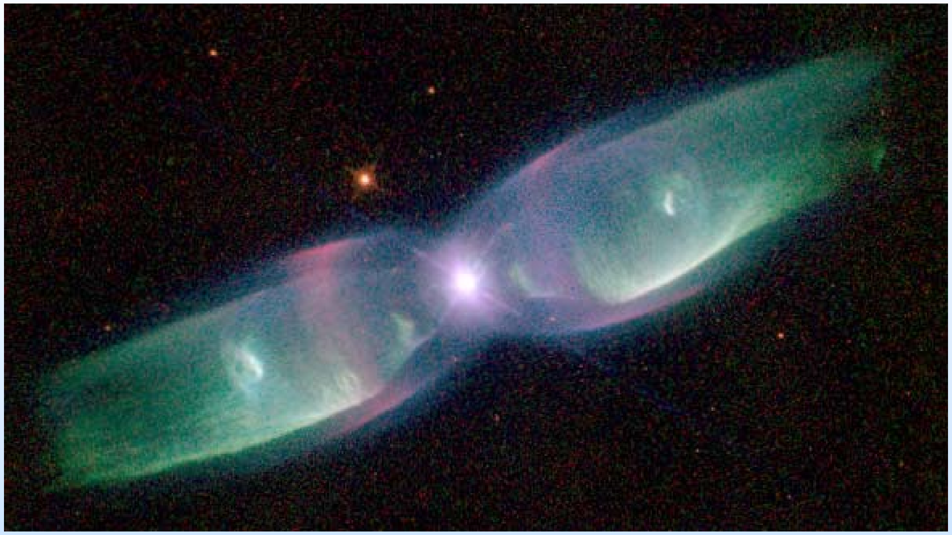
# A NASA Perspective on Validation and Testing of Design Hardening for the Natural Space Radiation Environment



Hubble Space Telescope has utilized a robust system design to conquer radiation challenges

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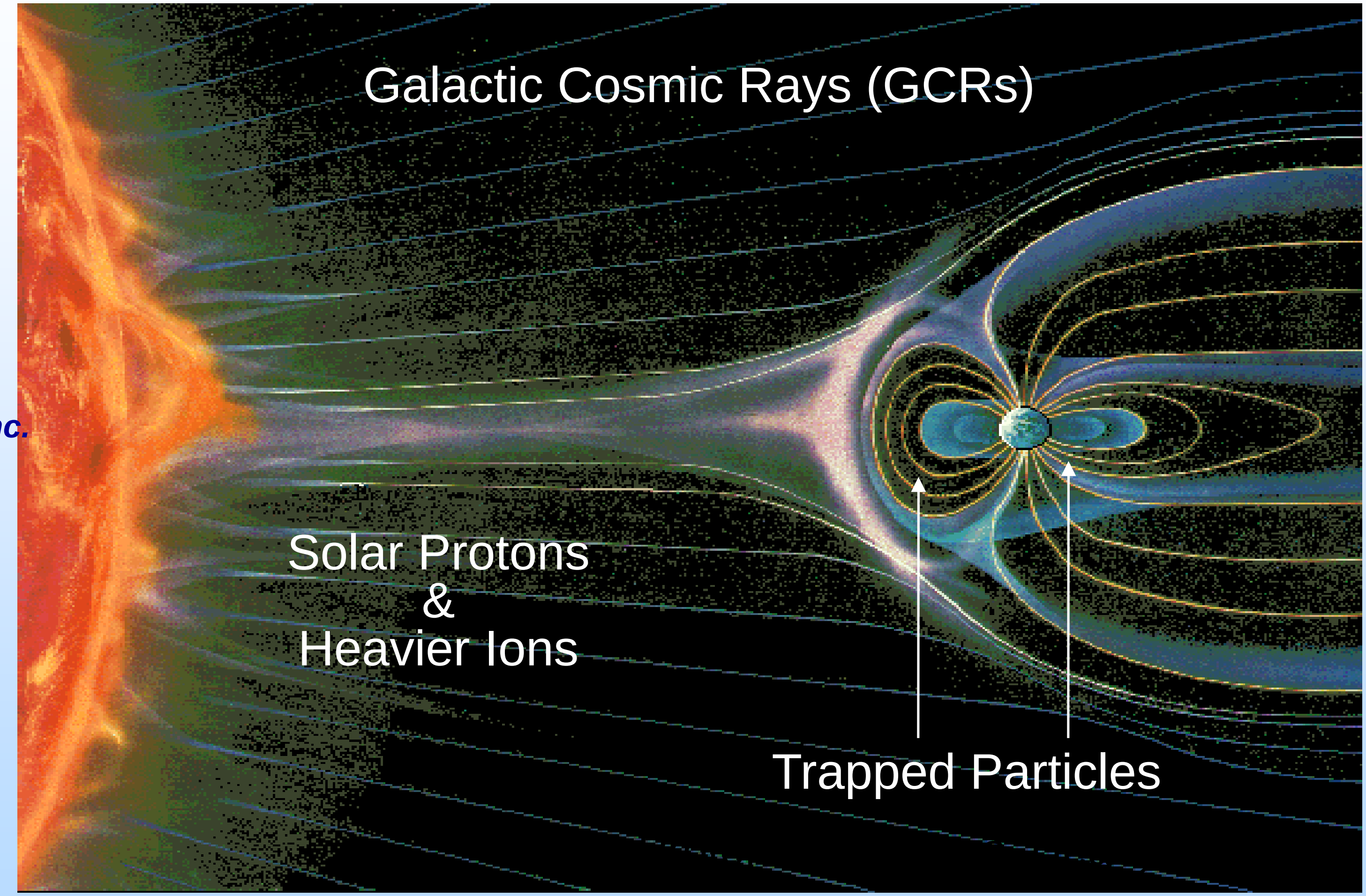
# Outline

