Next-Generation Functional Safety Architecture

Dev Pradhan

AMP Engineering Director

October 2018 | AMF-AUT-T3378

SECURE CONNECTIONS FOR A SMARTER WORLD

Agenda

- Recap on Functional Safety
- Recap on ISO 26262
- Next Generation Safety Concept
  - Process
  - Hardware
  - Software
  - Tools
- Getting Safety Support

Recap on Functional Safety

What is Functional Safety?

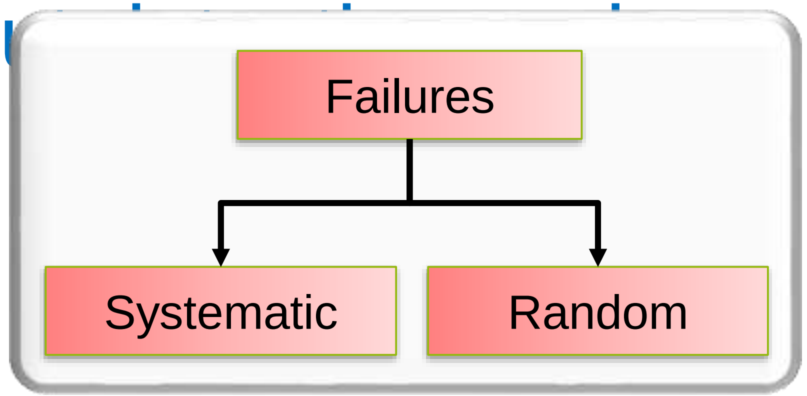
ISO 26262 Definition:

Absence of unacceptable risk due to hazards caused by mal-functional behavior of electrical and/or electronic systems

IEC 61508 Definition:

- Safety is the freedom from unacceptable risk of physical injury or of damage to the health of people, either directly, or indirectly as a result of damage to property or to the environment.
- Functional Safety is part of the overall safety that depends on a system or equipment operating correctly in response to its inputs.

Implementing Functional Safety is abou
managing failures



How products are developed:

Addresses the aspect of Systematic Failures

- Result from a failure in design or manufacturing
- Relevant to Hardware and Software
- Occurrence of failures can be reduced through continual and rigorous process improvement

Products that detect and handle faults:

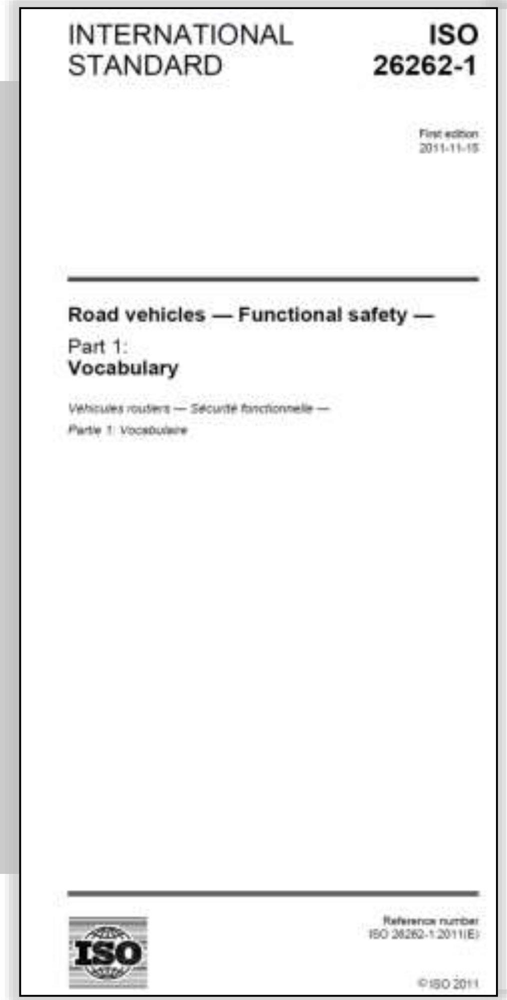
Addresses the aspect of Random Failures

- Inclusion of mechanisms to detect and handle random defects inherent to process or usage condition
- Relevant to Hardware only
- Supported by FMEDA*, Dependency and Fault Tree Analysis and communicated as FIT*

- FMEDA – Failure Mode Effects and Diagnostic Analysis
- FIT – Failure in Time

Recap on ISO 26262

ISO 26262 – Functional Safety of Road Vehicles



INTERNATIONAL STANDARD

ISO 26262-1

First edition
2011-11-15

Road vehicles — Functional safety —

Part 1:
Vocabulary

Véhicules routiers — Sécurité fonctionnelle —
Partie 1: Vocabulaire

Reference number
ISO 26262-1:2011(E)

© ISO 2011

- Vertical standard, performance based.
- First edition published in 2011.
- Follows similar structure to IEC 61508, but totally replaces instead of augmenting.
- Separates system design from hardware component design. As a result, most components used require compliance.
- 2nd edition to be released this year: ISO 26262:2018

Determining ISO 26262 ASIL Level

- To determine the ASIL level of a system a Risk Assessment must be performed for all Hazards identified.
- Risk is comprised of three components: **Severity, Exposure & Controllability**

S = Severity

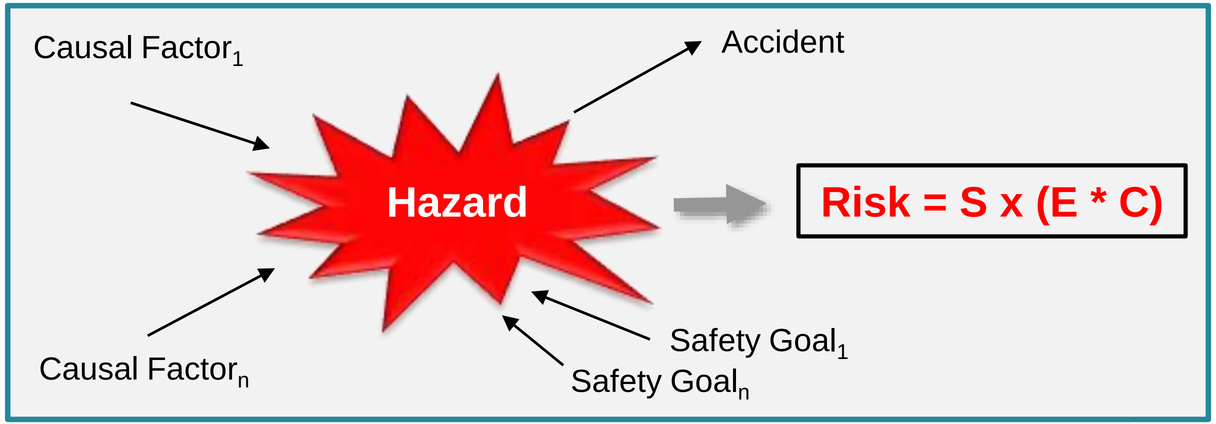
Class	Description
S0	No injuries
S1	Light and moderate injuries
S2	Severe and life-threatening injuries (survival probable)
S3	Life-threatening injuries (survival uncertain), fatal injuries

C = Controllability

Class	Description
C0	Controllable in general
C1	Simply controllable
C2	Normally controllable
C3	Difficult to control or uncontrollable

E = Exposure

Class	Description
E0	Incredible
E1	Very low probability
E2	Low probability
E3	Medium probability
E4	High probability



Causal Factor$_1$

Accident

Hazard

Risk = S x (E * C)

Causal Factor$_n$

Safety Goal$_1$

Safety Goal$_n$

Automotive Application Safety levels (e.g.)

