

Paris, 16-18 October 2018



Organizer:  TESTING  
SOLUTIONS  
& SERVICES

# INTEGRATED FRAMEWORK FOR DEVELOPMENT AND TESTING OF SAFETY-CRITICAL AUTOMOTIVE MECHATRONIC SYSTEMS

Presented by Nick VAN KELECOM

**SIEMENS**  
*Ingenuity for life*



# Industry challenges

Extensive testing is necessary to solve these challenges...



... But current testing methods seem incapable.



# Industry Testing Flaws

Disconnect between  
requirements and test  
cases

Loading incorrect version

~~Derive~~

Test Cases

Initiate

Test Environment Model for:  
Unit Testing  
Integration Testing

Validate



Trigger incorrect  
tests / Skip  
important tests

Disconnect between results  
and test cases/requirements

# Problem Identification

Requirement – Test Case Traceability

Test Trigger Management

Test Environment Management

Test Result Management



# Central requirement and test case management

## Enable tracing through unique identifiers

Requirement – Test Case Traceability

Test Trigger Management

Test Environment Management

Test Result Management

### HP\_T\_Ctrl

**EN-1979** roller must calculate the desired load of the hydraulic pump (Load\_HP) [-1..1] and the actual power of the HP (actual\_W) [W] based on:

- The absolute target rotational speed of the hydraulic pump (w\_HP\_target\_radps) [rad/s]
- The absolute current rotational speed of the hydraulic pump (w\_HP\_actual\_radps) [rad/s]
- The power that is requested from the ICE (P\_ICE\_W) [W]
- Power split factor ζ [0..1]
- The pressure difference between the high and low pressure line (delta\_p\_Pa) [Pa]
- The maximum displacement of the hydraulic pump (vehicle\_parameters HP\_max\_V) [m<sup>3</sup>/rad]

based on following formulas:

$$V = \frac{P}{\Delta p \cdot \omega}$$

$$Load = \frac{V}{V_{max}}$$

### HP\_T\_Ctrl Test Cases

1 EN-1979

**EN-2044** when w\_HP\_actual and w\_HP\_target is positive. This means a positive corrective action by the PID. The error stays the same, however the corrective action of the PID will increase linearly. This means that T\_HP\_Target and subsequently Load\_HP will always decrease, and around t=4s, it will be lower than the upper bound of 1.

time [s]	w_HP_Target_radps [rad/s]	P_HP_Target_W [W]	delta_p_Pa [Pa]	w_HP_actual_radps [rad/s]	Ref_Out_Load_HP [0..1]
0	157	20000	15000000	50	1
1	157	20000	15000000	50	1
2	157	20000	15000000	50	1
3	157	20000	15000000	50	1
4	157	20000	15000000	50	1
5	157	20000	15000000	50	0.999173
6	157	20000	15000000	50	0.910155

#### Linked Work Items

Suspect	Role	Title
	is verified by	EN-2044 - [HP_T_Ctrl_1] The controller must c
	is verified by	EN-2155 - [HP_T_Ctrl_2] The controller must c
	is verified by	EN-2425 - [HP_T_Ctrl_3] The controller must c

#### Linked Work Items

Suspect	Role	Title
	verifies	EN-1979 - [HP_T_Ctrl] The controller must ca

Ensure bidirectional traceability

Requirement – Test Case Traceability

## Model-based architecture representation Track development status for test trigger

Test Trigger Management

Test Environment Management

Test Result Management

EN-2457 - E_MGMT status: Under Development progress: Finalizing	EN-2492 - Hyd_F status: Implemented progress: Done	EN-2567 - HM_P_T_limit status: Implemented progress: Done	EN-2571 - Zerodiv_Protection status: Implemented progress: Done
	EN-2493 - Comb_F status: Under Development progress: Ongoing	EN-2499 - ICE_P_Target status: Under Development progress: Finalizing	
		EN-2500 - ICE_T_Target status: Under Development progress: Finalizing	
		EN-2501 - HP_V_Target status: Under Development progress: Finalizing	EN-2502 - HP_T_Ctrl status: Under Development progress: Ongoing
		EN-2570 - Powersplit_factor status: Implemented progress: Done	EN-2571 - Zerodiv_Protection status: Implemented progress: Done
		EN-2554 - ICE_Efficiency_Target status: Implemented progress: Done	

Filter models on status for correct testing phase

Model Identity Card containing:

