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Field Programmable Gate Arrays in Nuclear Power Plants
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**Introduction of Class 1 FPGA Platform
vCOSS S-zero for the UK ABWR**

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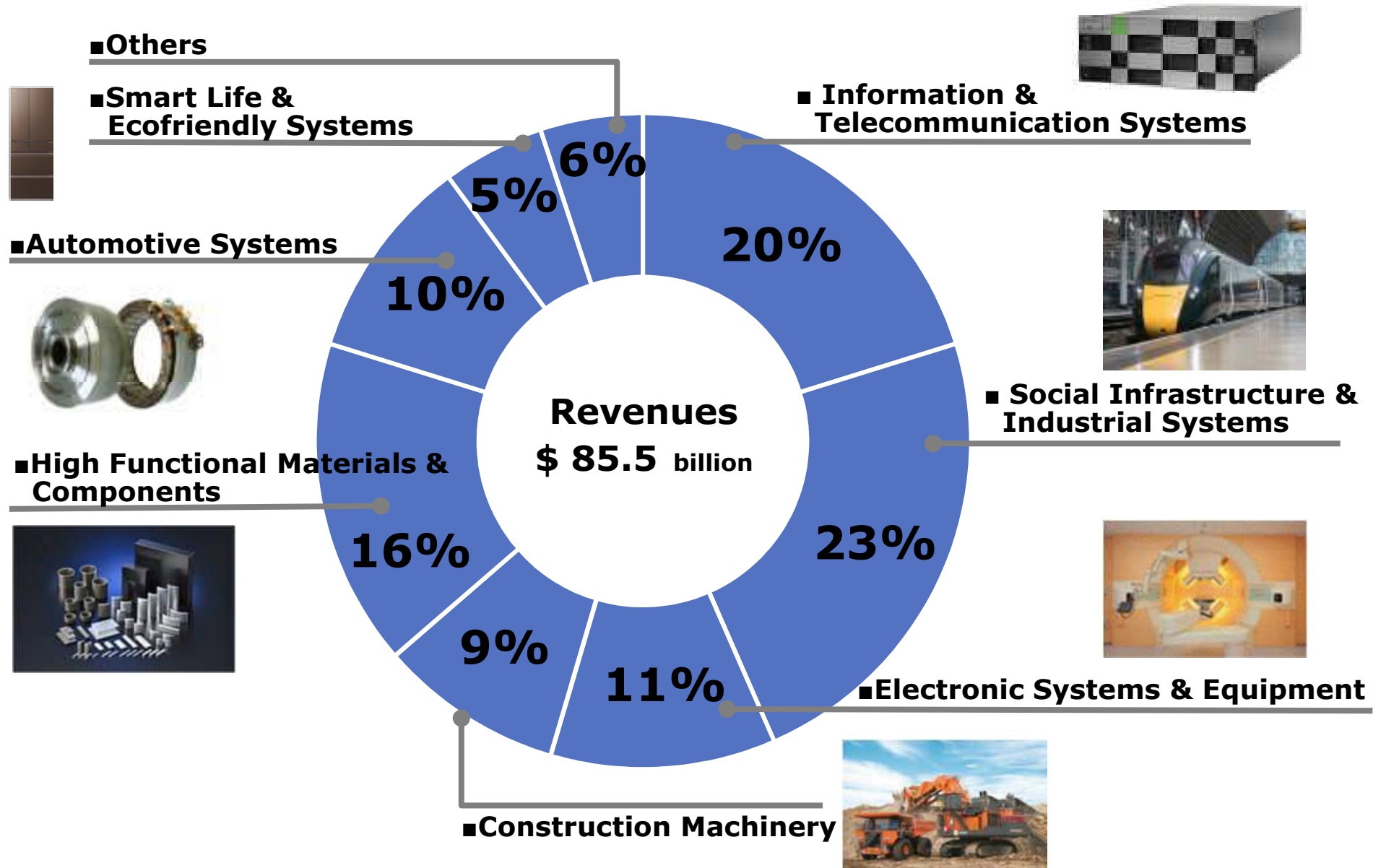
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1. About Hitachi and Hitachi's C&I
2. UK ABWR Project Overview
3. UK ABWR C&I System Architecture
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About Hitachi, Ltd. (FY2017)



Global Expansion* (FY2017)

Europe

- Revenues: **\$ 8.8** billion
- Number of companies: **139**
- Number of employees: **16** thousand

North America

- Revenues: **\$ 10.7** billion
- Number of companies: **100**
- Number of employees: **21** thousand

China

- Revenues: **\$ 9.5** billion yen
- Number of companies: **143**
- Number of employees: **44** thousand

Japan

- Revenues: **\$ 42.4** billion
- Number of companies: **202**
- Number of employees: **168** thousand

Asia (incl. China)

- Revenues: **\$ 19.0** billion
- Number of companies: **332**
- Number of employees: **88** thousand

