NSREC 2021 Virtual

July 16-23, 2021

www.nsrec.com
www.ieee.org

As of May 7, 2021

Tentative NSREC VIRTUAL SCHEDULE
Friday, July 16 - Friday, July 23, 2021
(Times listed as EDT)

On-Demand Recordings and Exhibit Hall
Open July 19 - August 15, 2021

Short Course On-Demand,
Friday, July 16, 8:00 AM to Monday, July 19, 8:00 AM EDT
Short Course On-Demand Resumes July 23 – August 15

15 Minutes	**Introduction: Short Course,** Dr. Marta Bagatin, Chair	**Pre-recorded & ON DEMAND for 72 hours, starting at 8:00 AM, Friday and ending at 8:00 AM, Monday EDT**
75 Minutes	**Part 1: HARDENING TECHNIQUES FOR DIGITAL CIRCUITS,** Dr. Balaji Narasimham	
75 Minutes	**Part 2: HARDENING TECHNIQUES FOR IMAGE SENSORS,** Dr. Vincent Goiffin	
75 Minutes	**Part 3: HARDENING TECHNIQUES FOR ANALOG AND MIXED-SIGNAL CIRCUITS,** Dr. Daniel Loveless	
75 Minutes	**Part 4: SYSTEM-LEVEL HARDENING - WHAT COULD GO WRONG, AND HOW TO MAKE IT RIGHT,** Kay Chesnut	

Monday, July 19

8:00 - 9:00	**DEDICATED TIME** **Session A - Basic Mechanisms of Radiation Effects,** Marc Gaillardin; **Session B - Single Event Effects: Mechanisms and Modeling,** Gilles Gasiot ***Note: View Sessions A and B before Live Q and A on Tuesday at 11:30 EDT***	**Pre-Recorded *On Demand thru August 15***
8:00 - 9:00	**DEDICATED TIME** **Poster and Data Workshop PREVIEW. (Viewing is available at any time through August 15.) (Authors are not present for the Posters and Data Workshop).** ***Note: View Posters in preparation for Poster Session on Tuesday at 12:30 EDT***	**Static Display**
9:00 - 9:10	**Opening Remarks,** Steven McClure, Chair	**Pre-Recorded**
9:10 - 9:35	**Awards,** Janet Barth, Radiation Effects Steering Group Chair	
9:35 - 9:45	**Technical Session Introduction:** Brian Sierawski, Technical Program Chair	
9:45 - 11:00	**DEDICATED TIME** **Session A and B Orals, Posters, and Data Workshop Open for Viewing (Authors are not present for the Posters and Data Workshop).** ***Note: View Posters before Live Poster Session, Tuesday 12:30 – 14:30 EDT***	**Pre-Recorded & Static Display *On Demand thru August 15***
11:00 - 11:30	**BREAK – GatherTown**	**LIVE**
11:00 – 12:30	**Visit the Exhibits - Exhibit Hall (Exhibits will be staffed)**	**LIVE**
11:30 – 12:30	**Short Course Q and A:** Marta Bagatin and Short Course Presenters	**LIVE CHAT**
12:30 – 15:30	**Industrial Exhibit Reception & Webinars – Exhibit Hall (Exhibits will be staffed)**	**LIVE Attend Webinars – Access from Exhibitor Booths**
12:30 – 12:50	Webinar Company, Title – two webinars per time slot	
12:50 – 13:10	Webinar Company, Title – two webinars per time slot	
13:10 – 13:30	Webinar Company, Title – two webinars per time slot	
13:30 – 13:50	Webinar Company, Title – two webinars per time slot	
13:50 – 14:10	Webinar Company, Title – two webinars per time slot	
14:10 – 14:30	Webinar Company, Title – two webinars per time slot	
14:30 – 14:50	Webinar Company, Title – two webinars per time slot	
14:50 – 15:10	Webinar Company, Title – two webinars per time slot	
15:10 – 15:30	Webinar Company, Title – two webinars per time slot	

Tentative NSREC VIRTUAL SCHEDULE
Friday, July 16 - Friday, July 23, 2021
(Times listed as EDT)

On-Demand Recordings and Exhibit Hall
Open July 19 - August 15, 2021

Tuesday, July 20

8:00 - 9:00	**DEDICATED TIME** **Session C - Radiation Effects in Devices and Integrated Circuits,** John Bird ***Note: View Session C before Live Q and A on Wednesday at 11:30 EDT***	**Pre-Recorded** ***On Demand thru August 15***
8:00 - 9:00	**DEDICATED TIME** **Poster and Data Workshop Preview. (Viewing is available at any time through August 15.) (Authors are not present for the Posters and Data Workshop).** ***Note: View Posters in preparation for Poster Session on Tuesday at 12:30 EDT***	**Static Display**
9:00 - 10:00	**Young Professionals Talk** **Completing the Young Professional Stage – Looking Back, and Where to Go from Here?** Dr. Rubén García Alía	**Pre-Recorded & LIVE CHAT**
10:00 – 11:00	**Invited Talk: How I Met Steve,** Eric Donovan, PhD	**Pre-Recorded**
11:00 - 11:30	**BREAK – GatherTown**	**LIVE**
11:00 – 11:30	**Visit the Exhibits - Exhibit Hall (Exhibits will be staffed)**	**LIVE**
11:30 – 12:00	**Live Q and A for Session A**	
12:00 – 12:30	**Live Q and A for Session B**	
12:30 – 14:30	**Poster Session with Introduction:** Ted Wilcox: **GatherTown.** ***Note: Presenters will be available for questions in real time.***	
14:30 – 15:30	**Visit the Exhibits & Exhibit Webinars – Exhibit Hall (Exhibits will be staffed)**	**LIVE** **Attend Webinars – Access from Exhibitor Booths**
14:30 – 14:50 14:50 – 15:10 15:10 – 15:30	Webinar Company, Title – two webinars per time slot Webinar Company, Title – two webinars per time slot Webinar Company, Title – two webinars per time slot	

Wednesday, July 21

8:00 - 9:00	**DEDICATED TIME** **Session D – Hardness Assurance Technologies, Modeling, and Testing,** Amanda Bozovich; **Session E – Single-Event Effects: Devices and Integrated Circuits,** Nadia Rezzak ***Note: View Sessions D and E before Live Q and A on Thursday at 11:30 EDT***	**Pre-Recorded** ***On Demand thru August 15***
8:00 - 9:00	**DEDICATED TIME** **Poster and Data Workshop Preview. (Viewing is available at any time through August 15.)**	**Static Display**
9:00 - 10:00	**NSREC Diversity Panel -** *NSREC Listens: A Community Conversation around Diversity, Equity, and Inclusion*	**PANEL & LIVE CHAT**
10:00 – 11:00	**DEDICATED TIME** **Sessions D and E Orals and Data Workshop Open for Viewing (Authors are not present for the Data Workshop).** ***All of these will now be on demand through August 15.***	**Pre-Recorded & Static Display** ***On Demand thru August 15***
11:00 - 11:30	**BREAK – GatherTown**	**LIVE**
11:00 – 12:30	**Visit the Exhibits - Exhibit Hall (Exhibits will be staffed)**	**LIVE**
11:30 – 12:30	**Live Q and A for Session C**	
12:30 – 14:30	**NSREC Social – GatherTown**	

Tentative NSREC VIRTUAL SCHEDULE
Friday, July 16 - Friday, July 23, 2021
(Times listed as EDT)

On-Demand Recordings and Exhibit Hall
Open July 19 - August 15, 2021

Thursday, July 22

8:00 - 9:00	**DEDICATED TIME** **Session F - Dosimetry,** Arto Javanainen; **Session G - Radiation Hardening by Design,** Li Chen ***Note: View Sessions F and G before Live Q and A on Friday at 11:30 EDT***	**Pre-Recorded** ***On Demand thru August 15***
8:00 - 9:00	**DEDICATED TIME** **Poster and Data Workshop Preview. (Viewing is available at any time through August 15.)**	**Static Display**
9:00 – 10:00	**EXHIBIT WEBINARS – Exhibit Hall (Exhibits will be staffed)**	**LIVE** **Attend Webinars – Access from Exhibitor Booths**
9:00 – 9:20 9:20 – 9:40 9:40 – 10:00	Webinar Company, Title – two webinars per time slot Webinar Company, Title – two webinars per time slot Webinar Company, Title – two webinars per time slot	
10:00 – 11:00	**Invited Talk: LIGO: The Journey of Detecting Gravitational Waves and the Start of a New Astrophysics Field,** Dr. Anamaria Effler	**Pre-Recorded**
11:00 - 11:30	**BREAK – GatherTown**	**LIVE**
11:00 – 11:30	**Visit the Exhibits - Exhibit Hall (Exhibits will be staffed)**	**LIVE**
11:30 – 12:00	**Live Q and A for Session D**	
12:00 – 12:30	**Live Q and A for Session E**	
12:30 – 14:30	**Radiation Effects Data Workshop Session with Introduction:** Helmut Puchner **– GatherTown** ***Note: Presenters will be available for questions in real time.***	**Pre-Recorded & LIVE CHAT**
14:30 – 15:30	**Visit the Exhibits & Exhibit Webinars – Exhibit Hall (Exhibits will be staffed)**	**LIVE** **Attend Webinars – Access from Exhibitor Booths**
14:30 – 14:50 14:50 – 15:10 15:10 – 15:30	Webinar Company, Title – two webinars per time slot Webinar Company, Title – two webinars per time slot Webinar Company, Title – two webinars per time slot	

Friday, July 23

8:00 - 9:00	**DEDICATED TIME** **Session H - Terrestrial and Space Environments,** Alex Hand; **Session I – Photonic Devices and Integrated Circuits,** Scott Davis ***Note: View Sessions H and I before Live Q and A on Friday at 12:15 EDT***	**Pre-Recorded** ***On Demand thru August 15***
9:00 - 10:00	**Women in Engineering Talk: How Can Space Radiation Help Us To Understand the Universe?,** Dr. Alessandra Menicucci	**Pre-Recorded & LIVE CHAT**
10:00 – 11:00	**DEDICATED TIME** **Sessions F,G,H, and I Orals (Authors are not present for the Data Workshop).** ***All of these will now be on demand through August 15.***	**Pre-Recorded & Static Display** ***On Demand thru August 15***
11:00 - 11:30	**BREAK – GatherTown**	**LIVE**
11:30 – 11:45 11:45 – 12:00	**Live Q and A for Session F** **Live Q and A for Session G**	**LIVE CHAT**
12:30 – 12:45 12:45 – 13:00	**Live Q and A for Session H** **Live Q and A for Session I**	
13:00 – 14:30	**RADIATION EFFECTS COMMITTEE ANNUAL OPEN MEETING**	

Chairman's Invitation

"It is my great pleasure to invite you to attend the IEEE NSREC 2021. This year's conference will again be held in a world-wide online format. While we are beginning to see the "light at the end of the tunnel" with respect to the COVID-19 Pandemic, too many uncertainties remain to hold an in-person conference in our time frame. With both your safety and your ability to travel in mind, our conference committee is designing an online format that best assures the conference is both technically informative, easy to navigate, and provides a personally interactive experience. These continue to be profound times, but we are confident that the program will be well worth it! I would like to thank the many volunteers, supporters, staff, and exhibitors for their important contributions to making the NSREC 2021 conference a great success. Looking forward to "see you" in the virtual conference venue."

Steve McClure
NSREC 2021 General Chair
Jet Propulsion Laboratory

On behalf of the Institute of Electrical and Electronics Engineers (IEEE), its Nuclear and Plasma Sciences Society (NPSS), the Radiation Effects Steering Group (RESG) and the 2021 Nuclear and Space Radiation Effects Conference (NSREC) committee and volunteers, it is my pleasure to invite you to attend the 58th NSREC to be held July 17-23, 2021 in a world-wide interactive virtual setting.

As I had stated in my last letter, due to the uncertainties in planning for and holding live in-person events, we had been looking at all the possible alternatives should this not be possible. After much deliberation, the conference committee decided to hold the conference in an interactive virtual setting and release our in-person venue to be enjoyed for a latter year.

As is customary, the conference will begin with a Short Course "Challenges and Opportunities for Radiation Hardening in Advanced Technologies" organized by **Marta Bagatin**, Padova University. The course consists of four lectures given by subject matter experts. An extensive set of written notes (that can be downloaded) will be a useful study guide and a valued technical reference.

The Technical Program Chair, **Brian Sierawski**, Vanderbilt University, along with his technical committee, have recruited abstracts for presentation and the review process is presently in progress. A very useful Radiation Effects Data Workshop will be part of the program. Brian will have engaging guest speakers to give general interest presentations as part of the schedule.

Larisa Milic, EMPC, is formulating plans for a Virtual Industrial Exhibit and Exhibitor Webinars. The Virtual Exhibits will allow one-on-one discussions between attendees and exhibitors in areas such as radiation survivable electronics, test resources, engineering services, equipment, and modeling.

Local Arrangements Chair, **Michael Trinczek**, TRIUMF, has found his job has changed significantly since our change in venue. He is working with the committee to ensure we have a conference which strives to maintain the social interactions that are an essential part of our community.

I, along with the committee members mentioned above and the remainder of the NSREC 2021 Conference Committee, including Publicity Chair **Teresa Farris** (Archon-LLC), Finance Chair **Greg Allen** (JPL), Awards Chair **Jeff Black** (Sandia), Web Developer **Dolores Black** (Sandia), Poster Chair **Ted Wilcox** (NASA GSFC) and Radiation Effects Data Workshop Chair **Helmut Puchner** (Infineon), welcome you to our virtual venue.

Visit us on the web at:
www.nsrec.com

Short Course Program

CHALLENGES AND OPPORTUNITIES FOR RADIATION HARDENING IN ADVANCED TECHNOLOGIES

IEEE NSREC 2021 VIRTUAL SHORT COURSE

The IEEE NSREC 2021 Short Course will be available on-demand for 72 hours starting 8:00 EDT Friday, July 16 and ending at 8:00 EDT Monday, July 19. It will also be available on-demand from July 23 through August 15 for registered attendees. A live Q&A session will be held with the lecturers on Monday, July 19 from 11:30 to 12:30 EDT. Questions for this session will be selected from questions provided by "chat" during the lectures.

The Short Course Notes will be available for download by registered attendees. Please remember that the Short Course material has an IEEE copyright and is intended for the use of the attendee.

SHORT COURSE INTRODUCTION
Dr. Marta Bagatin, *Padova University*

PART I - HARDENING TECHNIQUES FOR DIGITAL CIRCUITS
Dr. Balaji Narasimham, *Broadcom*

PART II - HARDENING TECHNIQUES FOR ANALOG AND MIXED-SIGNAL CIRCUITS
Dr. Daniel Loveless, *University of Tennessee at Chattanooga*

PART III - HARDENING TECHNIQUES FOR IMAGE SENSORS
Dr. Vincent Goiffon, *ISAE-SUPAERO, University of Toulouse*

PART IV - SYSTEM-LEVEL HARDENING - WHAT COULD GO WRONG, AND HOW TO MAKE IT RIGHT
Kay Chesnut, *Raytheon Technologies*

EXAM (available online only for students requesting CEU credit)

Short Course attendees will receive an electronic copy of the 2021 Short Course Notes.

Short Course

COURSE DESCRIPTION

A short course, *"Challenges and Opportunities for Radiation Hardening in Advanced Technologies"*, will be presented at the 2021 IEEE Nuclear and Space Radiation Effects Conference. Semiconductor technology evolution has led to circuits that are more vulnerable to some radiation effects, while mitigating others. Choosing the most suitable technique to harden electronics against radiation and finding the right tradeoff between protection and performance penalty, is crucial to design effective and reliable space or safety-critical systems.

The short course is organized into four sections, all featuring introductory material and advanced topics, with an emphasis on radiation hardening. The first section addresses hardening for digital circuits, with emphasis on single-event effects, spanning from traditional techniques to recent developments in novel technologies. The second part focuses on hardening for analog and mixed-signal circuits, discussing layout and circuit-level approaches for the mitigation of single-event and total ionizing dose effects. The third section illustrates hardening in imagers, but includes solutions applicable to other ASICs: it is centered on total dose effects mitigation and briefly covers also ultra-high-dose applications. The final course deals with system-level approaches, providing case studies, lessons learnt, and solutions for the use of commercial components in spacecraft electronics. More detailed descriptions of each lecture are provided below. The topics covered should benefit people new to the field as well as experienced engineers and scientists, by providing up-to-date material and insights.

The short course is intended for radiation effects engineers, component specialists, system designers, and other technical and management personnel involved in developing reliable systems designed to operate in radiation environments. It provides a unique opportunity for IEEE NSREC attendees to benefit from the expertise of excellent instructors, along with a critical review of state-of-the-art knowledge in the field. Electronic copies of detailed course notes will be provided to each participant.

CONTINUING EDUCATION UNITS (CEUs)

For those interested in Continuing Education units (CEUS) will be available. For those attendees interested, an exam will be available online only for students requesting CEU credit. The course is valued at 0.6 CEUs, and is endorsed by the IEEE and by the International Association for Continuing Education and Training (IACET).

SHORT COURSE CHAIR

Dr. Marta Bagatin
University of Padova
Short Course Chair

Marta Bagatin received a Ph.D. in Information Science and Technology in 2010 from the University of Padova, Italy. She is now a Senior Assistant Professor in Electronics at the University of Padova. Her research interests are focused on the experimental study, analysis, and modeling of radiation effects and reliability issues on electronic devices for space, nuclear, and terrestrial, dependable applications. She actively collaborates with space agencies, semiconductor manufacturers, research institutes, and universities all over the world.

Marta is the author or co-author of 4 book chapters, 70 papers published in peer-reviewed journals, more than 80 presentations at international conferences on reliability and radiation effects in electronics, and editor of one book. The results of her work were recognized with 10 awards at NSREC and RADECS conferences. Marta served in the technical committee of conferences such as NSREC, RADECS, and IRPS, and she contributes as a reviewer for several IEEE journals.

Balaji Narasimham received his Ph.D. in electrical engineering from Vanderbilt University, Nashville, TN, in 2008. He joined Broadcom, Irvine, CA in 2008 where he is currently a Master R&D Engineer and leads the reliability team. Dr. Narasimham's work focusses on CMOS circuit design, radiation effects, and reliability of semiconductor devices and circuits. He architects design reliability and soft error guidelines for Broadcom's diverse products. He has been instrumental in developing techniques to characterize and mitigate radiation effects in memory and logic circuits from planar to FinFET technologies enabling Broadcom products to achieve reliability targets at low performance overhead and has guided product designs in new satellite markets. He has authored or co-authored over 75 peer-reviewed papers related to his research, has authored a book chapter on single-event transients and has three US patents on efficient soft error mitigation. He was the recipient of the IEEE NSREC Outstanding Paper Award in 2013 and 2015 and the IEEE RADECS Conference Best Paper Award in 2007. He received the Broadcom President's Award for Excellence in 2013. He has served in the technical program committees and chaired sessions at both the IEEE NSREC and IEEE IRPS. He also serves as a reviewer for various IEEE journals. He is a Senior Member of the IEEE.

