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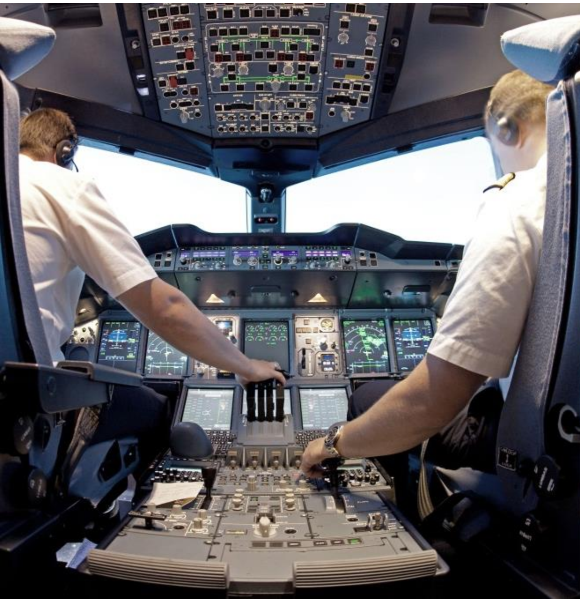
SCADE User Group Conference, 15.10.2015

Developing Software for the A350 XWB Slat Flap Control Computer with SCADE



Paul Linder, Diehl Aerospace

Overview

1 **Company Presentation**

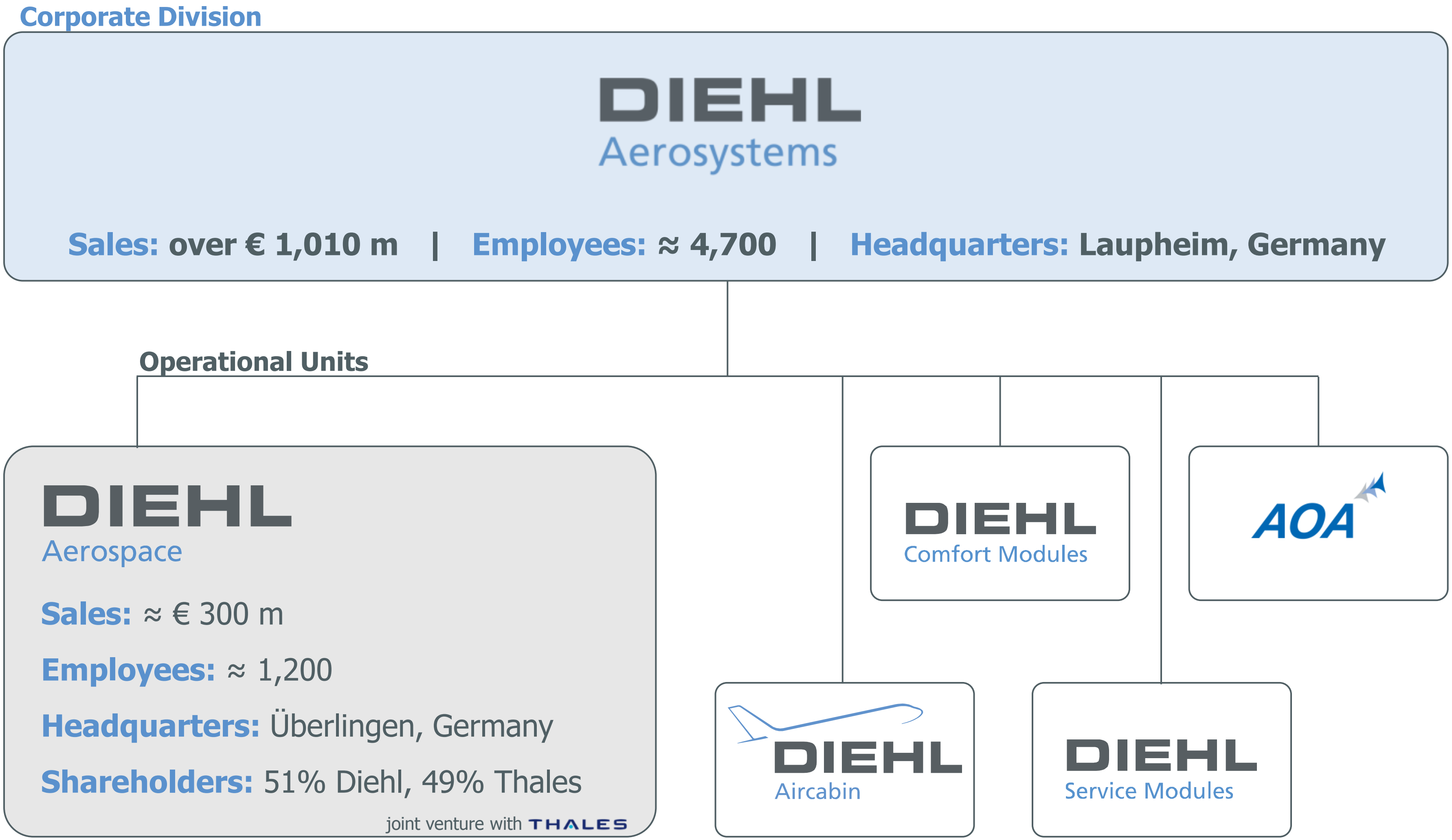
2 Introduction to the A350 XWB SFCC

3 Development Procedure

4 Modeling Guidelines and Verification Methods

5 Experiences

Diehl Aerospace (DAs)



Corporate Division

DIEHL Aerosystems

Sales: over € 1,010 m | **Employees:** ≈ 4,700 | **Headquarters:** Laupheim, Germany

