

INCLUSION OF RADIATION ENVIRONMENT VARIABILITY IN TOTAL DOSE HARDNESS ASSURANCE METHODOLOGY

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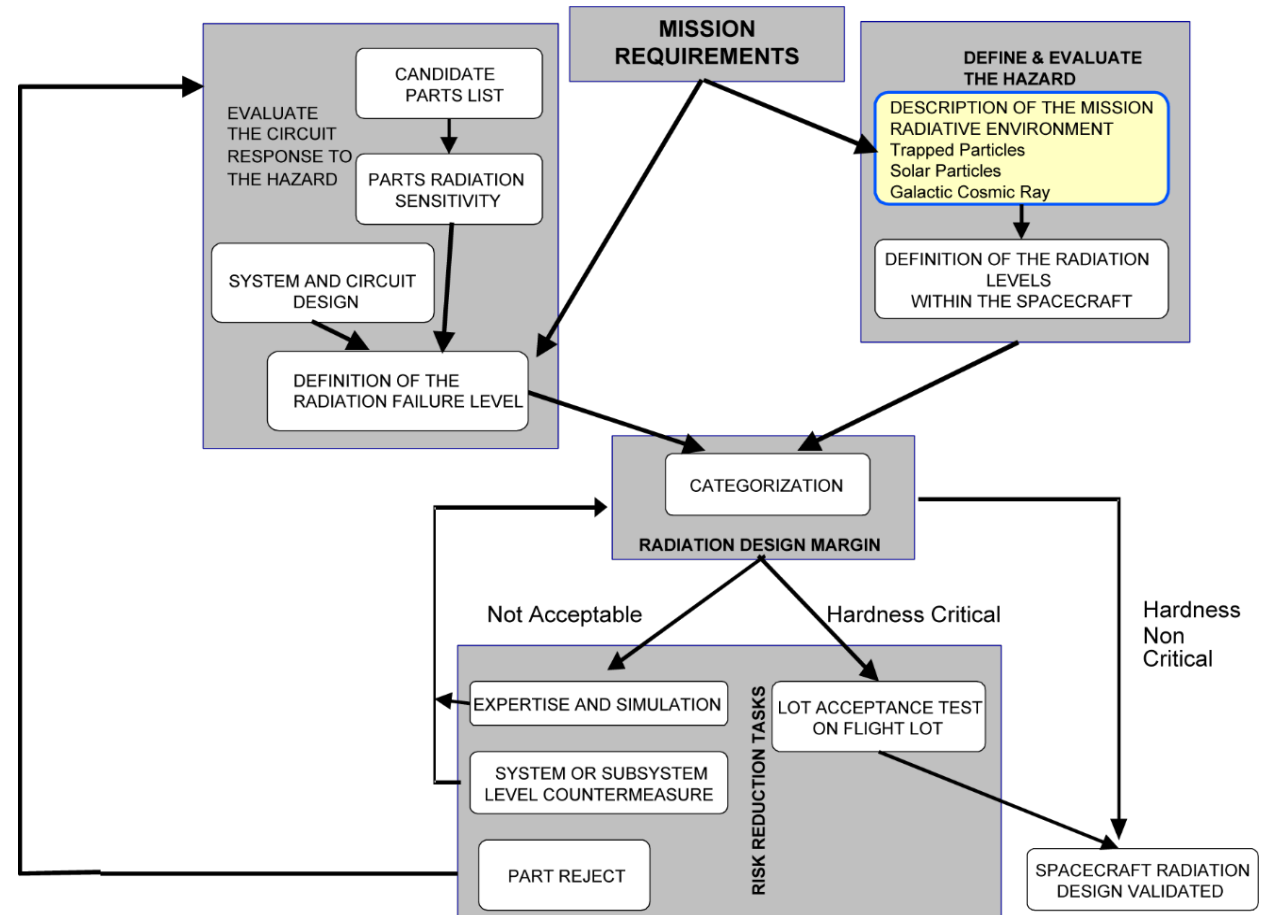
Supported by the NASA Living With a Star Space Environment Testbed Program

Outline

- **Background**
- **Device Failure Distributions**
- **Total Dose Distributions in Space**
- **Device Failure Probability during a Mission**
- **Conclusions**
 - **Failure Probability (FP) vs. Radiation Design Margin (RDM)**

Radiation Hardness Assurance Overview

- **Starting with mission requirements, radiation hardness assurance methodology consists of 2 branches of analyses feeding into parts categorization**
 - **Define total dose failure level of part from lot(s) of devices and analysis of circuit and system**
 - **Determine total dose level of space environment within spacecraft**



