4-12-2018

Radiation Damage Threshold of Satellite COTS Components: Raspberry Pi Zero for OPAL CubeSat

Jonh Mojica Decena
Utah State University

Brian Wood
Utah State University

Ryan J. Martineau
Utah State University

Michael Tayor
Utah State University

JR Dennison
Utah State Univesity

Radiation Damage Threshold of Satellite COTS Components: Raspberry Pi Zero for Opal CubeSat

Jonh Carlos Mojica Decena, JR Dennison, Brian Wood, Ryan Martineau, Michael J. Taylor

Material Physics Group, Physics Department , Utah State University; Space Dynamics Laboratory

Introduction

The purposed of this experiment is to study the radiation survivability of a *Raspberry Pi Zero* in a simulated space environment to determine the amount of ionizing radiation that the memory and processor of this commercial off-the-shelf (COTS) unit can be exposed to before they exhibit radiation-induced damage or stop working altogether.

Motivation

The *Raspberry Pi* is an inexpensive and tiny computer, about the size of a credit card that normally runs with the Raspbian OS (Figure 1). A *Raspberry Pi Zero* will be placed inside the Space Survivability Test (SST) chamber, where it will be radiated by an Sr^{90} source (0.2 - 2.5 MeV) until the computer stops working (Figure 2).

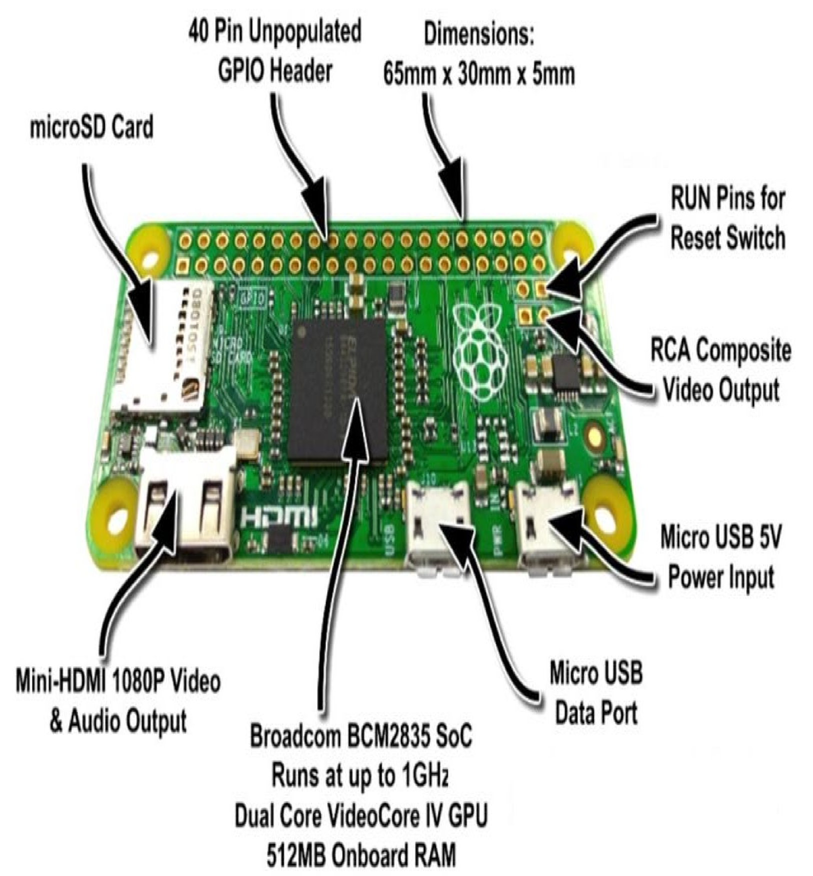

Figure 1. Description of the Raspberry Pi Zero

Figure 2. USU MPG SST chamber

The Sr^{90} source produce a TID of 0.1 krad/hr (Figure 3). For electronics, radiation creates a profound effect since they can alter the electrons to any excited state easily. By being exposed to radiation, microprocessors can experience a variety of failure modes, these are known as Single-event effect (SEE) [1]. For the proposed experiment we will look for Single-event latch-up (SEL) which are critical errors

Procedure

In our experiment we will put a *Raspberry Pi* inside of the SST for a period of 8.4 hours at a dose rate of 0.4 krad/hr to simulate the LEO TID (~2krad/yr).

