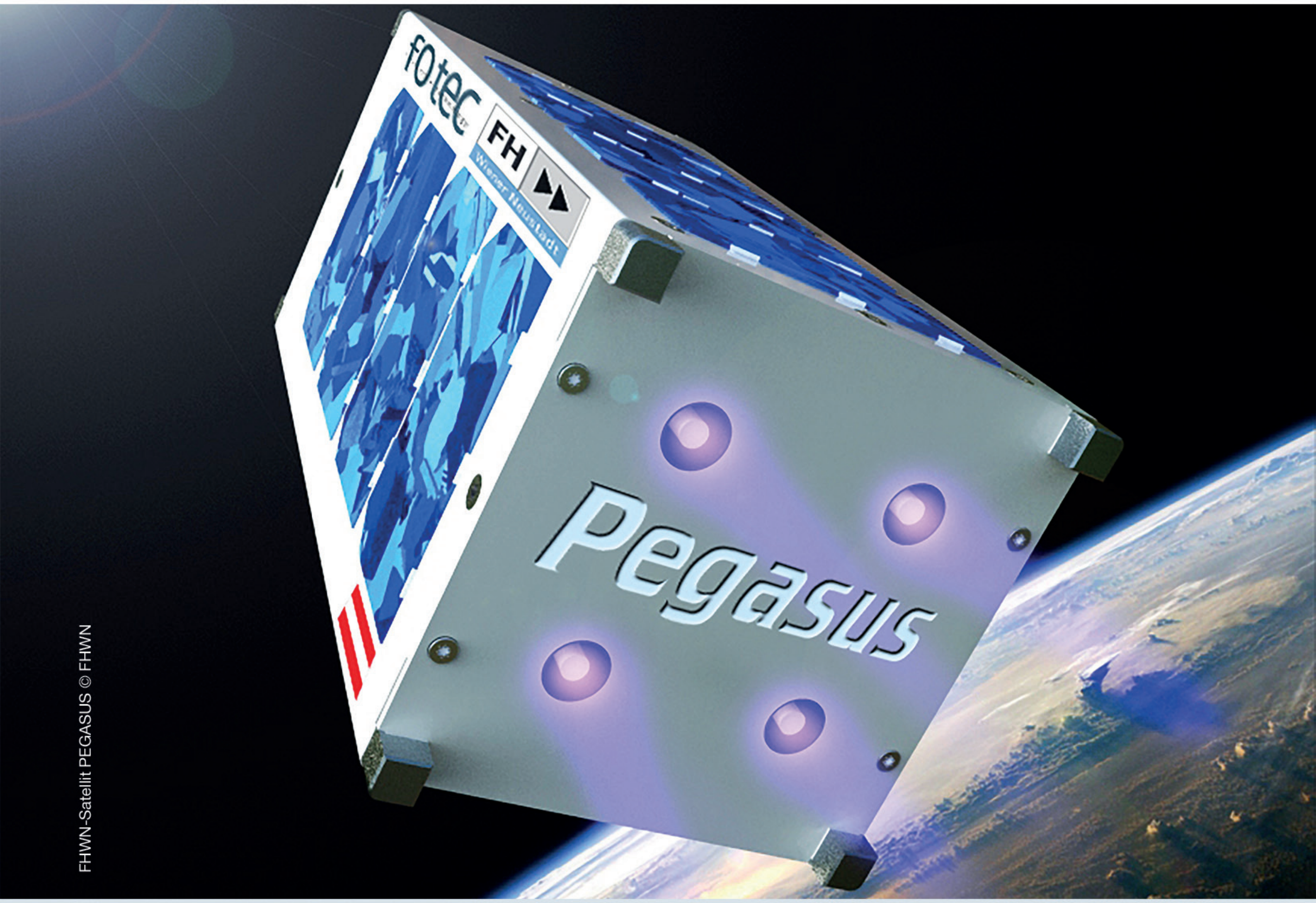
RADHARD SYMPOSIUM

Book of Abstracts

April 9th - 10th, 2019



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Chairman‘s Invitation

On behalf of the RADHARD Symposium 2019 organising team, it is my pleasure to invite you to the 4th Edition of the RADHARD Symposium, held at the Seibersdorf Laboratories, close to Vienna, Austria.

The mission of the RADHARD Symposium is to provide you, complementary to the RADECS conference, with a forum for exchanging practical experiences in radiation hardness assurance, relevant for industrial applications as well as for research and science.

Our vision is that the RADHARD Symposium offers a space with plenty of room for communication, initiating new joint projects and inviting you to attend the upcoming RADECS Conference 2019 at Montpellier, France (www.radecs2019.org).

The RADHARD 2019 - Symposium focuses on:

- SmallSats and COTS components
- Practical aspects of radiation hardness assurance
- Innovative testing developments and future needs

The RADHARD-Symposium is addressed to space systems integrators, EEE manufacturers, industry, research and science as well as students interested in radiation and its effects to components and systems. International experts present new results and highlighting reviews. We strongly encourage students to present their early research on radiation hardness effects and discuss it with radiation hardness assurance (RHA) experts from research and industry.