HARDENING TECHNIQUES FOR DIGITAL CIRCUITS

Dr. Balaji Narasimham
Broadcom

Dr. Balaji Narasimham, Broadcom, will provide an overview of the single-event effects in digital circuits and discuss traditional to current techniques in radiation-hardening and radiation-tolerant designs. The semiconductor industry has been striving to keep up with Moore's law scaling predictions through innovative process solutions from planar to current FinFET processes. This has helped develop high-performance application specific integrated circuits (ASIC) to suit a variety of space and terrestrial applications. On the other hand, with technology scaling and the associated increase in packing densities and reduction in operating voltages, the critical charge needed to cause single-event effects in digital circuits has decreased significantly resulting in increased vulnerability to radiation. This short course will review hardening-by-design approaches used for overcoming single-events in memories, latches and logic circuits. Error correction techniques for memories along with spacial- and time- redundancy based approaches for latches and logic circuits will be presented. Recent advancement in the radiation-tolerant design approaches that tradeoff performance penalty with the extent of radiation tolerance to suit different applications will be discussed along with the performance overhead vs. radiation tolerance comparisons. Finally, the course will review scaling trends and bias dependence of single-event upset rates from planar to FinFET processes with an emphasis on the opportunities and challenges for radiation hardening in highly scaled technologies.

A top-level outline of the presentation is as follows:

- Introduction
  - Radiation effects in digital circuits
  - Importance of SEE hardening
- Memory SEU Hardening
  - Design hardening
  - Error detection and correction
- Latch/Flip-Flop SEU Hardening
  - Traditional – DICE/ redundancy-based
  - Commercial – BISER/ hysteresis/ charge-steering
- Combinational Logic SET Hardening
  - Traditional – spatial & temporal redundancy
  - Commercial – targeted hardening
- Challenges and Opportunities
  - Scaling trends from planar to FinFETs
  - Bias dependence of SEUs and implications for system SE-Rates
- Conclusions

HARDENING TECHNIQUES FOR ANALOG AND MIXED-SIGNAL CIRCUITS

Dr. Daniel Loveless
University of Tennessee at Chattanooga

Dr. Daniel Loveless, University of Tennessee at Chattanooga, will present an overview of basic and state-of-the-art approaches for the mitigation of radiation effects in analog and mixed-signal (analog + digital) circuits. The hardening of such components is typically thought to require a "brute force" approach; that is, area and power are often sacrificed through the increase of capacitance, device size, and current drive. Moreover, there are no standard metrics for radiation effects in analog and mixed-signal (AMS) circuits as the responses are dependent on the circuit topology, implementation, operating mode, and technology. This presentation addresses these challenges by classifying various techniques based on a few underlying principles and illustrates how these mitigation principles can be manifest in topology-specific examples. Part 1 of the presentation will discuss mitigation strategies that are generally focused on either increasing the critical charge to upset or on reducing the amount of collected charge at metallurgical junctions. Part 2 continues by providing examples of hardened circuits, and catalogues the techniques based on the underlying mitigation principles. The primary focus of the presentation will be on layout and circuit-level approaches to the mitigation of single event effects and total ionizing dose.

A top-level outline of the presentation is as follows:

- Introduction
  - Key concepts in analog, digital, and mixed-signal electronics
  - Total ionizing dose (TID) effects in AMS circuits
  - Single event effects (SEE) in AMS circuits
- Basic Approaches to TID Mitigation
- Basic Approaches to SEE Mitigation
  - Reducing the collected charge
  - Reducing the critical charge
- Radiation hardening by design (RHBD)
  - Redundancy
  - Filtering
  - Gain, bandwidth, and speed
  - Differential design
  - Multi-path hardening
  - System approaches
- The evolution of RHBD and a look to the future

T. Daniel Loveless is a UC Foundation Associate Professor of Electrical Engineering at the University of Tennessee at Chattanooga (UTC). He received the B.S. degree in electrical engineering from the Georgia Institute of Technology in 2004 and the M.S. and Ph.D. degrees in electrical engineering from Vanderbilt University in 2007 and 2009, respectively. Prior to joining UTC, he was a Senior Engineer and Research Assistant Professor at the Vanderbilt University Institute for Space and Defense Electronics from 2009 to 2014, where he was involved in radiation effects research related to high-speed analog and mixed-signal circuits, and the modeling and design of integrated circuits for the evaluation of radiation effects in advanced CMOS technologies. Dr. Loveless joined UTC in 2014 and established a microelectronics research program focused on radiation effects and reliability in electronic and photonic integrated circuits. Additionally, he founded the UTChattSat program focused on undergraduate and graduate research and education in small-satellites, space systems engineering, and radiation effects. Dr. Loveless has authored approximately 100 journal articles and conference papers. He is a Senior Member of the IEEE and serves as an Associate Editor of the IEEE Transactions on Nuclear Science. He has received five best conference paper awards, the 2019 Radiation Effects Early Achievement Award, and the IEEE Nuclear and Plasma Sciences Society (NPSS) Graduate Scholarship Award for his contributions to the fields of nuclear and plasma sciences.

Vincent Goiffon received his Ph.D. in EE from the University of Toulouse in 2008. The same year he joined the ISAE-SUPAERO Image Sensor Research group as Associate Professor and he has been a Full Professor of Electronics at the Institute since 2018. He has contributed to advance the understanding of radiation effects on solid-state image sensors, notably by identifying original degradation mechanisms in pinned photodiode pixels and by clarifying the role of interface and bulk defects in the mysterious dark current random telegraph signal phenomenon.
Besides his contributions to various space R&D projects, Vincent has been leading the development of radiation hardened CMOS image sensors (CIS) and cameras for nuclear fusion experiments (e.g. ITER and CEA Laser MegaJoule) and nuclear power plant safety. Vincent Goiffon is the author of one book chapter and more than 90 publications, including more than 10 conference awards at NSREC, RADECS and IISW. He has been an associate editor of the IEEE Transactions on Nuclear Science since 2017 and has served the community as reviewer and session chair.

HARDENING TECHNIQUES FOR IMAGE SENSORS

Dr. Vincent Goiffon
ISAE-SUPAERO, University of Toulouse

Dr. Vincent Goiffon, ISAE-SUPAERO, University of Toulouse, will provide an overview of the main radiation-induced degradations in solid state image sensors and present mitigation techniques to improve their radiation hardness and enable their use in harsh radiation environments. Among the wide variety of radiation effects relevant for pixel arrays and detectors, radiation-induced leakage currents in PN junctions are by far the main factor limiting the performances of these mixed signal integrated circuits when exposed to fields of high energy particles. How Total Ionizing Dose affects these leakages and how design and process optimizations can reduce the dark current in irradiated sensors will be discussed. What can enhance or reduce the sensitivity of an image sensor to more specific effects such as displacement damage and radiation induced random telegraph signal will also be addressed. The presentation will primarily focus on the CMOS Image Sensor technology, but will also explore the applicability of the presented concepts to other solid state image sensor technologies, as well as the similarities with other leakage sensitive devices such as DRAMs. This presentation will conclude by an overview of the relevant pixel radiation hardening techniques to use depending on the application requirements: from Earth observation space instruments to the exploration of the Jovian system and nuclear fusion instrumentation.

A top-level outline of the presentation is as follows:

- Introduction
  - Image Sensor Technology Overview
  - Image Sensor Use in Radiation Environments
- Total Ionizing Dose Hardening Techniques
  - TID Effects and Mitigations
  - The War Against Leakages
- Mitigating Other Radiation Effects
  - Displacement Damage Effects
  - Single Event Effects
- Conclusion
  - Hardening vs Application Requirements

Kay Chesnut, Engineering Fellow, Radiation Effects Engineering, Raytheon Intelligence & Space at Raytheon Technologies has worked on space systems and communication satellite hardware for over 40 years. She developed and delivered over 20 new systems over her career using new technologies that had to operate in harsh radiation environments including both nuclear and natural environments. Kay started extensively working with the radiation community in 1993, where collaboration on the then new technology insertion of a 500MHz digital GaAs direct digital synthesizer, formed a solid foundation for the proper mitigation approaches.

Kay has served as the Financial Chair for the IEEE's 2003 NSREC, Local Arrangements Chair for the 2005 NSREC, 2009 NSREC Short Course Instructor (with Dr. Kirk Kohnen), Conference Chair of the 2011 NSREC, 2008 Radiation Effects Steering Group Secretary, and the 2012-2015 Radiation Effects representative on the IEEE Nuclear Plasma Sciences Society AdCom.

SYSTEM-LEVEL HARDENING - WHAT COULD GO WRONG, AND HOW TO MAKE IT RIGHT

Kay Chesnut
Raytheon Technologies

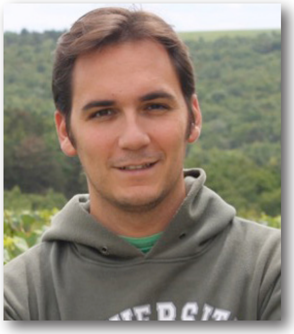
Kay Chesnut, Engineering Fellow, Radiation Effects Engineering, Raytheon Intelligence & Space at Raytheon Technologies will briefly review historical space failures, known root causes, and the resulting requirements that drive system mitigation strategies for use of commercial components in spacecraft electronics. The talk, "What Could Go Wrong, and How To Make It Right" will tackle system level hardening strategies by looking at the main components of space systems, the applicable radiation environments that particularly plague those components, and the design approaches used to work around those radiation impacts. Examples, pulled from the public domain, illustrate the techniques. Flexible platforms brought online using re-programmable FPGAs are used as an illustration of some of the system considerations.

A top-level outline of the presentation is as follows:

- Understanding of Space by Anomaly (History)
- Sources of Satellite Failures
- Satellite Subsystems
- Radiation Impact on Satellite Subsystems
  - Spacecraft charging
  - Ionizing radiation
- Brief Review of Satellite Orbits/Environments
- Mitigation Strategies
  - Digital Systems with Flexible Platforms
  - Power Systems
- Power Distribution
  - Floating Metal Management

Young Professional Presentation
Tuesday, July 20 , 9-10 EDT

IEEE youngprofessionals



Rubén García Alía, PhD
Applied Physicist Staff
Accelerator Systems Department
European Organization for Nuclear Research (CERN)

ruben.garcia.alia@cern.ch
www.linkedin.com/in/ruben-garcia-alia (LinkedIn profile)

YOUNG PROFESSIONALS TALK:
Completing the Young Professional Stage – looking back, and where to go from here?

Rubén García Alía, PhD
European Organization for Nuclear Research (CERN)

Summary

Radiation environments and effects in space have been studied for decades, and their potentially critical impact on missions is well understood by the radiation effects community. In contrast, the significance of radiation effects in high-energy accelerators is less known and will be the focus of Rubén's Young Professional talk. Rubén will explain why, in spite of the capacity to repair radiation-induced failures in terrestrial accelerators, radiation effects still remain crucial for electronics system development, ultimately ensuring a successful operation of the accelerator infrastructure. While outlining his career steps and future outlook, Rubén will highlight similarities and contrasts between the space and accelerator Radiation Hardness Assurance process, focusing on the approaches (and challenges) which he has encountered so far in his professional path.

Biographical Sketch

Rubén García Alía is part of the "Radiation to Electronics" (R2E) project at CERN, which he has led since 2018. After studying nuclear and high-energy physics at the Complutense University in Madrid (Spain), he started his career in radiation effects as a Young Graduate Trainee at the European Space Agency, in the Netherlands. From there, he completed his PhD with CERN and the University of Montpellier, focusing on the effect of highly energetic particles on Single Event Effects in the Large Hadron Collider (LHC) accelerator. During this period, he was recognized with the "Best Student Paper" award at RADECS 2012, and the IEEE NPSS Paul Phelps Continuing Education Grant in 2015. Since then, he has kept a strong involvement in radiation effects research, focusing on high-energy accelerator applications, and has co-authored more than 75 publications in peer-reviewed journals. He has co-authored a RADECS Short Course, has been session chair at NSREC and RADECS, and is currently technical chair for RADECS 2021. Recently he was elected Junior Member-at-Large of the IEEE NPSS Radiation Effects Steering Group (RESG).

At CERN, Rubén's main task is managing the R2E project, which is responsible for all radiation effects in the LHC accelerator and its injector chair, with the mandate of ensuring successful operation with regards to stochastic failures and lifetime degradation induced by radiation. The project, which is composed of more than 50 members, embeds a rich variety of activities and expertise, ranging from the monitoring and calculation of radiation levels, the operation of CERN radiation facilities, and testing for radiation effects at both component and system level.

Rubén has coordinated the RADSAGA (RADiation and reliability challenges for electronics used in Space, Aviation, Ground and Accelerators) project, an innovative training Marie Curie PhD network since 2017, and led the RADNEXT proposal for creating a radiation test infrastructure network in Europe, which was accepted for funding and is currently in its implementation phase.

During the NSREC 2021 "Young Professional" event, Rubén will share with us his experiences and the future prospects as he transitions to the next stage of his professional career.

Eric Donovan, PhD
Professor of Physics and Astronomy
University of Calgary

INVITED TALK:
How I Met Steve

Eric Donovan, PhD
Professor of Physics and Astronomy, University of Calgary

Summary

One of the most fun things that has happened to Prof. Eric Donovan during his entire career has been his involvement in the discovery (by science) of an upper atmospheric luminous phenomenon (that was well known to amateur night-sky photographers around the world) that we now know as STEVE. The acronym, or more appropriate 'backronym', was coined by Bob Lysak of the University of Minnesota in response to Eric's challenge to the space physicists to turn 'Steve' the name into STEVE the scientifically appropriate acronym.

In this talk, Eric tells the story of how he came upon a new-to-science phenomenon that we now know as STEVE (Strong Thermal Emission Velocity Enhancement). This involves a 2016 chance meeting with a so-called Alberta Aurora Chaser at a pub in Calgary, using Facebook for real science research, the explosive technological growth we now find ourselves in, and the fabulous network of scientific spacecraft that has grown to give us a transformative view of geospace. Spoiler alert: STEVE is not an aurora.

Biographical Sketch

Eric Donovan, PhD is a Professor of Physics and Astronomy at the University of Calgary. He received his Ph.D. in Physics from the University of Alberta in 1993, and moved to Calgary in 1995 after a postdoc in Uppsala, Sweden. Eric is a Space Physicist whose research focus is on multi-scale processes in 'geospace' (the coupled ionosphere-thermosphere-magnetosphere). He began as a modeller, developing tools to do magnetic mappings between the ionosphere and magnetosphere, particularly along magnetic field lines that thread the zone of active aurora. Around 2000, frustrated by fundamental uncertainties with the modelling approach to mapping, he started to explore 'physical mapping', namely using quantitative observations of the aurora to make connections between things we see in the ionosphere and things we know are going on in the magnetosphere. This led Eric to develop a network of all-sky imagers and other instruments distributed across much of Canada and designed to remote sense physical processes in the magnetosphere. As part of NASA's five-satellite THEMIS mission, a team led by Eric and Stephen Mende of UC Berkeley developed and deployed a network of all-sky imagers that provides contiguous coverage of the aurora from the east cost of Canada to the west coast of Alaska. After nearly twenty years of operation, 'THEMIS-ASI' has revolutionized the role of auroral observations in geospace research, and enabled a number of interesting discoveries. Looking forward, Eric is the PI of the UV auroral imager that is scheduled to fly on SMILE, a joint European Space Agency/Chinese Academy of Sciences mission that is scheduled to be launched into a very high altitude (~1 Re X ~20 Re) high inclination orbit in 2024.

Anamaria Effler, PhD
Scientist, Caltech-LIGO Livingston Observatory

INVITED TALK:
LIGO: The Journey of Detecting Gravitational Waves and the Start of a New Astrophysics Field

Anamaria Effler, PhD
Scientist, Caltech-LIGO Livingston Observatory

Summary

The Laser Interferometric Gravitational-wave Observatory (LIGO) is the largest project funded by the National Science Foundation (NSF). It was a risky endeavor; a plan to build one of the most precise instruments ever attempted to detect what Einstein himself thought was undetectable. Nevertheless, on September 14, 2015, LIGO directly detected the first gravitational wave from the collision of two 30-solar-mass black holes. Thus, the field of gravitational-wave astronomy was born. In 2017, the Nobel Prize in Physics was awarded to the founders of LIGO, Rainer Weiss, Kip Thorne, and Barry Barish for this discovery. Today, Caltech and MIT operate the two LIGO sites in Hanford, WA and Livingston, LA, and the LIGO Scientific Collaboration extends to more than 1,000 members at over 100 universities across the world. In this talk, Dr. Effler will discuss the LIGO history, the amazing LIGO instruments, and some of the astrophysical discoveries since 2015.

Biographical Sketch

Dr. Anamaria Effler is a Caltech scientist stationed at the LIGO Livingston Observatory in Louisiana. She earned her Ph.D. at Louisiana State University in 2014 while working on the LIGO Livingston interferometer, then transitioned to permanent staff at the observatory. She works on quantifying noise sources and improving the sensitivity of the LIGO detectors, whatever that may entail.

Women in Engineering Presentation
Friday, July 23, 9-10 EDT

Alessandra Menicucci, PhD
Delft University of Technology

WOMEN IN ENGINEERING TALK:
How can space radiation help us to understand the Universe?"

Alessandra Menicucci, PhD
Delft University of Technology

Summary

For any spacecraft, the radiation environment is a hazard which threatens the achievement of the mission goals and therefore requires mitigation measures. However, the study of radiation in space has also the potential to contribute to answering fundamental science questions such as the nature of the dark matter, whether biological life exist beyond Earth or planetary formation. In this talk, Dr. Menicucci will review some examples of past and future space exploration missions where particle measurements has a central role. She will also share her experience of a career across particle physics and space engineering, two domains where the gender gap unfolds in a rather different way.

