



# Connecting Mission Profiles and Radiation Vulnerability Assessments

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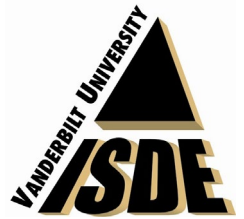
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*NASA Goddard Space Flight Center (GSFC)*

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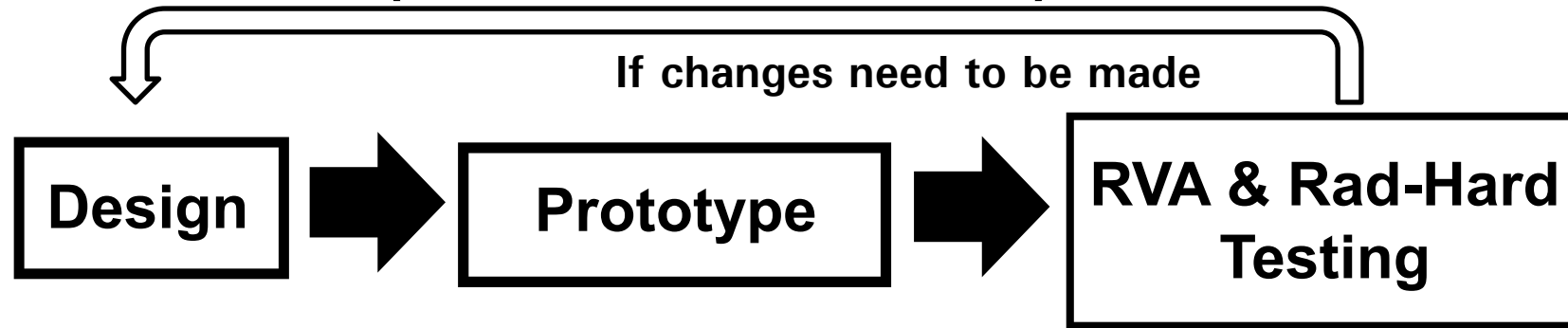


# Radiation Vulnerability Assessment (RVA): Earlier vs. Later in Spacecraft Development



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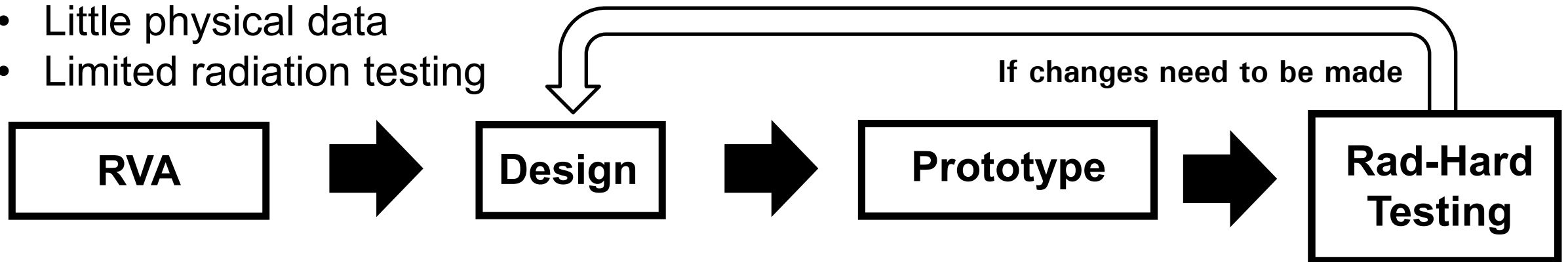
## Later in Spacecraft Development (Conventional Flow)



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

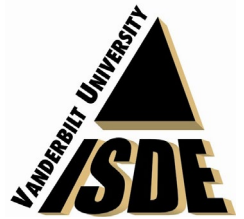
- Commercial parts
- Little physical data
- Limited radiation testing

## Earlier in Spacecraft Development (Novel Flow)



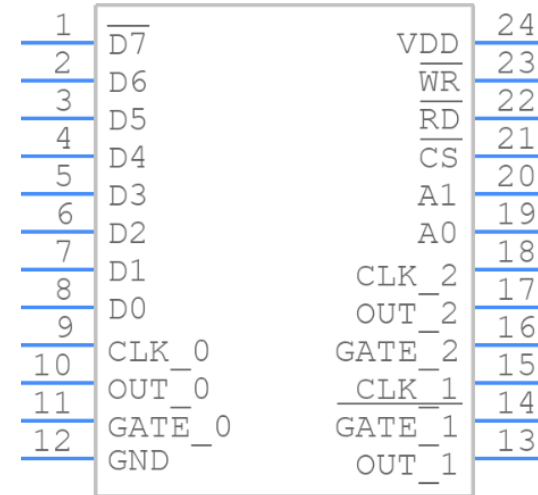


# Expected Users of Radiation Vulnerability Assessment



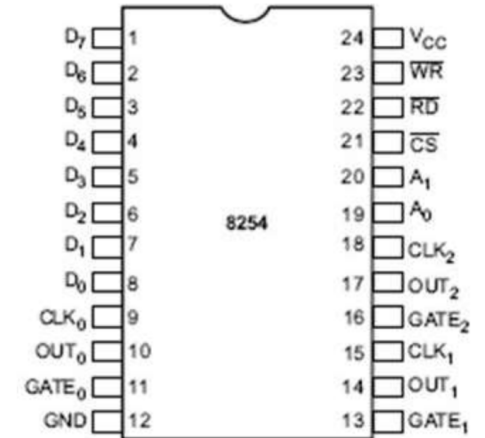
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- Teams most likely to:
  - Use commercial-off-the-shelf (COTS) components
  - Lack (at least initially) radiation effects experts
- Rad-hardened components are more expensive than their non-rad-hardened counterparts
- These groups include:
  - Small 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**

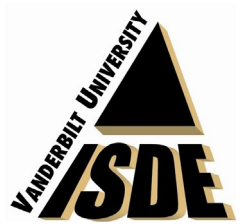
vs.