Subsystem	ASIL Safety Level
ADAS – Vision/Radar	B-D
Airbags	D
Alternator	C-D
Body Control Module	A-B
Brake System (ABS, ESC, Boost)	A-D
Collision Warning -	A-B
Cruise Control	A-D
Drowsiness Monitor	A-B
E-Call / Telematics	A-B
Fuel Pump	B
Engine Oil Pump	B
Electric Mirrors	A-B
Electrochromatic Mirrors	A-B
Engine Control	B-D
Lighting	A-B
Night Vision	A-B
Power Door, Liftgate, Roof, Trunk	A-B
Rain Sense Wipers	A-B
Steering (EPS)	D
Throttle Control	A-D
Tire Pressure Warning	A-B
Transmission	B-D
Transmission Oil Pump	B-C
Window Lift	A-B

- Many applications that don’t have strict safety requirements today may have them in the future.
- For example, **SAE** is providing guidelines for determining ASILs. Applying these guidelines will mean that auto apps that haven’t been “safety” to-date could be held subject to ISO26262.
- Over time the expectations on sub-systems will change depending on how much the safety of the vehicle depends on them.

Note: that in the context of Autonomous there is the concept of SOTIF (Safety of the Intended Function) that is not covered by ISO 26262 and any ASIL

Next Generation Safety Concept

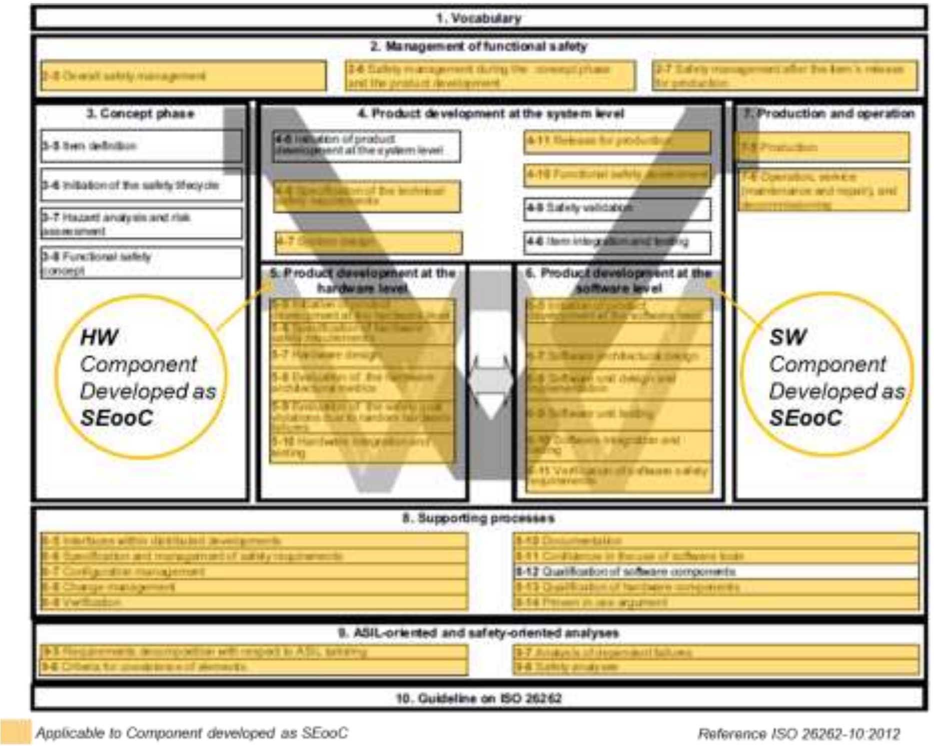
Process, Hardware, Software

Functional Safety Process – assessed to meet ISO 26262 ASIL-D

TÜV SÜD

Product Service

ISO 26262 PROCESS



1. Vocabulary

2. Management of functional safety
- 2-5 Overall safety management
- 2-6 Safety management during the concept phase and the product development
- 2-7 Safety management after the item's release for production

3. Concept phase
- 3-5 Item definition
- 3-6 Initiation of the safety lifecycle
- 3-7 Hazard analysis and risk assessment
- 3-8 Functional safety concept

4. Product development at the system level
- 4-5 Initiation of product development at the system level
- 4-6 Specification of the technical safety requirements
- 4-7 System design
- 4-11 Release for production
- 4-10 Functional safety assessment
- 4-9 Safety validation
- 4-8 Item integration and testing

7. Production and operation
- 7-5 Production
- 7-6 Operation, service (maintenance and repair), and decommissioning

5. Product development at the hardware level
- 5-5 Initiation of product development at the hardware level
- 5-6 Specification of hardware safety requirements
- 5-7 Hardware design
- 5-8 Evaluation of the hardware architectural metrics
- 5-9 Evaluation of the safety goal violations due to random hardware failures
- 5-10 Hardware integration and testing

6. Product development at the software level
- 6-5 Initiation of product development at the software level
- 6-7 Software architectural design
- 6-8 Software unit design and implementation
- 6-9 Software unit testing
- 6-10 Software integration and testing
- 6-11 Verification of software safety requirements

HW Component Developed as SEooC

SW Component Developed as SEooC

8. Supporting processes
- 8-5 Interfaces within distributed developments
- 8-6 Specification and management of safety requirements
- 8-7 Configuration management
- 8-8 Change management
- 8-9 Verification
- 8-10 Documentation
- 8-11 Confidence in the use of software tools
- 8-12 Qualification of software components
- 8-13 Qualification of hardware components
- 8-14 Proven in use argument

9. ASIL-oriented and safety-oriented analyses
- 9-5 Requirements decomposition with respect to ASIL tailoring
- 9-6 Criteria for coexistence of elements
- 9-7 Analysis of dependent failures
- 9-8 Safety analyses

