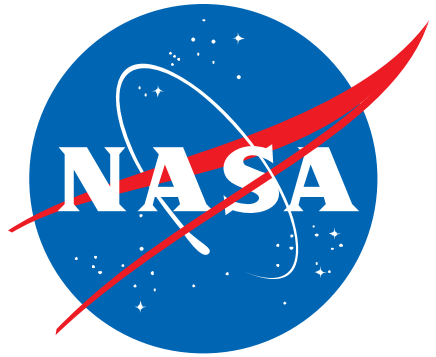


Quantitative Assessment of Risk for Modeling Radiation Impact on System Functions

Rebekah A. Austin
NASA Goddard Space Flight Center (GSFC)
NASA Electronic Parts and Packaging (NEPP) Program

Acronyms

GSFC	Goddard Space Flight Center
GSN	Goal Structuring Notation
NEPP	NASA Electronic Parts and Packaging
RHA	Radiation Hardness Assurance
SEE	Single Event Effects
SEFI	Single Event Functional Interrupt
SEL	Single Event Latch-up
SysML	System Modeling Language

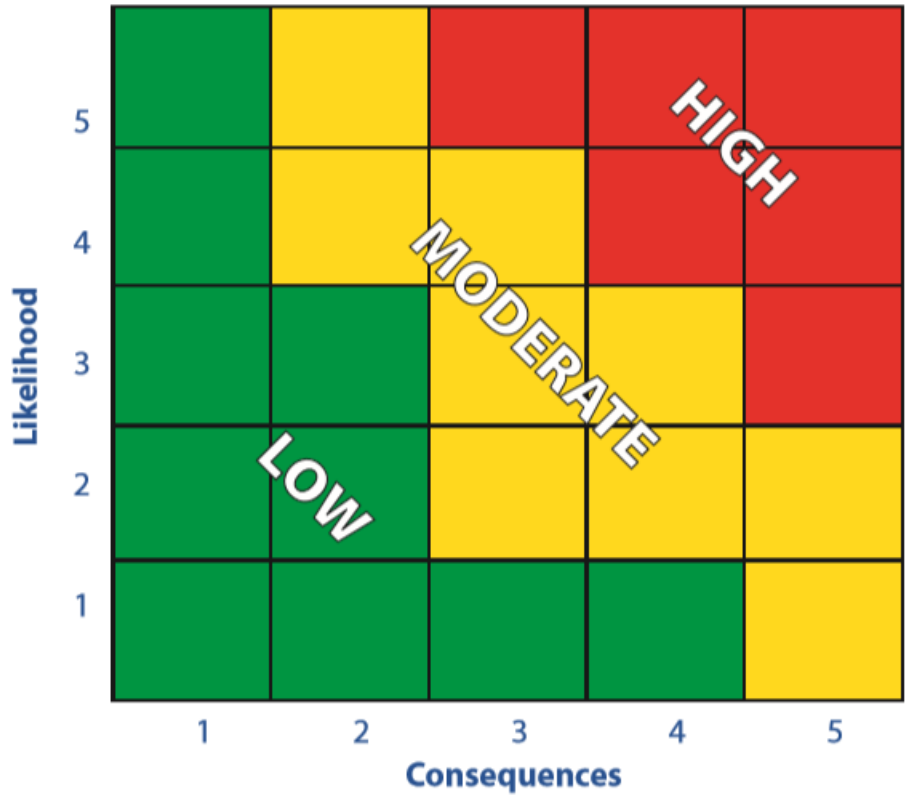
Risk Assessment and Management

- Risk: potential for performance shortfalls
(NASA Risk Management Handbook)

- Risk = Probability of failure X Consequence of failure

- Risk Assessment
  1. Identify possible faults
  2. Determine likelihood of faults
  3. Determine consequence of faults

- Risk Management
  1. Reduce types of faults
  2. Reduce likelihood of faults
  3. Reduce consequence of faults



Risk Matrix from NASA Systems Engineering Handbook Rev. 1: https://www.nasa.gov/sites/default/files/atoms/files/nasa_systems_engineering_handbook.pdf

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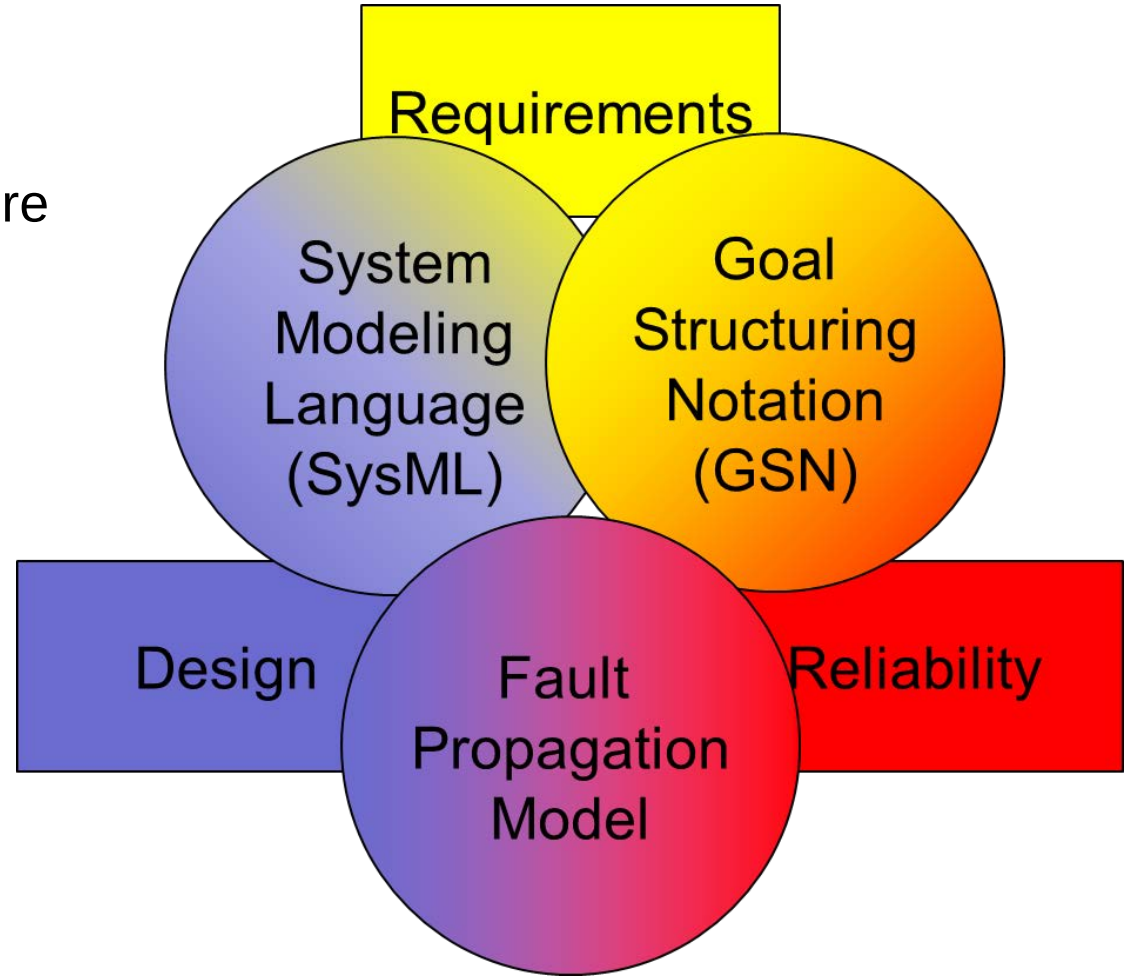
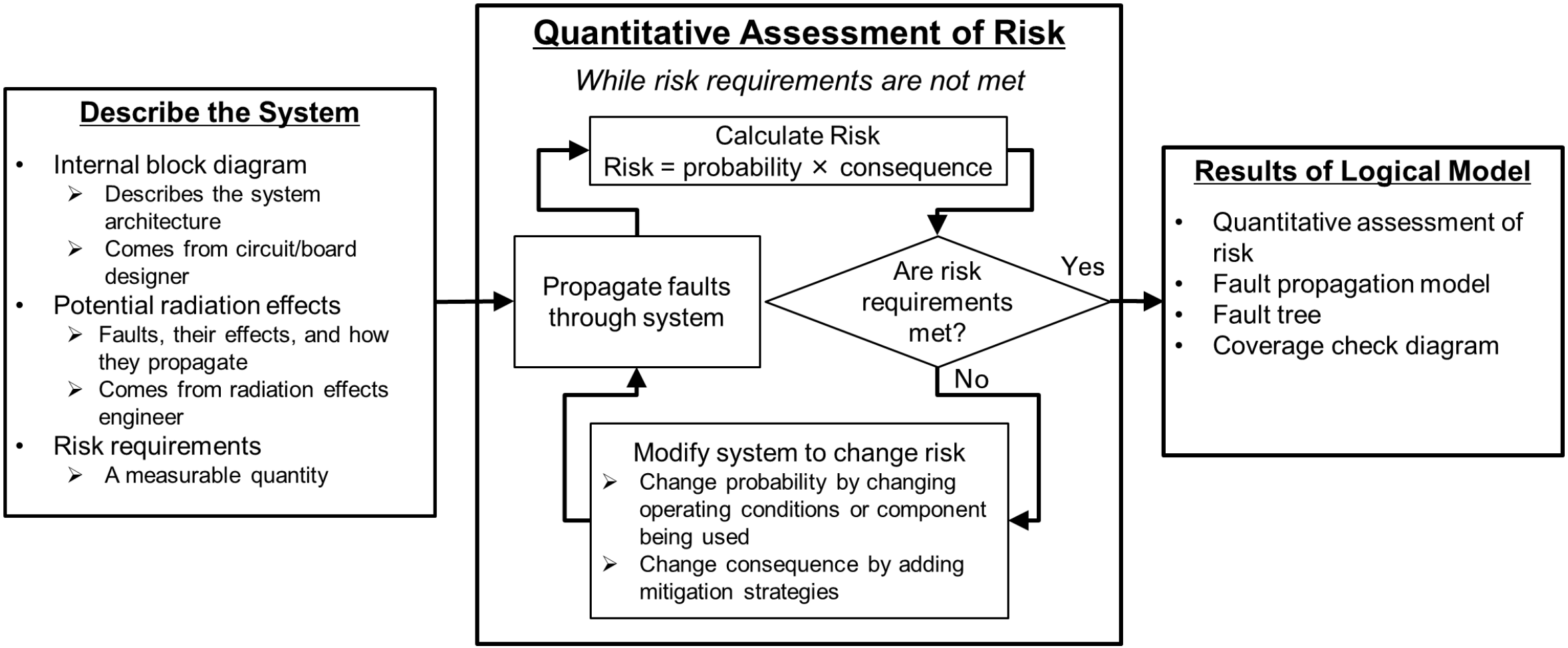
Quantify and compare to technical risk from different domain

