Connecting Mission Profiles and Radiation Vulnerability Assessments

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This work is sponsored by NEPP Grant and Cooperative Agreement Number 80NSSC20K0424

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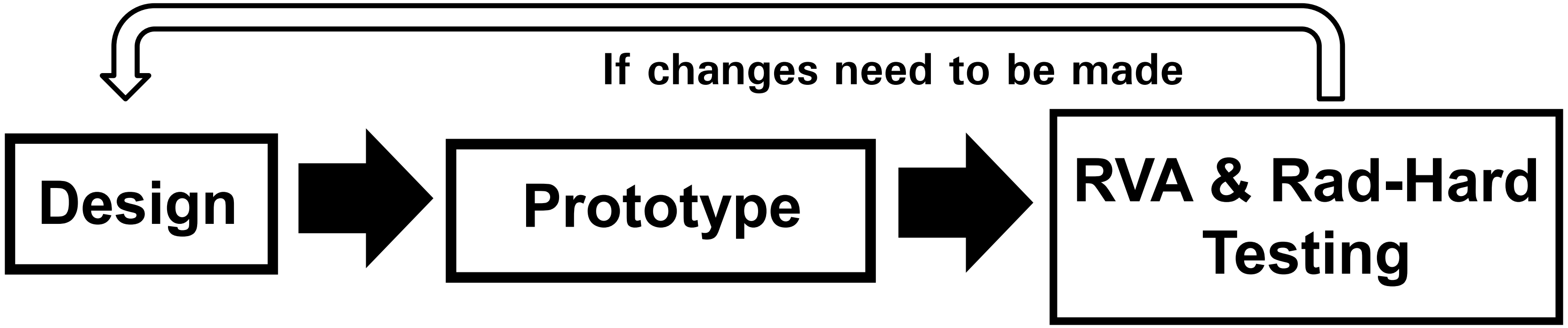
Radiation Vulnerability Assessment (RVA): Earlier vs. Later in Spacecraft Development

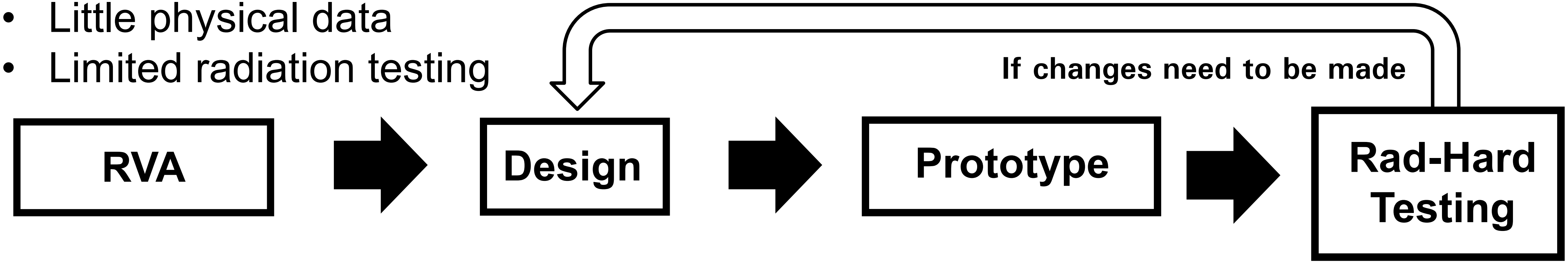
Later in Spacecraft Development (Conventional Flow)



- Assuming lots of physical data for parts
- Significant radiation testing

- Commercial parts
- Little physical data
- Limited radiation testing

Earlier in Spacecraft Development (Novel Flow)



Expected Users of Radiation Vulnerability Assessment

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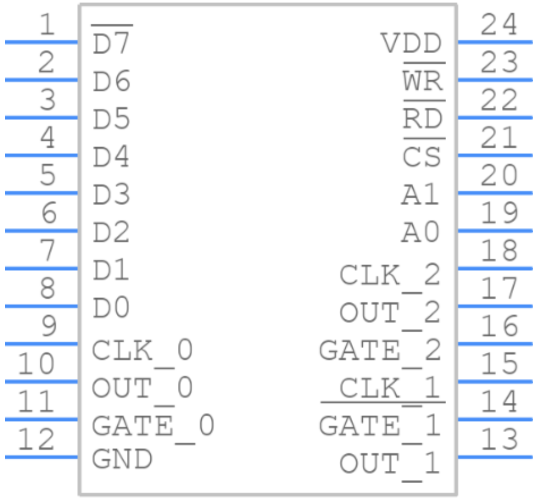
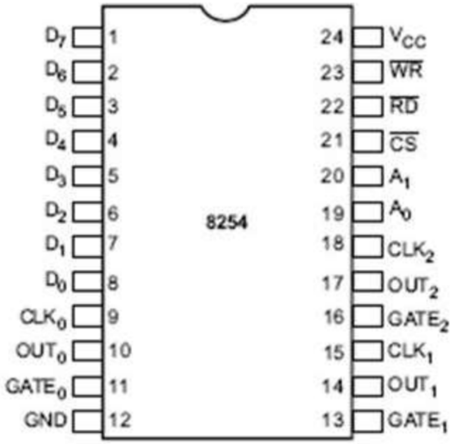
- Teams most likely to:
  - Use commercial-off-the-shelf (COTS) components
  - Lack (at least initially) radiation effects experts
- Rad-hardened components are more expensive than their non-rad-hardened counterparts
- These groups include:
  - Small satellite (e.g., CubeSat) teams
  - Academic design teams
  - Satellite startups



Renesas Electronics HS1-82C54RH-Q: Rad-hard Programmable Timer
Price: ~$3,100
Lead Time: 21 Weeks and 2 Days

vs.



