12th International Workshop on the Application of FPGAs in Nuclear Power Plants

Licensing History and Common Cause Failure Mitigation for FPGA Based Systems in the US Market

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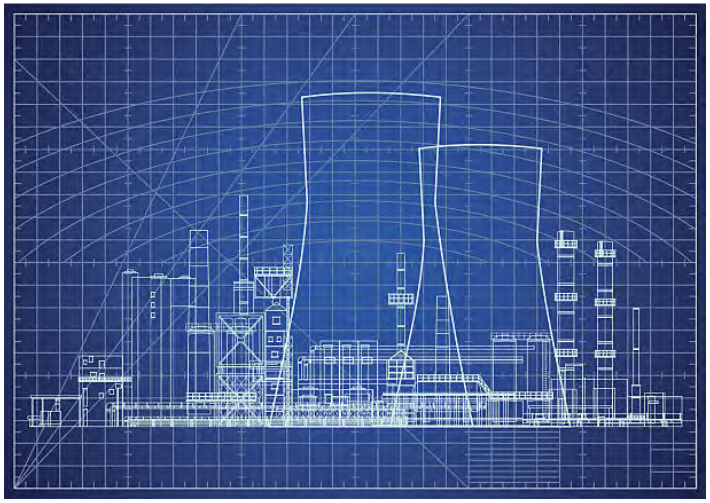
Purpose

Discuss various innovative FPGA-based platforms and devices approved for use in U.S.

- **Background**
- **Approach to Common Cause Failure (CCF) Mitigation**



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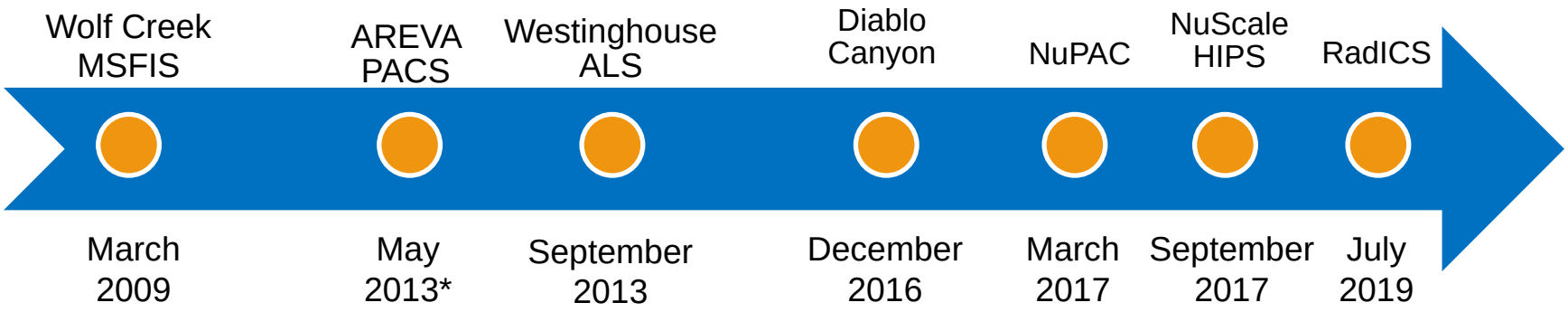
The Journey

Path blazed by innovators, with the support and guidance from the regulator



* Date of Submittal – Never Approved

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Wolf Creek MSFIS 1/3

- **Background**
  - First US Safety Related FPGA based application (Approval March 2009)
  - Application specific Wolf Creek Generating Station MSFIS
  - Originally proposed as a hardware only digital solution (i.e., not a software based digital solution) in 2008
  - NRC requested additional review including verification and validation documents
  - Precedent set - FPGA based systems reviewed against SW development standards

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Wolf Creek MSFIS 2/3

- **Approach to CCF Mitigation**
  - FPGAs with diverse logic core - independently computes parallel application specific logic
  - Differing Synthesis directives implement diverse logic paths
  - Diverse logic for platform functions and self testing
  - Parallel computing logics mismatch deemed a failure and sets outputs to safe state