Keynote and training lectures on topics such as space radiation and radiation effects are an integral part of the RADHARD symposium. We are very pleased and proud that a RHA expert from the European Space Agency, ESA gives a keynote lecture on „News on Standardisation of COTS Testing“. Experts from Seibersdorf Laboratories give training lectures on “Space Radiation Environment at LEO, MEO and GEO” and “Space Radiation Effects to Components and Systems”. The practical aspect of radiation hardness assurance is of particular importance. Therefore an expert from Seibersdorf Laboratories picked up the proposal of the RADHARD community and provides an overview on “Aspects of Using Radiation Effects Databases”.

Further, five talks present during the session on “Current Activities and Results of COTS Testing” on-going space activities related to radiation and its effects on components and systems by University of Applied Sciences Wiener Neustadt, Graz University of Technology and the Czech Aerospace Research Center, and give an update of the ESA CubeSat project PRETTY and provide news about the ESA project CORHA on Radiation Screening and Verification of RHA Approach of COTS. In the session “Practical Aspects of COTS in Space and RHA Testing” experts discuss in four papers investigations of radiation dose rate effects in modern transistors using shallow trench insulation, radiation effects in complex devices such as SRAM and FPGA, as well as investigation of ionizing radiation shielding of composite materials using the Timepix sensor.

The RADHARD Symposium 2019 is organized by Seibersdorf Laboratories, and supported by the Austrian Research Promotion Agency (FFG), and AUSTROSPACE, in liaison with Graz University of Technology (TUG), University of Applied Sciences Wiener Neustadt (FHWN), and with RADECS Association.

In particular, we would like to thank our sponsors, the AUSTROSPACE and the Austrian Research Promotion Agency (FFG), which enable us to offer again the RADHARD Symposium without participation fee this year.

The RADHARD Symposium is held in two half days, 9th and 10th April 2019. On the evening of the 1st day a come-together dinner is organized at the already well known “Heurigen” location at Gumpoldskirchen.

We wish you interesting days at the RADHARD 2019 Symposium at Seibersdorf Laboratories!

Peter Beck
On behalf of the RADHARD Symposium 2019 Organizing Team

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Program 1st Day: Tuesday, April 9th, 2019

13:00	Registration
14:00	**Welcome Notes by the General Manager** Martina Schwaiger, Seibersdorf Laboratories, Austria
	Welcome Notes by the Head of Austrian Aeronautics and Space Agency Andreas Geisler, Austrian Aeronautics and Space Agency, Austria
14:15	**Introduction and Scope of the Symposium** Peter Beck, Seibersdorf Laboratories, Austria
14:30	**Keynote** **News on Standardization of COTS Testing** Marc Poizat, European Space Agency, ESA
Session:	Space Radiation Environment
15:15	**Space Radiation Environment at LEO, MEO and GEO** Christoph Tscherne, Seibersdorf Laboratories, Austria
16:00	**Coffee Break** Photo of the Participants
Session:	Space Radiation Effects and Radiation Effects Databases
16:30	**Space Radiation Effects to Components and Systems** Michael Wind, Seibersdorf Laboratories, Austria
17:15	**Aspects of Using Radiation Effects Databases** Michael Wind, Seibersdorf Laboratories, Austria
17:35	**Concluding Remarks & Discussions**
17:50	**Closing**
20:00	**Social Dinner „Heuriger“** KRUG - Altes Zechhaus Am Kirchenplatz 1, 2352 Gumpoldskirchen www.alteszechhaus.at T: +43 2252 62247

Program status at the editorial deadline.

Program 2nd Day: Wednesday, April 10th, 2019

08:30	Registration
09:00	**Welcome Notes by ecoplus - The Business Agency of Lower Austria** Rainer Gotsbacher, Technopol Manager Wiener Neustadt, Austria
Session:	Current Activities and Results of COTS Testing
09:15	**Recent and Past CubSat Activity at FH-Wiener Neustadt** Carsten Scharlemann, University of Applied Sciences Wiener Neustadt, Austria
09:35	**COTS Components: Practical Experience in CubeSat Missions** Otto Koudelka, Technical University Graz, Austria
09:55	**Assessment of Space Radiation in LEO Orbit on Czech CubeSat - VZLUSAT-1** Vladimir Daniel, Czech Aerospace Reseach Centre, Czech Republic
10:15	**Concluding the preliminary design Phase: PRETTY results from the Phase B study** Heinrich Fragner, RUAG Space (Vienna), Austria
10:35	**CORHA - Radiation Screening of COTS Components and Verification of COTS RHA Approach** Peter Beck, Seibersdorf Laboratories, Austria
10:55	**Coffee Break** Photo of the Participants
Session:	Practical Aspects of COTS in Space and RHA Testing
11:40	**Dose Rate Effects in MOS Transistors** Varvara Bezhenova, Graz University of Technology, Austria
12:00	**SRAM and Flash-based FPGA testing and mitigation solutions** Luca Sterpone, Politecnico di Torino, Italy
12:20	**Review of radiation effects in GaN HEMTs** Teng Ma, University of Padova, Italy
12:40	**Investigation of Composite Materials for Radiation Shielding using Timepix** Carlos Granja, ADVACAM, Czech Republic
13:00	**Concluding Remarks & Discussions**
13:15	**Lunch Buffet**
14:00	**Laboratory Visits and Networking**
16:00	**Closing**

Program status at the editorial deadline.

