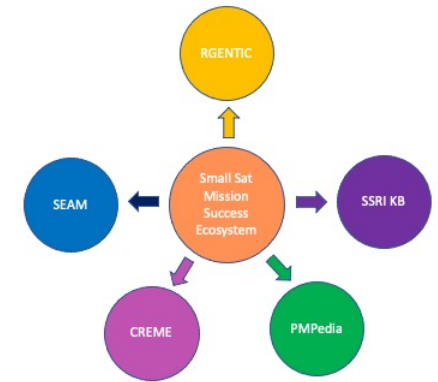




SSC21-WKI-04

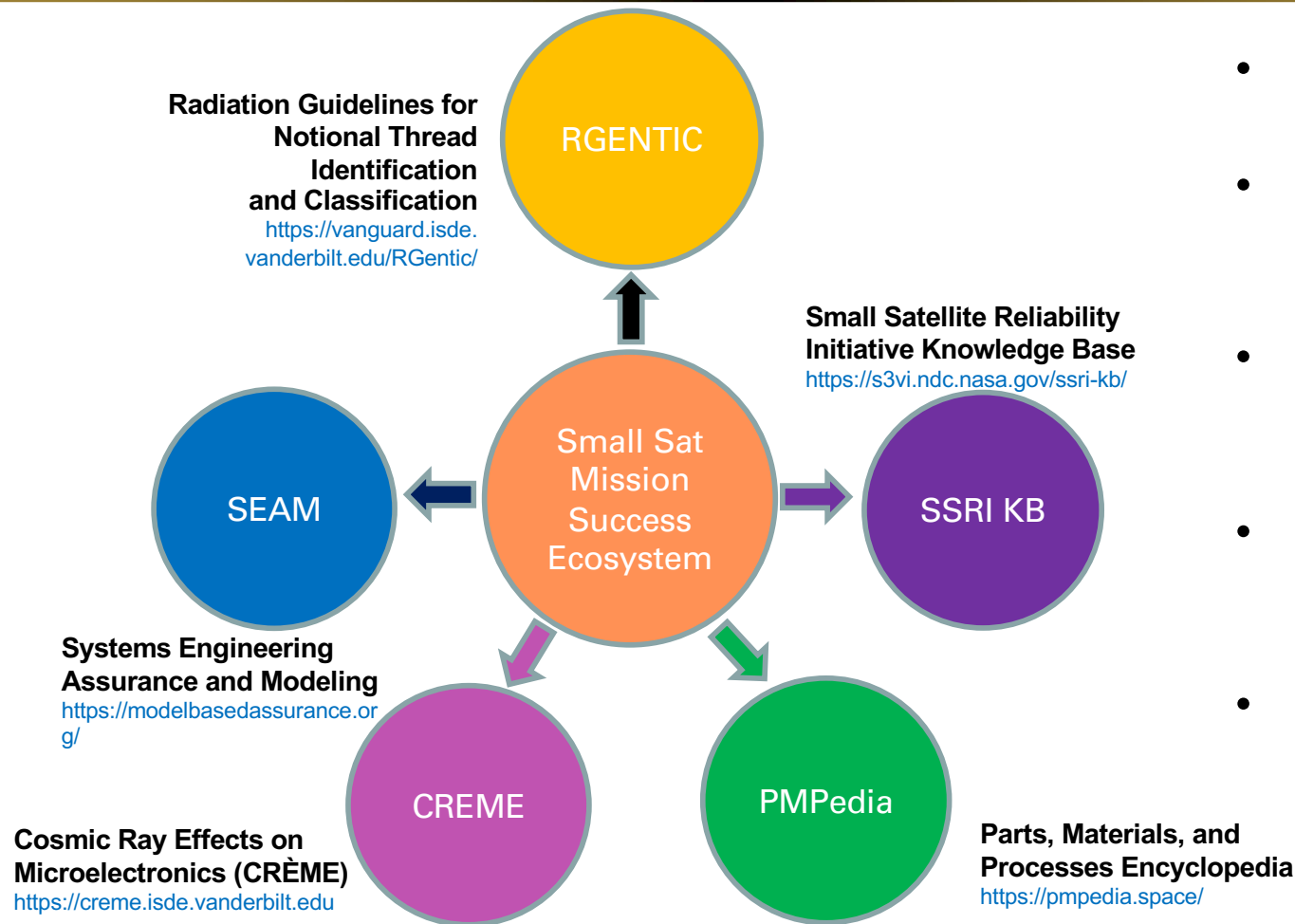
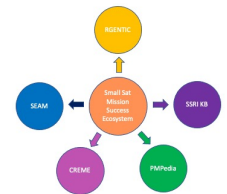


Online Small-Sat Knowledge Repositories and Modeling Tools for Risk Reduction and Enhanced Mission Success