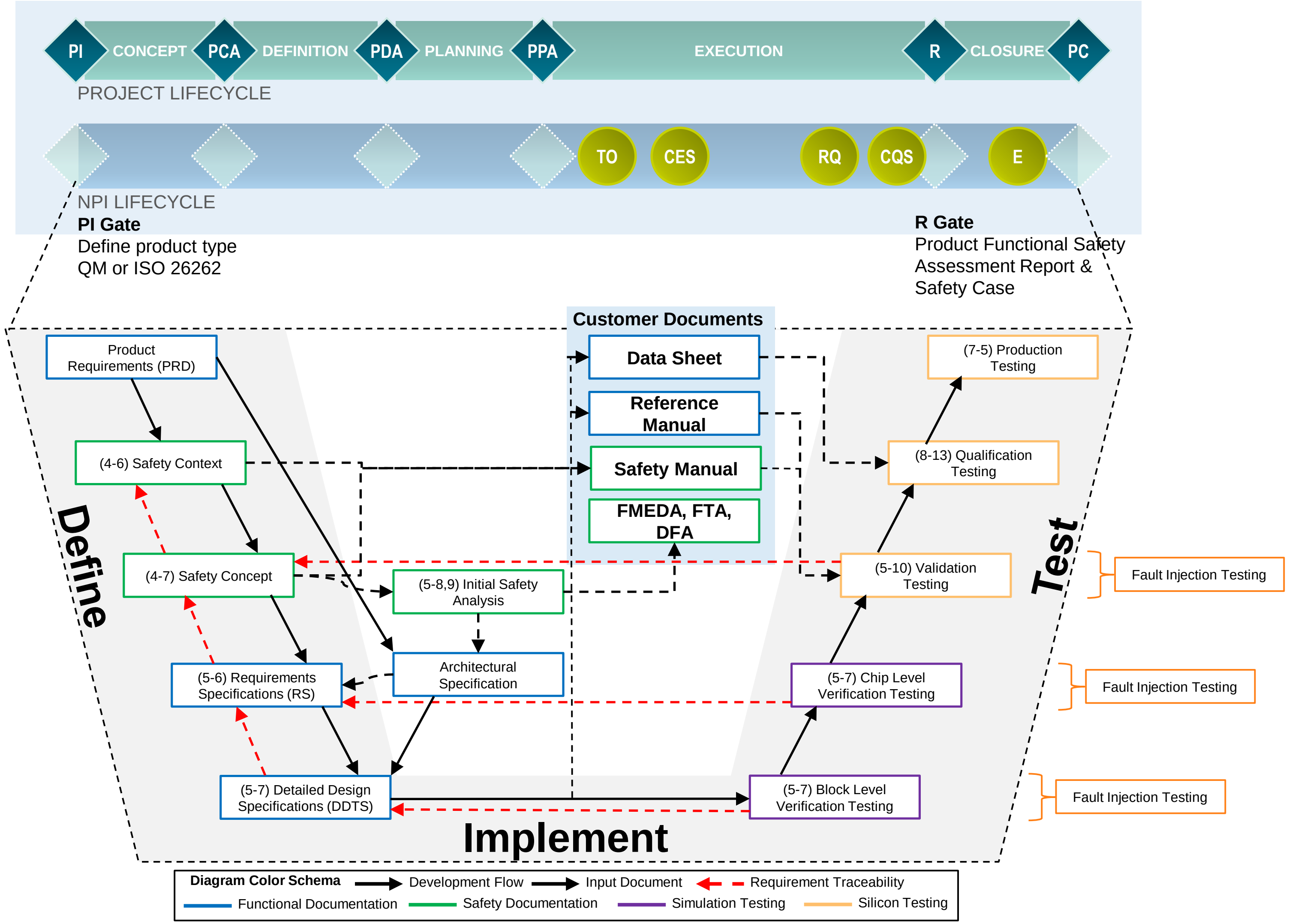
10. Guideline on ISO 26262

▨ *Applicable to Component developed as SEooC*

Reference ISO 26262-10:2012

Input Requirements

Standard
Customer
Marketing (MRD)
Internal



PI – CONCEPT – PCA – DEFINITION – PDA – PLANNING – PPA – EXECUTION – R – CLOSURE – PC

PROJECT LIFECYCLE

TO – CES – RQ – CQS – E

NPI LIFECYCLE

PI Gate
Define product type
QM or ISO 26262

R Gate
Product Functional Safety
Assessment Report &
Safety Case

Customer Documents
- Data Sheet
- Reference Manual
- Safety Manual
- FMEDA, FTA, DFA

Define

- Product Requirements (PRD)
- (4-6) Safety Context
- (4-7) Safety Concept
- (5-8,9) Initial Safety Analysis
- Architectural Specification
- (5-6) Requirements Specifications (RS)
- (5-7) Detailed Design Specifications (DDTS)

Implement

Test

- (5-7) Block Level Verification Testing
- (5-7) Chip Level Verification Testing
- (5-10) Validation Testing
- (8-13) Qualification Testing
- (7-5) Production Testing