Keynote
News on Standardization of COTS Testing

Marc Poizat[1]
[1] European Space Agency, ESA

Abstract

The use of COTS components is increasing on mainstream projects for both cost and performance reasons. However, the use of COTS has its dis-advantages such as traceability, obsolescence, cost increase due to up-screening etc.

An ESA COTS Steering Committee has been set up in 2018 with the following mandate: *"Bring together all ESA stake holders related to COTS based development, COTS end users, testing facilities and standards/specification entities in order to manage the evolution of the use of COTS in a coordinated manner in ESA's current and future programmes, and in support to industrial requests"*.

In this lecture, the basics of radiation hardness assurance will be introduced. Test methods and applicable standards for total ionizing dose, displacement damage and single event effects testing will be presented. The usage of COTS in ESA space programs will be discussed as well as ESA's current approach and timeline on COTS. Considerations and RHA best practices for COTS will be proposed. Application examples will be presented.

References

- ECSS-Q-ST-60-15C: Radiation Hardness Assurance – EEE components
- ECSS-E-HB-10-12A: Calculation of radiation and its effects and margin policy handbook
- ECSS-Q-ST-60C: Electrical, Electronic, Electromechanical (EEE) components
- ESCC22900 (Iss5): Total dose steady-state irradiation test method
- ESCC25100 (Iss2): Single Event Effects Test Method and Guidelines
- NSREC conference 2017 Short Course
- ESCCON conference 2019

Session:
Space Radiation Environment

Space Radiation Environment at LEO, MEO and GEO

Christoph Tscherne[1], Peter Beck[1], Marcin Latocha[1], Michael Wind[1]
[1] Seibersdorf Labor GmbH, Austria

Abstract

Spacecraft in near-Earth orbits are exposed to a complex and harsh radiation environment that poses a great challenge to space mission design. Radiation accelerates the aging of EEE components, eventually leading to a decrease in performance or to a complete loss of functionality [1]. In order to face these challenges, it is necessary to understand the nature and effects of space radiation. The space radiation environments at Low Earth Orbits (LEO), Medium Earth Orbits (MEO) and Geostationary Earth Orbits (GEO) compose of three main types of primary radiation: Solar energetic particles (SEP), galactic cosmic radiation (GCR) and charged particles trapped in the Earth's magnetic field [2, 3]. All three types are of different origin, vary greatly in energy and flux and underlie short-term and long-term variations modulated by the sun's activity [4]. The presentation introduces the different types of orbits and discusses the origin and effects of the space radiation environment at LEO, MEO and GEO in detail. Characteristics of SEP, GCR and trapped particles are described and their influence on mission design and radiation hardness assurance (RHA) is reviewed [5, 6, 7].

References

[1] Poivey, Christian. „Total Ionizing and Non-Ionizing Dose Radiation Hardness Assurance.“ Short Course of NSREC 2017, 17 July 2017, New Orleans. USA. Presentation.
[2] Holmes-Siedle, Andrew G., and Len Adams. Handbook of radiation effects. 2nd ed., Oxford University Press, 2002.
[3] Santin, Giovanni. „Radiation Environments: Space, Avionics, Ground and Below.“ Short Course of RADECS 2017, 2 Oct. 2017, Geneva. Switzerland. Presentation.
[4] Viereck, Rodney. „Space Weather: What is it? How Will it Affect You?“ NOAA Space Environment Center, 2007, Boulder Colorado. USA. Presentation.
[5] ECSS-Q-ST-60-15C. "Radiation hardness assurance – EEE components", October 2012
[6] ECSS-E-ST-10-04C. "Space Environment", November 2008
[7] SPENVIS - The European Space Agency (ESA) Space Environment Information System (SPENVIS), available online at http://swe.ssa.esa.int/; https://www.spenvis.oma.be/

Acknowledgments

We acknowledge the insightful talks and presentations of the lecturers of the RADECS and NSREC short courses and the information provided by SPENVIS, ESA's Space Environment Information System (http://swe.ssa.esa.int/; https://www.spenvis.oma.be/).