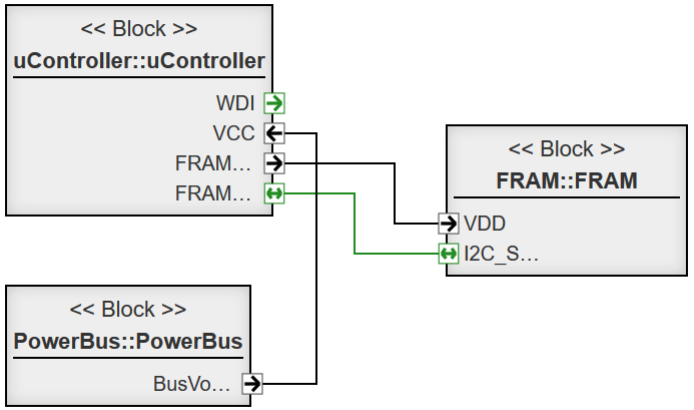


Model-Based Quantitative Risk Assessment



Radiation-induced Fault Identification and Propagation

- SEFIs and SELs in the microcontroller lead to the satellite bus turning off the experiment



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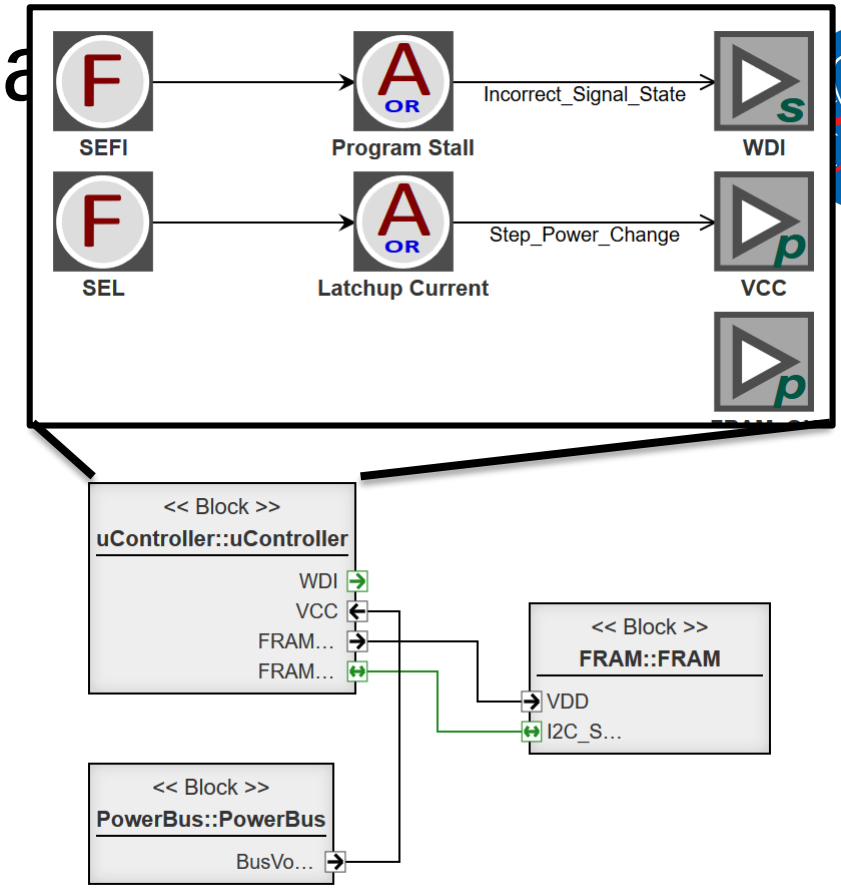

