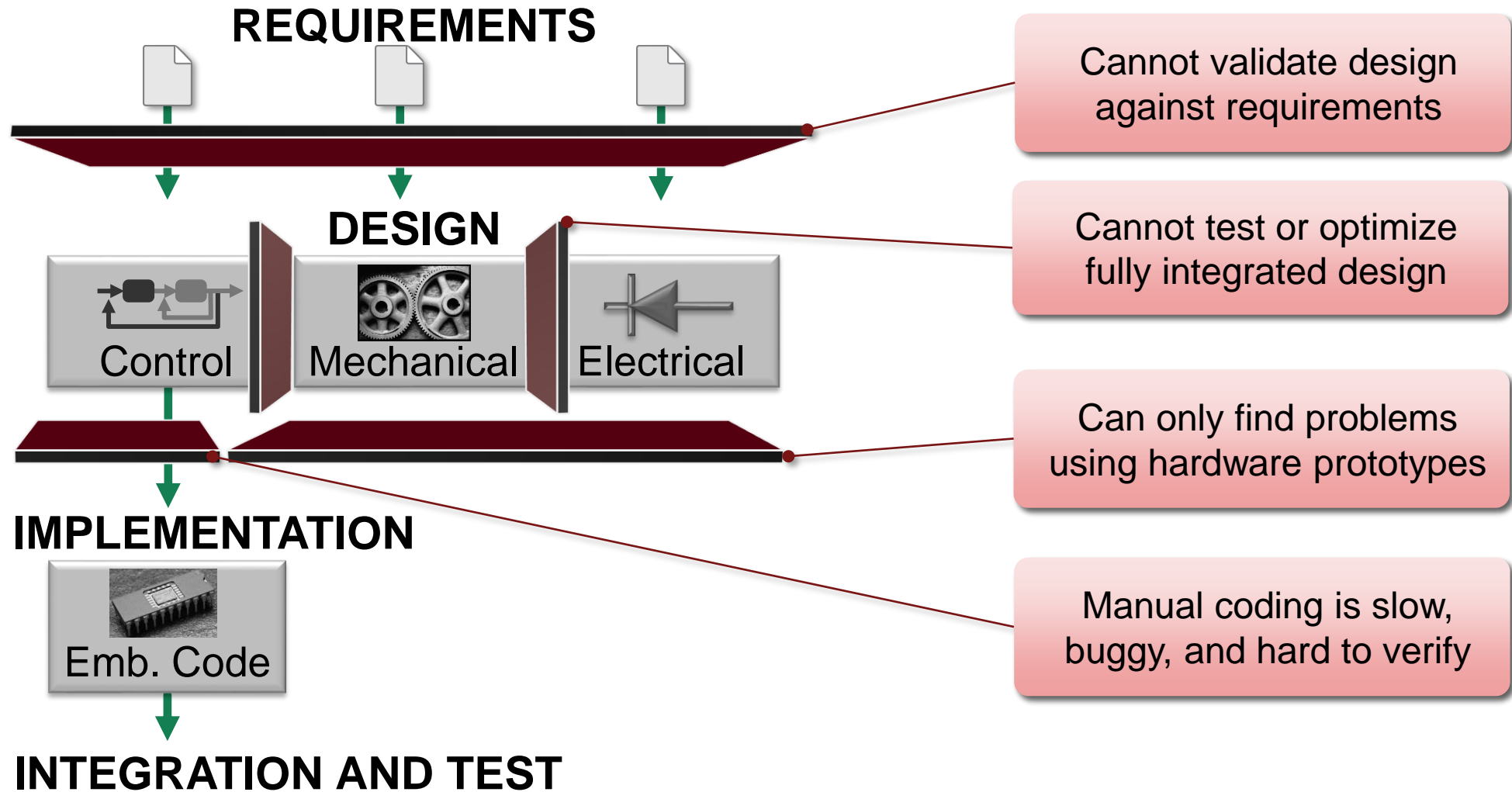
Apr 14th, 2017

Source: [Intelligent Aerospace](#)

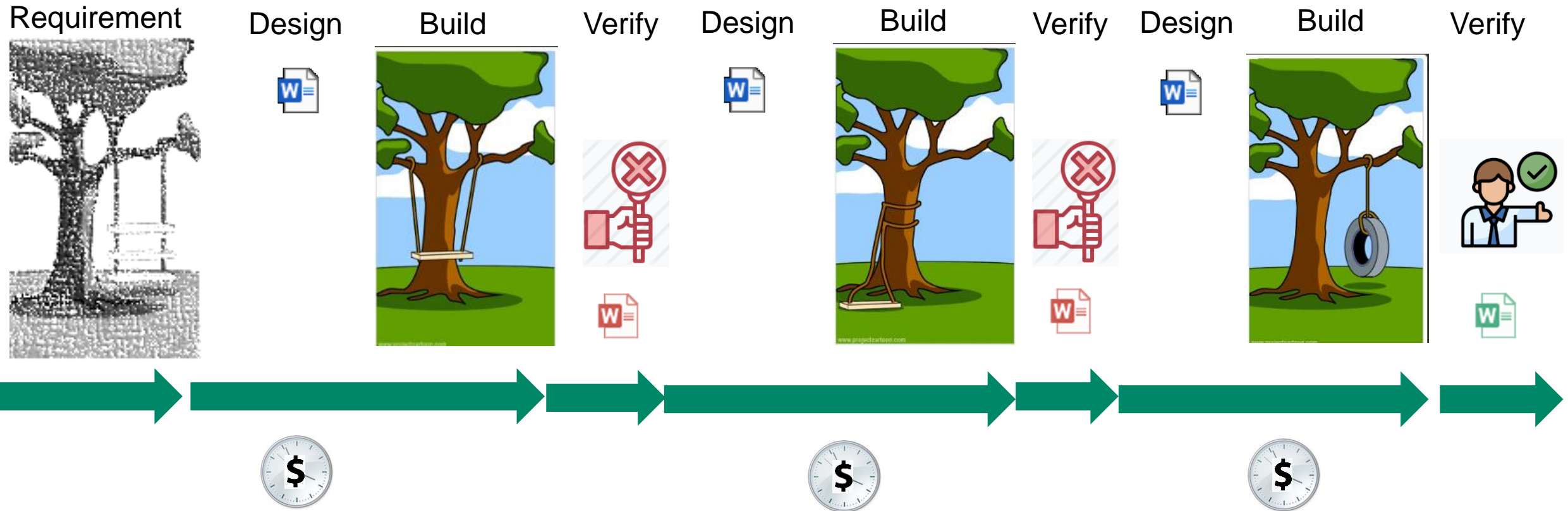
03

Our Traditional workflow

Typical Design Process



Traditional design and verification



How to reduce time and cost with quality?