Operational Units

DIEHL Aerospace

Sales: ≈ € 300 m

Employees: ≈ 1,200

Headquarters: Überlingen, Germany

Shareholders: 51% Diehl, 49% Thales

joint venture with THALES

DIEHL Comfort Modules

AOA

DIEHL Aircabin

DIEHL Service Modules

Numbers are based on forecast 2015

System Expertise

Flight Control

- Slat Flap Control Computer
- Flaps Lever
- Position Pick-Off Unit

Doors & Slides Management System

- Doors & Slides Management Control Unit
- Local Door Controller
- Autonomous Standby Power Supply Unit
- Control Panels & Indicators
- Sensing
- Swivel Actuator

Integrated Modular Avionics

- Core Processing Input/Output Module (CPIOM)
- Standardized hardware module, I/O capabilities & mechanical packaging
- IMA Tool Suite

Lighting & Interior Functions

- Cabin Lighting Systems
- Cabin Mood Lighting Systems
- Emergency Lighting Systems
- Starlight Systems
- Noise Masking Systems
- Full Automatic Hat Rack Systems

Major Customers and Platforms

Civil

AIRBUS

- A300/310 Family
- A320 Family
- A330/340 Family
- A380 Family
- A350 XWB Family

BOEING

- 737 Family
- 747 Family
- 767 Family
- 777 Family
- 787 Family

BOMBARDIER

- Bombardier Q400
- Global 7000/8000

EMBRAER

- E170/190
- E135/140
- Legacy 600

Military

- A400M
- Eurofighter
- KC-46A Tanker
- NH90
- Tiger
- Tornado

Company Trailer

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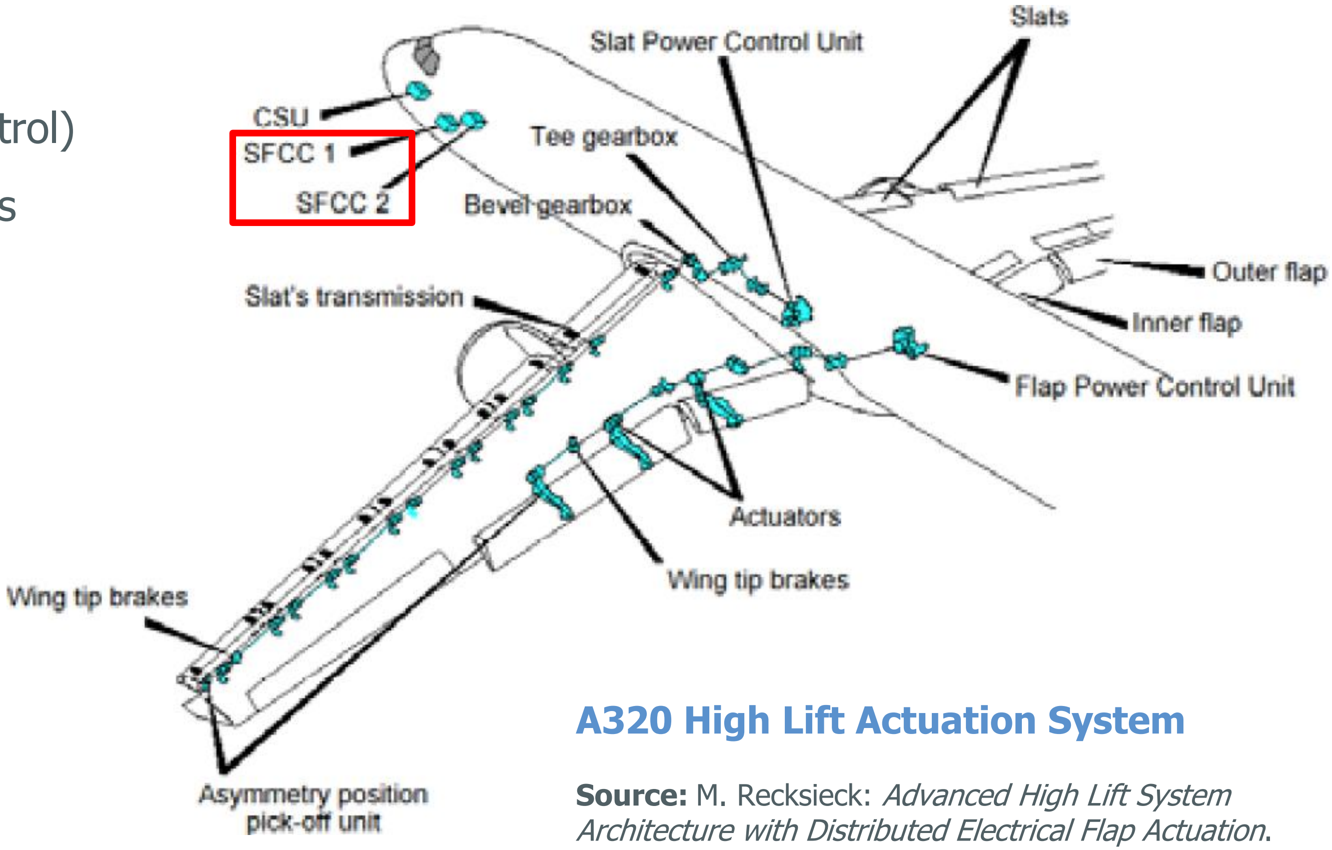
What is a Slat Flap Control Computer?