Intel 8254: Non-rad-hard Programmable Timer
Price: ~$7.00
Lead Time: In Stock

Assessing
Radiation Vulnerability Assessment

User-Input

- Spacecraft’s mission environment
- Spacecraft’s electronic part portfolio

→

Radiation Vulnerability Assessment

- Model of radiation-induced fault propagation through spacecraft’s electronic parts

Radiation Fault Propagation Model Template

User Information

- Part List
  - Detailed
  - Part numbers, manufacturer numbers
- System Information:
  - Bias conditions
  - Mitigation techniques
  - Mission Profile

RGENTIC Parts List

- **Part List:**
  - Radiation assessment for each vulnerability per part type

SEAM Fault Model Templates

- Part type models
- Contains radiation-induced faults for typical part types

SEAM SysML Model

- User can interconnect part type models according to their design and complete system architectural models in SEAM

Interfacing RGENTIC and SEAM

RGENTIC

- Creates a part list associating components with rad risks based on user-specified environment

Transferred via Config. File →

SEAM

- Allows user to create fault propagation model through spacecraft system through part list matching

RGENTIC's Part Type Families

- Families Present (66 total part types):
  - Clocks/Timing (4 part types)
  - Digital (5 part types)
  - Discrete (4 part types)
  - Discrete Power (7 part types)
  - Discrete RF (8 part types)
  - Embedded (4 part types)
  - Interfaces (6 part types)
  - Linear (5 part types)
  - Logic (2 part types)
  - Memory (4 part types)
  - Mixed Signal (5 part types)
  - Opto-Electronics (4 part types)
  - Power Hybrid (4 part types)
  - Sensors (4 part types)

- Radiation Concerns Present:
  - Single Event Latch-up
  - Single Event Burnout
  - Single Event Transient
  - Single Event Function Interrupt
  - Single Event Gate-Rupture
  - Single Event Upset
  - Multiple Bit Upset
  - Total Ionizing Dose
  - Displacement Damage Dose

RGENTIC: Radiation GuidelinEs for Notional Threat Identification and Classification

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- Free platform developed at NASA Goddard Space Flight Center (GSFC)
- Provides guidance on assessing rad-hardness of EEE components
- RGENTIC Process:
  - User Mission
  - Environment Comparison
  - Device Response
  - Guidelines

R-GENTIC

Tool Guide:

This tool is meant to be used as guidance for understanding the radiation risks that apply to a specific set of circumstances, not to replace modeling one's own environment or replacing the need to test a device. When used from start to finish you can get guidelines to help mitigate radiation effects and understand where you can avoid risks, based on simplified inputs, for a parts list in question.

Each Navigation Tab is a step in the process:

1. User Mission - Begin with selecting the options that apply to you for an intended mission, each input will directly impact the output of the tool that is to follow. At any time, you can choose to begin again, or follow the path for a new mission design under question. By selecting a mission class, lifetime, orbit, and architecture you are returned an environment severity with contributions and the EEE threats the tool will focus on.

2. Environment Comparison - Using the inputs from section 1, the tool displays past mission modeling efforts that have been done. It returns the details of a mission that has been calculated to be close to yours when normalized for one year. This panel allows selection of multiple missions to compare and explore. It should be noted that the Solar cycle has an impact on the dose based on the launch year, and the normalization is for approximation. This piece of the tool is to show how shielding can be used to mitigate dose levels, and how mission characteristics impact your SEE concerns. Two plots are available, the TID vs. shielding depth curve and the GCR spectra. The tool also returns data tables for all plots rendered.

3. Device Response -Using the top level selections from section 1, the device susceptibility and basic radiation concerns are called out when the user inputs the device information. Here the tool returns examples of the most prevalent radiation concerns through plots and references of similar components where possible.

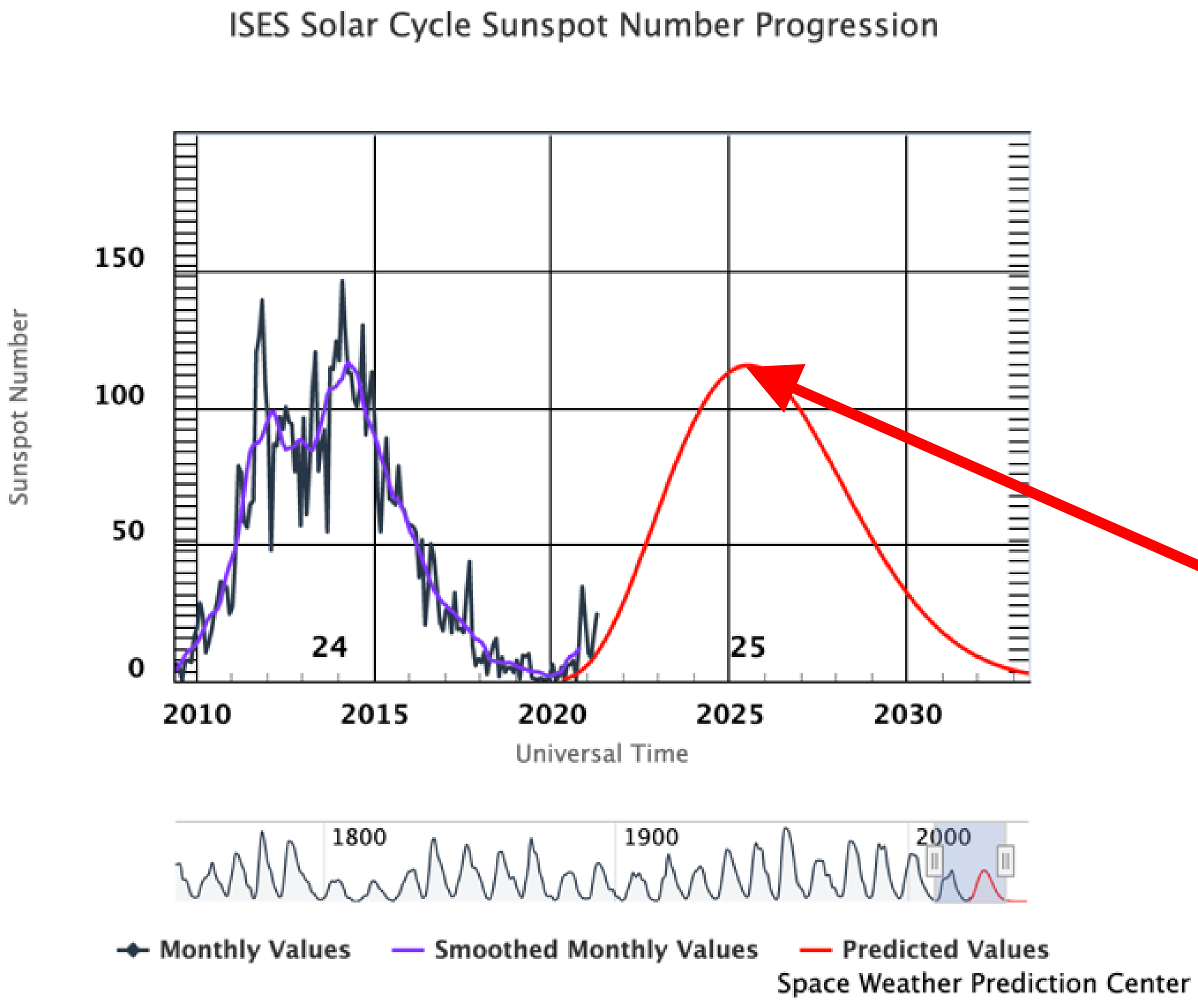
4. Guidelines -The final step captures radiation line of questioning that is tailored to the user inputs, the major concerns are clarified and the user is presented with mitigation strategies. You can also see a listing of class guidelines with respect to radiation using the dropdown. In an effort to document failure modes and reduce the threat/risk to the system from a radiation standpoint, a line of risk pre and post mitigation is returned. This output can be saved and added to a table in the summary.

