Radiation Hardness Assurance (RHA) Guideline

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National Aeronautics and Space Administration

RHA Definition and Consideration

RHA consists of all activities undertaken to ensure that the electronics and materials of a space system perform to their *design* specifications after exposure to the mission space environment.

The subset of interests for NEPP and the REAG, are EEE parts. It is important to register that all of these undertakings are in a feedback loop and require constant iteration and updating throughout the mission life. More detail can be found in the reference materials on applicable test data for usage on parts.

Reference Materials

Heavily Relied Upon Documentation for RHA

- **NASA Documents**
  Guidelines and Lessons Learned found on radhome
- **Military Performance Specifications**
  19500, 38510, 38534, 38535
- **Military Handbooks**
  814,815,816,817,339
- **Military Test Methods**
  MIL-STD-750, MIL-STD-883
- **DTRA Documents**
  DNA-H-93-52, DNA-H-95-61, DNA-H-93-140
- **ASTM Standards By Subcommittee**
  F1.11, E10.07, E13.09
- **EIA/JEDEC Test Methods and Guides**
  JESD57, JESD89, JEP133, FOTP-64
- **ESA Test Methods and Guides**
  ESA/SCC No. 22900 and 25100, ESA PSS-01-609

Often Utilized Tools

- **Radiation Databases**
  GSFC radhome, JPL radcentral, ESA escies
- **Environment Modeling**
  SPENVIS, CRÈME, OMERE, NOVICE
- **Radiation effects in devices/materials**
  CRÈME, MRED, GEANT, SRIM, MULASSIS

Drivers for a new approach and Future Considerations

Varied Missions – National Assets to CubeSats

- Risk Tolerant vs. Risk Avoidance
- Low budget, shortened schedule
- Short mission duration
- High data rates
- On board processing
- Multi-instrument dependent datasets
- Data continuity from one satellite to the next

Emerging Technologies and COTS parts usage increasing

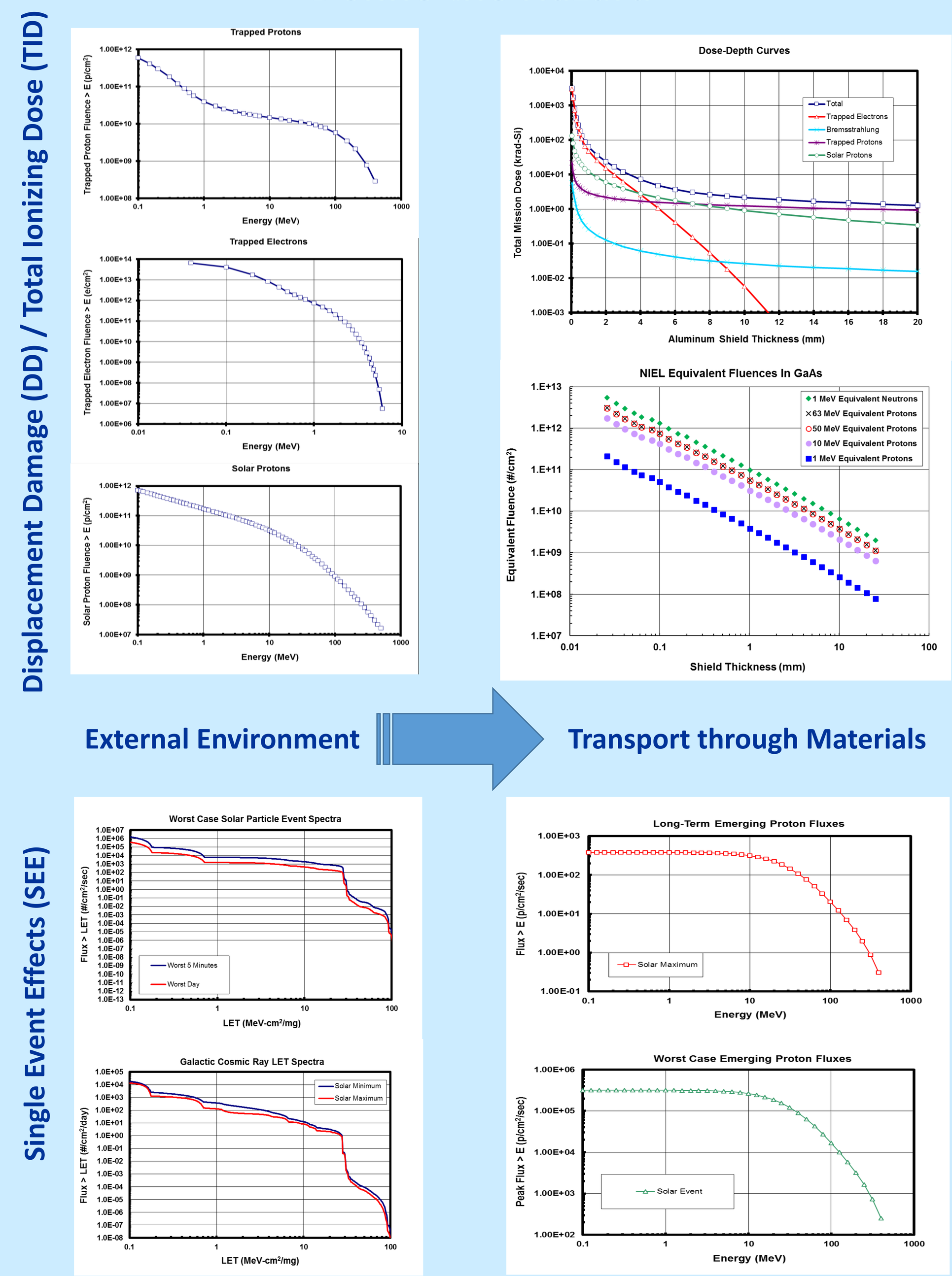
- System on a chip solutions, COTS parts are meeting complex needs
- Highly coveted performance
- 3D structures
- Complex radiation response
- Experimentation cannot cover state space