- **NASA Requirements for Radiation Hardness**
  - **What NASA needs and what environment/effects we care about**
- **Testing HBD devices: Test Considerations**
- **NASA Evaluation Task: Using a Microcontroller as a Test Vehicle**
- **Final Considerations**

# Space Radiation Environment: The Hazard for NASA

*Nikkei Science, Inc. of Japan, by K. Endo*

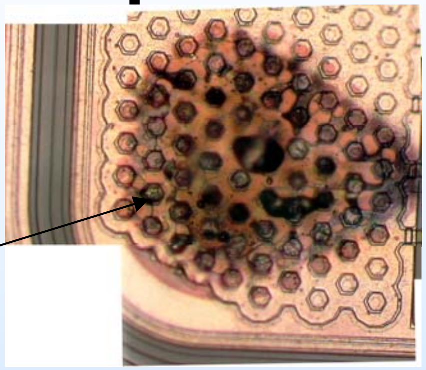



***Deep-space missions may also see: neutrons from background or radioisotope thermal generators (RTGs);***
***Avionics may observe GCRs/neutrons at altitude***

# Space Radiation Effects

- **Critical areas for design in the natural space radiation environment**
  - **Long-term effects**
    - **Total ionizing dose (TID)**
    - **Displacement damage (DD)**
  - **Transient or single particle effects (Single event effects or SEE)**
    - **Soft or hard errors**
- **Mission requirements and philosophies vary to ensure mission performance**
  - ***What works for a shuttle mission may not apply to a deep-space mission***

*Destructive SEE in a COTS 120V DC-DC Converter*



# Radiation Device Regimes for the Natural Space Environment

- **High**
  - > 100 krads (Si)
  - May have
    - long mission duration
    - intense single event environment
    - intense displacement damage environment
- **Moderate**
  - 10-100 krads (Si)
  - May have
    - medium mission duration
    - intense single event environment
    - moderate displacement damage environment
- **Low**
  - < 10 krads (Si)
  - May have
    - short mission duration
    - moderate single event environment
    - low displacement damage environment

