



Automated Physical Model Verification

Model Verification Framework using Simulink Test

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Schindler

About the Company



Founded in Switzerland in 1874, the Schindler Group is a leading global provider of elevators, escalators and related services.

Its innovative and environmentally-friendly access and transit management systems make an important contribution to mobility in urban societies.

In 2017, the Schindler Group generated revenue of almost CHF 10.2 billion. Schindler mobility solutions move more than one billion people every day all over the world. Behind the company's success are over 60,000 employees in more than 100 countries.

Model Based Engineering in Schindler

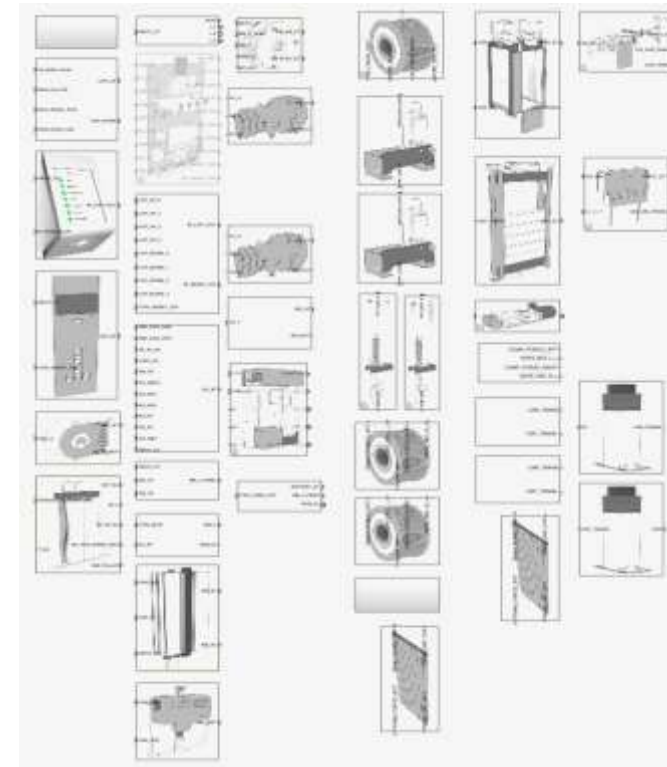
Introduction – MBE Enablers

EDEn – Elevator Dynamics Environment

An elevator modelling and simulation framework including model libraries, system models and applications. The models are capturing the core dynamic behaviour of an elevator system, as a multi-physics problem (mostly 1D). EDEn is the basis to perform elevator system level simulations and calculations

MATHS – Models' Automated Test Harnesses

An automated MIL verification and validation framework for EDEn models. MATHS includes automation of system and component tests, release tests, automated nightly builds and overall management of test cases and harnesses.