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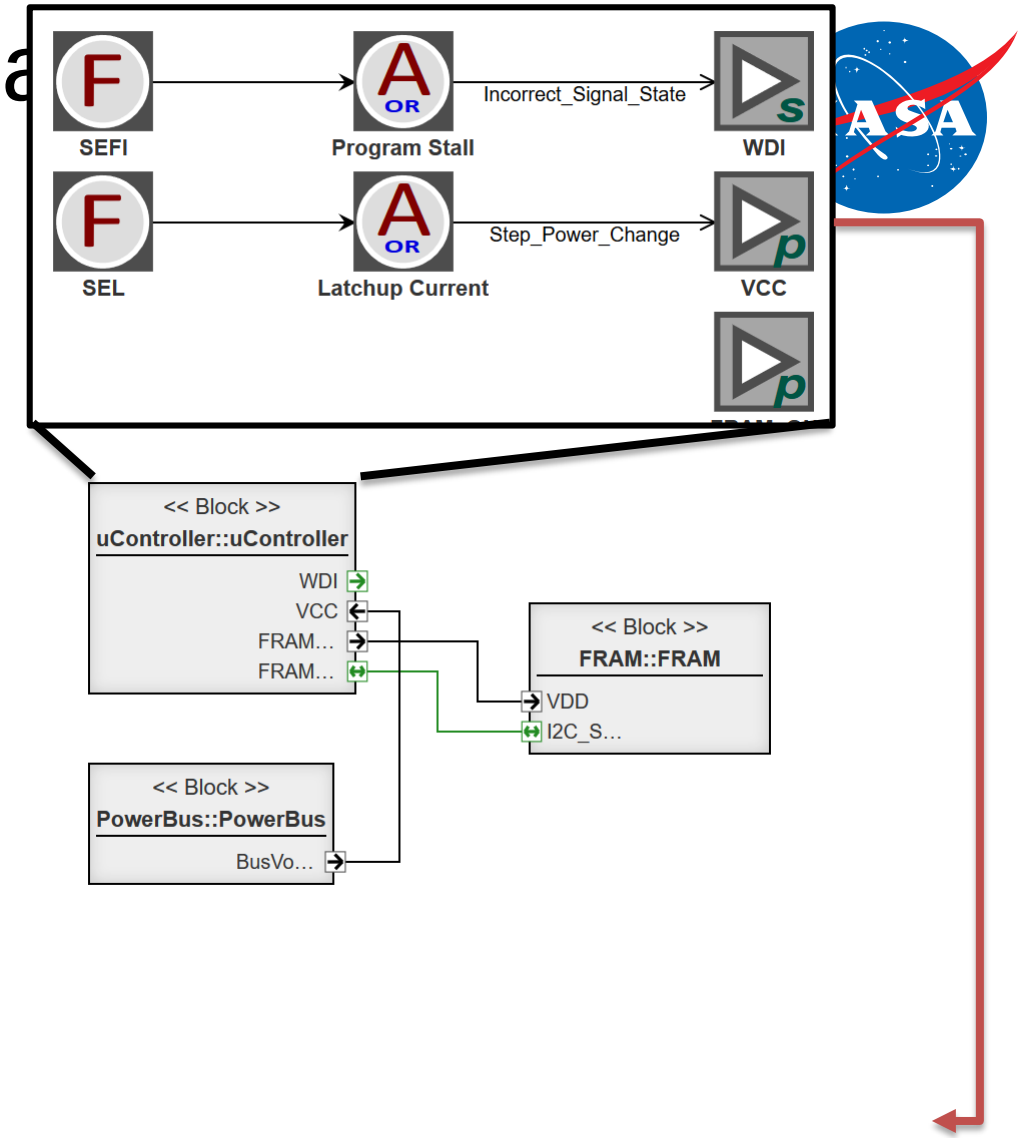

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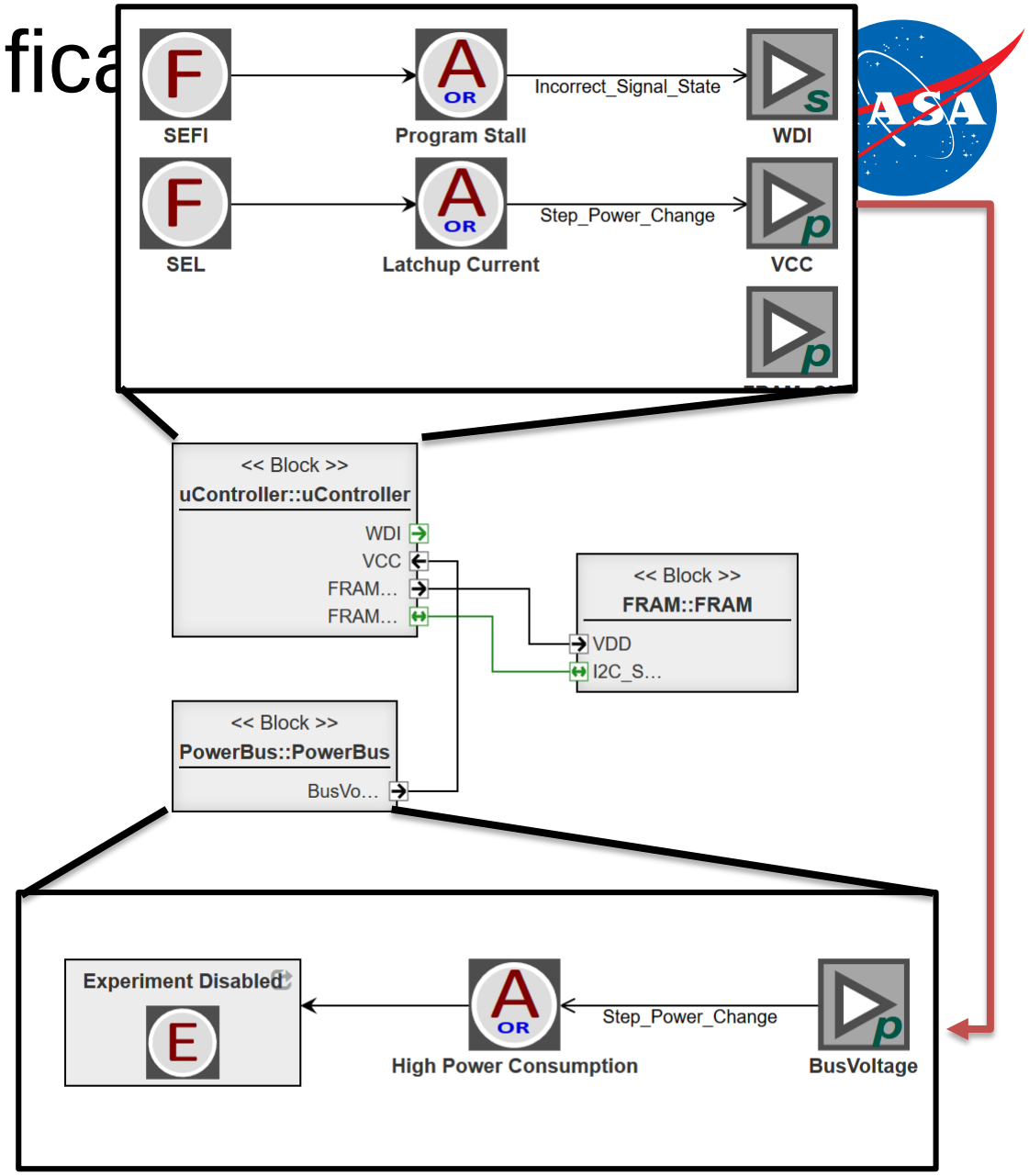
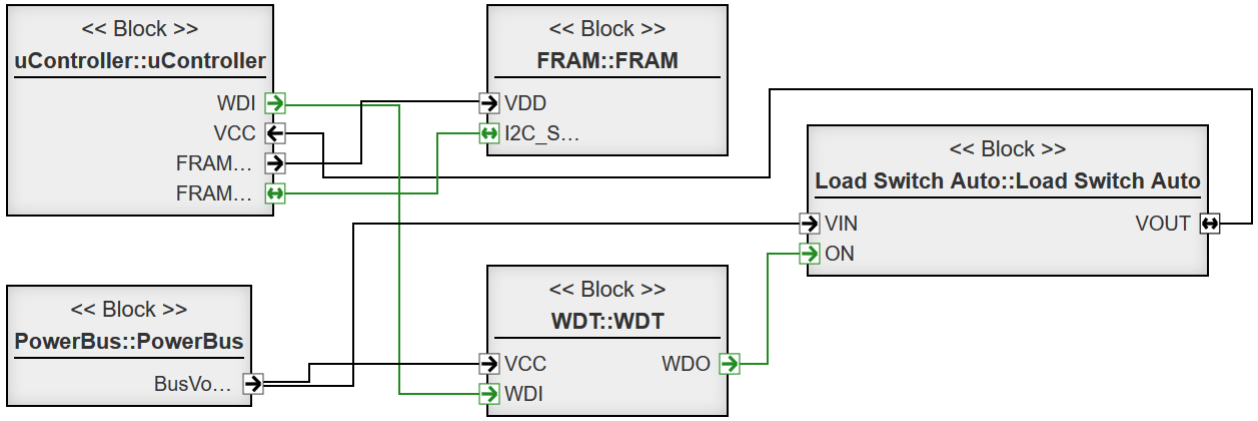