Session:
Space Radiation Effects and Radiation Effects Databases

Space Radiation Effects to Components and Systems

Michael Wind[1], Peter Beck[1], Marcin Latocha[1], Christoph Tscherne[1]
[1] Seibersdorf Labor GmbH, Austria

Abstract

Semiconductor devices are pervasively deployed in analog and digital applications for earth and space due to being cheap, small, fast, light weighted, and offering high functionality. When exposed to ionizing radiation semiconductor devices are vulnerable to a variety of damaging mechanisms. Effects due to radiation have been observed and investigated for many decades by now and a lot of insight into the phenomena has been gathered and documented in literature ([1] - [6]). This presentation gives an overview on the major types of radiation effects, i.e. Total Ionizing Dose (TID), Single Event Effects (SEE) and Total Non-Ionizing Dose (TNID) effects. The basic radiation effects are illustrated that occur in electronics when they are exposed to the different radiation sources. Semiconductor parts being scheduled for operation in a radiation environment, e.g. satellite's electronics, require a decent knowledge on their susceptibility to the present radiation environment which raises the need for radiation tests. To assure the significance of such test and the comparability of the results testing is typically performed according to standards ([7] - [9]). Basic information on test procedures and available test standards is given.

References

[1] A. Holmes-Siedle, L. Adams, Handbook of radiation effects, 2nd edition, Oxford University Press, 2002
[2] Proceedings of the Nuclear and Space Radiation Effects Conference (NSREC) Conference, published yearly in the December issue of IEEE-Trans. Nucl. Sci
[3] Proceedings of the Radiation Effects on Components and Systems (RADECS) Conference, published yearly by IEEE.
[4] M. Wind, J. V. Bagalkote, P. Clemens, T. Kündgen, M. Latocha, W. Lennartz, S. Metzger, M. Poizat, Sven Ruge, M. Steffens, P. Beck, Comprehensive Radiation Characterization of Digital Isolators, 16th European Conference on Radiation Effects on Components and Systems (RADECS), Proceedings, 2016
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[7] European Space Component Coordination, Total Dose Steady-State Irradiation Test Method, ESCC Basic Specification No. 22900, issue 5, 2016
[8] MIL-STD-750-F Test Method Standard, Method 1019.5, Steady-State Total Dose Irradiation Procedure, Department of Defense, 2016
[9] European Space Component Coordination, Single Event Effects Test Method and Guidelines, ESCC Basic Specification No. 25100, issue 2, 2014

Aspects of Using Radiation Effects Databases

Michael Wind[1], Peter Beck[1], Marcin Latocha[1], Christoph Tscherne[1]
[1] Seibersdorf Labor GmbH, Austria

Abstract

The success of a space mission is vitally correlated with the radiation hardness of the used electronic parts. Thus, the selection of the built-in parts will decide whether the electronics can withstand the radiation environment of a specific space mission or not. To assure for a proper part selection radiation hardness assurance measures need to be undertaken that are executed according specific standards [1]. According to this standard, Radiation Hardness Assurance (RHA) consists of all activities undertaken to ensure that the electronics of a space system perform to their design specifications after exposure to the space environment. A decent RHA that is performed on all the used electronic parts is costly in terms of time and money and is a burden especially for low-cost space missions that are using Components-Off-The-Shelf (COTS) parts [2].

In this light the use of existing knowledge, i.e. test and flight heritage, is of advantage to efficiently reduce development time and costs. However, the existing knowledge needs to be made available and conditioned for use – which could be realized by the usage of radiation effects databases.

Within the scope of this lecture, we present available radiation effects databases [3] - [6]. The structure of the databases are described and their differences are discussed. Useful characteristics of a database are reflected. Pro and Cons of database usage are discussed.

References

[1] ECSS-Q-ST-60-15C, Radiation Hardness Assurance – EEE Components, ECSS, Oct 2012

[2] M. Poizat, A. Zadeh, C. Poivey, R. Walker, Radiation Hardness Assurance for Commercial-Off-The-Shelf (COTS) components for Small Satellites, RADHARD Symposium 2018, https://www.seibersdorf-laboratories.at/en/radhard/archive/2018-radhard-symposium, ISBN (Print) 978-3-902780-12-6, ISBN (Ebook) 978-3-902780-13-3, Editor: Peter Beck, Seibersdorf Labor GmbH, 2444 Seibersdorf, Austria, Publisher: Seibersdorf Laboratories Publishing, Austria, April 2018.

[3] ESCIES Radiation Database, https://escies.org/webdocument/showArticle?id=982, last visited 2nd April 2019

[4] CERN Radiation Test Base, http://radwg.web.cern.ch/content/radiation-test-database, last visited 2nd April 2019

[5] GSFC Radiation Data Base, https://radhome.gsfc.nasa.gov/radhomraddatabase/raddatabase.html, last visited 2nd April 2019

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Session:
Current Activities and Results of COTS Testing

Recent and Past CubSat Activity at FH-Wiener Neustadt

C. Scharlemann[1], R. Schnitzer[1], A. Sousanis[1], K. Repän[1], C. Obertscheider[1]
[1] University of Applied Sciences Wiener Neustadt, Austria

Abstract

Originally, CubeSats have been developed as educational instruments but during the last 10 years it was shown that this concept was also very useful for science, Earth observation, and, as proven by the NASA mission INSIGHT, also for space exploration. However, the two Nanosatellites, which have been flown with INSIGHT are small as CubeSats but, in terms of costs, they are significantly more expensive than a standard university CubeSat.