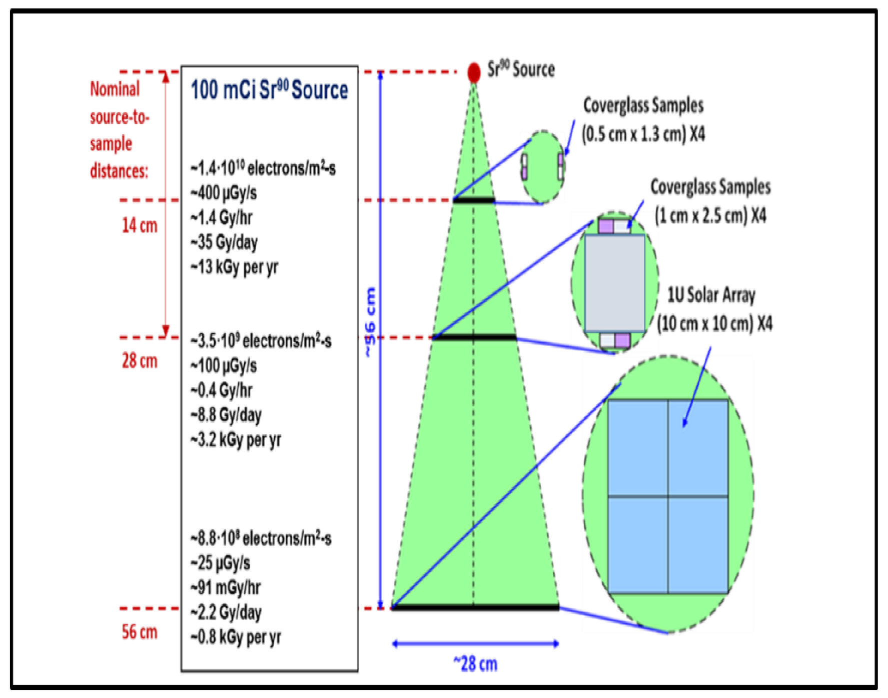

Figure 3. Approximate sample dose from Sr^{90} source as a function of source-to-sample distance.

$$krad := 10 \cdot Gy$$

$$DR_o := 0.1 \cdot \frac{krad}{hr}$$

$$DR := DR_o \cdot \left(\frac{6 \cdot in}{2.75 \cdot in}\right)^2 = 10.476 \cdot \frac{krad}{hr}$$

$$TID_{yr} := 2 \cdot \frac{krad}{yr}$$

$$T_{mission} := 1yr$$

$$sf := 2$$

$$TID_{Mission} := TID_{yr} \cdot T_{mission} \cdot sf = 40 \frac{m^2}{s^2}$$

$$T_{exp} := \frac{TID_{Mission}}{DR} = 8.403\,hr$$

Figure 4. Calculation of the time of exposure and TID

To monitor the performance of the *Raspberry Pi* we will be using the Wi-Fi connection to control it from the outside via secure shell. When connection has being stablished, we will use a stress test to look for errors on the CPU, RAM and USB connections (Figure 4). Once an error has been detected, a look at the map of the processor will allow to identify the origin of the error and the data acquisition will determine the type of error produced