Biographical Sketch

Dr. Alessandra Menicucci graduated in 2000 with a Laurea degree in experimental particle physics from the University of Rome La Sapienza. She carried out her thesis at the National Laboratory of Frascati where she worked on the data analysis of the KLOE experiment, at the Daphne accelerator. In 2004 she received a PhD in Physics from the University of Rome "Tor Vergata" working on the data acquisition system for the space-borne experiment PAMELA, dedicated to the detection of antimatter in cosmic rays. In 2005 she was granted a Marie-Curie post doc fellow at AGFA Gevaert where she developed the simulation for X-ray health diagnostic systems. In 2006 she joined the European Space Agency (ESTEC) in the Space Environment and Effects section where she was leading several radiation monitor developments. Since 2015 she has been a tenured assistant professor at the faculty of Aerospace Engineering of the Delft University of Technology, in the Space System Engineering section. Her research interest focuses on the development of miniaturized radiation sensors which can be distributed on-board of micro-satellites and on the radiation tolerance assurance of COTS components. She is the project manager of the Delfi Space Program. Dr. Menicucci lives with her husband, 13-year-old daughter, and 11-year-old son in Leiden (The Netherlands). In her spare time she enjoys sport, traveling, and photography.

Technical Program

TECHNICAL INFORMATION

"On behalf of the Technical Program Committee, I would like to invite you to attend the 2021 NSREC Virtual and On-Demand Technical Sessions. The committee is pleased to present a virtual conference environment including opportunities to meet with authors and colleagues. Our sincere thanks goes out to the authors, chairpersons, and reviewers who have contributed to the conference through this challenging year."

Brian Sierawski
Vanderbilt University
Technical Program Chair

The NSREC technical program consists of contributed oral and poster papers, a data workshop and invited talks. The oral presentations will be 12 minutes in duration with a subsequent question and answer period for the session held on Zoom. The technical sessions and their chairpersons are:

- **Basic Mechanisms of Radiation Effects**
  Chair: Marc Gaillardin, CEA
- **Dosimetry**
  Chair: Arto Javanainen, University of Jyväskylä
- **Hardness Assurance Technologies, Modeling, and Testing**
  Chair: Amanda Bozovich, Jet Propulsion Laboratory
- **Hardening by Design**
  Chair: Li Chen, University of Saskatchewan
- **Radiation Effects in Devices and Integrated Circuits**
  Chair: John Bird, Radiation Test Solutions
- **Photonic Devices and Integrated Circuits**
  Chair: Scott Davis, Aerospace Corporation
- **Single-Event Effects: Mechanisms and Modeling**
  Chair: Gilles Gasiot, STMicroelectronics
- **Single-Event Effects: Devices and Integrated Circuits**
  Chair: Nadia Rezzak, Microchip
- **Space and Terrestrial Environments**
  Chair: Alex Hands, University of Surrey

POSTER SESSION

Those papers that can be presented more effectively in a visual format with group discussion will be displayed in the Poster Session within Gather.Town. The virtual Poster Session will be held on Tuesday, July 20 from 12:30 – 14:30 PM EDT and the authors will be available at that time to discuss their work. Posters are available for viewing July 19 – August 16 within Gather.Town. The Poster Session is chaired by Ted Wilcox from NASA Goddard Space Flight Center.

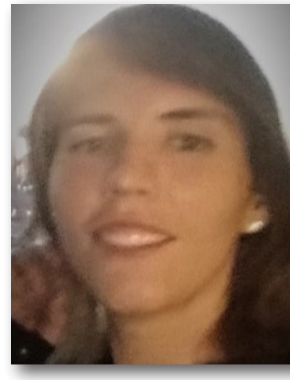
RADIATION EFFECTS DATA WORKSHOP

Workshop papers provide piece part radiation response data and radiation test facilities technical information. The intent of the workshop is to provide data and facilities information to support design and radiation testing activities. Workshop posters can be viewed July 19 – August 15 within Gather.Town. Authors will be available on Thursday, July 22 to discuss their work from 12:30 to 14:30 EDT. A workshop record will be mailed to all registered conference attendees. The workshop chair is Helmut Puchner from Infineon Technologies.

Session Chairs

Marc Gaillardin, CEA
Basic Mechanisms of Radiation Effects

Arto Javanainen, University of Jyväskylä
Dosimetry



Amanda Bozovich, Jet Propulsion Laboratory
Hardness Assurance Technologies, Modeling, and Testing

Li Chen, University of Saskatchewan
Hardening by Design

John Bird, Radiation Test Solutions
Radiation Effects in Devices and Integrated Circuits

Scott Davis, Aerospace Corporation
Photonic Devices and Integrated Circuits

Gilles Gasiot, STMicroelectronics
Single-Event Effects: Mechanisms and Modeling

Nadia Rezzak, Microchip
Single-Event Effects: Devices and Integrated Circuits

Alex Hands, University of Surrey
Space and Terrestrial Environments

Technical Program

Session A: BASIC MECHANISMS

Available for On Demand July 19 - August 15

Live Q&A - Tuesday, July 20 • 11:30-12:00 EDT

Chair: Marc Gaillardin (CEA)

A-1 **Investigation of Deep-Level Traps in AlGaN/GaN HEMTs Using Variable-Wavelength Laser Light**

A. Khachatrian[1], A. Ildefonso[1], S. Buchner[1], J. Hales[2], G. Foster[1], A. Koehler[1], J. Mittereder[1], D. McMorrow[1]

1. US Naval Research Laboratory, USA
2. Jacobs and NRL, USA

Pulsed laser-light with continuously variable wavelength is used to study deep-level traps in AlGaN/GaN HEMTs. Single-event transient characteristics vary with wavelength through single-photon absorption, two-photon absorption, and the presence of traps.

A-2 **A Comparison of Radiation-Induced and High-Field Electrically Stress Induced Interface Defects in Si/SiO_2 MOSFETs via Electrically Detected Magnetic Resonance**

F. Sharov[1], S. Moxim[1], P. Lenahan[1], G. Haase[2], D. Hughart[2]

1. The Pennsylvania State University, USA
2. Sandia National Laboratories, USA

Direct-current current-voltage and high-field electrically detected magnetic resonance measurements reveal differences in atomic scale interface and bulk defect creation in SiO_2 gates when comparing devices irradiated with ^{60}Co to unirradiated devices stressed at high fields.

A-3 **Effects of Ion-Induced Displacement Damage on GaN/AlN MEMS Resonators**

W. Sui[1], X. Zheng[1], J. Lin[2], J. Davidson[3], R. Reed[3], R. Schrimpf[3], B. Alphenaar[2], M. Alles[3], P. Feng[1]

1. University of Florida, USA
2. University of Louisville, USA
3. Vanderbilt University, USA

The effects of radiation-induced displacement damage on GaN/AlN resonant microelectromechanical systems (MEMS) are reported. The resonance frequencies decrease because of reduction in built-in stress and Young's modulus, and the GaN/AlN structural deformation.

PA-1 **Radiation Hardness and Damage Mechanism of Carbon Nanotube Thin Film-Based Field-Effect Transistors Under Low-Energy Proton Irradiation**

M. Li[1], H. Zhu[2], X. Zhang[2], S. Peng[2], L. Wang[2], X. Li[3], J. Yang[3], B. Li[2], J. Zhang[4], F. Zhao[2]

1. IMECAS, CAS; N. China Univ. Technol, China
2. Inst. Microelectron., CAS, China
3. Harbin Inst. Technol., China
4. N. China Univ. Technol, China

Radiation effects of CNT-TFTs under 150 keV proton irradiation are investigated. A high radiation tolerance of 5×10^{13} p/cm^2 is demonstrated, and a deep insight into damage mechanisms under higher fluence is given.

PA-2 **Effects of Total Ionizing Dose on PEDOT/PSS Organic Memory Devices**

C. Bennett[1], D. Robinson[1], T. Xiao[1], A. Melianas[2], D. Hughart[1], S. Agarwal[1], E. Fuller[1], Y. Li[3], A. Salleo[2], M. Allendorf[1], A. Talin[1], M. Marinella[1]
1. Sandia National Laboratories, USA
2. Stanford University, USA
3. University of Michigan, USA

Electrochemical random-access memory (EC-RAM) is a promising non-volatile memory, but its response to total ionizing dose (TID) is unexplored. We expose several ECRAM devices (PEDOT/PSS bulk) to Co-60 gamma radiation and find significant responses.

PA-3 **Influence of LDD Spacers on Total Ionizing Dose Response of Bulk MOSFETs at Cryogenic Temperature**

G. Cussac[1], T. Nuns[1], S. Ducret[2], S. Duzellier[1], L. Artola[1]
1. ONERA, France
2. Lynred, France

This work presents electrical characteristics of irradiated MOSFET transistors up to 300 krad, at three different temperatures. Transconductance improves with ionizing dose at low temperature due to trapped charges in spacers near LDD regions.

PA-4 **Evolution and Mechanism of P-GaN Under Proton Irradiation**

L. Wang[1], Y. Tang[2], H. Zhu[1], X. Cai[1], X. Zhang[1], J. Gao[1], N. Liu[3], X. Li[4], J. Yang[4], B. Li[1], F. Zhao[1]
1. IMECAS, China
2. IMECAS;Key Laboratory of Science and Technology on Silicon Devices, Chinese Academy of Sciences, China
3. Guangdong Institute of Semiconductor Industrial Technology, China
4. Harbin Inst. Technol., China

Electrical properties deterioration of P-GaN under 150 keV proton irradiation was investigated. It was confirmed that P-GaN is transformed into N-type as fluence increases. Primary defects generated by irradiation were revealed by PL measurements.

Session B: SINGLE EVENT EFFECTS: MECHANISMS AND MODELING

Available for On Demand July 19 - August 15

Live Q&A - Tuesday, July 20 • 11:30-12:00 EDT

Chair: Gilles Gasiot (STMicroelectronics)

B-1 **An SRAM SEU Cross Section Curve Physics Model**

D. Kobayashi[1], K. Hirose[1], K. Sakamoto[2], Y. Tsuchiya[2], S. Okamoto[2], S. Baba[2], H. Shindou[2], O. Kawasaki[2], T. Makino[3], T. Ohshima[3]
1. ISAS/JAXA, Japan
2. R&D/JAXA, Japan
3. QST, Japan

We propose a unified equation that describes both LET and VDD dependence of SRAM SEU cross sections. It comprises only parameters physically defined, indicating the potential for non-beam variation-aware prediction. Heavy-ion experiments suggest its validity.

B-2 **Energy Deposition by Ultra High-Energy Ions in Large and Small Sensitive Volumes**

M. Bagatin[1], S. Gerardin[2], A. Paccagnella[1], G. Santin[3], A. Costantino[3], V. Ferlet-Cavrois[3], M. Muschitiello[3], S. Beltrami[4]

1. *University of Padova, Italy*
2. *DEI - Padova University, Italy*
3. *ESA, Netherlands*
4. *Micron Technology - Process R&D, Italy*

We studied energy deposition after ultra-high energy ion irradiation. We prove that the energy increase previously reported in PIPS detectors due to delta electrons occurs only in large sensitive volumes, but not in small volumes.

B-3 **Analysis of Heavy-Ion-Induced Leakage Current in SiC Power Devices**

R. Johnson[1], R. Reed[1], K. Galloway[1], R. Schrimpf[1], A. Witulski[1], M. Alles[1], D. Ball[1], A. Sternberg[1], J. Hutson[2], J.-M. Lauenstein[3]

1. *Vanderbilt University, USA*
2. *Lipscomb University, USA*
3. *NASA GSFC, USA*

A method of analyzing ion-induced reverse leakage current in SiC power devices is described, resulting in a model that enables estimation of the number of non-destructive ion strikes and creation of cross-sections from broad-beam data.

B-4 **Single-Event Effects in Multi-Die 3D NAND Memories**

M. Breeding[1], E. Wilcox[2], R. Reed[1], R. Schrimpf[1], K. Warren[1], B. Sierawski[1], M. Alles[1]

1. *Vanderbilt University, USA*
2. *NASA GSFC, USA*

The response of multi-die 3D NAND memories to heavy-ion and proton irradiation is characterized as a function of depth and environment by extending experimentally validated Monte Carlo simulation tools.

PB-1 **Numerical Modeling of Proton Direct Ionization Single Event Effects in Sub-Micron Technology**

S. Lüdeke[1], A. Javanainen[1]

1. *University of Jyväskylä, Finland*

A numerical algorithm for the calculation of proton direct ionization cross-sections based on a linear energy transfer and a straggling model is presented and benchmarked against experimental and simulated data.

PB-2 **Using Machine Learning to Determine Proton Cross-Sections from Heavy-Ion Data**

D. Hansen[1], D. Czjkowski[1], B. Vermeire[1]

1. *Space Micro, USA*

This paper reports on the calculation of proton SEU cross-sections using heavy-ion data with machine-learning techniques. Model-averaging techniques are applied and improve the accuracy of the calculation.

PB-3 G4SEE: A Geant4-Based Single Event Effect Simulation Tool and Its Validation Through Mono-Energetic Neutron Measurements

D. Lucsányi[1], R. García Alía[1], K. Biłko[1], M. Cecchetto[1], S. Fiore[2]
1. CERN, Switzerland
2. ENEA Frascati Research Center, Italy

A novel, SEE simulation tool has been developed for the radiation effects community. It has been demonstrated and validated by inelastic energy deposition events of 14.8 MeV neutrons measured with a silicon diode detector.

PB-4 Threshold Contributions to Heavy Ion Soft Error in FinFETs using GEANT4

P. Johnson[1], D. Valencia[1], D. Larsen[1], S. Aghara[2]
1. The Charles Stark Draper Laboratory, Inc., USA
2. University of Massachusetts Lowell, USA

Heavy-ion induced soft errors in SRAM with FinFETs are influenced by events far from average quantities due to straggling and spatial limits. GEANT4 is used to model 16nm FinFET soft error cross sections.

Session C: RADIATION EFFECTS IN DEVICES AND INTEGRATED CIRCUITS

Available for On Demand July 20 - August 15

Live Q&A - Wednesday, July 21 • 11:30-12:30 EDT

Chair: John Bird (Radiation Test Solutions)

C-1 Response of Integrated Silicon RF pin Diodes to X-ray and Fast Neutron Irradiation

J. Teng[1], D. Nergui[1], H. Parameswaran[1], G. Tzintzarov[1], H. Ying[1], C. Cheon[1], S. Rao[1], A. Ildefonso[2], N. Dodds[3], N. Nowlin[3], M. Gorchichko[4], E. Zhang[4], D. Fleetwood[4], J. Cressler[1]
1. Georgia Institute of Technology, USA
2. Naval Research Laboratory, USA
3. Sandia National Laboratories, USA
4. Vanderbilt University, USA

The response of integrated RF pin diodes to 14-MeV fast neutron and 10-keV X-ray exposure is examined. No significant RF performance degradation is observed, making pin diodes radiation-tolerant candidates for RF systems in space applications.

C-2 Total-Ionizing-Dose Response of SiGe HBTs at Elevated Temperatures

D. Nergui[1], J. Teng[1], A. Ildefonso[2], M. Gorchichko[3], E. Zhang[3], D. Fleetwood[3], J. Cressler[1]
1. Georgia Institute of Technology, USA
2. US Naval Research Laboratory, USA
3. Vanderbilt University, USA

The total-ionizing-dose response of third-generation SiGe HBTs is investigated for irradiation at elevated temperatures, up to 130°C. The devices showed less degradation to irradiation at higher temperatures when biased for forward-active operation.

C-3 **Radiation Induced Junction Leakage Random Telegraph Signal**

H. Dewitte[1], V. Goiffon[1], A. Le Roch[1], S. Rizzolo[2], C. Virmontois[3], C. Marcandella[4], P. Paillet[4]
1. *ISAE-SUPAERO, France*
2. *Airbus Defense and Space, France*
3. *CNES, France*
4. *CEA, France*

The radiation effects on junction leakage random telegraph signals have been studied in MOSFET junctions. The influences of the radiation type, the design of the junction, and the electric field are discussed.

C-4 **Negative Bias-Temperature Instabilities and Total-Ionizing-Dose Effects in Deeply Scaled Ge-GAA Nanowire pFETs**

M. Rony[1], E. Zhang[1], S. Toguchi[1], X. Luo[1], M. Reaz[1], K. Li[1], R. Reed[1], D. Fleetwood[1], R. Schrimpf[1], D. Linten[2], J. Mitard[2]
1. *Vanderbilt University, USA*
2. *imec, Belgium*

Off-state leakage current in Ge GAA nanowires increases with dose due to enhanced band-to-band tunneling caused by charge trapping in STI. NBTI-induced degradation originates primarily from interface- and border-trap generation.

C-5 **Influence of Fin- and Finger-Number on TID Degradation of 16 nm Bulk FinFETs Irradiated to Ultra-High Doses**

S. Bonaldo[1], T. Ma[1], S. Mattiazzo[2], A. Baschilotto[3], C. Enz[4], A. Paccagnella[5], S. Gerardin[5]
1. *University of Padova, Italy*
2. *University of Bergamo, Italy*
3. *University of Milano Bicocca, Italy*
4. *Institute of Microengineering, EPFL, Switzerland*
5. *DEI - Padova University, Italy*

The TID degradation is investigated in 16 nm bulk FinFETs designed with different numbers of fins and fingers. At ultra-high doses, pFinFETs with the lower number of fins exhibit the worse degradation.

C-6 **Investigation of Total Ionizing Dose on Domain-Wall Magnetic Tunnel Junction Logic Devices**

C. Bennett[1], T. Xiao[1], T. Leonard[2], M. Alamdar[2], R. Jacobs-Gedrim[1], L. Xue[3], J. Incorvia[2], M. Marinella[1]
1. *Sandia National Laboratories, USA*
2. *University of Texas at Austin, USA*
3. *Applied Materials, USA*

We evaluate the resilience of domain-wall magnetic tunnel junction logic devices to total ionizing dose by gamma radiation. While devices are resilient to this effect overall, small magnetoresistance changes are produced by a 1Mrad dose.

C-7 **Total-Ionizing-Dose Effects on Polycrystalline-Si Channel Vertical-Charge-Trapping NAND Devices with SiON Tunneling Oxide**

J. Cao[1], P. Wang[1], X. Li[1], Z. Guo[1], E. Zhang[1], R. Reed[1], M. Alles[1], R. Schrimpf[1], D. Fleetwood[1], A. Arreghini[2], M. Rosmeulen[2], J. Bastos[2], G. Van den Bosch[2], D. Linten[2]
1. *Vanderbilt University, USA*
2. *imec, Belgium*

Total-ionizing-dose effects are evaluated in vertical-charge-trapping NAND devices with SiON tunneling layers. Trapped holes compensate deeply trapped electrons, but threshold voltages remain large enough to enable successful NV memory application.

PC-1 Total-Ionizing-Dose Effects on Read Noise of MLC 3D NAND Memories

U. Surendranathan[1], M. Wasiolek[2], K. Hattar[2], D. Fleetwood[3], B. Ray[4]
1. The University of Alabama in Huntsville, USA
2. Sandia National Laboratories, USA
3. Vanderbilt University, USA
4. University of Alabama in Huntsville, USA

We find that bit errors caused by read-noise are significant on irradiated MLC 3D NAND chips. Bit-flip noise was more dominant on cells in an erased state during irradiation compared to programmed cells.

