This presentation reports the results of recent proton and heavy ion Single Event Effect (SEE) testing on a variety of COTS and non-COTS electronic devices and assemblies tested for the Space Shuttle, International Space Station (ISS), and Multi-Purpose Crew Vehicle (MPCV).

**INTRODUCTION**

NASA JSC has supported 3 programs (Shuttle, ISS, and MPCV) and must test electronic devices in a method that will meet the applicable program requirements. LEO – Space Shuttle and ISS are Low Earth Orbit (LEO) applications and are tested using 200MeV protons as documented by Dr. O'Neill [1]. The 200MeV beam has been used for over a decade with positive results and this method is especially valuable for testing block level assemblies and COTS units are commonly tested using this method.

Deep Space – Multi-Purpose Crew Vehicle (MPCV) or Orion 2 is a deep space mission profile and generally all hardware used for Orion-2 requires heavy ion characterisation but Proton Testing has also been used to quickly screen out "soft" hardware and select the best candidate device when hardware was available from multiple vendors. In 2008 through 2011 the Specialty Engineering Branch of the Avionics Division of the JSC Engineering Directorate tested at the Indiana University Cyclotron Facility (IUCF), Texas A&M University Cyclotron (TAMU), Lawrence Berkeley National Laboratory (NLB) and NASA Space Radiation Laboratory (MSRL) at Brookhaven National Laboratory. A variety of COTS parts such as FPGAs, memories, wireless routers and processors were tested at block level using the high-energy proton at IUCF.

**TESTING & EXPERIMENTAL METHODS**

### A. PROTON TESTING

The majority of JSC hardware used for Shuttle and ISS is tested using 200MeV protons, at IUCF. The proton beam passes through the target device with less than 10% of the initial energy. While the incident protons themselves usually do not cause direct device upset, they do collide with the nuclei of atoms in the target device. This collision can fragment the nucleus and then generate a shower of high-energy secondary particles that can cause direct ionisation in the surrounding atomic nuclei [2]. It is these secondary particles that cause the electronic device to upset, if enough recoil energy is deposited in the sensitive volume. These reactions are rare, with approximately one nuclear collision in every 1E+6 incident protons. However, the primary drawback of proton testing is that the effective linear-energy-transfer (LET) of the secondary particles are limited to less than 14 KeV/mg and have a short range [2]. Protons do not fully characterize the device’s response to radiation compared to heavy ions with the same effective LET.

In preparation for proton testing an initial meeting is held with the potential project to understand the hardware and its application as well as specific radiation success criteria. The hardware criticality, mission duration, and any mitigation methods that can cause direct ionisation in the surrounding atomic nuclei are mapped out for the candidate hardware. The general project information, parts list, beam positions and hardware setup and configuration is captured in the project test plans and procedures for documentation.

### CONCLUSIONS

Presented in this body of work is a small summary of the ongoing testing the NASA-JSC Radiation Effects Group has tested over the past years. We frequently test many commercial microelectronic devices, boards and assemblies for short-term use in LEO applications. Actual on-orbit radiation performance obtained has also been very consistent with our proton-based predictions. Caution must be used in interpreting these results as the data we measured is very dependent on the part’s lot-date code, the host board circuit design, DUT setup, and test software used. The duty cycle, input/output signals, and DUT resource utilisation are directly related to the device’s SEE performance. As NASA continues to develop plans for returning to deep space, new radiation-related challenges exist. Mission durations will be longer and the radiation environments are harsher and the avionics used will therefore need to be more reliable, fault-tolerant, and autonomous. The JSC Radiation Effects Team has implemented changes to our current test philosophy and analysis methods in order to meet this challenge.

**REFERENCES**


**ACKNOWLEDGEMENTS**

The authors wish to acknowledge the support of the NASA Electronics Parts & Packaging Program, the JSC Engineering Directorate & Avionics Systems Division, International Space Science Institute, RSJ Program Office and the Indiana University Cyclotron Facility, Lawrence Berkeley National Laboratory, and Texas A&M Cyclotron for their support of this project.

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