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

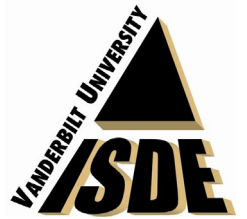


## Radiation Vulnerability Assessment

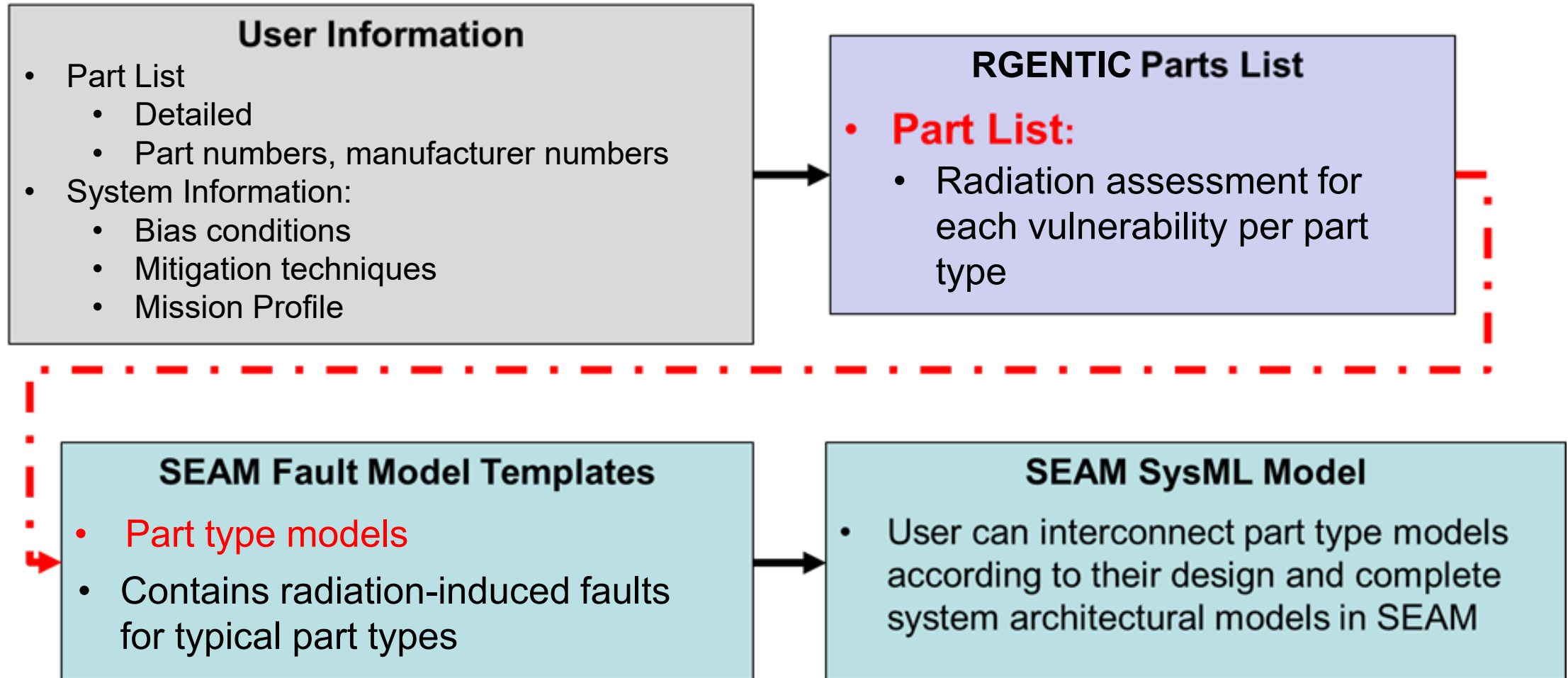
- Model of radiation-induced fault propagation through spacecraft's electronic parts



# Radiation Fault Propagation Model Template

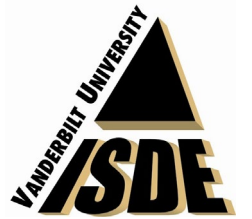


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# Interfacing RGENTIC and SEAM



## RGENTIC

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

Transferred via  
Config. File

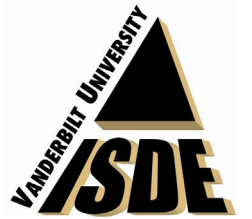


## SEAM

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



# RGENTIC's Part Type Families

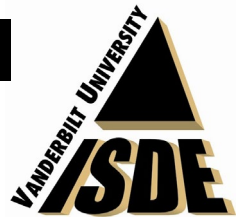


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- Families Present (66 total part types):
  - Clocks/Timing (4 part types)
  - Digital (5 part types)
  - Discrete (4 part types)
  - Discrete Power (7 part types)
  - Discrete RF (8 part types)
  - Embedded (4 part types)
  - Interfaces (6 part types)
  - 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



- 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.

