Systematic Approach to Parts Selection and Radiation Assessment for Mission Profiles

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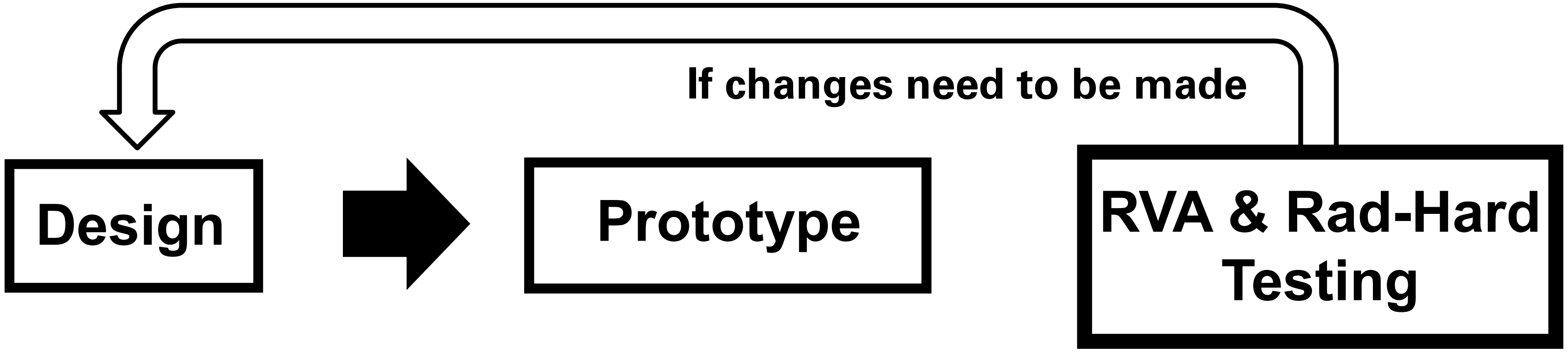
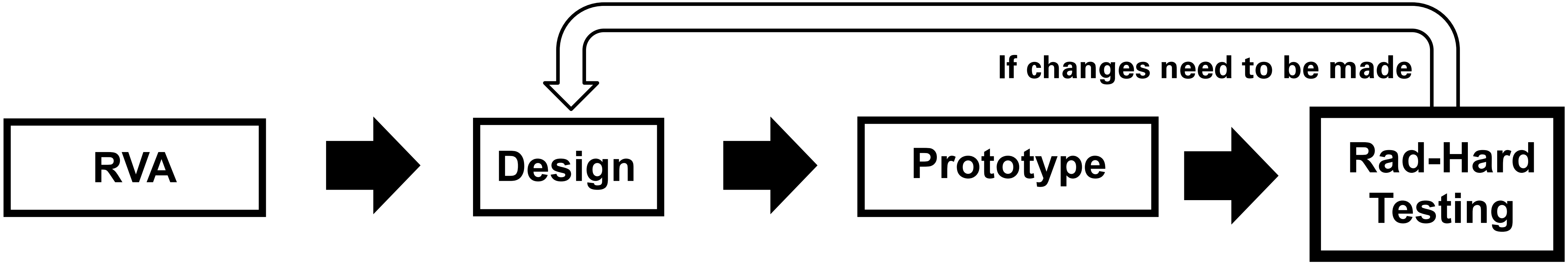
Radiation Vulnerability Assessment (RVA): Earlier vs. Later in Spacecraft Development

Later in Spacecraft Development (Conventional Flow)



Earlier in Spacecraft Development (Novel Flow)



Expected Users of Radiation Vulnerability Assessment

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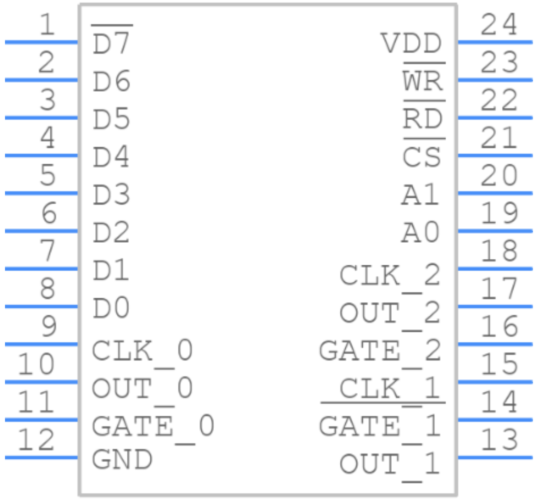
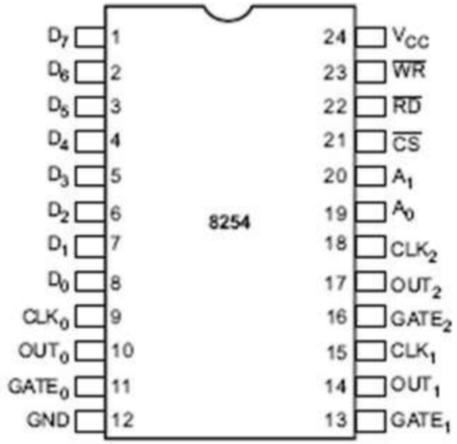
- Teams most likely to:
  - Use commercial-off-the-shelf (COTS) components
  - Lack (at least initially) radiation effects experts
- Rad-hardened components are more expensive than their non-rad-hardened counterparts
- These groups include:
  - Small satellite (e.g., CubeSat) teams
  - Academic design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



Renesas Electronics HS1-82C54RH-Q: Rad-hard Programmable Timer
Price: ~$3,100

vs.