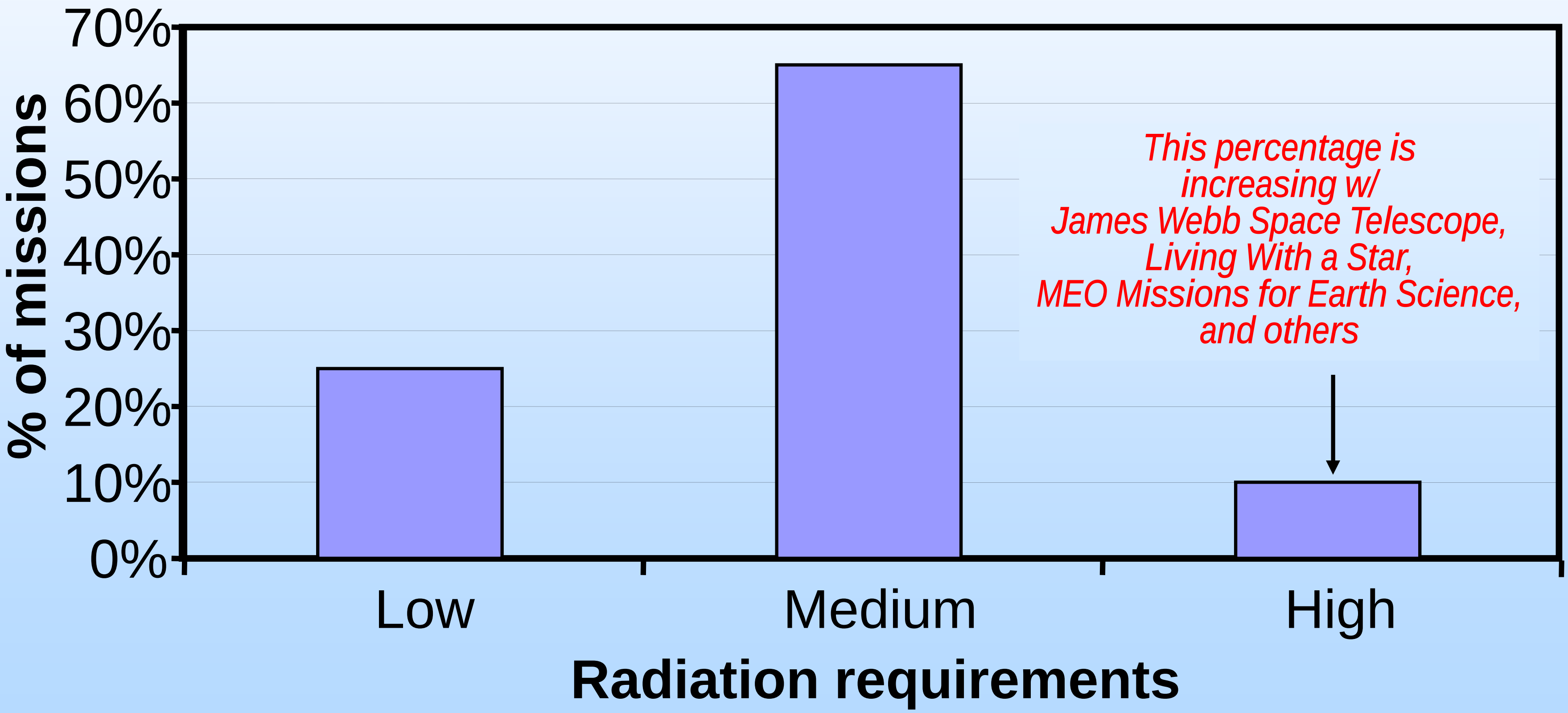
| | | |
|---|---|---|
| Examples:<br>Europa, GTO, MEO<br>Type of device:<br>Rad hard (RH) | Examples:<br>Polar, highLEO, L1, L2, ISSA<br>Type of device needed:<br>Rad tolerant (RT) | Examples:<br>Hubble Space Telescope, Shuttle, LEO (low-inclination)<br>Type of device needed:<br>Commercial with SEE mitigation |