The next logical step is to develop CubeSats suitable for space exploration but within the cost frame of universities. If successful, this would open a new chapter in the already very successful CubeSat story. To achieve this challenging goal, several important advances are necessary of which the two most important ones are:

- Implementation of a propulsion system with significant dv capability
- Introduction of subsystems with sufficient lifetime and radiation resistance

For this reason, the mission CLIMB was developed. The technology of CLIMB is largely based on the successful mission PEGASUS of the Fachhochschule Wiener Neustadt. Similar as PEGASUS, CLIMB will be a 3U and it will utilize several subsystems, which have been developed for PEGASUS. However, the mission concept will be very different. By using an advanced propulsion system, the satellite will start from a Low Earth Orbit (LEO) and then slowly increase its apogee up to 1 000 to 1 500 km.

The goal of this effort is to reach the inner layer of the Van Allen Belt (starting roughly at an altitude of 1 000 km). Mission analysis has shown that it will take about one year to increase the apogee from an initial value of ~500 km up to 1 000 km. During this time, measurements of the accumulated radiation dose and the magnetic field will be conducted.

After having reached the final apogee altitude and conducted all the desired measurements, the spacecraft will start to decrease its perigee altitude. This will ensure that the spacecraft is removed from LEO and, according to the Austrian space law, does not constitute a danger for future spacecraft missions in similar orbits.

In order to facilitate the survival of the satellite during the 2 year mission and the increased radiation it will accumulate, all sensitive electronic parts of CLIMB will be radiation tested. Initial testing at the TEC-Laboratory of the Seibersdorf Laboratories have already been conducted and more are planned with SEE facilities.

COTS Components: Practical Experience in CubeSat Missions

Otto Koudelka[1], Rainer Kuschnig[1], Manuela Wenger[1], Andreas Hörmer[1], Reinhard Zeif[1]
[1] Institute of Communication Networks and Satellite Communications
Graz University of Technology, Austria

Abstract

CubeSat missions make use of industry-grade instead of radiation-hardened electronics components for cost reasons. The other rationale is that the mission duration is typically short and higher risks can be taken.

In February 2013 the first Austrian satellite TUGSAT-1/BRITE-Austria and its sister satellite UniBRITE were launched. The design lifetime was two years. Now the satellites are successfully in orbit for more than six years and exhibit an excellent health status. The most critical components are the CCD sensors of the telescopes which show natural degradation due to radiation. Due to an image processing technique, well known in astronomy, called chopping, the effects could be minimised and the quality of the science data is still very good. Analyses show that the spacecraft will be able to produce science data meeting the requirements for at least two more years.

The Institute is responsible for two ESA nanosatellite missions: OPS-SAT and PRETTY. OPS-SAT has the goal to demonstrate new operational concepts and to carry out on-board RF and optical communications, camera, attitude control and hardware/software experiments. PRETTY is concerned with altimetry and dosimetry. A special GNSS receiver developed by RUAG and TU Graz is carrying out passive reflectometry. A novel dosimeter measuring the radiation environment is developed by Seibersdorf Laboratories.

For both missions TU Graz developed a high-performance on-board processor and a software-defined radio front-end based on COTS components. They were successfully tested for total dose at the Co^{60} facility at ESTEC and for SEUs at the Paul Scherrer Institute.

The paper will present performance results of the BRITE mission and discuss design considerations as well as operational procedures to ensure spacecraft safety.

Assessment of Space Radiation in LEO Orbit on Czech CubeSat - VZLUSAT-1

Vladimír Dániel[1], Tomas Baca[2], Petr Svoboda[1], Martin Jilek[2], Carlos Granja[3], Lenka Mikulickova[4]
[1] Czech Aerospace Research Centre, Prague, Czech Republic
[2] Czech Technical University, Faculty of Electrical Engineering, Prague, Czech Republic
[3] Advacam, Prague, Czech Republic
[4] TTS, Prague, Czech Republic

Abstract

A miniaturized X-ray telescope operating in LEO orbit since 2017 on board the 2U CubeSat VZLUSAT-1 is equipped with the pixel Timepix detector as focal plane detector [1]. Besides the primary observation of X-rays, the detector registers also all charged particles including secondary radiation from the CubeSat structure. In addition, several semiconductor diodes are also on board to register the integrated radiation field behind composite materials for radiation shielding. Timepix data are collected in high-resolution (full frames) but mostly in reduced (pixel-binned) format. For the later, a conversion methodology has been developed to extract more complete radiation environment and dosimetry results from the binned data [2]. Earth-wide maps of the radiation field can be thus generated on regular basis. Results produced include particle-type resolving power. Results are compared and validated with detailed full-res Timepix data. Results from the diodes on board are included.

References

[1] T. Baca, M. Platkevic, J. Jakubek, et al., Miniaturized X-ray telescope for VZLUSAT-1 nanosatellite with Timepix detector, J. of Instrumentation 11 (2016) C10007.

[2] T. Baca, M. Jilek, I. Vertat, et al., Timepix in LEO orbit on board the VZLUSAT-1 nanosatellite: 1-year of space radiation dosimetry measurements, J. of Instrumentation JINST 13 (2018) C11010.