Intel 8254: Non-rad-hard Programmable Timer
Price:~$7.00

Assessing
Radiation Vulnerability Assessment

User-Input

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

Simulated RVA

- 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:**
  - Simplified
  - Generic part types
  - NO part numbers

SEAM Fault Model Templates
- Part type models
- Contain generalized 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

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RGENTIC

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

Transferred via CSV File →

SEAM

- Matches RGENTIC's part list against its own part list to allow the user to create a model showing fault propagation through the spacecraft system

RGENTIC Look-Up Table

- 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 Transients
  - 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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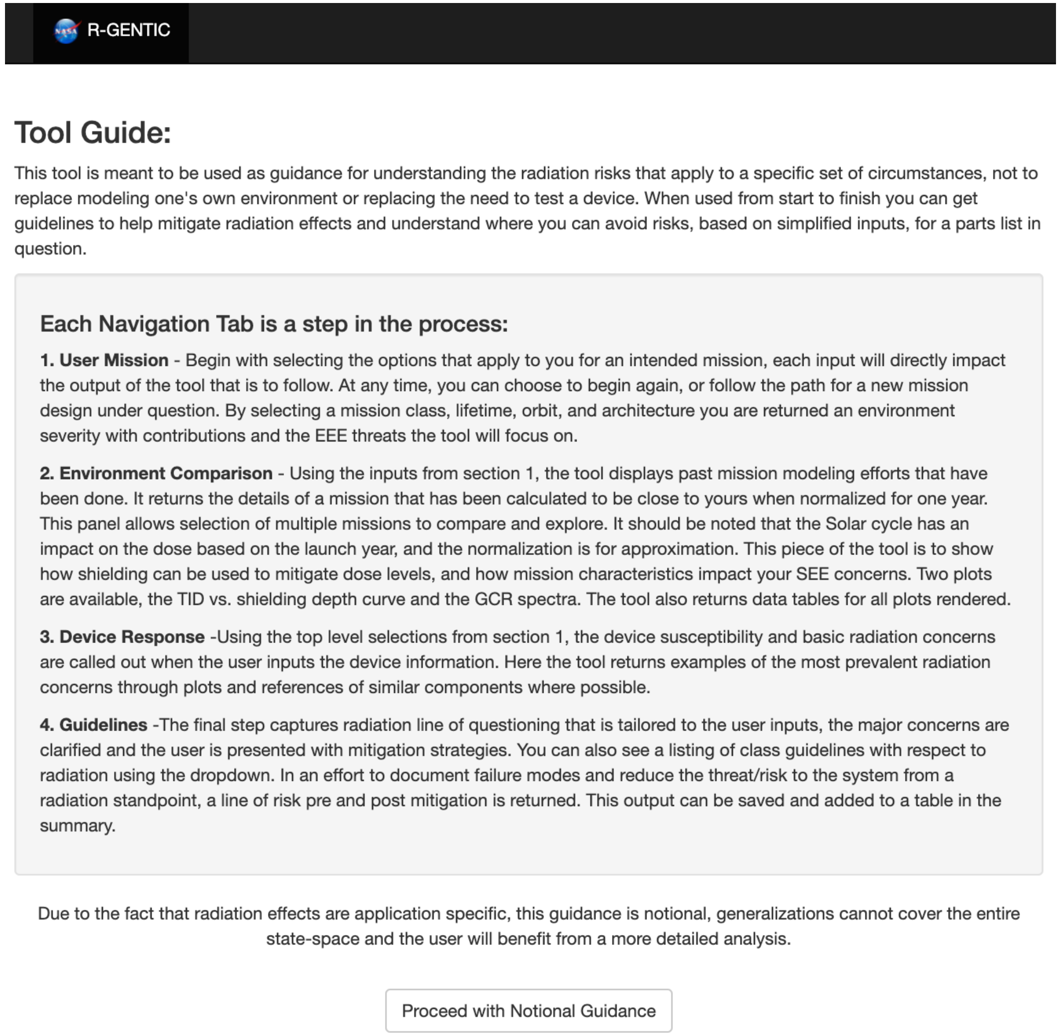
- Developed at NASA Goddard Space Flight Center (GSFC)
- Associates user-inputted EEE components to potential rad-hard risks based on user-inputted mission environment
- Provides guidance on assessing rad-hardness of EEE components
- RGENTIC Process:
  - User Mission
  - Environment Comparison:
  - Device 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/