Acronyms

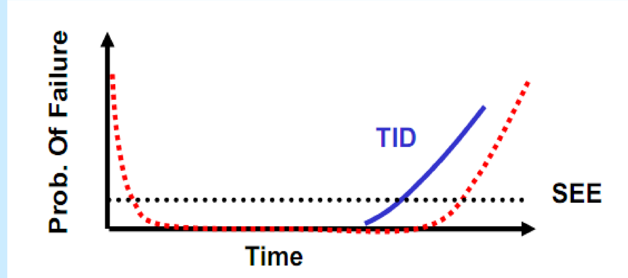
3D	Three Dimensional
ASTM	American Society for Testing and Materials
CDR	Critical Design Review
COTS	Commercial-Off-The-Shelf
CREME	Cosmic Ray Effects on Micro-Electronics
DD	Displacement Damage
DTRA	Defense Threat Reduction Agency
EEE	Electrical, Electronic and Electromechanical
EIA	Electronic Industries Alliance
ELDRS	Enhanced Low Dose Rate Sensitive
ESA	European Space Agency
ETW	Electronics and Technology Workshop
FETs	Field Effect Transistor
GSFC	Goddard Space Flight Center
JEDEC	Joint Electron Device Engineering Council
JPL	Jet Propulsion Laboratory
LET	Linear Energy Transfer
MOSFETs	Metal Oxide Semiconductor Field Effect Transistor
NASA	National Aeronautics and Space Administration
NEPP	NASAS Electronics Parts and Packaging
PDR	Preliminary Design Review
REAG	Radiation Effects and Analysis Group
RHA	Radiation Hardness Assurance
RLAT	Radiation Lot Acceptance Testing
SCC	Space Components Coordination Group
SEB	Single Event Burnout
SEE	Single Event Effects
SEFI	Single Event Functional Interrupt
SEGR	Single Event Gate Rupture
SEL	Single Event Latchup
SER	Single Event Rate
SET	Single Event Transient
SEU	Single Event Upset
TID	Total Ionizing Dose