¹Arthur Witulski, ¹Brian Sierawski, ¹Gabor Karsai, ¹Nag Mahadevan, ¹Robert Reed,
¹Ronald Schrimpf, ²Allyson Yarbrough, ³Neil White, ⁴Michael Campola, ⁴Rebekah Austin,
⁴Michael Johnson, ⁴Kaitlyn Ryder, ⁵Craig Burkhard, ⁶Robbie Robertson

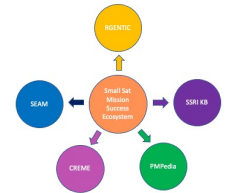
¹Vanderbilt University, ²The Aerospace Corporation, ³Laboratory for Atmospheric
and Space Physics (LASP), ⁴Goddard Space Flight Center (GSFC), NASA,
⁵Ames Research Center (ARC), NASA, ⁶Sedaro Technologies

Small Sat Mission Success Online Ecosystem

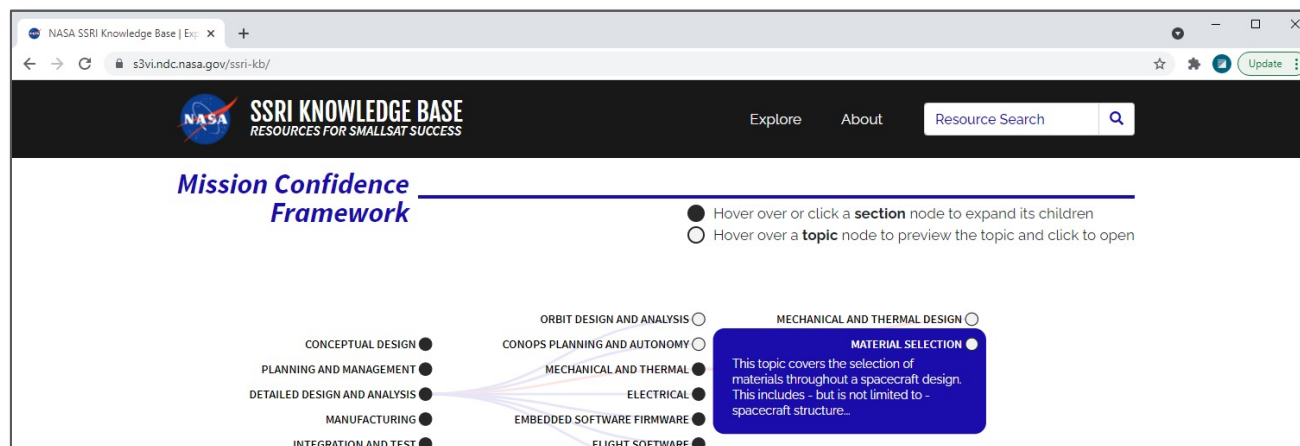


- What are Small-Sat best practices?
- How do I know the radiation vulnerabilities of electronic parts?
- How can I construct a radiation assurance case?
- What is the radiation environment in my orbit?
- Where can I find radiation test data for parts?

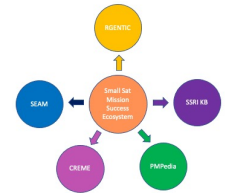
SSRI Knowledge Base: Overview



- Public-private collaboration led by the SSRI and NASA's S3VI
- Crowdsourced website providing resources and guidance on a broad range of smallsat topics
- Final moderation of all content by the SSRI, not the user community
- Publicly available now at <https://s3vi.ndc.nasa.gov/ssri-kb/>

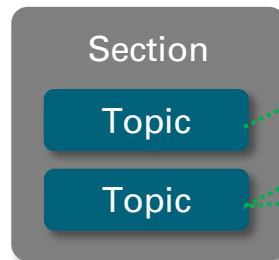
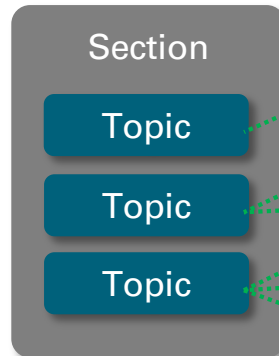


SSRI Knowledge Base: Structure



Mission Confidence Framework

- Order, structure, context
- Best practices & lessons learned
- User interfaces for submitting feedback and recommendations

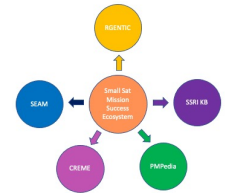


Resource Library



- Third-party content
- Articles, books, software tools, white papers, standards, and websites
- Access to resource
- Smallsat context
- Ratings

SSRI Knowledge Base: Upcoming Enhancements



- Expanded content - additional 18 topic pages and 180 unique resource items
- Application Programming Interface (API) - to allow access from other software programs & websites
- Improved interfaces for user input

SSRI KNOWLEDGE BASE
RESOURCES FOR SMALLSAT SUCCESS

Explore About Resource Search

This tool provides high-quality resources on topics that drive smallsat mission confidence. Explore the Mission Confidence Framework to find your desired topic page. The topic page will include best practices and lessons learned from experienced smallsat developers and will provide you with links to high-quality, curated resources (books, articles, software tools, websites, articles and white papers). You can also search the resource library directly using the search bar above.