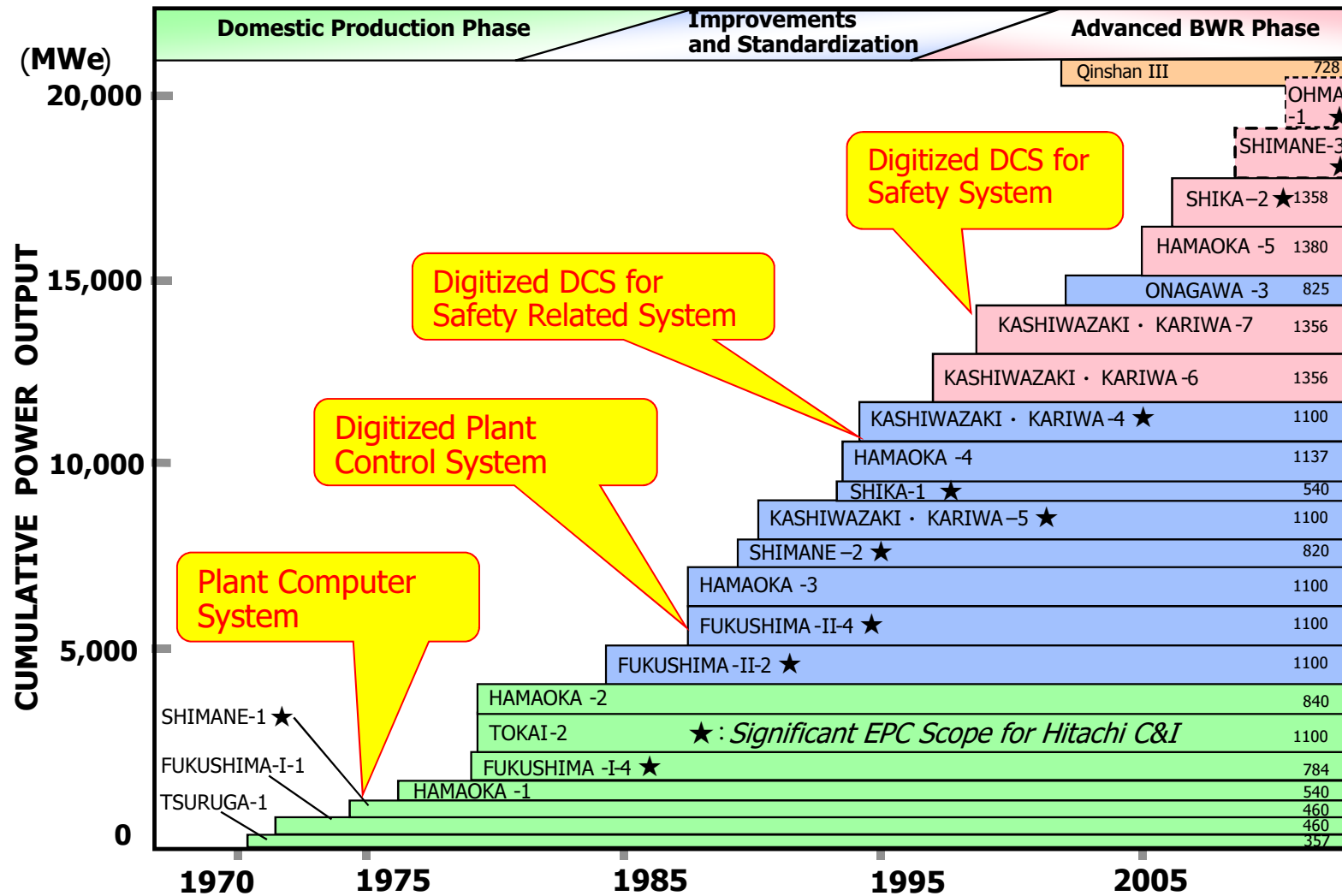
Other Areas

- Revenues: **\$ 4.5** billion
- Number of companies: **106**
- Number of employees: **12** thousand

Japan	Revenues: \$ 42.4 billion/Number of companies: 202 /Number of employees: 168 thousand
Outside Japan	Revenues: \$ 43.1 billion/Number of companies: 677 /Number of employees: 139 thousand
Total	Revenues: \$ 85.5 billion/Number of companies: 879 /Number of employees: 307 thousand

* Revenues: FY2017, Number of companies and employees: As of end of FY2017 © Hitachi-GE Nuclear Energy, Ltd., Hitachi, Ltd. 2018. All rights reserved.

Hitachi Nuclear Application History



DCS: Distributed Control System

Note: Definition of Safety System and Safety Related System is based on IAEA Safety Glossary 2007

Ohma Unit 1 (NI and TI), FAT finished (FSS), completed in 2016

Kashiwazaki-Kariwa Unit 6 (TI), C/O in 1996
Unit 7 (NI), C/O in 1997

Shika Unit 2 (NI and TI), C/O in 2006

C/O : Commercial Operation
TI : Turbine Island
NI : Nuclear Island
FSS : Full Scope Simulator
FAT: Factory AccEptance Test

