Critical Issues and Lessons Learned in the Deployment of FPGA Based Systems in NPPs

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Outline

- Background
- Significant Issues
- Licensing Process
- Licensing Challenges
- Lessons Learned
- Questions

Background

- Much has been accomplished in recent years
  - Twelve annual FPGA workshops
  - Publication of IEC standards
  - Publications of EPRI guides
  - Publication of International guides
    - IAEA NP-T-3.17
    - MDEP DICWG-5
- Development of nuclear specific vendor base
- Acceptance of many FPGA-based platforms for use in NPPs

Licensing and Topical Reports in the US that included FPGAs or CPLDs

- Westinghouse - ALS Platform
- Westinghouse - SSPS
- Lockheed Martin - NuPAC platform
- NuScale - HIPS
- Radiy - RadIC platform
- Toshiba Power Range Monitoring (in review)

Significant Issues

- Lack of understanding of the key advantages of the technology
  - FPGAs (and CPLDs) can be designed to simplify safety demonstration
  - More resistant to cybersecurity issues
  - FPGAs appear to be more resilient to hardware obsolescence due to portability of HDL to new chips
  - Hardware based fault detection and isolation

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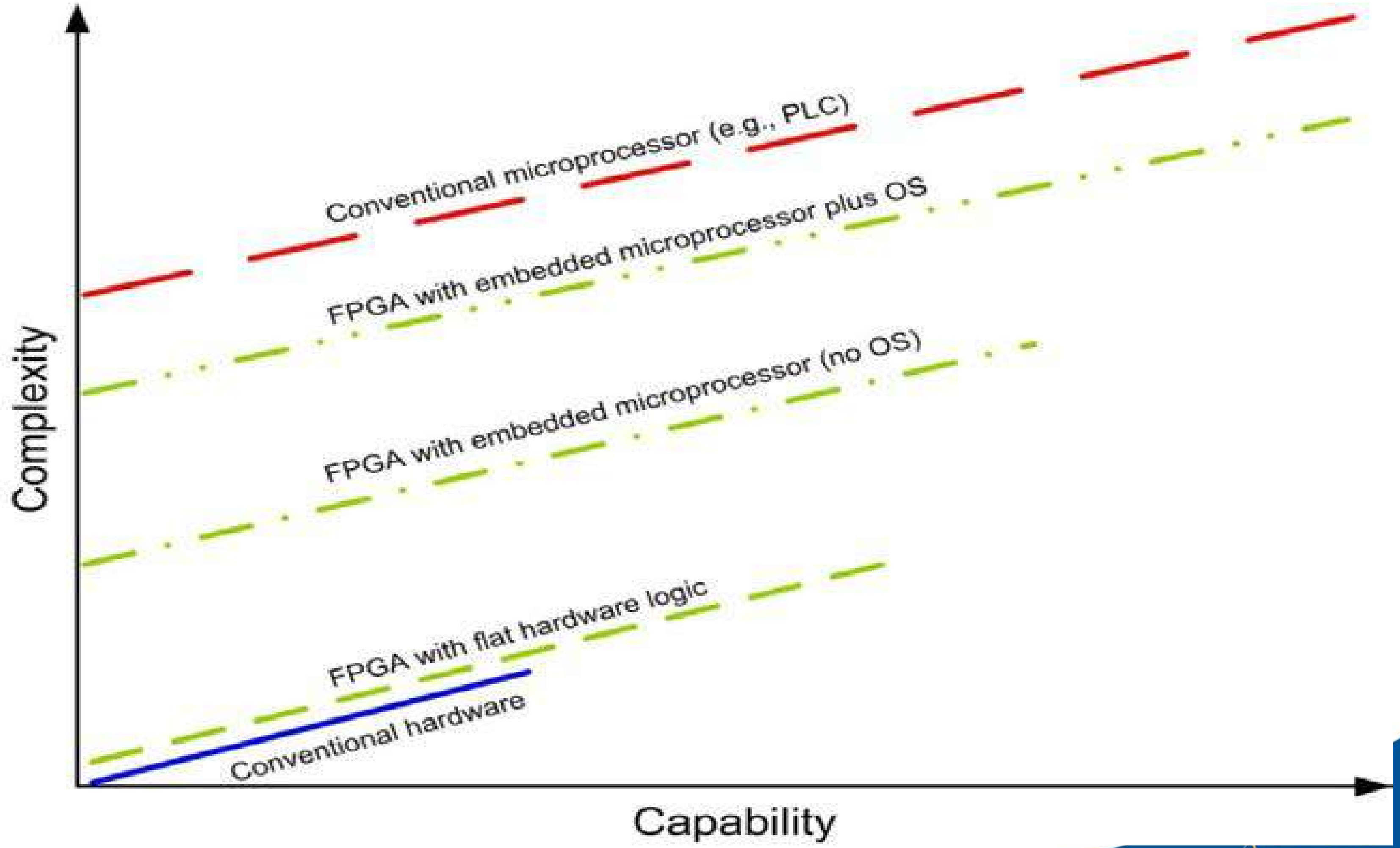
Significant Issues



