Short Course Program

SPACE RADIATION ENVIRONMENTS AND THEIR EFFECTS ON DEVICES AND SYSTEMS: BACK TO THE BASICS

GRAND BALLROOM – MONDAY, JULY 25

7:15 AM	**REGISTRATION/CONTINENTAL BREAKFAST (VALENCIA BALLROOM)**
8:00 AM	**SHORT COURSE INTRODUCTION** Steve McClure *Jet Propulsion Laboratory*
8:10 AM	**PART 1 – SPACECRAFT ENVIRONMENT INTERACTIONS** Henry B. Garrett *Jet Propulsion Laboratory*
9:45 AM	**BREAK (GRAND AND MARQUIS BALLROOMS FOYERS)**
10:10 AM	**PART 2 – TOTAL IONIZING DOSE AND DISPLACEMENT DAMAGE EFFECTS IN CMOS AND BIPOLAR DEVICES** Timothy R. Oldham *Dell-Perot Systems, Inc.*
11:50 AM	**SHORT COURSE LUNCHEON (VALENCIA BALLROOM)**
1:20 PM	**PART 3 – SINGLE EVENT EFFECTS IN DIGITAL AND LINEAR ICS** Mark P. Baze *Boeing (retired)*
2:55 PM	**BREAK (GRAND AND MARQUIS BALLROOMS FOYERS)**
3:20 PM	**PART 4 – ON-ORBIT ANOMALIES: INVESTIGATIONS AND ROOT CAUSE DETERMINATION** Robert Ecoffet *CNES*
4:45 PM	**WRAP-UP**
4:55 PM	**EXAM (only for students requesting CEU credit)**
5:25 PM	**END OF SHORT COURSE**

Short Course

COURSE DESCRIPTION

A one-day Short Course "Space Radiation Environments and Their Effects on Devices and Systems: Back to the Basics" will be presented at the 2011 IEEE Nuclear and Space Radiation Effects Conference (NSREC). This short course is intended to provide both a broad brush introduction to the basics of space radiation environments and their effects on devices and systems to engineers and providers new to the field, as well as to provide a review and reference material to those experienced in the field. The 2011 Short Course will cover topics spanning the space radiation environment to its ultimate effects on space system performance.

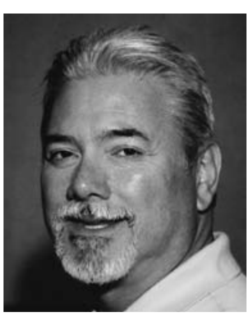
The Short Course is organized into four sessions starting with a session defining the space radiation environment and its transport through the spacecraft materials and electronics. The second session focuses on the mechanisms of accumulated damage effects due to total ionizing dose and displacement damage effects from space radiation, while the third session focuses on single event effects in electronic devices induced by charged particles in space. The last session addresses on-orbit anomalies in space systems with respect to the space radiation environment. The presenters for the 2011 Short Course are all well-published experts in their respective areas. They will present the knowledge base in their topical areas with an emphasis on providing a broad introduction to the subject matter, as well as addressing current topics of significant relevance to spacecraft design.

The course is intended for designers, radiation effects engineers, component specialists, and other technical and management personnel who are involved in developing reliable systems designed to operate in space environments. This course provides a unique opportunity for NSREC attendees to benefit from the expertise of the instructors, as well as the in-depth coverage and application-oriented perspective provided by the short course format. The instructors will develop the core content of their respective topics from background material largely found in the literature and from their unique interactions with actual space system design and evaluation efforts. As such, the course will benefit both new and experienced engineers, scientists, and managers. In-depth notes will be provided at registration.

CONTINUING EDUCATION UNITS (CEUS)

For those interested in Continuing Education Units (CEUs), there will be an open-book test at the end of the course. The course is valued at 0.6 CEUs and is endorsed by the IEEE and the International Association for Continuing Education and Training (IACET).

SHORT COURSE CHAIRMAN



Steve McClure
Short Course Chairman

Steve McClure received his B.S. in physics from the California Polytechnic State University, San Luis Obispo, and did his graduate work in nuclear physics at the Department of Applied Science, UC Davis/Lawrence Livermore National Laboratory. He joined the Jet Propulsion Laboratory in 2000 and is presently the group supervisor of the Radiation Effects Group of the Electronic Parts Engineering Office. Prior to joining JPL he performed radiation effects analysis at the device and system level for a variety of aircraft and spacecraft development programs having nuclear weapon and/or natural space radiation environments. He has authored/co-authored over 30 papers on radiation effects in semiconductor devices and holds a patent for a radiation hardening technique for CMOS microcircuits.

Dr. Garrett has 120 publications in atmospheric physics, radiation, space environments, and effects on spacecraft. He served as Project Scientist for the SCATHA program which characterized the geosynchronous charging environment for which he received the Harold Brown Award (top AF scientist), AF Systems Command Officer of the Year, and the AF R&D Award. Moving to JPL in 1980, he has defined the space environment and its effects for major NASA missions from Galileo to Juno. He has two textbooks on spacecraft environmental design and served as Associate Editor of the *Journal of Spacecraft and Rockets*. He headed the team responsible for monitoring the optical corrections developed for the Hubble Space Telescope. In 1992, he was an IPA for the Ballistic Missile Defense Organization serving as Deputy Program Manager for the DoD/NASA Clementine Lunar Mission and Program Manager for the Clementine InterStage Adapter Satellite for which he was awarded NASA's Medal for Exceptional Engineering Achievement. Returning to JPL in 1994, he is Chief Technologist for the Office of Safety and Mission Success. Dr. Garrett has consulted for INTELSAT, L'Garde, NASDA, and CNES and is an Associate Fellow of the AIAA. Until 2002, he served as a colonel in the USAF Reserves, assigned as Senior Reserve Officer for the AF Space and Missile Center for which he received the AF's Legion of Merit Medal. In 2006, Dr. Garrett received NASA's Exceptional Service Medal.

