IAC-20 E1.VP.12.

OUTLAST-1: International Collaboration and Disruptive Education via PocketQubes

Beau T. Kimler[a*], Maya Mohanty[b], Kevin L. Simmons[c]

[a] *Wolverine CubeSat Development Team, 4176 Burns Road, Palm Beach Gardens, Florida, United States 33410*, bkimler321@gmail.com

[b] *Wolverine CubeSat Development Team, 4176 Burns Road, Palm Beach Gardens, Florida, United States 33410*, mayamohanty@icloud.com

[c] *BLUECUBE Aerospace, 2300 Giralda Circle E#102, Palm Beach Gardens, Florida, United States 33410*, ksimmons@bluecubesat.com

Corresponding author

Abstract

The proposed nanosatellite, The Outlast-1, is a 5 cm by 5 cm by 15 cm PocketQube that will utilize watchdog timers and redundancy methods to prevent bitflips in COTS hardware. PocketQubes are a subdivision of SmallSats that have been recently developed. The most common SmallSat is a CubeSat, a 10cm^3 platform that is used for launching missions to space. CubeSats are used in the educational setting because of their affordable price. CubeSats have been commonly used to teach students about designing, building, and testing. The CubeSat has been recognized as a great tool for students and will be used for years to come. One alternative to the CubeSat is a PocketQube, which is even smaller and comes at a lower price point. They are a lesser known platform for students because of how recently they were developed. PocketQubes are also cost effective but smaller than CubeSats. They are ~~also~~ developed in Scotland which is important to the Outlast-1 mission. The Outlast-1 aims to stay in space for a total of 3-4 years using hardware and electronics. Data is something that all satellites send back to Earth so it can be analysed. That data can get corrupted due to high energy radiation such as UV or X-ray hitting the main processor and changing the bits of data such as a 1 to a 0 and vice versa. The Outlast-1 aims to prove and validate watchdog timers and redundancy as a way to protect data in space. The Outlast-1 will bring students of all different nations together satellites work and improve their use of technologies [1]. Through designing, building, and testing, students gain experience and knowledge that they can use in the SmallSat industry. The Outlast-1 will help future space missions and help the future of space.

KEYWORDS: PocketQubes, Small Satellites, Bitflips, watchdog timers, STEM Education

Nomenclature

ε is the dielectric constant,
k_B is the Boltzmann's constant,
T is the absolute temperature in Kelvin,
q is the elementary charge, and
N_{dop} is the net density of dopants (either donors or acceptors).

Acronyms/Abbreviations

Commercial Off the Shelf (COTS), Dynamic Random Access Memory (DRAM), SATS International Traffic in Arms Regulations. (ITAR) low earth orbit (LEO) Project based learning (PBL). Picosats (Picosatellites) Single event upsets (SEUs), Ultraviolet (UV).

1. Introduction

1.1 Education and PocketQubes

The proposed Outlast-1 is PocketQube with a mission to provide disruptive education around the world. PocketQubes, made in Scotland. are a variant of the nanosatellite, which means they are smaller than a CubeSat and are able to perform missions more cost effectively. CubeSats are part of another family of SmallSats call the Picosat. Since they are made in Scotland and not the US they can be shared and collaborated on with other students from all around the world. The ability to share the CubeSat technology is limited because of ITAR restrictions to other countries in the field of SmallSats. PocketQubes can be shared freely with students from all around the globe.

PocketQubes come in different sizes from 1p ($125cm^3$ to 2p. The Outlast-1 will use the 2p size which is 5 cm * 5cm * 15cm. Currently only a few high schools and colleges have access to SmallSats and the many great benefits they have to offer. From 2012 to 2019, 348 SmallSats were launched by academic organizations and schools [2]. The hands-on experience that students receive is something that is only matched by working in the SmallSat industry. When a disruptive education device is introduced such as a SmallSat a whole new world can seemingly open up for these students.

1.2 Data loss and bitflips

The Outlast-1, while providing a great educational experience, also aims to provide information on data protection in space. Data is the most important part of any mission. Without results due to communication errors, the mission is less successful and valuable information is lost. The main way information is lost or corrupted is through bitflips which are also called (SEUs). Bitflip occurs when high energy radiation (ultra violet to gamma) collides with the processer on the satellite [3]. The energy from the radiation changes the stored information value.

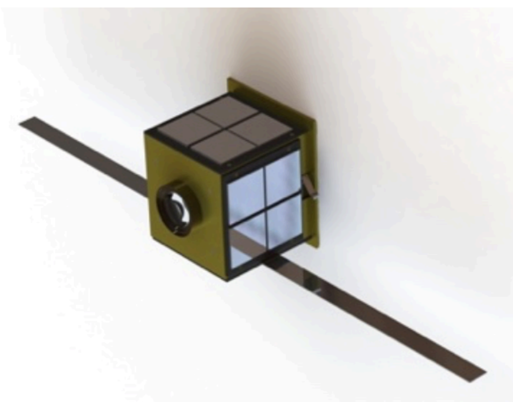

Fig 1. 1p PocketQube. Image Courtesy Alba Orbital

The information flips from a 1 to a 0 and vice versa. It can also short circuit the hardware on a SmallSat. The Outlast-1 uses Watchdog timers and two types of redundancy to try to protect against bitflips and radiation. First, redundancy is having backup systems that can take over for the primary system if it experiences trouble [4]. The Outlast-1 will have 6 Arduinos with one being the main processor and the other 5 being able to take over at any moment. The other redundancy method is triple redundancy. Triple redundancy is a voting method for the command boards in space. If the information from one board out of six wrong or corrupted instead of sending that bad information down to the ground the other five will see that one is not alike and send down the majorities info. Watchdog timers are a program that makes the boards hard reset on a certain interval of time. If the Outlast-1 was to be selected it would test the methods to see if they are viable for future missions.