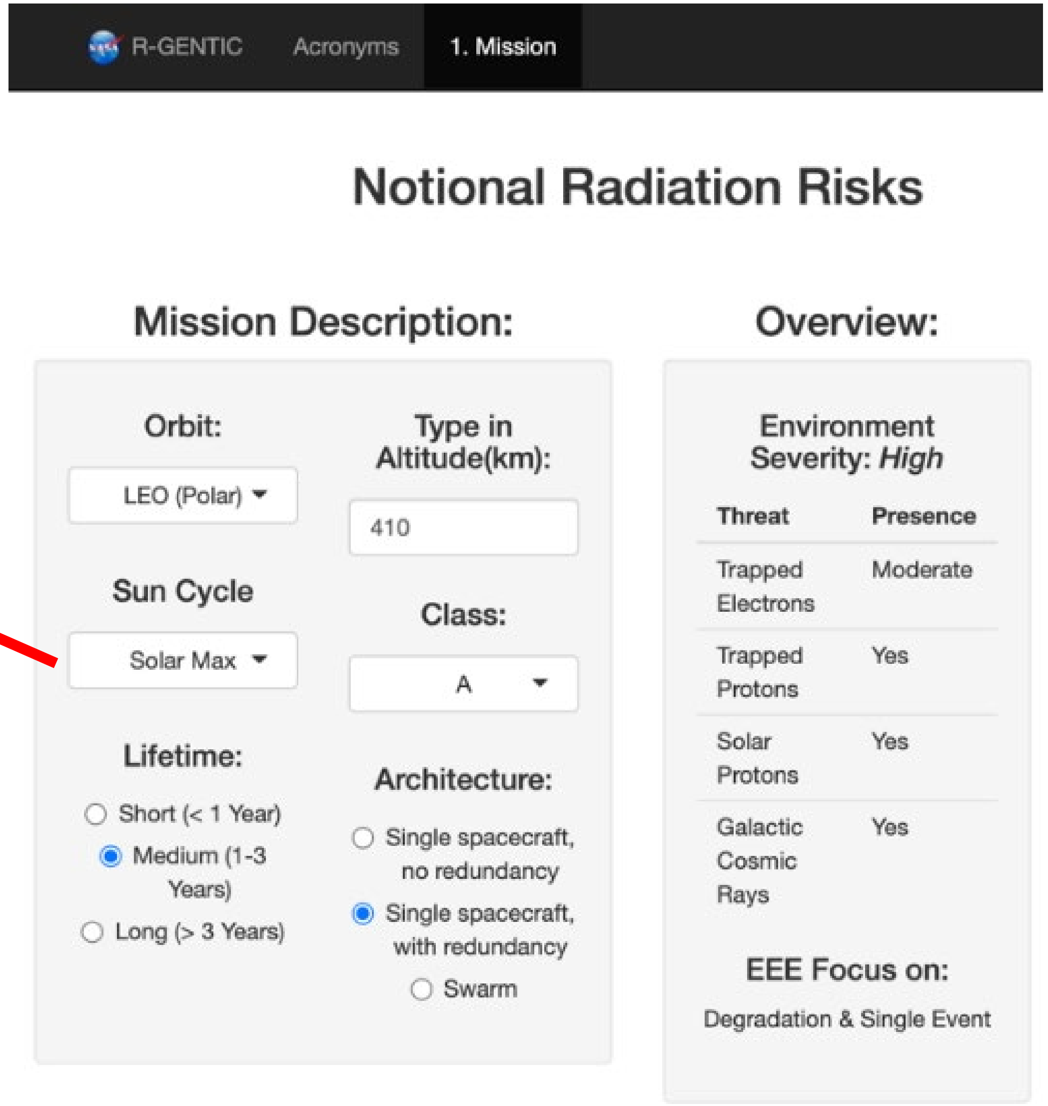
Due to the fact that radiation effects are application specific, this guidance is notional, generalizations cannot cover the entire state-space and the user will benefit from a more detailed analysis.

Proceed with Notional Guidance

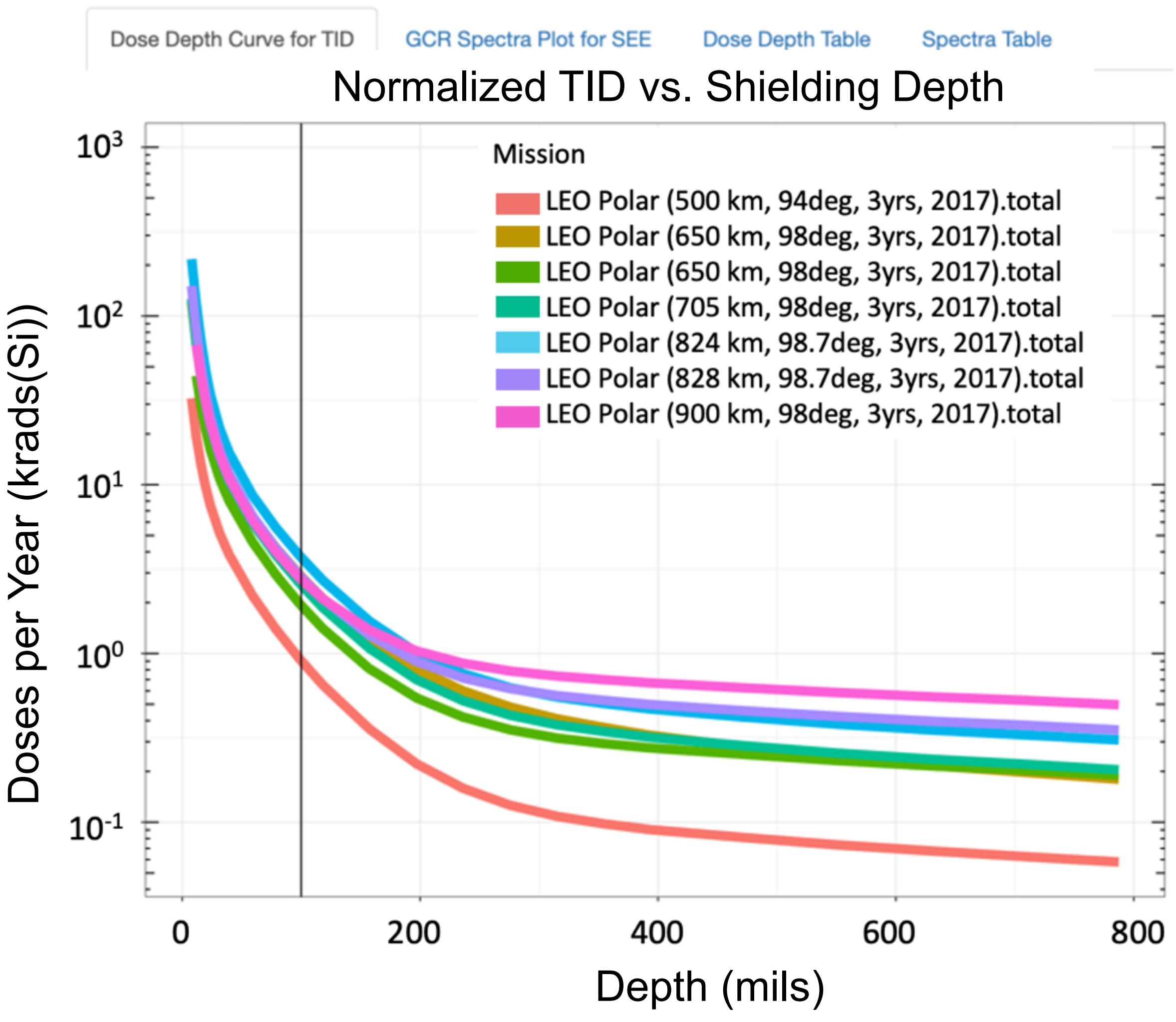
https://vanguard.isde.vanderbilt.edu/RGentic/