Radiation Hardness Assurance Overview

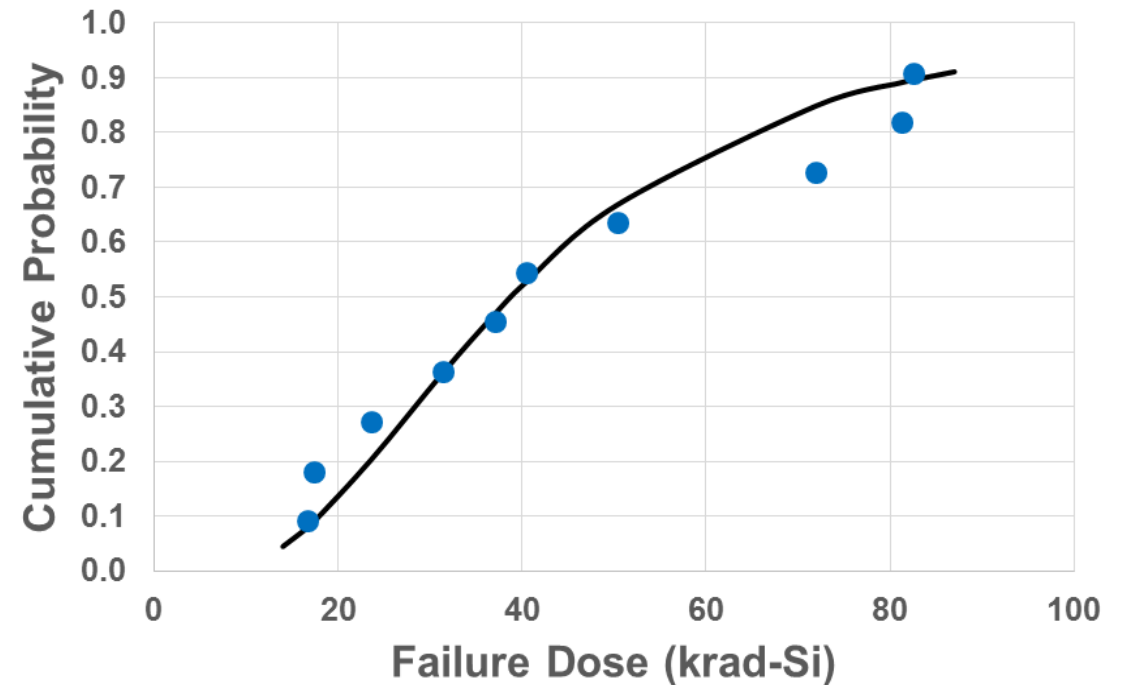
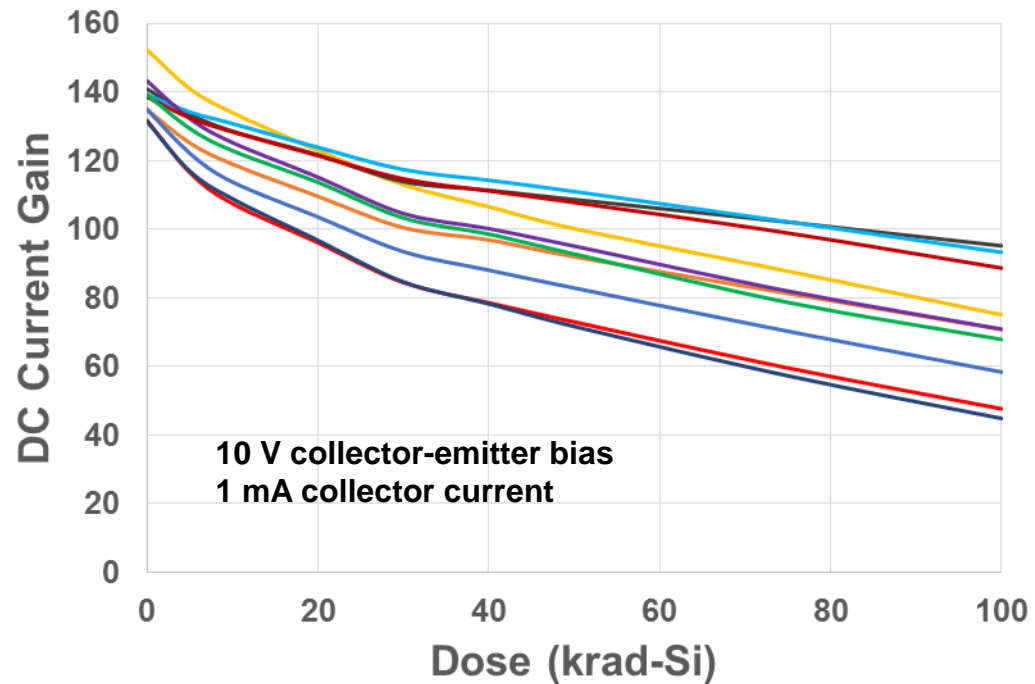
- **Flight lot Parts are then categorized for acceptability by Radiation Design Margin (RDM).**
- **$RDM = R_{mf} / R_{spec}$**
- **R_{mf} is mean failure level of part**
 - Part failure levels can vary substantially from the mean
 - Choice of failure level can be arbitrary
- **R_{spec} is total dose level of space environment**
 - Environment is dynamic and must be predicted years in advance
 - Some environment models are deterministic; some are probabilistic
 - Choice is arbitrary
- **RDM used as a “catch-all” to cover all uncertainties and lack of consistency of environmental models used**
- **Propose modified approach**
 - Use probabilistic environment models to evaluate device failure probability during a space mission rather than using RDM