PC-2 Exploration of Synergistic Behavior of Operational Amplifiers in Combined Ion and Electron Environments

J. Young[1], J. Manuel[1], G. Vizkelethy[1], E. Bielejec[1]
1. Sandia National Laboratories, USA

Degradation of op-amps in combined and individual environments was explored using simultaneous irradiation with ions and electrons. Input bias and offset currents were lower for the mixed-field irradiation compared to the sum of separate environments.

PC-3 Effect of Frequency on Total Ionizing Dose Response of Ring Oscillator Circuits at the 7-nm Bulk FinFET Node

A. Feeley[1], Y. Xiong[1], B. Bhuva[1]
1. Vanderbilt University, USA

RO circuits under dynamic and static test conditions are used to characterize the effects of frequency on TID response. Results show that static conditions overestimate the effects of TID on RO circuits.

PC-4 Ionizing Radiation Effect in SRAM Physical Unclonable Function (PUF) with 4 Type-Specific Cells Using 28nm FDSOI

Z. Su[1], B. Li[2], J. Gao[2], X. Su[2], G. Zhang[2], H. Ren[1], P. Lu[2], F. Liu[2], F. Zhao[2], Z. Han[1]
1. Institute of Microelectronics, Chinese Academy of Sciences; University of Chinese Academy of Sciences; Key Laboratory of Science and Technology on Silicon Devices, Chinese Academy of Sciences, China
2. IMECAS, China

Radiation effects on four type-specific SRAM PUFs were studied in terms of stability and uniqueness. PUF stability can be improved about 2X with smaller cells using cascade PMOS transistors which also makes its uniqueness better.

PC-5 Investigation on Transient Ionizing Radiation Effects in a 4Mb SRAM with Dual Supply Voltages

T. Li[1], Y. Zhao[1], L. Wang[1]
1. Beijing Microelectronics Technology Institute, China

The impact of transient ionizing radiation effects in an SRAM circuit was studied. Results indicate that core supply voltage suffers more serious disturbance. Voltage disturbance mitigation methods are presented.

PC-6 Effects of Ionizing Radiation on SRAM Physical Unclonable Functions

S. Lawrence[1], J. Cannon[2], J. Carpenter[1], D. Loveless[1]
1. University of Tennessee at Chattanooga, USA
2. University of Colorado Boulder, USA

The effects of TID on SRAM Physical Unclonable Functions and implications for authentication are studied through proton irradiation. Unhardened COTS SRAMs exhibit minor negative shifts in the intra- and inter-die Hamming Distance distributions with TID.

PC-7 **Comparison of Total Ionizing Dose Effects in SOI FinFETs Between RT and High Temperature**

X. Zhang[1], F. Liu[2], B. Li[2], C. Yang[2], G. Wang[2], P. Lu[2], S. Chen[2], J. Zhou[3], J. Yang[3], J. Luo[2]
1. *Institute of Microelectronics, Chinese Academy of Sciences; University of Chinese Academy of Sciences; Key Laboratory of Science and Technology on Silicon Devices, Chinese Academy of Sciences, China*
2. *C2. CMEI, China*
3. *X LAB, The Second Academy of CASIC, China*

TID effects at room and high temperature are investigated for SOI FinFETs, which are experimentally explained from different trapped-charges in gate oxide. The synergetic effects of TID and temperature worsen degradation for n-SOI FinFETs.

PC-8 **In-Situ Measurement of TID-Induced Leakage Using On-Chip Current Modulation**

S. Vibbert[1], C. Watkins[1], J. D'Amico[1], M. Mckinney[1], D. Vibbert[1], D. Ball[1], T. Haeffner[1], J. Kauppila[1], L. Massengill[1]
1. *Vanderbilt University, USA*

We have developed the on-chip Photocurrent Measurement Circuit (PMC), providing a means to capture device-level TID-induced leakage in sub-50nm technologies. Leakage data were gathered using the PMC and is compared to direct measurements.

Session D: HARDNESS ASSURANCE

Available for On Demand July 19 - August 15

Live Q&A - Wednesday, July 21 • 11:30-12:00 EDT

Chair(s): Amanda Bozovich (NASA JPL)

D-1 **Model- and Testing-Based Assurance of Cache Memory of a Single-Board Computing System in Radiation Environments**

M. Reaz[1], P. Koncelik[1], A. Witulski[1], B. Bhuva[1], G. Karsai[1], N. Mahadevan[1], M. Rony[1], K. Li[1], B. Sierawski[1], A. Sternberg[1], R. Reed[1], R. Schrimpf[1], M. Turowski[2]
1. *Vanderbilt University, USA*
2. *Alphacore, Inc., USA*

Radiation-induced error propagation of a single-board computing system is analyzed at the subsystem-level. A single-event measurement procedure is developed that distinguishes data faults from those occurring in instruction memory and pathways.

D-2 **Modelling the Influence of Package in Focused X-ray Testing of Power GaN COTS**

C. Ngom[1], V. Pouget[2], M. Zerarka[3], F. Coccetti[3], A. Touboul[4], M. Matmat[3]
1. *IRT Saint Exupery and IES-University of Montpellier, France*
2. *IES-CNRS, University of Montpellier, France*
3. *IRT Saint Exupery, France*
4. *IES-University of Montpellier, France*

In the context of using the focused x-ray technique for SEE testing of power GaN COTS, we present a simulation-based study of the impact of the package structure on the charge distribution in the active layers as a function of photon energy. Implications for RHA are discussed.

D-3 Using Machine Learning to Mitigate Single-Event Upsets in RF Circuits and Systems

A. Ildefonso[1], J. Kimball[2], J. Cressler[2], D. McMorrow[1]
1. Naval Research Laboratory, USA
2. Georgia Institute of Technology, USA

Machine learning algorithms are used to detect and correct single-event upsets in an RF receiver carrying modulated data. This approach is able to detect > 95% and correct approximately 50% of upsets.

PD-1 Total-Ionizing-Dose Effects on Long-Term Data Retention Characteristics of Commercial 3D NAND Memories

M. Buddhanoy[1], P. Kumari[1], U. Surendranathan[1], M. Wasiolek[2], K. Hattar[2], B. Ray[1]
1. The University of Alabama in Huntsville, USA
2. Sandia National Laboratories, USA

We find that data retention properties of MLC 3D NAND chips are significantly degraded with irradiation. Erase cells suffer more degradation compared to programmed cells suggesting pre-programming of memory modules before deploying in radiation-prone environments.

PD-2 Dealing with Ion LET Uncertainties: An Application of Generalized Linear Models

R. Ladbury[1]
1. NASA GSFC, USA

We propose Generalized Linear Models for understanding errors in SEE rate arising from uncertainties in LET of the ion responsible for the event. Applications are suggested and assessed for suitability of treatment by the model.

PD-3 Investigation of Radiation Effects in RF Devices Based on a Software-Defined Radio Test Setup

J. Budroweit[1], J. Häseker[1], N. Aksteiner[1]
1. DLR, Germany

A software-defined radio-based test setup for the radiation effects characterization on radio frequency devices is proposed. The setup is intended to reduce test complexity, equipment and costs, and to improve test automation and flexibility.

PD-4 Total-Ionizing-Dose Resistant Novel Data Encoding Technique for NAND Memory

S. Sakib[1], M. Wasiolek[2], K. Hattar[2], A. Milenković[1], B. Ray[1]
1. The University of Alabama in Huntsville, USA
2. Sandia National Laboratories, USA

We propose a non-charge-based novel data encoding technique that is more resistant to total-ionizing-dose effects than the traditional charge-based storage of NAND flash memory.

Session E: SINGLE EVENT EFFECTS: DEVICES AND INTEGRATED CIRCUITS

Available for On Demand July 21 - August 15

Live Q&A - Thursday, July 22 • 11:30-12:00 EDT

Chair(s): Nadia Rezzak (Microchip)

E-1 **Single Event Effects Induced by Heavy Ions in SONOS Charge Trapping Memory Arrays**

T. Xiao[1], C. Bennett[1], S. Agarwal[1], D. Hughart[1], H. Barnaby[2], H. Puchner[3], A. Talin[1], M. Marinella[1]

1. *Sandia National Laboratories, USA*
2. *Arizona State University, USA*
3. *Infineon Technologies, USA*

The sensitivity of 40nm SONOS charge trapping memory to heavy ion induced single event effects is experimentally studied. Threshold voltage distributions of irradiated cells show stronger resilience to single event effects relative to floating-gate memory.

E-2 **Measurement and Modeling of Single Event Transients in 12nm Inverters**

S. Agarwal[1], L. Clark[2], C. YoungSciortino[2], G. Ng[1], D. Black[1], M. Cannon[1], J. Black[1], H. Quinn[3], H. Barnaby[2], J. Brunhaver[2], M. Marinella[1]

1. *Sandia National Laboratories, USA*
2. *Arizona State University, USA*
3. *Los Alamos National Laboratory*

A unique method of measuring SET sensitivity in 12-nm FinFETs that uses clock SETs on a DFF scan chain to approximately measure the length of the SET is demonstrated and modeled.

E-3 **Modeling Single-Event Cross-Sections for Logic Circuits at the 7-nm Bulk FinFET Technology Node**

Y. Xiong[1], A. Feeley[1], D. Ball[1], B. Bhuva[1], L. Massengill[1]

1. *Vanderbilt University, USA*

Single event cross-section for logic circuits is experimentally investigated at the 7-nm bulk FinFET node. Results for threshold voltage options, supply voltage, frequency, and particle LET are presented and compared with 16-nm node.

E-4 **Pulsed-Laser Testing to Quantitatively Evaluate Latchup Sensitivity in Mixed-Signal ASICs**

J. Hales[1], A. Khachatrian[1], A. Ildefonso[1], S. Buchner[1], D. Adams[2], D. Wheeler[2], S. Messenger[2], C. Mishler[2], N. Budzinski[2], S. Jordan[3], R. Van Art[3], D. McMorrow[1]

1. *Naval Research Laboratory, USA*
2. *Northrop Grumman Corporation, USA*
3. *Jazz Semiconductor Trusted Foundry, Inc, USA*

Pulsed-laser testing is used to accurately determine SEL thresholds for SRAMs with different body tie to drain spacings on a mixed-signal ASIC, a study which could not be completed using only broad beam heavy-ion testing.

PE-1 **Impact of Aging Degradation on Heavy-Ion SEU Response of 28 nm UTBB FD-SOI Technology**

M. Mounir Mahmoud[1], J. Prinzie[1], P. Leroux[1], D. Söderström[2], K. Niskanen[2], V. Pouget[3], A. Cathelin[4], S. Clerc[4]

1. *KU Leuven, Belgium*
2. *University of Jyväskylä, Finland*
3. *IES-CNRS, France*
4. *STMicroelectronics, France*

Negative bias temperature instability aging degradation has been experimentally proven to increase the SEU sensitivity for 28 nm FD-SOI flip-flops. Aging-aware simulation and Monte-Carlo simulation of radiation effects are presented to analyze the underlying mechanisms.

PE-2 **Experimental Findings on the Sources of Detected Unrecoverable Errors in GPUs**

F. Fernandes dos Santos[1], S. Malde[2], C. Cazzaniga[2], C. Frost[2], L. Carro[1], P. Rech[3]

1. *Universidade Federal do Rio Grande do Sul (UFRGS), Brazil*
2. *ISIS Neutron and Muon Facility, United Kingdom*
3. *Politecnico di Torino, Italy*

We investigate the sources of Detected Unrecoverable Errors (DUEs) in GPUs exposed to neutron beams. Illegal memory- accesses and interface errors are among the more likely sources of DUEs. ECC increases the launch failure events.

PE-3 **Comparison of Parallel Implementation Strategies in GPU-Based System-on-Chip Under Proton Radiation**

J. Badia[1], G. Leon[1], J. Belloch[2], M. García-Valderas[2], A. Lindoso[2], L. Entrena[2]

1. *Universitat Jaume I de Castellon, Spain*
2. *Universidad Carlos III de Madrid, Spain*

Emerging GPU-based Systems-on-Chips are highly parallel programmable co-processors. An efficient management of their computational resources is a challenging task. Experiments show that the cross-section depends on the parallelization strategy and problem size.

PE-4 **The Measurement of Heavy-Ion-Induced Charge Sharing in 14/16 nm Bulk FinFET Technology**

Y. Fang[1], B. Liang[1], P. Huang[1], Y. Chi[1], Q. Sun[1], Z. Zhao[1], J. Chen[1], S. He[2]

1. *National University of Defense Technology, China*
2. *Chengdu CORPRO Technology Co., Ltd., China*

To measure charge sharing in 14/16 nm bulk FinFET technology, a single event multiple transient (SEMT) test circuitry is designed. The heavy-ion experiment results reveal that charge sharing can induce SEMT.

Session F: HARDENING BY DESIGN

Available for On Demand July 22 - August 15

Live Q&A - Friday, July 23 • 11:30-12:15 EDT

Chair: Li Chen (University of Saskatchewan)

F-1 Radiation Hardening Using Back-gate Bias in Double-SOI Structure

Y. Huang[1], F. Liu[2], B. Li[2], B. Li[2], Z. Han[1], J. Gao[2], G. Zhang[2], L. Wang[2], D. Li[2], F. Zhao[2], T. Ye[2]
1. Inst. of Microelectron., CAS; University of CAS, China
2. Inst. of Microelectron., CAS, China

The back-gate biases during both irradiation and test on the impacts of total ionizing dose in a 0.2 µm Double-SOI technology are studied at both device and circuit level with experiment and TCAD simulation.

F-2 Evaluation of a Multiprocessor System Hardened with Macro-Synchronized Lockstep with FreeRTOS OS Using Proton Irradiation

P. Aviles[1], A. Lindoso[1], J. Belloch[1], M. García-Valderas[1], Y. Morilla[2], L. Entrena[1]
1. Universidad Carlos III de Madrid, Spain
2. CNA, Spain

This work presents a multiprocessor hardened with a macro synchronized lockstep and additional protections. Experimental results with low energy protons demonstrate the high error coverage, reducing the cross section by two orders of magnitude.

F-3 A SET-Tolerant Multipath-Coupled Ring VCO with Low-Phase-Noise and High Frequency

H. Sang[1], H. Yuan[1], B. Liang[1], J. Chen[1], Y. Chi[1], Y. Guo[1]
1. National University of Defense Technology, China

A high-frequency and low-phase-noise multipath-coupled ring VCO is proposed. The frequency of the VCO ranges from 1.1GHz to 5GHz, and phase noise is 96.7dBc/Hz@1MHz at 2.5GHz. Laser experiments show that the irradiation threshold is 500pJ.

F-4 Analyzing Reduced Precision Triple Modular Redundancy Under Proton Irradiation

L. García-Astudillo[1], A. Lindoso[1], L. Entrena[1], H. Martín[1], M. García-Valderas[1]
1. Universidad Carlos III de Madrid, Spain

We evaluate Reduced Precision TMR under low energy protons using several versions of an FFT IP as a case study. We show that RPR uses less resources and is less prone to Common Mode Failures.

PF-1 Study the Impact of SEE Reliability of CNN Architectures and Hardening Approaches Implemented on SRAM FPGA

Y. Wang[1], C. Jin[1], S. Shi[1], H. Tian[1], Z. Yang[1], L. Chen[1], D. Hiemstra[2]
1. University of Saskatchewan, Canada
2. MDA, Canada

FPGA-based CNN acceleration designs were implemented with both streaming and single computation engine architectures along with hardened versions, and evaluated with proton irradiation. It showed that hardened designs can effectively improve SEE resilience.

PF-2 **Evaluation of the Radiation Tolerance Convolution Neural Networks with Selective Hardening and Various Acceleration Algorithms in FPGAs**

H. Tian[1], Y. Wang[1], J. Chen[1], S. Shi[1], Z. Yang[1], L. Chen[1], D. Hiemstra[2]
1. *University of Saskatchewan, Canada*
2. *MDA Inc., Canada*

FPGA-based CNN acceleration designs were implemented with selective hardening, also with winograd and systolic array acceleration algorithms. The proton irradiation results showed SEU resilience can be effectively improved by selective hardening and acceleration algorithm implemented.

PF-3 **Radiation Effect and Hardening Technique of a Mixed-Signal Spike Neural Network**

Q. Jiale[1], L. Zhen[1], L. Bo[1], G. Jiantou[1], L. Jiajun[1], S. Xiaohui[1], L. Peng[1]
1. *Inst. of Microelectron., CAS, China*

TID effect decreases the average spike rate and spike amplitude of a mixed-signal Spike Neural Network (SNN). The radiation-sensitive node of SNN is identified, and a guidance towards radiation-hardening SNN is proposed.

Session G: DOSIMETRY

Available for On Demand July 22 - August 15

Live Q&A - Friday, July 23 • 11:30-12:15 EDT *Chair(s): Arto Javanainen (University of Jyväskylä)*

G-1 **Optical Fiber-based Monitoring of X-Ray Pulse Series from a Linear Accelerator**

J. Vidalot[1], A. Morana[2], G. Assaillit[3], M. Gaillardin[3], H. El Hamzaoui[4], G. Bouwmans[4], A. Cassez[4], B. Capoen[4], M. Bouazaoui[4], Y. Ouerdane[2], A. Boukenter[2], S. Girard[5], P. Paillet[3]
1. *CEA / Université Jean Monnet St Etienne, France*
2. *Laboratory Hubert Curien, France*
3. *CEA, France*
4. *PhLAM - University of Lille, France*
5. *Université de Saint Etienne, France*

We demonstrate the monitoring of series of X-ray pulses using optical fiber radiation-induced emission. The tested fibers are suitable to count the number of pulses, their frequencies as well as the associated dose rates.

G-2 **Design Considerations for Flash Memory Based Dosimeter**

P. Kumari[1], B. Ray[1]
1. *The University of Alabama in Huntsville, USA*

We discuss the design rules for the flash memory-based dosimeter for high sensitivity and accuracy. We find that ~10 rad can be sensed with good accuracy using commercial unmodified memory chips.

PG-1 **Measurements of Low-Energy Protons Using a Silicon Detector for Application to SEE Testing**

C. Cazzaniga[1], R. García Alia[2], A. Coronetti[2,6], K. Bilko[2], Y. Morilla[3], P. Martín-Holgado[4], M. Kastriotou[1], C. Frost[5]
1. *STFC, United Kingdom*
2. *CERN, Switzerland*
3. *CNA, Spain*
4. *Centro Nacional de Aceleradores, Spain*
5. *ISIS Neutron and Muon Facility, United Kingdom*
6. *University of Jyväskylä, Finland*

A silicon detector with a fast electronics chain is used for the dosimetry of protons in the range 0.5-5 MeV. Measurements of flux and deposited energy are used to enable SEE testing on selected SRAMs.