Significant Issues

- Limitation of the standards and guidelines
  - Although this is quickly becoming a non-issue, new guidelines are slow to be implemented
  - Many systems not developed to nuclear standards
- Less access to internal signals for monitoring, testing and analysis/troubleshooting
- Understanding that tools are a critical part of the safety case/demonstration
  - Insufficient understanding of roles of software tools
- Insufficient guidance for FPGA use in embedded digital technologies including smart devices

Licensing Process

- There are several different general methods for review and approval of FPGA-based systems
  - RG 1.152 (IEEE 7-4.3.2) and RG 1.168 (IEEE 1012) based reviews
  - IEC 62566 and IEC 62566-2 based reviews
  - Other review processes (including the use of Formal Methods)
- Key differences in these approaches include
  - Life cycle requirements including verification and validation
  - Level of detail in requirements
  - Credit for testing and fault tolerance features

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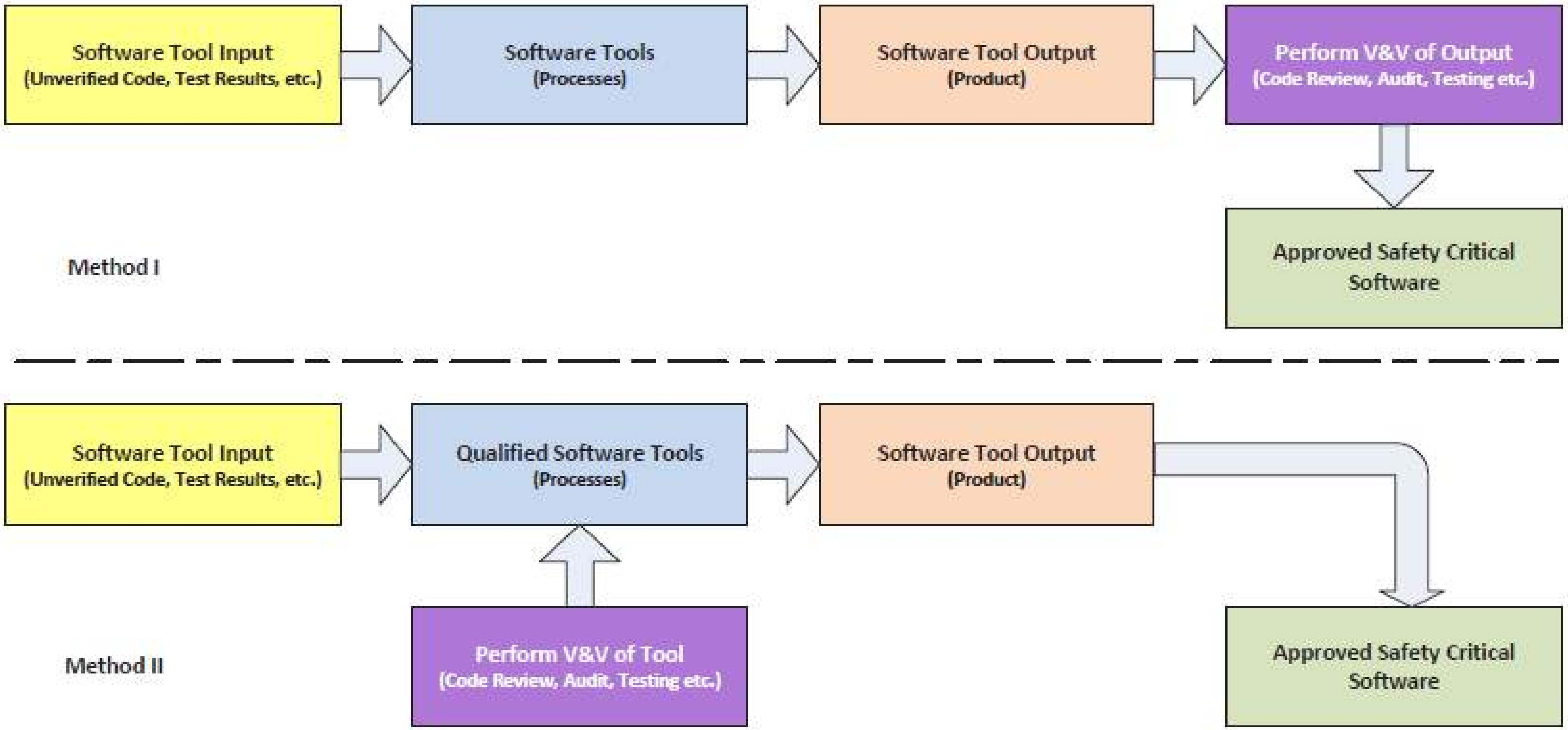
Licensing Challenges