Hamaoka Unit 5 (TI), C/O in 2005

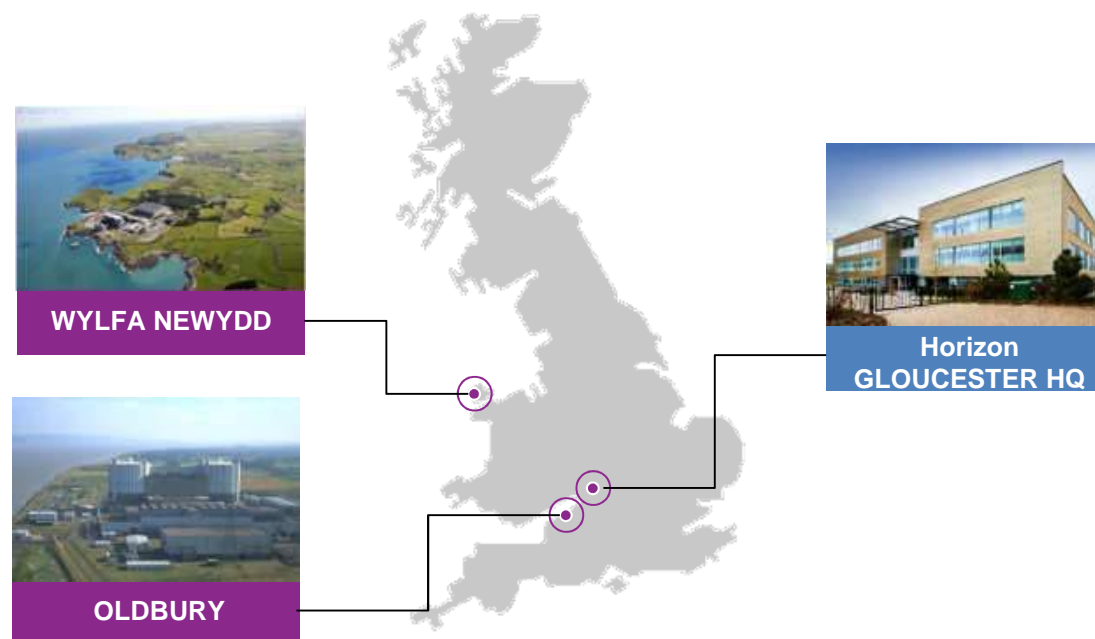
Shimane Unit 3 (NI and TI), under preoperational test at the site (FSS), completed in 2009

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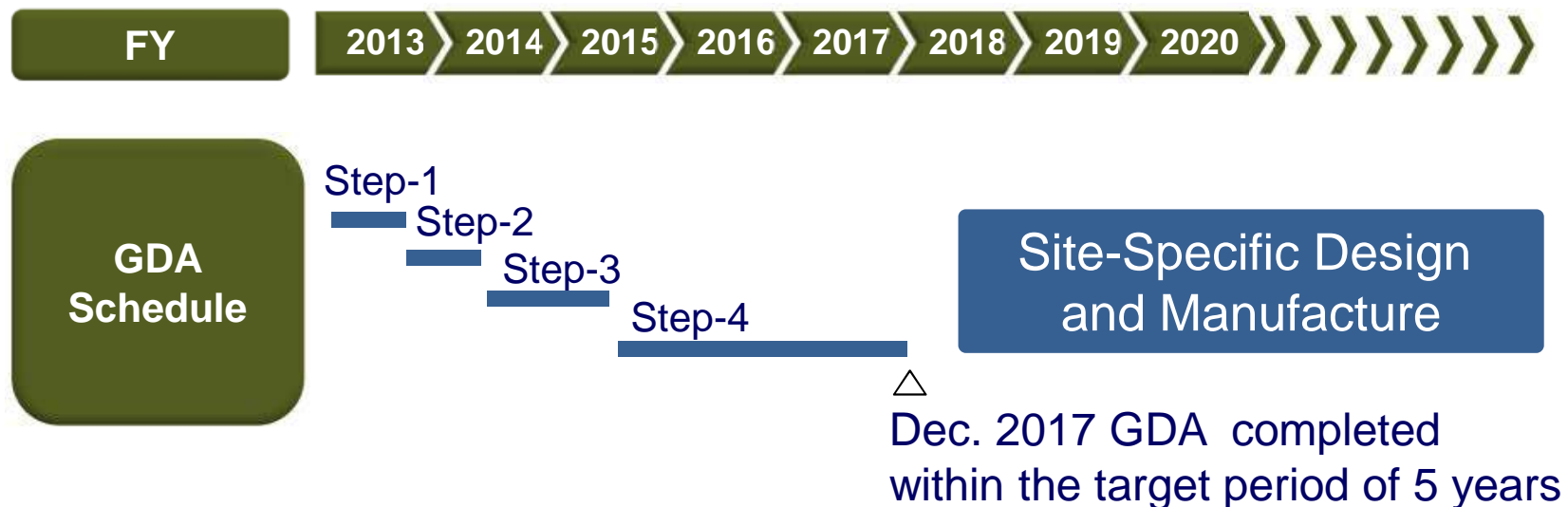
UK ABWR Project Overview

- Horizon Nuclear Power is planning to build 1,350 MWe class Advanced Boiling Water Reactors (ABWR) in Wylfa and Oldbury.
- The primary focus is to secure all key agreements and permissions in place for the Final Investment Decision in 2019.
- Commercial operation of the 1st unit at Wylfa is planned to be in the middle 2020s.



UK ABWR Project Assessment Status

- Hitachi-GE Nuclear Energy as an ABWR supplier, officially applied Generic Design Assessment (GDA) licensing process to the UK regulator in 2013.
- Final process of Step-4 was completed in December 2017.
- Currently at pre-engineering phase.