Fault Injection Testing

Fault Injection Testing

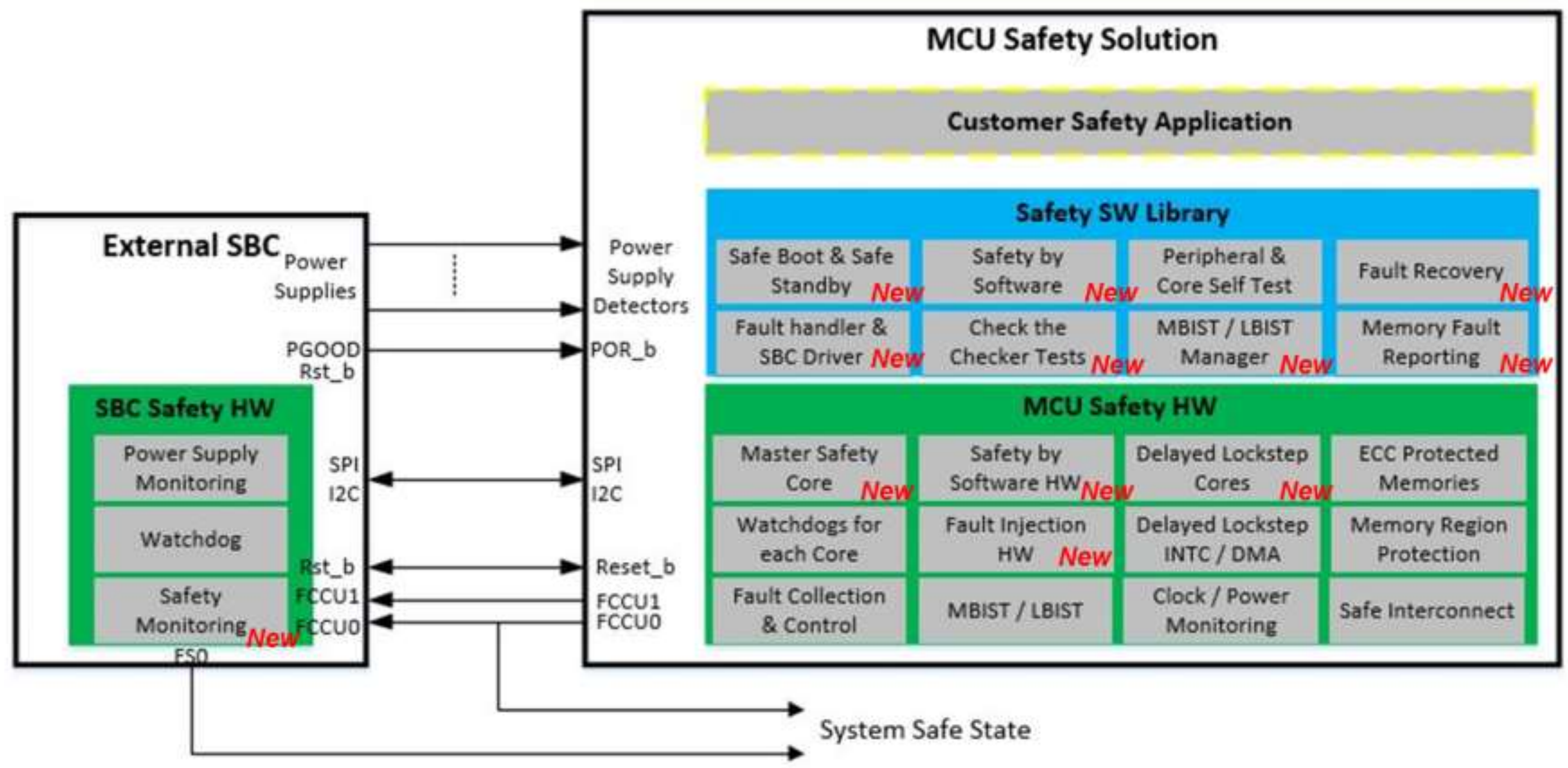
Fault Injection Testing

Diagram Color Schema
- Development Flow
- Input Document
- Requirement Traceability
- Functional Documentation
- Safety Documentation
- Simulation Testing
- Silicon Testing

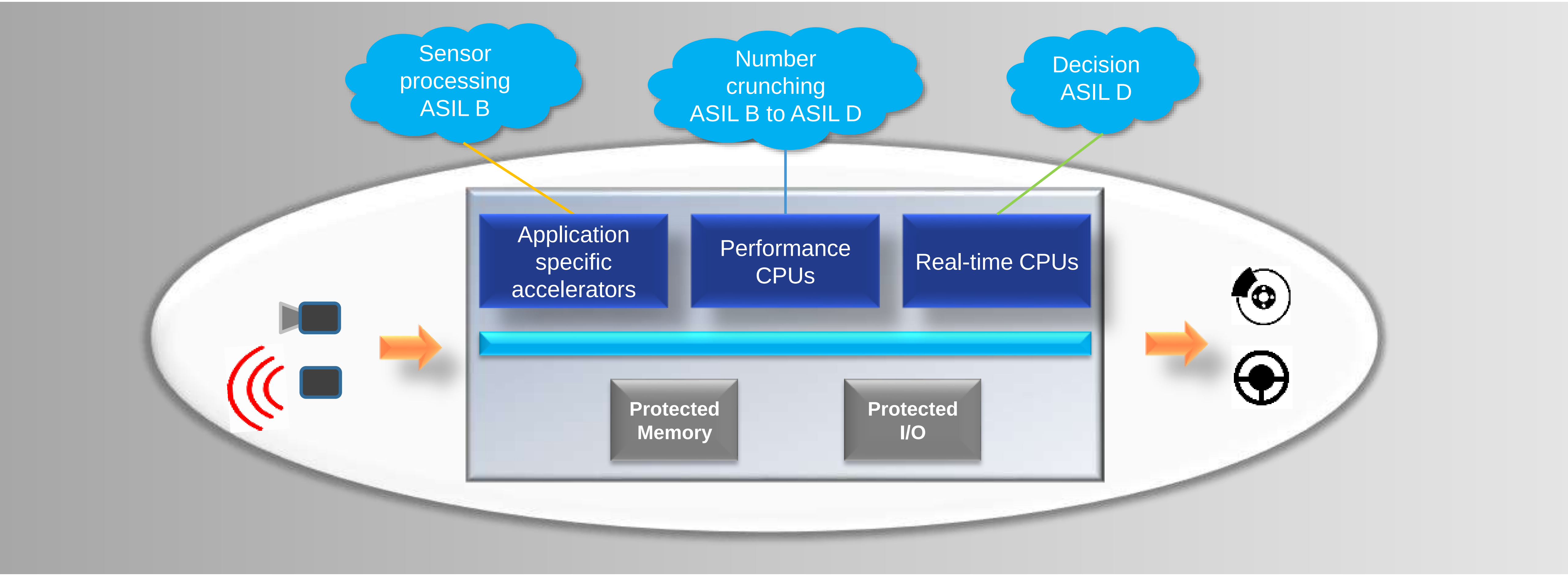
NXP BCAM7 PROCESS

Safety Chipset = SoC (Hardware/Software) + Power Supply

- **ASIL-D ready Safety**
  - Certified Process
  - Random Failure Detection
  - Collateral
- **System Solution**
  - SW Safety Library
  - MCU
  - SBC
- **Differentiation**
  - Highest ASIL-D DMIPs
  - Failure Recovery
  - ASIL-B Acceleration