Requirement



Design



Build



Verify



Design



Build



Verify



Design



Build



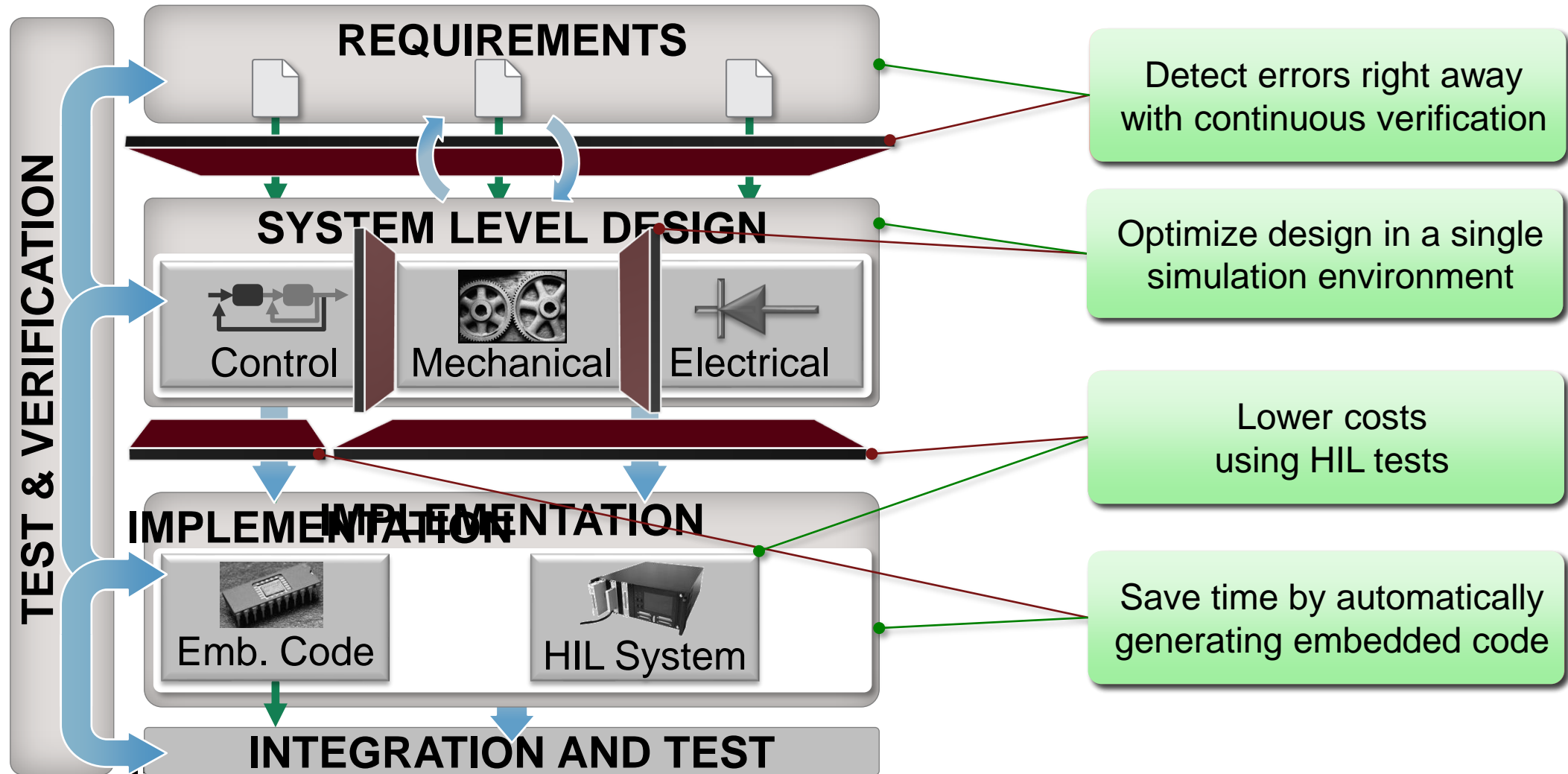
Verify



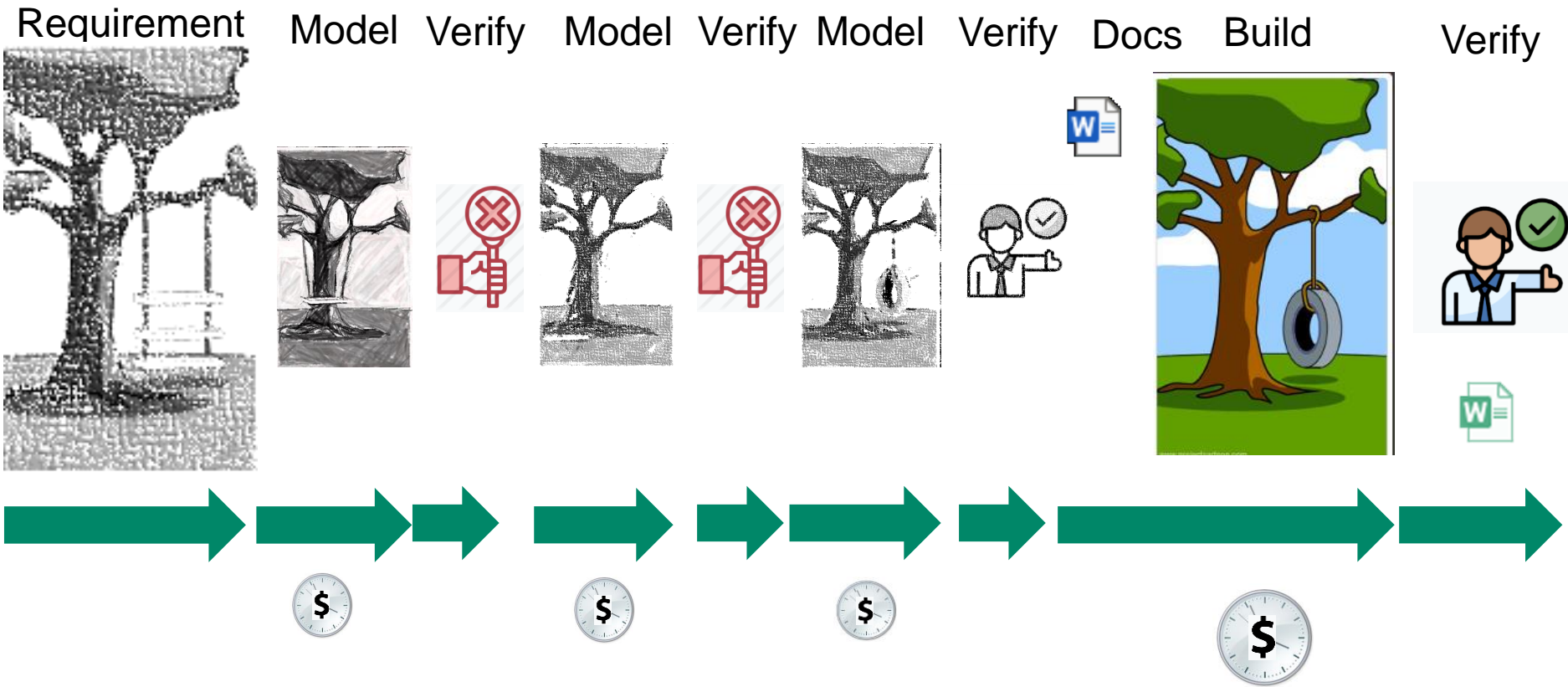
04