Radiation-induced Fault Identification and Propagation after Mitigation

- Watchdog timer and load switch added to mitigate risk



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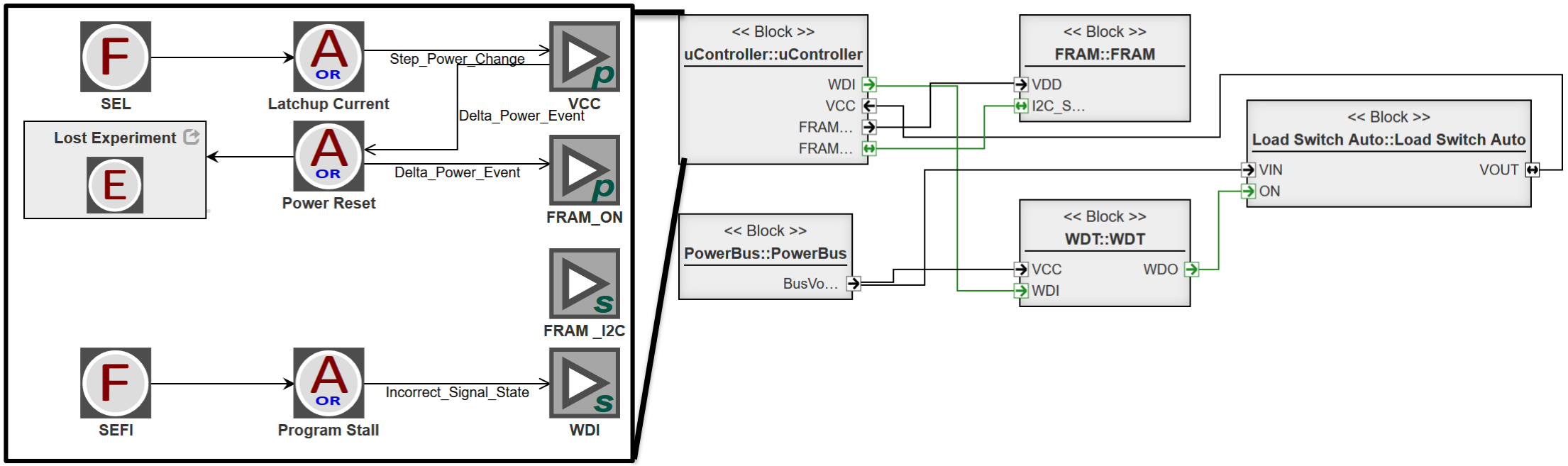

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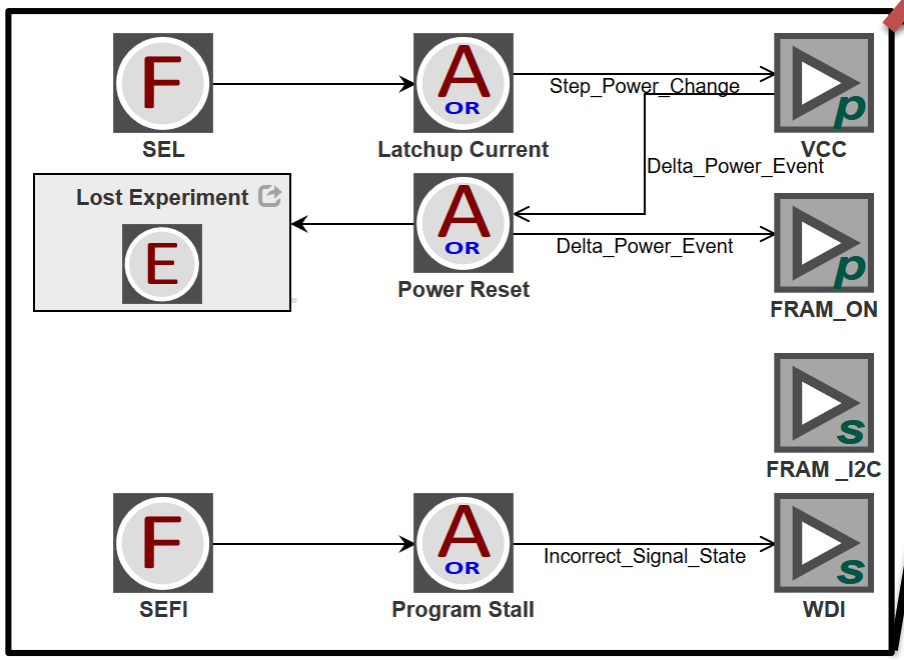