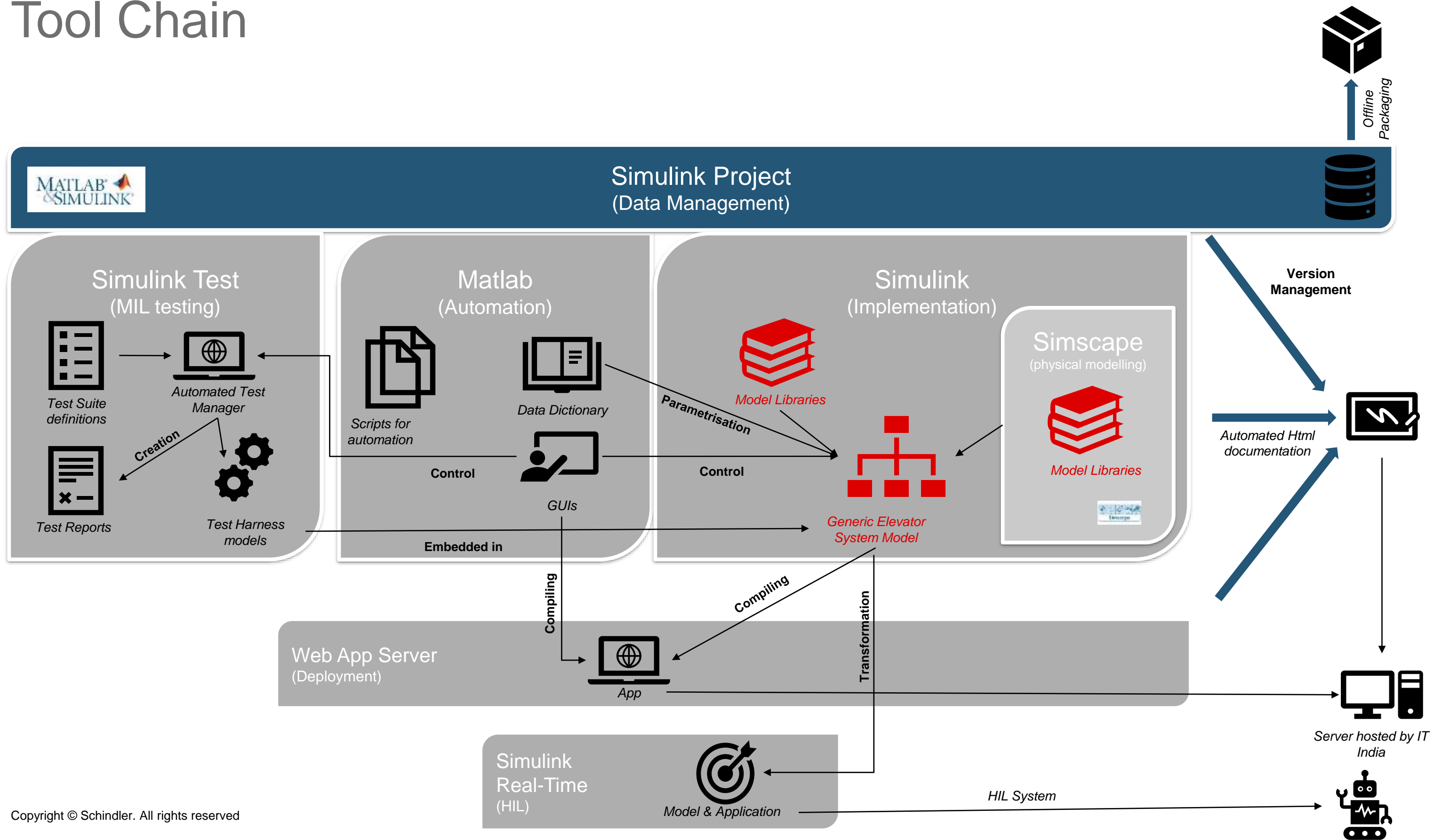


 Elevator System Simulation App by DT-M-MT Perform customized virtual elevator trips. There is even the possibility to conduct special operations such as: version 14.0	 PEBO App by DT-M-MT The PEBO app provides resulting evacuation distances and required battery charges for the pulsed version 14.0
 Seismic Oscillation App by DT-M-MT Seismic oscillations of the magnetic band of SALSIS are simulated and the displacement of the lower version 14.0	 Load Factor App by DT-M-MT The Load Factor App simulates load cases and calculates all relevant load factors. version 14.0

MathWorks
Simulink Test

Elevator System Models

Tool Chain



MATHS

Challenges for EDEn Model Verification

High complexity of system

- Generic models and different Use Cases
- High number of possible configurations (>2000 only from variant subsystems)
- Different variants of components
- Custom Simscape models

Baseline for the physical system

- No unique response – different for different configurations
- Time series based signals

Continuous improvement in EDEn

- Change in interfaces
- Change in Inputs and Outputs
- Reusability of Test Harnesses