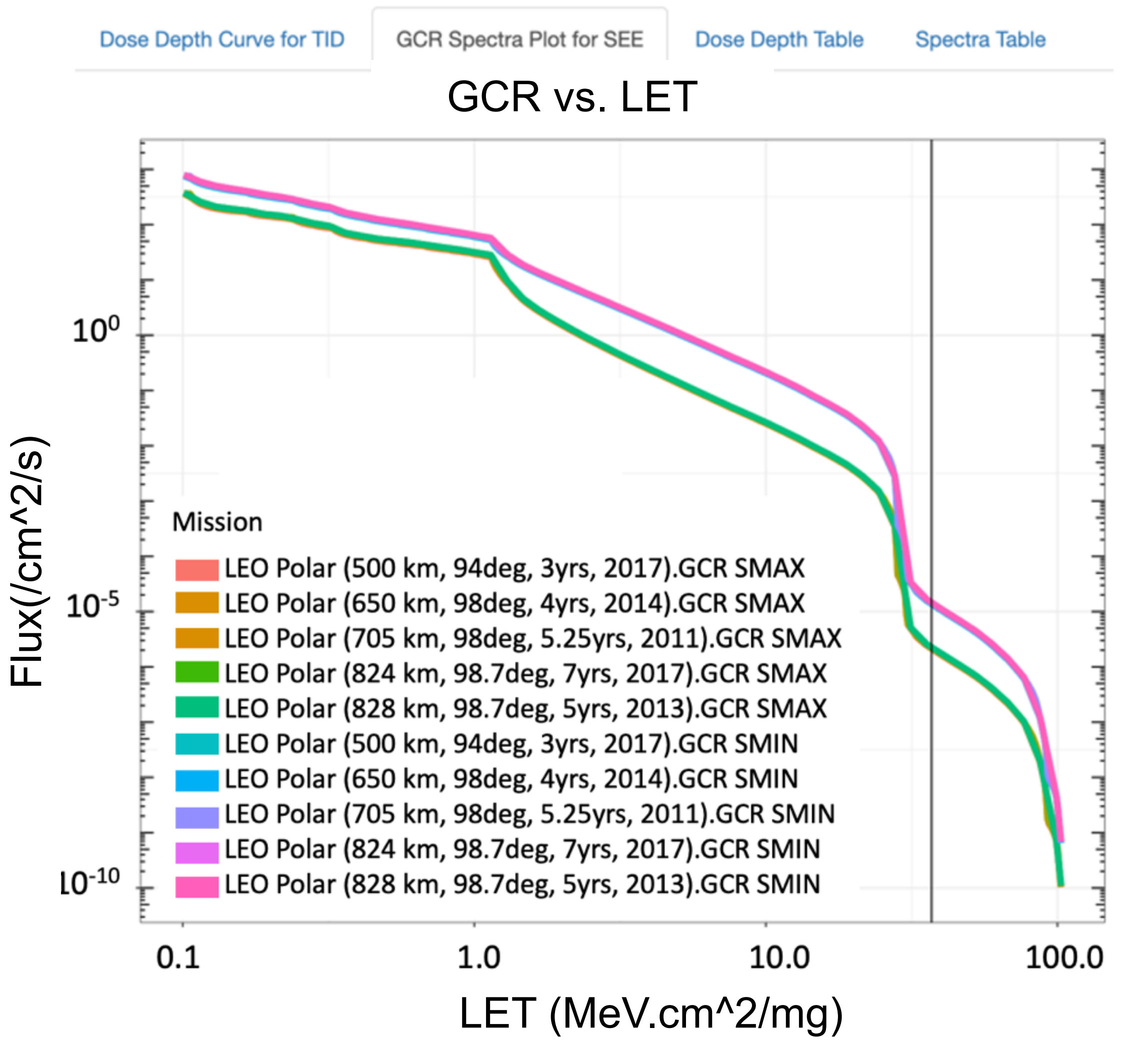
Step 1: User Mission





Step 2: Radiation Environment Comparison





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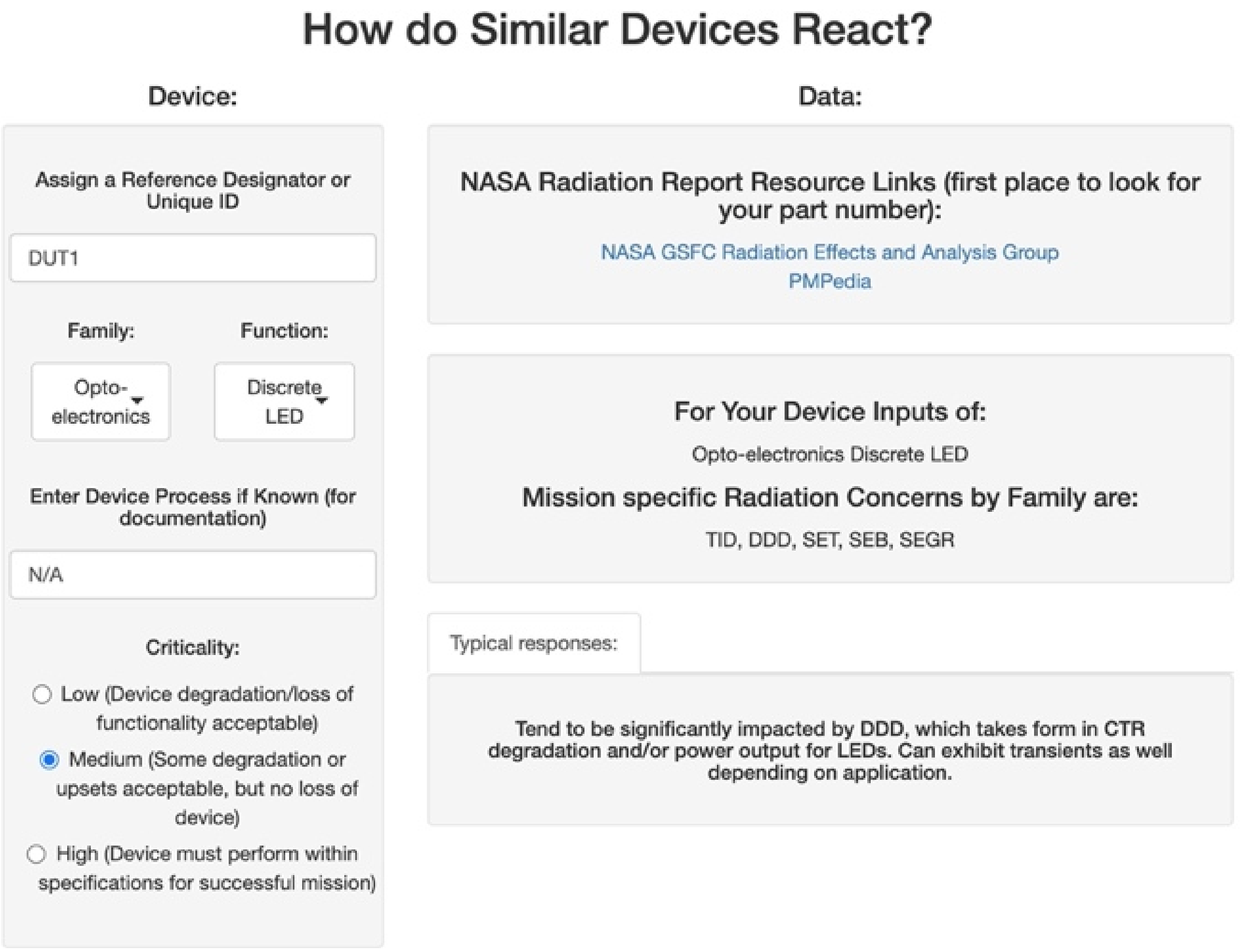
Step 3: Mission-Specific Device Vulnerability

- Input device type so RGENTIC can identify radiation concerns
- Device susceptibility to various potential radiation concerns are shown
- Only generic part-types considered