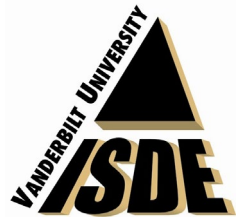
Proceed with Notional Guidance

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





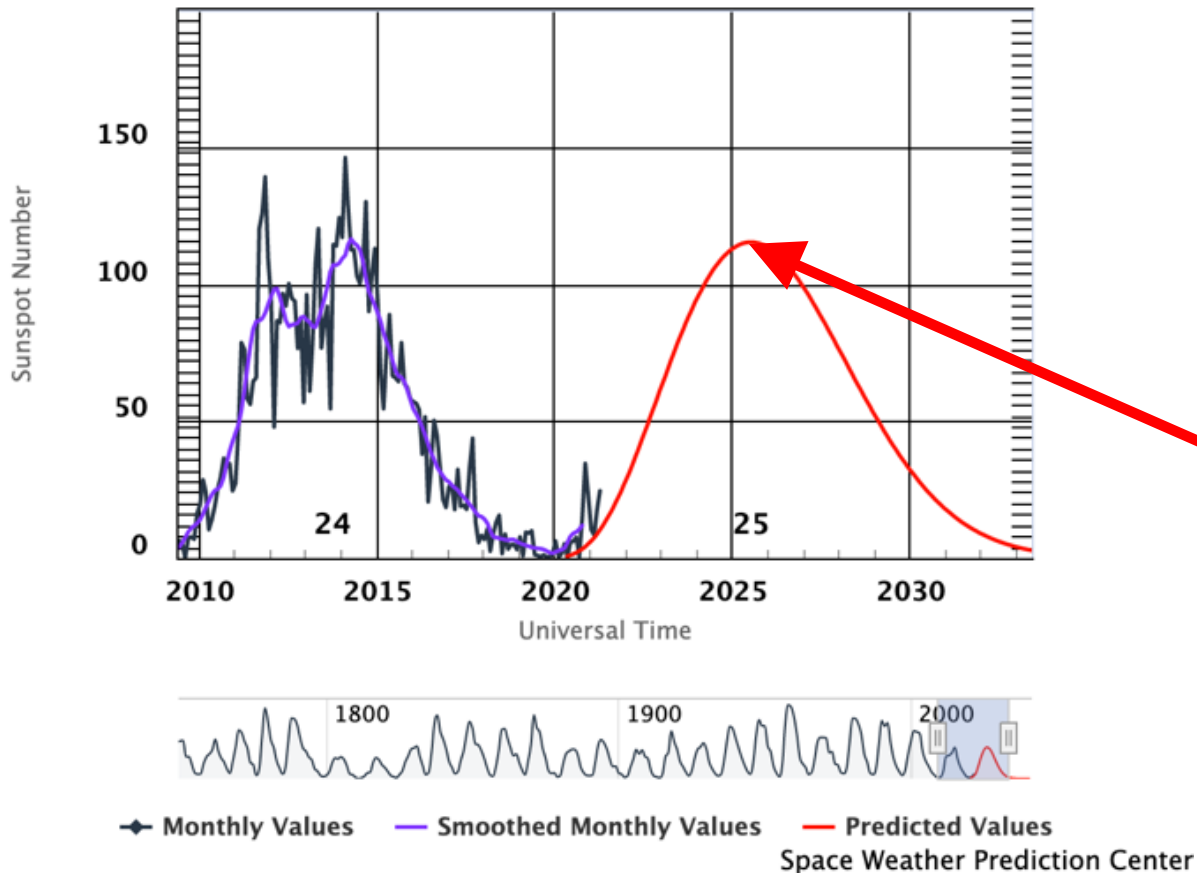
# Step 1: User Mission



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R-GENTIC    Acronyms    **1. Mission**

ISES Solar Cycle Sunspot Number Progression



## Notional Radiation Risks

### Mission Description:

**Orbit:**

**Sun Cycle:**

**Lifetime:**  
 Short (< 1 Year)  
 Medium (1-3 Years)  
 Long (> 3 Years)

**Type in Altitude(km):**

**Class:**

**Architecture:**  
 Single spacecraft, no redundancy  
 Single spacecraft, with redundancy  
 Swarm

### Overview:

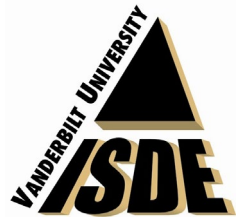
**Environment Severity: High**

Threat	Presence
Trapped Electrons	Moderate
Trapped Protons	Yes
Solar Protons	Yes
Galactic Cosmic Rays	Yes

