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

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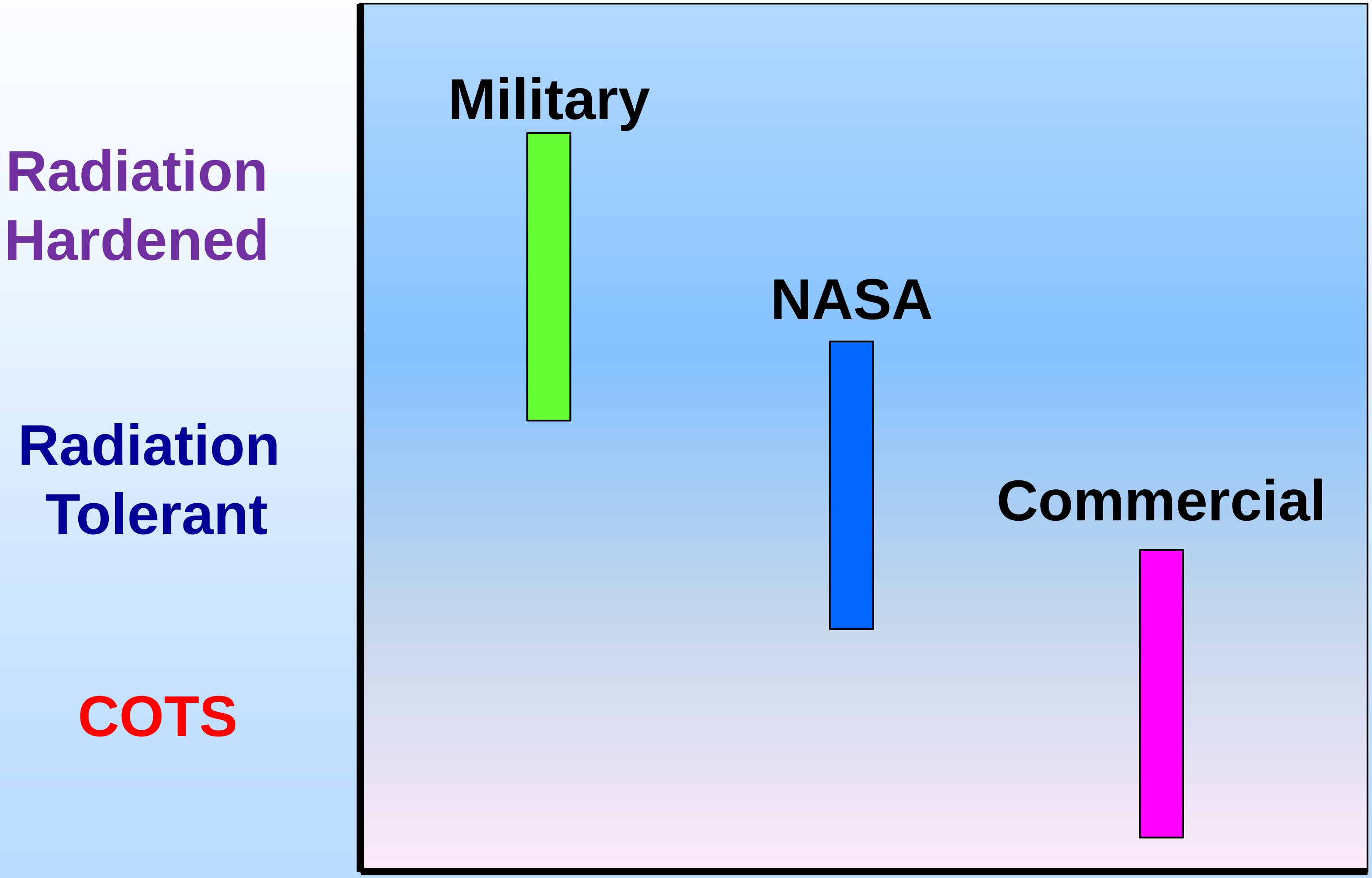
Abstract

- **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

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

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 *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 know 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!**