SSRI KNOWLEDGE BASE
RESOURCES FOR SMALLSAT SUCCESS

Explore About radiation

Resource Search Results

Article Book Software Tool White Paper Standard Website Filter

Help Grow the Knowledge Base! Please contribute by rating resources and providing recommendations and feedback at the bottom of this topic page.

MCF > Conceptual Design >

Mission Architecture Design

Scope and Description

This topic covers the conceptual design of all high-level elements of a smallsat mission. This includes payload, spacecraft bus, launch system, orbit, ground system, and mission operations. The trade space in which to architect a satellite mission can be huge. This is especially true for smallsats which, compared to traditional space missions, can more readily take advantage of innovative technologies, commercial components, and distributed architectures. The goal of mission architecture design is to pare down this large trade space, evaluate alternative mission concepts, and arrive at a mission architecture that satisfies mission requirements with minimal cost, schedule, and risk of failure.

Resources in this topic area are primarily traditional mission design references and case studies for specific smallsat missions - occasionally presented alongside novel methodologies for smallsat mission architecture design. Note that because this is an overarching task involving every element of a given mission, completing it may require you to reference content from throughout this knowledge base.

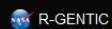
Best Practices and Lessons Learned

- Smallsats lend themselves to distributed architectures - constellations, precision formations, or swarms that can provide larger effective apertures and improved resilience, coverage, or revisit times. The number of satellites, how they are distributed in orbit, and manner in which they are deployed (all at once, in batches, or individually) are all connected to mission performance and mission confidence.

R-GENTIC: Overview



“RADIATION GUIDELINES FOR NOTIONAL THREAT IDENTIFICATION AND CLASSIFICATION (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.

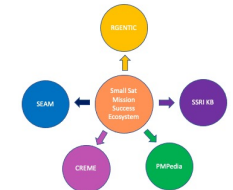
Due to the fact that radiation effects are application specific, this guidance is notional, generalizations cannot cover the entire state-space and the user will benefit from a more detailed analysis.

Proceed with Notional Guidance

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

- User inputs Mission Info
 - Length
 - Orbit, etc.
- Output is basic guidance on radiation risks

R-GENTIC: Typical Use Case



R-GENTIC Flow:

1. User Mission – input orbit, mission lifetime, risk tolerance
2. Environment Comparison – radiation environments from known missions with similar orbits
3. Device Response – input electronics device types of interest, basic radiation concerns are given
4. Guidelines – major concerns are clarified, radiation specific class guidelines are given

Notional Radiation Risks

Mission Description: Orbit: LEO (Equatorial), Type in Altitude(km):, Sun Cycle: Solar Max, Class: Do No Harm, Lifetime: Short (< 1 Year), Architecture: Single spacecraft, no redundancy.

Overview: Environment Severity: Low, Threat: Trapped Electrons (Moderate), Trapped Protons (Moderate), Solar Protons (No), Galactic Cosmic Rays (Moderate), EEE Focus on: Single Event.

What does a Similar Environment Look Like?

Inspect & Compare: Dose Depth Curve for TID, GCR Spectra Plot for SEE, Dose Depth Table, Spectra Table.

Normalized TID vs. Shielding Depth graph showing dose rate vs. depth for various orbits and shielding levels.

How do Similar Devices React?

Device: Clock/Timer, Function: Circuit-Based Oscillator.

NASA Radiation Report Resource Links (first place to look for your part number): NASA GSFC Radiation Effects and Analysis Group, PMPedia.

For Your Device Inputs of: Clock/Timer Circuit-Based Oscillator, Mission specific Radiation Concerns by Family are: SEU, SET, MBU, SEFI, SEL.

Typical responses: Reliability of clock timing may degrade, or have interruptions.

What should you do to bring down the risk?

The typical line of radiation questioning for: Clock/Timer Circuit-Based Oscillator with regard to SEU, SET, MBU, SEFI, SEL. Device may exhibit Latch-up. Is there redundancy? Will you be able to power cycle? SEUs are a concern. No concern for SEFI. Concern: Concern.

Considered for Low critically component on a Single spacecraft, no redundancy ...