**EEE Focus on:**  
Degradation & Single Event



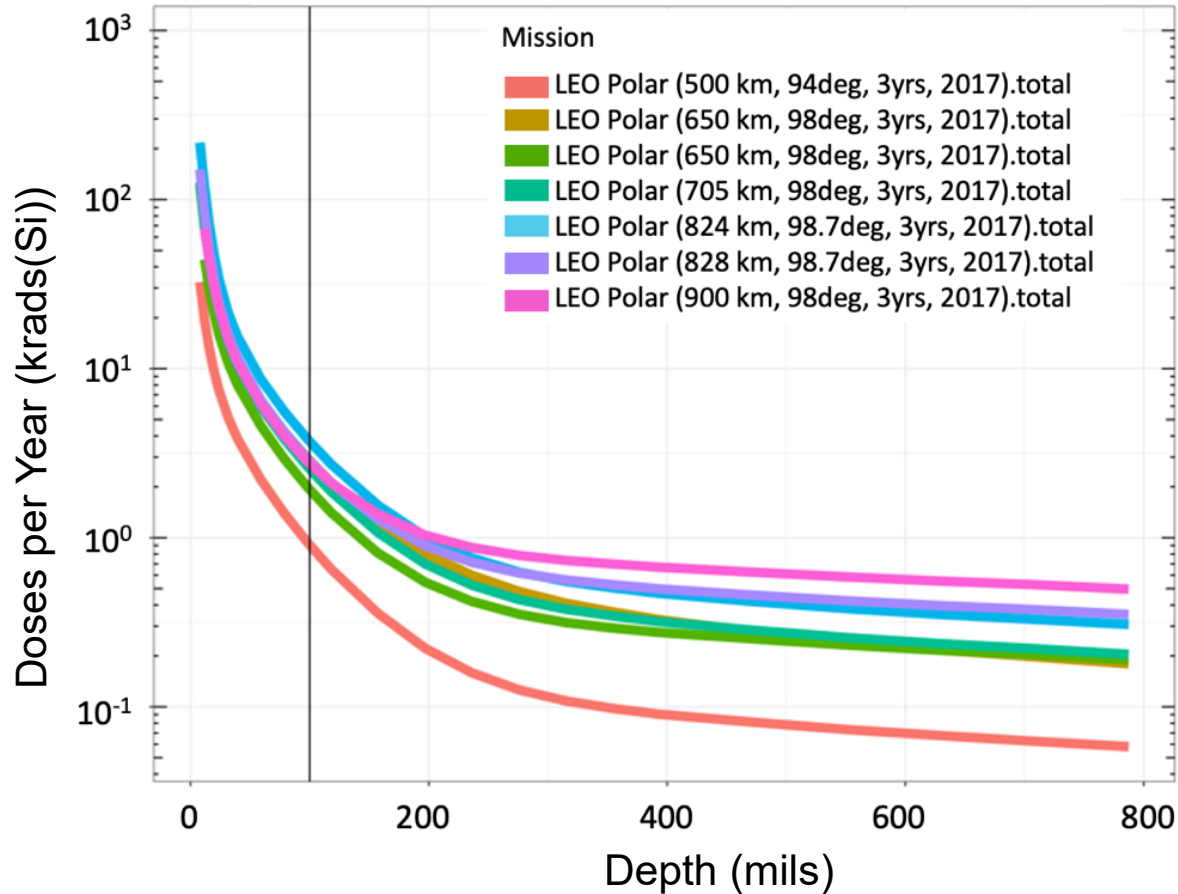
# Step 2: Radiation Environment Comparison



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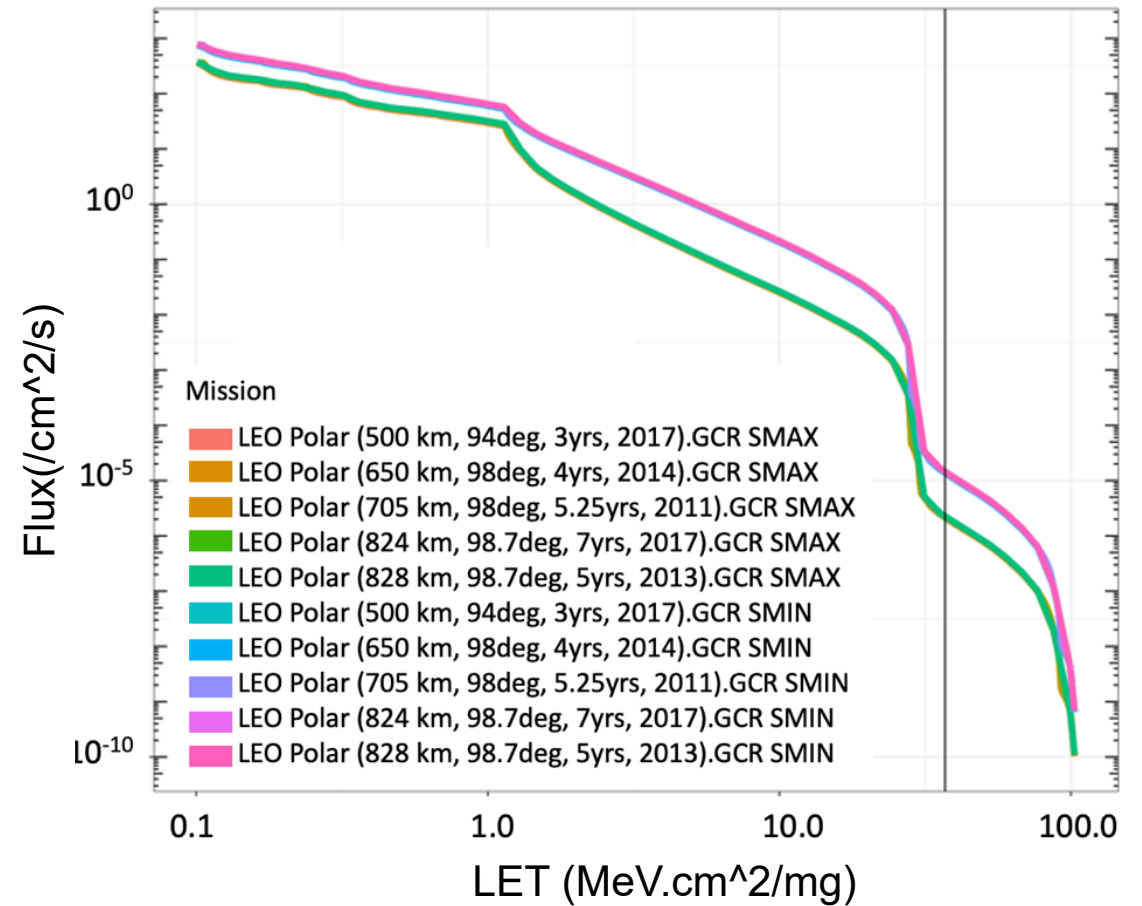
Dose Depth Curve for TID   GCR Spectra Plot for SEE   Dose Depth Table   Spectra Table