***Aeronautics must deal with neutron SEE environment***

# Mix of NASA Missions and Radiation Requirements

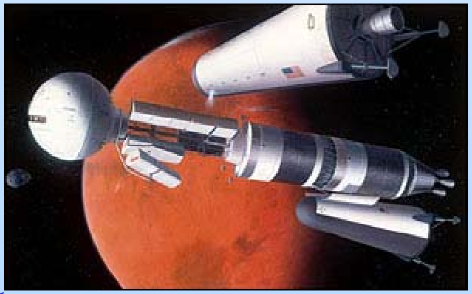
## >200 missions are currently in some stage of development

- **Informal study has been performed of percent of missions in each category**



# Implications of Radiation Needs for Hardening

- NASA philosophy has always been performance-driven
  - Increased capability within reduced spacecraft volume/weight/power – COTS?
  - Radiation has usually been a secondary consideration
- NASA Radiation Hardness Needs
  - SEE: hard to destructive issues, tolerant (or manageable) to non-destructive
  - TID/DD: 100 krad(Si) covers lots of ground for NASA
    - Few missions require above this level (even with design margin)
      - Europa being an obvious exception
    - DD becomes a larger issue for new nuclear propulsion missions
      - Added neutrons to the environment exposure

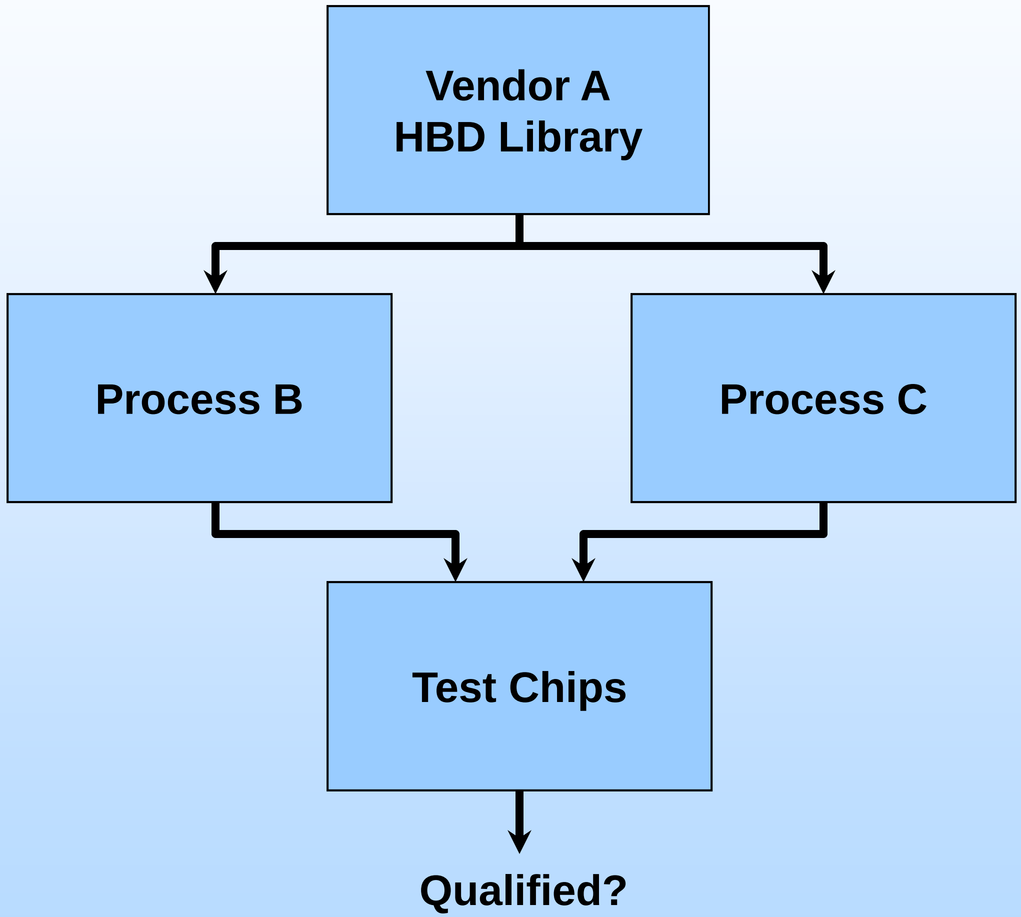


*Artist's conception of a nuclear-powered MARS mission*

# Radiation Test Considerations

- Standard items
  - Existing microelectronics test standards and guidelines for devices
    - ASTM, MIL-STD, JEDEC
    - Flux, fluence, rates, particle, etc…
  - Radiation test structures
    - Qualify a process
  - ASIC test methods
    - Qualifying a single design/chip
- Unique aspects of HBD
  - HBD can be a mix of minimally-invasive process tweaks and/or design methods (re: circuits like the Mission Research Corp.'s temporal latch)
    - Some are "process-independent"
  - The question becomes
    - How do you qualify a HBD library that's portable?

# Sample HBD Test Consideration Scenario – Initial Flow



# New Design: Is it already qualified?

| NASA Project | Does HBD cover relevant effects? | Any process changes? | Test chip coverage? | Chip operation? |
|---|---|---|---|---|
| New chip design using HBD library; 9 months after test chip is qualified | Was library designed for hardness to all relevant environments? Nuclear dose rate hardness does not imply SEE hardness | Was any hardness characteristic a function of the process? Might drive process selection (B versus C) | Did the test chip cover all the library cells? Statistically? If new test, some portion may be waived based on inherent hardness | Were speed, operating voltages, etc. of the test adequate for the new chip? Items like single event transients can be missed |

# Summary of HBD-specific Test Considerations

- **These recommendations are mostly common sense**
  - **Know the design library**
  - **Know the library coverage during "qualification"**
  - **Know how it was tested (versus your application)**
  - **Know the foundry/process**
- **If all these items are known and applicable to the new chip design, then no new radiation testing may be required**