Your Part concerns	Greatest System Risk Concern	As-is Risk	Post Rec Risk
SEU, SET, MBU, SEFI, SEL	Single Event	Low	Low

Recommendation and Guidelines: If SEUs are not tolerable, look for a crystal based oscillator as a replacement with good rad data.

Criticality vs. Environment: COTS upscreening/testing optional; no harm (to others). NASA Class Do No Harm Guidelines: Selective radiation effects evaluation shall be performed with emphasis on mission- and safety-critical components and assemblies. Flight of radiation testing for mission- and safety-critical components and assemblies is suggested. Fault-based designs for COTS parts are suggested. There will be known risks that cannot be quantified. Impacts include cost, schedule, and high technical risk acceptance.

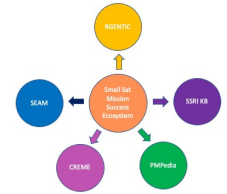
Save to Summary Sheet | Add my next part | Download Summary Sheet | Download JSON file Sheet

Your tailored table summary of saved runs has Rows: 1

Undo delete

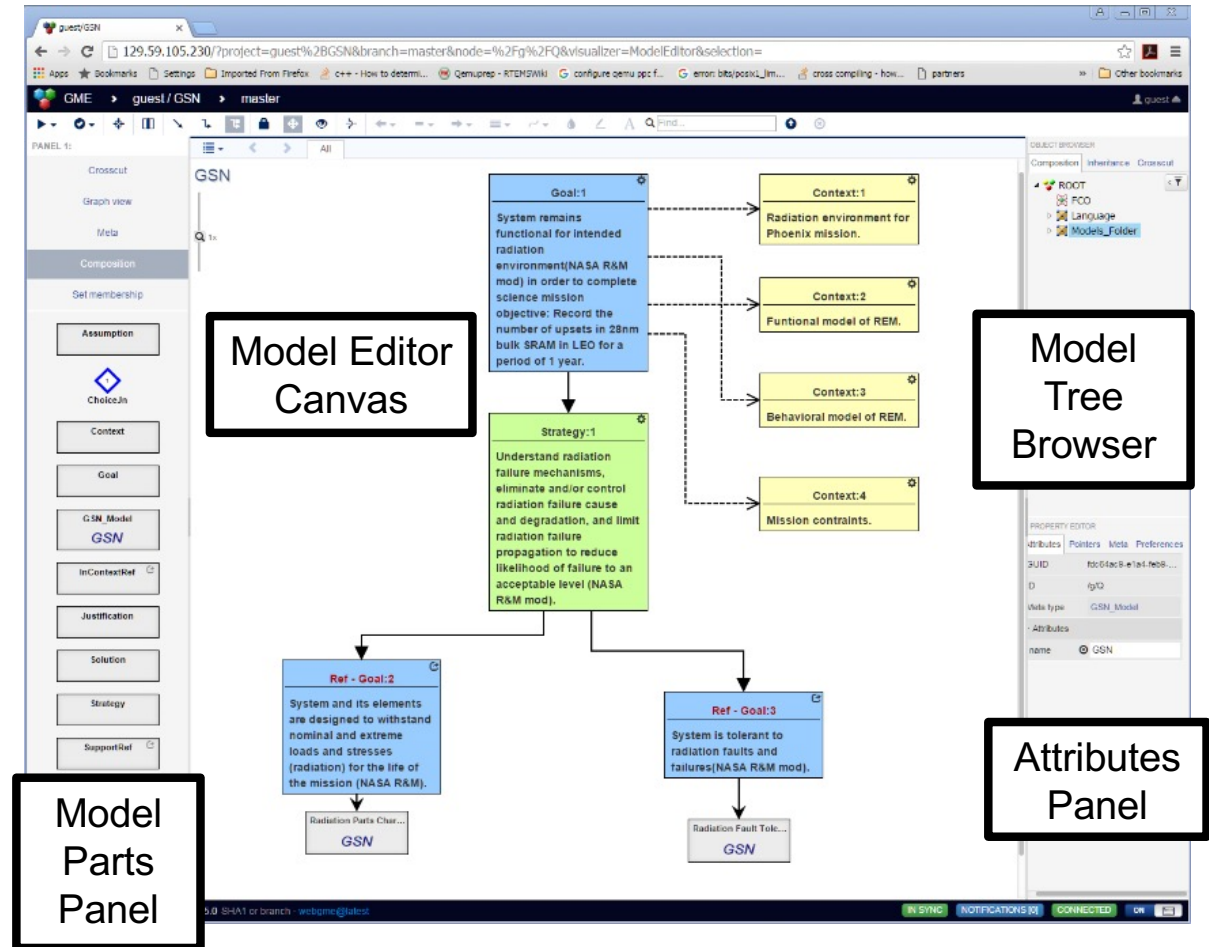
SEAM Details

Modeling paradigm and tool



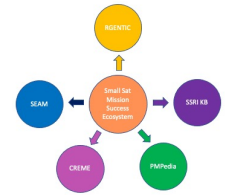
- Web-based collaborative platform
- A set of linked modeling languages to evaluate impact of part-level radiation effects on system functions
- Integrates Radiation Hardness Assurance activities into overall system design process