Model-Based Design Modelling instead of documenting Failing Fast

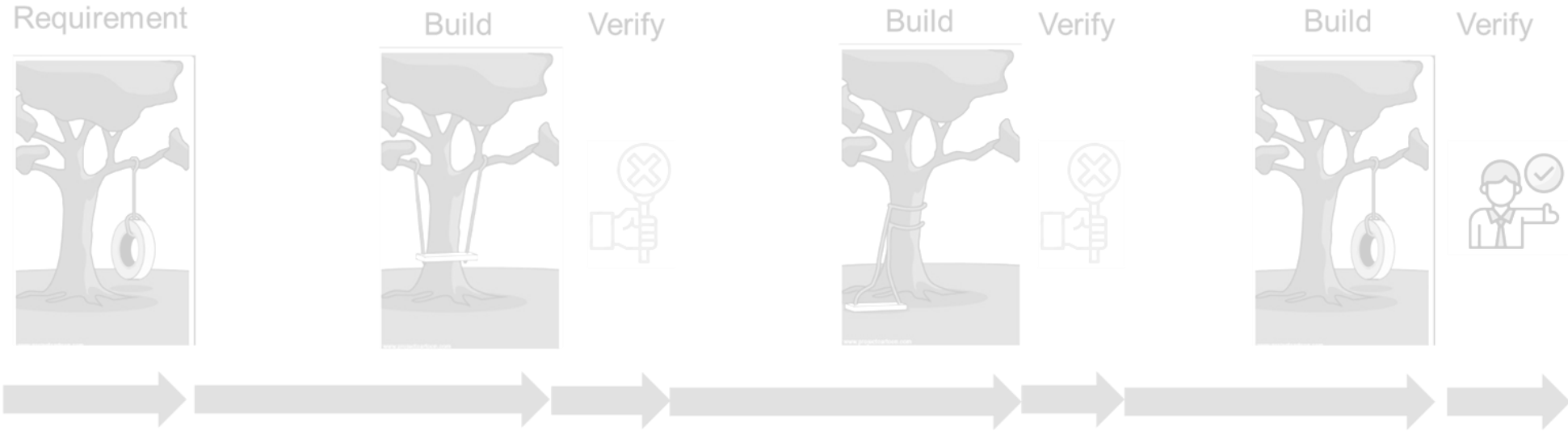
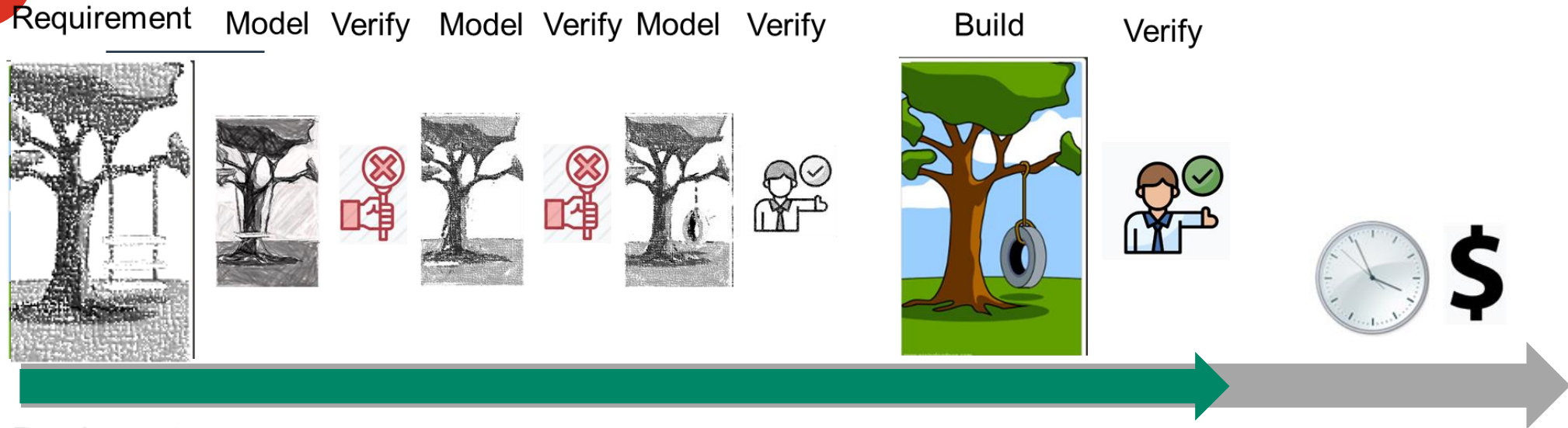
Model-Based Design Benefits



Fail Fast - Detect errors early with Model-Based Design (MBD)

