INTRODUCTION

NASA JSC has supported 3 programs (Shuttle, ISS, and MPCC) that 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 and has positive results and this method is especially valuable for testing board 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 characterization 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 Speciality 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 (LBNL) and NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory. A wide variety of COTS parts such as FPGAs, memories, wireless routers and processors were tested at board level using the high energy protons 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 detector (Fig. 1) to a thickness of less than 10% of the initial energy. While the incident protons themselves usually do not cause direct device upsets, they do collide with the nuclei of atoms within the target device. This collision can fragment the nucleus and then generate a shower of high-energy secondary particles that can cause direct ionization and excitation inside surrounding atomic nuclei [2]. It is these secondary particles that cause single event effects in electronic devices, to upset to a sufficient extent to deposit energy in the sensitive device. 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 MeV/cm and have a short range [2]. Protons do not fully contribute 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 device vendor and the target device is to be tested. The vendor presents the full specification of the application as well as specific radiation success criteria. The hardware requirements, mission duration, and any mitigation methods are taken into account when planning the radiation test. A parts list of the hardware is generated and a sequence of beam positions or target areas is 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.

ANALYSIS METHODS

A. PROTON ANALYSIS

To analyze the proton data, the SEEs are grouped by type, frequency, and severity. The errors are counted and inputted into a program called PROTEST [3]. PROTEST derives the equivalent 10 year MTBF for the proton test. The output of PROTEST is the calculated Mean-Time-Between-Failure (MTBF) rate expected for operating the hardware in LEO orbit (expressed in terms of days between failures). An MTBF is calculated for each beam position, as well as a final low-level comparative rate. These estimates assume the hardware is operating continuously on orbit and does not take into account the actual mission timeline in which it will be used. For these devices that showed no SEE effects in a typical 1E+6 exposure, we estimate the LEO on orbit MTBF to be greater than 10 years. This is the same methodology that has been used at JSC for more than 15 years to evaluate the radiative hardness of mostly COTS hardware.

SUMMARY OF RADIATION TESTING

The following section will summarize Proton radiation testing on select COTS, Non-COTS hardware and individual electronic parts in a series of summary tables. Also a summary of ITS Laptop testing which is also shown in this section along with a summarized section of the hardware tested.

The T61-P Laptop was an upgrade to the A31-P IBM Thinkpad and was completely dissembled down to the motherboard in order to create a detailed parts list of the components of the laptop (Fig. 2). The T61P Laptop was powered using a modified AC adapter cord that was connected to a Sorensen power supply, with the operating parameters set at 16V out and max current at 4.5A. With this modified AC adapter we were able to monitor current to the laptop and voltage at the power supply and going to the laptop.

The following section will summarize Proton radiation testing on select COTS, Non-COTS hardware and individual electronic parts in a series of summary tables. Also a summary of the ISS Laptop testing will be included in this section along with a summarized section of the hardware tested.

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 decade. We frequently test many commercial microelectronic devices, boards and assemblies for short-term use in LEI 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 parts’ lot-date code, the host board circuit design, DUT setup, and test software used. The duty cycle, input/output signals, and DUT resource utilization 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


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