- Slat Flap Control Computer (SFCC)
  - Safety-related fly-by-wire system (secondary flight control)
  - Controls and monitors high lift system
- High lift system
  - Increases lift for take-off and landing

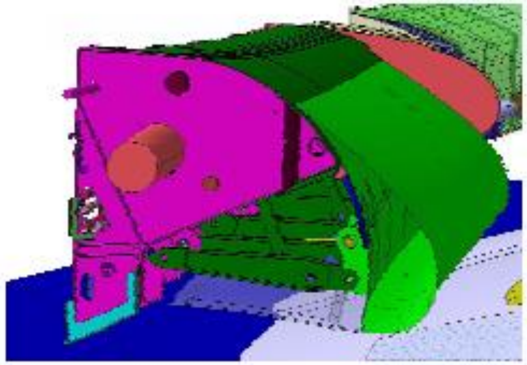


A320 High Lift Actuation System

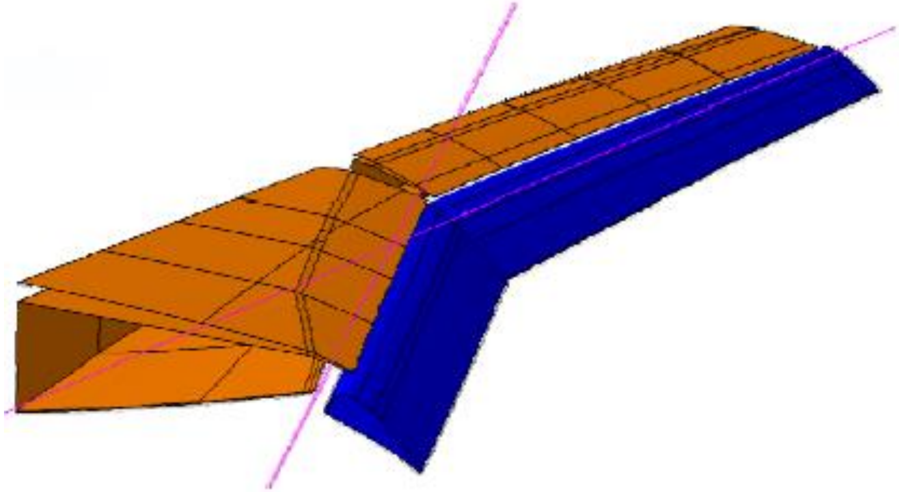
Source: M. Recksieck: *Advanced High Lift System Architecture with Distributed Electrical Flap Actuation*. Workshop on Aviation System Technology (AST) 2009.

A350 XWB High Lift System

- Technologies
  - – Droop-nose device on inboard wing
  - – Multifunctional trailing edge flap system: Adaptive Dropped Hinge Flap
  - – Integrated use as high-lift device and for in-flight adaptation of cruise wing shape



- Benefits
  - – Fuel burn reduction through drag saving
  - – Load alleviation functions and cruise efficiency enhancement



Source: D. Hills: *The Airbus Challenge* : EADS Engineering Europe, Budapest 9-10th May 08.

A350 XWB Slat Flap Control Computer

- Functionality
  - Determination and control of surface position including load alleviation functions
  - Monitoring of high lift system and components (e.g. power control unit)
  - Test functions and maintenance services (BITE)
  - AFDX data loading for SW update

- Design
  - 2 exchangeable SFCCs with 2 independent channels (slat/flap) per SFCC
  - Redundant and dissimilar design
  - Overall 16 micro controllers and several DSPs
  - Level A design assurance

Note: A350 XWB SFCC similar to depicted A380 SFCC.

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Project Context

- Project context
  - Equipment development project according to ARP-4754 / DO-254 / DO-178B level A
  - Schedule DAs: 07/2008 – ongoing (type certification on 30.09.2014)
- SCADE involvement
  - SCADE applied for level A development of SFCC application SW
    - Parallel to development of manually coded basic software (e.g. scheduling, driver, data loading)
    - ~150 application SW modules (e.g. high-lift system monitors, component monitors)
  - SCADE version 5.1 applied
    - Only data flow diagrams
    - No state-charts (due to tool qualification constraints), no higher-order functions