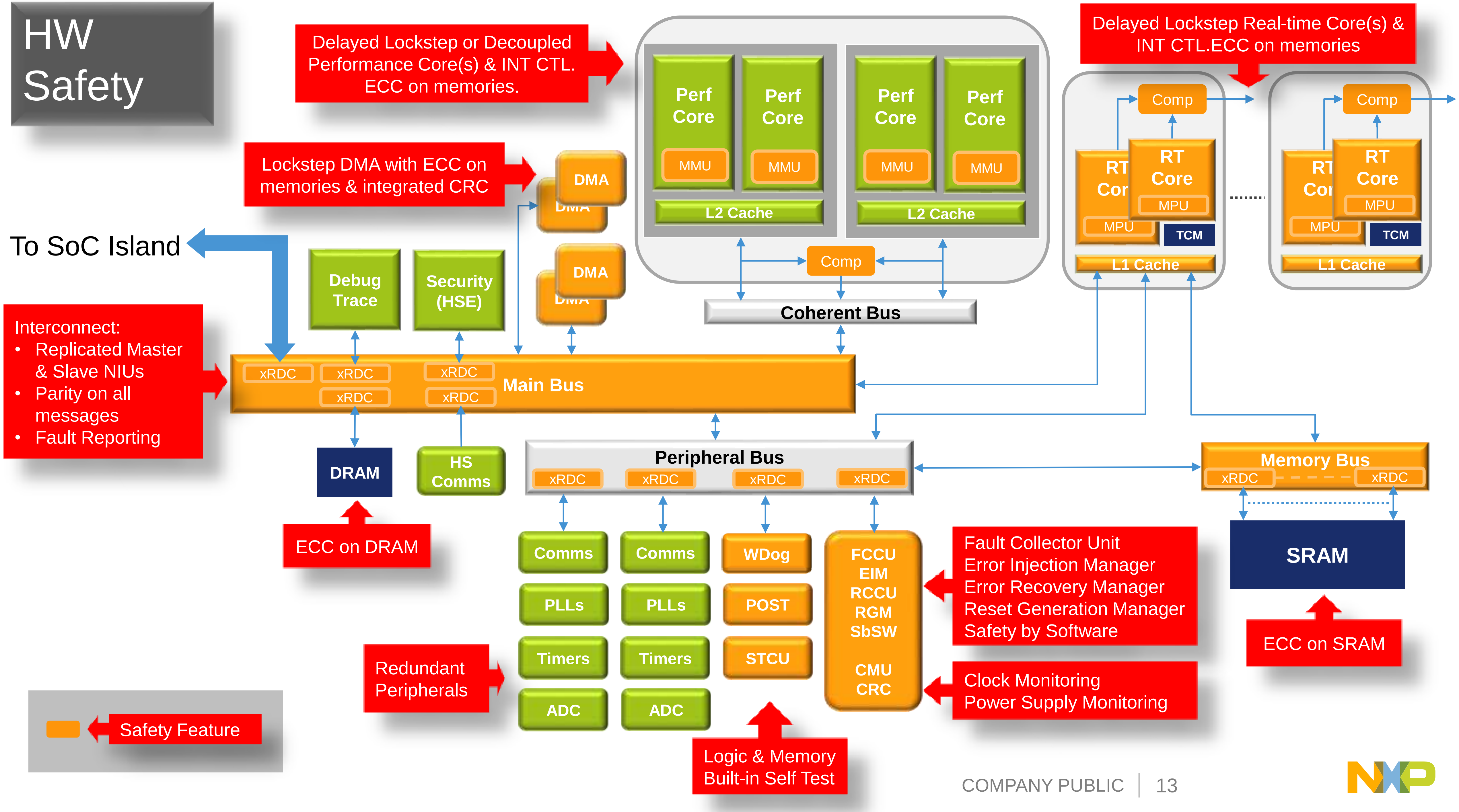


Safety targets for Next-Generation Platform



- Developed as a Safety Element out of Context (SEooC)
- Following an ISO 26262 ASIL-D Safety Development Process
- Supported with complementary safety collateral

HW Safety



Delayed Lockstep or Decoupled Performance Core(s) & INT CTL. ECC on memories.

Delayed Lockstep Real-time Core(s) & INT CTL.ECC on memories

Lockstep DMA with ECC on memories & integrated CRC

Interconnect:

- Replicated Master & Slave NIUs
- Parity on all messages
- Fault Reporting

ECC on DRAM

Fault Collector Unit
Error Injection Manager
Error Recovery Manager
Reset Generation Manager
Safety by Software

