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THE WOLVERINE CUBESAT DEVELOPMENT TEAM FLIPSAT PROPOSAL: ANALYSIS OF SINGLE BIT FLIPS AS A FUNCTION OF RADIATION HARDENING

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Abstract

"FlipSat-1" is a 2U CubeSat that will be investigating the volatility of single event upsets in printed circuit boards that utilize various radiation protection methods. "FlipSat-1", colloquially and henceforth mentioned as FlipSat, is both a proof-of-concept of watchdog timers in cheap low earth orbit satellites and optimization of levels of radiation hardening. FlipSat is a crucial step in space exploration by providing insight on the electrical phenomena of single event upsets and protection methods. The information that FlipSat harvests will enable space programs, corporations, schools, and individuals to prevent data corruption on their satellites. Even with the ever decreasing costs of launching satellites, it is still an encumbrance for entities to fund the cost to launch heavy radiation hardening or budget enough power to supply watchdog timers. Therefore, the FlipSat-1.

Keywords: single event upsets, radiation, bit flip

1. Introduction

1.1 Single Event Upsets

Single event upsets, also known as bit flips, are a type of change in the sequence of computer program. Single event upsets are commonly caused by ionized particles hitting the binary code and flipping the charge level. A bit is a binary unit of data. Single event upsets, henceforth bit flips, change the binary code's electric charge so when a computer reads a string of "1s" and "0s," it will read the wrong digit. (ex. Original Code: 101w. Bit Flipped Code: 100). These changes have the ability to corrupt data to extreme levels, resulting in mission failure. This may be caused by the on board satellite's processing chips not being able to run the experiment or process the data from the experiment. This may also be caused by the satellite's inability to maintain attitude, transmit data, utilize propellant, or charge sufficiently.

1.2 Mission of the FlipSat

The FlipSat-1 mission will test the utilization of error correcting code, varying levels of radiation hardening, electronic watchdog timers, and mechanical watchdog timers on the protection of printed circuit boards from single-event upsets.

1.3 Wolverine CubeSat Development Team and the FlipSat-1 Team

The Wolverine CubeSat Development Team (WCDT) was established in 2015 by The Weiss School science teacher Mr. Kevin Simmons and is composed of sixth through eight grade students. Mr. Simmons is the founder of BLUECUBE Aerospace, which aims to build, launch, utilize, and educate using CubeSat technology with student teams. In December 2018 WCDT has successfully launched WeissSat-1, a 1U CubeSat selected in the 24th round of NASA's Educational Launch of Nanosatellites (ELaNa). WCDT has also launched 3 high altitude balloons (HAB) as a means of training for building the WeissSat-1. Students of the WCDT also compose legislation and are attendees of many legislative blitzes, lead by their educator Ms. Shawna Christenson, the founder of the Aerospace Public Policy Institute (APPI) and a Space Foundation Teacher Liaison. As part of their work in APPI, students participate in legislative blitzes and work on resolutions at the State and Federal level to help expand STEM education and increase public awareness of the educational benefits of the CubeSat Launch Initiative.

The FlipSat-1 team was established in 2018 to design and engineer the FlipSat-1 CubeSat. It was composed of eight students, three of which are authors of this paper. The FlipSat-1 team presented a PDR to an array of engineers in October of 2018. Additionally, the team has presented to experts in various fields such as a lead engineer at IBM and Janet Ivy of ExploreMars.

1.4 Similar Satellites and Distinguishing Factors

In 2012, via the CubeSat Launch Initiative, the ARDUSAT was launched into space using various sensors. One of these sensors were a Geiger counter. It, like the FlipSat, looked at radiation in space. The FlipSat satellite will be looking at single event upsets and watchdog timers. This is in contrast to the ARDUSAT as the ARDUSAT specifically looked at the amount of ionized radiation going near the Geiger counter, though it did not measure the effects of radiation on computer components, nor did it research any protection methods against single event upsets.