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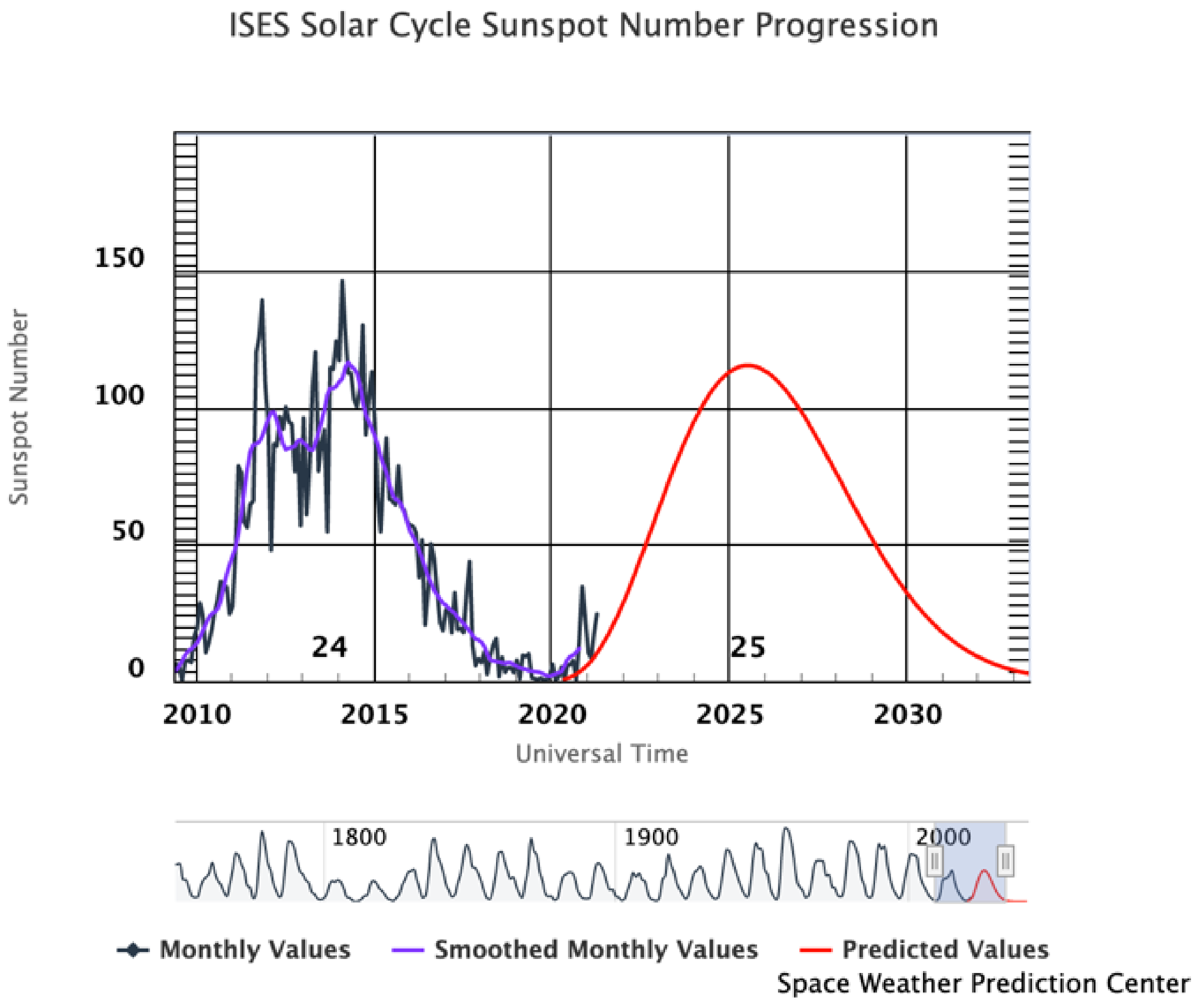
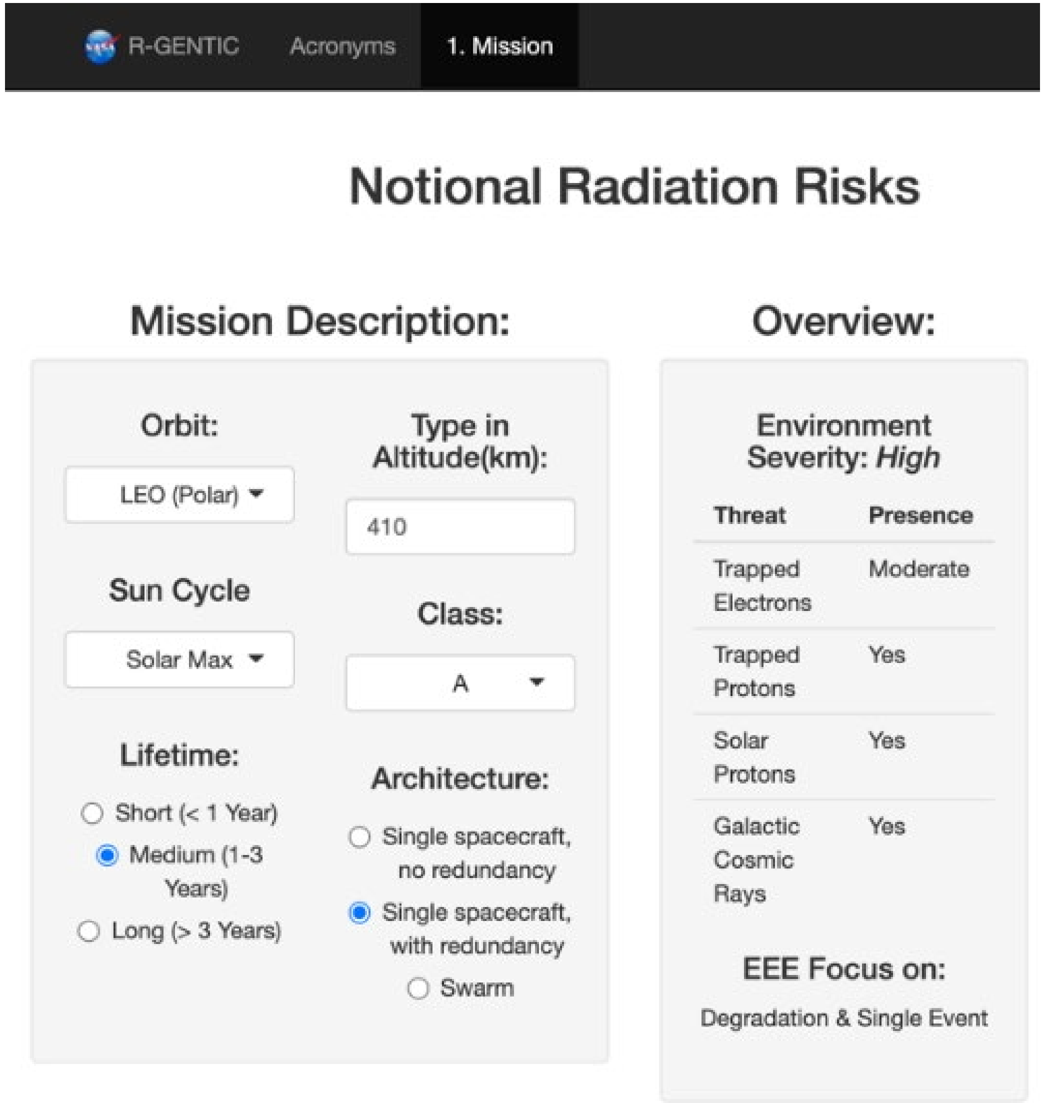
Step 1: User Mission