Devices Tested

- **Solid State Devices, Inc. SFT2907A bipolar transistors**
- **Used for high speed, low power applications**
- **10 devices tested for Magnetospheric MultiScale (MMS) project at NASA Goddard Space Flight Center gamma ray facility to 100 krad(Si) with all leads grounded**
- **Amptek, Inc. HV801 optocouplers rated for 8kV operation of detection photodiode**
- **GaAlAs parts manufactured in liquid phase epitaxially grown process**
- **6 parts irradiated with 50 MeV protons at University of California, Davis cyclotron facility**

Device Failure Distribution

SFT2907A Bipolar Transistors

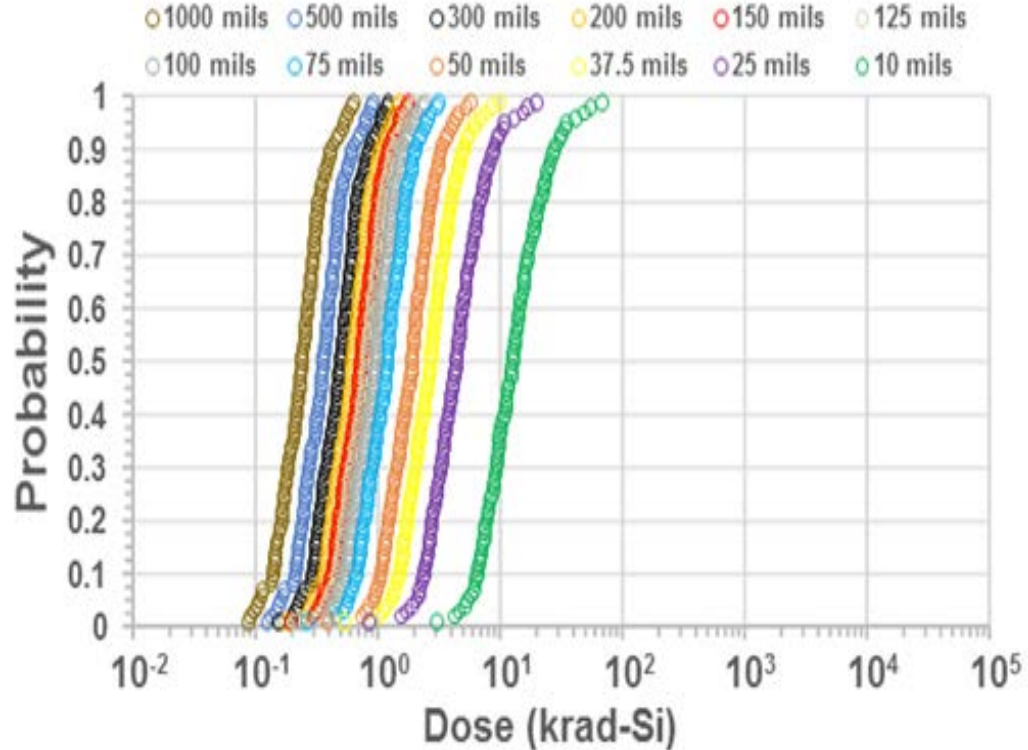


Space Radiation Environment Calculations

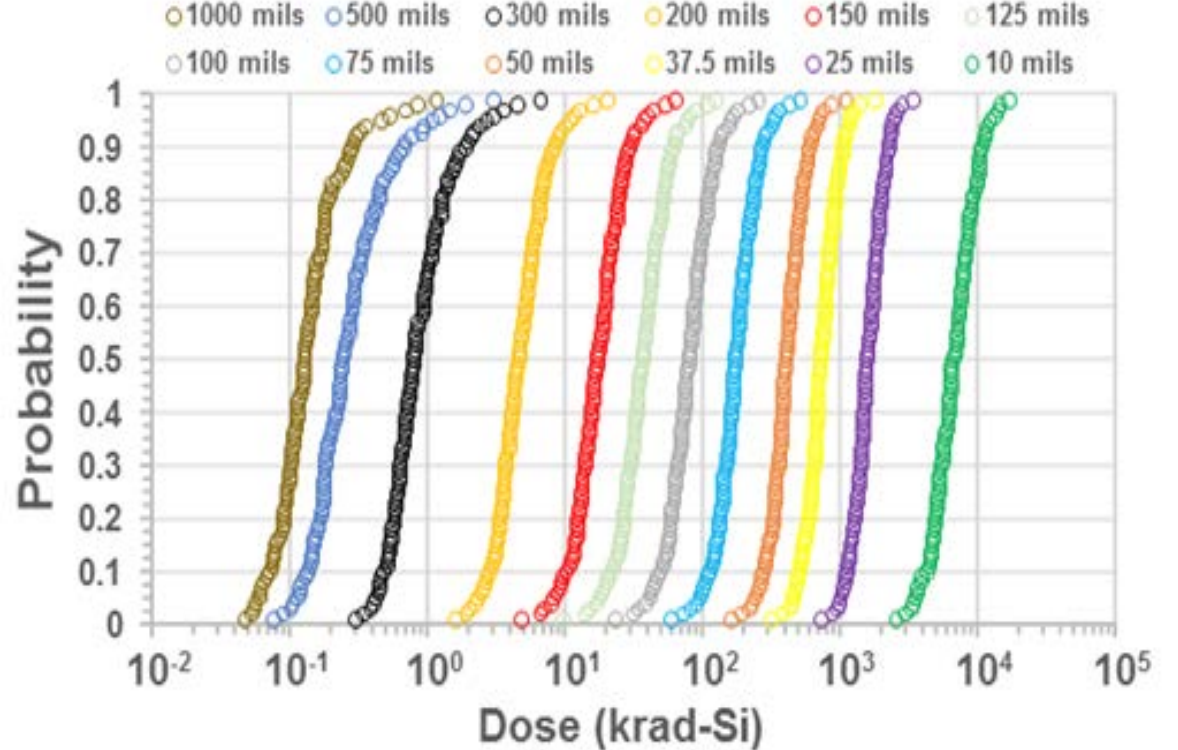
- **Total Ionizing Dose (TID) and Displacement Damage Dose (DDD) probability distributions were calculated for each orbit and mission duration**
 - **Aerospace Proton-9/Aerospace Electron-9 (AP9/AE9) Monte Carlo code used to simulate 99 histories for each mission**
 - **Emission of Solar Protons (ESP) model calculations done for confidence levels ranging from 1 to 99%**
 - **Trapped proton, trapped electron and solar proton energy spectra were transported through shielding levels from 10 to 1000 mils Al using Numerical Optimizations, Visualizations, and Integrations on Computer Aided Design (CAD)/Constructive Solid Geometry (CSG) Edifices (NOVICE) and converted to doses**
 - **Doses for each radiation were separately ranked for confidence levels ranging from 1 to 99% and summed for same confidence and shielding levels**

TID Probability Distributions for 1 Year 10 – 1000 mils Aluminum

Low Inclination Low Earth Orbit (LEO)



Geostationary Earth Orbit (GEO)