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Wolf Creek MSFIS 3/3

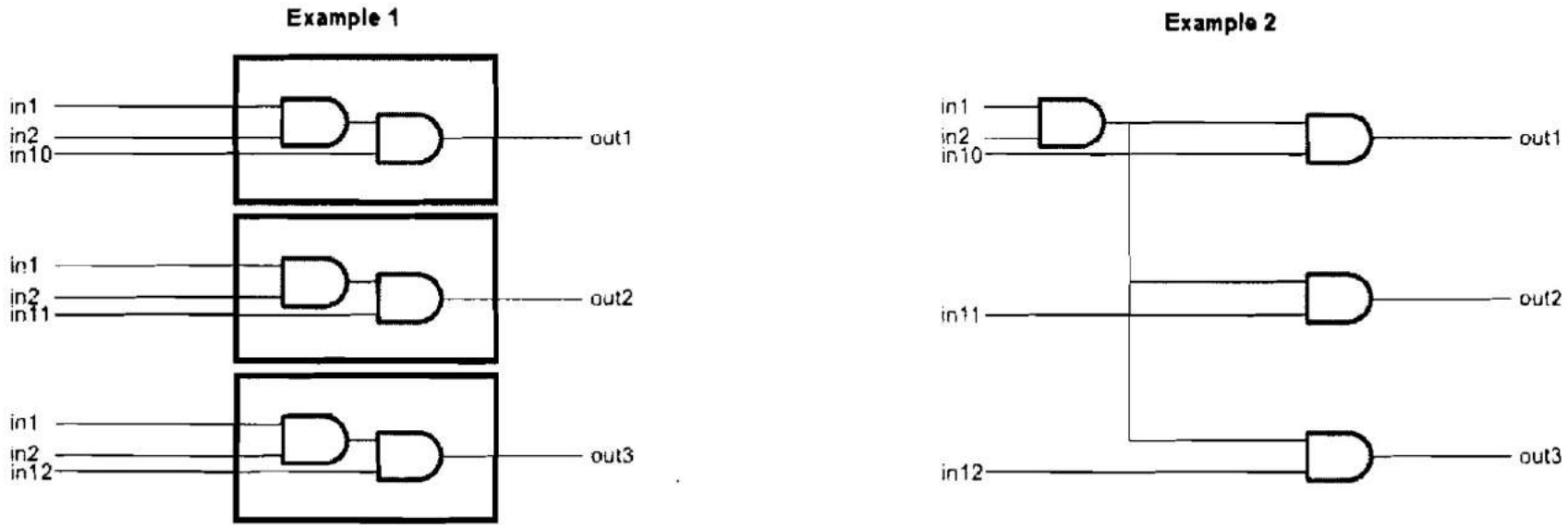

Figure 9 - Example of Diverse Logic Implementation

NRC determined sufficient diversity, due to low level of complexity and IV&V detailed review of core logics

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AREVA PACS 1/3

- **Background**
  - Priority Actuation modules integrate Safety/Non-Safety for actuator control and monitoring
  - Intended for U.S. EPR new build (Submittal in May 2013)
  - Utilized two separate modules: a safety-related priority module and non-safety-related communication module (micro-processor based)
  - Both modules qualified to same safety-related requirements

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AREVA PACS 2/3

- **Approach to CCF Mitigation**
  - 100% combinatorial testing
  - IEEE 7-4.3.2-2003 and D&IC-ISG-04 supports 100% testing methodology for CCF mitigation
  - Achievable only for simple devices/applications
  - NRC review not completed due to ending of U.S. EPR licensing efforts

Although licensing process not completed, NRC appeared to be on a path for approval