[News Release] <http://www.hitachi.com/New/cnews/month/2017/12/171214.html>

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UK regulatory expectations for C&I are;

- Complying with International Code and Standards such as IEC 61513
- Referring to assessment guides such as SAP, TAGs
- Referring to relevant good practice such as feedbacks from other GDA

Based on the above expectations, Design features of UK ABWR system are determined, such as;

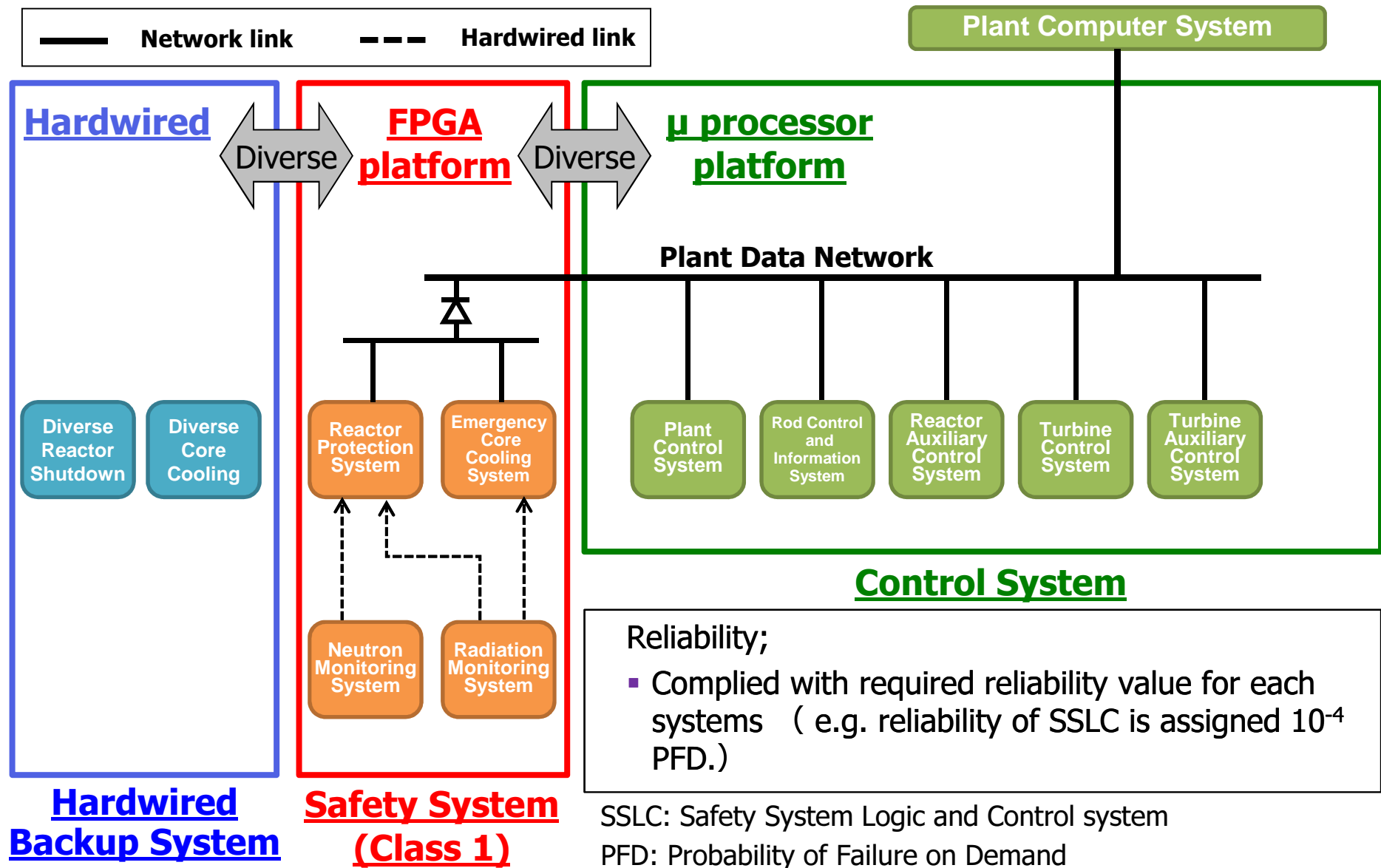
- System reliability according to Category & Class
- Redundancy
- Separation
- Diversity