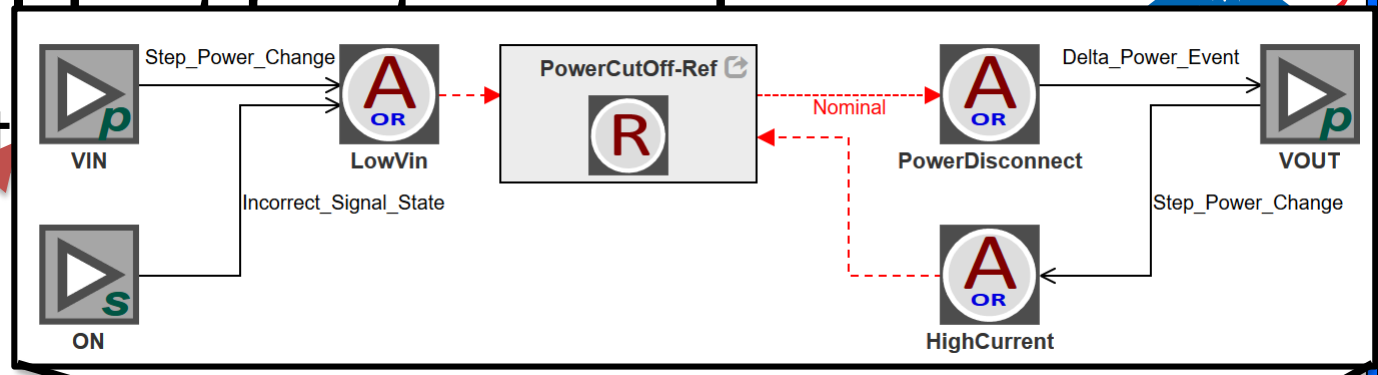

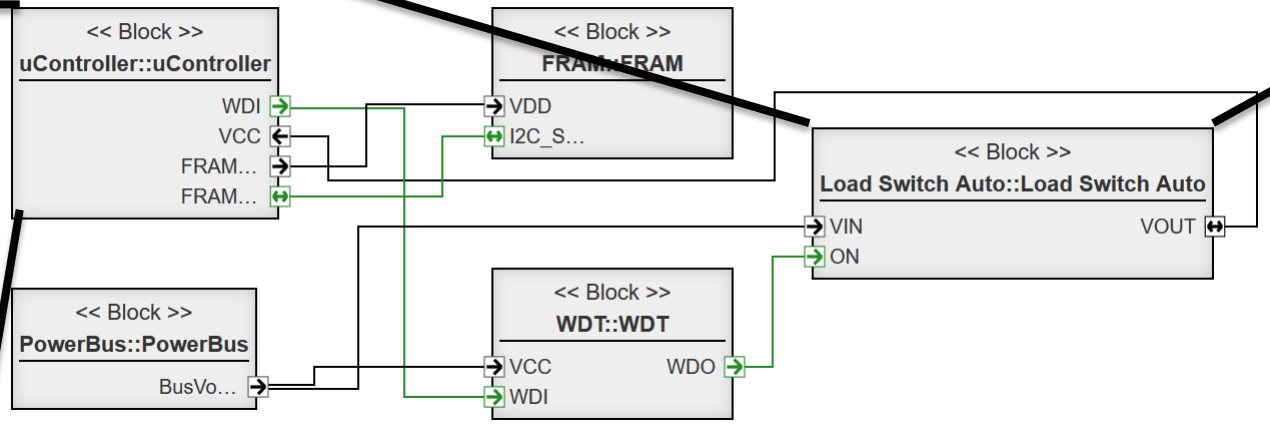

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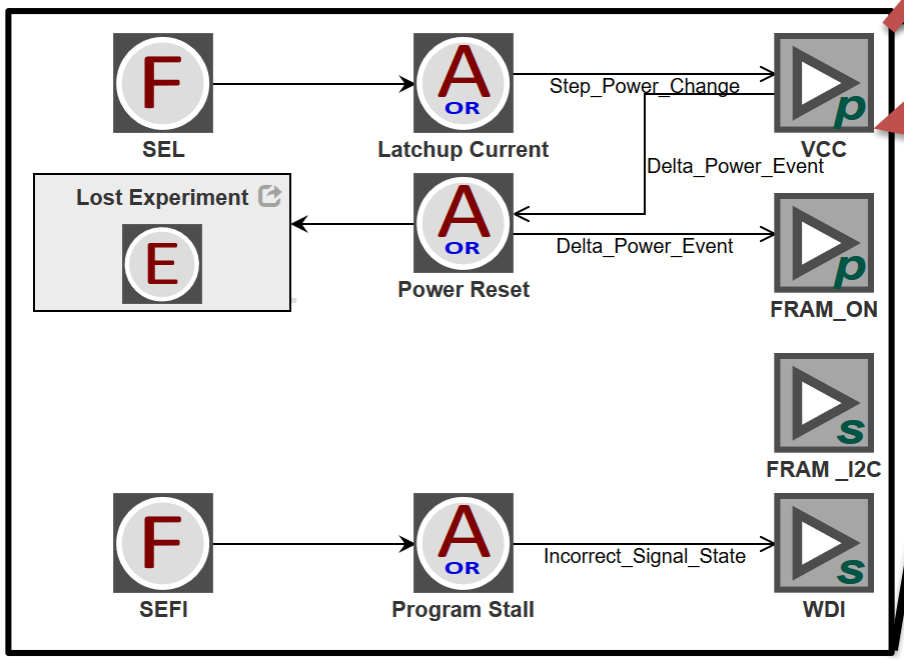