Step 2: Environment Comparison

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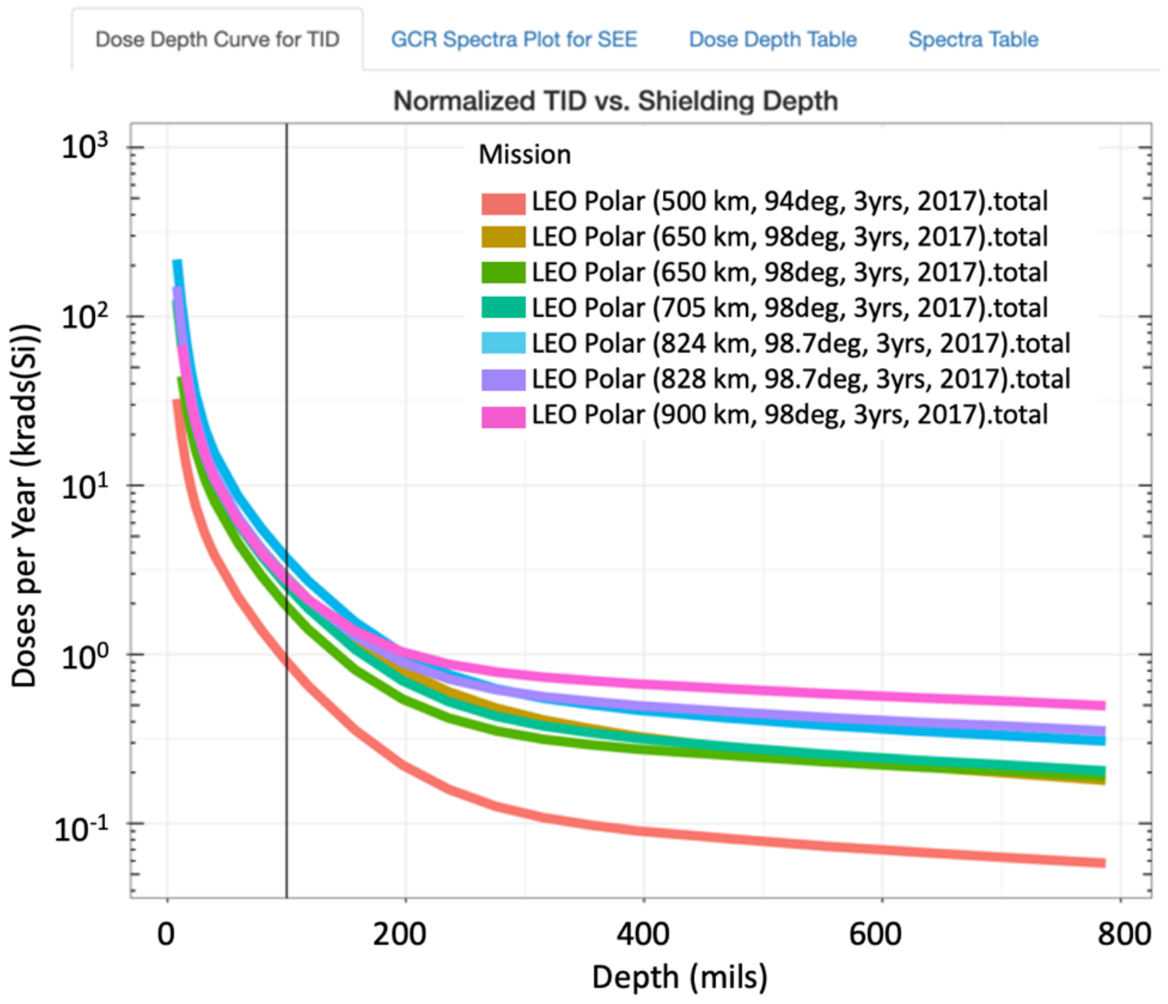