DAs SCADE Development Procedure

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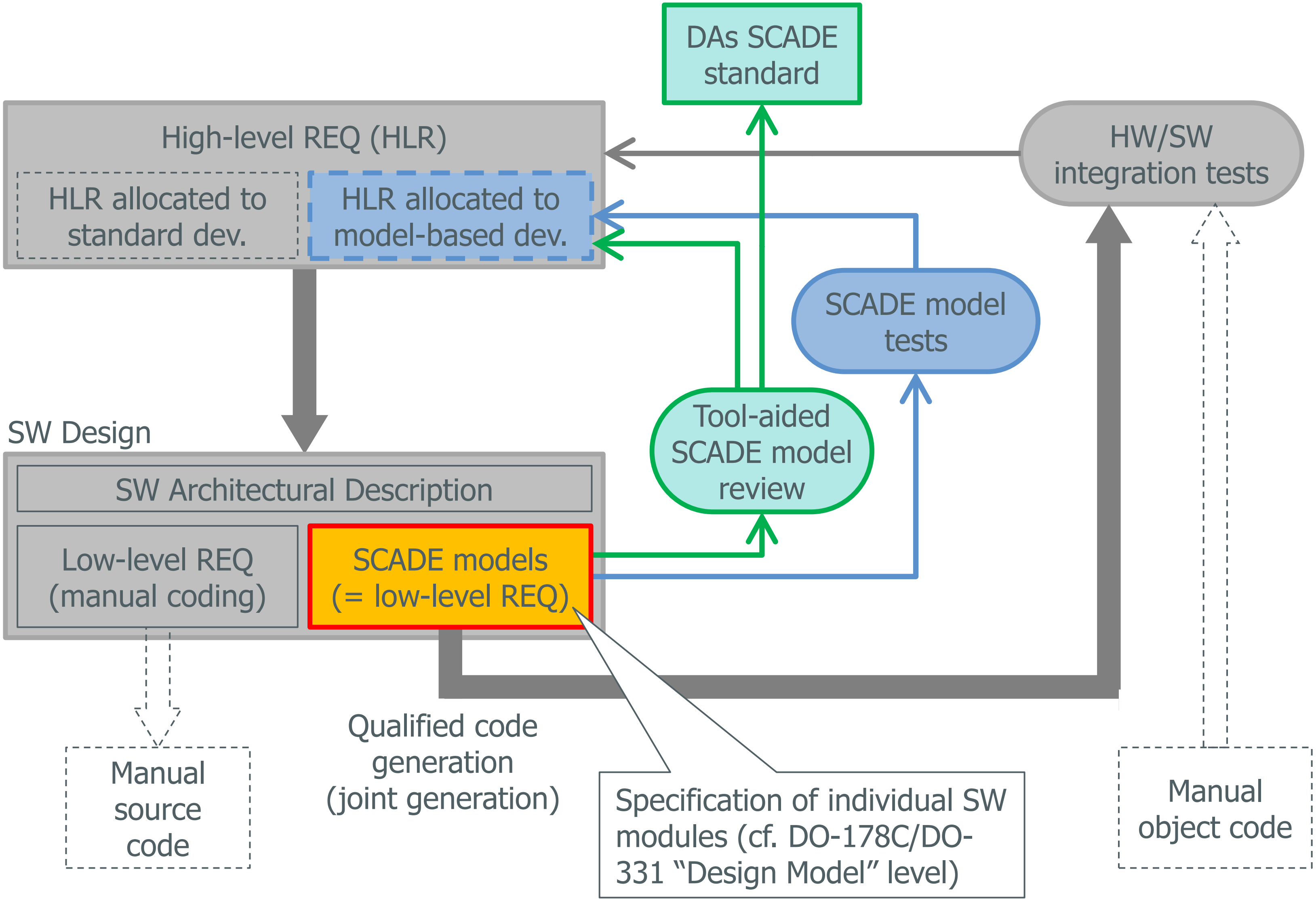
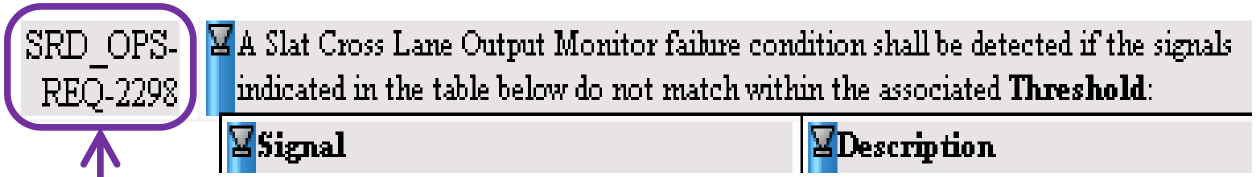

DAs SCADE standard
High-level REQ (HLR)
HLR allocated to standard dev.
HLR allocated to model-based dev.
HW/SW integration tests
SCADE model tests
Tool-aided SCADE model review
SW Design
SW Architectural Description
Low-level REQ (manual coding)
SCADE models (= low-level REQ)
Qualified code generation (joint generation)
Manual source code
Manual object code

Specification of individual SW modules (cf. DO-178C/DO-331 “Design Model” level)

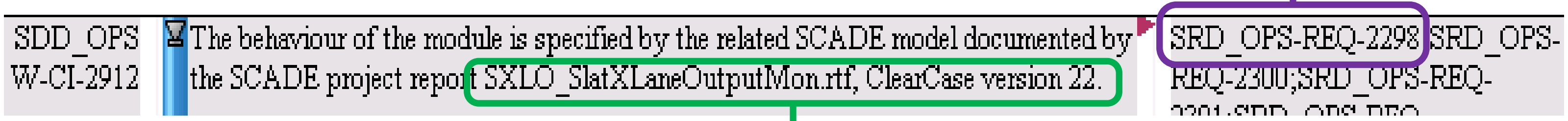
DAs SCADE Model Design

- High-level REQ

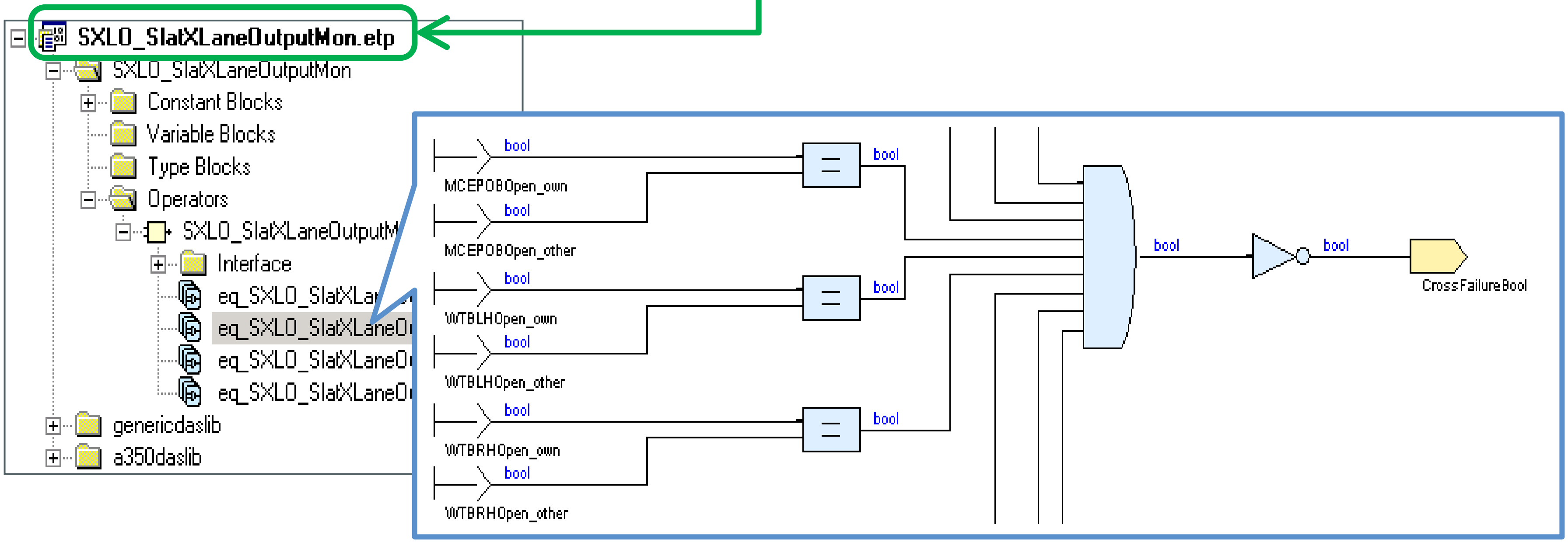


SRD_OPS-REQ-2298	A Slat Cross Lane Output Monitor failure condition shall be detected if the signals indicated in the table below do not match within the associated **Threshold**:	
	Signal	**Description**