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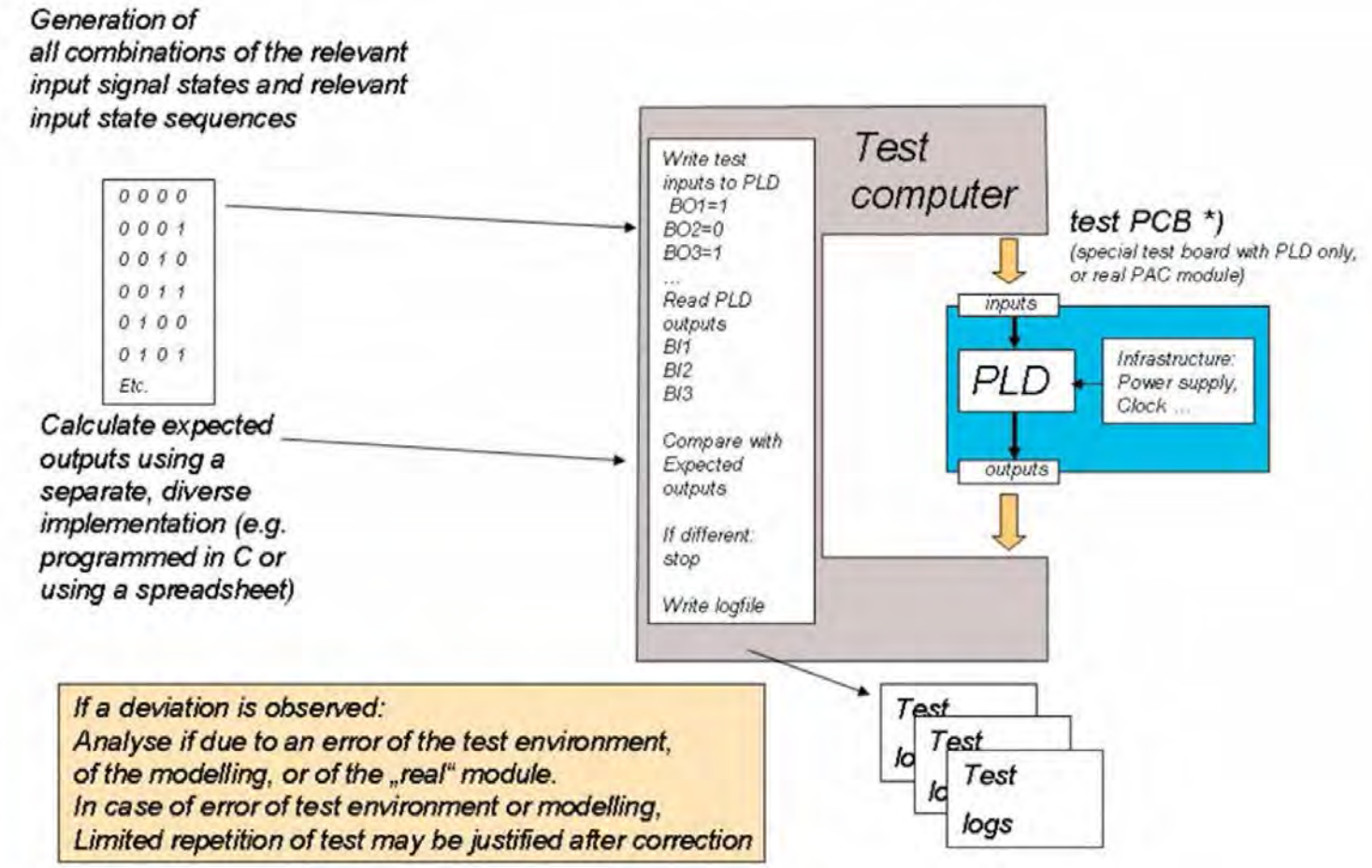
AREVA PACS 3/3

Overall Test Concept



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Westinghouse ALS 1/5

- **Background**
  - Westinghouse ALS CS Innovations technology advancement to a generic platform approval (September 2013)
  - Evolution of development method, architecture, board suite, and communication interfaces used in the Wolf Creek MSFIS ALS application
  - Diablo Canyon utilized in hybrid system replacing Eagle 21 digital PPS with a new digital PPS based on two platform, a PLC and Westinghouse ALS FPGA system