Possibilities explored

Partners

- MathWorks ✓
- Third parties ✗

Technology

- MATLAB Script based solution ✗
- Simulink Test toolbox ✓

Test Harnesses

- Internal ✗
- External ✓

MATHS

Use Cases

ID	Use Case	Short Text	System Level	SS&C Level
UC01	Development tests for new features/functionalities implemented (“Unit Tests”)	Tests under this Use Case shall check physical and/or logic behaviour of new models against expected results. New/additional Test cases will be developed based on specifications used to develop the models.	No	Yes
UC02	Development tests for finding bugs/inconsistencies due to model migrations or conversion	Tests under this Use Case shall compare results of (older) stable EDEn release with new models developed in current sprint.	Yes	Yes
UC03	EDEn Sprint Release Tests	Test Campaign will be executed to cover different model configurations/variants	Yes	No
UC04	Schindler Product Validation Tests	E.g. Software Release Tests (SRTs) constituting AATs, BOTs, FMTs, special test cases	Yes	No
UC05	Validation	Tests under this Use Case shall cover the validation of EDEn system/ component with real test data. Test cases will base on the real tests (e.g. correlation of velocity profile and car position with test data)	Yes	Yes
UC06	System Identification and Parameter Estimation	This Use Case shall target the parameter tuning of EDEn components/subsystems (e.g. belt parameters, shaft friction, etc....)	No	Yes

MATHS Framework

Elements of MATHS

Overview

- Test Cases
- Components
- Scenarios
- Iterations
- Coverage
- Test Case ID

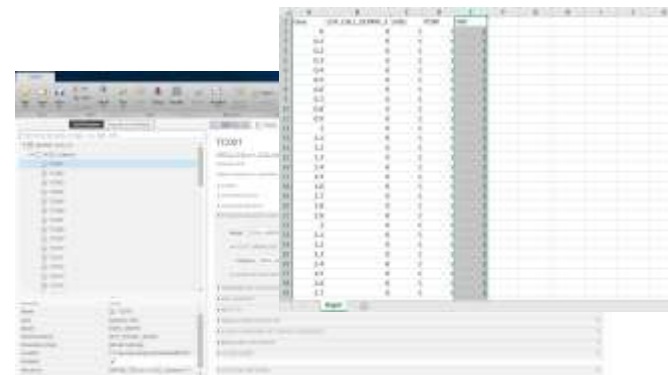
Excel based sheet
- Test Case Master



Test Components

- Test Harnesses
- Test Manager
- Input files
- Baseline files

- Simulink Test Toolbox
- Excel based input and baseline files



Test Management

- Test Specification
- Preconditions
- Tolerances
- Pass/fail conditions
- Documentation

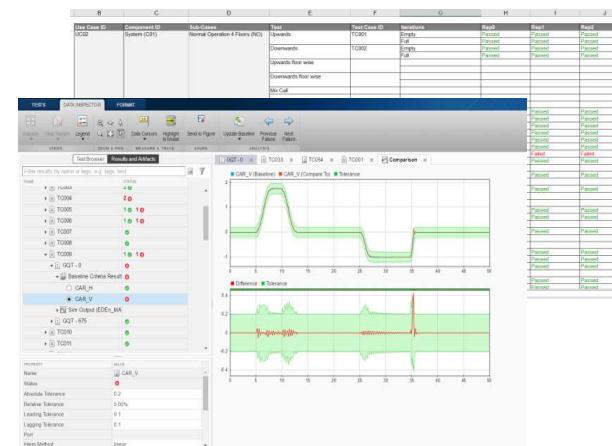
Excel based sheet
– Test Case Repository



Reporting

- Comprehensive Report
- Test information
- Detailed comparison graphs
- Configurations

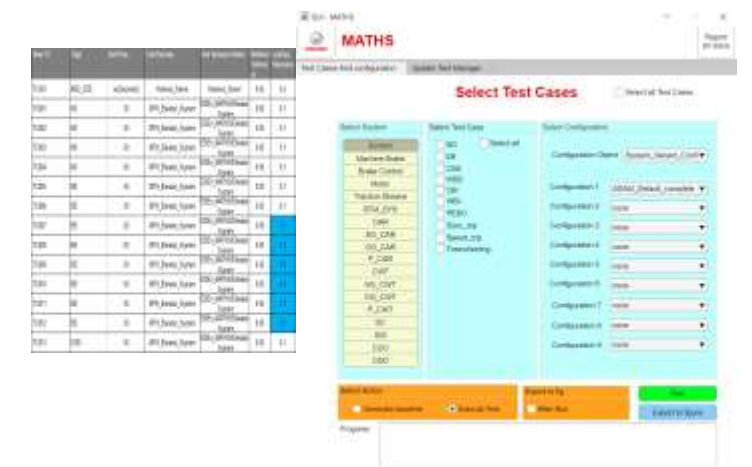
- Excel based sheet – Sprint Test Report
- .mldtax files