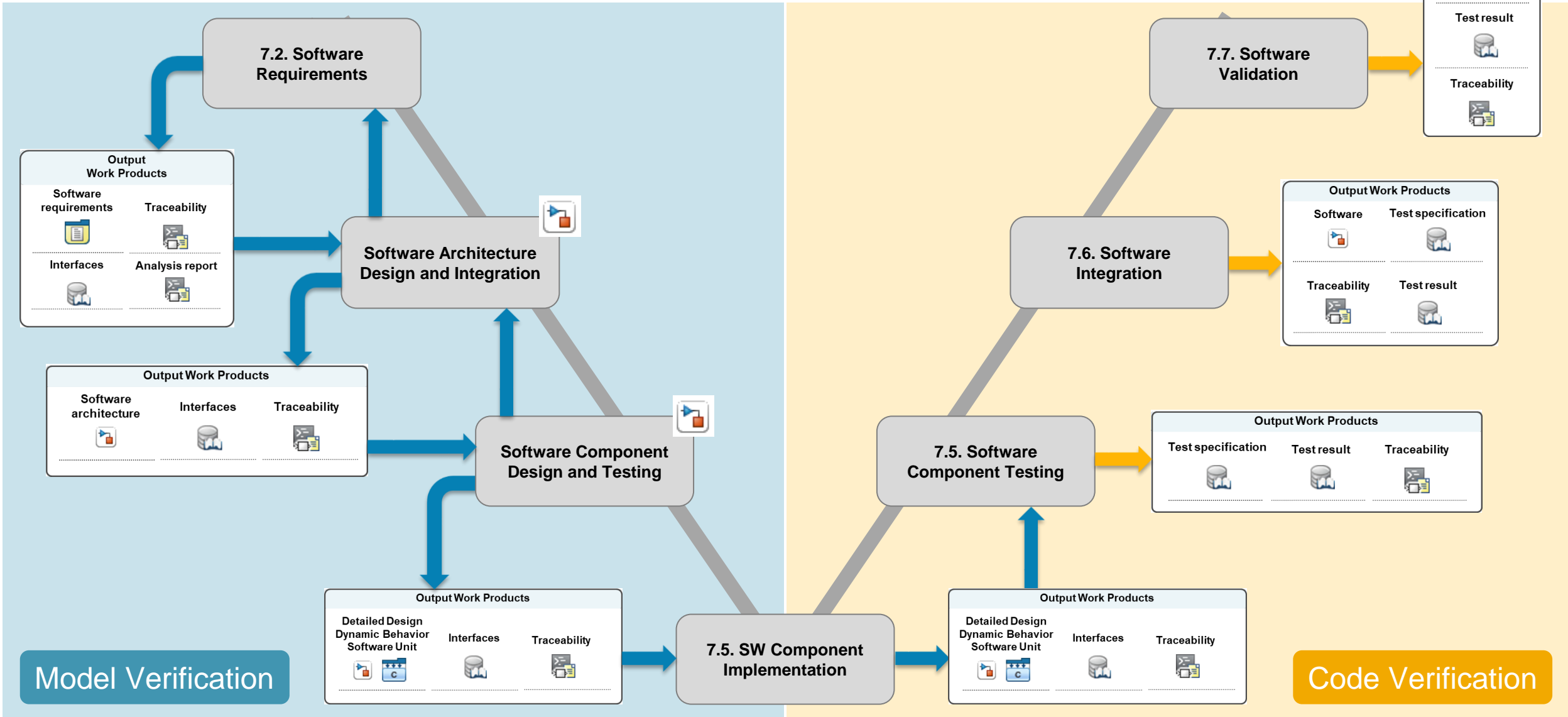


Model-Based Design compared to traditional approach



Software Development Process for Safety-Critical Applications


EN 50128 / EN 50657



Model-Based Design: Software development

Source Requirements

EOS_PSW_RS-1978



The manual DC selector switch has three positions.
The switch shall be supervised via two binary inputs for status code 1 and 2.

EOS_PSW_SWRS.reqifz

Automatic Requirement Document

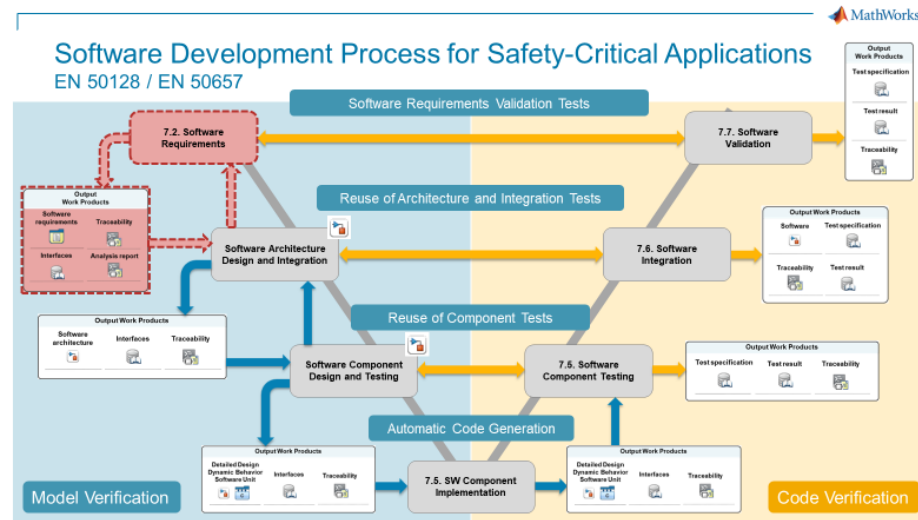


Index: 3.1.7.2
Custom ID: 1978
Summary:
Description Rationale
The manual DC selector switch has three positions. The switch shall be supervised via two binary inputs for

Custom Attributes

Links

- Implemented by: [SwC_DcSelSw](#)
- Verified by:



Model-Based Design: Software development

Source Requirements

EOS_PSW_RS-1978
 The manual DC selector switch has three positions.
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IBM Rational

EOS_PSW_SWRS.reqifz

Automatic Requirement Document



Index: 3.1.7.2
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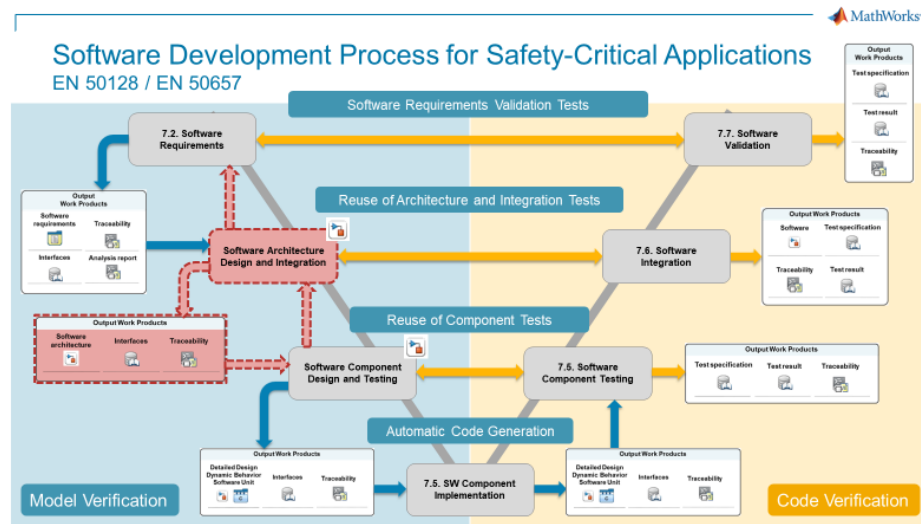
Custom Attributes

Links

Implemented by:
[SwC_DcSelSw](#)

Verified by:

Design Link



Automatic Checks

Automatic Design Documents

Model Advisor - SwC_DcSelSw C:\Projects\PCU_NG\branches\4585\PCU_NG\vr

File Edit Run Settings Highlighting Help

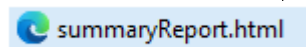
Model Advisor

- BT model check configuration
 - Model Development Checks
 - Simulink
 - EN 50128 Checks
 - MAAB Checks
 - JMAAB Checks
 - Model Metrics
 - Simulink Requirements
 - BT Checks
 - Block settings
 - FT blocks used
 - FO blocks used

Simulink version: 10.0
 System: SwC_DcSelSw

Run Summary
 Pass 12
 Fail 0

Automatic review Documents



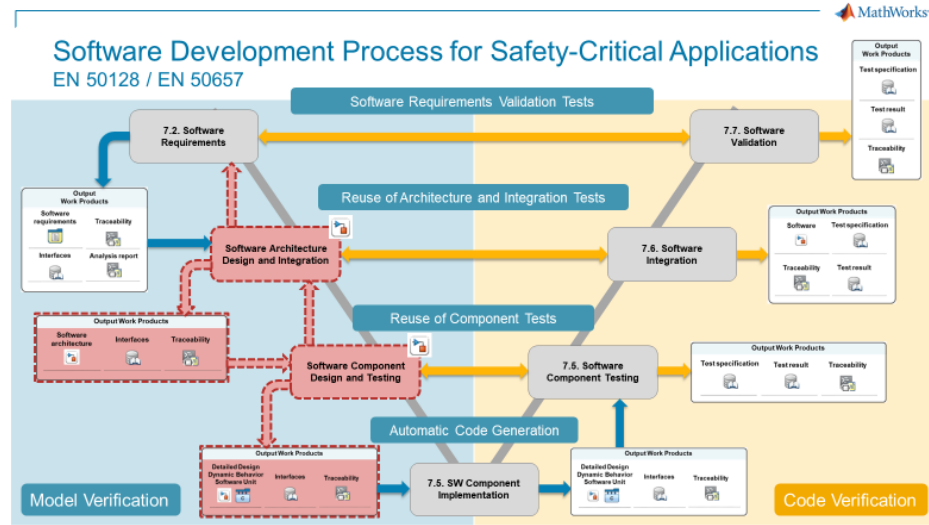
Model-Based Design: Software development