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Westinghouse ALS 2/5

- **Approach to CCF Mitigation**
  - Added built-in design diversity beyond CS Innovations technology
  - “Core Diversity Design” - two redundant logic implementations within each FPGA (Core 1 and Core 2)
  - Different synthesis directives for each logic implementation
  - Core outputs combined in a hardwired “OR” ensuring protective action if either path commands actuation

NRC determined platform level diversity alone was not enough and required application-specific diversity reviews

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Westinghouse ALS 3/5

- **Approach to CCF Mitigation (cont.)**
  - "Embedded Design Diversity" - "Option" for additional diversity
  - Requires two versions of hardware descriptive language files
  - Independent design teams utilized to implement
  - Implementing and maintaining independent design teams can prove costly and add organizational complexity

"Embedded Design Diversity" is an application level decision NRC determined project specific reviews are needed

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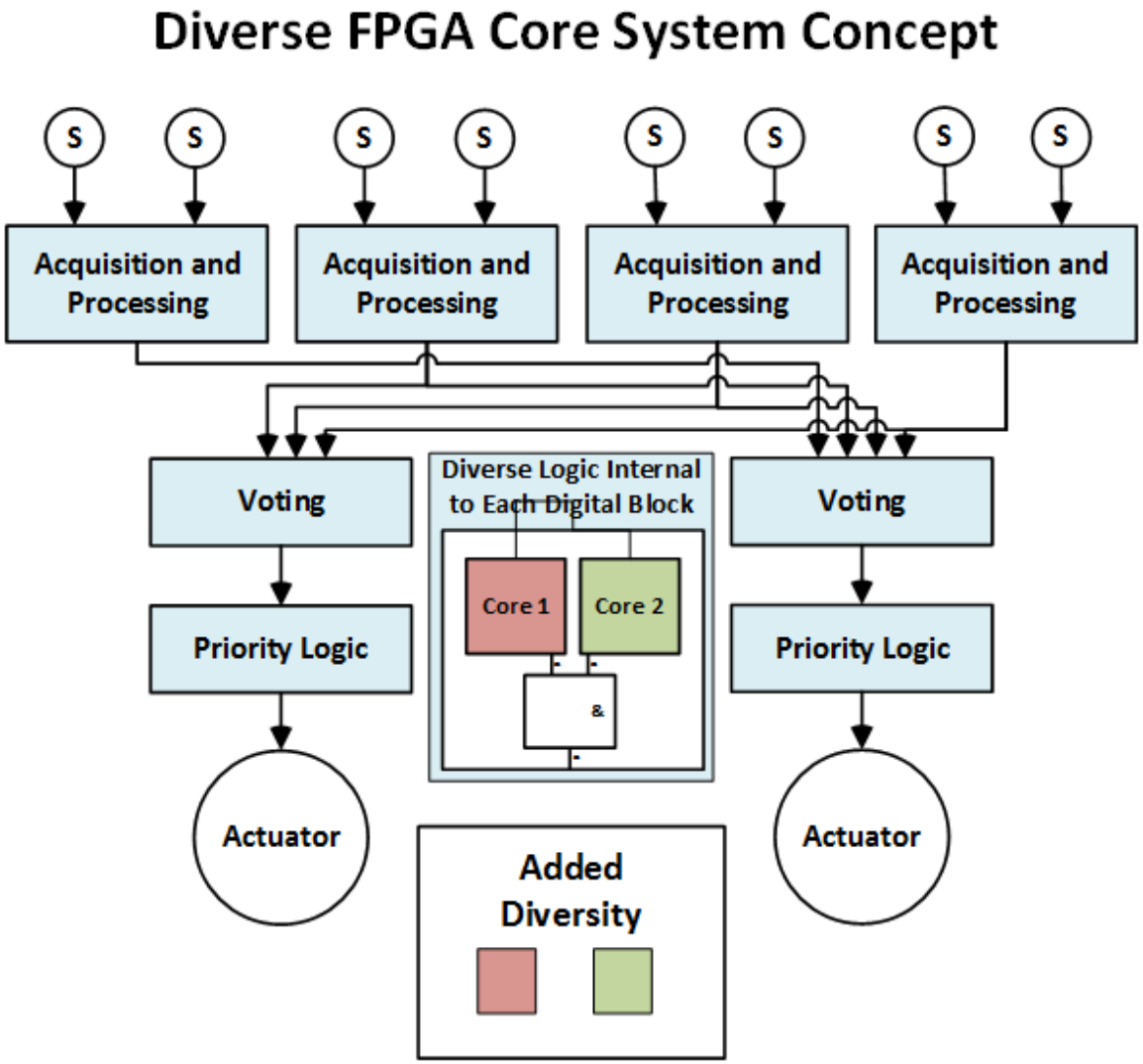
Westinghouse ALS 4/5