The Tracking and Data Relay Satellite, TDRS-1, was launched in 1983. It suffered launch problems that it left in an orbit that was not optimal for its mission. Therefore, the TDRS-1 used its station keeping thrusters to bring it to the right orbit. On the way to its optimal orbit, anomalies, later classified as single event upsets, caused computer errors in the data, affecting the attitude control system of the TDRS-1. These single event upsets occurred from 1984 to 1990, per a 1991 paper by the Institute of Electrical and Electronics Engineers. While the TDRS-1 did have single event upsets happen on its not protected computing functions, it did not have anyway to watch the amount of radiation hitting the processor. It also did not have anyway to see how the single event upset rate was affected by protective materials.

2. Material and Methods

FlipSat will be using multiple printed circuit boards for its experiments. These printed circuit boards are currently planned to be manufactured by Prototron Circuits. These printed circuit boards will have a string of code in plain binary digits. The code will read, "010101." Every 20 minutes the code from each circuit board will be collected and transmitted to the GlobalStar satellite constellation. The GlobalStar constellation will then upload the mission data into the graphical user interface, or GUI. Members of the FlipSat will from then take that data and do data analysis on the data, or they will automate the method allowing the data to be automatically transferred into a spreadsheet, which will then do the data analysis.

The printed circuit boards that FlipSat will be using shall be differentiated in three ways. The first of the three ways will be that there will be a set of printed circuit boards using only watchdog timers of various "kicking" intervals. The second of the three ways will be a different set of printed circuit boards that use different amounts of radiation hardening to protect against radiation. The third of the three ways will be utilizing error correcting code to prevent the code on the printed circuit boards from corrupting. It should be noted that for the watchdog timers, both electronic and manual watchdog timers will be used.

The DeBye lengths of ionized radiation capable of causing a printed circuit board to have a single event upset would be larger than the CubeSat itself. Therefore, the location of the printed circuit board would be negligible.

Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

3. Theory and calculation

The following are the calculations and theories related to the FlipSat.

3.1 Equation numbers

3.1.1 Debye Length Equations

$$\lambda_D = \sqrt{\frac{\varepsilon_0 K_b T_e}{n_0 e^2}}$$

λ_D = Debye Length
ε = Permittivity of Vacuum
K_b = Boltzmann Constant
T_e = Temperature of Electrons
e^2 = electronic charge
n_0 = Number Density of charged Species

4. Predicted Results

The predicted results for this experiment are as follows.

4.1 Predicted Results for Unprotected Code

Longer binary codes will result in logarithmically increasing amount of single event upsets as the space that the code consumes will increase with code amount. This in turn allows for higher probability of single event upsets

4.2 Predicted Results for Watchdog Timers and Error Correcting Code

It is predicted that the watchdog timers and error correcting code will be energy efficient and highly effective in protecting their components.

4.3 Radiation Hardening

Radiation hardening is expected to be less weight to protection efficient as watchdog timers or error correcting code. It is also expected to be more expensive.

5. Discussion

This mission will give insight to the optimal amount of radiation hardening needed to protect a satellite's electronic subsystems and data. Organizations involved in building satellites could benefit from this information as it will allow them to do accurate assessment and budgeting for radiation hardening materials.

Additionally, this mission will give people a greater understanding of how radiation corrupts data and electronic subsystems. With this knowledge satellite component manufacturers will be able to create a more efficient radiation hardening materials.

Furthermore, increased understanding of how radiation affects electronic subsystems and satellite data will lead to more cost-effective solutions for radiation hardening, therefore lowering the cost of radiation hardening on satellites.

6. Conclusions

FlipSat-1 is aimed at finding the optimal amount of radiation hardening needed to protect satellite's electronic subsystems and data. In order to carry out this mission FlipSat-1 will be utilizing various Protron Circuit Board, which will be used in 3 different ways. These ways include putting on - watchdog timers, different amounts of radiation hardening, and error correcting code. (For further information on this topic refer back to Section 2 Materials and Methods.)

FlipSat will help satellites cut down on radiation hardening, which will allow more cost-efficient satellites, without risking damage from ultra-high energy cosmic rays. Also, it will give us a greater understanding of how radiation affects and corrupts data leading to more efficient and cost effective radiation hardening technologies.

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