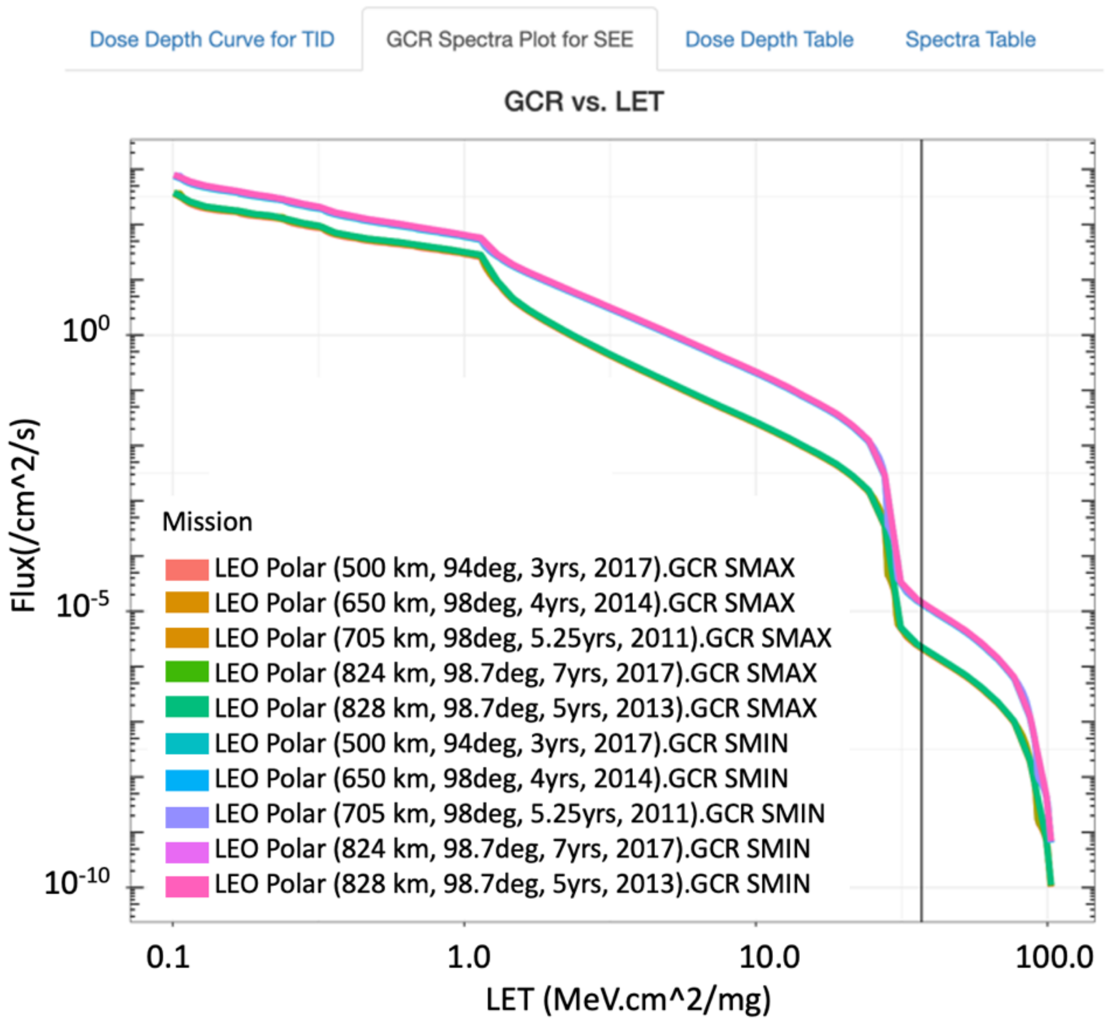

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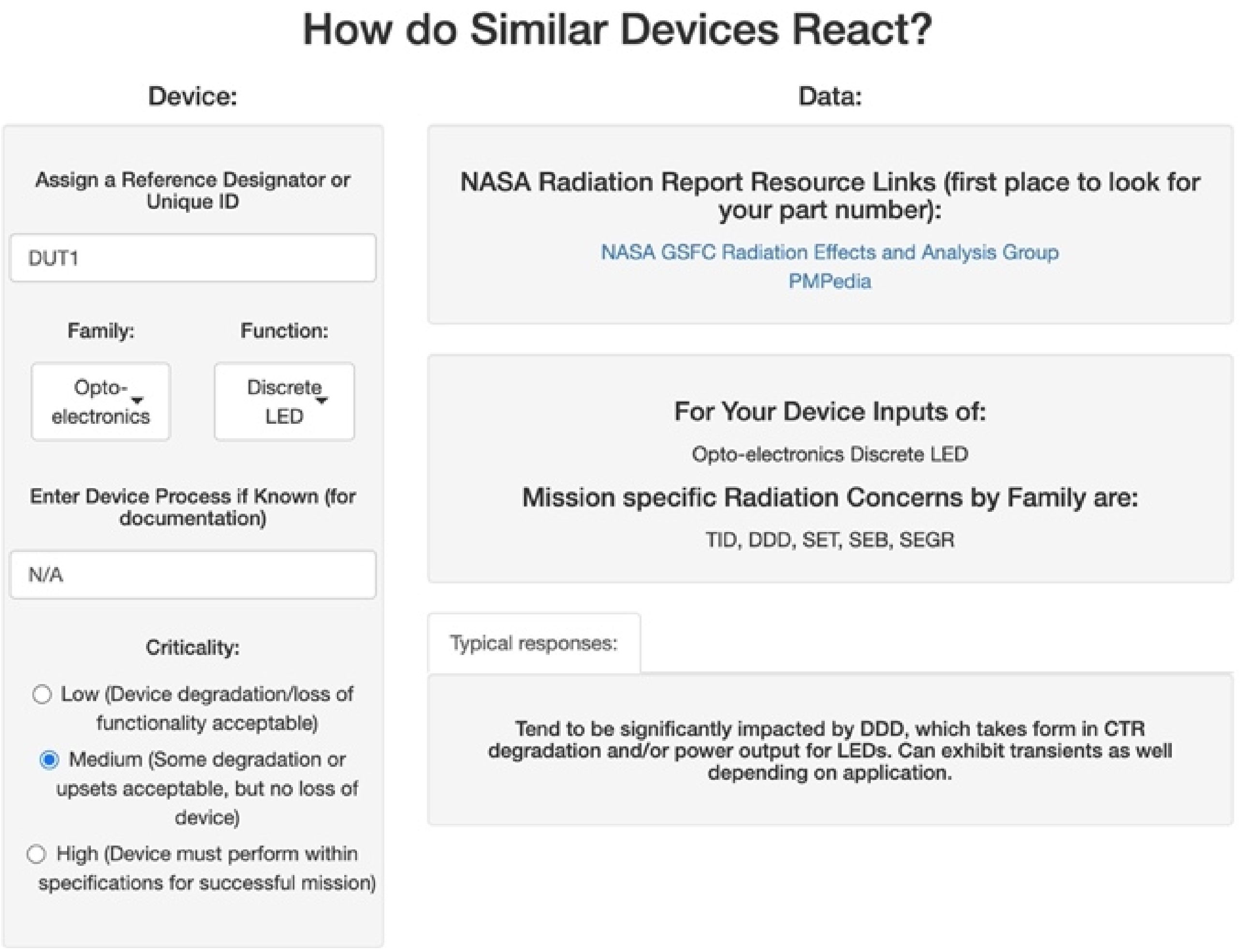
Step 3: Device Response

- User inputs electronic device types of interest so RGENTIC can identify basic radiation concerns
- Device susceptibility to various potential radiation concerns are shown once the user inputs the component's information.
- Only generic part-types are considered.



Step 4: Guidelines

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- Top-left box gives typical line of radiation questioning for the Family of the device, with device-specific information given beneath

- Lower- left box provides recommendations based on the part's criticality, the environment's severity, and the 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:

Undo delete

Show 10 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

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Examples of Guidelines for Complex Component

What should you do to bring down the risk?

The typical line of radiation questioning for: Embedded N/A uProcessor with regard to TID, DDD, SEFI, SEGR, SEB, SEL, MBU, SEU

Criticality vs. Environment:

COTS upscreening/testing recommended; fault-tolerance recommended

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
DUT2	TID, DDD, SEFI, SEGR, SEB, SEL, MBU, SEU	Degradation & Single Event	Medium	Low

Recommendation and Guidelines:

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:

Undo delete

Show 10 entries   Search:

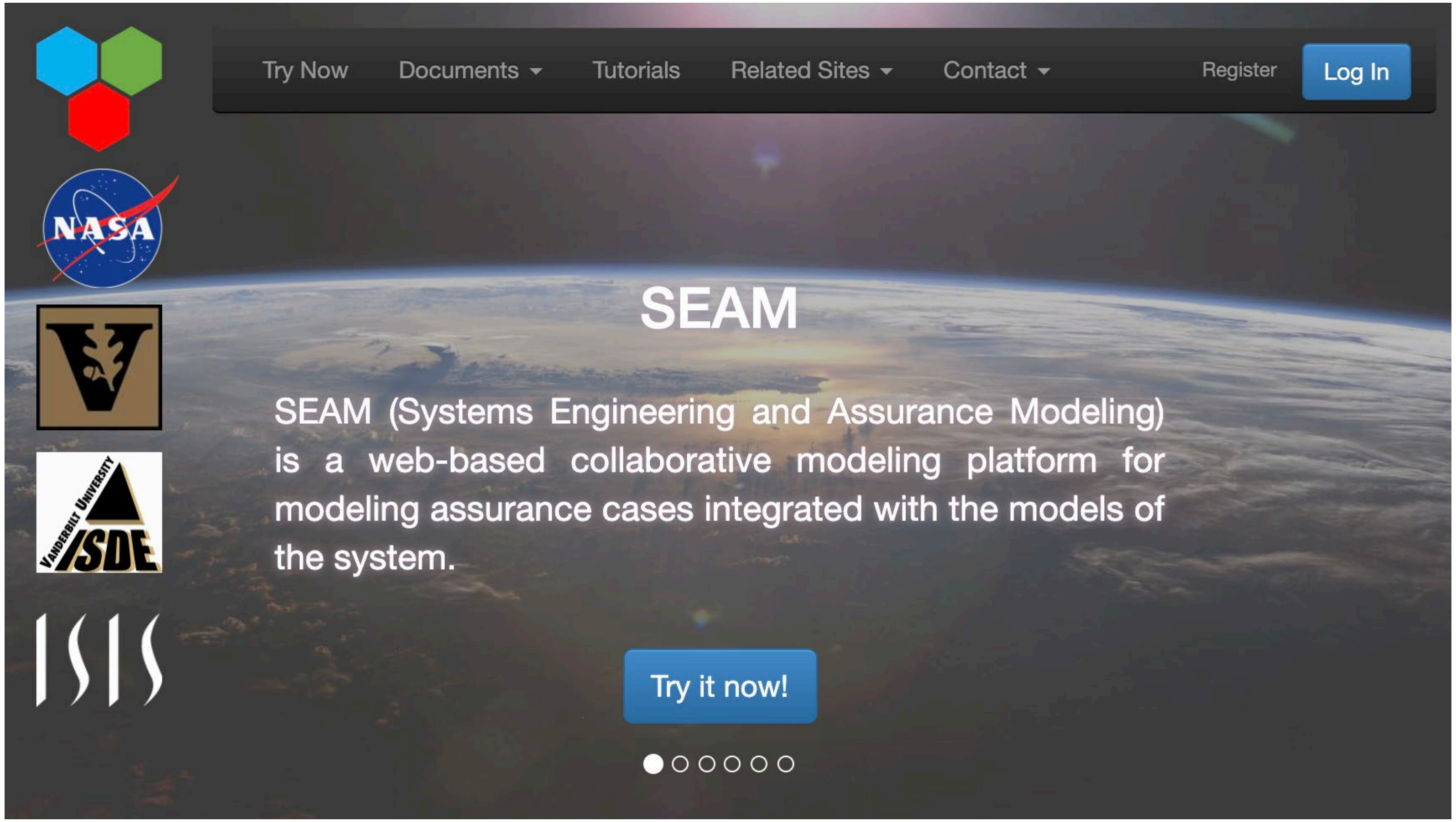
	delete	Orbit	Mission Architecture	Environment Severity	RefDes	Function	Device Criticality	Highest Threat	As-is Risk	Post mitigation risk
1		LEO	Single spacecraft, with redundancy	Medium	DUT2	uProcessor	Medium	Degradation & Single Event	Medium	Low

Showing 1 to 1 of 1 entries   Previous 1 Next

Output for Microprocessor

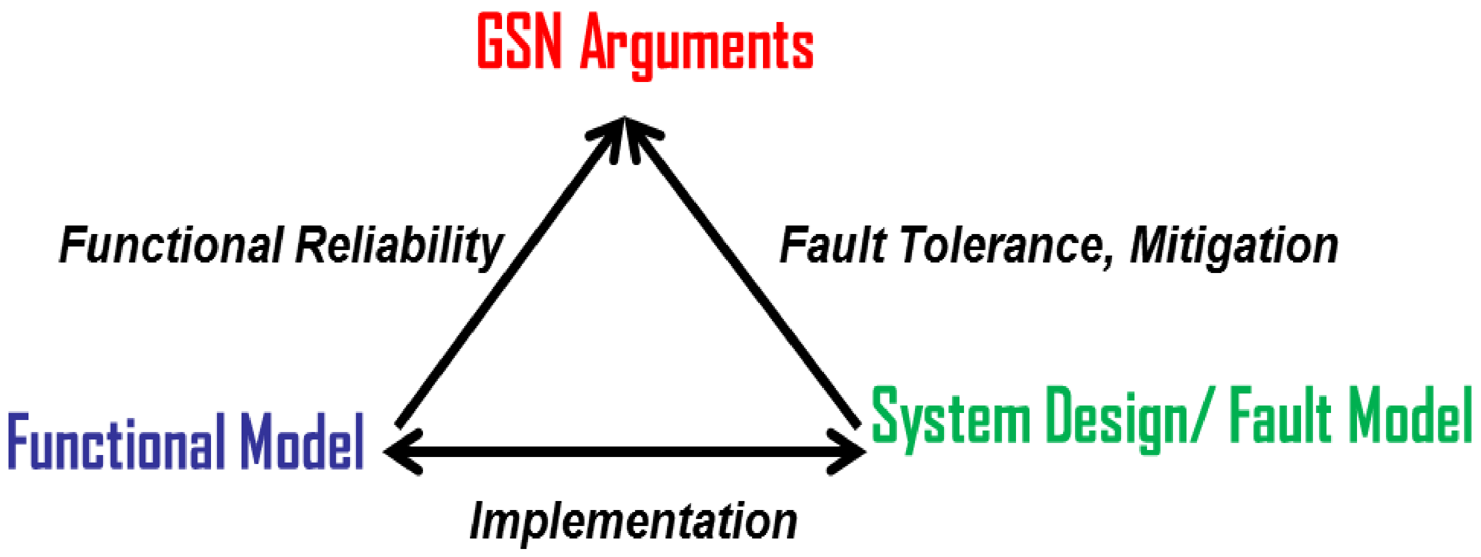
SEAM: Systems Engineering and Assurance Modeling