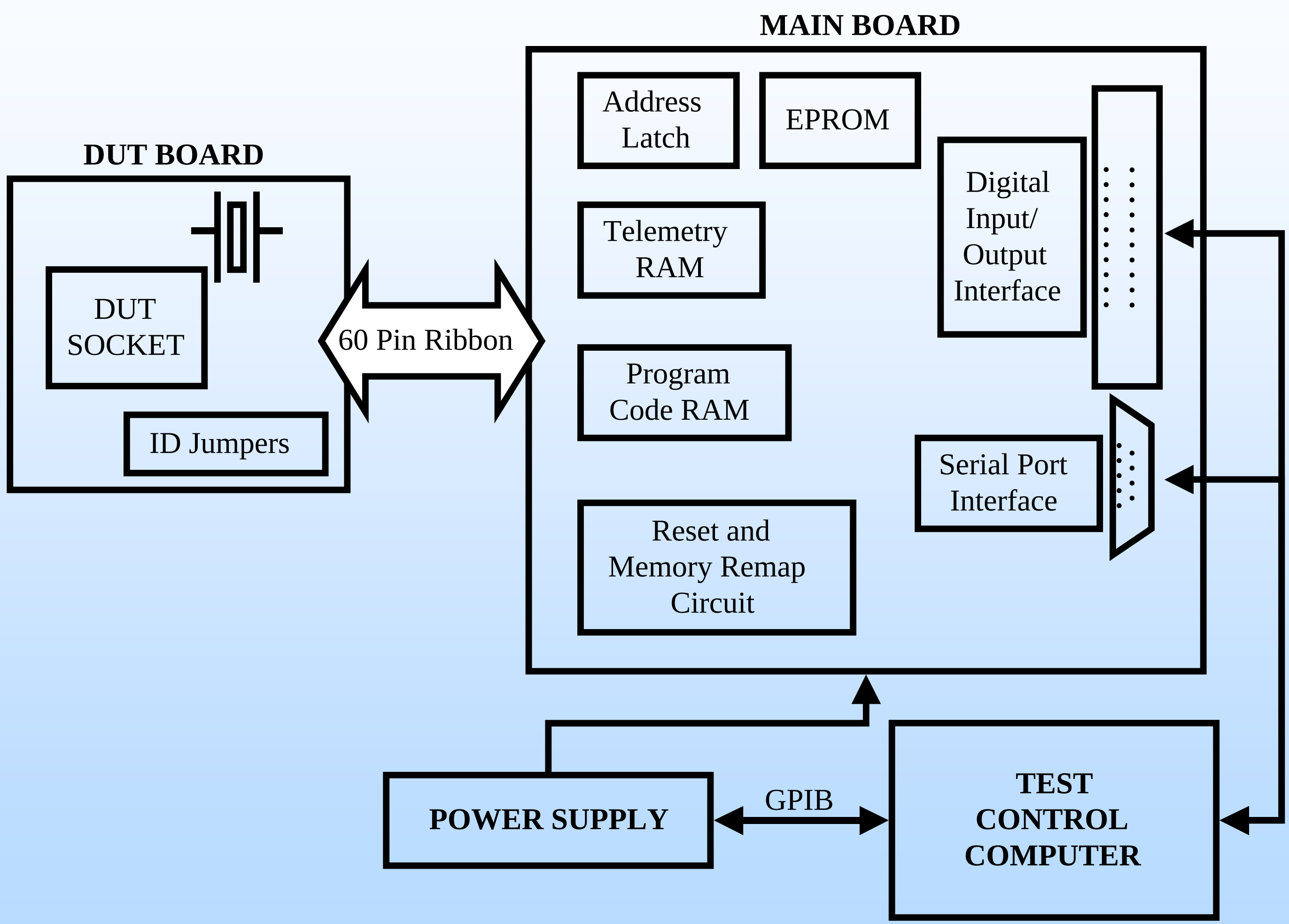
# NASA Approach to HBD Evaluation

- In FY03, we have begun the process of evaluating different HBD techniques for NASA usage
  - Some have previous evaluation, while some are in development
- We have chosen the 8051 microcontroller as the test article
  - Industry standard device with COTS and HBD options available
    - Inexpensive test set development versus other complex devices
  - Mix of logic types: memory and combinatorial
  - Capable of operating at different clock speeds
    - Different power supply versions available
  - Moderately complex (realistic)
- Plan is to use the same test setup to evaluate SEE performance on both COTS and HBD devices in FY03
  - Example vendors include
    - Intel, Aeroflex-UTMC and University of Idaho’s CMOS Ultra-Low Power Radiation Tolerant (CULPRiT)