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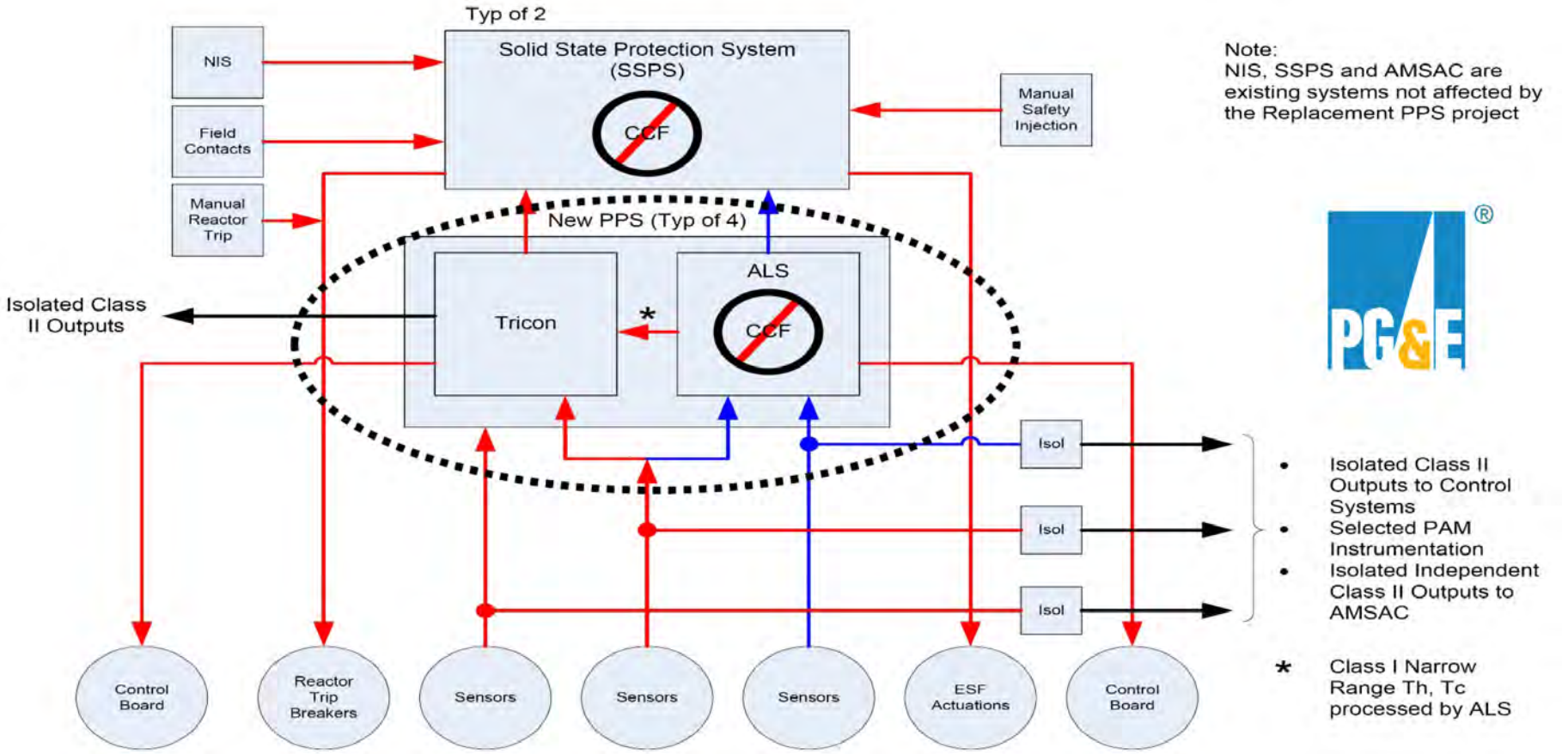
Westinghouse ALS 5/5