Step 4: Risk Mitigation Guidelines

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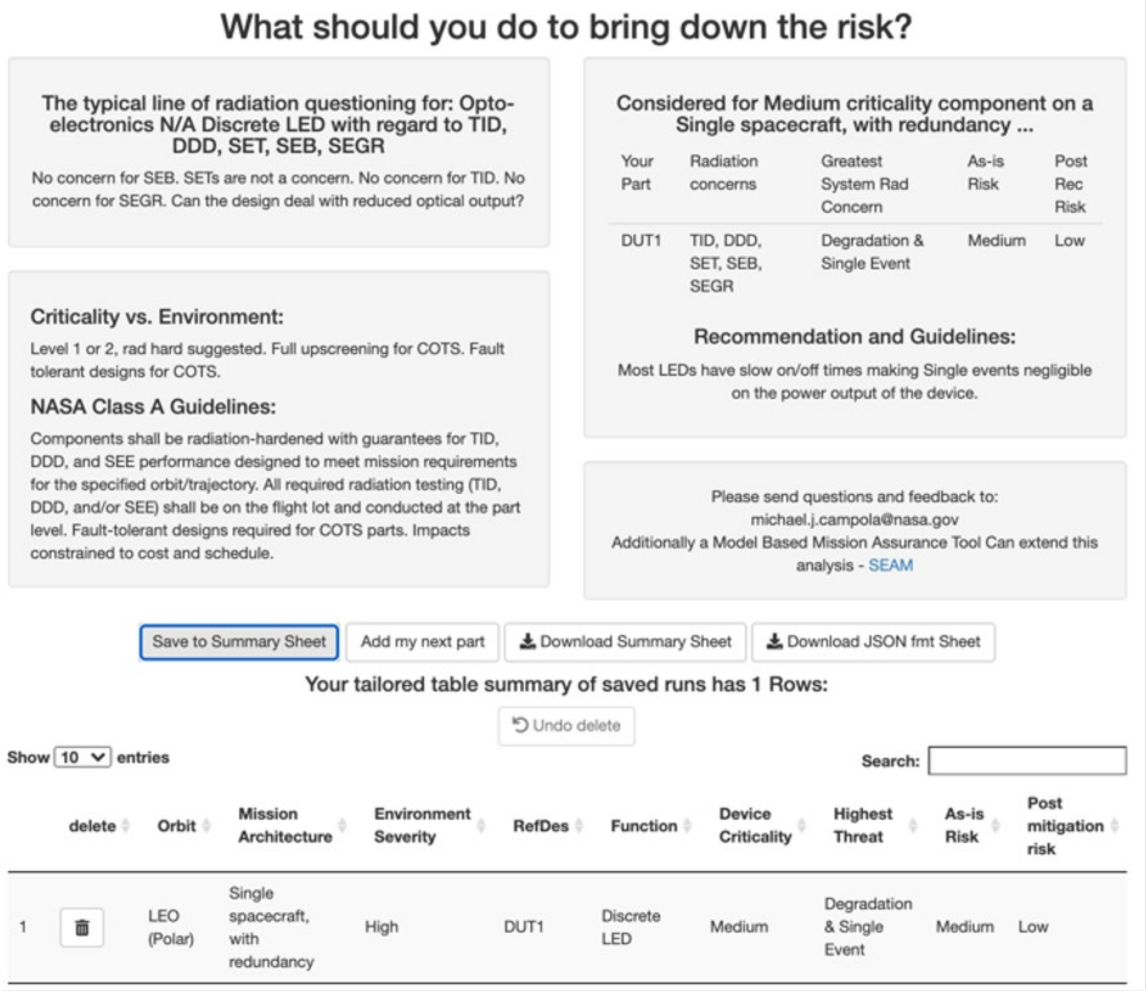
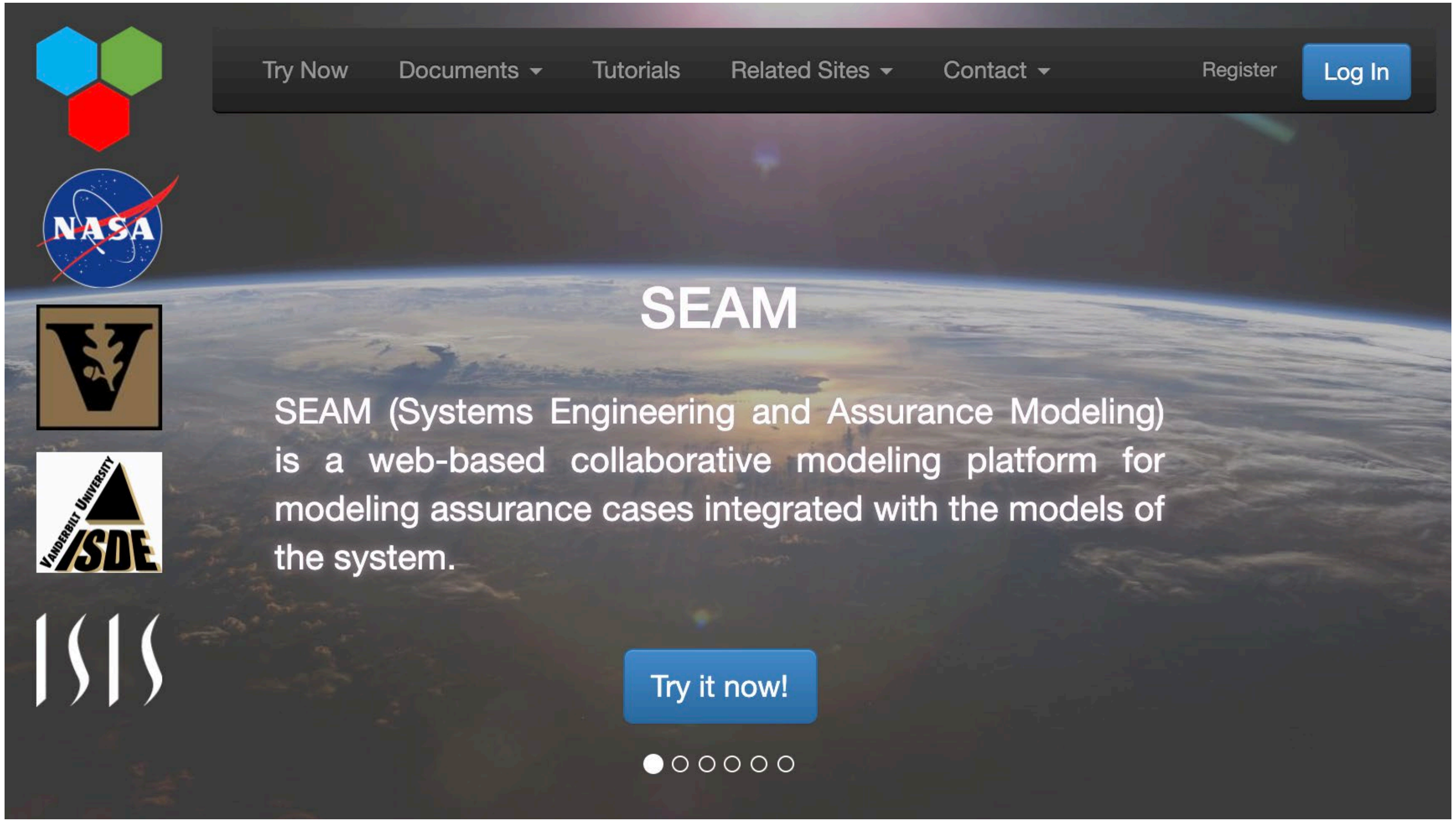
- Top-left box:
  - Typical line of radiation questioning for Family of device