- Evaluating predeveloped blocks (PDBs) or IP cores can be frequently challenging
  - Information from vendors not always available
  - Commercial qualification no always available
- Testing completeness
- Software tools
  - Configuration control of tools
  - Validation of tools
  - Documentation

Licensing Challenges



Two possible methods that the NRC considers to be acceptable for approval of tools. V&V — verification and validation

Lessons Learned

- Common Cause Failure
  - Most regulators required protection from CCF for digital safety systems
  - FPGA-based systems provide opportunities to address CCF
    - Use of FPGA technology as a diverse actuation systems (DAS)
    - Use of FPGA and CPLD as devise from each other
    - Use of different vendors or different tools to make FPGAs diverse from each other

Lessons Learned

- Examples of FPGA-based methods used to address CCF
  - Two channels of computer based processors coupled with two other channels of diverse FPGAs with common requirements
  - Two diverse FPGA chip technologies with common requirements
  - Single FPGA to implement the required safety functions with diverse CPLD device to monitor and identify FPGA faults
- Other FPGA-based methods that are used to address CCF include extensive testing and analysis

FPGAs (and CPLD) based systems provide an alternative for addressing CCF concerns

Lessons Learned

- NRC has conducted a number of reviews of FPGA based systems using IEEE 1012
  - SIL Level - Graded Approach to V&V
  - Software Criticality Emphasis
  - Hardware and System Processes Introduced in Later Revisions
- NRC has had adapted software tasks to FPGA equivalent tasks
  - HDL Code = Software Instructions / code
  - Development Tool / Environment is software based and is similar
  - Audit / CM / Test Coverage / Traceability / Criticality / Risk / Hazard analyses Tasks, etc.
- IEC 62566 may be a better choice for FPGAs in the new revision of NRC regulatory guidance

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Conclusion

- Various vendors and regulators are quickly getting to the point where they can and do treat FPGA-based systems as routine
- Although some issues remain, vendors and regulators have accepted FPGA-based systems, to address CCF issues
- Updating guidance and experience are the largest remaining challenges

Questions ?

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