Acknowledgments

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Concluding the preliminary design Phase: PRETTY results from the Phase B study

H. Fragner[1], P. Beck[2], A. Dielacher[1], A. Hörmer[3], O. Koudelka[3], C. Tscherne[2], M. Wenger[3], M. Wind[2]
[1] RUAG Space GmbH, Austria
[2] Seibersdorf Labor GmbH, Seibersdorf, Austria
[3] Graz University of Technology, IKS, Austria

Abstract

As announced last year [1] in the frame of the RADHARD Symposium, the consortium RUAG Space GmbH, TU Graz and Seibersdorf Laboratories have now finalized the Phase B study of a CubeSat mission by conducting a successful PDR under supervision of ESA.

Within this Phase B study the platform and the payload design was substantially advanced. The platform consists of several COTS components which have been selected in the preliminary design phase. Most of them have flight heritage from other missions with exception of the horizon detector used for attitude determination. The need for such a detector became evident due to the requirements put on the mission by the passive reflectometer and its operation during eclipse. The detector is currently developed by GomSpace and will provide in combination with the magnetometers the required determination accuracy.

The implementation of the passive reflectometer payload has been significantly advanced and the SW and firmware is in a shape to accurately predict the reflection points and to set up the PACO FPGA with the correct parameters. The implemented earth model allows distinguishing between sea and land surface and also includes a height mapping.

The original plan for the dosimeter was to measure the TID by means of RADFETs. In the course of the Phase B study the idea for the dosimeter has been substantially advanced and the design baseline of the dosimeter now foresees two different sensors for TID measurements: The RADFET and the relatively new floating gate dosimeter (FGDOS). Both sensors will be available on board of PRETTY in an unshielded and a shielded configuration. The comparison of the measurement results under real space radiation environment will allow valuable insights in the characteristics of these two measurement devices.

Another improvement of the dosimeter is the implementation of a LET spectrometer, which allows characterizing the radiation environment based on histograms obtained by counting SEE occurrences within a certain amplitude range. The LET spectrometer sensor is a single PIN diode, which will have a certain angular dependency of the LET by a single particle due to geometry of the p-n barrier. Extensive simulations have been performed in order to characterize this angular dependency and trade it off against other concepts, e.g. dual sensor geometry.

References

[1] H. Fragner, P. Beck, A. Dielacher, O. Koudelka, C. Tscherne, M. Wenger, M. Wind, „PRETTY: Passive Reflectometry based on the Interferometric Method and Dosimetry Measurements", RADHARD Symposium 2018, https://www.seibersdorf-laboratories.at/en/radhard/archive/2018-radhard-symposium, ISBN (Print) 978-3-902780-12-6, ISBN (Ebook) 978-3-902780-13-3, Editor: Peter Beck, Seibersdorf Labor GmbH, 2444 Seibersdorf, Austria, Publisher: Seibersdorf Laboratories Publishing, Austria, April 2018.

Acknowledgments

The Phase B study for the PRETTY mission has been funded by ESA GSTP Programme.
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CORHA - Radiation Screening of COTS Components and Verification of COTS RHA Approach

Peter Beck[1], Marta Bagatin[2], Simone Gerardin[2], Marcin Latocha[1], Alessandro Paccagnella[2], Christoph Tscherne[1], Michael Wind[1], Marc Poizat[3]
[1] Seibersdorf Labor GmbH, Austria
[2] University of Padova, Italy
[3] European Space Agency, ESA

Abstract

Small satellites, such as CubeSat, have become a popular and cost effective manner of accessing space [1]. The increased interest in flying small satellite missions and initiation of the European Space Agency, ESA projects to improve reliability of CubeSat has resulted in an increased utilization of COTS components. Besides, COTS are not only used for small satellite applications, but there is an increase in the use of COTS also on mainstream missions. Therefore, ESA initiated a study on radiation screening of COTS components and verification of COTS Radiation Hardness Assurance (RHA) approach (CORHA). The CORHA project is coordinated by the Seibersdorf Laboratories (SL) and is performed in collaboration with the University of Padova (UPD). ESA is making use of COTS components and popular examples are, amongst others, FPGAs and memory devices (FLASH, SDRAMs, DDR2, etc.) [1]. This increase in the use of COTS components is owed to the fact that COTS often have superior performance compared to space qualified components and might work with lower resource requirements (e.g. power consumption). Although COTS components performance capabilities often outperform traditional space qualified components, there are limitations strongly complicating their use for space applications. Limitations inlcude lack of traceability, packaging constraints, radiation sensitivity and questions regarding board level and component level testing, rapid obsolescence, cost increase due to up-screening and others.