modelbasedassurance.org



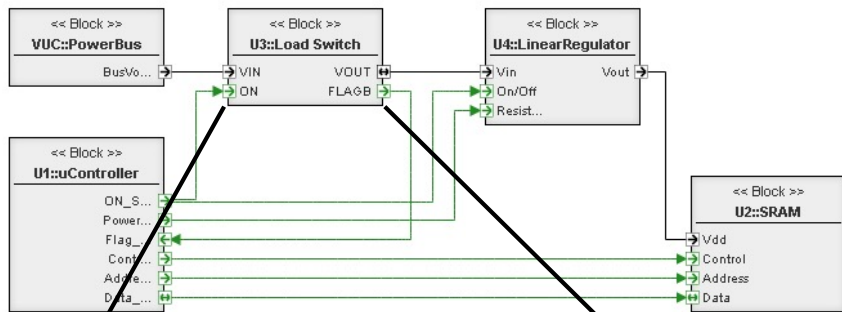
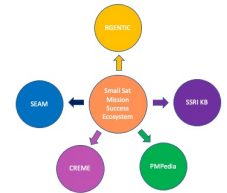
SEAM

Overview of Modeling Languages Used



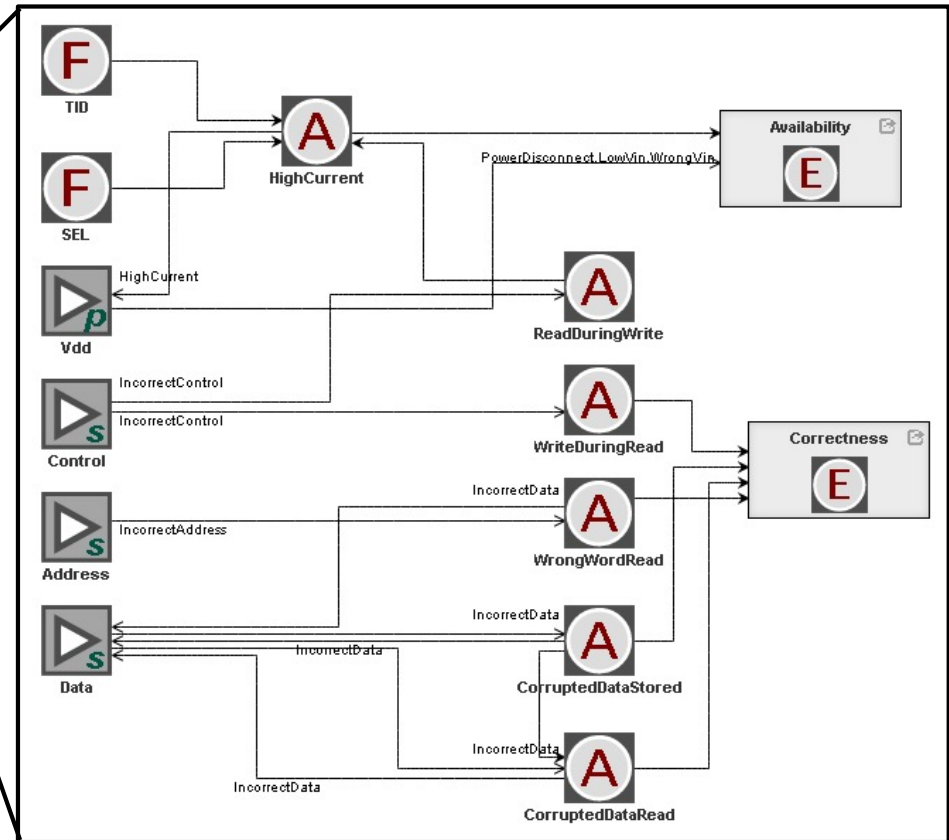
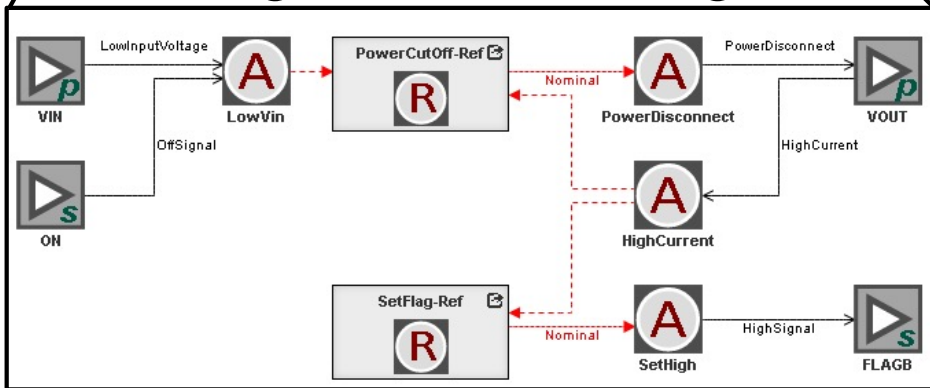
System Mod.	GSN	Bayes Net or FT
<ul style="list-style-type: none"> • Specification of systems through standard notation • Added fault propagation paths 	<ul style="list-style-type: none"> • Visual representation of argument • Goals, Strategies, and Solutions 	<ul style="list-style-type: none"> • Nodes describe probabilities of states • Calculate conditional probabilities from observations