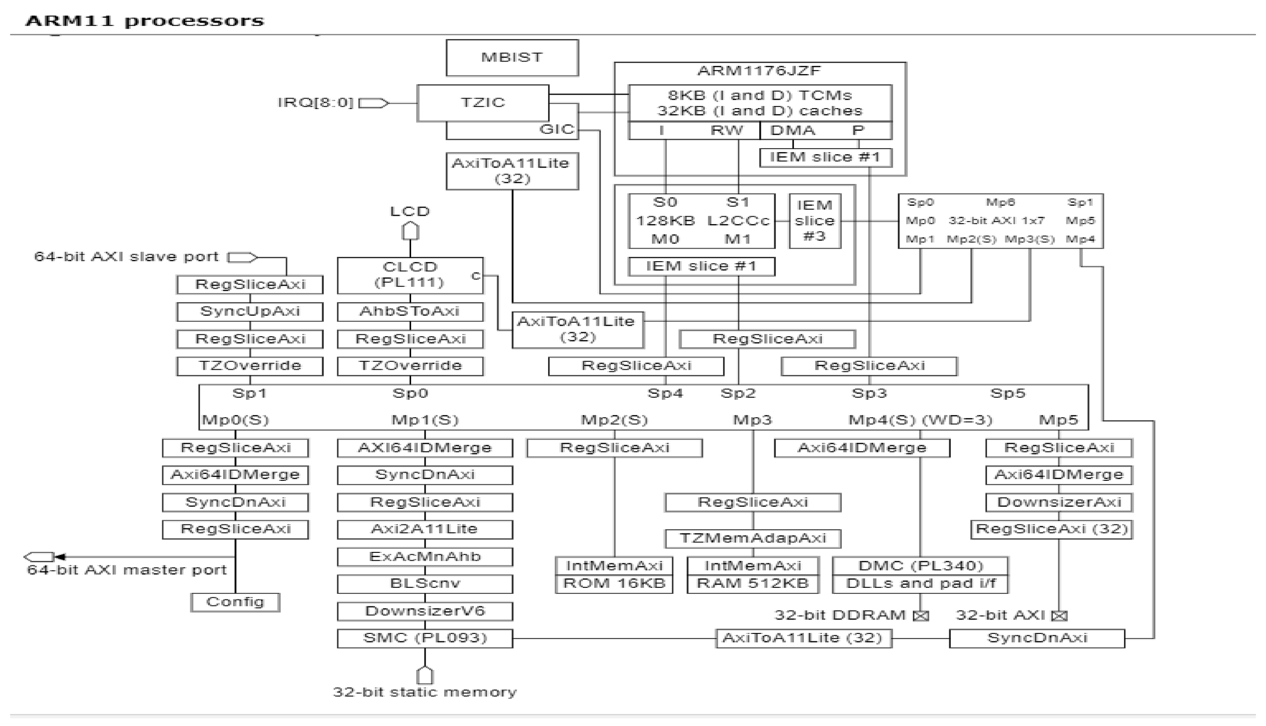

Figure 4. Diagram of the Raspberry Pi zero processor

In the first run, it will be determined the stability of the *Raspberry Pi Zero* for the OPAL CubeSat mission of ~1 yr in LEO. Then our second run will be to determine the TID at which the *Raspberry Pi* stop working and which area was affected the most by mapping the source of the error and the analysis of the data collected directly from the *Raspberry Pi*.