Source Requirements

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Automatic Requirement Document



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Custom Attributes

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Implemented by:
 SwC_DcSelSw

Verified by:

Link

Design Link

Automatic Checks

Test Environment

Test Manager

Automatic Design Documents

Model Advisor - SwC_DcSelSw

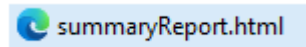
Model Advisor

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 - JMAAB Checks
 - Model Metrics
 - Simulink Requirements
 - BT Checks
 - Block settings
 - FT blocks used
 - FO blocks used

Simulink version: 10.0
 System: SwC_DcSelSw

Run Summary
 Pass 12
 Fail 0

Automatic review Documents



Automatic Test Specification



Code Coverage

Code Coverage analysis tool showing analyzed model results for SwC_DcSelSw.

ANALYZED MODEL	REPORT	COMPLEX	EXECUTION
GAULTA	11	100%	100%
ELS	11	100%	100%
SwC_DcSelSw	65	100%	100%
CLD	4	100%	100%

Test Manager interface showing test results and artifacts.

Test Results:

- Results: 2019-Apr-15 09:21:07 (1)
- Results: 2019-Apr-15 09:56:47 (1)
- Results: 2019-Apr-15 09:57:20 (1)
- Results: 2019-Apr-15 10:04:25 (1)
- Results: 2019-Apr-15 10:22:30 (1)

Baseline Criteria Result:

- S_DstPis (Active_Step) (1)
- S_DstPis (C_EnDstPis) (1)
- S_DstPis (C_RstDat) (1)
- Vc_Veh (1)
- Vc_Veh (1)

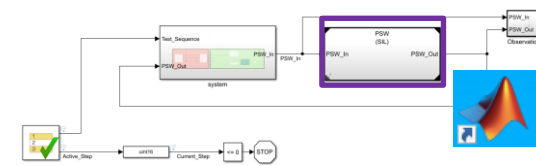
SIL

SIL analysis tool showing file SwC_DcSelSw.c and code generated for Simulink model.

Automatic Test Report



Integration Test



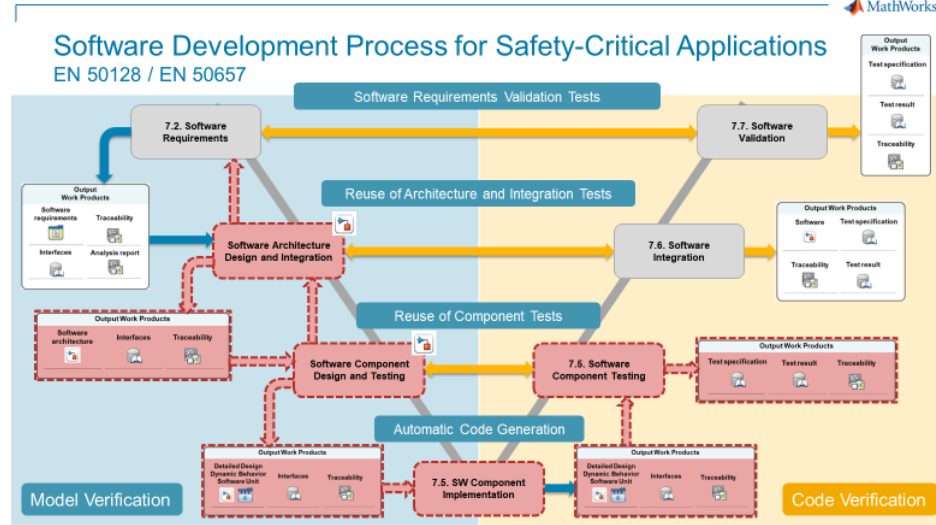
Model-Based Design: Software development

Source Requirements

EOS_PSW_RS-1978
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IBM Rational

EOS_PSW_SWRS.reqifz



Automatic Requirement Document



Index: 3.1.7.2
 Custom ID: 1978
 Summary: The manual DC selector switch has three positions. The switch shall be supervised via two binary inputs for

Description Rationale

Custom Attributes

Links

Implemented by: SwC_DcSelSw

Verified by:

Link

Design Link

Automatic Design Documents



Automatic Checks

Model Advisor - SwC_DcSelSw C:\Projects\PCU_NG\branches\4585\PCU_NG\yr

Model Advisor

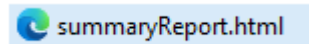
- BT model check configuration
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 - Simulink
 - EN 50128 Checks
 - MAAB Checks
 - JMAAB Checks
 - Model Metrics
 - Simulink Requirements
 - BT Checks
 - Block settings
 - FT blocks used
 - FO blocks used

Simulink version: 10.0
 System: SwC_DcSelSw

Run Summary

Pass 12
 Fail 0

Automatic review Documents



Test Environment

SwC_DcSelSw

- S_DcSelSwCst1 C_DcLibOpDcSelSw DcLibOpDcSelSw
- S_DcSelSwCst2 S_DcSelSwCst2 C_HrmDcSelSw HrmDcSelSw
- S_HvEn S_HvEn C_PrSelSw PrSelSw
- S_LeaderHc S_LeaderHc E_DcSelSwGnd DcSelSwGnd
- V_HvDcCst V_HvDcCst E_DcSelSwPb DcSelSwPb
- S_StuS1 S_StuS1 E_DcSelSwW DcSelSwW

Active_Step

uint16 CurrentStep == 0 STOP

Code Coverage

Code Coverage Report

ANALYZED MODEL	REPORT	COMPLEX	EXECUTION
GAUSS	11	100%	100%
ELS	11	100%	100%
SwC_DcSelSw	65	100%	100%
CLD	4	100%	100%

Automatic Test Specification



Test Manager

Test Manager

Test Browser Results and Artifacts

Filter results by name or tags, e.g. tags: test

- Results: 2019-Apr-15 09:21:07
- Results: 2019-Apr-15 09:56:47
- Results: 2019-Apr-15 09:57:20
- Results: 2019-Apr-15 10:04:25
- Results: 2019-Apr-15 10:22:30

Baseline Criteria Result

- S_DstPis
- Active_Step
- C_EnDstPis
- C_RstDat
- V_Veh

SIL

SIL Code Snippet

```

1 /*
2 * File: SwC_DcSelSw.c
3 *
4 * Code generated for Simulink model
5 *
6 * Model version
7 * Simulink Coder version
8 *
9 * /
```