- Model status
- Model progress
- Requirements
- Test cases
- Description
- Test results

Requirement – Test Case Traceability

Test Trigger Management

Test Environment Management

Test Result Management

## Model status triggers correct test phase Support for continuous integration



User initiates status change



User checks results and takes appropriate next action



Central management software running on remote server (with SVN capabilities)

Extract model properties and pass to CI server



Dedicated testing server using Jenkins for communication (with SVN capabilities)

Commit results back

EN-2501 +  
EN-2502 - HP\_T\_Ctrl  
EN-2571 +

Type: Atomic Model

\*Status: Under Development → Implemented

\*Progress: Ongoing



Requirement – Test  
Case Traceability

Test Trigger  
Management

Test Environment  
Management

Test Result  
Management

## Automatically build correct test environment Improve test case reusability



Test cases written textually



Dedicated testing server using Jenkins for  
communication (with SVN capabilities)

Requirement – Test Case Traceability

Test Trigger Management

Test Environment Management

Test Result Management

## Automatically build correct test environment Improve test case reusability



Test cases written textually



Dedicated testing server using Jenkins for communication (with SVN capabilities)

Create empty data sheet customized to MUT

Manually translate into actual test data



Generic platform for optimal test data reuse

	A	B	C	D
1	time	Throttle	Brake	Ref_Out_Pedal_info_open_loop
2	0	0	0	0
3	1	0.2	0	0.2
4	2	0.3	0	0.3
5	3	0.4	0	0.4
6	3	0.4	-0.7	-0.7
7	4	0	-0.6	-0.6
8	5	0	-0.3	-0.3

Requirement – Test Case Traceability

Test Trigger Management

Test Environment Management

Test Result Management

## Automatically build correct test environment Improve test case reusability

Dependent on XiL testing platform:



Automatic test environment created customized to MUT:

- Functional unit testing with
  - Reference output signals (MiL) (with SVN capabilities)
  - Back-to-back test (SiL)



- Performance integration testing with high-fidelity plant models

→ Proven re-usability of test cases



- Hardware – Software integration testing with high fidelity plant models running in real-time

Create custom model-specific testing environment



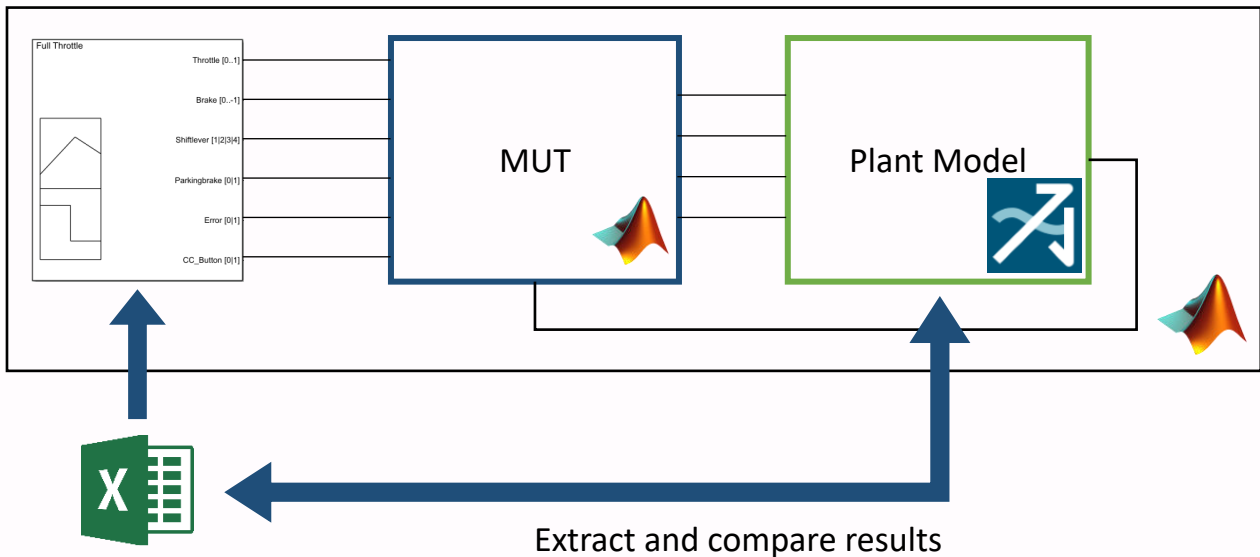
Requirement – Test Case Traceability

Test Trigger Management

Test Environment Management

Test Result Management

# Example: Testing Black Box for MiL integration test



Requirement – Test Case Traceability

Test Trigger Management

Test Environment Management

Test Result Management

## Automatically build correct test environment Improve test case reusability



Test cases written textually

Activate



Dedicated testing server using Jenkins for communication (with SVN capabilities)