SAP: Safety Assessment Principle

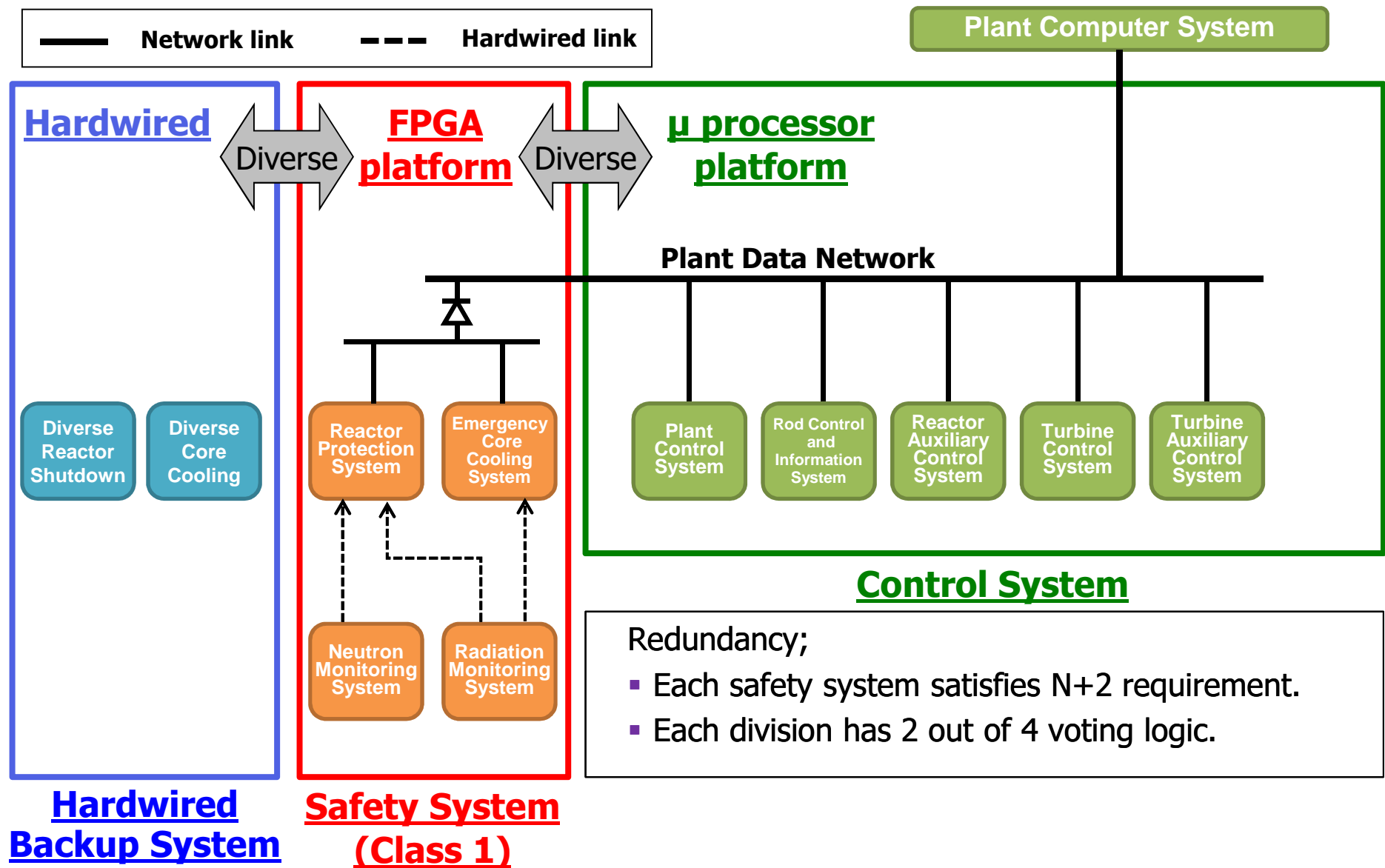
TAG: Technical Assessment Guide

IEC: International Electro technical Commission

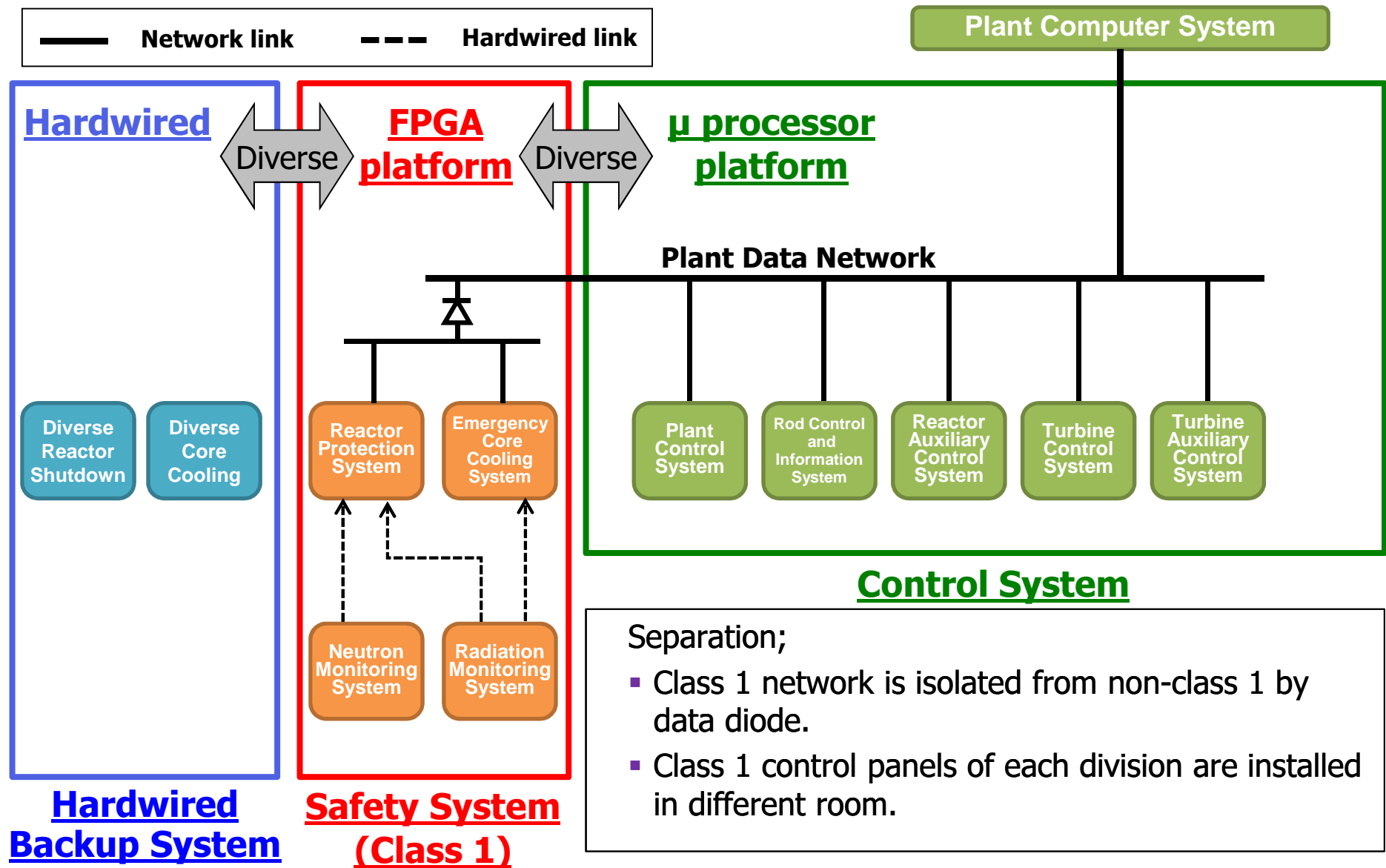
Overall UK ABWR C&I Architecture



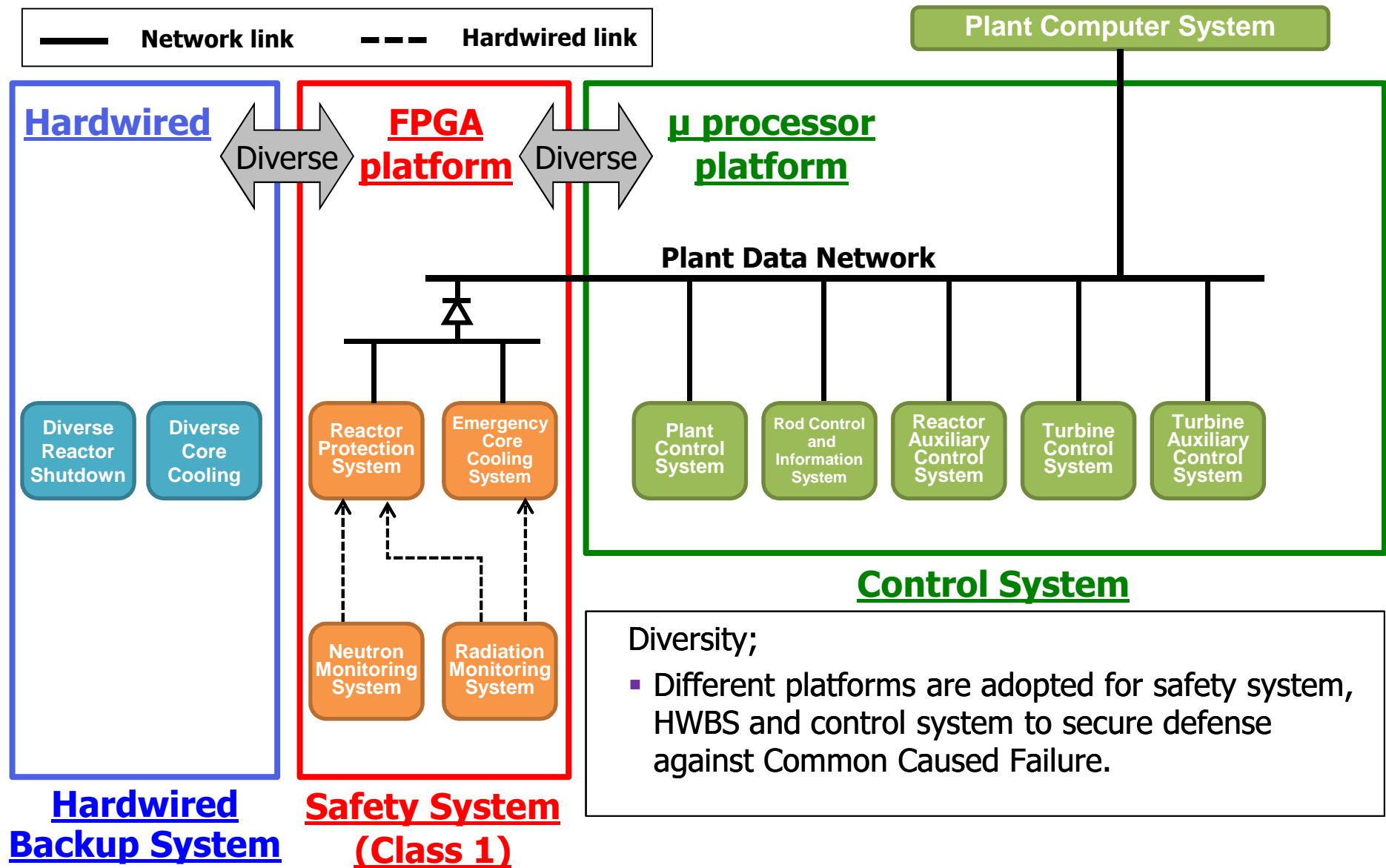
Overall UK ABWR C&I Architecture



Overall UK ABWR C&I Architecture



Overall UK ABWR C&I Architecture



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Overview of the Class 1 FPGA Platform

Hitachi developed a Class 1 Platform **vCOSS S-zero**

The main features are:

- Each module has FPGAs inside and connected to safety field bus.
- Development process complies with IEC 61513, 62566, 61508 and 62443
- Without processor, firmware, OS, middleware
- Supporting floating-point arithmetic without FPGA vendor's floating-point IP cores



Certification for the Class 1 FPGA Platform

Reliability requirement assigned to SSLC is 10^{-4} [PFD] .

The platform is required IEC 61508 SIL 3 as single configuration in order to satisfying 10^{-4} PFD as a whole system.



Certified as following from TÜV Rheinland in Jan. 2018.