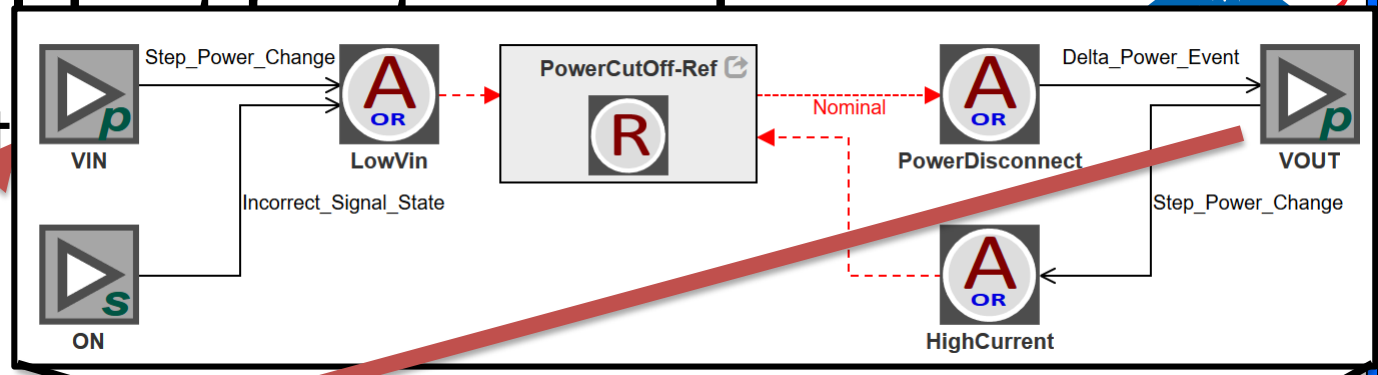

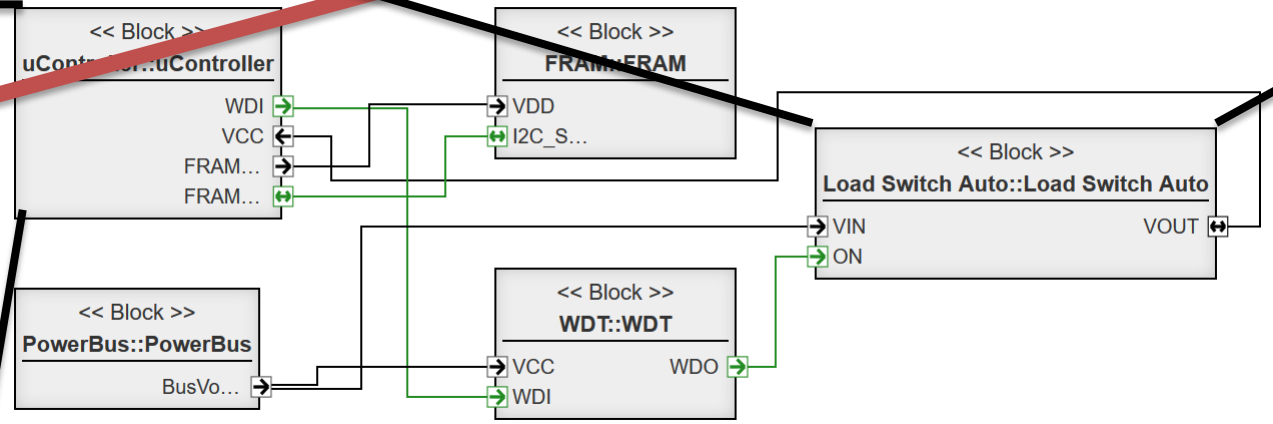

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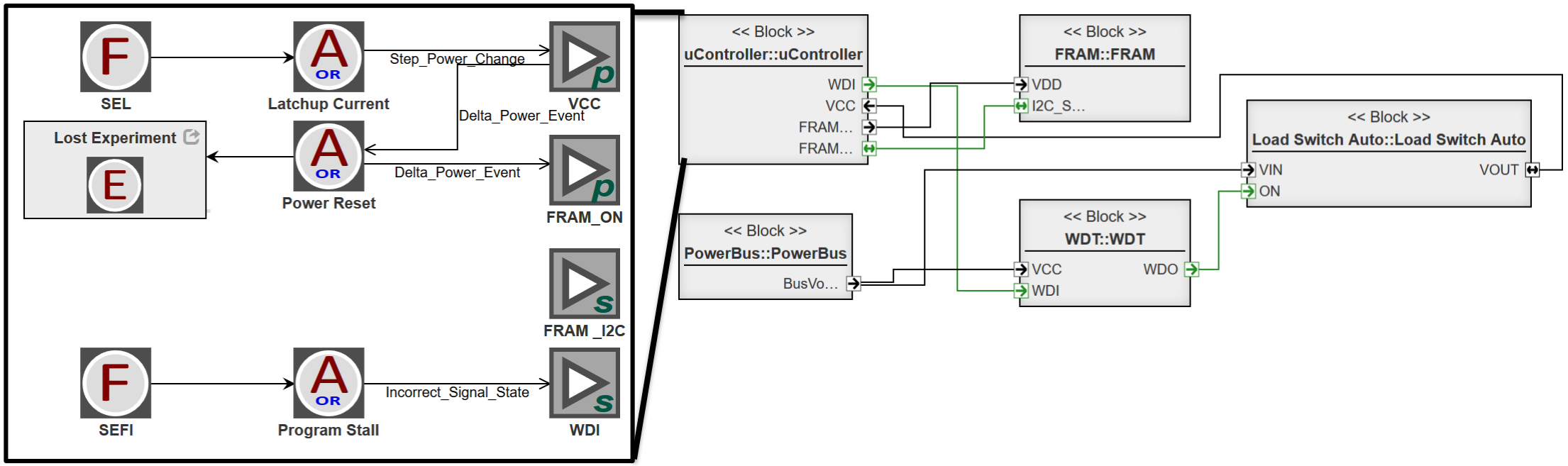

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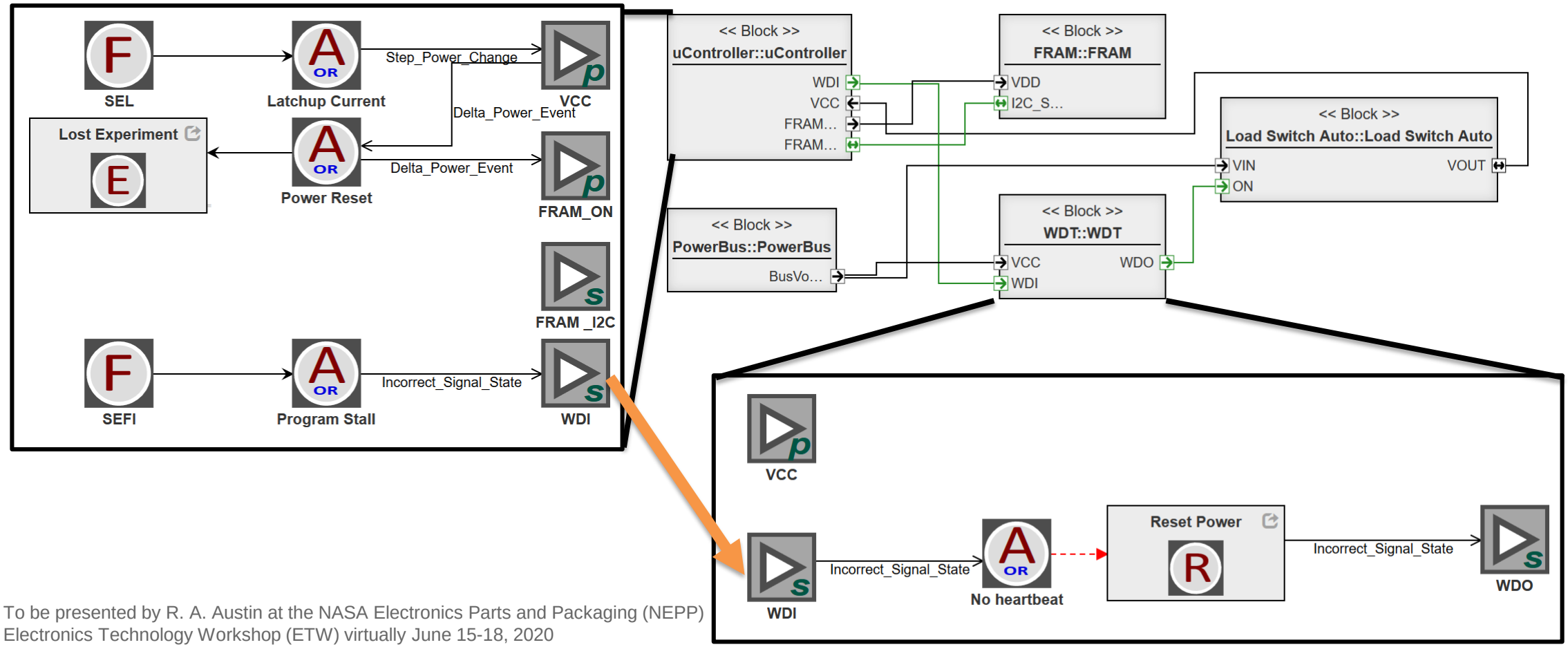