PG-2 **Impact of Beam Collimation for Single Event Effects Testing Using a Clinical Proton Delivery System**

J. Younkin[1], J. Bird[2], H. Stuckey[1], J. Shen[1], J. Stoker[1], D. Robertson[1]
1. *Mayo Clinic, USA*
2. *Radiation Test Solutions, USA*

Proton beam collimation for single event testing changes energy profiles. These impacts were modeled for a synchrotron-based proton delivery system. The TID, TNID, particle fluence, and uniformity impacts to electronics under test are discussed.

RADIATION EFFECTS DATA WORKSHOP

Available for viewing July 19 - August 15

Data Workshop Session - Thursday, July 22 • 12:30-14:30 EDT with Live Author Chat

Chair(s): Helmut Puchner (Infineon Technologies)

DW-1 **Compendium of Radiation Effects Test Results from NASA Goddard Space Flight Center**

A. Topper[1], M. Casey[2], E. Wilcox[2], M. Campola[2], D. Cochran[1], M. O'Bryan[3], J. Pellish[2], P. Majewicz[2]
1. *SSAI, USA*
2. *NASA GSFC, USA*
3. *AS&D, Inc (soon to change to SSAI), USA*

Total ionizing dose, displacement damage dose, and single event effects testing were performed to characterize and determine the suitability of candidate electronics for NASA space utilization.

DW-2 **The Aerospace Corporation's Compendium of Recent Radiation Testing Results**

S. Davis[1], A. Yarbrough[1], R. Koga[1], A. Wright[1], J. Taggart[1], B. Davis[1]
1. *The Aerospace Corporation, USA*

Radiation testing was performed on several commercial components to determine the response of these components to the space radiation environment. Testing was performed mostly using low and high energy protons.

DW-3 **Guide to the 2020 IEEE Radiation Effects Data Workshop Record**

D. Hiemstra[1]

1. MDA, Canada

The 2020 Workshop Record has been reviewed and a table prepared to facilitate the search for radiation response data by part number, type, or effect.

DW-4 **Total Ionizing Dose and Single Event Effect Test Results for Chinese Radhard Electronics**

T. Maksimenko[1], *A. Koziukov*[1], *A. Kalashnikova*[1], *A. Klyayn*[1], *N. Bondarenko*[1], *K. Bu-Khasan*[1], *M. Vyrostkov*[1], *M. Tiurnikov*[1], *R. Mangushev*[1], *G. Protopopov*[1], *S. Iakovlev*[1], *P. Chubunov*[1]

1. Institute of Space Device Engineering, Russian Federation

In this paper we show single event effects and total ionizing dose testing results of Chinese components such as VCOs, RAMs, frequency synthesizers and power devices. Results are presented for electronic components with radhard label.

DW-5 **Comparative Study of TID and SEE Results of DDR4 SDRAMs**

P. Kohler[1], *A. Bosser*[1], *P. Wang*[1], *B. Huret*[1], *H. Kettunen*[2], *A. Javanainen*[2]

1. 3D PLUS, France

2. University of Jyväskylä, Finland

This paper presents the results of Total Ionizing Dose (TID) and Single Event Effects (SEE) test campaigns carried out on multiple DDR4 SDRAM components.

DW-6 **Single Event Effects Evaluation of the ST-DDR4 Spin-transfer Torque Magnetoresistive Random Access Memory (STT-MRAM)**

S. Vartanian[1], *J. Yang-Scharlotta*[1], *G. Allen*[1], *A. Daniel*[1], *F. Mancoff*[2], *D. Symalla*[2], *A. Olsen*[2]

1. NASA JPL, USA

2. Everspin Technologies, USA

We present preliminary single event effects (SEE) evaluation of the Everspin Technologies 1Gb non-volatile ST-DDR4 spin-transfer torque MRAM.

DW-7 **SEL and TID Characterization of a Cobham QCOTS 512Gb NAND Flash Nonvolatile Memory for Space Applications**

M. Von Thun[1], *P. Nelson*[1], *A. Turnbull*[1], *B. Baranski*[1]

1. Cobham Advanced Electronics Solutions, USA

Single Event Latch-up (SEL) and Total Ionizing Dose (TID) radiation characterization was performed on a Cobham quantified-off-the-shelf (QCOTS) 512Gb 3D NAND flash memory. The device was shown to be suitable for space applications.

DW-8 **Thermal-to-High-Energy Neutron SEU Characterization of Commercial SRAMs**

A. Coronetti[1,5], *R. García Alia*[1], *M. Letiche*[2], *C. Cazzaniga*[3], *M. Kastriotou*[3], *M. Cecchetto*[1], *K. Bilko*[1], *P. Martín-Holgado*[4]

1. CERN, Switzerland

2. Institut Laue Langevin, France

3. STFC, United Kingdom

4. Centro Nacional de Aceleradores, Spain

5. University of Jyväskylä, Finland

Several commercial SRAMs have been tested by the CERN R2E project with neutrons of various energy. The test data are used to cross-compare facilities and to analyze variabilities within SRAMs from the same manufacturer.

DW-9 SEE and Total Dose Results of the ISL73033SLHM Dri-GaN Power Stage with 100V GaN FET

W. Newman[1], N. van Vonno[1], L. Pearce[1], D. Wackley[1], E. Thomson[1]
1. Renesas Electronics America, USA

We report the single event performance and low dose rate results of the radiation-hardened ISL73033SLHM gate driver power stage with a 100V enhancement mode GaN FET in single package.

DW-10 Single Event Burnout in Vertical GaN Diodes

M. Martinez[1], A. Colon[1], B. Gunning[1], K. Kropka[1], J. Neely[1], G. Pickrell[1]
1. Sandia National Laboratories, USA

Heavy ion testing of homojunction GaN vertical diodes shows a vulnerability to single event burnout and indications that atomic number of the ion species is a dominant factor compared to Linear Energy Transfer.

DW-11 Single Event Latchup (SEL) and Single Event Upset (SEU) Evaluation of Xilinx 7nm Versal™ ACAP Programmable Logic (PL)

P. Maillard[1], Y. Chen[1], J. Barton[1], M. Voogel[1]
1. Xilinx, Inc, USA

The single-event response of Xilinx 7nm Versal™ ACAP programmable logic (PL) is characterized using neutron and 64 MeV proton irradiation sources. Single event latch, single-event upset and multi-bits upset results are presented.

DW-12 Preliminary Heavy Ion and Proton Test Results for Recent-Generation GPUs

I. Troxel[1], J. Schaefer[1], M. Gruber[1]
1. Troxel Aerospace Industries, Inc., USA

Preliminary heavy ion and proton results are presented for recent-generation AMD and NVIDIA GPUs. Data include destructive and non-destructive single event effects as well as proton TID.

DW-13 SEU Characterization of the Microsemi PolarFire Field Programmable Gate Array Functional Blocks Using Proton Irradiation

J. Waskowic[1], D. Hiemstra[2], S. Shi[1], L. Chen[1]
1. University of Saskatchewan, Canada
2. MDA, Canada

SEU cross-sections of certain functional blocks of the Microsemi PolarFire FPGA were tested under protonradiation. Suitability for low earth radiation environmentis is considered.

DW-14 SEE Test Results for SAMA5D3

S. Guertin[1], T. Turchan[1], A. Daniel[1]
1. NASA JPL, USA

SEE performance of SAMA5D3 is presented. SRAM sensitivity was observed starting at LET ~3 MeV-cm^2/mg, with saturated cross section of 2x10^{-8} cm^2/bit. Crash sensitivity was similar, with higher sensitivity for Linux compared to bare metal.

DW-15 Radiation Evaluation of the Texas Instruments TPS7H4001-SP 18 Amps Buck Converter

J. Cruz Colon[1], T. Lew[1], N. Cunningham[1]
1. Texas Instruments, USA

Heavy-ion single event effects on RHA units with LETEFF of 49 to 75 MeV-cm²/mg and total ionizing doseincluding LDR and HDR up to 100 krad(Si) are presented and discussed.

DW-16 Total Dose Performance at High and Low Dose Rate of a CMOS, Low Dropout Voltage Regulator Showing Enhanced Low Dose Rate Sensitivity

D. Hiemstra[1], S. Shi[2], Z. Yang[2], L. Chen[2]
1. MDA, Canada
2. University of Saskatchewan, Canada

Results of Cobalt-60 irradiation of a CMOS lowdropout voltage regulator at high and low dose rate arepresented. Hardness assurance implications due to observationof ELDRS for analog CMOS microcircuits are discussed.

DW-17 Dependence of Failure Total Dose Level of BiCMOS Linear Voltage Regulator on Supply Voltage in Wide Operation Temperature Range

A. Bakerenkov[1], V. Pershenkov[1], V. Felitsyn[1], A. Rodin[1], V. Telets[1], V. Belyakov[1], D. Veselov[1], A. Zhukov[1], D. Arzamatseva[1]
1. National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Russian Federation

It is shown experimentally that high supply voltages are worst case operating conditions for LD3985M33R BiCMOS linear voltage regulators in full operation temperature range. Corresponding analysis and explanation are also presented.

DW-18 Total Ionizing Dose and Heavy Ion Irradiation Test Results of MicroModule Regulators

B. Vermeire[1], D. Hansen[1]
1. Space Micro, USA

Total ionizing dose and heavy ion radiation test results are provided for two commercial MicroModule regulators that have no comparable space-qualified equivalents. Results suggest that these parts may not be suitable for most missions.

DW-19 Single Event Effects and Total Dose Performance at High and Low Dose Rate of a Switching Regulator

Z. Yang[1], D. Hiemstra[2], L. Chen[1], S. Shi[1]
1. University of Saskatchewan, Canada
2. MDA Inc, Canada

Results of proton and low dose rate Cobalt-60 irradiation of a switching regulator are presented. Performance in the space radiation environment is discussed.

DW-20 Single-Event Effects Test Methodology for Precision SAR ADCs

J. Harris[1], N. van Vonno[1], L. Pearce[1], E. Thomson[1]
1. Renesas Electronics America, USA

We describe a test methodology to adequately identify single event effects (SEE), namely single event transients (SET) and single event functional interrupts (SEFI) in precision SAR ADCs without user configurable registers.

DW-21 SEE and TID Evaluation of the ADC ADS8350 Using Proton Irradiation

S. Shi[1], D. Hiemstra[2], Z. Yang[1], L. Chen[1]
1. University of Saskatchewan, Canada
2. MDA, Canada

The susceptibility to both SEE and TID of the ADS8350 was tested using 105 MeV protons. No SEE was observed while the device failed at a the TID of 25 krad(Si).

DW-22 Total Ionizing Dose and Single Event Effects Test Results of Texas Instruments LMK04832-SP (5962R1722701VXC) 3.2 GHz JESD204B Clock Jitter Cleaner with 14 Outputs

K. Kruckmeyer[1], H. Castro[1], T. Trinh[1], A. Black[1], V. Vanjari[1], D. Payne[1], R. Gooty[1], S. Williams[1]
1. Texas Instruments, USA

The LMK04832-SP is a radiation hardened JESD24B compliant clock conditioner with integrated VCOs that can provide clock signals up to 3.2 GHz on up to 14 outputs. ELDRS and SEE test data are presented.

DW-23 Heavy Ion Single Event Effects (SEE) Results for OPA128 Electrometer Grade Operational Amplifier

S. Katz[1], J. Likar[1], C. Pham[1], D. Chen[2], N. Ahmed[1]
1. The Johns Hopkins University Applied Physics Laboratory, USA
2. Zero G Radiation, USA

Heavy Ion testing of the Burr-Brown OPA128 yielded a proposed Safe Operating Area (SOA); non-destructive events were observed and characterized for multiple applications.

DW-24 Heavy Ion Induced Single Event Effects Characterization of the XQE-0920 Commercial Off-the-Shelf CMOS Photonic Imager Microcircuit

R. Koga[1]
1. Aerospace, USA

We present observations of heavy ion induced single event effects on the XQE-0920 CMOS imager microcircuit. Pixel upsets as well as upsets accompanying a high level of bias current were observed.

DW-25 Radiation Test Results for the Glenair 0500-3011 DWDM Optical Transceiver

R. Logan[1], J. Schaefer[2], M. Gruber[2], I. Troxel2
1. Glenair, USA
2. Troxel Aerospace, USA

We report test results of proton testing on 1550nm optical transceiver modules for intersatellite links.

DW-26 Single Event Effects Testing of a Vertical Optocoupler with Unmodified Packaging

L. Ryder[1], T. Carstens[1], A. Phan[2], C. Seidleck[2], M. Campola[1]
1. NASA GSFC, USA
2. SSAI Inc., USA

Single event effects measurements were conducted on a ACPL-785E optocoupler at NASA Space Radiation Laboratory. Measurements with a periodic input signal show single event transients and a radiation-induced time delay of the output signal.

DW-27 Radiation Test Results of Total Ionizing Dose, Enhanced Low Dose Rate Sensitivity, and Neutron Displacement Damage for the Micropac JANSR4N49BU and JANSR4N49U Optocouplers

Y. Liu[1], B. Spitzer[1], D. Young[1], M. Tsecouras[1], B. Campanini[1]
1. Micropac Industries Inc, USA

This paper reports radiation test results of Total Ionizing Dose (TID) at High Dose Rate and Enhanced Low Dose Rate Sensitivity (ELDRS), as well as neutron displacement damage for the Micropac JANSR4N49BU and JANSR4N49U optocouplers.

DW-28 Total Ionizing Dose Effects of n-FinFET Transistor in iN14 Technology

L. Artola[1], C. Thomas[2], T. Nuns[1], G. Cussac[1], M. Jerome[2]
1. ONERA, France
2. imec, Belgium

This work presents the TID evaluation of iN14 technology developed by IMEC under gamma irradiations. The impacts of TID on electrical characteristics and on the transistor-to-transistor variability are presented for nFinFET for several gate lengths.

DW-29 First Results on BJTs in Space: ELDRS Experiment on NASA Space Electronic Testbed

A. Benedetto[1], H. Barnaby[1], C. Cook[1], M. Campola[2], A. Tender[3]
1. Arizona State University, USA
2. NASA, USA
3. Yale, USA

Flight data on bipolar junction transistors is recorded and the effect of low dose rate space irradiation on BJTs is studied, leading to results comparable to ground-based testing.

DW-30 A Low-Cost High Precision 2D Beam Scanning Device Based on a Consumer 3D Printer

E. Cascio[1], B. Gottschalk[2]
1. Burr Proton Therapy Center at MGH, USA
2. Harvard University Laboratory for Particle Physics and Cosmology, USA

We describe a very low-cost high precision 2D beam scanning system, based on a consumer 3D printer, that is suitable for radiation beam size and uniformity quality assurance measurements.

Session H: SPACE AND TERRESTRIAL ENVIRONMENTS

Available for On Demand July 23 - August 15

Live Q&A - Friday, July 23 • 12:15-13:00 EDT

Chair(s): Alex Hands (Surrey University)

H-1 The DIME-2 Experiment Flown as Part of NASA's SET-1 on the DSX Satellite

P. McNulty1, K. Poole1, J. Poole1
1. Clemson University, USA

A practical dosimetry system for potential SEE is tested on DIME-2 for doses exceeding 12 krad. Data are collected as a function of effective LET.

H-2 Application of an SOI Microdosimeter for Monitoring of Neutrons in Various Mixed Radiation Field Environments

V. Pan[1], L. Tran[1], B. James[1], K. Jakubowski[1], D. Bolst[1], F. Pagani[2], D. Cutajar[1], J. Poder[3], L. Chartier[4], E. Debrot[1], Z. Pastuovic[4], D. Prokopovich[5], S. Guatelli[1], M. Petasecca[1], M. Lerch[1], M. Povoli[6], A. Kok[6], A. Rosenfeld[1]

1. *University of Wollongong, Australia*
2. *40Factory SRL, Italy*
3. *St George Cancer Care Clinic, Australia*
4. *ANSTO, Australia*
5. *MedAustron, Austria*
6. *SINTEF, Norway*

An SOI microdosimeter is successfully utilized in a gamma-neutron mixed radiation field for characterizing the neutron component of the field. A CCE study is also presented for a newly developed 2 µm thick microdosimeter.

PH-1 The DIME-1 Experiment Flown as Part of NASA's SET-1 Project on the DSX Satellite

K. Poole[1], P. McNulty[1], J. Poole[1]

1. *Clemson University, USA*

DIME-1 is an experiment flying as part of NASA's SET-1 project on the Air Force's DSX satellite to compare novel dosimeters to the standard RadFET dosimeters.

PH-2 Real-Time Characterization of Neutron-induced SEUs in Fusion Experiment at WEST Tokamak During D-D Plasma Operation

S. Moindjie[1], D. Munteanu[2], M. Dentan[3], P. Moreau[4], F. Pellissier[4], J. Bucalossi[4], G. Borgese[5], V. Malherbe[6], T. Thery[6], G. Gasiot6, P. Roche[6], J.-L. Autran[1]

1. *Aix-Marseille University, France*
2. *CNRS, France*
3. *ITER Organization, France*
4. *CEA-IRFM, France*
5. *Vitrociset S.p.A., Italy*
6. *STMicroelectronics, France*

We conducted a real-time SER characterization of CMOS bulk 65nm SRAMs subjected to fusion neutrons during deuterium-deuterium plasma operation at WEST tokamak. Neutron spectrometry and numerical simulation have been also performed to analyze experimental results.

Session I: PHOTONIC DEVICES AND INTEGRATED CIRCUITS

Available for On Demand July 23 - August 15

Live Q&A - Friday, July 23 • 12:15-13:00 EDT

Chair(s): Scott Davis (The Aerospace Corporation)

I-1 Temperature Dependence of Low-Dose Radiation-Induced Attenuation of Germanium-Doped Optical Fiber at InfraRed Wavelengths

A. Morana[1], C. Campanella[1], M. Aubry[2], E. Marin[1], A. Boukenter[1], Y. Ouerdane[1], S. Girard[1]

1. *Laboratoire Hubert Curien, France*
2. *CNES / iXblue / Laboratoire Hubert Curien / Politecnico di Bari, France*

Combined temperature and radiation effects on Ge-doped fiber transmission are studied at telecom wavelengths, between -80°C and 80°C, up to 10 kGy(SiO_2) dose. Losses are an order of magnitude higher at -80°C than at 20°C.

I-2 **Modeling Transient Loss Due to Ionizing Particles in Silicon Photonic Waveguides**

P. Goley[1], G. Maggioni[2], E. Preisler[3], J. Cressler[1]
1. Georgia Institute of Technology, USA
2. Bayer AG, Germany
3. Tower Semiconductor, USA

A general, compact, physics-based framework for modeling transient loss due to ionizing particles in silicon photonic waveguides is presented. The model shows good agreement with 639-nm laser-induced free carrier absorption transient measurements.