### Normalized TID vs. Shielding Depth



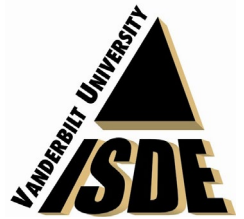
Dose Depth Curve for TID   GCR Spectra Plot for SEE   Dose Depth Table   Spectra Table

### GCR vs. LET





# Step 3: Mission-Specific Device Vulnerability



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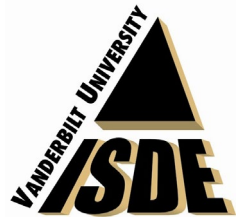
- Input device type so RGENTIC can identify radiation concerns
- Device susceptibility to various potential radiation concerns are shown
- Only generic part-types considered

## How do Similar Devices React?

Device:	Data:
<p>Assign a Reference Designator or Unique ID</p> <input type="text" value="DUT1"/>	<p>NASA Radiation Report Resource Links (first place to look for your part number):</p> <p><a href="#">NASA GSFC Radiation Effects and Analysis Group</a> <a href="#">PMPedia</a></p>
<p>Family:      Function:</p> <p><input type="button" value="Opto-electronics"/>      <input type="button" value="Discrete LED"/></p>	<p>For Your Device Inputs of:</p> <p>Opto-electronics Discrete LED</p> <p>Mission specific Radiation Concerns by Family are:</p> <p>TID, DDD, SET, SEB, SEGR</p>
<p>Enter Device Process if Known (for documentation)</p> <input type="text" value="N/A"/>	<p>Typical responses:</p> <p>Tend to be significantly impacted by DDD, which takes form in CTR degradation and/or power output for LEDs. Can exhibit transients as well depending on application.</p>
<p>Criticality:</p> <p><input type="radio"/> Low (Device degradation/loss of functionality acceptable)</p> <p><input checked="" type="radio"/> Medium (Some degradation or upsets acceptable, but no loss of device)</p> <p><input type="radio"/> High (Device must perform within specifications for successful mission)</p>	



# 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

### What should you do to bring down the risk?

**The typical line of radiation questioning for: Opto-electronics N/A Discrete LED with regard to TID, DDD, SET, SEB, SEGR**

No concern for SEB. SETs are not a concern. No concern for TID. No concern for SEGR. Can the design deal with reduced optical output?

**Criticality vs. Environment:**  
Level 1 or 2, rad hard suggested. Full upscreening for COTS. Fault tolerant designs for COTS.

**NASA Class A Guidelines:**  
Components shall be radiation-hardened with guarantees for TID, DDD, and SEE performance designed to meet mission requirements for the specified orbit/trajectory. All required radiation testing (TID, DDD, and/or SEE) shall be on the flight lot and conducted at the part level. Fault-tolerant designs required for COTS parts. Impacts constrained to cost and schedule.

**Considered for Medium criticality component on a Single spacecraft, with redundancy ...**

Your Part	Radiation concerns	Greatest System Rad Concern	As-is Risk	Post Rec Risk
DUT1	TID, DDD, SET, SEB, SEGR	Degradation & Single Event	Medium	Low

**Recommendation and Guidelines:**  
Most LEDs have slow on/off times making Single events negligible on the power output of the device.