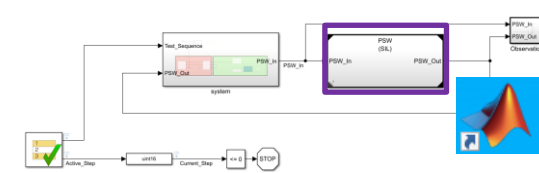
PIL

Emb. Code

Automatic Test Report



Integration Test



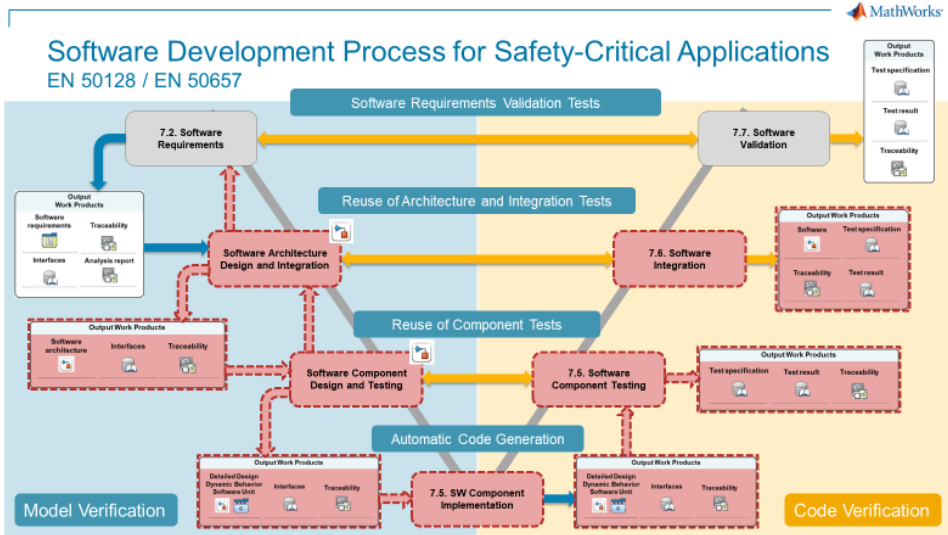
Model-Based Design: Software development

Source Requirements

EOS_PSW_RS-1978
 The manual DC selector switch has three positions.
 The switch shall be supervised via two binary inputs for status code 1 and 2.

IBM Rational

EOS_PSW_SWRS.reqifz



Automatic Requirement Document



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Custom Attributes

Links

Implemented by:
 SwC_DcSelSw

Verified by:

Link

Design Link

Automatic Design Documents

Automatic Design Documents



Automatic Checks

Model Advisor - SwC_DcSelSw
 C:\Projects\PCU_NG\branches\4585\PCU_NG\yr

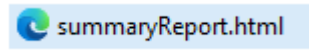
Model Advisor

- BT model check configuration
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 - MAAB Checks
 - JMAAB Checks
 - Model Metrics
 - Simulink Requirements
 - BT Checks
 - Block settings
 - FT blocks used
 - FO blocks used

Simulink version: 10.0
 System: SwC_DcSelSw

Run Summary
 Pass 12
 Fail 0

Automatic review Documents



Test Environment

SwC_DcSelSw

- S_DcSelSwCst1 C_DcLibOpDcSelSw DcLibOpDcSelSw
- S_DcSelSwCst2 S_HvEn C_PrSelSw HvmDcSelSw
- S_HvEn S_LeaderHc E_DcSelSwGnd DcSelSwGnd
- S_LeaderHc V_HvDcCst E_DcSelSwPb DcSelSwPb
- V_HvDcCst S_StuS E_DcSelSwW DcSelSwW
- S_StuS

unt16 CurrentStep ==> STOP

Code Coverage

Code Coverage analysis results showing analyzed models and their coverage percentages.

ANALYZED MODEL	REPORT	COMPLEX	EXECUTION
GAUSS	11	100%	
ELS	11	100%	
SwC_DcSelSw	65	100%	
CLD	4	100%	

Automatic Test Specification



Test Manager

Test Manager interface showing test results and artifacts.

Test Results:

- Results: 2019-Apr-15 09:21:07
- Results: 2019-Apr-15 09:56:47
- Results: 2019-Apr-15 09:57:20
- Results: 2019-Apr-15 10:04:25
- Results: 2019-Apr-15 10:22:30

Baseline Criteria Result

- S_DstPis
- Active_Step
- C_EnDstPis
- C_ResDat
- Vc_Vain
- Vc_Vain

SIL

File: SwC_DcSelSw.c

```

1 /*
2 * File: SwC_DcSelSw.c
3 *
4 * Code generated for Simulink model
5 *
6 * Model version
7 * Simulink Coder version
8 *
9 * /
```