PI-1 **Charge Collection Characterization of a Silicon Avalanche Photodiode (Si APD) under Alpha Irradiation**

R. Nederlander[1], F. Padgett[2], E. Zhang[1], M. McCurdy[1], L. Matei[2], A. Tonigan[1], L. Ryder[1], K. Ryder[1], R. Schrimpf[1], K. Stassun[1], R. Reed[1]
1. Vanderbilt University, USA
2. Fisk University, USA

APD's collected charge is measured in response to alphas from Am^{241} and compared against gain characteristics from 420 nm photons. Photon gain increases while alpha collected charge saturates due to modulation of APD's electrostatic potential.

Session: POSTER SESSION

Available for viewing July 19 - August 16

Chair(s): Ted Wilcox (NASA Goddard Space Flight Center)

PA-1 **Radiation Hardness and Damage Mechanism of Carbon Nanotube Thin Film-Based Field-Effect Transistors Under Low-Energy Proton Irradiation**

M. Li[1], H. Zhu[2], X. Zhang[2], S. Peng[2], L. Wang[2], X. Li[3], J. Yang[3], B. Li[2], J. Zhang[4], F. Zhao[2]
1. IMECAS, CAS; N. China Univ. Technol, China
2. Inst. Microelectron., CAS, China
3. Harbin Inst. Technol., China
4. N. China Univ. Technol, China

Radiation effects of CNT-TFTs under 150 keV proton irradiation are investigated. A high radiation tolerance of 5×10^{13} p/cm^2 is demonstrated, and a deep insight into damage mechanisms under higher fluence is given.

PA-2 **Effects of Total Ionizing Dose on PEDOT/PSS Organic Memory Devices**

C. Bennett[1], D. Robinson[1], T. Xiao[1], A. Melianas[2], D. Hughart[1], S. Agarwal[1], E. Fuller[1], Y. Li[3], A. Salleo[2], M. Allendorf[1], A. Talin[1], M. Marinella[1]
1. Sandia National Laboratories, USA
2. Stanford University, USA
3. University of Michigan, USA

Electrochemical random-access memory (EC-RAM) is a promising non-volatile memory, but its response to total ionizing dose (TID) is unexplored. We expose several ECRAM devices (PEDOT/PSS bulk) to Co-60 gamma radiation and find significant responses.

PA-3 **Influence of LDD Spacers on Total Ionizing Dose Response of Bulk MOSFETs at Cryogenic Temperature**

G. Cussac[1], T. Nuns[1], S. Ducret[2], S. Duzellier[1], L. Artola[1]
1. ONERA, France
2. Lynred, France

This work presents electrical characteristics of irradiated MOSFET transistors up to 300 krad, at three different temperatures. Transconductance improves with ionizing dose at low temperature due to trapped charges in spacers near LDD regions.

PA-4 **Evolution and Mechanism of P-GaN Under Proton Irradiation**

L. Wang[1], Y. Tang[2], H. Zhu[1], X. Cai[1], X. Zhang[1], J. Gao[1], N. Liu[3], X. Li[4], J. Yang[4], B. Li[1], F. Zhao[1]
1. IMECAS, China
2. IMECAS;Key Laboratory of Science and Technology on Silicon Devices, Chinese Academy of Sciences, China
3. Guangdong Institute of Semiconductor Industrial Technology, China
4. Harbin Inst. Technol., China

Electrical properties deterioration of P-GaN under 150 keV proton irradiation was investigated. It was confirmed that P-GaN is transformed into N-type as fluence increases. Primary defects generated by irradiation were revealed by PL measurements.

PB-1 **Numerical Modeling of Proton Direct Ionization Single Event Effects in Sub-Micron Technology**

S. Lüdeke[1], A. Javanainen[1]
1. University of Jyväskylä, Finland

A numerical algorithm for the calculation of proton direct ionization cross-sections based on a linear energy transfer and a straggling model is presented and benchmarked against experimental and simulated data.

PB-2 **Using Machine Learning to Determine Proton Cross-Sections from Heavy-Ion Data**

D. Hansen[1], D. Czjkowski[1], B. Vermeire[1]
1. Space Micro, USA

This paper reports on the calculation of proton SEU cross-sections using heavy-ion data with machine-learning techniques. Model-averaging techniques are applied and improve the accuracy of the calculation.

PB-3 **G4SEE: A Geant4-Based Single Event Effect Simulation Tool and Its Validation Through Mono-Energetic Neutron Measurements**

D. Lucsányi[1], R. García Alía[1], K. Biłko[1], M. Cecchetto[1], S. Fiore[2]
1. CERN, Switzerland
2. ENEA Frascati Research Center, Italy

A novel, SEE simulation tool has been developed for the radiation effects community. It has been demonstrated and validated by inelastic energy deposition events of 14.8 MeV neutrons measured with a silicon diode detector.

PB-4 **Threshold Contributions to Heavy Ion Soft Error in FinFETs using GEANT4**

P. Johnson[1], D. Valencia[1], D. Larsen[1], S. Aghara[2]
1. The Charles Stark Draper Laboratory, Inc., USA
2. University of Massachusetts Lowell, USA

Heavy-ion induced soft errors in SRAM with FinFETs are influenced by events far from average quantities due to straggling and spatial limits. GEANT4 is used to model 16nm FinFET soft error cross sections.

PC-1 **Total-Ionizing-Dose Effects on Read Noise of MLC 3D NAND Memories**

U. Surendranathan[1], M. Wasiolek[2], K. Hattar[2], D. Fleetwood[3], B. Ray[4]

1. The University of Alabama in Huntsville, USA
2. Sandia National Laboratories, USA
3. Vanderbilt University, USA
4. University of Alabama in Huntsville, USA

We find that bit errors caused by read-noise are significant on irradiated MLC 3D NAND chips. Bit-flip noise was more dominant on cells in an erased state during irradiation compared to programmed cells.

PC-2 **Exploration of Synergistic Behavior of Operational Amplifiers in Combined Ion and Electron Environments**

J. Young[1], J. Manuel[1], G. Vizkelethy[1], E. Bielejec[1]

1. Sandia National Laboratories, USA

Degradation of op-amps in combined and individual environments was explored using simultaneous irradiation with ions and electrons. Input bias and offset currents were lower for the mixed-field irradiation compared to the sum of separate environments.

PC-3 **Effect of Frequency on Total Ionizing Dose Response of Ring Oscillator Circuits at the 7-nm Bulk FinFET Node**

A. Feeley[1], Y. Xiong[1], B. Bhuva[1]

1. Vanderbilt University, USA

RO circuits under dynamic and static test conditions are used to characterize the effects of frequency on TID response. Results show that static conditions overestimate the effects of TID on RO circuits.

PC-4 **Ionizing Radiation Effect in SRAM Physical Unclonable Function (PUF) with 4 Type-Specific Cells Using 28nm FDSOI**

Z. Su[1], B. Li[2], J. Gao[2], X. Su[2], G. Zhang[2], H. Ren[1], P. Lu[2], F. Liu[2], F. Zhao[2], Z. Han[1]

1. Institute of Microelectronics, Chinese Academy of Sciences; University of Chinese Academy of Sciences; Key Laboratory of Science and Technology on Silicon Devices, Chinese Academy of Sciences, China
2. IMECAS, China

Radiation effects on four type-specific SRAM PUFs were studied in terms of stability and uniqueness. PUF stability can be improved about 2X with smaller cells using cascade PMOS transistors which also makes its uniqueness better.

PC-5 **Investigation on Transient Ionizing Radiation Effects in a 4Mb SRAM with Dual Supply Voltages**

T. Li[1], Y. Zhao[1], L. Wang[1]

1. Beijing Microelectronics Technology Institute, China

The impact of transient ionizing radiation effects in an SRAM circuit was studied. Results indicate that core supply voltage suffers more serious disturbance. Voltage disturbance mitigation methods are presented.

PC-6 **Effects of Ionizing Radiation on SRAM Physical Unclonable Functions**

S. Lawrence[1], J. Cannon[2], J. Carpenter[1], D. Loveless[1]

1. University of Tennessee at Chattanooga, USA
2. University of Colorado Boulder, USA

The effects of TID on SRAM Physical Unclonable Functions and implications for authentication are studied through proton irradiation. Unhardened COTS SRAMs exhibit minor negative shifts in the intra- and inter-die Hamming Distance distributions with TID.

PC-7 **Comparison of Total Ionizing Dose Effects in SOI FinFETs Between RT and High Temperature**

X. Zhang[1], F. Liu[2], B. Li[2], C. Yang[2], G. Wang[2], P. Lu[2], S. Chen[2], J. Zhou[3], J. Yang[3], J. Luo[2]
1. Institute of Microelectronics, Chinese Academy of Sciences; University of Chinese Academy of Sciences; Key Laboratory of Science and Technology on Silicon Devices, Chinese Academy of Sciences, China
2. C2. CMEI, China
3. X LAB, The Second Academy of CASIC, China

TID effects at room and high temperature are investigated for SOI FinFETs, which are experimentally explained from different trapped-charges in gate oxide. The synergetic effects of TID and temperature worsen degradation for n-SOI FinFETs.

PC-8 **In-Situ Measurement of TID-Induced Leakage Using On-Chip Current Modulation**

S. Vibbert[1], C. Watkins[1], J. D'Amico[1], M. Mckinney[1], D. Vibbert[1], D. Ball[1], T. Haeffner[1], J. Kauppila[1], L. Massengill[1]
1. Vanderbilt University, USA

We have developed the on-chip Photocurrent Measurement Circuit (PMC), providing a means to capture device-level TID-induced leakage in sub-50nm technologies. Leakage data were gathered using the PMC and is compared to direct measurements.

PD-1 **Total-Ionizing-Dose Effects on Long-Term Data Retention Characteristics of Commercial 3D NAND Memories**

M. Buddhanoy[1], P. Kumari[1], U. Surendranathan[1], M. Wasiolek[2], K. Hattar[2], B. Ray[1]
1. The University of Alabama in Huntsville, USA
2. Sandia National Laboratories, USA

We find that data retention properties of MLC 3D NAND chips are significantly degraded with irradiation. Erase cells suffer more degradation compared to programmed cells suggesting pre-programming of memory modules before deploying in radiation-prone environments.

PD-2 **Dealing with Ion LET Uncertainties: An Application of Generalized Linear Models**

R. Ladbury[1]
1. NASA GSFC, USA

We propose Generalized Linear Models for understanding errors in SEE rate arising from uncertainties in LET of the ion responsible for the event. Applications are suggested and assessed for suitability of treatment by the model.

PD-3 **Investigation of Radiation Effects in RF Devices Based on a Software-Defined Radio Test Setup**

J. Budroweit[1], J. Häseker[1], N. Aksteiner[1]
1. DLR, Germany

A software-defined radio-based test setup for the radiation effects characterization on radio frequency devices is proposed. The setup is intended to reduce test complexity, equipment and costs, and to improve test automation and flexibility.

PD-4 **Total-Ionizing-Dose Resistant Novel Data Encoding Technique for NAND Memory**

S. Sakib[1], M. Wasiolek[2], K. Hattar[2], A. Milenković[1], B. Ray[1]
1. The University of Alabama in Huntsville, USA
2. Sandia National Laboratories, USA

We propose a non-charge-based novel data encoding technique that is more resistant to total-ionizing-dose effects than the traditional charge-based storage of NAND flash memory.

PE-1 **Impact of Aging Degradation on Heavy-Ion SEU Response of 28 nm UTBB FD-SOI Technology**

M. Mounir Mahmoud[1], J. Prinzie[1], P. Leroux[1], D. Söderström[2], K. Niskanen[2], V. Pouget[3], A. Cathelin[4], S. Clerc[4]
1. KU Leuven, Belgium
2. University of Jyväskylä, Finland
3. IES-CNRS, France
4. STMicroelectronics, France

Negative bias temperature instability aging degradation has been experimentally proven to increase the SEU sensitivity for 28 nm FD-SOI flip-flops. Aging-aware simulation and Monte-Carlo simulation of radiation effects are presented to analyze the underlying mechanisms.

PE-2 **Experimental Findings on the Sources of Detected Unrecoverable Errors in GPUs**

F. Fernandes dos Santos[1], S. Malde[2], C. Cazzaniga[2], C. Frost[2], L. Carro[1], P. Rech[3]
1. Universidade Federal do Rio Grande do Sul (UFRGS), Brazil
2. ISIS Neutron and Muon Facility, United Kingdom
3. Politecnico di Torino, Italy

We investigate the sources of Detected Unrecoverable Errors (DUEs) in GPUs exposed to neutron beams. Illegal memory- accesses and interface errors are among the more likely sources of DUEs. ECC increases the launch failure events.

PE-3 **Comparison of Parallel Implementation Strategies in GPU-Based System-on-Chip Under Proton Radiation**

J. Badia[1], G. Leon[1], J. Belloch[2], M. García-Valderas[2], A. Lindoso[2], L. Entrena[2]
1. Universitat Jaume I de Castellon, Spain
2. Universidad Carlos III de Madrid, Spain

Emerging GPU-based Systems-on-Chips are highly parallel programmable co-processors. An efficient management of their computational resources is a challenging task. Experiments show that the cross-section depends on the parallelization strategy and problem size.

PE-4 **The Measurement of Heavy-Ion-Induced Charge Sharing in 14/16 nm Bulk FinFET Technology**

Y. Fang[1], B. Liang[1], P. Huang[1], Y. Chi[1], Q. Sun[1], Z. Zhao[1], J. Chen[1], S. He[2]
1. National University of Defense Technology, China
2. Chengdu CORPRO Technology Co., Ltd., China

To measure charge sharing in 14/16 nm bulk FinFET technology, a single event multiple transient (SEMT) test circuitry is designed. The heavy-ion experiment results reveal that charge sharing can induce SEMT.

PF-1 Study the Impact of SEE Reliability of CNN Architectures and Hardening Approaches Implemented on SRAM FPGA

Y. Wang[1], C. Jin[1], S. Shi[1], H. Tian[1], Z. Yang[1], L. Chen[1], D. Hiemstra[2]
1. University of Saskatchewan, Canada
2. MDA, Canada

FPGA-based CNN acceleration designs were implemented with both streaming and single computation engine architectures along with hardened versions, and evaluated with proton irradiation. It showed that hardened designs can effectively improve SEE resilience.

PF-2 Evaluation of the Radiation Tolerance Convolution Neural Networks with Selective Hardening and Various Acceleration Algorithms in FPGAs

H. Tian[1], Y. Wang[1], J. Chen[1], S. Shi[1], Z. Yang[1], L. Chen[1], D. Hiemstra[2]
1. University of Saskatchewan, Canada
2. MDA Inc., Canada

FPGA-based CNN acceleration designs were implemented with selective hardening, also with winograd and systolic array acceleration algorithms. The proton irradiation results showed SEU resilience can be effectively improved by selective hardening and acceleration algorithm implemented.

PF-3 Radiation Effect and Hardening Technique of a Mixed-Signal Spike Neural Network

Q. Jiale[1], L. Zhen[1], L. Bo[1], G. Jiantou[1], L. Jiajun[1], S. Xiaohui[1], L. Peng[1]
1. Inst. of Microelectron., CAS, China

TID effect decreases the average spike rate and spike amplitude of a mixed-signal Spike Neural Network (SNN). The radiation-sensitive node of SNN is identified, and a guidance towards radiation-hardening SNN is proposed.

PG-1 Measurements of Low-Energy Protons Using a Silicon Detector for Application to SEE Testing

C. Cazzaniga[1], R. García Alia[2], A. Coronetti[2,6], K. Bilko[2], Y. Morilla[3], P. Martín-Holgado[4], M. Kastriotou[1], C. Frost[5]
1. STFC, United Kingdom
2. CERN, Switzerland
3. CNA, Spain
4. Centro Nacional de Aceleradores, Spain
5. ISIS Neutron and Muon Facility, United Kingdom
6. University of Jyväskylä, Finland

A silicon detector with a fast electronics chain is used for the dosimetry of protons in the range 0.5-5 MeV. Measurements of flux and deposited energy are used to enable SEE testing on selected SRAMs.

PG-2 Impact of Beam Collimation for Single Event Effects Testing Using a Clinical Proton Delivery System

J. Younkin[1], J. Bird[2], H. Stuckey[1], J. Shen[1], J. Stoker[1], D. Robertson[1]
1. Mayo Clinic, USA
2. Radiation Test Solutions, USA

Proton beam collimation for single event testing changes energy profiles. These impacts were modeled for a synchrotron-based proton delivery system. The TID, TNID, particle fluence, and uniformity impacts to electronics under test are discussed.

PH-1 **The DIME-1 Experiment Flown as Part of NASA's SET-1 Project on the DSX Satellite**

K. Poole[1], P. McNulty[1], J. Poole[1]
1. *Clemson University, USA*

DIME-1 is an experiment flying as part of NASA's SET-1 project on the Air Force's DSX satellite to compare novel dosimeters to the standard RadFET dosimeters.

PH-2 **Real-Time Characterization of Neutron-induced SEUs in Fusion Experiment at WEST Tokamak During D-D Plasma Operation**

S. Moindjie[1], D. Munteanu[2], M. Dentan[3], P. Moreau[4], F. Pellissier[4], J. Bucalossi[4], G. Borgese[5], V. Malherbe[6], T. Thery[6], G. Gasiot6, P. Roche[6], J.-L. Autran[1]
1. *Aix-Marseille University, France*
2. *CNRS, France*
3. *ITER Organization, France*
4. *CEA-IRFM, France*
5. *Vitrociset S.p.A., Italy*
6. *STMicroelectronics, France*

We conducted a real-time SER characterization of CMOS bulk 65nm SRAMs subjected to fusion neutrons during deuterium-deuterium plasma operation at WEST tokamak. Neutron spectrometry and numerical simulation have been also performed to analyze experimental results.

PI-1 **Charge Collection Characterization of a Silicon Avalanche Photodiode (Si APD) under Alpha Irradiation**

R. Nederlander[1], F. Padgett[2], E. Zhang[1], M. McCurdy[1], L. Matei[2], A. Tonigan[1], L. Ryder[1], K. Ryder[1], R. Schrimpf[1], K. Stassun[1], R. Reed[1]
1. *Vanderbilt University, USA*
2. *Fisk University, USA*

APD’s collected charge is measured in response to alphas from Am^{241} and compared against gain characteristics from 420 nm photons. Photon gain increases while alpha collected charge saturates due to modulation of APD’s electrostatic potential.