SEAM SysML Model with Fault Propagation



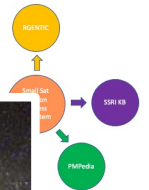
System Model

Mitigation Modeling



Fault Modeling

Alternate Grade EEE Parts Selection & Test Guidance



Crowd Sourced repository

Alternate Grade* EEE Parts Space Selection Guidance

Selecting or testing alternate grade EEE (electrical, electronic, electromechanical) parts for a space application? Answer a few questions about your mission in a simple decision tree, and quickly get the guidance to help you.

- Harness the capabilities of the most advanced electronic devices
- Accelerate design decisions
- Focus only on testing worth the investment
- Balance risk and grow design confidence

*e.g., automotive, aviation, commercial, industrial

What is the risk tolerance for

Select tolerance for only one individual

- Low
- Medium
- High

Select a part type to view test guidance.

- Assembly level
- Discrete semiconductors
- Microcircuit generic
- Passive generic

Shock	▼
Random Vibration	▼
Sinusoidal Vibration (for units when sine vibration present in Fig. 1)	▼
Acoustics (for acoustically sensitive units)	▼
Combined Thermal cycling (TC) and vacuum (TV)	▼
Thermal vacuum (TV)	▼
Burn-in	▼
Fatigue Life	▼

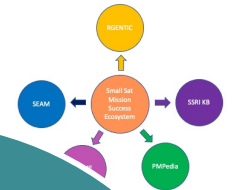
Workflow based on Mission attributes: Orbit, Duration, Cost, Risk

Content will evolve as user community experts offer updates and refinements

Common-sense, tailored guidance

- *Facilitates meeting requirement flow-downs*
- *Reduces duplicative and/or non-value-added testing and analyses*
- *Accelerates alternate grade parts decision-making*
- *Workflow mirrors that in NASA's modeling tool, R-GENTIC*

Alternate Grade EEE Parts Test Data Repository



Analog Devices AD7983

Analog-to-Digital Converter, 16-Bit, 1.33 MSPS PulsAR in MSOP/QFN

[+ Add to compare](#)

Technology type: CMOS
Approximate cost: \$\$

Datasheet specs

- 16 bit
- Throughput: 1300 kS/sec
- Max Power Dissipation: 12 mW

Radiation tests

SEE test — LASP, 2015

TID test — LASP, 2014

SEE test — LASP, 2015

Test date: 2015
Data source: LASP
Test facility: TAMU
Test objective: SEE
Results summary: Tested up to 55 MeV-cm²/mg

Test details

As-tested part number	AD7983BRMZ
Sample size ?	3
Radiation type	Heavy Ion
Flux	1.00E+04 particles/s
Fluence	1.00E+07 particles/cm ² /s
SEL LET ?	greater than 55 MeV-cm ² /mg
LETth ?	55 MeV-cm ² /mg

Example part data

TID test — LASP, 2014

Test date: 2014
Data source: LASP
Test facility: ATC UMass Lowell
Test objective: TID

Results summary: Tested up to 50 kRad(Si). No degradation at 30 kRad(Si). Slight increase in noise at 50 kRad(Si).