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Lockheed Martin NuPAC 1/2

- **Background**
  - Lockheed Martin Global, Inc. and State Nuclear Power Automation System (SNPAS) Engineering Company collaboration (Approval March 2017)
  - Two FPGAs: non-configurable, configurable
    - Non-Configurable - Platform level logics
    - Configurable - Application level logics

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NuPAC 2/2

- **Approach to CCF Mitigation**
  - Topical report specifies NuPAC platform utilizes hardware diversity and software program diversity
  - Specifics not given

Solutions and Acceptance are left open to be resolved by future submittals

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NuScale HIPS 1/3

- **Background**
  - Rock Creek Innovations LLC and NuScale Power LLC
  - Two FPGA types :
    - SRAM based
    - either a one-time programmable or flash based
  - FPGA types alternated throughout redundant architecture channels

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NuScale HIPS 2/3

- **Approach to CCF Mitigation**
  - HIPS Platform CCF Mitigation focused on equipment diversity (Two FPGA types)
  - Low-level architectural aspects inherently create configuration/operational differences
  - Each FPGA type has diverse development tools and programming methods
  - Development and IV&V lifecycles needed for each type (synthesis and simulation level)

Application specific action to verify design conforms to diversity attributed prescribed in Topical Report

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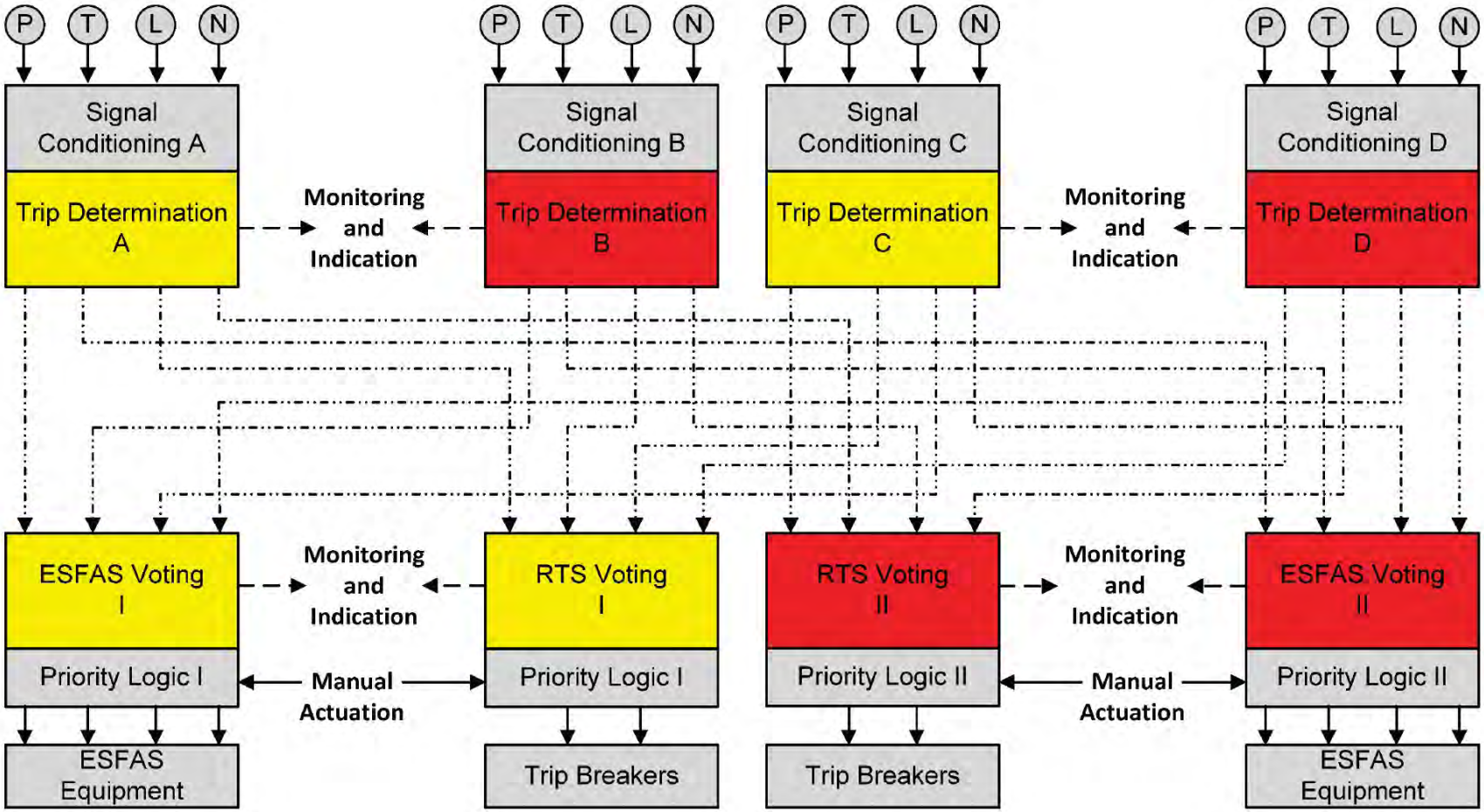
NuScale HIPS 3/3



Red and Yellow Indicate FPGA Diversity

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Radiy RadICS 1/3

- **Background**
  - 3rd Generation FPGA-based I&C equipment Nuclear Power Plants by Radiy
  - IEC 61508 SIL 3 certified (single channel configuration)
  - 9 NPP installations (Ukraine and Argentina)
    - 1 Reactor Trip System,
    - 2 Nuclear Island I&C,
    - 1 Conventional Island I&C,
    - 4 ESFAS,
    - 1 MCR and SCA Annunciation System
  - 80+ installations of previous 2nd Generation (Ukraine, Bulgaria, Brazil)

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Radiy RadICS 2/3

- **Approach to CCF Mitigation**
  - Diversity strategy uses internal design features applied at platform level addressing CCF vulnerabilities
  - Diverse PLD chips (FPGA vs CPLD):
    - CPLD separate and inherently diverse from FPGA
  - CPLD monitors FPGA – independent/functionally diverse (from FPGA) method ensuing system safe state

Simplifies overall I&C design: DAS or application specific design tasks NOT needed to address CCF

