NASA Perspective on Radiation Hardness Assurance (RHA) for Hybrid Devices†

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Outline

- Introduction/Problem Statement
- RHA Issues
- Hybrid RHA at NASA
- Test Issues
- Data Analysis Issues
- COTS
- Summary
Problem Statement

- To understand the radiation hardness level of a hybrid device that typically consists of many technologies, detailed testing and analysis is required.
- The current budgetary conditions of most NASA flight projects is in direct conflict with these requirements.
Sample RHA Issues

- Cost and Procurement Lead Time
- Traceability
- Everything can possibly go wrong
  - CMOS low dose rate, ELDRS, Displacement Damage, SEL, SEB, SEGR, SEU, SET, SEFI, etc.
- Worst Case vs. Application Specific
Hybrid RHA at NASA

- Working with the Vendor
  - Information
  - Cooperative investigations
  - Design modifications
- Testing
- Analysis
  - Piece-part Analysis
  - Test Data Analysis
  - System Level Impact Analysis
Cooperative Investigation with Micropac

Current Transfer Ratio vs. Dose (krad(Si))

- 1 mA
- 2 mA
- 5 mA
- 10 mA
Cooperative Investigation with Micropac

LED Degradation

Photodiode Leakage Increase

Transistor Gain Degradation

Relative CTR

Modeled Response

Test Data

Dose (krad(Si))
**Space Station (ISS) DC/DC Converters**

- High Voltage DC/DC converters from Modular Devices, Inc. (MDI) were tested to examine the possibility of their use on ISS. A mixture of devices with 120 volt inputs and single or dual 5, 12, or 15 volt outputs were used.
- Initial testing showed a low LET threshold for destructive burnout of the power MOSFET (see photo below).
- MDI cooperated in this effort by replacing the “very good” power MOSFET used in the original design with a RADHARD equivalent.
- Follow-on tests of these new devices showed a higher LET threshold for failure but not considered RADHARD.
- Could indicate a circuit-induced failure mode that is not solved by RADHARD part selection.
### Space Station DC/DC Converter Results Summary

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Volts</th>
<th>Load</th>
<th>LET</th>
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<td>50%</td>
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<td>Pass/Fail</td>
</tr>
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<td></td>
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<tr>
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<td>75%</td>
<td>60</td>
<td>Pass/Fail</td>
</tr>
</tbody>
</table>

**Parts with RadHard MOSFET**
Testing Issues

• Cost and Procurement Lead Time
  – Extremely Small Sample Size
  – Can lead to “late in the game” testing
• Everything can possibly go wrong
  – With the small sample size, testing has to be prioritized/combined
• Worst Case vs. Application Specific
  – With small sample size, testing is generally done application specific
  – Multiple applications within a project may force more generic testing
    • Can worst case conditions really be determined
    • Test parameter space can be extremely large for generic testing
• High Voltages and Currents
  – Care in testing due to destructive events and constrained sample size
  – Cooling of test structures often required which can be problematic when working in a vacuum
• Multiple devices exposed simultaneously
  – Don’t know which device may be the problem
  – May have some multiple event interactions
• Packaging can restrict device access
Data Analysis Issues

- Piece-part Analysis
  - If complete parts list and radiation data available, can treat as any other system analysis
  - Main issues are:
    - Rarely are both items available
    - The “system” designer is usually not available

- Test Data Analysis
  - Must go from test data to in-flight predictions
    - Multiple data sets
    - Multiple space environments

- System Level Impact Analysis
  - In-flight predictions for hybrid are then analyzed for system-level impact, mitigation options and risk assessment
  - Trades between mitigation, risk assessment and risk acceptance are at the system and project manager levels
Optocoupler Flight Predictions

A. Compute equivalent proton fluence ($\phi_{EQ}$)

B. Measure proton-induced CTR degradation on “Flight–Like” devices
   $\phi_{TEST} \leq 10 \phi_{EQ}$

C. Estimate degradation due to proton environment $R(\text{proton})$

D. Estimate mission total ionizing dose ($\text{TID}_{EST}$)

E. Measure gamma-induced CTR degradation on “Flight–Like” devices

F. Estimate degradation due to TID $R(\text{TID})$

G. $\text{CTR}_{PRED} = \text{CTR}_{INITIAL} R(\text{proton}) R(\text{TID})$

*Taken from Reed, et al., “Guideline for Optocoupler Ground Radiation Testing and Optocoupler Usage in the Space Radiation Environment”*
Commercial-Off-The-Shelf (COTS) Issues

- COTS Hybrids
  - Traceability is the real issue
  - Part-to-part variability can be significant
    - COTS parts are used
    - Various vendor parts may be used in same location
    - In general, no such thing as lot control
- COTS Printed Circuit Boards as “Hybrids”
  - COTS PCB can be treated as a hybrid on a larger scale
  - All the same issues apply as noted above
  - Often the PCB is integral to larger system and the observed effects can only be seen at that level
  - Heavy ion testing is often impossible
Summary

- There are numerous issues when dealing with hybrid devices
- NASA takes a system-level-down approach to RHA
- It cannot be overstated how critical radiation testing, how the devices are tested, to good RHA
- NASA also works to make the vendor an integral part of the RHA process, as much as the vendor is willing to participate
- Test data analysis to flight risk assessments can be a very complex business, especially when dealing with many applications within a flight project
- COTS is COTS