ECC on SRAM

Clock Monitoring
Power Supply Monitoring

Redundant Peripherals

Logic & Memory Built-in Self Test

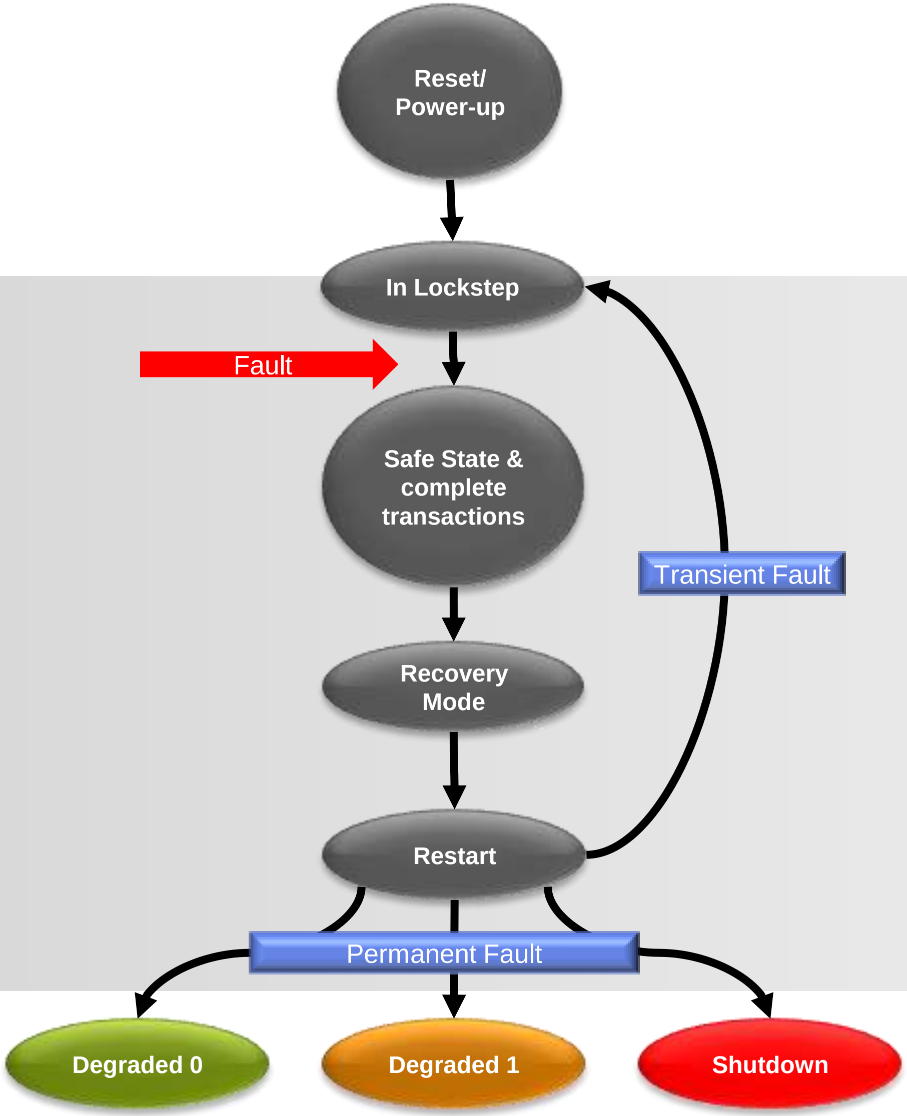
🟧 Safety Feature

Fault Management and availability

Previous Generation - State of the art functional safety 2012	S32x - Introducing availability 2018+
Lockstep mismatch → MCU reset	Lockstep mismatch → begin availability flow
No localization of fault beyond lockstep core pair	**Localization of fault** possible to individual core
No continued operation possible with safety coverage	Continued operation possible with loss of core, or loss of cluster **Remaining core/cluster functional**
Not possible to distinguish between permanent and transient faults in core complex	All transient faults recoverable Cache faults recoverable without BIST – reset only

Fail Safe Strategy

Fault Tolerant Strategy



Top level safety requirements

- The MCU itself is developed as a **SEooC** to provide the MCU functionalities with appropriate assumed safety integrity – **ASIL D**
  - **SPFM (Single Point Failure Metric): 99%** for transient & permanent faults
  - **LFM (Latent Failure Metric): 90%** for permanent faults
  - **PMHF (Probabilistic Metric Hardware Failure): 10^{-9} h^{-1}** (10% of system target for ASIL-D (<10^{-8} h^{-1}))

- Fault Tolerant Time Interval (time a Fault occurrence and the system transitions to a Safe state)
  - **$FTTI_{MCU}$= 10ms**

- Multiple Point Fault Detection Interval (multi-point faults are latent faults)
  - **$MPFDI_{MCU}$= 12hrs**

- To detect multiple-point faults in the **most critical MCU safety mechanisms**, **software initiated fault injection tests** can be periodically triggered within the FTTI.

Top level availability requirements

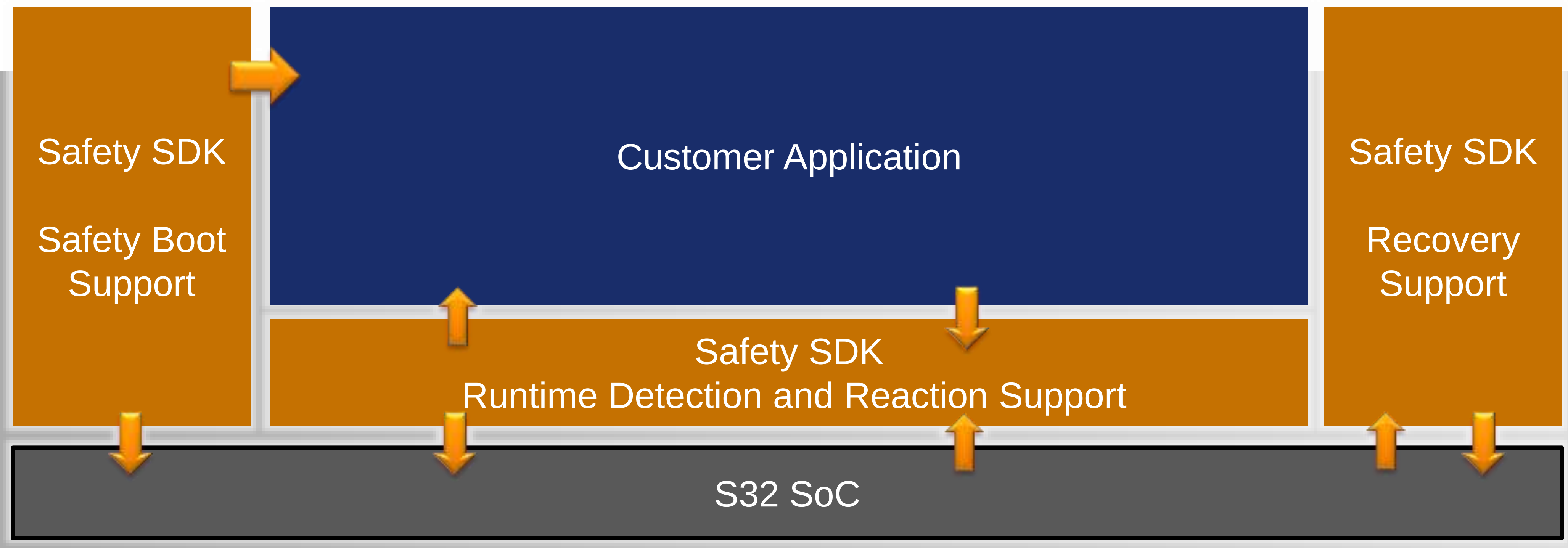
- The contribution of the SoC to the **Fault Recovery Time** of the application is targeted to be

  FRT <= 50 ms.
- This time is split between fault recovery (**$\mathbf{FRT_{MCU}}$**) and reset/boot (**$\mathbf{BootTime_{MCU}}$**)
  - Note: This includes the time to perform SoC fault diagnostics, reset and boot the SoC to the point to handover to load full application code. It does not include the application re-initialization time.

- Fault Tolerance (Availability) of the SoC is targeted to be:

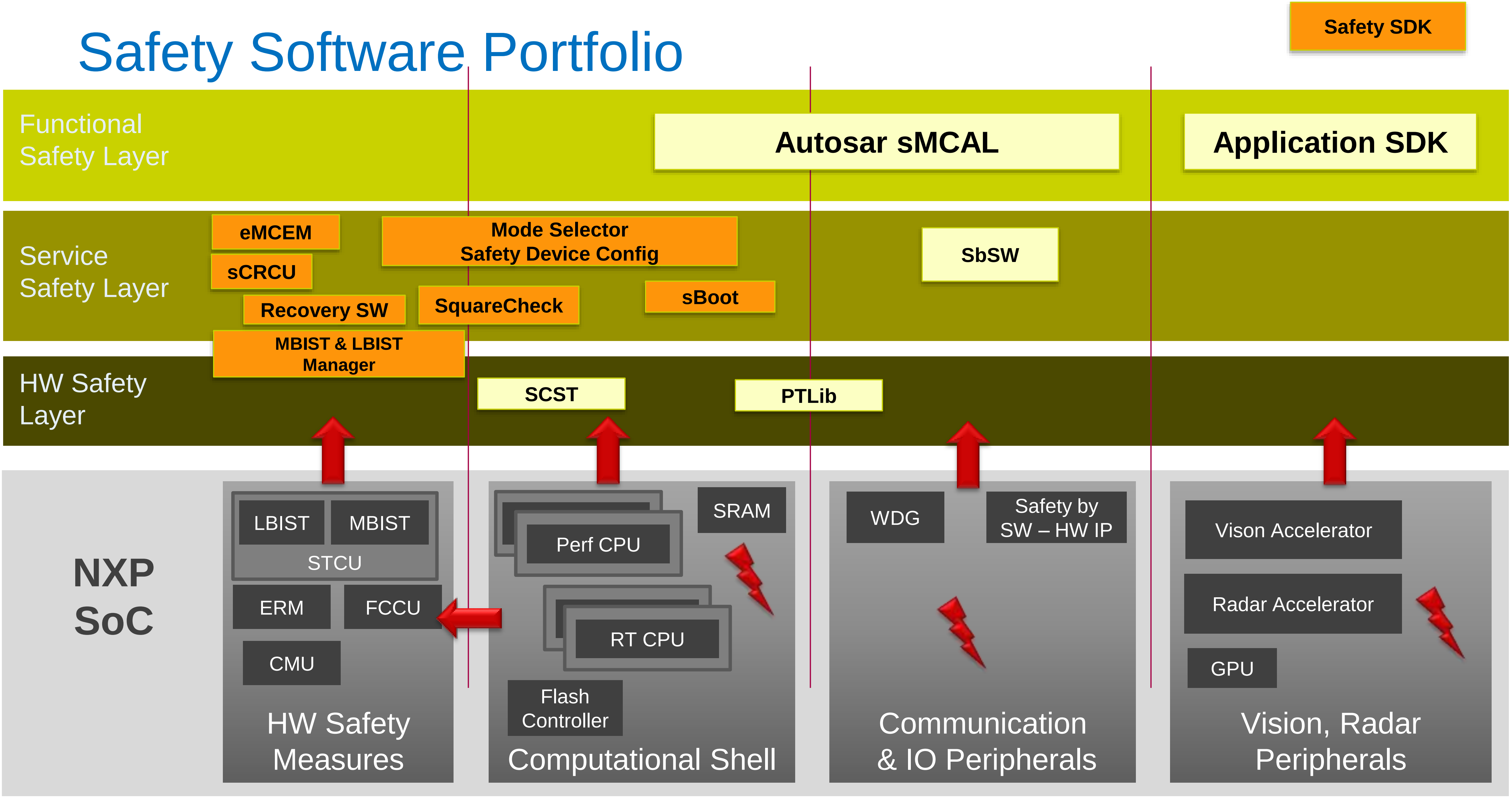
  < 100 FIT ($\mathbf{10^{-7}}$ $\mathbf{h^{-1}}$) of failures should lead to application Shutdown

Safety Software Support (Safety SDK)



- Successful boot of safety-related components is required to start a safety application.
- Runtime fault detection is mediated by Safety SDK – faults are detected by both HW and SW mechanisms
- Runtime error recovery is managed via Safety SDK
- Safety SDK manages a global, destructive SoC recovery.

Safety Software Portfolio



Safety SDK components

Detection components

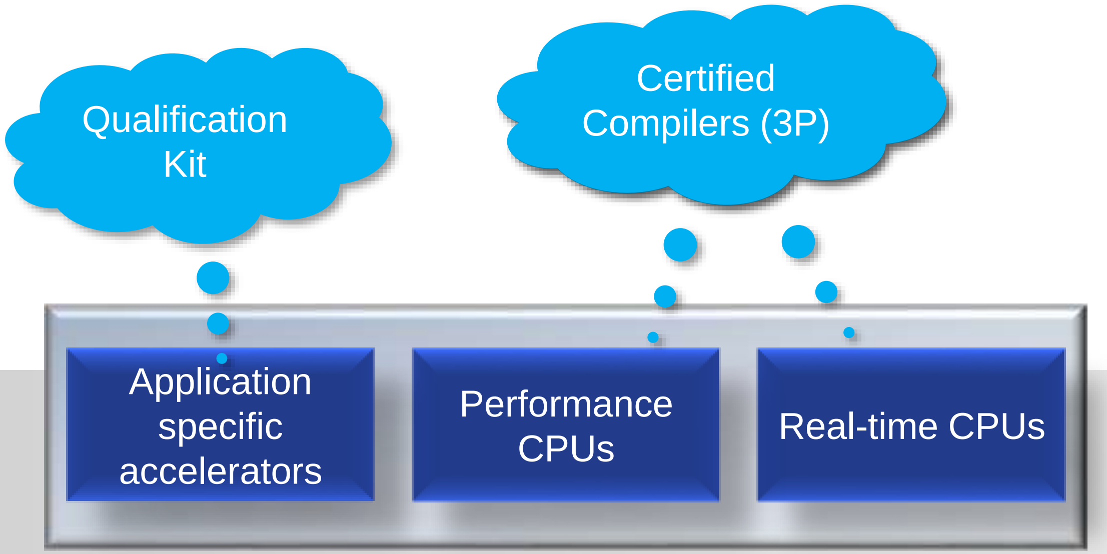
- SquareCheck – detects latent faults in HW safety mechanism
- BIST Manager – configures, initiates, and provides access to MBIST and LBIST
- sBoot – detects violations of HW safety configuration
- sCRCU – detects faults in CRC; also, it computes CRC

Reaction Components

- eMCEM – configures FCCU and provides handlers to faults signaled to FCCU.
- SW Recovery – initiates the global recovery process
- Mode Selector – depending on the MCU fault status selects the appropriate operating mode. Device configuration is part of the selection and invocation of the respective mode.

Tool Compliance

- Classification Report
- Qualification Plan
- Qualification Report
- Safety Manual
- ISO26262 compliance report