  - Device-specific information given beneath
- Lower-left box:
  - Recommendations based on:
    - Part’s criticality
    - Environment’s severity
    - Mission class



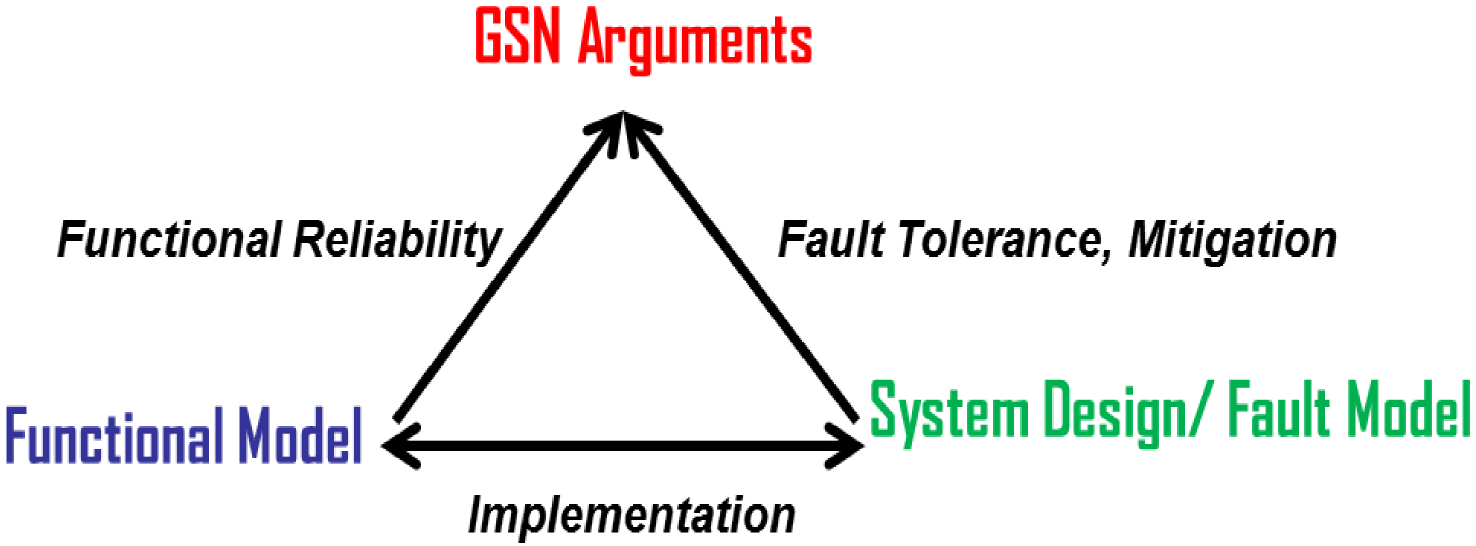
SEAM: Systems Engineering and Assurance Modeling

