Commercial Off The Shelf (COTS):
Radiation Effects Considerations and Approaches

Kenneth A. LaBel
NASA Electronic Parts and Packaging (NEPP) Program, co-Manager
NASA/GSFC
ken.label@nasa.gov

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Abstract

- This talk is focused on discussing some of the topics related to the use of COTS electronics in space radiation environments at a VERY top level.

- Disclaimers:
  - This is NOT intended to be either a recommendation nor attack on the use of COTS;
  - It is intended to provide discussion points based solely on technical merit.

- For this talk, COTS refers to any electronic device that does not have guaranteed radiation tolerant or hardened performance.
Notional View of Electronics Usage by Space Sector

Military tends to use less COTS than NASA who use less than Commercial Space.

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Does NASA Use COTS?

• Yes, and has since the early days of electronics
  – Use of higher electrically performing devices is common

• Note: NASA has a wide variety of mission profiles
  – Different orbits and lifetimes
    = Equally wide set of radiation exposure requirements
  – What works for a 2 week shuttle style orbit may not work for a Jovian moon mission
  – Conversely, what works for a Jovian moon mission may not be appropriate for a 2 week shuttle style orbit (the word “overkill” comes to mind)

• What we do recommend
  – Understand your risk
  – Understand your real needs
General COTS Approaches

- Approaches for using COTS
  - Do nothing (use as is)
  - “Upscreen” – testing to measure, not improve, reliability/tolerance
    - Piecepart or device level testing
    - Board level testing
  - Utilize fault tolerant architectures
    - Many differing options from redundancy to voting to error correction to ???

- The biggest concern is “unknowns”
  - If we don’t know how a device reacts to radiation (soft faults, hard faults, degradation,…), how can we determine adequacy of fault tolerant approaches?
Rationale For Use on Both Sides

• Devices that are radiation hardened (RH)
  – Usually controlled process (even minor process changes are known) with known radiation characteristics
    • Limits issues with variance
  – Simplifies system design (less mitigation for radiation)
  – Lower additional testing costs

• COTS
  – Generations better electrical performance (operating speeds, memory density,…)
  – More function packed into single package
  – More readily available and lower priced device purchase

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Electronics and Radiation Tolerance

- Radiation hardened devices typically are a mix of process and design to improve radiation tolerance versus inherent technology characteristics

  - COTS relies on inherent technology capability and user-added mitigation approaches

- Trade space example:

  - Using 10 radiation hardened memories versus 1 COTS + added mitigation
    - System complexity, power, weight, reliability, risk…

- Disclaimer: radiation data, by itself, may not be sufficient.

  - Understanding how to apply it in actual application (size of a transient propagating, for example) should be considered.
Sample Radiation Degradation and COTS

• Long-term issues (total dose and displacement damage)
  – Power consumption (leakage) increases
  – Speed reduction (skew)
  – Variability (part-to-part)

• Single particle issues
  – Soft errors
    • Detection, correction, acceptance of bit errors, transient signals
    • Operational (Functional Interrupt)
  – Hard errors
    • Hard failures (sometimes can circumvent, but may impact device lifetime)
Sample Concern: COTS with a Fault Tolerant Architecture

- Consider a triple voting scheme (three copies of a device being voted for majority)
  - Usual operation when a single particle fault occurs might be to resynchronize to a known state
- Now let’s say that 2 years has passed in a radiation exposure
  - Total dose degradation of the 3 device copies might show \textit{variance} (i.e., unequal degradation from sample to sample)
  - Now if the single particle fault occurs, the system may or may not resynchronize properly (hiccups from differing timing on each device)
- If the variance was known prior to flight build, it could be taken into account in the system design
Summary

• COTS can be used safely, but understanding of the risks is required
  – Acceptance of risk is a separate topic
• Radiation effects, like reliability, engenders probability and statistics (along with particle physics and circuit/process design)
  – Why margins and bounding are usually part of the radiation assurance process
• Unknowns are exactly that, unknown
  – Many examples exist where failures have occurred unexpectedly either during ground radiation tests or in space
  – Of course, many COTS devices have been safely used as well!

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