- Platform used to evaluate any spacecraft system
- Especially useful for small satellite applications with short development timeframes and significant utilization of COTS components



https://modelbasedassurance.org/

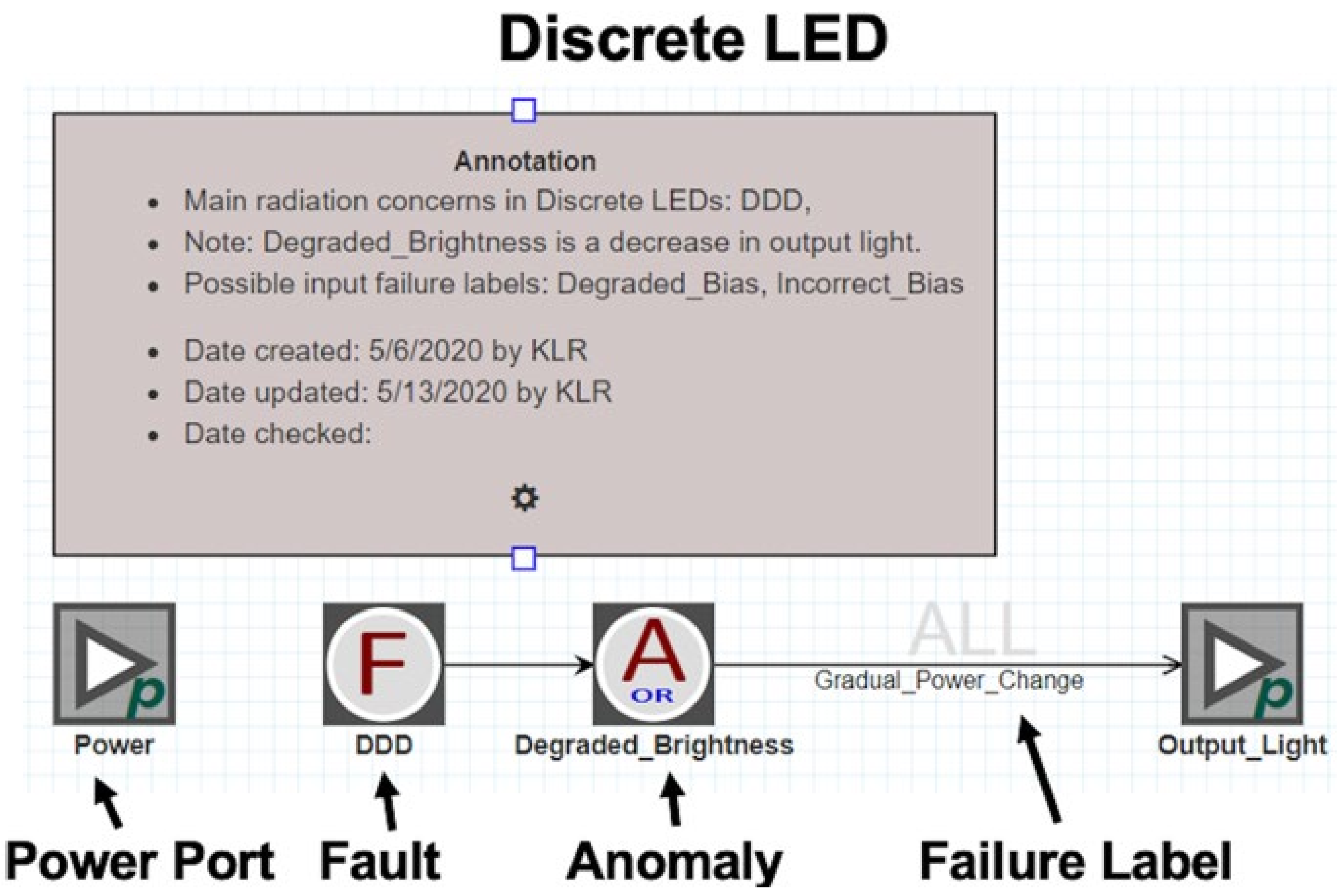
SEAM: Systems Engineering and Assurance Modeling



- SEAM incorporates SysML internal block diagrams
- SEAM capabilities allow assessment of the radiation performance of a spacecraft without relying on intensive radiation testing campaigns, or extensive physical knowledge of the electronic components.

SEAM Output based on Part-Type Templates Outputted from RGENTIC

- 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 based on Templates Outputted from RGENTIC (Complex Components)