- Low-level REQ / SCADE model



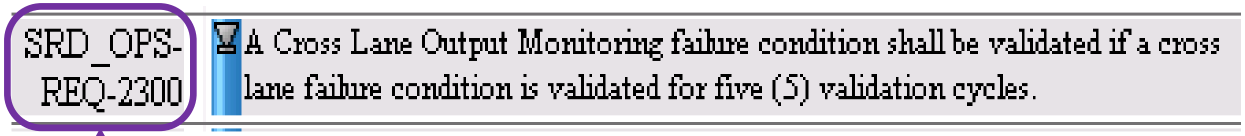
SDD_OPS W-CI-2912	The behaviour of the module is specified by the related SCADE model documented by the SCADE project report SXLO_SlatXLaneOutputMon.rtf, ClearCase version 22.	SRD_OPS-REQ-2298 SRD_OPS-REQ-2300;SRD_OPS-REQ-2301;SRD_OPS_REQ



SXLO_SlatXLaneOutputMon.etp
SXLO_SlatXLaneOutputMon
Constant Blocks
Variable Blocks
Type Blocks
Operators
SXLO_SlatXLaneOutputM
Interface
eq_SXLO_SlatXLa
eq_SXLO_SlatXLaneO
eq_SXLO_SlatXLaneO
eq_SXLO_SlatXLaneO
genericdaslib
a350daslib

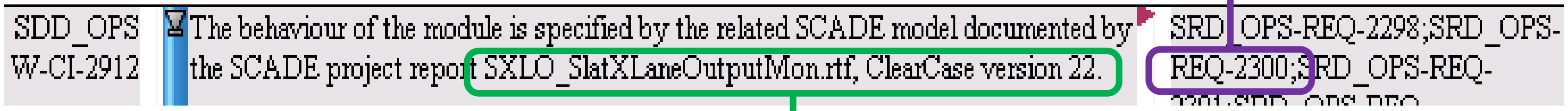
DAs SCADE Model Design (cont'd)

- High-level REQ

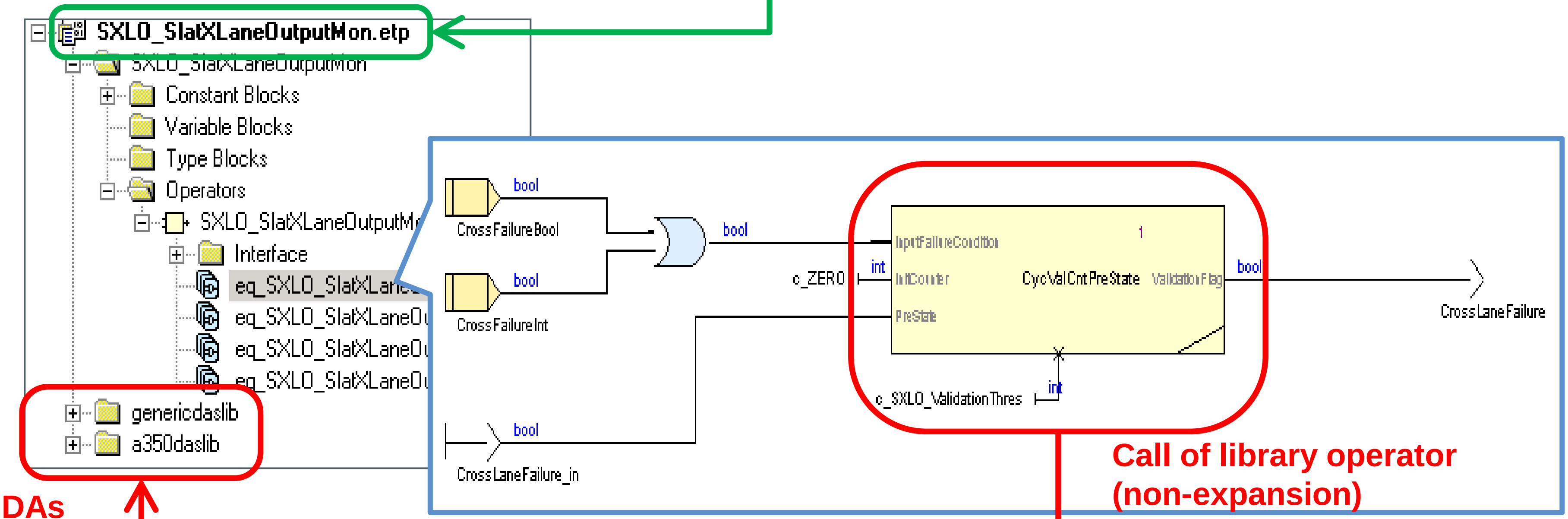


SRD_OPS-REQ-2300	A Cross Lane Output Monitoring failure condition shall be validated if a cross lane failure condition is validated for five (5) validation cycles.