Automation


- GUI
- Script for variants and configuration
- Update Test Cases
- Test Execution
- JIRA integration

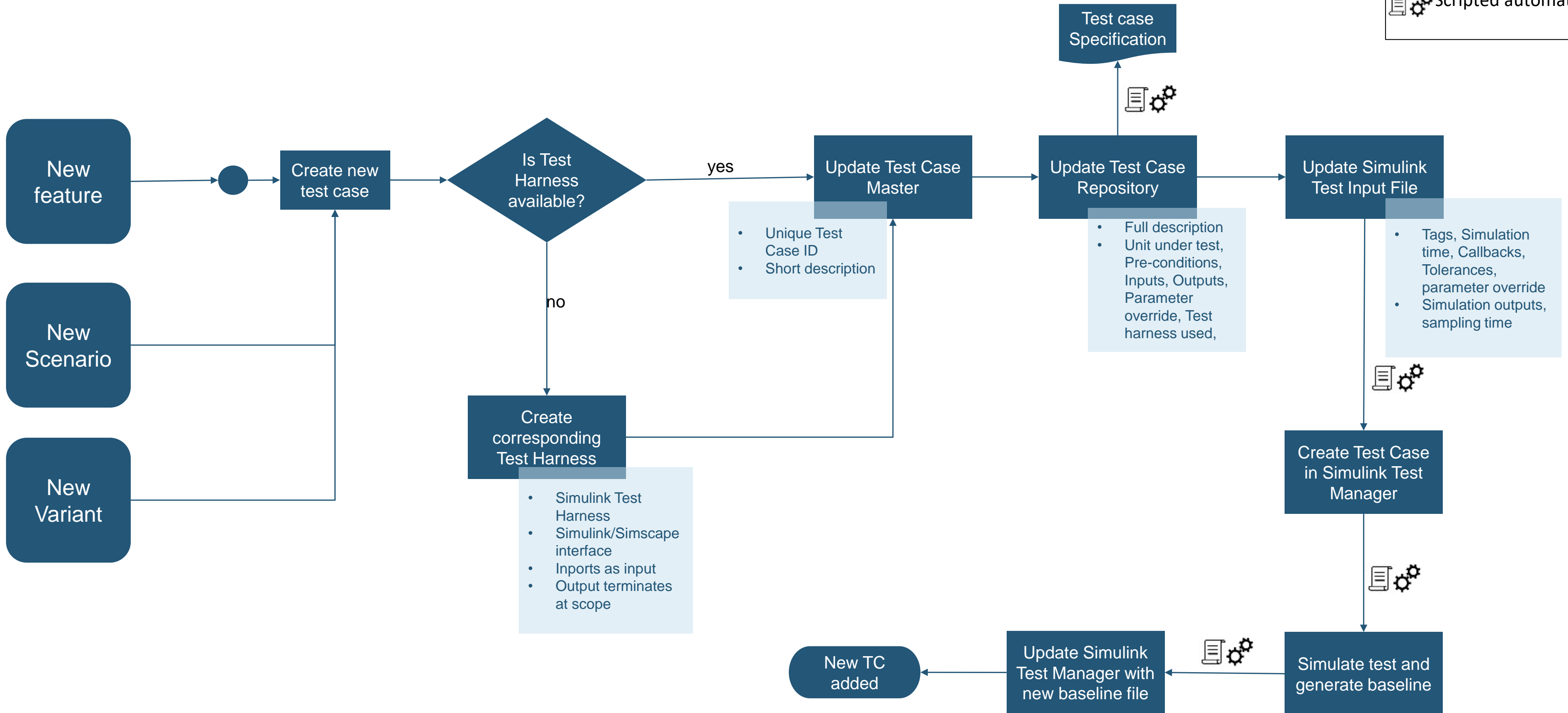
- MATHS_GUI
- Excel based sheet – Simulink Test Input file