According to the ECSS Radiation Hardness Assurance standard ECSS-Q-ST-60-15C standard [2] Radiation Hardness Assurance consists of all activities undertaken to ensure that the electronics of a space system perform within their design specifications after exposure to the space environment. In this context, RHA deals with the environment assessment, the part selection, the part testing, the spacecraft layout, the radiation tolerant design as well as with the mission, system, and subsystem requirements. In principle the ECSS-Q-ST-60-15C [2] that is embedded in the product assurance standard for Commercial EEE Components ECSS-Q-ST-60-13C [3] as an applicable document does also apply to COTS devices. However, the application of ECSS-Q-ST-60-15C to small satellites that are flying COTS devices may not be practical for technical and/or financial reasons. The RHA process for such missions is therefore often defined on a case-by-case basis. Hereby the RHA for COTS is commonly based on risk management in terms of acceptance of a given risk and not on risk avoidance [1].

As a first baseline, knowledge of the radiation environment is of crucial importance for a tailored RHA-approach. Various software tools are existing (e.g. SPENVIS [4], OMERE [5], etc.) that provide engineers with meaningful radiation environment data. These data are used to perform model calculations to determine TID and TNID dose levels inside the satellite at the location of the EEE components. With a well-known radiation environment, relevant hazards are identified. A detailed evaluation of the hazards serves as a good baseline for part selection and also for the definition of the radiation tests that need to be performed. A number of radiation effects may be mitigated by design. However, these mitigation techniques need to be fully understood as they may create additional problems [1]. Again, to achieve and implement effective mitigation a good knowledge of the radiation environment and associated potential radiation effects is necessary. There are numerous mitigation techniques that may be applied to increase the radiation performance of an equipment or system. Mitigation techniques comprise methods such as single event latch-up protection, soft error rate mitigation, use of extra shielding or positioning of sensitive parts in more shielded areas of the spacecraft. Within the RHA process, the design is critically assessed to identify risks and to decide what devices need to be tested.

A definition of dose level limits for TID and LET thresholds for SEE may be used as a criterion whether to perform testing of a specific device or not. The criteria for part selection should comprise the use of technologies that are less sensitive and the selection of components being testable. Available test data and flight heritage should be considered for part selection. Board-level testing might be an effective tool. The major advantages of board level testing are the reduced test time and the fact that tested parts are exposed in application conditions. The advantages come at the cost of reduced observability; i.e. the test can be considered as go / no go tests. Also, the results cannot be reused for another application. Board level proton testing allows for SEE testing on entire boards as large-area beams are available. Also, high energy protons have a good penetration depth. However, proton SEE testing has major limitations that are small sample sizes, difficulties in identifying the SEE error mode, complicated test sequence and that testing is only applicable for the specific application. Also, the fluence needed to get sufficient SEE statistics may result in high TID and TNID dose levels.

Using COTS offers great benefits, however they come also with some serious disadvantages. Thus, the use of COTS components requires a solid understanding of the relevant processes and must be based on a comprehensive risk management. In this context it is of crucial importance that RHA for COTS is implemented already in the early phases of the project development and that there is an awareness for the need of a suitable risk management strategy. Within the scope of a critical system analysis, a large number of radiation effects may be avoided by effective mitigation techniques. Nevertheless, irradiation testing of COTS devices is important in particular for critical devices that need to be properly identified. Currently no universal RHA standards are available that are dedicated to COTS. For this reason, RHA for COTS is handled on a case-to-case base and thus is realized as tailored RHA solution for each specific application. The unfavorable situation of lacking dedicated RHA standards for COTS needs to be addressed promptly by providing standards that regulate testing of COTS components to facilitate the achievement of significant test results.

The objectives of the CORHA study are to (1) screen COTS components, (2) prepare and execute radiation test campaigns, (3) and propose an ad-hoc RHA approach for COTS components. The CORHA team will evaluate COTS technologies available on the market with respect to their TID response and to their susceptibility for SEE. During the presentation, we show a set of proposed candidates for further radiation hardness investigations. Further, based on the gathered data, review of existing standards and the most recent scientific and technical literature, we outline an ad-hoc RHA approach for COTS components, which will be investigated in more detail in the CORHA study.

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Session:
Practical Aspects of COTS in Space and RHA Testing

Dose Rate Effects in MOS Transistors

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Abstract

Enhanced low dose rate sensitivity (ELDRS) has been a subject as well as a concern for radiation hardness assurance testing over several decades, in particular because of the underestimation of the effects in the accelerated testing [1]. ELDRS is prominent in bipolar transistors, where more pronounced gain reduction is observed at low dose rate. This phenomenon is related to thick layers of soft oxides [1]. Such oxides are also used in modern CMOS process nodes as shallow trench insulation. Thus the differences in oxide space charge build-up at low and high dose rates are worth considering also for the MOS transistors [2]. In this context, the to-date reported results on dose rate effects in MOS transistors over several CMOS process nodes will be reviewed [2, 3]. Also, our recent experimental results will be presented. The considerations for TID testing of MOS transistors will be discussed on an example of MOS transistor characteristics irradiated under two different dose rates.