Please send questions and feedback to: michael.j.campola@nasa.gov  
Additionally a Model Based Mission Assurance Tool Can extend this analysis - [SEAM](#)

[Save to Summary Sheet](#)
[Add my next part](#)
[Download Summary Sheet](#)
[Download JSON fmt Sheet](#)

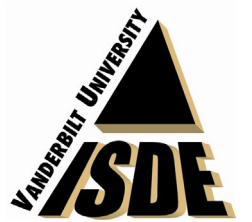
Your tailored table summary of saved runs has 1 Rows:

Show  entries Search:

delete	Orbit	Mission Architecture	Environment Severity	RefDes	Function	Device Criticality	Highest Threat	As-is Risk	Post mitigation risk
1	LEO (Polar)	Single spacecraft, with redundancy	High	DUT1	Discrete LED	Medium	Degradation & Single Event	Medium	Low



# SEAM: Systems Engineering and Assurance Modeling



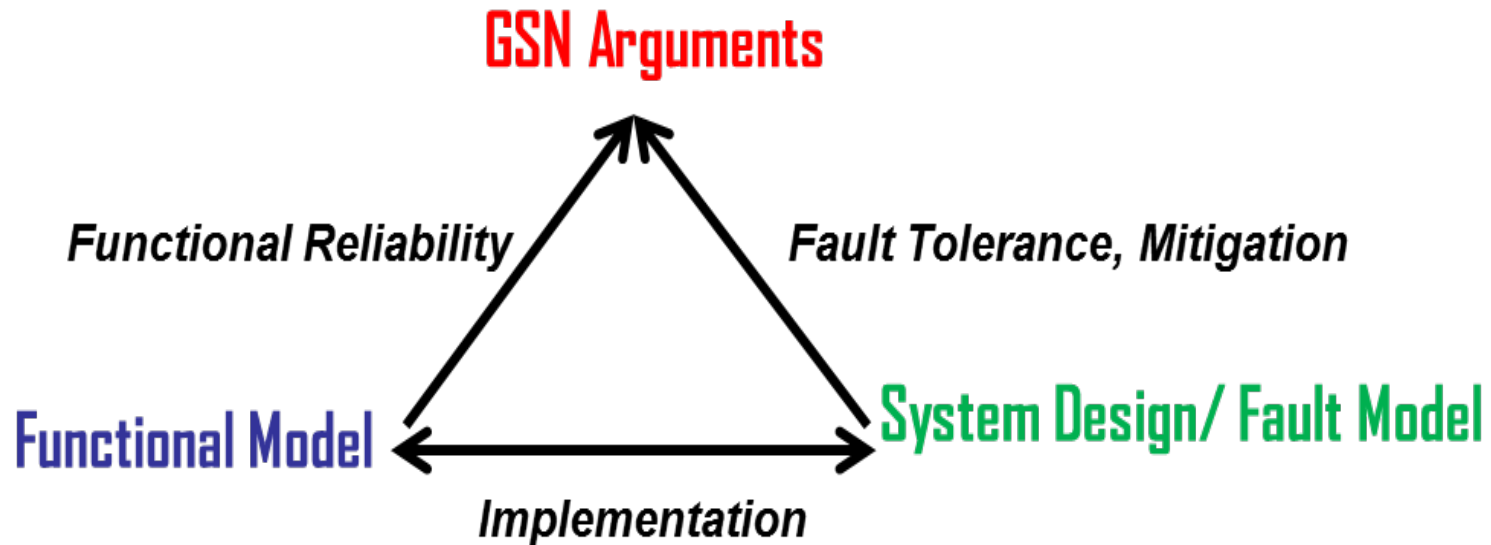
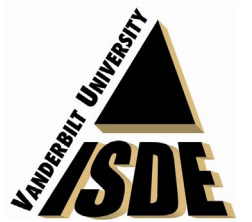
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- Free platform used to evaluate any spacecraft system
- Useful for radiation fault modeling and radiation case development
- Applications with short development timeframes and COTS usage

<https://modelbasedassurance.org/>



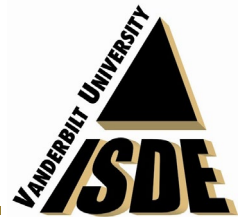
# SEAM: Systems Engineering and Assurance Modeling