Create empty data sheet

Manually translate into actual test data



Push test data

Create custom model-specific testing environment



Run tests and bring results back

# Easy overview of nightly test run results Initiator for team planning

Requirement – Test Case Traceability

Test Trigger Management

Test Environment Management

Test Result Management

## General Overview

ID	Model Name	Completion	Decision	MDCDC Cov (%)	Execution Cov (%)	Condition Cov (%)	Decision Cov (%)	Warning (License) (Pct)	ISO 26262 (Pct)	Block count	OpenChange
001-0044	Driver_Memories	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0045	DRM_1000_001	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0046	DRM_1000_002	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0047	DRM_1000_003	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0048	DRM_1000_004	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0049	DRM_1000_005	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0050	DRM_1000_006	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0051	DRM_1000_007	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0052	DRM_1000_008	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0053	DRM_1000_009	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0054	DRM_1000_010	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0055	DRM_1000_011	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0056	DRM_1000_012	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0057	DRM_1000_013	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0058	DRM_1000_014	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0059	DRM_1000_015	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0060	DRM_1000_016	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0061	DRM_1000_017	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0062	DRM_1000_018	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0063	DRM_1000_019	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0064	DRM_1000_020	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0065	DRM_1000_021	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0066	DRM_1000_022	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0067	DRM_1000_023	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0068	DRM_1000_024	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0069	DRM_1000_025	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0070	DRM_1000_026	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0071	DRM_1000_027	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0072	DRM_1000_028	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0073	DRM_1000_029	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0074	DRM_1000_030	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0075	DRM_1000_031	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0076	DRM_1000_032	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0077	DRM_1000_033	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0078	DRM_1000_034	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0079	DRM_1000_035	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0080	DRM_1000_036	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0081	DRM_1000_037	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0082	DRM_1000_038	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0083	DRM_1000_039	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0084	DRM_1000_040	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0085	DRM_1000_041	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0086	DRM_1000_042	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0087	DRM_1000_043	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0088	DRM_1000_044	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0089	DRM_1000_045	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0090	DRM_1000_046	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0091	DRM_1000_047	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0092	DRM_1000_048	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0093	DRM_1000_049	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0094	DRM_1000_050	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0095	DRM_1000_051	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0096	DRM_1000_052	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0097	DRM_1000_053	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0098	DRM_1000_054	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0099	DRM_1000_055	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0100	DRM_1000_056	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0101	DRM_1000_057	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0102	DRM_1000_058	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0103	DRM_1000_059	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0104	DRM_1000_060	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0105	DRM_1000_061	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0106	DRM_1000_062	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0107	DRM_1000_063	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0108	DRM_1000_064	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0109	DRM_1000_065	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0110	DRM_1000_066	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0111	DRM_1000_067	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0112	DRM_1000_068	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0113	DRM_1000_069	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0114	DRM_1000_070	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0115	DRM_1000_071	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0116	DRM_1000_072	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0117	DRM_1000_073	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0118	DRM_1000_074	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0119	DRM_1000_075	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0120	DRM_1000_076	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0121	DRM_1000_077	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0122	DRM_1000_078	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0123	DRM_1000_079	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0124	DRM_1000_080	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0125	DRM_1000_081	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0126	DRM_1000_082	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0127	DRM_1000_083	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0128	DRM_1000_084	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0129	DRM_1000_085	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0130	DRM_1000_086	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0131	DRM_1000_087	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0132	DRM_1000_088	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0133	DRM_1000_089	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0134	DRM_1000_090	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0135	DRM_1000_091	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0136	DRM_1000_092	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0137	DRM_1000_093	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0138	DRM_1000_094	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0139	DRM_1000_095	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0140	DRM_1000_096	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0141	DRM_1000_097	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0142	DRM_1000_098	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0143	DRM_1000_099	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0
001-0144	DRM_1000_100	FAIL	FAIL	0%	0%	0%	0%	0%	0%	0	0