Hazard Analysis

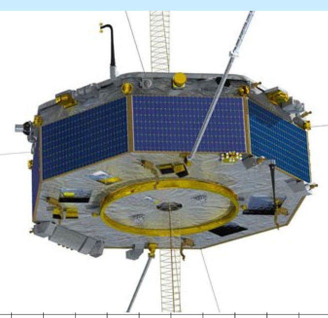
Define the Hazard



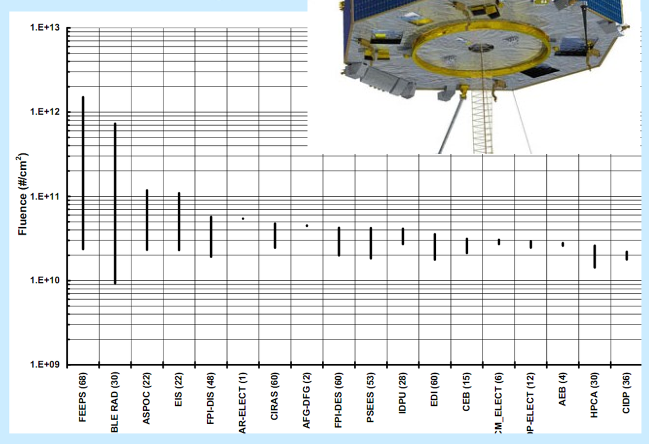
Evaluate the Hazard



Probability of TID failures increase over mission life, SEE probability is uniform



3D Ray Trace can give localized dose through spacecraft shielding

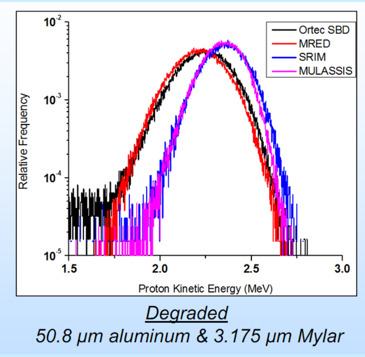


Depending on hazard and requirement assessments, parts testing may be necessary.

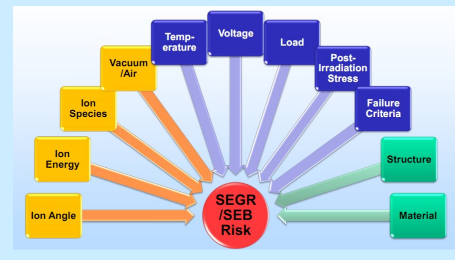
Applicable Parts Data
(*The good stuff is hard to find*)

Know the test facility

Know your facility through dosimetry in order to understand results, choose the right facility based on the physics of failure.
Protons: soft parts with low LET upsets / displacement damage / small sensitive areas
Electrons: charging / electron rich environments
Heavy Ions: sufficient range? Appropriate flux?
Gamma Rays / X-rays: TID / appropriate dose rate?



Degraded proton beam energies



Parameters going into a SEE test on power MOSFETs

Know your parts

What failure mechanisms are dominant? How do you interrogate the part with the flight application in mind? What are the corner cases?