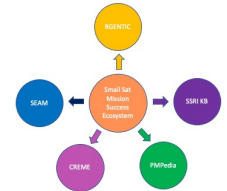
Test details

As-tested part number	AD7983BRMZ
Sample size ?	3
Radiation type	Gamma
Dose rate	13000 mrad/s
TID ?	50 kRad(Si)
Max allowable TID ?	30 kRad(Si)
Other test conditions	4 units, decapped, monitor current draw on 3.3V and 5V ADC power lines

Alternate Grade Part Construction, Test & Usage Data

- Growing list of part types. (We need more, please!)
- Data types: radiation test data (TID, SEE, SEU), physical analyses
- Suggestions for upcoming radiation tests are welcome

Alternate Grade EEE Parts User Discussion Forum



In reply to: **What scope of power-on/turn-on data do you review?**

Search for “Part Reliability”



PMPedia Admin

2020-06-19 at 12:19 pm #1444

Suggestions, Observations and Lessons Learned

In some sense, extremely short missions seem simpler than other types, just by virtue of their duration. Alternate-grade EEE parts' mean time to failure may far exceed the mission duration itself. On the other hand, these missions can be very challenging because the stakes are so high in the event of an anomaly. Therefore, prudent approaches to mitigating a mission-ending event might be to employ overly conservative redundancy schemes; selectively upgrade to higher-reliability devices for mission-critical functions; perform independent testing on a statistically significant sample of parts identical those in the mission or leverage heritage flight data, if it exists. However, these options incur costs which, in aggregate, must be weighed against the cost savings of procuring the alternate-grade part.

In reply to: **Are the parts used in an application that is mission-critical?**



PMPedia Admin

2020-06-19 at 12:10 pm #1434

Suggestions, Observations and Lessons Learned

In a single-point failure or mission-critical part application, a few options are available to prevent premature end of the mission. The designers could significantly derate the part, consider selective use of a higher-quality part, add selective redundancy or invest in independent testing of identical samples.

Also as part of your architecture design and risk trade studies, it is important to evaluate the option of a single string of highly reliable units vs use of lower reliability, redundant units.

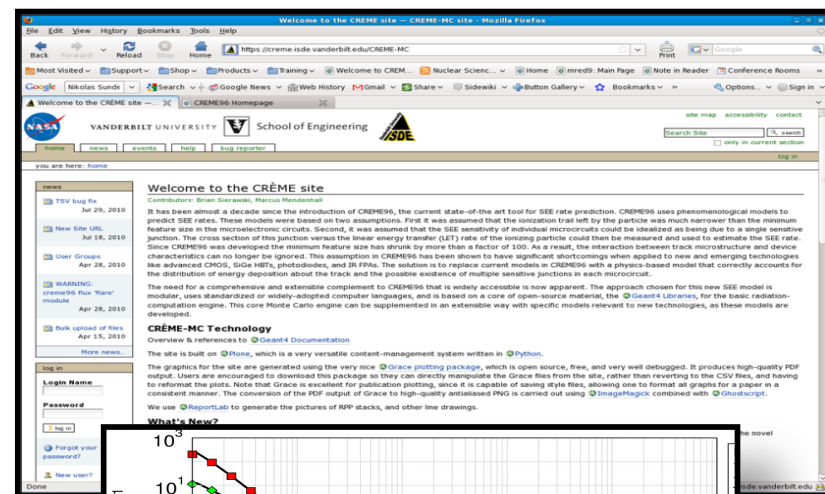
- Moderated forum
 - Q & A
 - Parts application advice
 - Common practices
 - Experience sharing
- User feedback on improvements to PMPedia™ content and usability