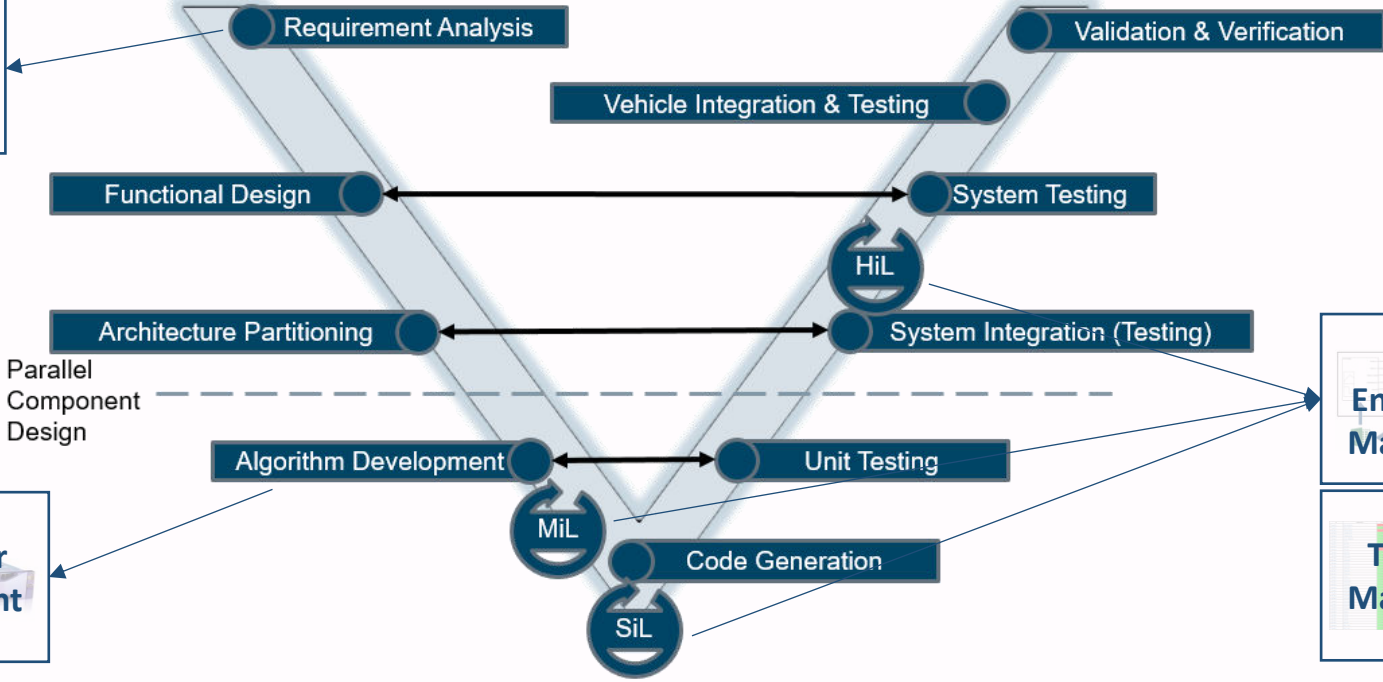
## Model-Specific Overview

- General
  - Linked Model: EN-2502
  - Compile Check: SUCCESS
  - Compile Error Message:
  - Model Block Count: 24
  - Cyclomatic Complexity: 6
- Model Analysis results
  - General Passed: 60
  - General Warning: 7
  - General Failed: 0
  - ISO 26262 Passed: 6
  - ISO 26262 Warning: 2
  - ISO 26262 Failed: 0
- Performance tests
  - Functionality Error Pass: 23
  - Functionality Error Fail: 1
- Code Coverage results
  - MDCDC Coverage (%): N/A
  - Decision Coverage (%): 50
  - Condition Coverage (%): N/A
  - Execution Coverage (%): 100



**More effort spent upstream to reduce later re-work**

**Requirement/  
Test Case  
Management**



**Test Trigger  
Management**

**Test  
Environment  
Management**

**Test Result  
Management**

# Future Work

- Extend framework to HiL testing
- Improve architecture capabilities
  - Architecture design
  - Architecture testing
- Improve functional safety capabilities
- ...

# Thank You

Nick Van Kelecom

Research Engineer MBSE

Embedded Systems & Controls

Simulation & Testing Solutions

Siemens Industry Software NV

[nick.van\\_kelecom@siemens.com](mailto:nick.van_kelecom@siemens.com)