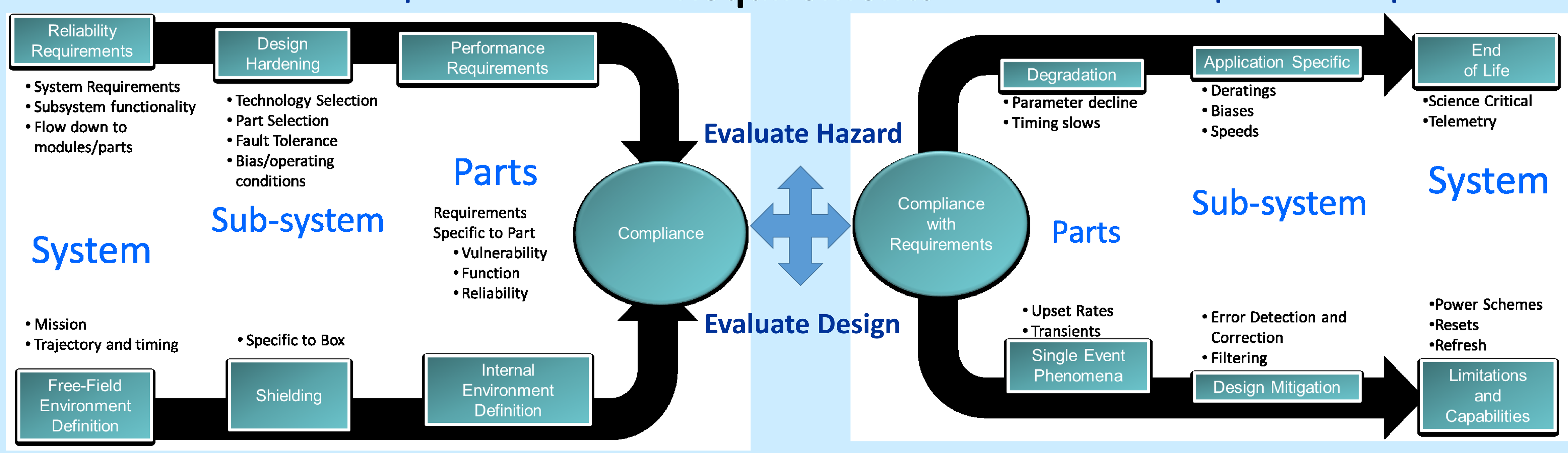
Comprehend the results

Know when and how to apply the results from an applicable radiation test. Utilize the information from the hazard analysis to evaluate the hazard from the part level up to the system.

Requirements

Define the Radiation Requirements

Evaluate the Operational Requirements



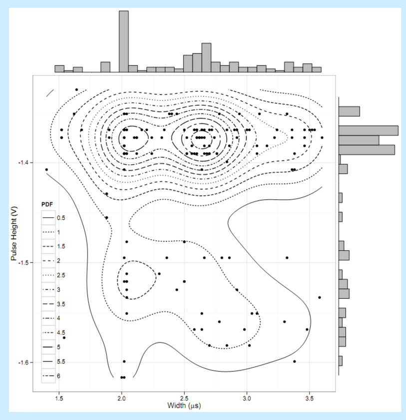
Requirements need to be written and incorporated into mission documents such that they are able to flow down from mission level to subsystem and then to the parts selection. These requirements are determined from the hazard definition and evaluation.

The requirements need to be understood in the context of mission success and then updated and applied such that meeting those requirements provides assurance to a working system in the intended environment. This is iterated throughout mission design lifecycle to build a set of requirements that are useful, driving cost and schedule.

Parts' Response

SEL/ SEGR/ SEB: Parts that are susceptible to these types of failures are strongly suggested for test, a waiver would have to depend on redundancy that would allow for failures during the mission lifetime. For FETs there is a need to verify application gate voltage. Testing is required if application gate voltage is below -5V. If above this, a waiver may be able to justify the parts usage.
SEU: In all cases, verifying that the EDAC used on the instrument can handle the rate, or verification that the Single Event Rate (SER) will not affect the mission, will remove risk of the system level.
SET: All listed parts suggested for test will exhibit SET of some magnitude. Risk to the circuit from SET can be resolved by analyzing the affect of the worst case SET on the circuit for each instance of the part. Filtering and/or circuit design that follows can be used to warrant the effect of the transient as negligible.
SEFI: In all cases, verifying that the EDAC used on the instrument can handle the rate, or verification that the Single Event Rate (SER) will not affect the mission, will remove risk of the system level.
TID/ELDRS: Parts are very susceptible to gain degradation, especially when operated at low current, so verification that the gain requirements of the circuit can be met by the worst case data. ELDRS robustness is determined by an RLAT from the manufacturer. These data must to provided for verification of lot hardness to fully approve the part. Alternatively, an LDR RLAT can be performed on these devices. In other words a waiver could use the worst case data if it exists to approve the parts.
DD: Parts are very susceptible to gain degradation, especially when operated at low current, so verification that the gain requirements of the circuit can be met by the worst case data. Robustness is determined by an RLAT from the manufacturer. These data must to provided for verification of lot hardness to fully approve the part. Alternatively, an RLAT displacement damage test can be performed on these devices. In other words a waiver could use the worst case data if it exists to approve the parts.