2. Material and methods

The Outlast-1 will use six Arduinos Unos complete its mission in LEO. These Arduinos will have a specific code sequence that will be broadcast back down to the ground via the Global star Network every 15 minuets. The Arduinos will have a watchdog timer installed along with a program with triple redundancy. If one of the Arduinos short circuits the PocketQube the other 5 Arduinos can continue on the mission. The watchdog timer will reset the system every 5 seconds and the triple redundancy method will run the minute before the data pattern is sent down. Watchdog timers perform a hard reset in whatever time is best for the mission [5]. This prevents errors in the system due to malfunctions. The triple redundancy system will check the code that it will send and compare it to the other Arduinos. If one is wrong and the other 5 are correct the other 5 will outvote the wrong pattern. Once the data pattern is sent the Outlast-1 team will analyse it to see if the data is correct. If the pattern is incorrect the team will know a bitflip occurred and it made it through the watchdog timer and the redundancy methods.

3. Theory and calculation

3.1 Debye Length Equation

$$L_{\mathrm{D}} = \sqrt{\frac{\varepsilon k_{\mathrm{B}} T}{q^2 N_{\mathrm{dop}}}}$$

ε - dielectric constant, k_B - Boltzmann's constant,
T - absolute temp. in Kelvin, q - elementary charge
N_{dop} - net density of dopants (either donors or acceptors).

3.2 Theory

Row hammer is an exploit in dynamic random-access memory which memory cells can leak through interactions with other memory cells [6]. When cells leak, they can change the content of the memory cells. Row hammer has many similarities to bit flip but is also very different. While bit flips are caused by cosmic radiation the row hammer effect happens when memory access patterns that access the same cell multiple times which can cause a leak. DRAM memory cells lose their memory state which then forces the rewriting of all the memory cells. With a certain code which simulates the DRAM memory cells it is possible to manually cause a bitflip. Similarly, to boards in space the DRAM memory is prone to data changes. These data changes can occur because of cosmic radiation, just like how a bit flip can occur. Mitigation methods for the row hammer effect is error correcting code and lockstep systems. Information from the Outlast-1 could bring awareness to new types of data/memory protection not just for satellites.

4. Predicted Results

The prediction for the proposed Outlast-1 mission is that watchdog timers and redundancy are the key to having a SmallSat last longer in LEO. It is also predicted that there will be little to no bitflips in the lifetime of the Outlast-1 due to the protection. The Outlast-1 is estimated to live a minimum of 4 years in LEO. In terms of education, students in foreign countries will be better prepared to succeed in the field of STEM. The Outlast-1 will provide valuable information in the field of data protection and mission longevity in the environment in space. It will also provide a great learning experience for children who have had no experience with SmallSats and want to thrive in the field of STEM.

5. Discussion

The data and information in all satellites is important. Protecting data is expensive when using traditional radiation hardening. One of those ways is radiation hardening for SmallSat hardware. It is very expensive for schools and other organizations to use. This can lead to missions where data is corrupted, and information is lost. The Outlast-1 will help change that through data protection methods that are both cost and time effective. Watchdog timers and redundancy are free to use on all satellites. and take one hour to code. The Outlast-1's team wants to make the Outlast-1 the first mission of many that will look into protection of data and sustaining of CubeSats.

6. Conclusions

The Outlast-1 is 2p PocketQube which may be utilized to provide education to children from all around the world while also furthering the longevity of SmallSat missions in space. Since the PocketQubes are made in Scotland where there are no ITAR restrictions the valuable information and experience of designing, building, and testing a PocketQube can be shared with foreign students. The STEM industry is very important but shrinking due to lack of student interest and awareness. The Outlast-1's goal in space is to use COTS hardware (Arduinos) with redundancy and watchdog timers to increase the lifespan of missions in space and protect against data loss and corruption. The Oulast-1 hopes to bring disruptive change to the STEM industry through hands on education. Students will move beyond basic projects and make real world changes with SmallSats.

Acknowledgement

Alba Orbital for providing information and support to the conception to the Outlast-1.

References

[1] Bybee, R. W. (2010). What is STEM education? Retrieved July 23, 2020, retrieved from https://science.sciencemag.org/content/329/5995/996

[2] Smallsats by the Numbers. (2019) Retrieved July 23, 2020, retrieved from https://brycetech.com/reports/report-documents/Bryce_Smallsats_2020.pdf

[3] Bit Flips: Was that a Zero or a One? (2018) Retrieved July, 1, 2020, retrieved from https://www.itprotoday.com/cloud-computing/bit-flips-was-zero-or-one

[4] Hassan, R., & Crossley, W. (2008) Retrieved July, 18, 2020, retrieved from Spacecraft reliability-based design optimization under uncertainty including discrete variables. *Journal of Spacecraft and Rockets*, *45*(2), 394-405.

[5] Watchdog Timer - Cookbook. (2019). Retrieved July, 6, 2020, retrieved from https://os.mbed.com/cookbook/WatchDog-Timer\

[6] Kim, Y. (2014). Flipping Bits in Memory Without Accessing Them: An Experimental Study of DRAM Disturbance Errors. Retrieved July 30, 2020, retrieved from http://users.ece.cmu.edu/~yoonguk/papers/kim-isca14.pdf