MATHS Workflow

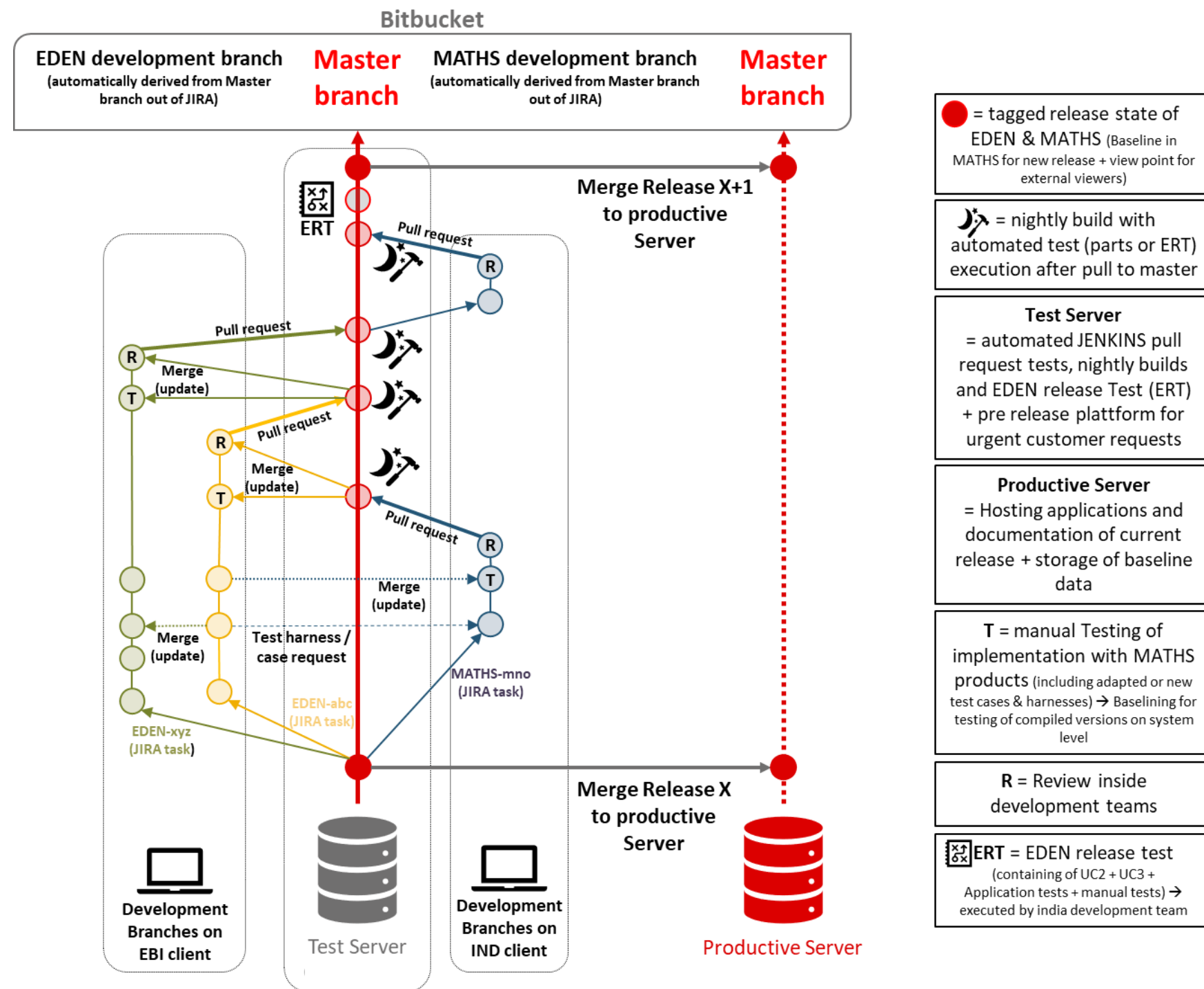
Add New Test Cases

 Scripted automation



MATHS Integration with EDEN

Collaboration between Development and Testing



- This workflow outlines the automated test routine for new features, bug fixes and release test.