- 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

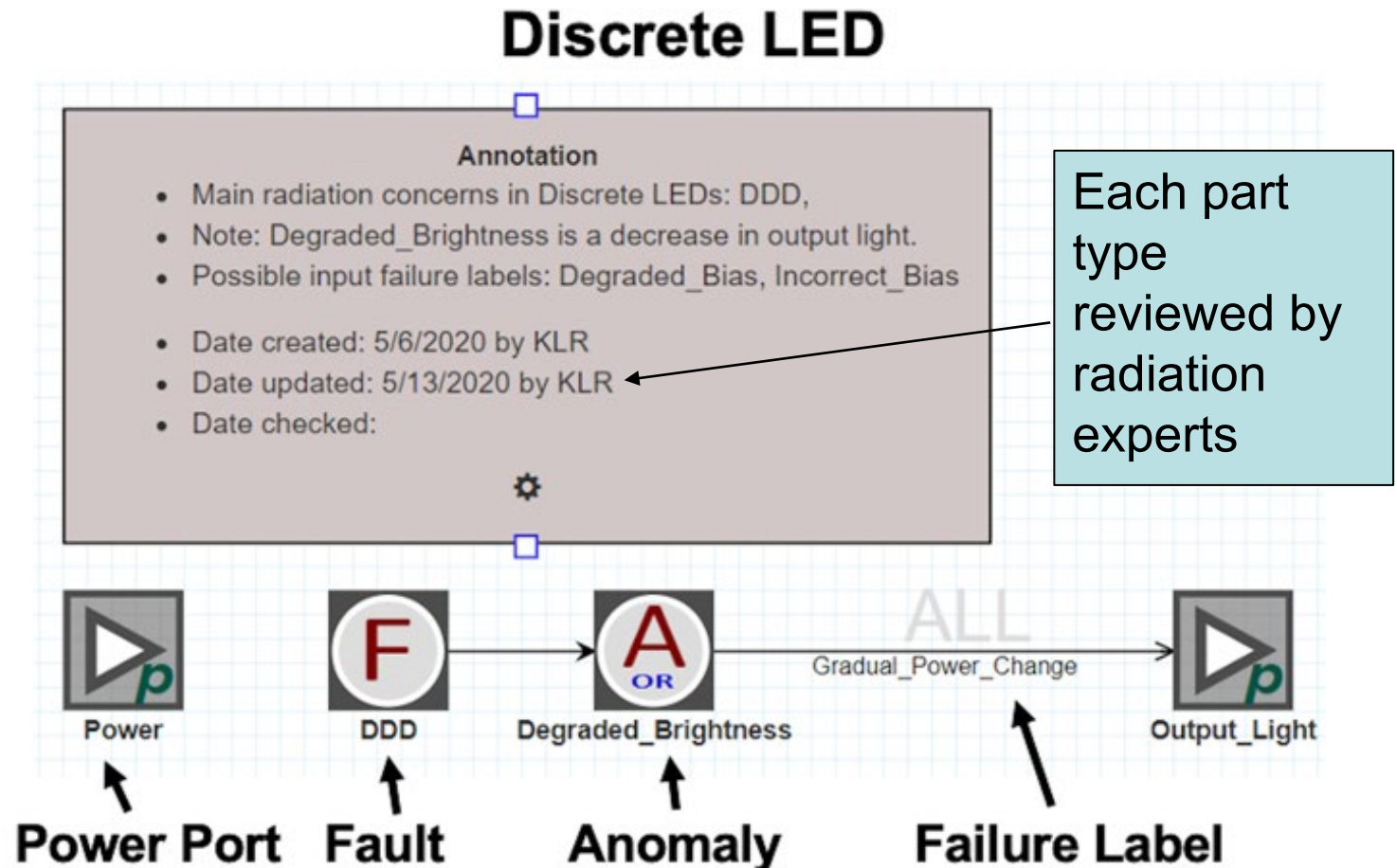


# SEAM Templates Based on RGENTIC Part Categories



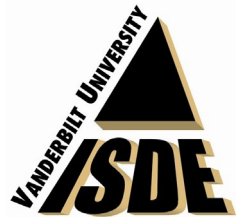
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- SEAM model of Discrete LED shown in the editor canvas.
- Engineers can choose modeling elements from the model parts panel on the same page as this figure.
- SEAM allows users to create project libraries for both components and failure labels.