- Free platform used to evaluate any spacecraft system
- Useful for radiation fault modeling and radiation case development
- Applications with short development timeframes and COTS usage



https://modelbasedassurance.org/

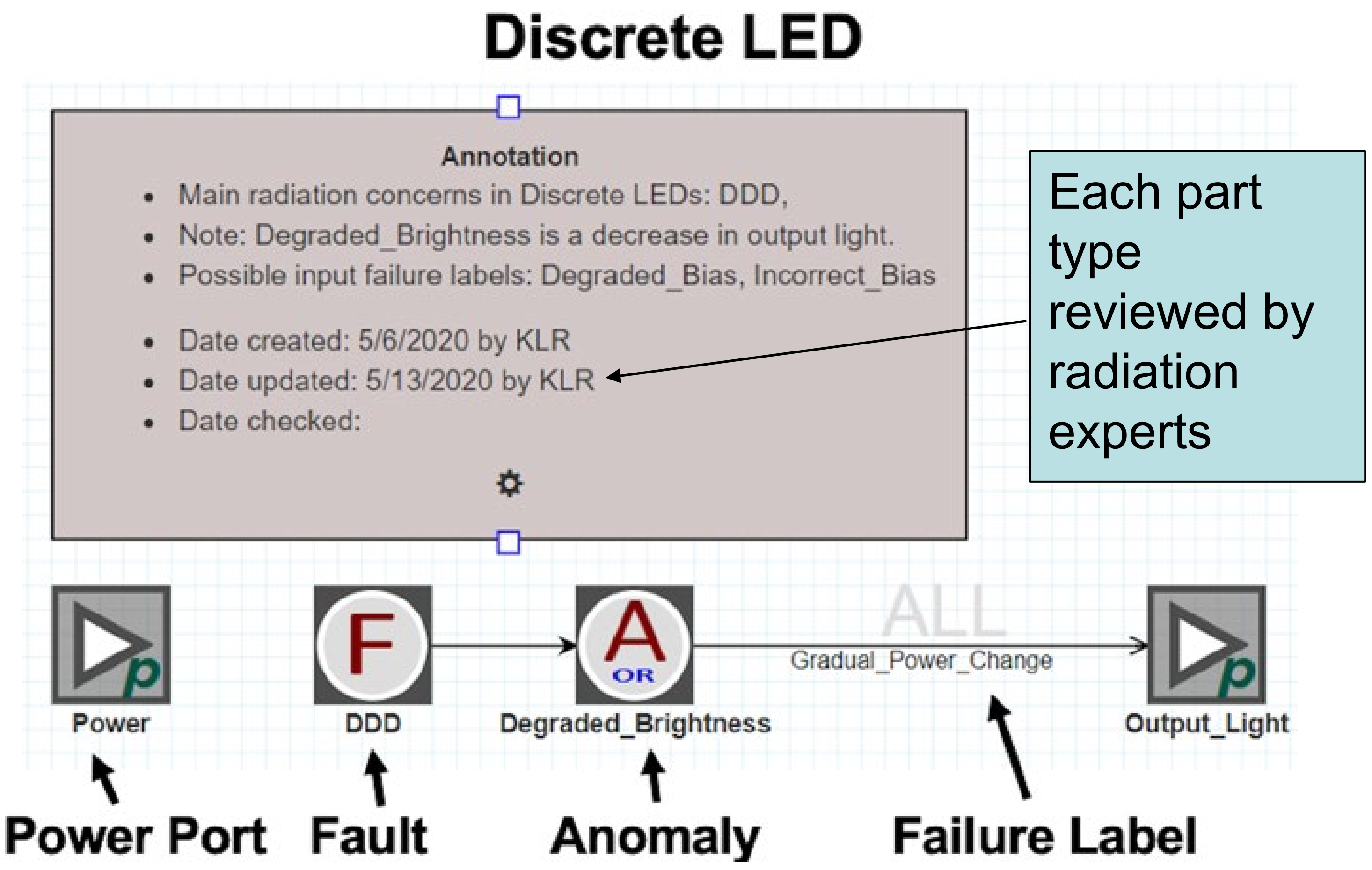
SEAM: Systems Engineering and Assurance Modeling



- SEAM incorporates SysML internal block diagrams
- SEAM has the following capabilities:
  - Assessment of radiation performance of a spacecraft without relying on intensive radiation testing campaigns
  - Does not require extensive physical knowledge of the electronic components

SEAM Templates Based on RGENTIC Part Categories

- SEAM model of Discrete LED shown in the editor canvas.
- Engineers can choose modeling elements from the model parts panel on the same page as this figure.
- SEAM allows users to create project libraries for both components and failure labels.