Test Execution and Reporting MATHS GUI

GUI - MATHS

MATHS Report an issue

Test Cases And configuration | Update Test Manager

Select Test Cases

Select all Test Cases

Select System

- System
- Machine Brake
- Brake Control
- Motor
- Traction Sheave
- STM_SYS
- CAR
- SG_CAR
- OG_CAR
- P_CAR
- CWT
- SG_CWT
- OG_CWT
- P_CWT
- SC
- SIS
- CDO
- CDD

Select Test Case

NO Select all

EB

CSB

WSB

CBI

WBI

PEBO

Sync_trip

Speed_trip

Freewheeling

Select Configuration

Configuration Object: DefaultConfig

Configuration 1: Configuration 1

Configuration 2: Configuration 2

Configuration 3: Configuration 3

Configuration 4: Configuration 4

Configuration 5: Configuration 5

Configuration 6: none

Configuration 7: none

Configuration 8: none

Configuration 9: none

Select Action | **Export to fig** | **Run**

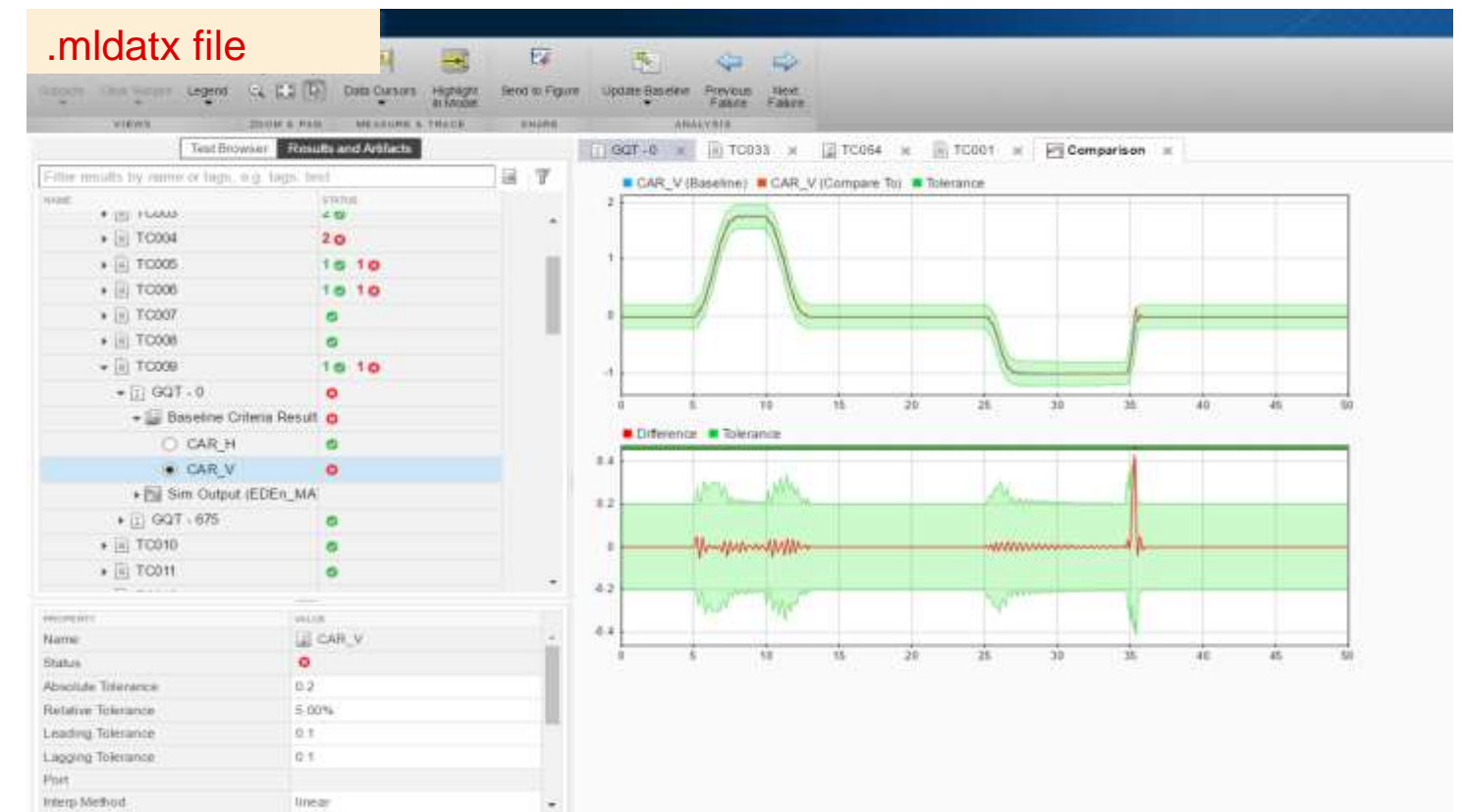
Generate baseline | Execute Test | After Run | **Export to figure**