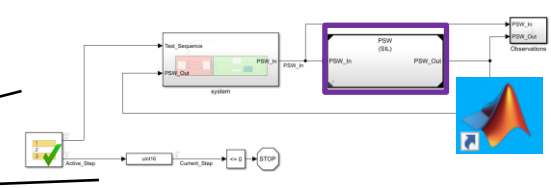
PIL

Emb. Code

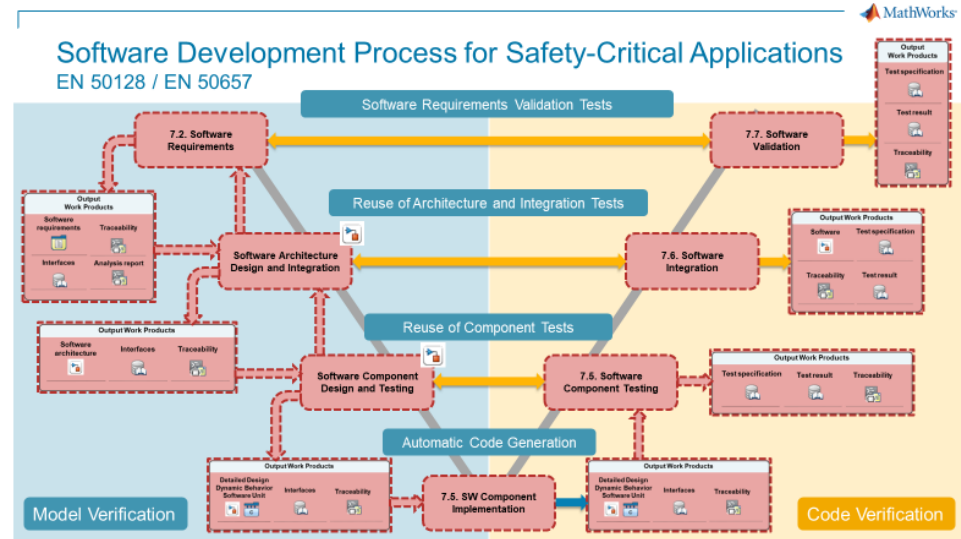
Automatic Test Report



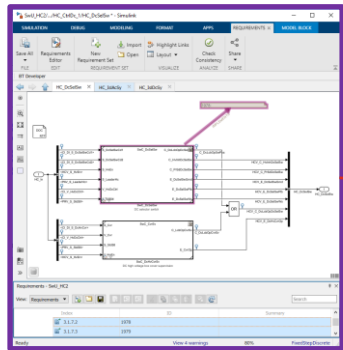
Integration Test



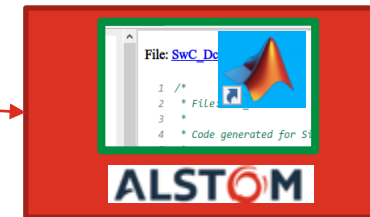
Model Based Design: Deployment



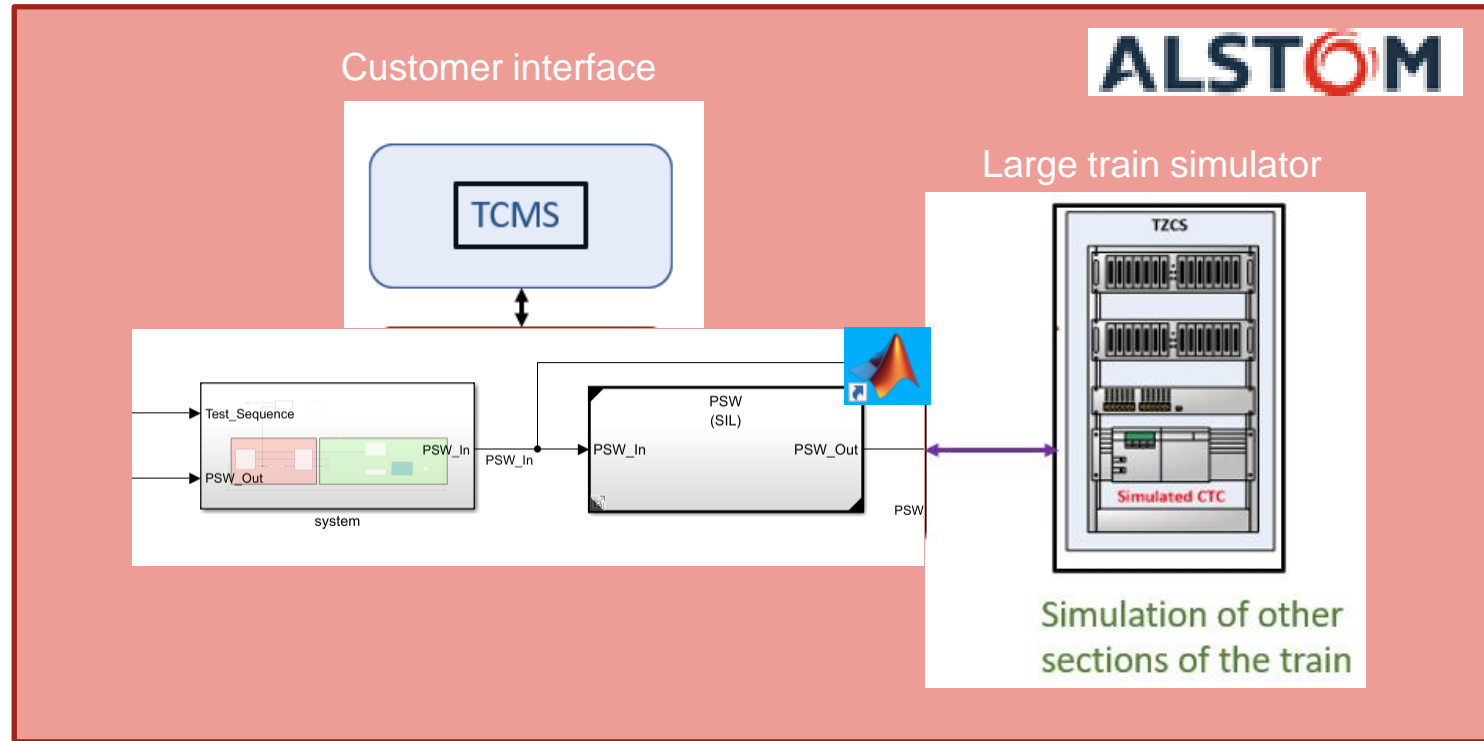
Design



Code Generation + Target Code



Model Based Design: Simulate together - Share models



Timeline – How far we have come

10 Year Journey and more to come

2013 - 2018

- MathWorks Model-Based Design Workflow running on controllers controlling 4MW traction systems
- Traction System functions verified with MBD
- First Software Development Process using MBD
- Targeted First order project
- Training and upskilling Traction Control Department

MathWorks®

MATLAB EXPO 2018 SWEDEN

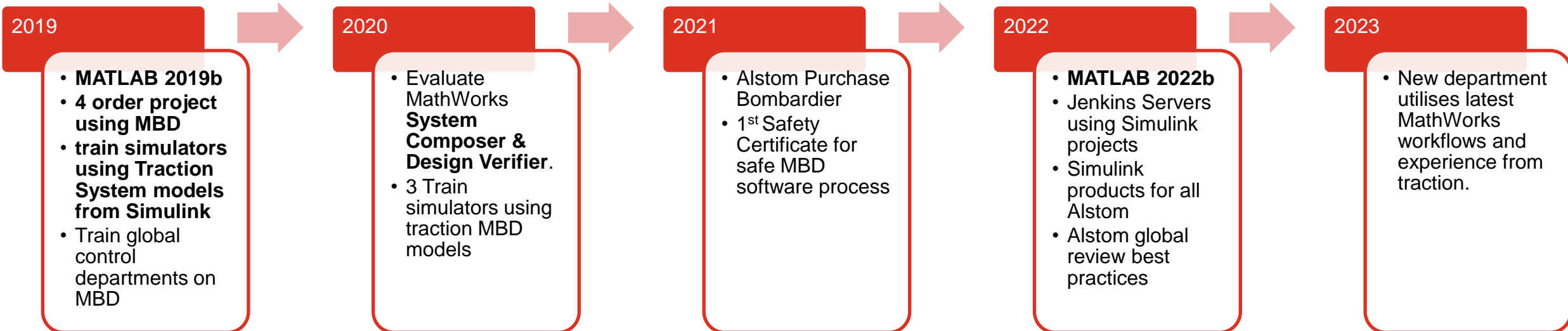
A Model-Based Design Adoption Story from Bombardier Transportation
15:00–15:30

Bombardier Transportation, Rolling Stock Equipment delivers world-class propulsion systems for trains. The propulsion system's main functionality is to convert electrical power to tractive effort to make the train move. The control system consists of multiple different sub-parts that together control various parts of a joint electrical circuit. With new development and applications including major customization needs, there is a consistent challenge to deliver on time with maintained quality. The propulsion system and control teams at Bombardier Transportation in Västerås decided to adopt Model-Based Design to address these challenges.

The goal of this presentation is to share the experience of transforming from virtually no use of Model-Based Design to where we are today. The presentation outlines the vital steps of our adoption story, including the need for changes, problem statements, use cases, commercial aspects, challenges, and the business case.