Design Mitigation

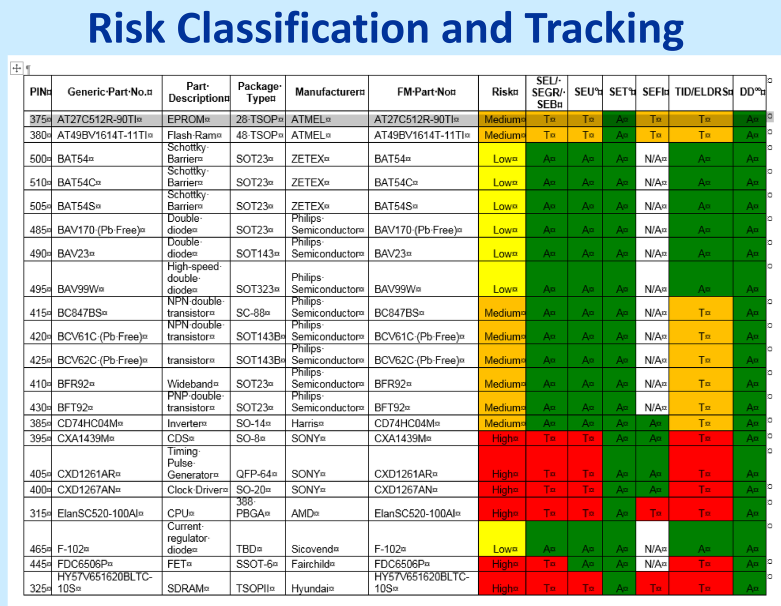


Transients shown with statistics can help designers what to expect and mitigate

- Filter Transients on Analog outputs
- Derate power devices to be used in a safe operating area
- Spot shielding of devices to bring down local TID
- Refresh / reset rates of parts
- Current Limiting
- Supply Balancing
- Triplication or complex logic architecture tailoring

Evaluate the Design

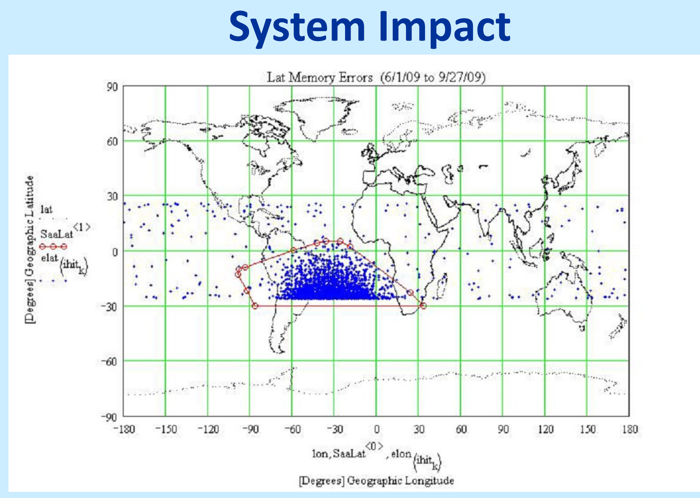
Risk Classification and Tracking



Risks Called out by part and available data

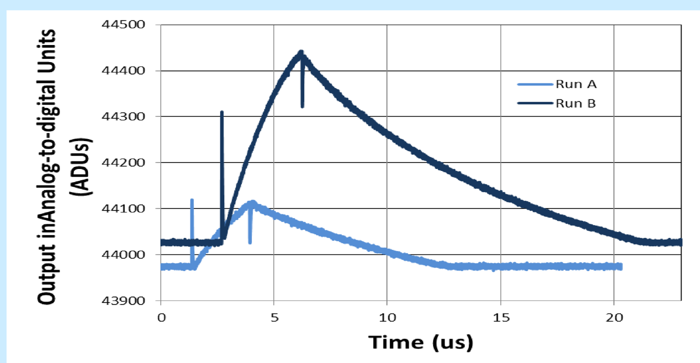
Documentation of the risks and available data on the part are kept with the official parts identification lists, the as designed lists, and finally the as built lists to incorporate changes in the design as it matures. Risk classification helps with trade studies on whether or not the system requirements are being met and where testing can buy down risk to the project.