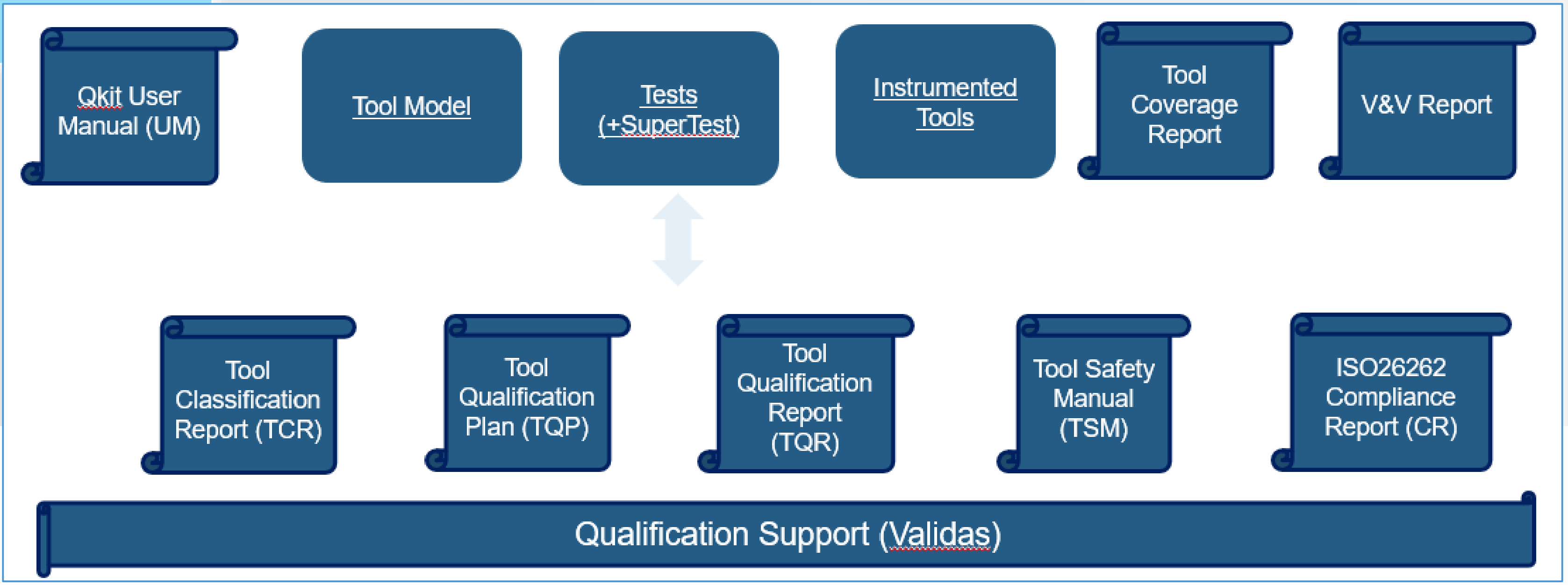
Qualification Kit

Certified Compilers (3P)

Application specific accelerators

Performance CPUs

Real-time CPUs



Qkit User Manual (UM)

Tool Model

Tests (+SuperTest)

Instrumented Tools

Tool Coverage Report

V&V Report

Tool Classification Report (TCR)

Tool Qualification Plan (TQP)

Tool Qualification Report (TQR)

Tool Safety Manual (TSM)

ISO26262 Compliance Report (CR)

Qualification Support (Validas)

Validas AG

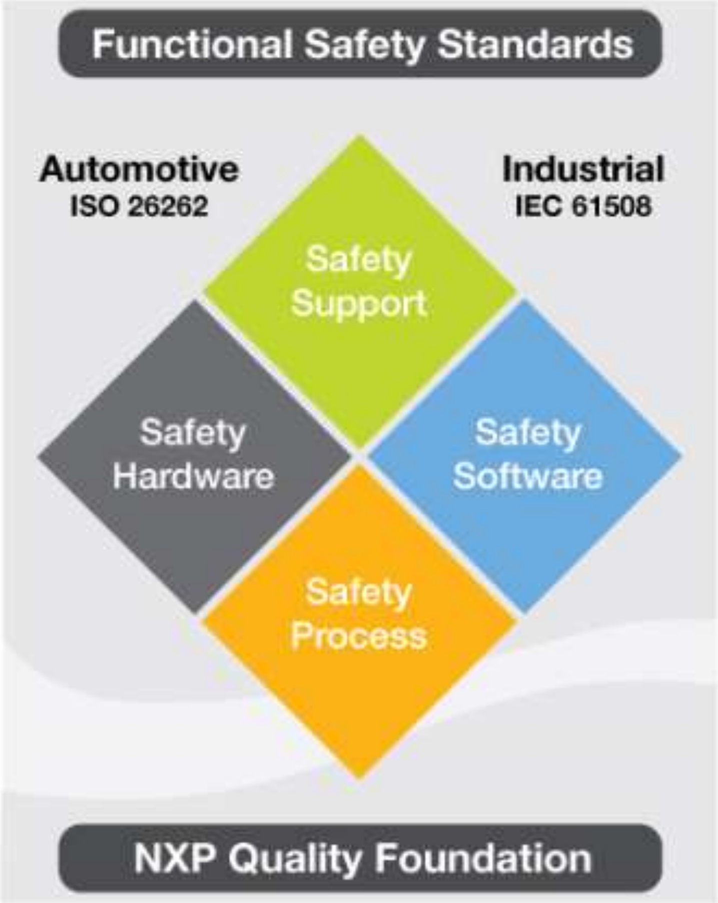
Getting Safety Support

NXP SafeAssure™ Products

To support the customer to build his safety system, the following deliverables are provided **as standard** for **all** ISO 26262 developed products.

- **Public Information available via NXP Website**
  - Quality Certificates
  - Reference Manual
  - Data Sheet

- **Confidential Information available under NDA**
  - Safety Plan
  - Safety Manual
  - Permanent Failure Rate data (Die & Package) - IEC/TR 62380 or SN29500
  - Transient Failure Rate data (Die) - JEDEC Standard JESD89
  - Safety Analysis (FMEDA, FTA, DFA) & Report
  - PPAP
  - Confirmation Measures Report (summary of all applicable confirmation measures)



NXP ISO 26262 Confirmation Measures

NXP performs ISO 26262 Confirmation Reviews (CR), Audit and Assessment as required by ISO 26262 for SEooC development

Confirmation Measures	ASIL A	ASIL B	ASIL C	ASIL D
CR Safety Analysis	Yes	Yes	Yes	Yes
CR Safety Plan		Yes	Yes	Yes
CR Safety Case		Yes	Yes	Yes
CR Software Tools			Yes	Yes
Audit			Yes	Yes
Assessment			Yes	Yes

Note: The following confirmation reviews are not applicable: hazard analysis and risk assessment, item integration and testing, validation plan & proven in use argument

Confirmation Measures (CM) performed depending on ASIL

- All checks executed with **independence level I3** by NXP Quality organization
- NXP Assessors **certified** by SGS-TÜV Saar as *Automotive Functional Safety Professional (AFSP)*
- NXP CM process **certified** by SGS-TÜV Saar as ISO 26262 ASIL D

SafeAssure Community
Customer support for Functional Safety

SafeAssure Community

Public Space for knowledge distribution and industry-wide news
here

SafeAssure NDA

Private NDA space for customer to access safety documentation
here

Support

Safety Expert Group composed of Safety Managers and Architects, Field and Application Engineers

Self Sufficient

Community users find answers to their questions and safety documentation requests

SECURE CONNECTIONS
FOR A SMARTER WORLD

www.nxp.com