- Low-level REQ / SCADE model



SDD_OPS W-CI-2912	The behaviour of the module is specified by the related SCADE model documented by the SCADE project report SXLO_SlatXLaneOutputMon.rtf, ClearCase version 22.	SRD_OPS-REQ-2298;SRD_OPS-REQ-2300;SRD_OPS-REQ-2301;SRD_OPS-REQ-



Call of library operator (non-expansion)

DAs Libraries

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Model Review: DAs SCADE Standard

- Guidance on following issues:
  - Tool settings and options to ensure conditions imposed by SCADE tool qualification
    - » E.g. interdiction of unary minus operator to avoid SCADE 5.1 maintenance issue CR ID 5137
  - Modeling conventions to support DAs model verification procedures
    - » E.g. naming and traceability conventions, complexity restrictions, algorithmic constraints

- Overview of rules
  - 16 mandatory rules to avoid undefined and failure-prone features (cf. tool qualification)
  - 23 required rules related to modeling conventions (cf. verification procedures) ➔ Justifications allowed
  - No optional or recommended rules applied

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Dok. Nr./Pub. No.	PD1000006084
Ausgabe/Issue	000_07
Seite/Page	1/58
Datei/File Name	PD1000006084_000_07_SCDSTD.docx

SCADE Development Standard
(SCDSTD)
for
A350 XWB Slat Flap Control Computer
and Sensors (A350 XWB SFCC)
(ATA 27)
for the
Airbus A350XWB Program

	Name/Name Funktion/Function	Datum/Date	Unterschrift/Signature
Erstellt / Prepared	Paul Linder Software Engineer	15. 8. 2013	Paul Linder
Technisch verifiziert / Technical checked			
Freigabe Qualität / Quality approved			
Technisch Autorisiert / Technical Authorized			

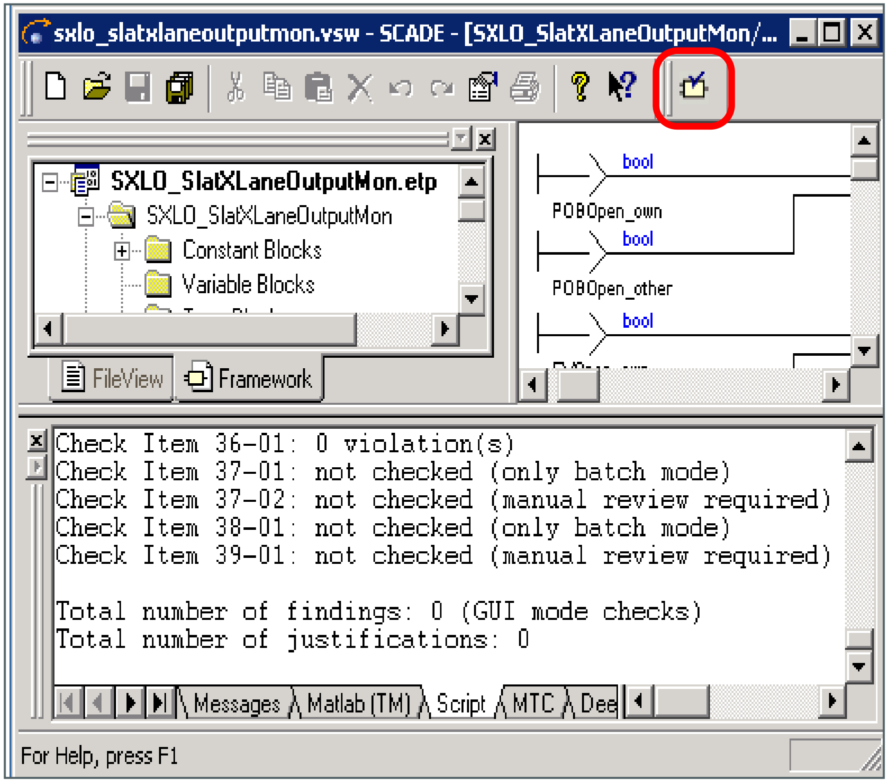
PD1000006084_000_07_SCDSTD.docx E-00-0001-07

Model Review: DAs SCADE StyleChecker

- Automatic check of 26 rules of the DAs SCADE Development Standard
  - Checks generation options, modeling elements, complexity restrictions, naming conventions, model/report/autocode consistency
  - Remaining 13 rules subject to manual review (based on SCADE report)

- Developed with TCL and Python
  - TCL scripts using SCADE API
    - » E.g. `MapRole $model node CountForbiddenModelOperators`
  - Python checking source/report generation and producing HTML report

- Qualified as verification tool
  - Qualified "batch mode"
  - Engineering "GUI mode" (see figure)