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SRAM and Flash-based FPGA testing and mitigation solutions

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Abstract

Radiation effects on VLSI technology are provoked when radiation particles such as neutrons, protons or heavy ions hit a sensitive region of the integrated circuits. Due to the progressive technology scaling, VLSI devices are becoming, more and more vulnerable to Single Event Effects (SEEs) and are subject to cumulative ionizing damage known as Total Ionization Dose (TID). This presentation will firstly describe the state-of-the-art methodologies used for analyzing the impact of radiation effects on modern SRAM and Flash-based FPGAs by means of Computer Aided Design (CAD) tools and secondly, it will describe the state-of-the-art CAD design techniques for their mitigation.

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Review of radiation effects in GaN HEMTs

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Abstract

Gallium Nitride-based high electron mobility transistors (HEMTs) are promising for space-based high-frequency, high-power and high-temperature electronic applications because of their high performance and resistance to total ionizing dose (TID) effects and displacement damage in typical space radiation environments. The response of GaN-based HEMT to radiation damage is a function of radiation type, dose and energy, as well as the carrier density, impurity content and dislocation density in the GaN. We review data on the radiation resistance of GaN-based devices to different types of radiation and discuss the primary degradation mechanisms. Proton and electron irradiation damage in HEMTs creates positive threshold voltage shifts due to a decrease in the two dimensional electron gas concentration resulting from electron trapping at defect sites, as well as a decrease in carrier mobility and degradation of drain current and transconductance, while 60Co γ-ray irradiation leads to much smaller changes in HEMT drain current relative to the other forms of radiation. In addition, some of the important factors that could affect the electrical characteristics after the γ-ray irradiations include the presence of a passivation layer, the metals used in the gate and Ohmic contacts, the native defect density in the barrier and GaN layers, and the gate length and gate width. Moreover, GaN-based HEMTs did not exhibit enhanced low-dose-rate sensitivity and threshold voltage shifts and transconductance degradation are larger at high dose rate than at low dose rate.

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Investigation of Composite Materials for Radiation Shielding using Timepix

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Abstract

We study the radiation response and shielding effectiveness of composite materials customized for spacecraft and aerospace applications. We use different types of radiations at selected fluxes, energies and geometry. Measurements were performed in defined fields with X-rays (RTG units, broad spectrum up to 150 keV), gamma rays (discrete spectrum, ^{60}Co source – 1173 keV, 1333 keV), electrons (10–20 MeV) and protons (10–30 MeV). The technique measures in detail the transmitted radiation field behind the targets which also contains induced secondary radiation – see Fig. 1a. Changes in the flux, dose rate, composition, spectrum, LET spectra, spatial distribution and beam size/ profile are registered – see Fig. 1b,c,d. Such detailed studies are made possible by the high-resolution position- and spectral-sensitive semiconductor pixel detector Timepix [1-3]. We used the detector in a miniaturized camera Minipix-Timepix architecture (full size 75mm × 16mm × 10mm). Samples studied included composite materials and glass-based samples as well as conventional shielding materials (Al, plastic, Copper, Lead).

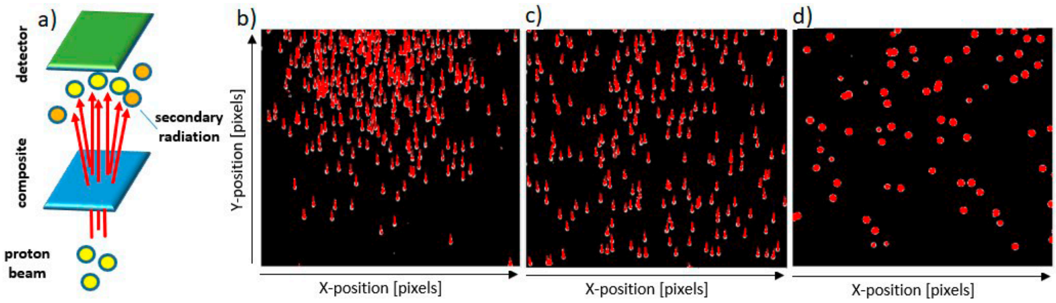

Figure 1: (a) Illustration of principle of technique. Radiation field at the detector position for (b) bare/free beam, i.e. no target, and for two selected samples (c, d). Full sensor size shown (14mm×14mm). Data registered by a MiniPix-Timepix 300 µm Si detector for 31 MeV protons produced at the NPI Prague Cyclotron.

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List of Lecturers

Beck Peter, Seibersdorf Laboratories, Austria
CORHA - Radiation Screening of COTS Components and Verification of COTS RHA Approach

Bezhenova Varvara, Graz University of Technology, Austria
Dose Rate Effects in MOS Transistors

Fragner Heinrich, RUAG Space (Vienna), Austria
Concluding the preliminary design Phase: PRETTY results from the Phase B study

Daniel Vladimir, Czech Aerospace Reseach Centre, Czech Republic
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Tscherne Christoph, Seibersdorf Laboratories, Austria
Space Radiation Environment at LEO, MEO and GEO

Wind Michael, Seibersdorf Laboratories, Austria
Space Radiation Effects to Components and Systems

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Aspects of Using Radiation Effects Databases

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