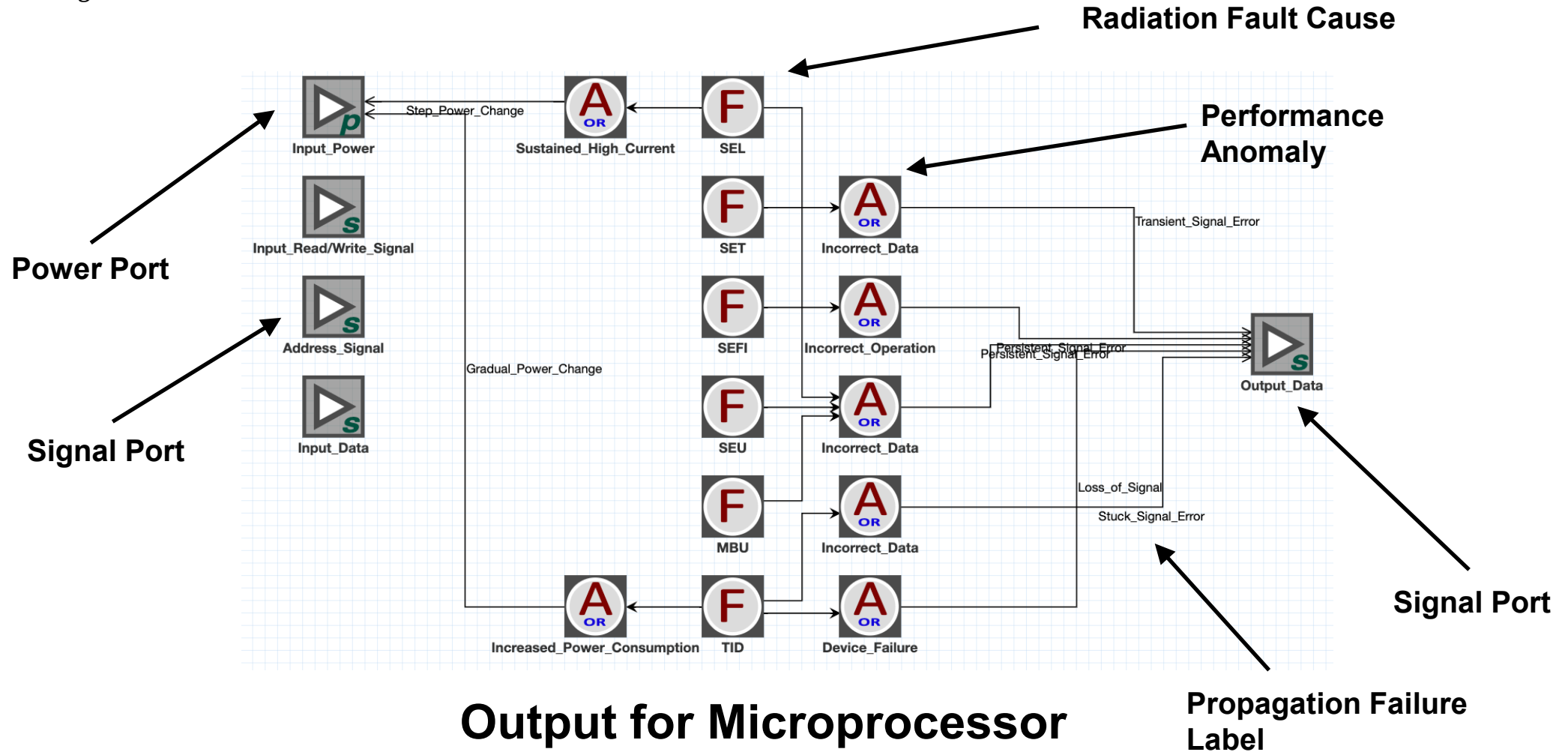




# SEAM Output



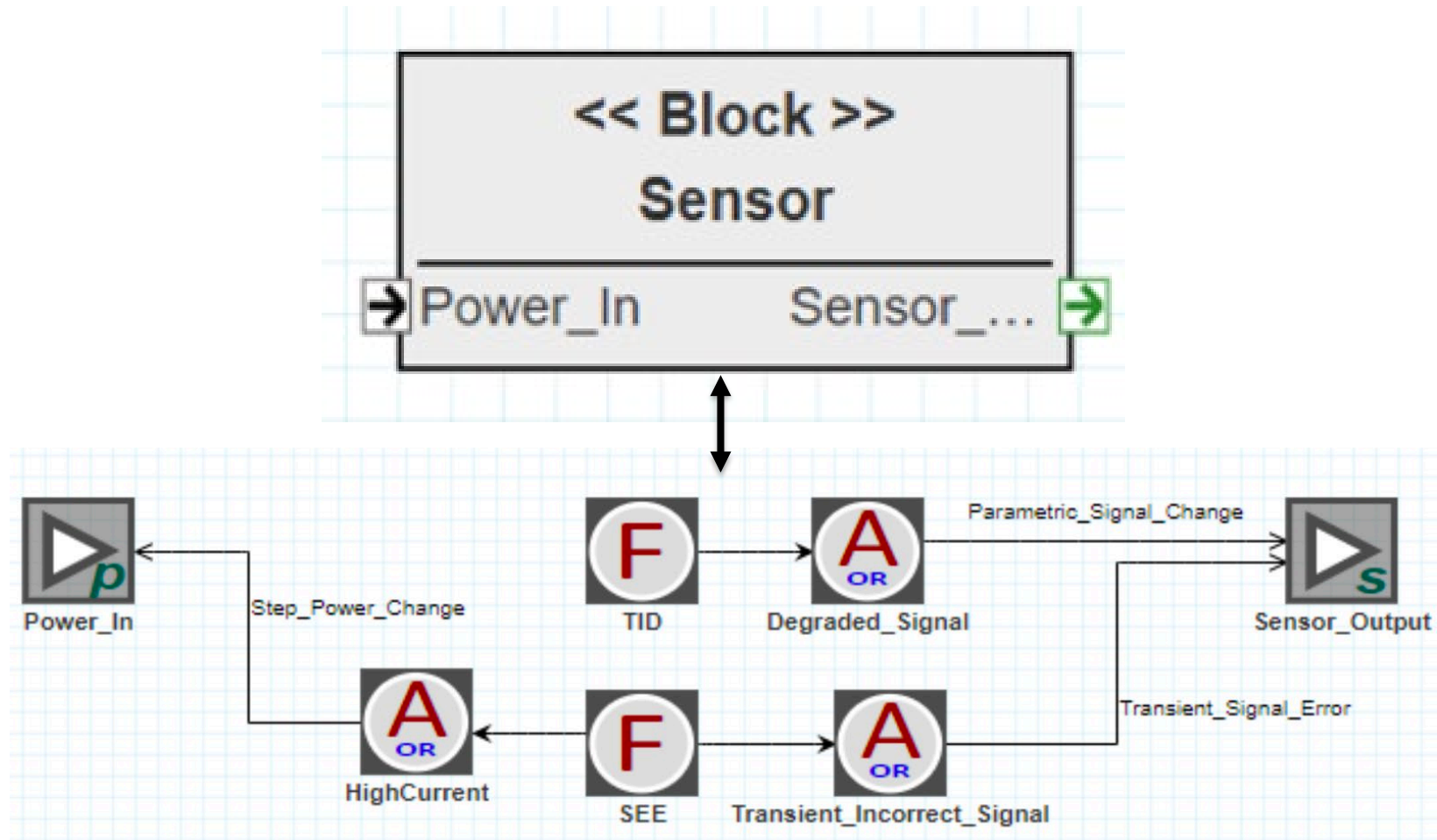
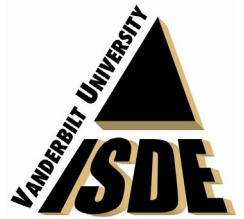
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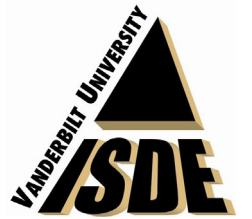
# Sensor Part-Type Output from SEAM



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