RESG NEWS

Janet Barth
Executive Chair

Robert Reed
Executive Vice-Chair

The purposes of the Radiation Effects Committee (REC) of the IEEE Nuclear and Plasma Sciences Society are to advance the theory and application of radiation effects and its allied sciences, to disseminate information pertaining to those fields, and to maintain high scientific and technical standards in our community. The REC aids in promoting close cooperation and the exchange of technical information among its members. This is done by running conferences for the presentation and discussion of original contributions, assisting in the publication of technical papers on radiation effects in the IEEE Transactions on Nuclear Science, coordinating development of radiation effects measurement definitions and standards within IEEE and other standards organizations, providing a sounding board for radiation effects specialists, providing for the continued professional development and needs of its members, and providing liaisons between IEEE and other technical organizations in the areas of radiation effects.

Each year, the REC provides a forum for the technical exchange of information by holding the Nuclear and Space Radiation Effects Conference (NSREC). The NSREC is an international forum for presentation of research papers on nuclear and space radiation effects. This includes effects on electronic and photonic materials, devices, circuits, sensors, and systems, and semiconductor processing technology and design techniques for producing radiation-tolerant (hardened) devices and integrated circuits. Papers presented at the NSREC are submitted for possible publication in the January issue of the IEEE Transactions on Nuclear Science in the year following the conference, subject to an additional review. A data workshop is also held each year at the NSREC. The REC oversees publication of a special Data Workshop issue of papers presented at the conference. The Data Workshop is published in the fall of the year.

NSREC 2021 will be held virtually July 17-23, 2021 with On-Demand Viewing through August 16, 2021. Steven McClure of The Jet Propulsion Laboratory is the Conference Chair. Supporters of the 2021 NSREC include The Aerospace Corporation, Boeing, CAES, EMPC, IR HiRel Products, an Infineon Technologies Company, Jet Propulsion Laboratory, L3 Harris, NASA Electronic Parts and Packaging Program, Radiation Test Solutions, Renesas, Skywater Technology, and Southwest Research Institute. We thank our supporters for their significant and continuing commitments to the conference and welcome other organizations to consider becoming supporters of the IEEE NSREC.

NSREC 2022 will be held in Provo, Utah, July 18-22, 2022, at the Utah Valley Convention Center. Tom Turflinger, The Aerospace Corporation, is the 2022 NSREC Chair. Keith Avery, Air Force Research Laboratory, is the Chair of NSREC 2023, which will be held in Kansas City, Missouri.

Papers presented at the 2021 NSREC are eligible for publication in the January 2022 issue of the IEEE Transactions on Nuclear Science. Authors must upload their papers prior to the conference for consideration for publication in the January 2022 TNS Special Issue. Detailed instructions can be found at ***www.nsrec.com.***

Keep visiting our web site at ***www.nsrec.com*** for author information, paper submission details, exhibitor links, on-line registration, and the latest NSREC information.

EDITORS
Dan Fleetwood
Vice-Chair of Publications

All papers accepted for oral or poster presentation in the technical program will be eligible for publication in a special issue of the *IEEE Transactions on Nuclear Science* (January 2022), based on a separate submission of a complete paper. Each paper will be subject to the standard full peer review given all papers submitted to the *IEEE Transactions on Nuclear Science.* All papers must be submitted on IEEE ScholarOne. Instructions for submitting papers can be found at the Conference web site ***www.nsrec.com.*** The deadline for submission of papers is July 16, 2021. Data Workshop papers are published in a Workshop Record and are not candidates for publication in the *IEEE Transactions on Nuclear Science.* The process for the Workshop Record is managed by the Workshop Chair.

The review process for papers submitted to the *Transactions* is managed by a team of editors. To provide consistent review of papers, this editorial team manages the review process for all radiation effects papers submitted to the *Transactions* throughout the year. The editorial team consists of a senior editor and seven associate editors who are technically knowledgeable in one or more specializations and are experienced in the publication process. If you would like to serve as a reviewer for the December issue of the *Transactions* or for radiation effects papers submitted throughout the year, please contact one of the editors. The editors for the 2021 NSREC are:

Dan Fleetwood, Senior Editor, Vanderbilt University
Email: dan.fleetwood@vanderbilt.edu

Dennis Brown, Associate Editor, IEEE NPSS
Email: brownden_1@yahoo.com

Heather Quinn, Associate Editor, Los Alamos National Laboratory
Email: hquinn@lanl.gov

William Robinson, Associate Editor, Vanderbilt University
Email: william.h.robinson@vanderbilt.edu

Steven Moss, Associate Editor, The Aerospace Corporation, retired
Email: scmosshb@aol.com

Vincent Goiffon, Associate Editor, ISAE-Supaero
Email: vincent.goiffon@isae.fr

Philippe Paillet, Associate Editor, CEA
Email: philippe.paillet@cea.fr

Lili Ding, Associate Editor, NINT China
Email: lili03_ding@126.com

Daniel Loveless, Guest Editor, University of Tennessee at Chattanooga
Email: daniel-loveless@utc.edu

ARE YOU A MEMBER OF IEEE?

Now is the time to join the Institute of Electrical and Electronics Engineers (IEEE) and the Nuclear Plasma Sciences Society (NPSS). Why? First of all, you'll become a member of the largest professional engineering society in the world. About 60% of NSREC attendees are IEEE members. The cost of membership in the IEEE depends on your country and your career phase. IEEE members receive access to a broad range of benefits, including a terrific insurance program, on-line access to IEEE publications, and reduced rates at all IEEE sponsored conferences, including, of course, the IEEE NSREC and Short Course!

NPSS membership is $35. NPSS members receive a free subscription to NPSS News, and free on-line electronic access via IEEE Xplore to the IEEE Transactions on Nuclear Science (TNS) and the NSREC Data Workshop Record. Now members can search and view digital copies of all IEEE TNS papers on-line all the way back to the first IEEE NSREC in 1964. NPSS members get to vote in our NSREC elections, held at the annual open meeting held during the conference. What are you waiting for? Apply for membership at ***http://ieee-npss.org/why-join-npss-and-ieee/*** or visit the IEEE registration desk at the conference.

NSREC PUBLICATIONS

NSREC has two publications each year:

- ***IEEE Transactions on Nuclear Science.*** This IEEE journal is the official archive of research papers presented at NSREC. Papers presented at the conference undergo an additional review before they are accepted for the January 2022 issue.

- ***Radiation Effects Data Workshop Record.*** Published each year in October, this IEEE proceedings has become the source for radiation test data on semiconductor components.

A complimentary copy of the 2021 *IEEE Radiation Effects Data Workshop Record* and the January 2022 special NSREC issue of the *IEEE Transactions on Nuclear Science* will be mailed to each NSREC technical session attendee if the attendee registered to be listed on the attendee list.

RADITION EFFECTS COMMITTEE ANNUAL OPEN MEETING

FRIDAY, JULY 23 13:00 – 14:00

You are invited to attend the IEEE Radiation Effects Committee's Virtual Annual Open Meeting on Friday, July 23, 13:00 – 14:30 EDT. All conference attendees are encouraged to attend.

We will introduce the new Chair, Vice-Chair, and Secretary of the Radiation Effects Steering Group who were elected by IEEE NPSS members in the spring. Candidates for the election were selected by the Radiation Effects Nomination Committee chaired by Allan Johnston. The new committee members will serve three-year terms and will begin their terms by running the 2021 open meeting. During the meeting, we will discuss the 2021 conference and future IEEE Nuclear and Space Radiation Effects Conferences. A report on the nomination processes for the 2021 Junior Member at-Large on the Radiation Effect Steering Group will be presented. Voting instructions for IEEE NPSS members will be provided.

Awards

2020 OUTSTANDING PAPER AWARD

Optical Single-Event Transients Induced in Integrated Silicon-Photonic Waveguides by Two-Photon Absorption
George N. Tzintzarov, Adrian Ildefonso, Jeffrey W. Teng, Milad Frounchi, Albert Djikeng, Prahlad Iyengar, Patrick S. Goley, Ani Khachatrian, Joel Hales, Ryan Bahr, Stephen P. Buchner, Dale McMorrow, and John D. Cressler

2020 MERITORIOUS PAPER AWARD

Effects of Bias and Temperature on the Dose-Rate Sensitivity of 65 nm CMOS Transistors
Giulio Borghello, Federico Faccio, Gennaro Termo, Stefano Michelis, Sebastiano Costanzo, Henri D. Koch and Daniel M. Fleetwood

2020 OUTSTANDING STUDENT PAPER AWARD

Optical Single-Event Transients Induced in Integrated Silicon-Photonic Waveguides by Two-Photon Absorption
George N. Tzintzarov, Adrian Ildefonso, Jeffrey W. Teng, Milad Frounchi, Albert Djikeng, Prahlad Iyengar, Patrick S. Goley, Ani Khachatrian, Joel Hales, Ryan Bahr, Stephen P. Buchner, Dale McMorrow, and John D. Cressler

2020 OUTSTANDING DATA WORKSHOP PRESENTATION AWARD

Energy-Dependent Single-Event Effects in Power MOSFETs from a Broad-Spectrum Neutron Beam
J. Pritts, S. Wender, J. George, T. Fairbanks, J. O'Donnell

2020 RADIATION EFFECTS AWARD

Dr. Philippe Calvel, RADCONSULT, received the 2020 Radiation Effects Award for leadership in the development of the RADECS Association, in the development of strong links between RADECS and IEEE/NPSS, and the growth and federation of the Radiation Effects Community.

2020 RADIATON EFFECTS EARLY ACHIEVEMENT AWARD

Dr. Cédric Virmontois, Centre National d'Études Spatiales (CNES), received the 2020 Radiation Effects Early Achievement Award for contributions to the understanding of radiation effects on solid-state image sensors, particularly the origins of radiation-induced dark current random telegraph signals.

2021 RADIATION EFFECTS AWARD

The winners of the 2021 Radiation Effects and Radiation Effects Early Achievement Awards will be announced Monday, July 19, 9:10-9:35 EDT. The purpose of the Radiation Effects Award is to recognize individuals who have had a sustained history of outstanding and innovative technical and/or leadership contributions to the radiation effects community. The purpose of the Radiation Effects Early Achievement Award is to recognize an individual early in his or her career whose technical contributions and leadership have had a significant impact on the field of radiation effects.

2022 RADIATION EFFECTS AWARD

Nominations are currently being accepted for the 2022 IEEE Nuclear and Plasma Sciences Society (NPSS) Radiation Effects Award. The basis of the award is for individuals who have: (1) a substantial, long-term history of technical contributions that have had major impact on the radiation effects community. Examples include benchmark work that initiated major research and development activities or a major body of work that provided a solution to a widely recognized problem in radiation effects; and/or (2) a demonstrated long-term history of outstanding and innovative leadership contributions in support of the radiation effects community. Examples include initiation or development of innovative approaches for promoting cooperation and exchange of technical information or outstanding leadership in support of the professional development of the members of the radiation effects community.

Awards

Nominations are currently being accepted for the 2022 Radiation Effects Early Achievement Award. The basis of the award is for individuals whose technical contributions and leadership during the first ten years of the recipient's career that have had a major impact on the Radiation Effects Community. Examples include work that provides a solution to important technical problems in radiation effects or work that identifies significant new issues in the field. Other factors are cumulative research contributions over the first part of the career, internationally recognized leadership, and mentorship. It is the intent of the RESG to give special consideration for this award to members of the community who are IEEE/NPSS members.

Cash awards and plaques will be presented at the 2022 IEEE NSREC in Provo, Utah in July 2022. Nomination forms are available electronically in PDF Format or in Microsoft Word format at ***http://ieee-npss.org/technical-committees/radiationeffects/.*** Forms should be sent to Michael Campola, Member-at-Large, NASA/Goddard, for the Radiation Effects Steering Group. Michael can be reached at ***michael.j.campola@nasa.gov.***

Registration and Travel

CONFERENCE REGISTRATION

NSREC encourages Pre-Registration and offers a lower registration rate, “Early Registration”, if the payment is received no later than Friday, June 18. After that date, the “Late Registration” rates apply.

There are three acceptable forms of payment for registration and activity fees:
1) check made payable to “IEEE NSREC” in U.S. dollars and drawn on a U.S. bank,
2) MasterCard, VISA, Discover and American Express credit card.

Registrations can be submitted by using the link at the NSREC website: ***www.nsrec.com.*** E-mailed or faxed registrations will be accepted with a credit card payment or you can mail the conference registration form, along with your payment, to ETCic. All mailed registration payments must arrive by no later than July 16. Telephone registrations will not be accepted.

ETC Incentives & Conferences (ETCic)
2254 Emerald Drive
Castle Rock, CO 80104
Tel: 720-733-2003
Fax: 720-733-2046
etc@etcic.us

CONFERENCE CANCELLATION

A $50 processing fee will be withheld from all conference attendee refunds. Due to advance financial commitments, refunds of registration fees requested after June 18, 2021, cannot be guaranteed. Consideration of requests for refunds will be processed after the conference. To request a refund, you must notify ETCic by fax at 720-733-2046 or e-mail at ***etc@etcic.us.***

Industrial Exhibits

Larisa Milic
Industrial Exhibits Chair
EMPC

The 2021 IEEE Nuclear and Radiation Effects Conference (NSREC) being held as a Virtual Conference. NSREC Virtual Live is July 16-23 with a Short Course, Technical and Poster Sessions, a Data Workshop and Industrial Exhibits.

The Exhibits are available On Demand to registered attendees 24/7 starting Monday, July 19 through August 15, 2021.

Booth Space:
$1,500 per single booth, $3000 per double booth. NSREC's Virtual Provider will build your booth per your input. ***The Last Day to purchase a booth is June 10!***
Note: The 2020 booth model will be used (see photos at end). Booth material will be due June 17.

Included:

- One complimentary Short Course/Technical registration per each single booth and Two complimentary Short Course/Technical registrations per each double booth.
- Four complimentary staff badges for virtual exhibit booth staff for a single booth and Eight staff badges for a double booth. Note: Staff badges have access to Exhibit Hall only.
- 12.5 Hours of Staffed Exhibit Time!
- 27 Days of On Demand Exhibit Viewing!
- 38 Time Slots for Exhibitor Webinars!
- Exhibitor Reception on Monday, July 19
- Exhibitors may conduct their own Raffles
- Web Link to your company from NSREC.com
- NEW – NSREC Supporter and Exhibitor Brochure! Posted on Virtual Platform and provided to Attendees
- NEW - More PR – Staffed Exhibit Time and Webinar Schedule promoted daily at Virtual Event and by Attendee Email News
- Virtual Exhibitor Platform Training before NSREC
- Alphabetical Company Listing in the Exhibit Hall

Exhibit Registration is open and will end June 10, 2021.
To see the current Exhibitors and or more information contact::

Larisa Milic
EMPC
Phone: 301-869-2317
Email: lmili@empc.com

Or visit the 2021 NSREC Industrial Exhibits web site:
http://www.nsrec.com/industrial-exhibits.html

2021 Exhibitors

2021 Exhibitor Webinars

2021 IEEE NSREC Technical Sessions and Short Course Registration Form

Registration is available on-line at www.nsrec.com

Name ______________________________________
Last Name   First Name   Middle Initial

Name to appear on badge ____________________

Company/Agency ____________________________

Address ___________________________________

Address ___________________________________

City ______________________________________

State/Province _____________________________

Zip or Postal Code __________________________

Country ___________________________________

Telephone Number ___________________________

Fax Number ________________________________

E-mail Address ______________________________

IEEE Membership Number ____________

* For IEEE member or student rates, the IEEE membership number must appear on this form.

CANCELLATIONS

A $50 processing fee will be withheld from all refunds. Due to advance financial commitment, conference registration fee refunds requested after June 18, 2021, cannot be guaranteed. Consideration of requests for refunds will be processed after the conference. You must notify NSREC Registration by no later than June 18, 2021 via E-mail: etc@etcic.us or Fax: 720 -733 -2046,

REGISTRATION FEES (in U.S. dollars)

Late fee REQUIRED if payment received after June 18, 2021

	Early	Late	
IEEE Member*			
Short Course & Technical Sessions	$330	$395	$________
Non-IEEE Member			
Short Course & Technical Sessions	$415	$495	$________
IEEE Student Member*			
Short Course & Technical Sessions	$50	$395	$________
IEEE Life Member*			
Short Course & Technical Sessions	$110	$395	$________

TOTAL AMOUNT ENCLOSED: $________

PAYMENT OF FEES

☐ Enclosed is a check in **U.S. DOLLARS ONLY**, drawn on or payable through a U.S. bank. Payable to: **IEEE NSREC**

☐ Charge registration fees to my credit card (U.S. dollars):

☐ American Express ☐ Master Card
☐ Visa ☐ Discover

Card No. ___________________________________

Expiration Date __________ Security Code ____________

Name on card ______________________________

Cardholder Signature ________________________

Billing address _____________________________

____

IEEE Privacy Policy and Event Terms and Conditions:

At IEEE , we respect your privacy. We want to ensure that you get the information, content, and experiences that matter most to you. IEEE is committed to protecting the privacy of its members, customers, volunteers, and other contacts.

Acceptance of IEEE Policies is required to register for this event By submitting your registration, you acknowledge that:

You have read and are in agreement with the IEEE Privacy Policy found at:
https://www.ieee.org/security-privacy.html ☐ I accept the IEEE Privacy Policy

You have read and are in agreement with the IEEE Event Terms and Conditions found at: https://www.ieee.org/conferences/event-terms-and-conditions.html
☐ I accept the IEEE Event Terms and Conditions

2021 IEEE NSREC Technical Sessions and Short Course Registration Form

The IEEE NSREC must divulge any use of the contact information derived from your registration. These are:

1) Contact data is included in an Attendee Directory provided to all IEEE NSREC conference attendees following the conclusion of the conference.
2) Contact data is used as the IEEE mailing list for the Conference and Workshop proceedings which are sent to all Technical Session attendees.
3) IEEE NSREC exhibitors who obtain the Attendee Directory could, potentially, use the Attendee Directory to send marketing materials.
4) Using IEEE guidelines, the IEEE NSREC utilizes the Attendee Directory contact information to provide future conference data and details to each past registrant.