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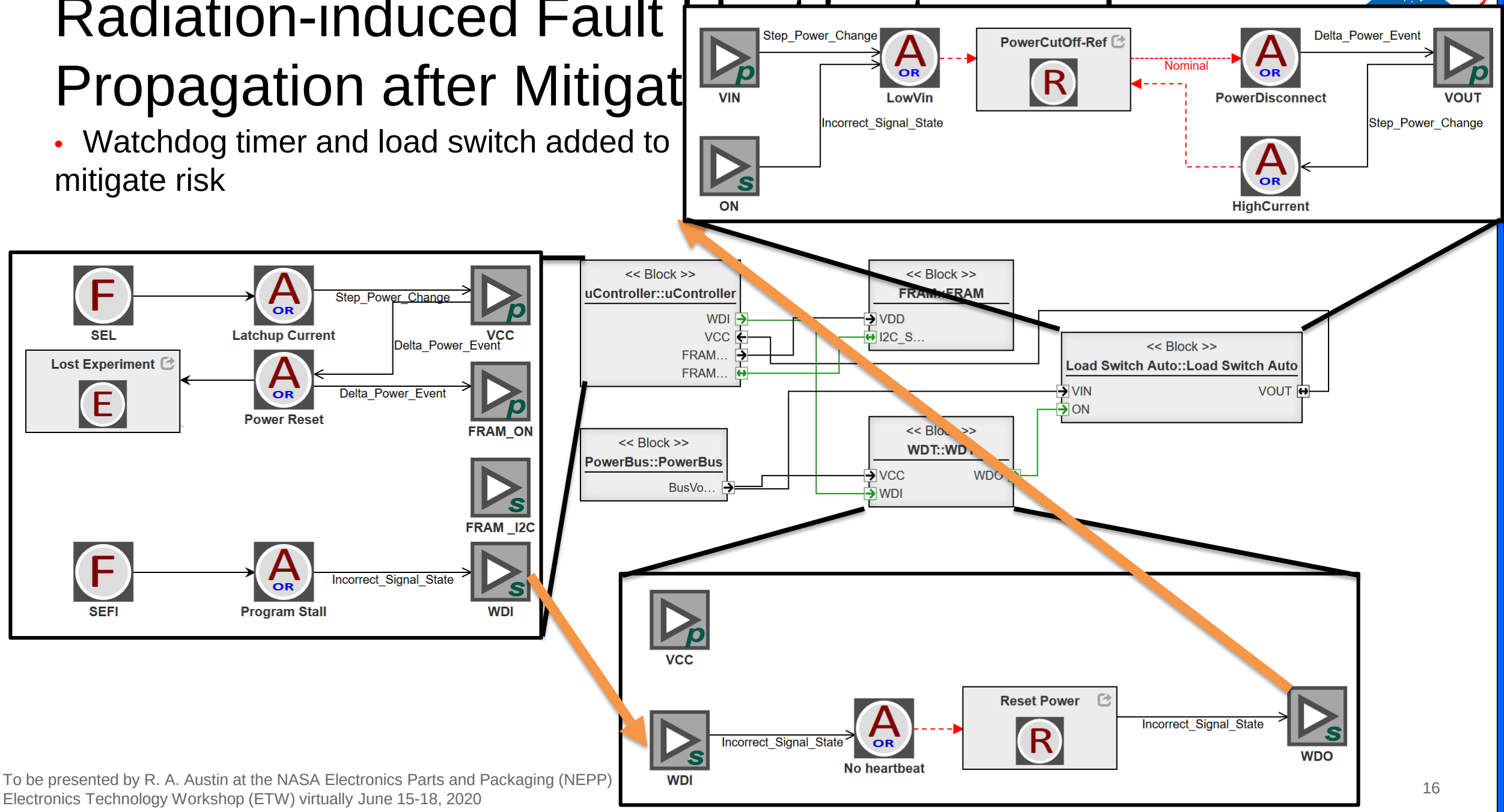
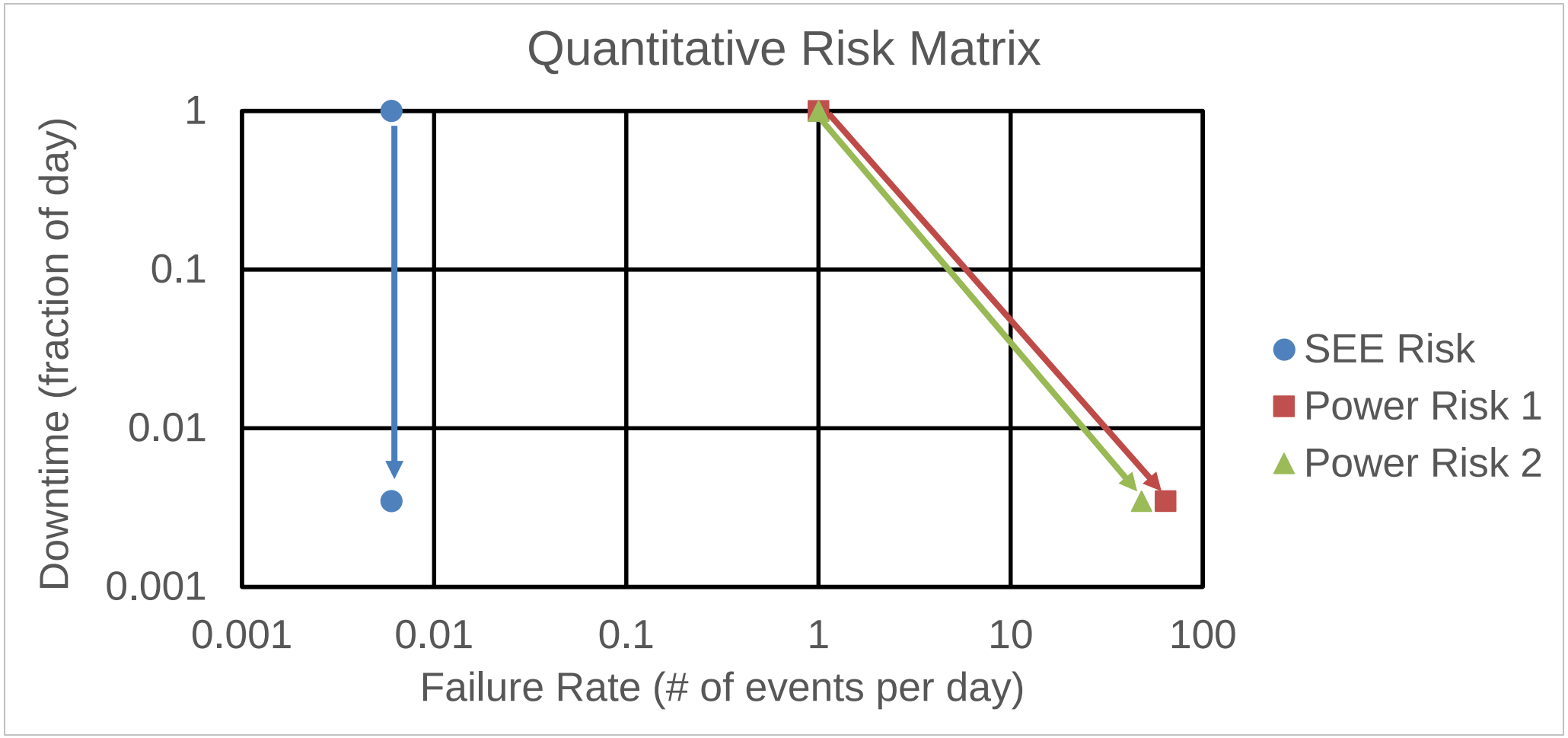


Quantification of Risk to Downtime

Technical Risk	Mitigated?	Failure Rate (# of events/day)	Consequence (fraction of downtime per day)	Risk Factor
SEE in Microcontroller	No	$6x10^{-3}$	1	$6x10^{-3}$
SEE in Microcontroller	Yes	$6x10^{-3}$	$3.5x10^{-3}$	$2.08x10^{-5}$
Experiment Board v1 exceeds power budget	No	1	1	1
Experiment Board v1 exceeds power budget	Yes	64	$3.5x10^{-3}$	$2.22x10^{-1}$
Experiment Board v2 exceeds power budget	No	1	1	1
Experiment Board v2 exceeds power budget	Yes	48	$3.5x10^{-3}$	$1.67x10^{-1}$

