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Formal Verification of High-Consequence Controls

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Problem

Nuclear weapons digital controls and critical systems need assurance for safety and security beyond current commercial/academic tools

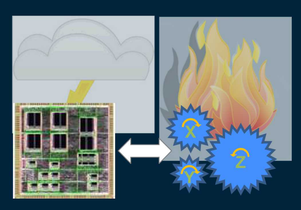
Safety requirements are *always/never* properties:

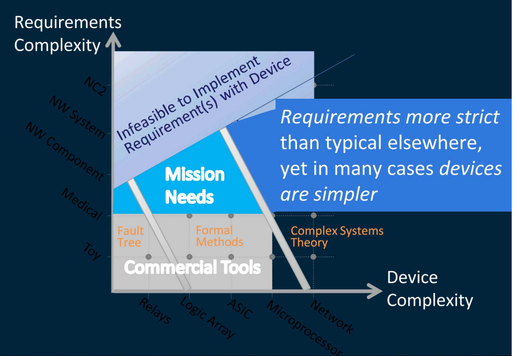
Testing ensures function, cannot ensure the absence of failure

Formal methods can ensure the absence of failure

Mission need exceeds even the usual formal tools

Ensure fail-safe in accident and extreme environments:





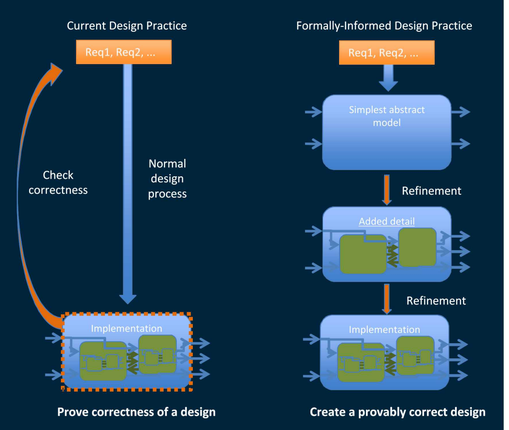
Approach

Formally informed design via abstraction refinement

Abstract model: easy to identify high-level requirements

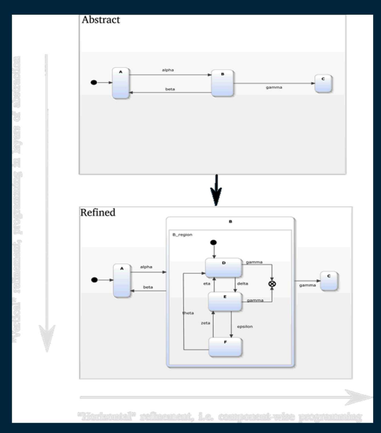
Refined model: closer to what is implementable in silicon

Abstraction/refinement formal methodology ensures safety and security (always/never) requirements from abstract idea through implementation



Domain-specific language based on statecharts: SNLcharts

- Similar to but more systematic than Event-B/iUML-B
- States are refined to encapsulate new states recursively
- Safety properties are formally preserved through refinement by "proof obligations" that must be discharged to complete the design



A variant of this methodology is used to design-in fail-safe modes for high-consequence digital controls

- View extreme environments as either an abstraction or a refinement

Results

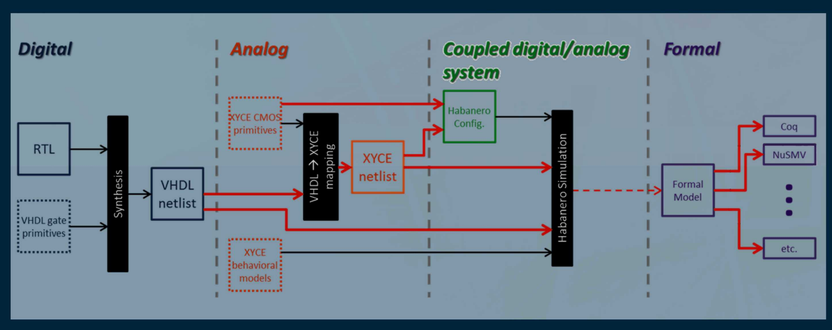
Formal Tool: Developed theory and statechart-like language similar to design methods in common use

Scalability: Tractable formal verification of safety and security even for complex designs

Fail Safe: Design methodology extends to out-of-nominal extreme environments that are otherwise difficult to guarantee for safety and security

Detail: Advancing formal analysis workflows for out-of-nominal electrical behavior of digital devices

- Mixed-signal simulation can reveal the digital imprint of a physical insult (e.g., radiation) on a circuit
- By including these digital upsets in a formal model, can then quantify effect on safety properties



Significance

Addressing needs for high-consequence digital control systems, where conventional design techniques are insufficient

- Provide *evidence* that "always/never" safety and security requirements are actually met by the controls
- Prevent these critical controls from being susceptible to all of the cyber-attacks, subversions, and abuses that conventional digital systems are heir to

This research is creating practical theories, tools, and methodology to ensure that safety and security requirements are met in high-consequence controls

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