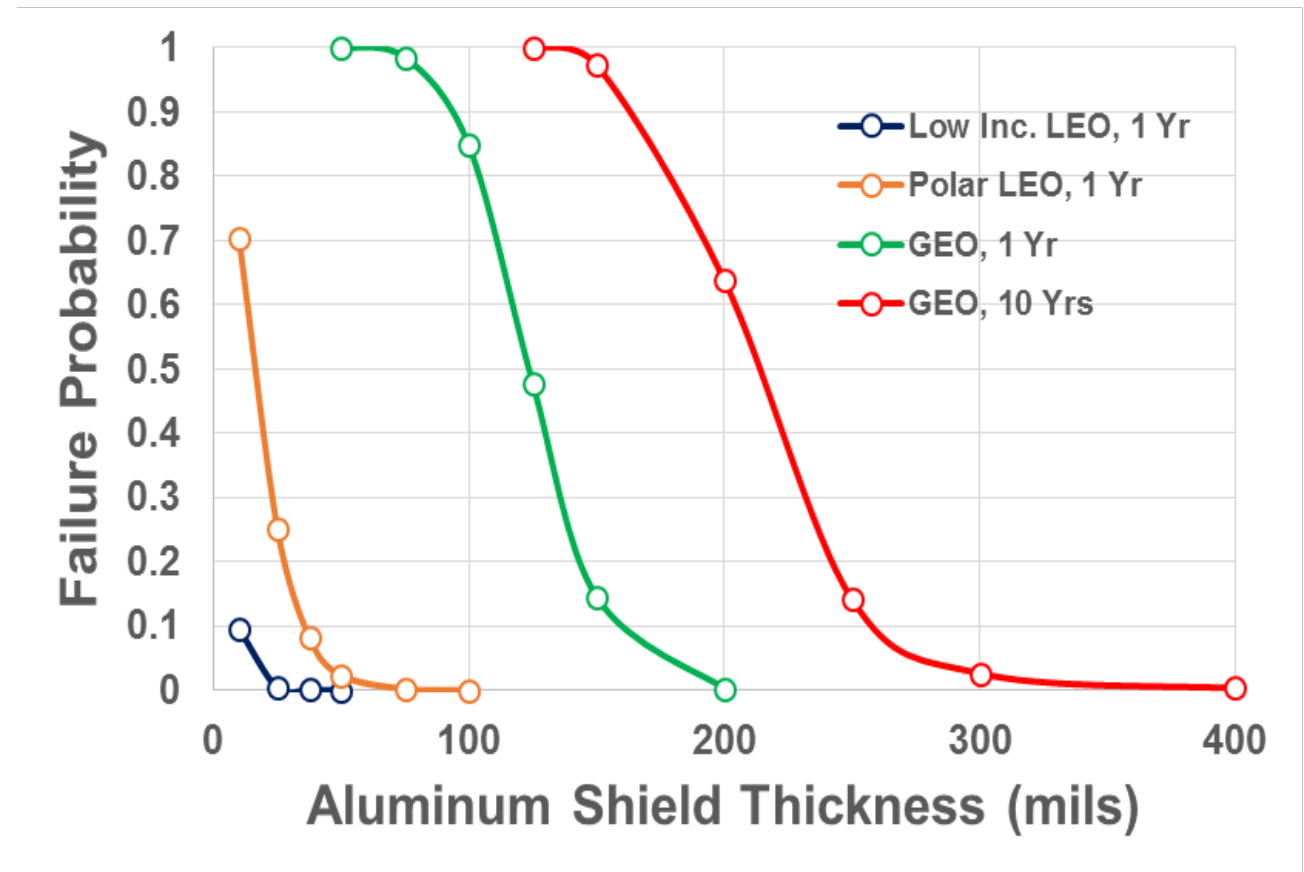


Failure Probabilities SFT2907A Bipolar Transistor

$$FP = \int [1 - H(x)] \cdot g(x) dx$$

$H(x)$ = Cumulative Distribution Function (CDF) for environment dose
 $g(x)$ = Probability Density Function (PDF) for device failure

Failure probability (FP) is the probability of a total dose failure for a device randomly selected from flight lot(s) characterized by $g(x)$ in space environment characterized by $H(x)$, where x is dose.



Conclusions

- **An approach to radiation hardness assurance was developed that includes variability of the space radiation environment.**
- **Examples showed this is at least as significant as device failure distributions measured in the laboratory, suggesting this is a more thorough and complete approach.**
- **Improvements are two-fold:**
 - **More consistent evaluation of the radiation environment using confidence levels across all radiations**
 - **Advantages of using FP instead of RDM are:**
 - **Objectively determined parameter by virtue of using complete probability distributions**
 - **Better characterization of device radiation performance**
 - **Allows direct comparison of the total dose threats for different devices, regardless of whether they degrade due to TID or DDD**
 - **More amenable to circuit, system and spacecraft reliability analysis**

Acronyms

- **AE9 – Aerospace electron model-9**
- **AP9 – Aerospace proton model-9**
- **CDF – cumulative distribution function**
- **DDD – displacement damage dose**
- **ESP – emission of solar protons (model)**
- **FP – failure probability**
- **GEO – geostationary Earth orbit**
- **HST – Hubble Space Telescope**
- **LEO – low Earth orbit**
- **MMS – Magnetospheric MultiScale**
- **NOVICE – Numerical Optimizations, Visualizations and Integrations on Computer Aided Design (CAD)/Constructive Solid Geometry (CSG) Edifices**
- **PDF – probability density function**
- **RDM – radiation design margin**
- **TID – total ionizing dose**