Quantified Risk Matrix



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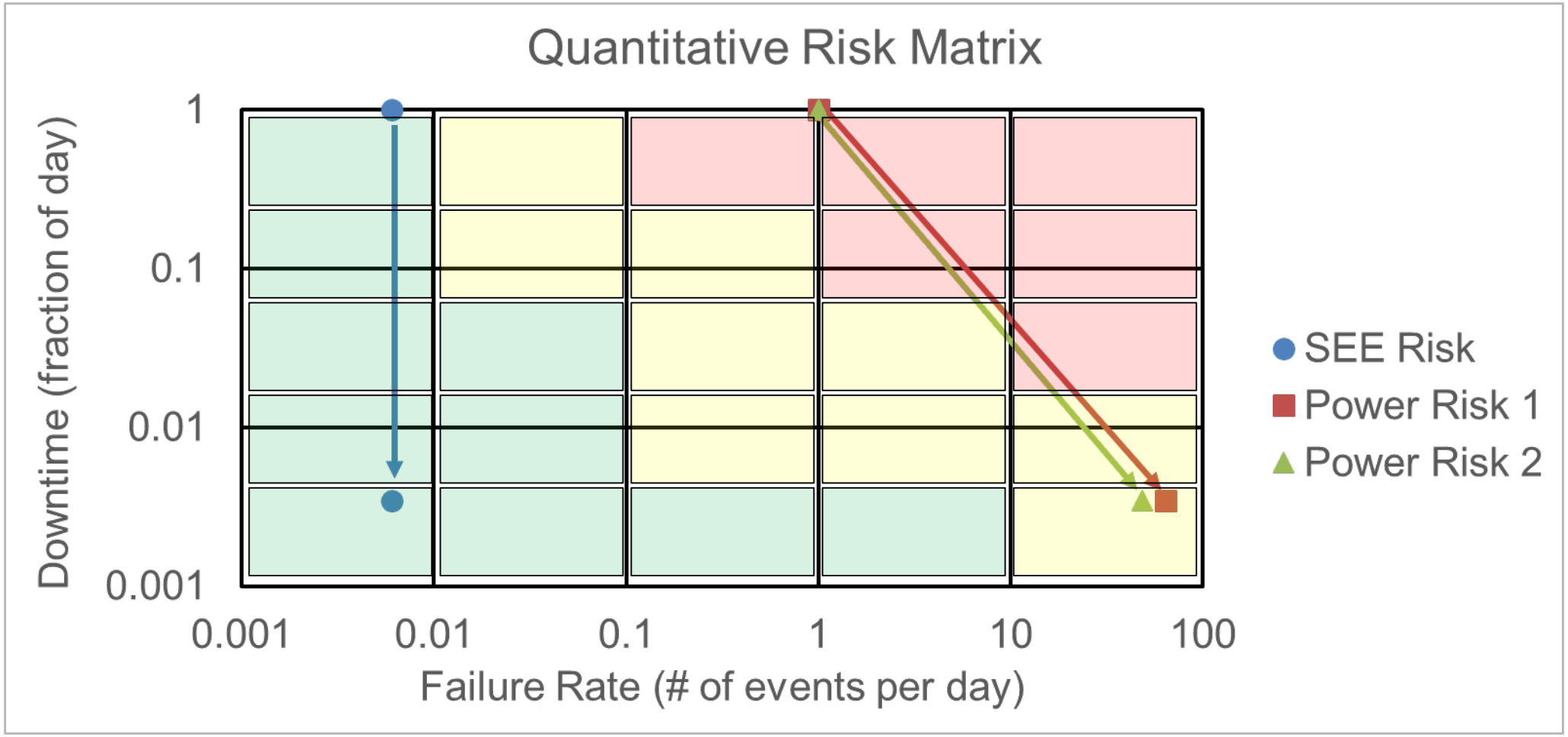
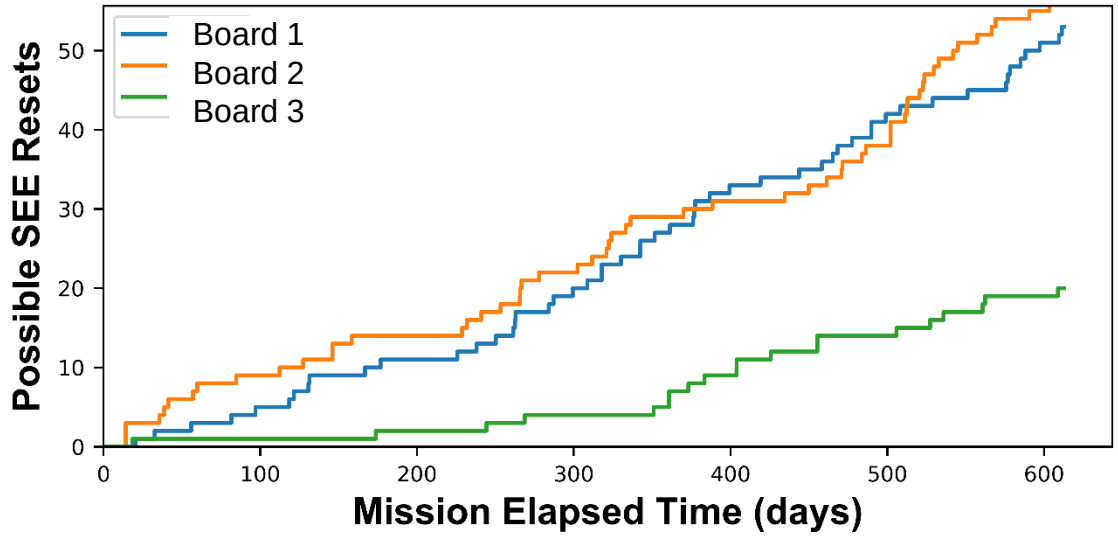


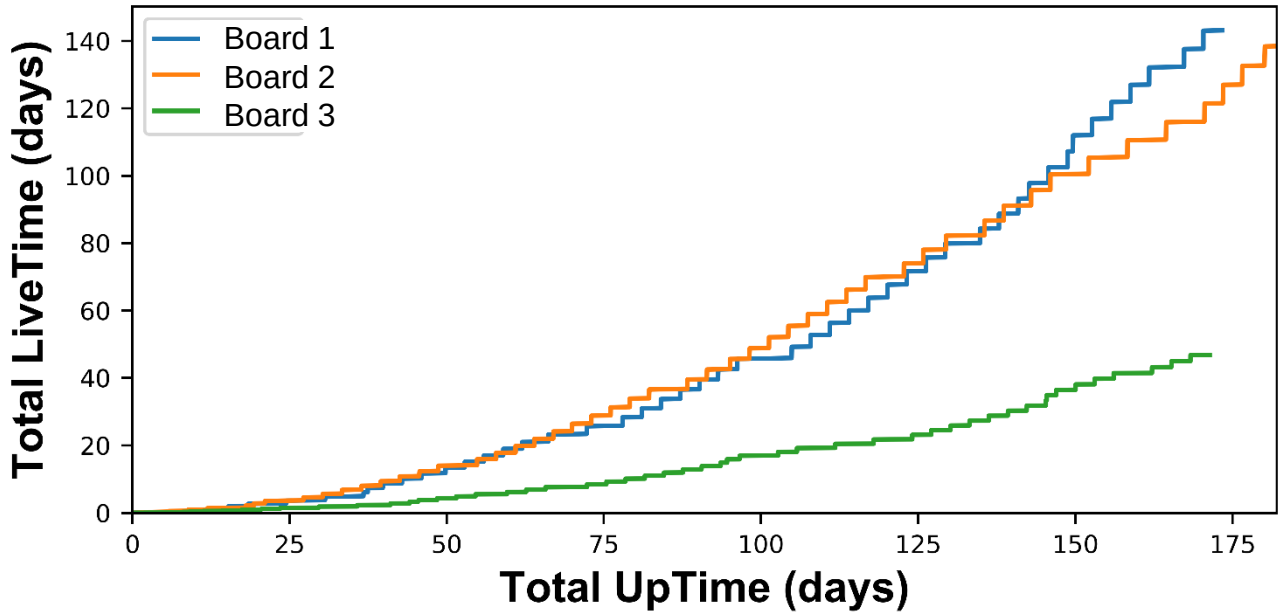
Comparison with Flight Data: SEE Risk

Experiment Board	Possible Resets from SEE	Uptime	Failure Rate (# of events/day)	Maximum Downtime (fraction of day)	Risk Factor from On-Orbit Data	Risk Factor from Risk Assessment
Board 1 (v2)	53	173	3.1×10^{-1}	3.5×10^{-3}	1.1×10^{-3}	2.08×10^{-5}
Board 2 (v2)	58	186	3.1×10^{-1}	3.5×10^{-3}	1.1×10^{-3}	2.08×10^{-5}
Board 3 (v1)	20	171	1.2×10^{-1}	3.5×10^{-3}	4.1×10^{-4}	2.08×10^{-5}
Total	4	530	2.5×10^{-1}	3.5×10^{-3}	8.6×10^{-4}	2.08×10^{-5}

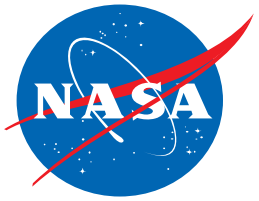


Comparison with Flight Data: Power Budget Risk

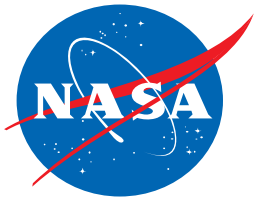
Experiment Board	Livetime	Uptime	Downtime from On-Orbit Data (fraction of day)	Downtime predicted for mitigation(fraction of day)
Board 1 (v2)	87	173	0.50	0.5
Board 2 (v2)	94	186	0.50	0.5
Board 3 (v1)	29	171	0.167	0.33



Summary



- The technical risk from SEEs in the microcontroller was mapped to the consequence of downtime
- The risk factor was calculated and tracked with and without mitigation and compared to a technical risk from the power budget
- This risk factor was compared with on-orbit data
- Sponsor: NASA Electronic Parts and Packaging (NEPP) Program, Grant #80NSSC20K0424



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THANK YOU