System Impact



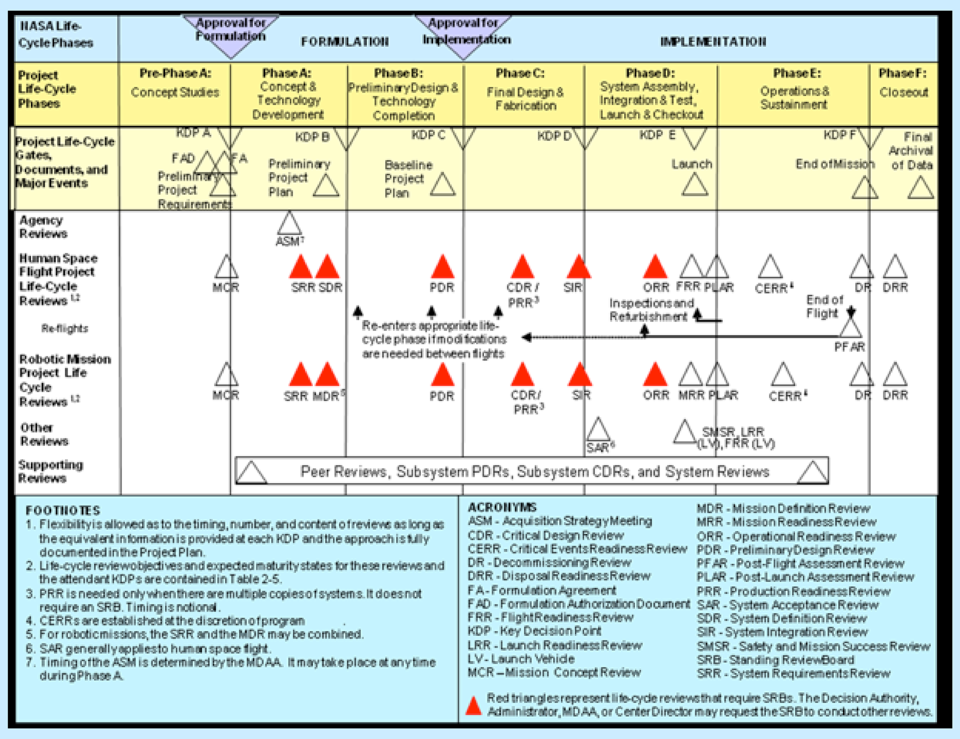
Proton upsets in the South Atlantic Anomaly

Capturing the system impact of radiation device responses is tied into the verification of requirements and system performance. If only looked at from the piece part level these types of effects could impact availability, critical functions, or mission success.



Extended response of device upsets when run through system configuration

Mission Timeline and Deliverables



NASA 7120.5

- **During the Proposal/Feasibility Phase**
  - Draft Environment definition
  - Draft Hardness assurance requirement
  - Preliminary studies
- **At the Preliminary Design Review (PDR)**
  - Final Environment definition
  - Electronic design approach
  - Preliminary spacecraft layout for shielding analysis
  - Preliminary shielding analysis
  - Final Hardness assurance requirement definition
- **At the Critical Design Review (CDR)**
  - Radiation test results
  - Final shielding analysis
  - Circuit design analysis results
- **After CDR**
  - Remaining Radiation Lot Acceptance tests
  - Approved As Built Parts Lists
- **After Launch**
  - Failure Analysis
  - Anomaly Root Cause

Acknowledgements

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FLIGHT DATA SYSTEMS & RADIATION EFFECTS
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