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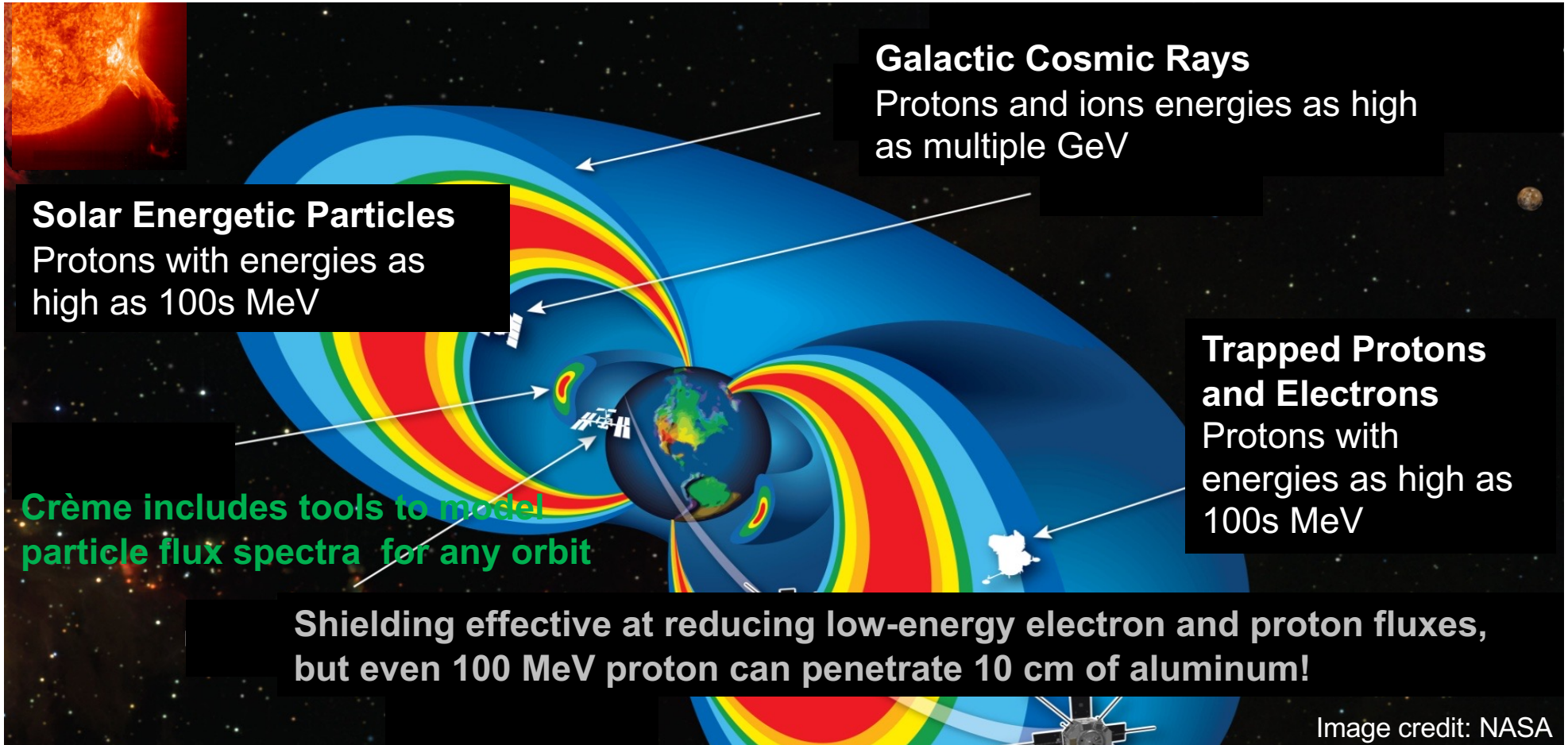
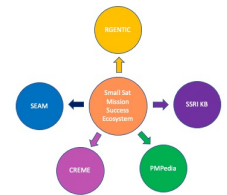
CRÈME Website



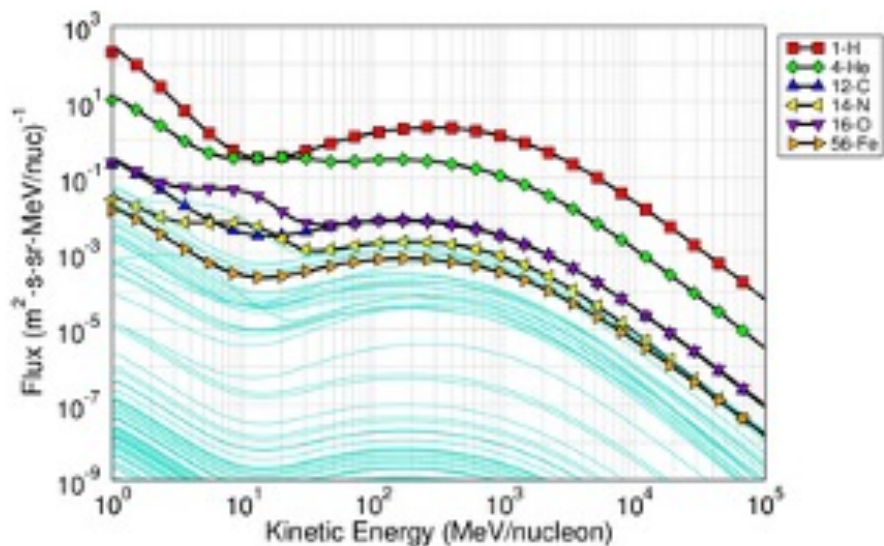
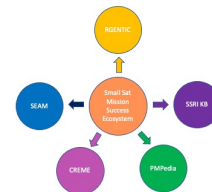
- **Single event effects** are unwanted or erroneous responses in a semiconductor device, triggered by the passage of a high energy particle
- Vanderbilt ISDE hosts the CRÈME tool suite for predicting **on-orbit error rates** and proton total ionizing dose in microelectronics
- Publicly available at <https://creme.isde.vanderbilt.edu>



CRÈME Radiation Environments



CRÈME Radiation Environments



Particle flux vs. energy
for different ion types
from CRÈME

- Near-earth rad environment modulated by magnetosphere
- Many ions are deflected
- Protons and electrons particles trapped in radiation belts
- Transport software shows how energetic particles interact with spacecraft materials
 - Low energy particles stopped
 - High energy particles slowed
- Information for single-event error rate prediction

Summary: Small Sat Mission Success Online Ecosystem