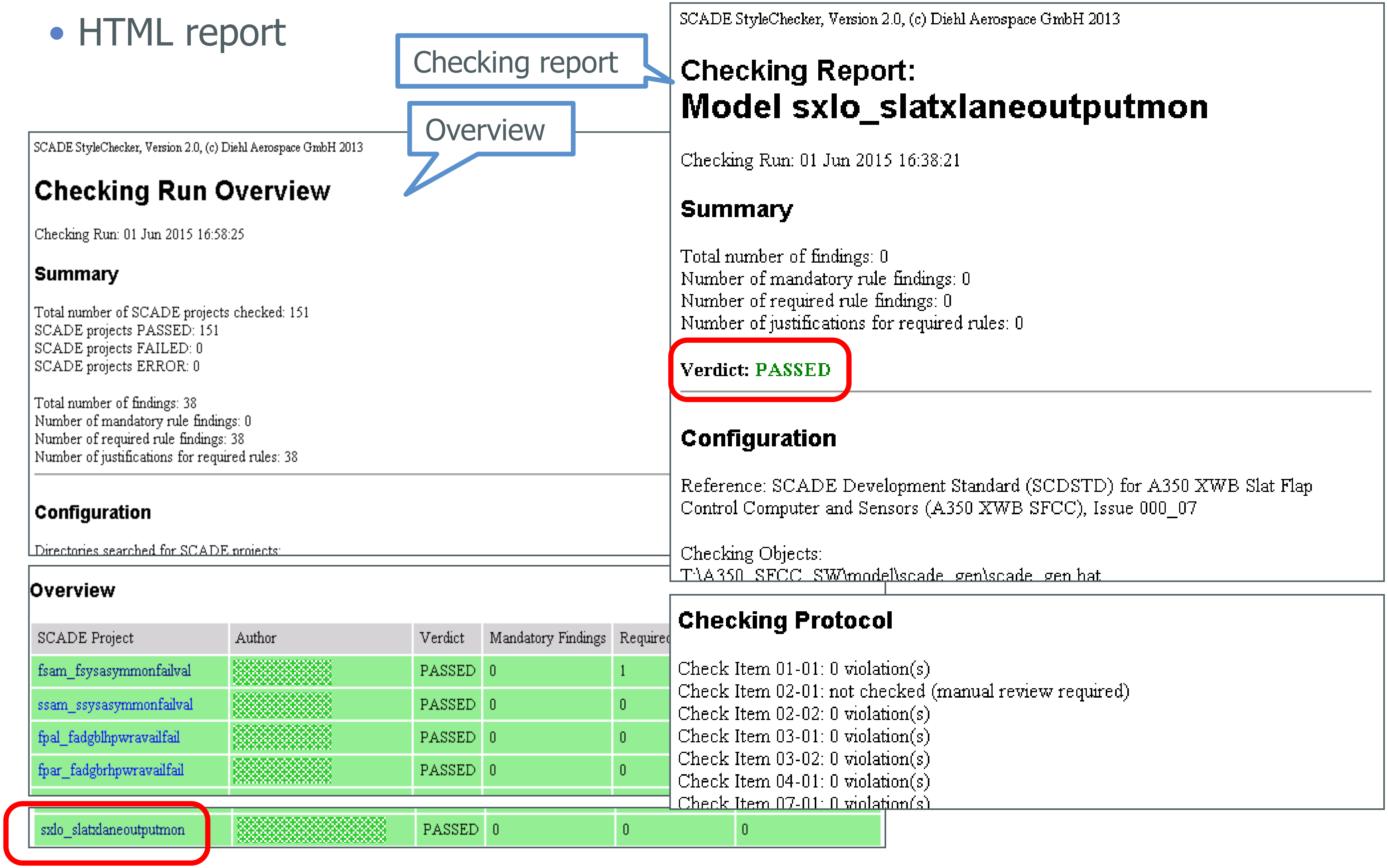


```
Check Item 36-01: 0 violation(s)
Check Item 37-01: not checked (only batch mode)
Check Item 37-02: not checked (manual review required)
Check Item 38-01: not checked (only batch mode)
Check Item 39-01: not checked (manual review required)

Total number of findings: 0 (GUI mode checks)
Total number of justifications: 0
```

Model Review: DAs SCADE StyleChecker (cont'd)

- HTML report



Checking report

Overview

SCADE StyleChecker, Version 2.0, (c) Diehl Aerospace GmbH 2013

Checking Run Overview

Checking Run: 01 Jun 2015 16:58:25

Summary

Total number of SCADE projects checked: 151
SCADE projects PASSED: 151
SCADE projects FAILED: 0
SCADE projects ERROR: 0

Total number of findings: 38
Number of mandatory rule findings: 0
Number of required rule findings: 38
Number of justifications for required rules: 38

Configuration

Directories searched for SCADE projects:

Overview

SCADE Project	Author	Verdict	Mandatory Findings	Required	
fsam_fsysasymmonfailval	[redacted]	PASSED	0	1	
ssam_ssysasymmonfailval	[redacted]	PASSED	0	0	
fpal_fadgblhpwravailfail	[redacted]	PASSED	0	0	
fpar_fadgbrhpwravailfail	[redacted]	PASSED	0	0	
sxlo_slatxlaneoutputmon	[redacted]	PASSED	0	0	0

SCADE StyleChecker, Version 2.0, (c) Diehl Aerospace GmbH 2013

Checking Report:
Model sxlo_slatxlaneoutputmon

Checking Run: 01 Jun 2015 16:38:21

Summary

Total number of findings: 0
Number of mandatory rule findings: 0
Number of required rule findings: 0
Number of justifications for required rules: 0

Verdict: PASSED

Configuration

Reference: SCADE Development Standard (SCDSTD) for A350 XWB Slat Flap Control Computer and Sensors (A350 XWB SFCC), Issue 000_07

Checking Objects:
T:\A350_SFCC_SW\model\scade_gen\scade_gen.bat

Checking Protocol

Check Item 01-01: 0 violation(s)
Check Item 02-01: not checked (manual review required)
Check Item 02-02: 0 violation(s)
Check Item 03-01: 0 violation(s)
Check Item 03-02: 0 violation(s)
Check Item 04-01: 0 violation(s)
Check Item 07-01: 0 violation(s)