Progress:

Excel sheet

UC02	System (C01)	Normal Operation 4 Floors (NO)	Test	Test Case ID	Iterations	Rep0	Rep1	Rep2
			Upwards	TC001	Empty	Passed	Passed	Passed
			Downwards	TC002	Full	Passed	Passed	Passed
			Upwards floor wise		Empty	Passed	Passed	Passed
			Downwards floor wise		Full	Passed	Passed	Passed
			Mix Call					
		Emergency Braking (EB)	upwards.power cut	TC003	Empty	Passed	Passed	Passed
			upwards, safety chain	TC004	Empty (VCK2 = 1.5)	Passed	Passed	Passed
			downwards.power cut	TC005	Full (VCK2 = 1.5)	Passed	Passed	Passed
			downwards, safety chain	TC006	Empty (VCK1= 1.5)	Failed	Failed	Failed
					Full (VCK1= 1.5)	Passed	Passed	Passed
		Car Safety Gear Braking (CSB)	Full downwards	TC007		Passed	Passed	Passed
		Counterweight Safety Gear Braking (WSB)	Empty upwards	TC008		Passed	Passed	Passed
		Car Buffer Impact (CBI)	Downwards Speed Trip (0)	TC009	Empty	Failed	Passed	Passed
					Full	Failed	Passed	Passed
		Counterweight Buffer Impact (WBI)	Upwards Speed Trip	TC010		Failed	Passed	Passed
		PEBO	Car Empty	TC022		Passed	Passed	Passed
			Car Full	TC023		Passed	Passed	Passed
			Car weight balancing CWT	TC024		Passed	Passed	Passed
		Synchronization Trip	In between floor	TC025		Passed	Passed	Passed
			Ground floor	TC027		Passed	Passed	Passed

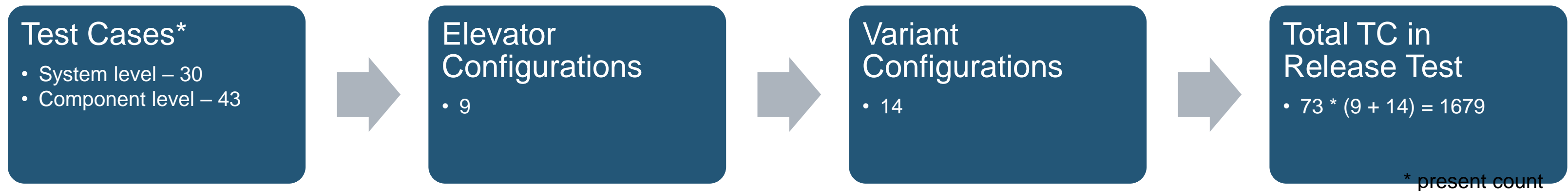
.mldatx file



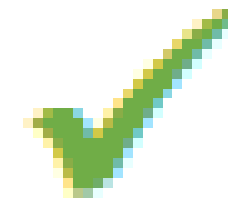
Result Achieved

Proper Implementation of Scrum Methodology in MBE

Automated testing helped us to implement proper development and testing cycle for sprint releases



- Full proof EDEn release with test time of 2 days – more development time
- Test execution synchronized with JIRA ticket closure (Triggered by Simulink Project branch merge)
- No manual intervention, except for harness modification and test case addition



- **Future – Extend MATHS to test EDEn App GUIs**

Take Away

The harmonized tool chain under one umbrella helped us achieve the seemingly difficult (complex due to our product configurations) task of implementing Model Based Engineering approach in product development cycle. MBE will not only be used for validation purposes but will, in the future, also become more and more important for qualification and certification.

MIL testing of the EDEn models is crucial, to ensure the quality and correctness of EDEn models. Simulink Test toolbox is central to our all MIL verification and validation activities. With the parallel test execution (Parallel Computing toolbox) option, we can substantially increase the number of configurations to be tested.



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