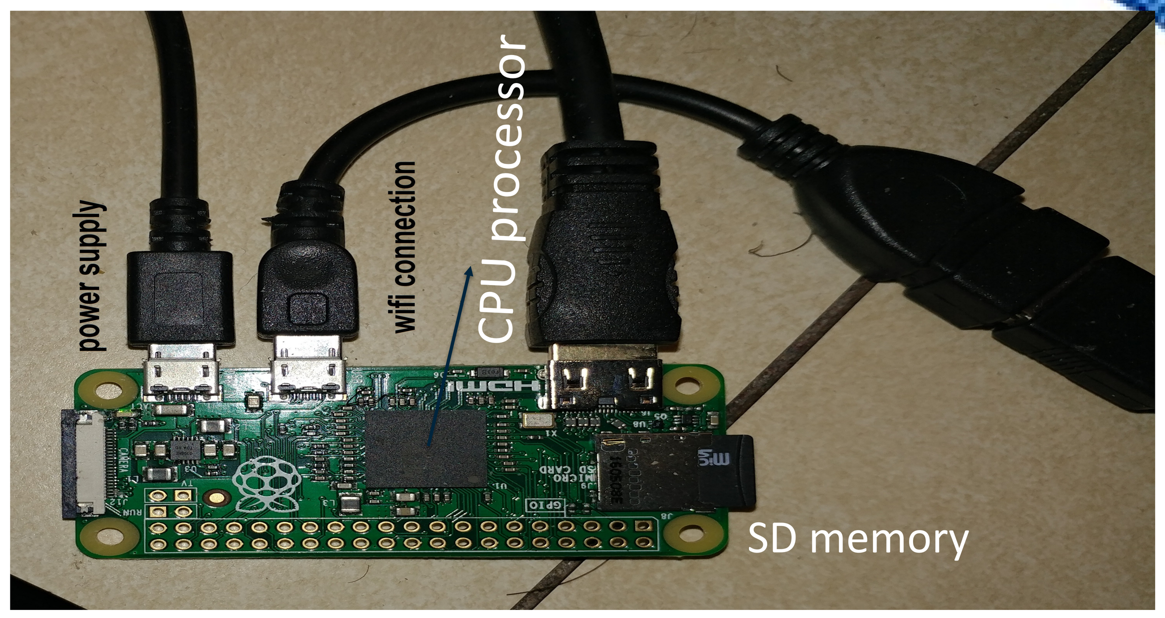

Figure 5. Raspberry Pi Zero connected for stress test and areas of testing

Results

Under environmental conditions, the *Raspberry Pi* has being fully operational for a period of 10 days, there has not been any source of error. In the Upcoming weeks the procedure to test at a simulated space environment will begin at the indicated dose rate.

Conclusions and Future Work

Conclusions:

Previous experiments done by the MPG with an Arduino shows that the TID to see the first SEL occurs at ~150 krads, but where the error occurred was undetermined. The period of testing under environmental conditions indicates that the *Raspberry Pi* is a good candidate for this mission, The implications of determining the impact of radiation exposure will be directly used in the creation of the USU OPAL CubeSat, and could be of benefit for consumers and manufacturers since determining what areas are most affected will provide a guide to which area to focus on when building or using these microcontrollers. And what areas would benefit most from additional shielding.

Future Work:

- Add peripheral components (GPIO connections) for testing .
- Add a camera to analyze the radiation effect on the pixels (see AWE FPA radiation test from SDL).
- Understand the property of Si-based ICs and memory to create a model for radiation effect on electronics components.
- Predict the proper amount of shielding necessary to ensure a component survivability.
- Test Solar effects on electronics with the Solar simulator (x-ray, and UV radiation).

UTAH STATE UNIVERSITY
MATERIALS PHYSICS GROUP

Scan code to access accompanying paper and references, as well as other USU MPG articles.

*Supported through partial funding from an URCO grant from the USU Office of Research and Graduate Studies.

REFERENCES

[1] Akihiro Nagata, Atsushi Yasuda, Hiromasa Watanabe, and Toshihiro Kameda, "Development of a Support System for Radiation Resistance Testing," *University of Tsukuba* (July 22, 2017).
[2] JR Dennison, Kent Hartley, Lisa Montierth Phillips, Justin Dekany, James S. Dyer, and Robert H. Johnson, "Small Satellite Space Environments Effects Tests Facility," *Proceedings of the 28th Annual AIAA/USU Conference on Small Satellites*, (Logan, UT, August 2-7, 2014), 7pp.
[3]Space Electronics Inc. "Space Radiation Effects Handbook for RAD-PAK Microelectronics." (1997).
[4] Windy Olsen, Brian Wood, Donald Rice, and JR Dennison, "Microcontroller Survivability in Space Conditions," Physics Department Utah State University, 2016.
[5] Violette, D. P. "Arduino-Raspberry Pi: Hobbyist Hardware and Radiation Total Dose Degradation." (2014).

Space Dynamics LABORATORY
Utah State University Research Foundation