DAs Model Testing Procedure

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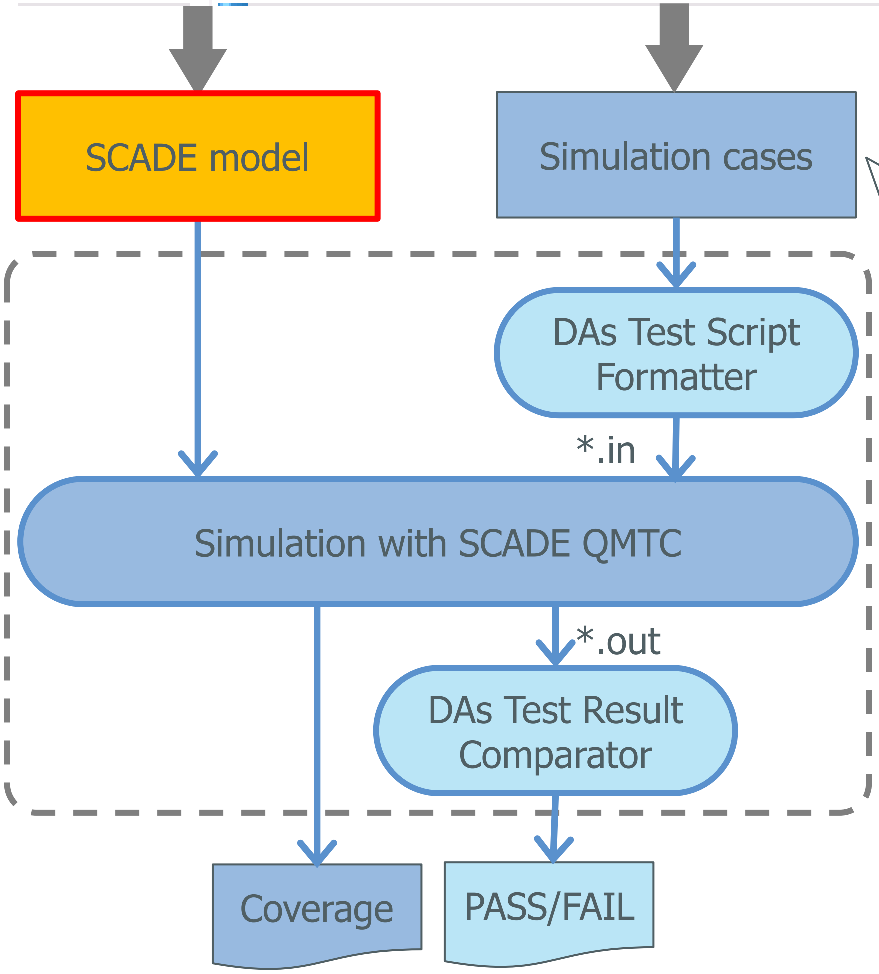
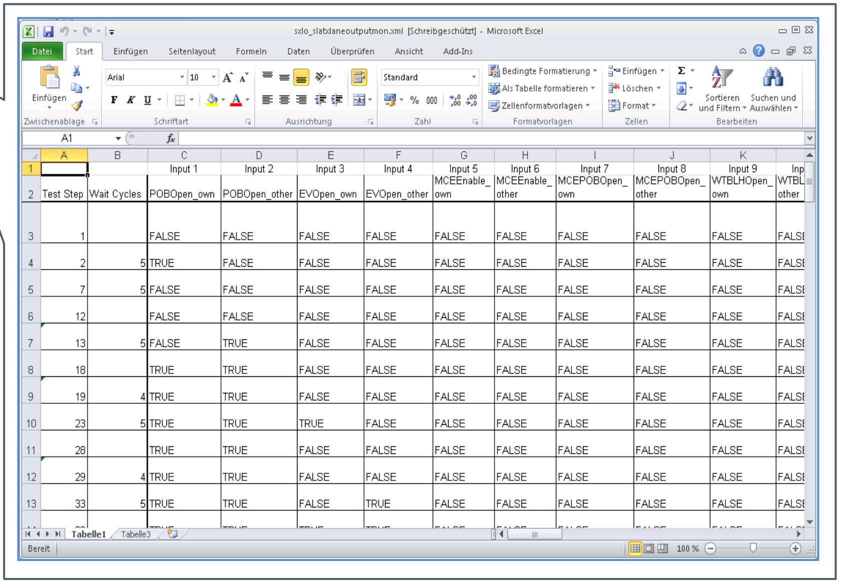
SRD_OPS-REQ-2300 A Cross Lane Output Monitoring failure condition shall be validated if a cross lane failure condition is validated for five (5) validation cycles.

High-level requirement


SCADE model
Simulation cases
DAs Test Script Formatter
*.in
Simulation with SCADE QMTC
*.out
DAs Test Result Comparator
Coverage
PASS/FAIL

Qualified toolchain



	A	B	C	D	E	F	G	H	I	J	K	L
1			Input 1	Input 2	Input 3	Input 4	Input 5	Input 6	Input 7	Input 8	Input 9	Inp
2	Test Step	Wait Cycles	POBOpen_own	POBOpen_other	EVOpen_own	EVOpen_other	MCEEnable_own	MCEEnable_other	MCEPOBOpen_own	MCEPOBOpen_other	WTBLHOpen_own	WTBL other
3	1		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
4	2	5	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
5	7	5	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
6	12		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
7	13	5	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
8	18		TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
9	19	4	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
10	23	5	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
11	28		TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
12	29	4	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
13	33	5	TRUE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE

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Experiences

- Successful certification of level A software! ☺
  - EASA type certification Airbus A350 XWB on 30.09.2014
- Estimated >2x higher efficiency for SW module development ☺
  - Omission of source code verification due to qualified source code generation
  - Bypass of effort-consuming conventional LLR specification and module testing
- Automatic consistency checks proved very valuable ☺

Some Remarks

- Set model expansion options in conformance to testing approach
  - 100% structural coverage may not be achieved with full expansion of libraries
  - Advice: Non-trivial library operators should not be expanded
- Mind the configuration management
  - Not only SCADE model and higher level requirements but also traceability data and review results (findings) have to be subject to version control
- Be aware of your modeling semantics
  - Identical syntax may have different meaning on different specification levels (cf. DO-178C/DO-331 “Design Model” vs. “Specification Model”)
  - Do not disregard quality conditions and design constraints requirements

DIEHL
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Contact

Diehl Aerospace GmbH
Alte Nussdorfer Str. 23
88662 Ueberlingen

Phone +49 7551 891 0
Fax +49 7551 891 4001

www.diehl.com/aerosystems

DIEHL
Aerospace