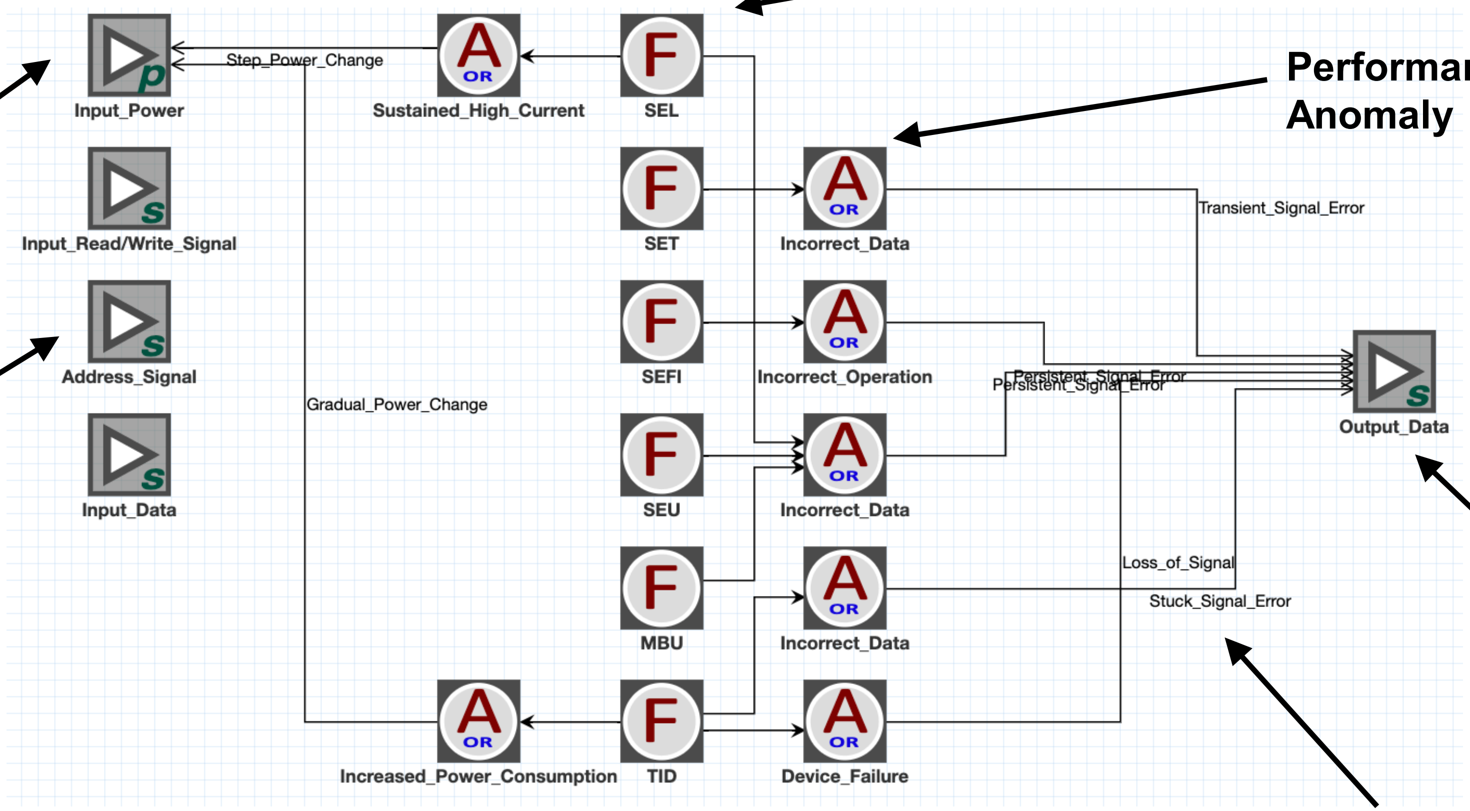
SEAM Output

Radiation Fault Cause

Performance Anomaly

Power Port

Signal Port



Signal Port

Propagation Failure Label

Output for Microprocessor

Sensor Part-Type Output from SEAM

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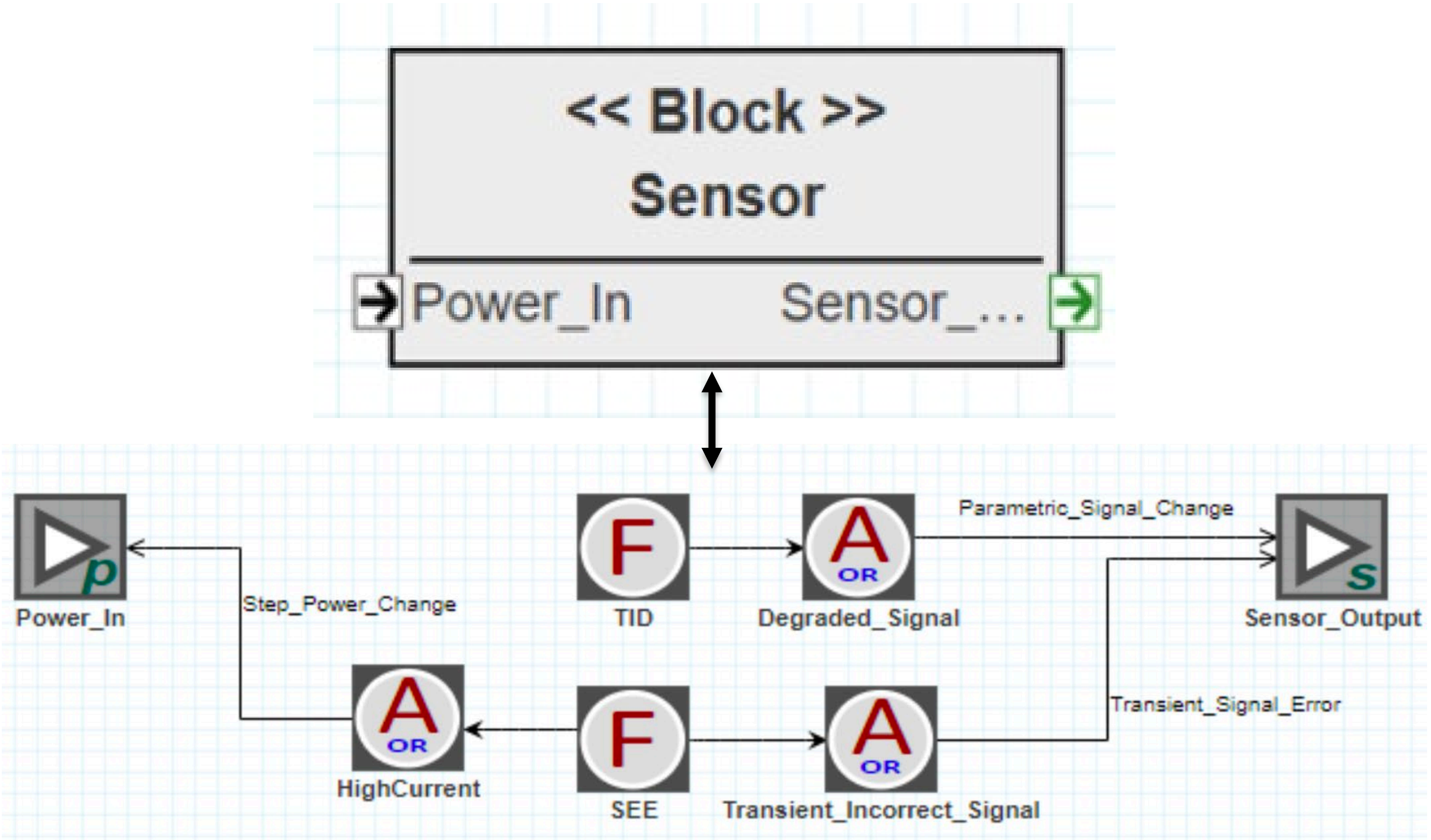

Systems Engineering and Assurance Modeling (SEAM): A Web-Based Solution for Integrated Mission Assurance, Kaitlyn Ryder et. al, Electronics and Energetics, 2021

Conclusion

- Radiation vulnerability assessment can reduce total time and money required to complete a spacecraft system
- RGENTIC and SEAM are two tools that provide early radiation assessment
- RGENTIC helps users identify radiation vulnerabilities based on mission parameters
- SEAM allows users to build a model of the radiation fault propagation in a system and a radiation assurance case