- **vCOSS S-zero** complies with IEC 61508 **SIL 3** as single configuration.
- Measures for fault avoidance is applied in accordance with IEC 61508 **SIL 4**.
- Furthermore, Certified as SL 1 (Cyber Security Standard)
IEC 62443-4-1:2018 (Edition 1.0),
IEC 62443-4-2:2017 (65/663/CDV)



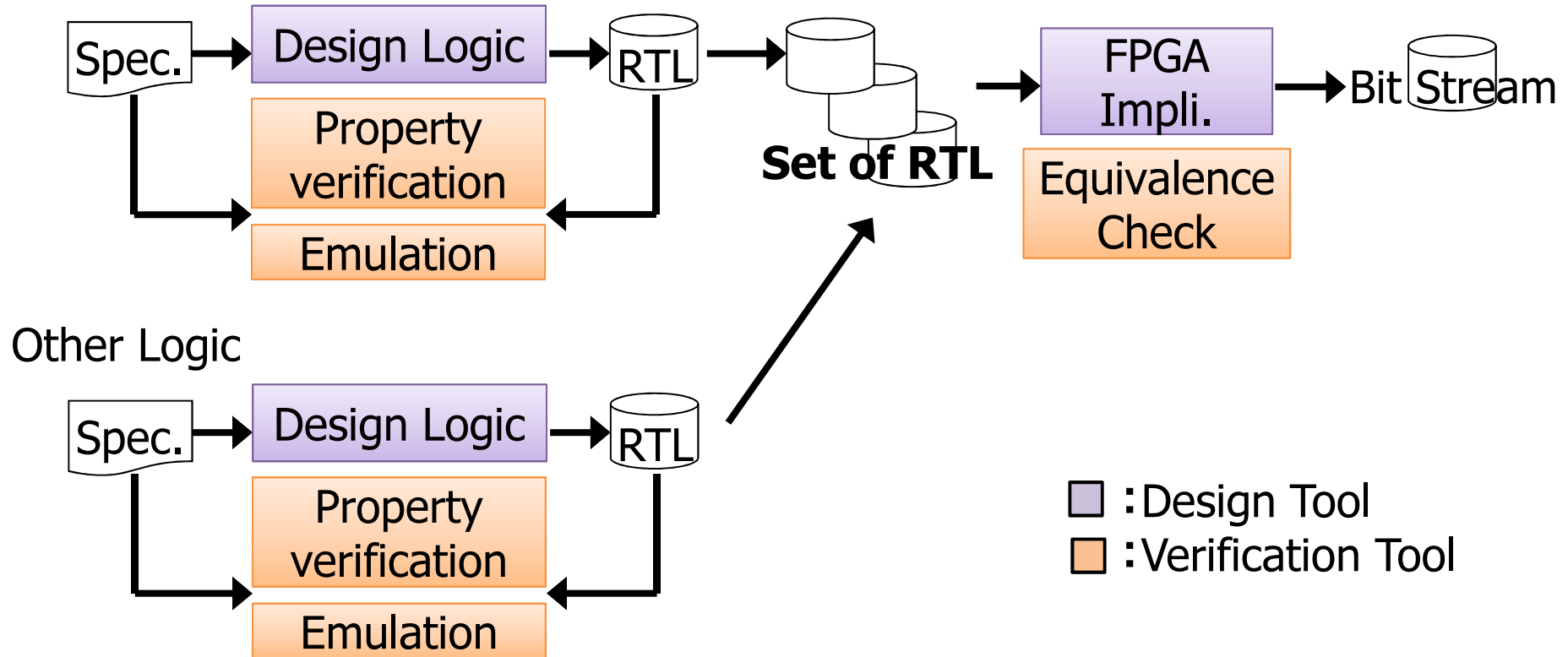
No.:968/FSP 1119.07/18

SSLC: Safety System Logic and Control system

PFD: Probability of Failure on Demand

Design and Development process for SIL 4

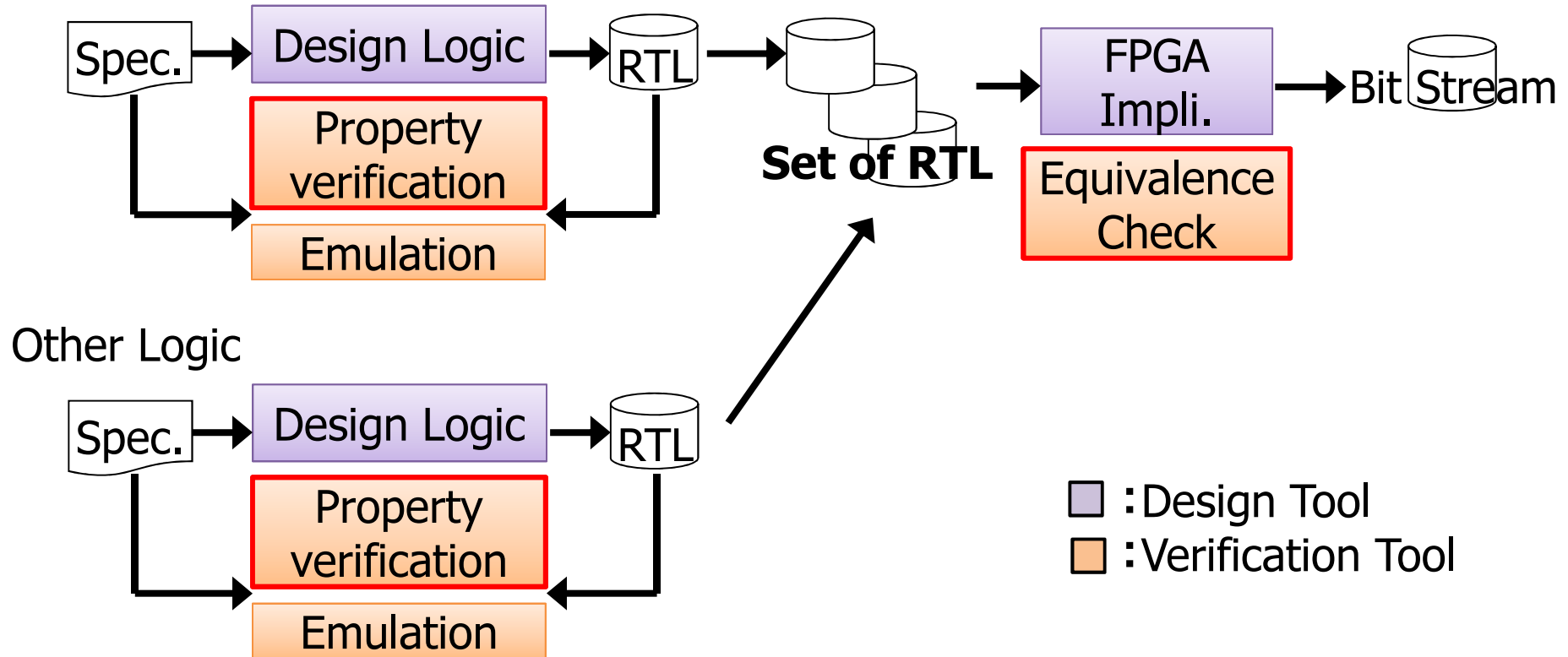
Calculation Macros



The figure focuses on the range of the FPGA bit stream from the specification.

Design and Development process for SIL 4

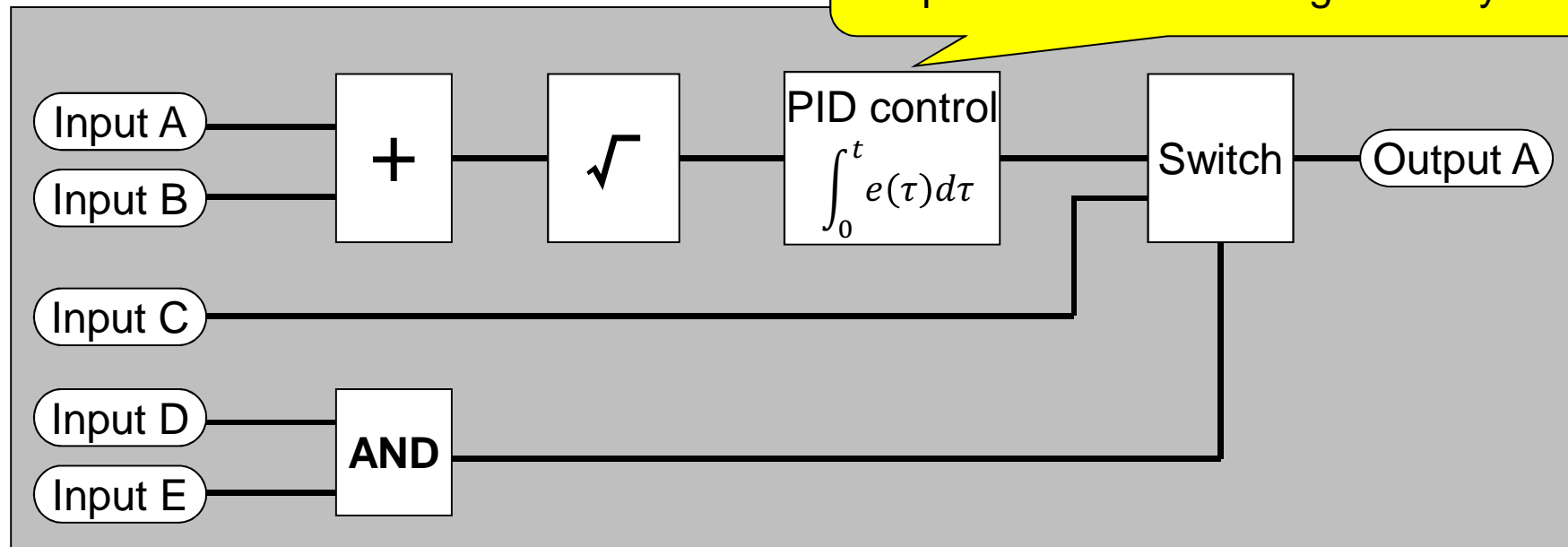
Calculation Macros



We applied the formal verification to the files generated from the specification to comply with SIL 4.

- Allow user to design as function block diagram using general design tool
- Support wide variety macros which are developed as white-box
 - Essential analog macro ; about 10 types (+, -, ×, ÷, √...)
 - Simple digital macro ; about 30 types(AND, OR, Flip Flop, ...)
 - Advanced function macro ; about 30 types(PID control, Switch, ...)
 - The others are under development.

Users are able to use over **10,000** macros per one LU and design flexibly !!



Hitachi completed GDA on schedule without GDA issues including C&I field.

Our design features

- Different Platforms are adopted to achieve the diversity.
- Developed **vCOSS S-zero** in accordance with IEC 61513 series.
- **vCOSS S-zero** has been certified for single SIL 3 according to IEC 61508.

Furthermore, the certificate confirmed that measures for fault avoidance is applied in accordance with IEC 61508 SIL 4.

- **vCOSS S-zero** has also been certified for Security Level 1 according to IEC 62443-4.

END

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