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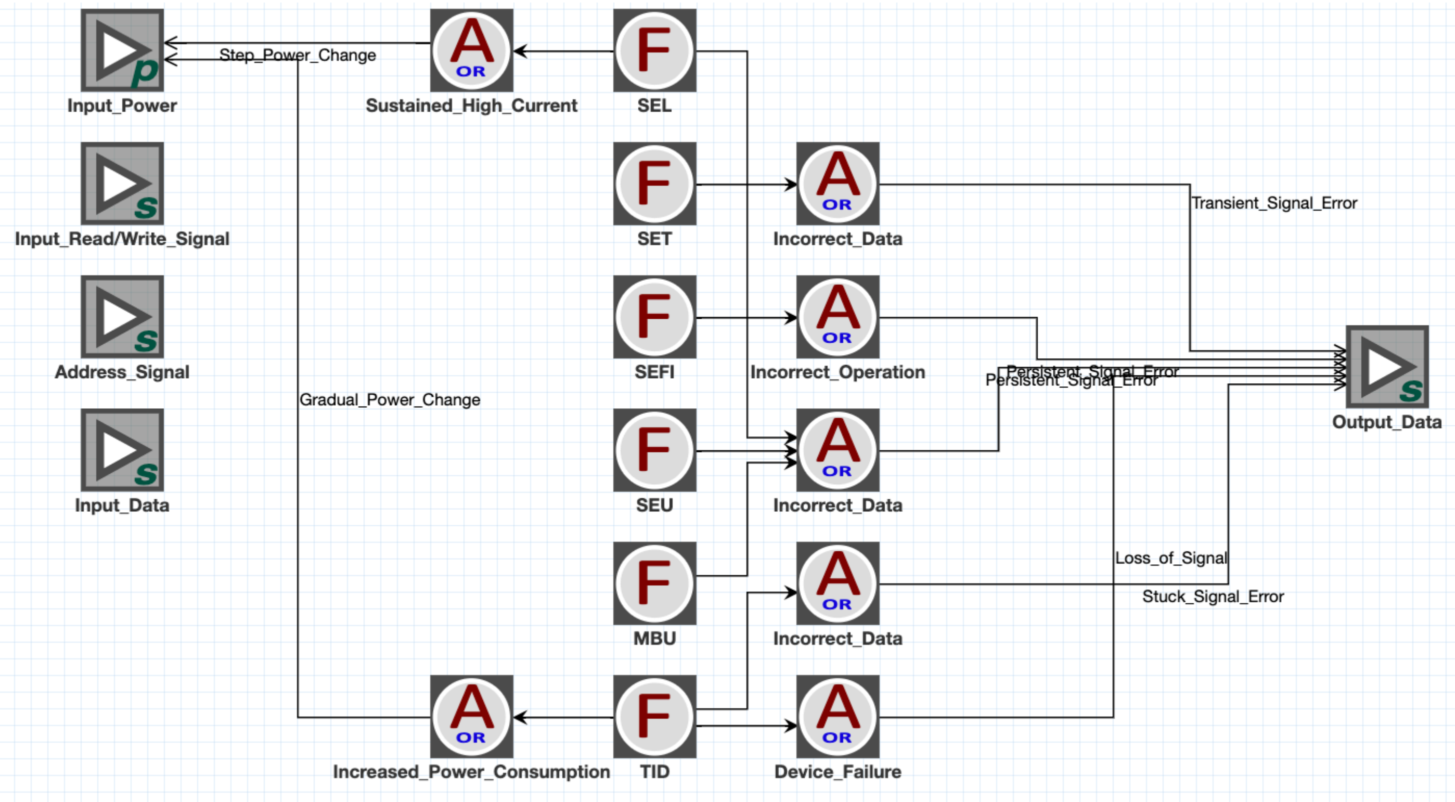

Output for Microprocessor

Star Tracker Part-Type Output from RGENTIC

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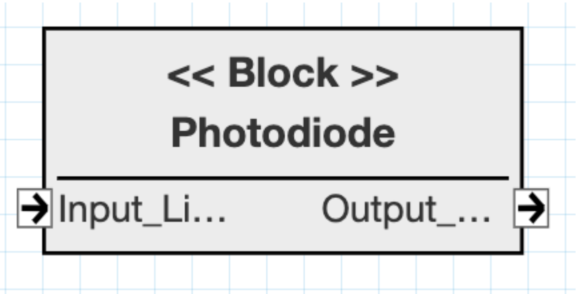
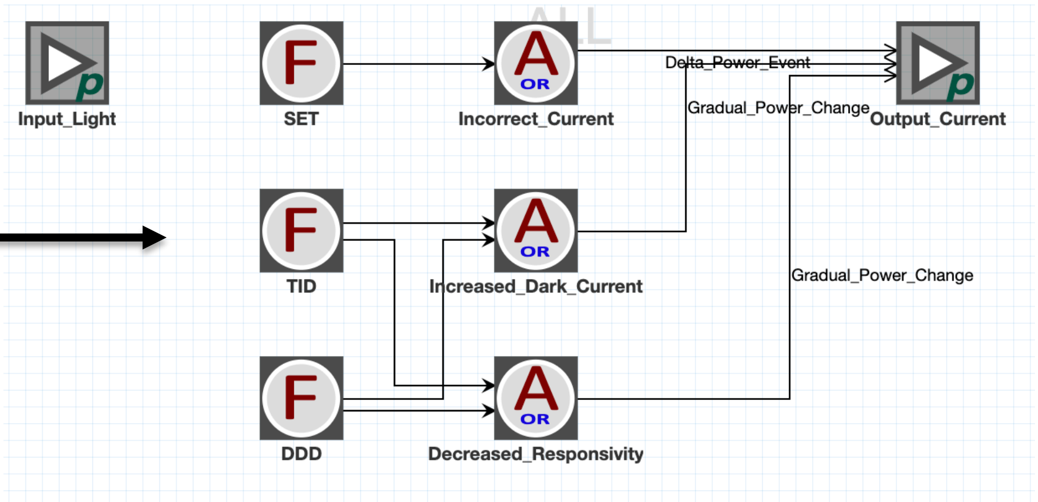
	delete	Orbit	Mission Architecture	Environment Severity	RefDes	Function
1		LEO	Single spacecraft, no redundancy	Low		Photodiode
2		LEO	Single spacecraft, no redundancy	Low		Power Supply
3		LEO	Single spacecraft, no redundancy	Low		CMOS Imager
4		LEO	Single spacecraft, no redundancy	Low		Discrete Logic Gates
5		LEO	Single spacecraft, no redundancy	Low		Op-amp
7		LEO	Single spacecraft, no redundancy	Low		Voltage Regulator

Showing 1 to 6 of 6 entries

RGENTIC Output





SEAM Model

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Establishing Relationships between Tools

RGENTIC

- Look-up table of parts and effects
- Generic parts list
- Information is descriptive, provides guidance
- No connection between components

SEAM

- Global part library
- Project-specific part library
- Information is Boolean, yes/no does an effect occur
- Shows connections between components

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Status of SEAM's Global Part Type Library

Currently Completed	In-Progress
Discrete Power	Clock/Timing
Discrete RF	Digital
Discrete Signal	Imager
Embedded	Linear
Memory	Mixed Signal
Opto-Electronics	Power Hybrid
Sensor	

Ongoing Work

- Finish creating part templates in SEAM global library
- Enable SEAM to upload exportable CSV files from RGENTIC
- Create GSN (Goal Structuring Notation) template for assurance cases
- Finish manual for SEAM
- Create instructional videos

Conclusion

- Beginning spacecraft development with radiation vulnerability assessment can reduce total time and money required to complete a spacecraft system.
- RGENTIC and SEAM are two tools that can provide this early assessment.
- RGENTIC outputs a parts list associated with the radiation effects it can experience in the user-specific environment
- SEAM allows a user to build a model of the radiation fault propagation in a system