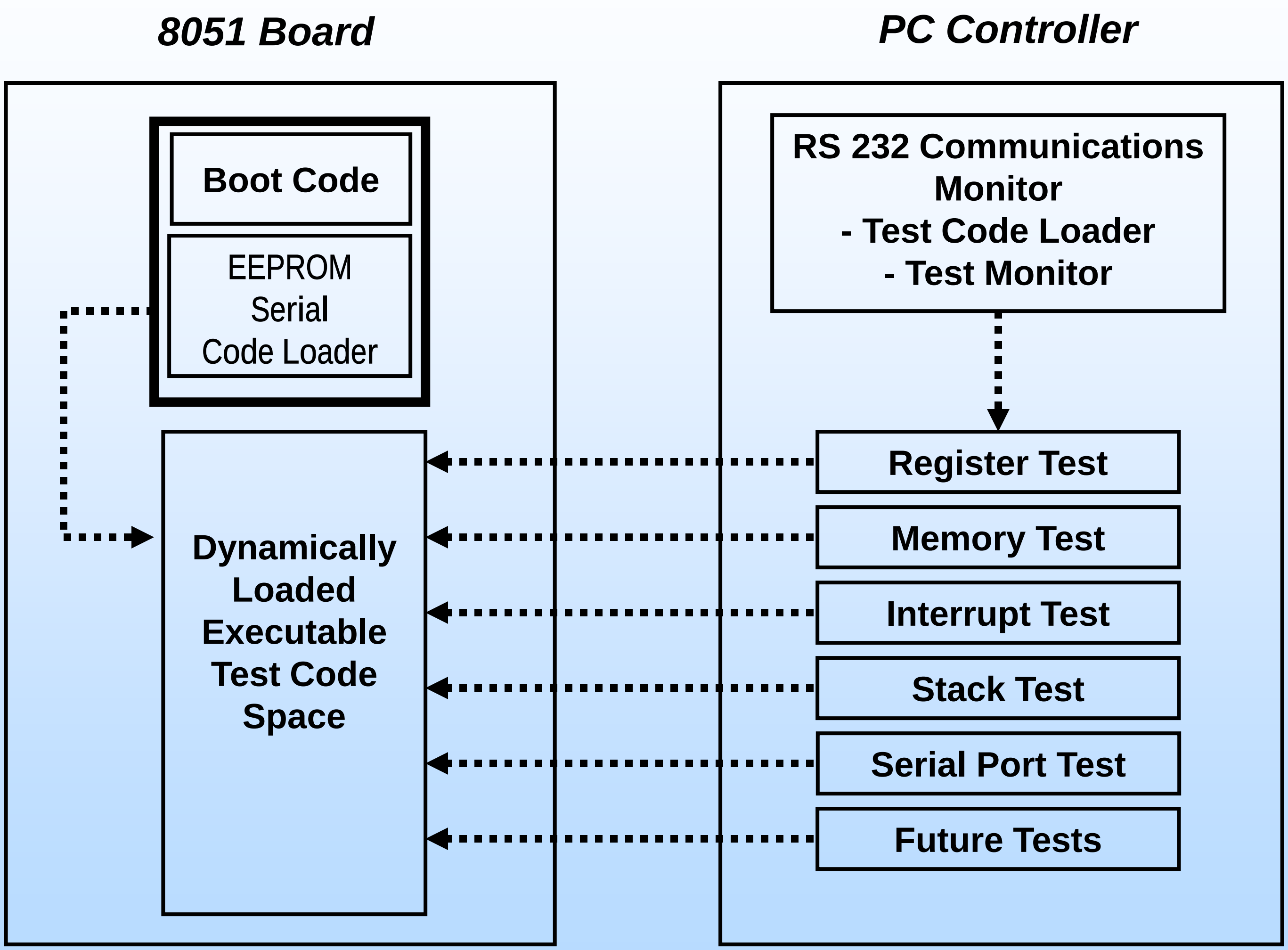
# 8051 Device Examples

- CULPRiT
  - ~0.5V Vdd device
  - Relies on inherent process TID hardness (AMI), but can tweak to gain additional hardness by use of backbiasing
  - SEL hardness by process
  - SEU hardness uses technique developed by Whitaker, Maki, et al for tolerant cell design
- Mission Research Corp
  - DoD technology development
  - Uses temporal latch designs
  - Foundry independent
- Intel
  - Strictly commercial
  - Used as a baseline for development and benchmarking

# 8051 Test Setup



# 8051 Software Testing



# Summary and Comments

- HBD is very applicable to many NASA missions
  - Not all missions have time to develop and qualify custom designs
    - If “pre-qualified”, problem is reduced
  - Performance parameters required using COTS
    - We did not discuss the impact of HBD on electrical (re: speed/power/size) performance
- Know what your testing and what has been tested and applicability