Please check **YES** if you allow usage of your contact information for these purposes and **NO** if you do not want your contact data to be used in any way. ❒ **YES** ❒ **NO**

Non-Discrimination Policy

IEEE is committed to the principle that all persons shall have equal access to programs, facilities, services, and employment without regard to personal characteristics not related to ability, performance, or qualifications as determined by IEEE policy and/or applicable laws. **For more information on the IEEE policy visit: *http://www.ieee.org/about/corporate/governance/p9-26.html?WT.mc_id=hpf_pol.***

Ethics and Compliance

IEEE strives to achieve the highest standards of integrity and endeavors to conduct business around the world in a responsible and ethical way. It is important that those who act on the organization's behalf ensure IEEE's compliance by adhering to the same standards and expectations . The IEEE code of Conduct describes the commitment of IEEE members and staff to the highest standards of integrity, responsible behavior, and ethical and professional conduct. **Find the IEEE Code of Conduct at: *https://www.ieee.org/about/ieee_code_of_conduct.pdf***

Reports of violations , or concerns regarding potential violations of IEEE Policies or the IEEE Code of Conduct can be filed anonymously through EthicsPoint at +1 888 359 6323 or by submitting an online report at ***https://secure.ethicspoint.com/domain/en/report_custom.asp?clientid=20410***

IEEE Event Safety and Conduct Statement

IEEE believes that science, technology, and engineering are fundamental human activities, for which openness, international collaboration, and the free flow of talent and ideas are essential. Its meetings, conferences, and other events seek to enable engaging, thought-provoking conversations that support IEEE's core mission of advancing technology for humanity. Accordingly, IEEE is committed to providing a safe, productive, and welcoming environment to all participants, including staff and vendors, at IEEE-related events. IEEE has no tolerance for discrimination, harassment, or bullying in any form at IEEE-related events. All participants have the right to pursue shared interests without harassment or discrimination in an environment that supports diversity and inclusion. Participants are expected to adhere to these principles and respect the rights of others. IEEE seeks to provide a secure environment at its events. Participants should report any behavior inconsistent with the principles outlined here, to on site staff, security or venue personnel, or to **eventconduct@ieee.org.**

By checking the box below, I AGREE to follow the IEEE policies as outlined in the NSREC website, including the following--

- *No photos or video/sound recordings will be permitted during the Short Course, Technical Sessions, Data Workshop or Poster Sessions.*
- *Conference attendees will not engage in harassment of any kind, including sexual harassment, or bullying behavior, nor discriminate against any person because of characteristics protected by law. In addition, attendees will not retaliate against any person who reports an act of misconduct, or who reports any violation of the IEEE Code of Ethics or Code of Conduct.*

I will follow the IEEE NSREC policies ❒ **YES** ❒ **NO**

Mail , Scan or Fax this form and your form and re mittance to:

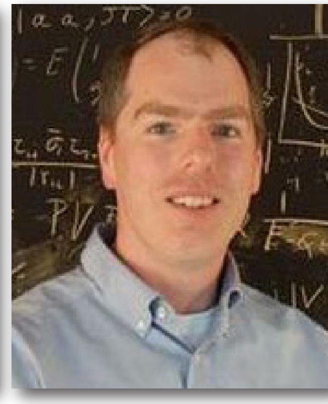
IEEE NSREC REGISTRATION, P.O. Box 398, Castle Rock, CO 80104

E-mail: etc@etcic.us Tel: 720-733-2003 Fax: 720-733-2046

2021 Conference Committee

General Chair
Steve McClure
Jet Propulsion Laboratory
Steven.mcclure@jpl.nasa.gov

Technical Program Chair
Brian Sierawski
Vanderbilt University
brian.sierawski@vanderbilt.edu



Local Arrangements Chair
Michael Trinczek
TRIUMF
trinczek@triumf.ca

Short Course Chair
Marta Bagatin
University of Padova
Marta.bagatin@dei.unipd.it

Publicity Chair
Teresa Farris
Archon LLC
Teresa.Farris@Archon-llc.com

Finance Chair
Greg Allen
Jet Propulsion Laboratory
grallen@jpl.nasa.gov

Awards Chair
Jeffrey Black
Sandia National Laboratories
jefblac@sandia.gov

Industrial Exhibits Chair
Larisa Milic
EMPC
lmilic@empc.com

Poster Chair
Ted Wilcox
NASA Goddard Space Flight Center
ted.wilcox@nasa.gov

Radiation Effect Data Workshop Chair
Helmut Puchner
Infineon Technologies
helmut.puchner@infineon.com

Vice-Chair Social Media
Adrian Ildefonso
U.S. Naval Research Lab
adrian.ildefonso@ieee.org

Web Developer
Dolores Black
Sandia National Laboratories
dablack@sandia.gov

Official Reviewers

Aguiar, Ygor - *CERN*

Artola, Laurent - *ONERA*

Austin, Rebekah - *NASA GSFC*

Bhuva, Bharat - *Vanderbilt University*

Bi, Jinshun - *IMECAS*

Blackmore, Ewart - *TRIUMF*

Bonaldo, Stefano - *University of Padova*

Budroweit, Jan - *DLR*

Casey, Megan - *NASA GSFC*

Chatterjee, Indranil - *Airbus*

Chen, Yanran - *Xilinx*

Clemente, Juan - *Universidad Complutense Madrid*

Davies, Robert - *Jet Propulsion Laboratory*

Decker, Tom - *ADI*

Dilillo, Luigi - *LIRMM*

Ding, Lili - *NINT China*

Dyer, Clive - *CSDRadConsultancy*

Evans, Adrian - *CEA*

Fleetwood, Daniel - *Vanderbilt University*

Fleetwood, Zachary - *SpaceX*

Gaspard, Nelson - *NASA ARC*

George, Jeffrey - *LANL*

Gloutnay, Eric - *CSA*

Goley, Patrick - *Georgia Institute of Technology*

Goncalves, Patricia - *Instituto Superior Técnico*

Guertin, Steve - *Jet Propulsion Laboratory*

Hales, Joel - *Naval Research Laboratory*

Han, Jianwei - *NSSC*

Hiemstra, David - *MDA*

Hubert, Guillaume - *ONERA*

Hughart, David - *Sandia National Laboratories*

Irom, Farokh - *Jet Propulsion Laboratory*

Kauppila, Jeffrey - *Vanderbilt University*

Kettunen, Heikki - *RADEF*

King, Michael - *Sandia National Laboratories*

Kobayashi, Daisuke - *ISAS/JAXA*

Koga, Rocky - *Aerospace Corporation*

Koziukov, Aleksandr - *Branch of JSC URSC - ISDE*

Kruckmeyer, Kirby - *Texas Instruments*

Kuznia, Charlie - *Ultra Communications*

Ladbury, Raymond - *NASA GSFC*

Lambert, Damien - *CEA*

Lawrence, Reed - *BAE Systems*

Likar, Justin - *JHU APL*

Malherbe, Victor - *STMicroelectronics*

Marinella, Matthew - *Sandia National Laboratories*

Mazur, Joe - *Aerospace Corporation*

Mee, Jesse - *Air Force Research Laboratory*

Miller, Kyle - *Ball Aerospace*

Monahan, Daniele - *Aerospace Corporation*

Oldham, Timothy - *Ball Aerospace*

Paillet, Philippe - *CEA*

Poivey, Christian - *ESA*

Ravotti, Federico - *CERN*

Rosenfeld, Anatoly - *University of Wollongong*

Santin, Giovanni - *ESA*

Schaefer, Justin - *Troxel Aerospace*

Sharp, Richard - *Radtest Ltd.*

Shen, Chen - *Cogenda*

Sturesson, Fredrik - *Cobham Gaisler*

Tran, Linh - *University of Wollongong*

Turflinger, Thomas - *Aerospace Corporation*

Tzintzarov, George - *Georgia Institute of Technology*

van Vonno, Nicolaas - *Renesas Electronics America*

Varotsou, Athina - *TRAD*

Vizkelethy, Gyorgy - *Sandia National Laboratories*

Wang, Pierre_xiao - *3D PLUS*

Wen, Shijie - *Cisco*

Wilkinson, Jeff - *Medtronic*

Zebrev, Gennady - *NRNU MEPHI*

Zhang, Enxia - *Vanderbilt University*

Radiation Effects Steering Group

Executive Chair
Janet Barth
NASA Retired Emeritus
jbarth@ieee.org
(Term expires: 7/21)

Executive Vice-Chair
Robert Reed
Vanderbilt University
robert.reed@vanderbilt.edu
(Term expires: 7/21)

Past Chair
Allan Johnston
J-K Associates
johnstonAH25@gmail.com
(Term expires: 7/21)

Senior Member-at-Large
Kyle Miller
Ball Aerospace
kbmiller@ball.com
(Term expires: 7/21)

Member-at-Large
Michael Campola
NASA GSFC
michael.j.campola@nasa.gov
(Term expires: 7/22)

Junior Member-at-Large
Rubén García Alía
CERN
ruben.garcia.alia@cern.ch
(Term expires: 7/23)

Secretary
Sarah Armstrong
NSWC Crane
sarah.armstrong@navy.mil
(Term expires: 7/21)

Vice-Chair, Publications
Dan Fleetwood
Vanderbilt University
dan.fleetwood@vanderbilt.edu
(Term expires: 7/21)

Vice-Chair, Exhibits & Publicity
Teresa Farris
Archon LLC
Teresa.Farris@Archon-llc.com
(Term expires: 7/21)

Vice-Chair, Finance/RESG Delegate
Marty Shaneyfelt
Sandia National Laboratories
shaneymr@sandia.gov
(Term expires: 7/21)

Special Publication Assignment
Paul Dressendorfer
Sandia National Labs (Retired)
p.dressendorfer@ieee.org

Vice-Chair, 2021 Conference
Steve McClure
NASA/JPL
steven.s.mcclure@jpl.nasa.gov

Vice-Chair, 2022 Conference
Thomas Turflinger
The Aerospace Corporation
thomas.l.turflinger@aero.org

Vice-Chair, 2023 Conference
Keith Avery
AFRL/RV
keith.avery.2@us.af.mil

Vice-Chair, 2024 Conference
Heather Quinn
Los Alamos National Laboratory
hquinn@lanl.gov

NPSS Adcom Member
Jeffrey D. Black
Sandia National Laboratories
jefblac@sandia.gov
(Term expires: 12/21)

NPSS Adcom Member
Keith Avery
AFRL/RV
keith.avery.2@us.af.mi.
(Term expires: 12/22)

NPSS Adcom Member
Ken Galloway
Vanderbilt University
kenneth.f.galloway@vanderbilt.edu
(Term expires: 12/23)

Web Developer
Dolores Black
Sandia National Laboratories
dablack@sandia.gov
(Term expires: 7/21)

RADECS Liaison
Philippe Paillet
CEA/DIF
philippe.paillet@cea.fr
(Term expires: 9/22)

Vice-Chair, Social Media
Adrian Ildefonso
U.S. Naval Research Lab
adrian.ildefonso@ieee.org
(Term expires: 7/23)

ANNOUNCEMENT and FIRST CALL FOR PAPERS

2022 IEEE NUCLEAR AND SPACE RADIATION EFFECTS CONFERENCE

Short Course and Radiation Effects Data Workshop

July 18-22, 2022
Utah Valley Convention Center
Provo, Utah

NSREC 2022
Provo, Utah

IEEE

www.nsrec.com

Sponsored By
IEEE/NPSS Radiation Effects Committee

Supported By
Aerospace Corporation
Boeing
CAES
EMPC
IR HiRel, an Infineon Technologies Company
Jet Propulsion Laboratory
L3Harris
NASA/NEPP
Radiation Test Solutions
Renesas
SkyWater Technology
Southwest Research Institute

Conference Committee

General Chair
Thomas Turflinger
The Aerospace Corporation
thomas.l.turflinger@aero.org

Technical Program Chair
Pascale Gouker
MIT Lincoln Laboratory
pgouker@ll.mit.edu

Short Course Chair
Sylvain Girard
University of St Etienne
sylvain.girard@univ-st-etienne.fr

Local Arrangements Chair
Daniel Loveless
University of Tennessee – Chattanooga
daniel-loveless@utc.edu

Assistant Local Arrangements Chair
Mike Wirthlin
Brigham Young University
wirthlin@byu.edu

Publicity Chair
Teresa Farris
Archon-LLC
Teresa.farris@archon-llc.com

Finance Chair
Matthew Gadlage
NAVSEA Crane
Matthew.gadlage@navy.mil

Awards Chair
Sarah Armstrong
NAVSEA Crane
Sarah.armstrong@navy.mil

Industrial Exhibits Chair
Bradley Ferguson
Skywater Technology
brad.ferguson@skywatertechnology.com

You are cordially invited to attend the 2022 IEEE Nuclear and Space Radiation Effects Conference to be held July 18-22, 2022 at the Utah Valley Convention Center, Provo, Utah. The conference features a technical program consisting of eight to ten technical sessions of contributed papers describing the latest observations in radiation effects, a Short Course on radiation effects issues with current relevance offered on July 18, a Radiation Effects Data Workshop, and an Industrial Exhibit. The technical program includes oral and poster sessions.

Papers on nuclear and space radiation effects on electronic and photonic materials, devices, circuits, sensors and systems, as well as semiconductor processing technology and design techniques for producing radiation-tolerant (hardened) devices and integrated circuits, will be presented at this meeting of engineers, scientists and managers. International participation is strongly encouraged.

We are soliciting papers describing significant new findings in the following or related areas:

Basic Mechanisms of Radiation Effects in Electronic Materials and Devices
- Single Event Charge Collection Phenomena and Mechanisms
- Ionizing Radiation Effects
- Displacement Damage
- Radiation Transport, Energy Deposition, and Dosimetry
- Materials and Device Effects
- Processing-Induced Radiation Effects

Radiation Effects on Electronic and Photonic Devices, Circuits, and Systems
- Single Event Effects, Total Dose, and Displacement Damage
- MOS, Bipolar, and Advanced Technologies
- Systems on a Chip, GPUs, FPGAs, Microprocessors
- Isolation Technologies, such as SOI and SOS
- Methods for Hardened Design and Manufacturing
- Modeling and Hardening of Devices and Circuits
- Cryogenic or High Temperature Effects
- Novel Device Structures, such as MEMS and Nanotechnologies
- Emerging Modeling and Experimental Techniques for Hardening Systems

Space, Atmospheric, and Terrestrial Radiation Effects
- Characterization and Modeling of Radiation Environments
- Space Weather Events and Effects
- Spacecraft Charging
- Predicting and Verifying Soft Error Rates (SER)

Hardness Assurance Technologies, Modeling, and Testing
- New Modeling and Testing Techniques, Guidelines, and Hardness Assurance Methodologies
- Unique Radiation Exposure Facilities or Novel Instrumentation Methods
- Dosimetry

New Developments of Interest to the Radiation Effects Community

PAPER SUMMARY DEADLINE: FEBRUARY 4, 2022

PROCEDURE FOR SUBMITTING SUMMARIES

Summaries must be received by February 4, 2022

Detailed submission and formatting instructions will be available after December 1, 2021 at www.nsrec.com

Authors must conform to the following requirements:

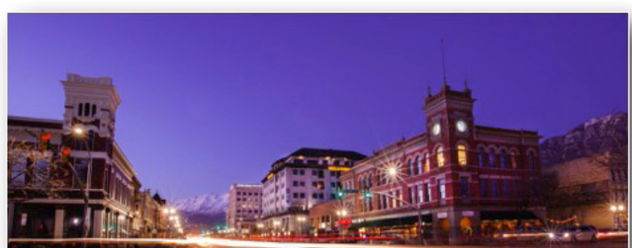
1. Prepare a single Adobe Acrobat file consisting of a cover page and an informative two to four page summary describing results appropriate for 12-minute oral or poster presentation. The cover page must provide an abstract no longer than 35 words, the title, name and company affiliation of the authors, and company address (city, state, country). Identify the author presenting the paper and provide telephone, and email address. The summary must include sufficient detail about the work to permit a meaningful technical review. In the summary, clearly indicate (a) the purpose of your work, (b) significant new results with supporting technical material, and (c) how your work advances the state of the art. Show key references to other related work. The summary must be no less than two and no more than four pages in length, including figures and tables. All figures and tables must be large enough to be clearly read. Note that this is more than an abstract, but do not exceed four pages.
2. Prepare your summary in single-column or IEEE TNS standard two-column format, using 11 point or greater font size, formatted for either U.S. Standard (8.5 x 11 inch) or A4 (21 x 29.7 cm) page layout, with 1 inch (2.5 cm) margins on all four sides.
3. Obtain all corporate, sponsor, and government approvals and releases necessary for presenting your paper at an open attendance international meeting.
4. Summary submission is electronic only, through **www.nsrec.com.** The submission process consists of entering the paper title, author(s) and affiliation(s), an abstract no longer than 35 words, and uploading the summary. Authors are prompted to state their preference for presentation (oral, poster, or data workshop poster) and for session. Details of the submission process may be found at **www.nsrec.com.** The final category of all papers will be determined by the Technical Program Committee, which is responsible for selecting final papers from initial submissions.

Papers accepted for oral or poster presentation at the technical program are expected to be submitted for publication in the IEEE Transactions on Nuclear Science (January 2023). Selection for this issue will be based on a separate submission of a complete paper. These papers will be subject to the standard full peer review given all papers submitted to the *IEEE Transactions on Nuclear Science.* Further information will be sent to prospective authors upon acceptance of their NSREC summary. It is not necessary to be an IEEE member to present a paper or attend the NSREC. However, we encourage IEEE and NPSS membership of all NSREC participants.

RADIATION EFFECTS DATA WORKSHOP

The Radiation Effects Data Workshop is a forum for papers on radiation effects data on electronic devices and systems. Workshop papers are intended to provide radiation response data to scientists and engineers who use electronic devices in a radiation environment, and for designers of radiation-hardened systems. Papers describing new simulation or radiation facilities are also welcomed. **The procedure for submitting a summary to the Workshop is identical to the procedure for submitting NSREC summaries.** Radiation Effects Data Workshop papers will be published in a Workshop Record and are not candidates for publication in the Conference issue of the *IEEE Transactions on Nuclear Science.*

PROVO, UTAH



Courtesy Utah Valley CVB

The location for NSREC 2022 will be the Utah Valley Convention Center, just 45 minutes south of Salt Lake City in historic Downtown Provo, Utah. Provo is situated in the heart of Utah Valley between the eastern shore of Utah Lake and the towering Wasatch Mountains. Mount Timpanogos dominates the northern part of the city at 11,957 feet (3,644 meters); these rugged mountains east of Provo create one of the most picturesque backdrops in Utah. Provo is a small city with a bustling downtown area with its variety of shops and activities and is home to Brigham Young University. It is a city steeped in history, with world-class museums, galleries, performing arts, and family attractions. And, Provo is the ideal starting point to visit the great American Southwest! With the Wasatch to the north, the High Uintas Wilderness to the east and Utah's five magnificent National Parks in the south (and the Grand Canyon just beyond), Provo provides endless opportunities for world-class outdoor activities. Prepare to be amazed! The Utah Valley Convention Center is ideally located in the city center and adjacent to the Provo Marriott and Hyatt Place, offering excellent accommodations. Within minutes, you will be within a thriving district where families and business professionals alike can enjoy the colorful scenery, historic buildings, vintage boutiques and over 50 restaurants. Alternatively, one can break on the roof top garden, offering breathtaking views of the Wasatch Mountains without leaving the venue. Come and join us for NSREC 2022 and experience it for yourself.