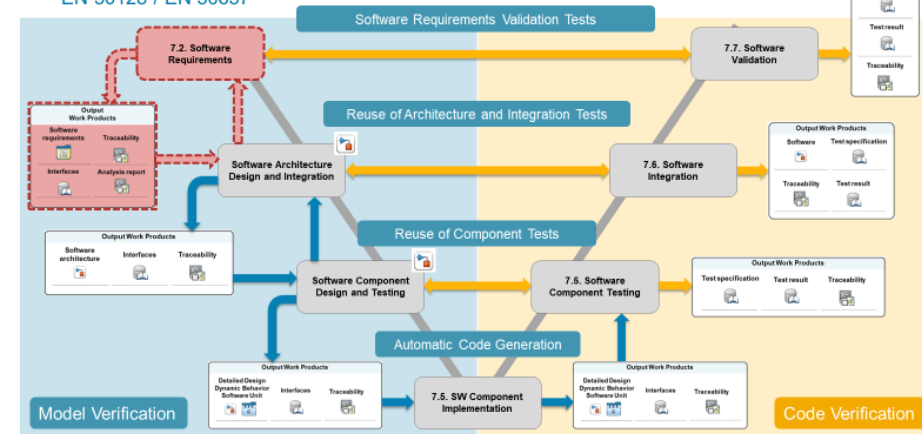
Erik Simonson, Bombardier



05

Future Model-Based Design Even Earlier modelling Failing Faster

Software Requirements Analysis



External Documents

Requirements Managements Tools

Import / Export

Author

Analyze

Trace

Index	ID	
✓	swe_req_BatteryManagementController	
1	BS-BMC-SW-1	Overview
2	BS-BMC-SW-2	BMC Software
2.1	BS-BMC-SW-2-1	Main State Ma
2.1.1	BS-BMC-SW-2-1-1	Main State Ma
2.1.2	BS-BMC-SW-2-1-2	Main State Ma
2.1.3	BS-BMC-SW-2-1-3	Main State Ma

Description	Rationale
Main State Machine software component	
<ul style="list-style-type: none"> Divide operational states of BMC into <ul style="list-style-type: none"> Standby State Fault State Charging State Driving State Manage transitions between operation from supervisory controller, contactor state measurements. 	

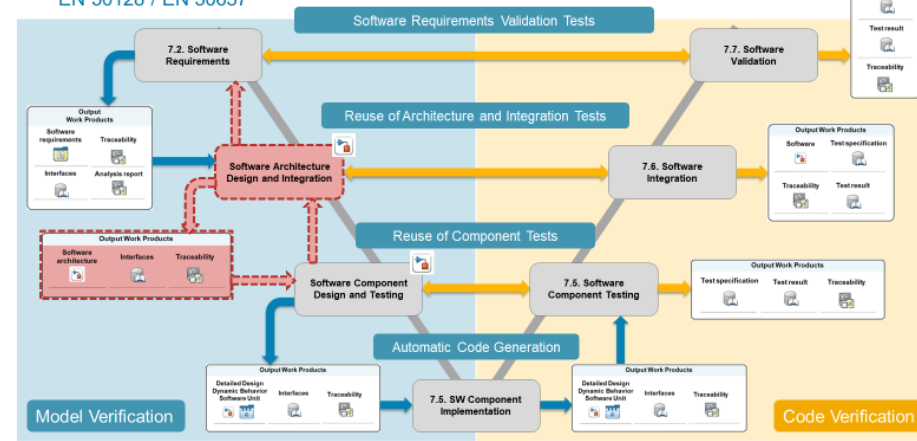
Requirements	Assumptions
Summary	
1	Requirement 1: Lock when evse compatible
2	Requirement 2: Unlock during normal shutdown

Exceptional conditions	shortest_path.m	shortest_path	isNodeValid	isAdjMatrixValid
Returns -9 for invalid adjacency				
Returns -19 if the start node is				
Returns -29 if end node is enco				

Output Work Products

- Software requirements
- Interfaces
- Traceability
- Analysis report

Software Architecture Design



External Documents

Requirements Managements Tools

Design

Define

Describe

Evaluate

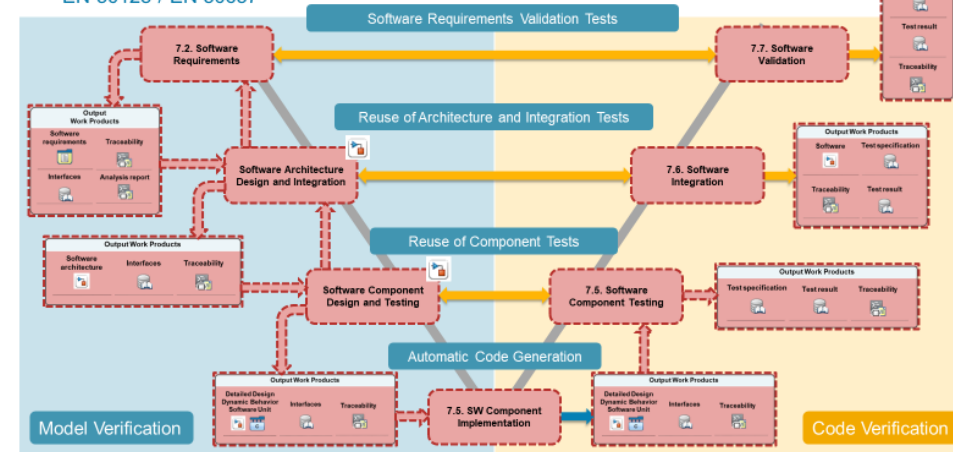
OUT	Type	Dimensions	Units	Complexity	Minimum	Maximum
BattV	double	1		real	0	0
BattCurr	double	1		real	0	0
BattPwr	double	1		real	0	0
BattSoc	double	1		real	0	0
HighV	double	1		real	0	0
Cell_Volt	single	6	V	real	0	5
Pack_Vo	single	1	V	real	0	480
Pack_Cu	single	1	A	real	-100	100
Cell_Ter	single	6	K	real	0	333.15
Vout_Ch	single	1	V	real	-500	500
Vout_Inr	single	1	V	real	-500	500

ECU	Select
ID	'ED1243'
Part_Number	'C124322'
Supplier	'Supplier_1'
Domain	
Sub_Domain	
Cost	0 Euro
Weight	0 Kg

Output Work Products

- Software architecture
- Interfaces
- Traceability

7.7 Software Validation



External Documents

Requirements Managements Tools

Specify

Select

Test

NAME	STATUS
Results: 2022-Sep-16 10:10:44	3 ✓
TC-01-BMC State-Initial	3 ✓
Driving_Charging_Rest	✓
Charging	✓
Driving	✓
Sim Output (BatteryManager)	
SOC_CC	
SOC_NN	—

Output Work Products

- Test specification
- Test result
- Traceability

Thank You
Welcome

[Jobsearch.alstom.com](https://www.jobsearch.alstom.com)
www.alstom.com



ALSTOM
• mobility by nature •