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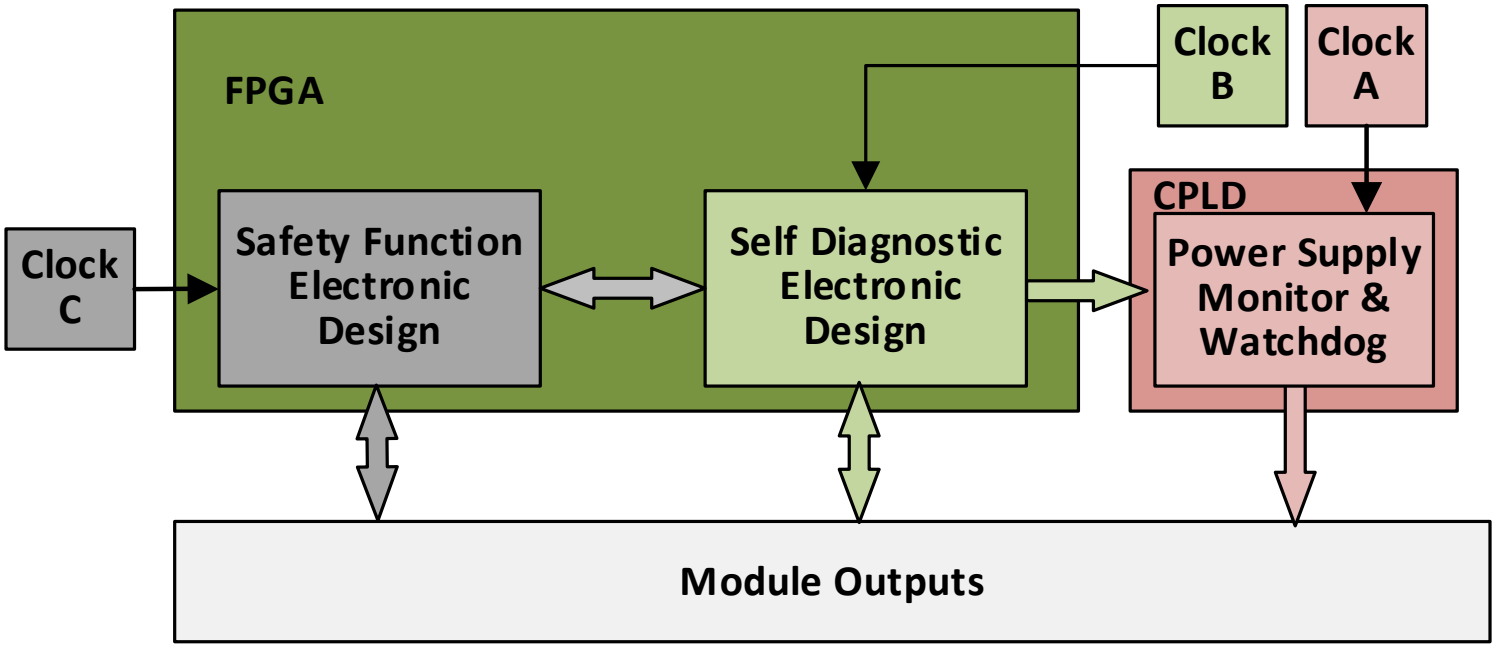
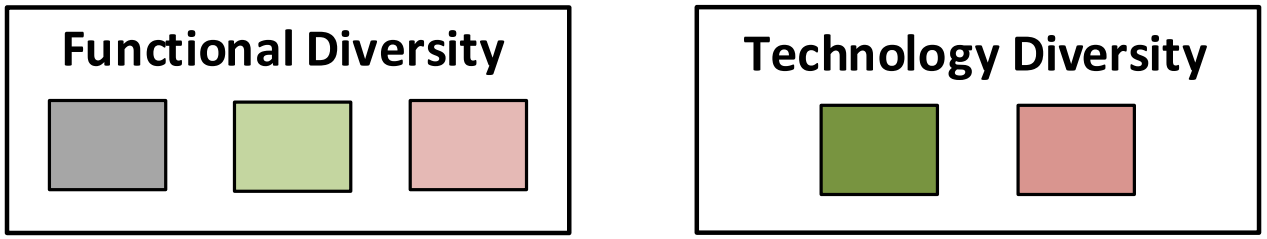
Radiy RadICS 3/3



Single Channel Shown



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Moving Forward

- Innovators working with receptive regulators has led to great strides in FPGA technologies for nuclear applications
- Collaborative effort must continue as we design and install new systems
- As we do this, Technologies, Designs, and Projects will continue to improve

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Thank you

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