SPACECRAFT ENVIRONMENT INTERACTIONS

Henry B. Garrett
Jet Propulsion Laboratory

With spacecraft systems steadily growing more complex and with commercial, off-the-shelf components seeing increasing utilization in space, it is not surprising that the environment and its effects have become major concerns for the spacecraft engineer. This tutorial will address these concerns and provide the students with the tools necessary to limit the effects of the space environment on their systems. It will emphasize methods of identifying environmental issues associated with radiation early in a program when design changes are inexpensive. The tutorial will concentrate primarily on the natural environments associated with the Sun, trapped radiation, cosmic rays, and solar proton events. On the practical side, radiation shielding and transport models will be briefly discussed and appropriate guidelines and requirements presented to assist the spacecraft engineer in developing a coherent programmatic approach to the mitigation of the space environment radiation effects. The tutorial will help those who take it to develop reliable, more survivable spacecraft and to be able to anticipate the effects of the space radiation environment on their systems. The tutorial is based on the book: Hastings, D,. and H. B. Garrett, Spacecraft-Environment Interactions, Cambridge Press, Cambridge, England, October, 292 pages, 1996.

Introduction

- Why are we concerned with the space environment and its effects?

Basic Concepts

- What are the basic units for measuring the space environment?
- How do we measure the effects on space systems?

Environments

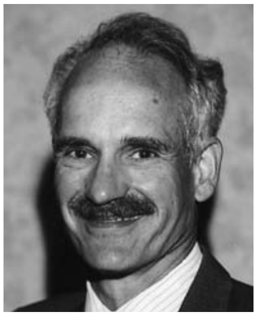
- How does the Sun affect space operations?
- Why is the Earth's environment such a challenge?
- Are there other environments of concern?

Applications

- What radiation shielding and transport models are available?
- In practical terms, what can a spacecraft engineer do to prevent or limit adverse environmental effects?

The Future

- Where do we go from here?
- Where can one find more information?
- What are the Web resources?



Timothy R. Oldham received his B.S. from Michigan State University (1969), his M.S. from American University (1975), and his Ph. D. from Catholic University of America (1982), all in Physics. He started as a summer student and worked at the Army Research Laboratory and its predecessors, for more than 34 years, on a variety of radiation and electronics reliability research problems. Since 2002, he has been a member of the Radiation Effects and Analysis Group at the NASA Goddard Space Flight Center, as a contractor with Dell-Perot Systems, Inc. Recently, he has been working primarily on radiation effects in spacecraft electronics with emphasis on nonvolatile memory technology. He has been elected Fellow of the IEEE for his technical contributions, which are documented in about 40 journal articles, plus a book and two book chapters. Most of this work was first presented at this conference. He has served as Technical Program Chairman for the NSREC (1990), as General Conference Chairman (1994), as Awards Chairman (2001), and as an Editor for the conference issue of the *Transactions on Nuclear Science (TNS)* (1997-1999). He was also one of three editors for the special TNS issue commemorating the 40th NSREC in 2003. He has also served on the Radiation Effects Steering Group since 2003, first as Executive Vice Chairman, then as Chairman, and currently as Past Chairman.

TOTAL IONIZING DOSE AND DISPLACEMENT DAMAGE EFFECTS IN CMOS AND BIPOLAR DEVICES

Timothy R. Oldham
Dell-Perot Systems, Inc.

Dr. Timothy Oldham will discuss the basic mechanisms of total ionizing dose (TID) and displacement damage dose (DDD) in CMOS and bipolar devices. For TID, charge generation, recombination, transport and trapping are among the processes that will be included, along with interface trap formation. Isolation structures, testing implications, and the impact of continued scaling will be discussed. For bipolar devices, the TID discussion will focus on the enhanced low dose rate sensitivity (ELDRS) problem. Displacement damage in bipolar devices will be discussed, along with effects in CMOS.

Introduction

Total Ionizing Dose Effects in CMOS

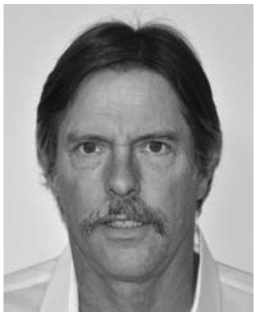
- Introduction—time dependent effects
- Electron/Hole pair creation energy
- Recombination and hole yield
- Hole Transport
- Hole Trapping, Detrapping, Reliability
- Interface Trap formation
- Micro-dose
- Testing Implications
- Scaling-oxide thinning
- Isolation Structures

Bipolar Devices—ELDRS

- Introduction—bipolar TID degradation
- Discovery of ELDRS
- Characteristics of ELDRS
- ELDRS Models
- ELDRS HA and accelerated test methods
- ELDRS in CMOS

Displacement Damage

- Displacement damage mechanisms
- Radiation-induced defects in silicon, and their properties
- Particle energy dependence of Displacement Damage
- Damage coefficients and damage correlations
- Neutron effects on Si
- Damage mechanisms for bipolar transistors and ICs
- Radiation effects on Optoelectronic devices



Mark P. Baze received a Bachelor of Science in Physics in 1973 from Washington State University. He subsequently joined Boeing's Physics Technology Group. His work at the Physics Technology Group included radiation transport studies and shield design, hardness assurance testing, development of laser simulation techniques for dose rate effects, and total dose effects studies. In 1991 he joined Boeing's ASIC design group. While there he developed a single event model for large scale circuits, single event hardening techniques, special purpose SEE test structures, specialized SEE test techniques, and hardening methods for advance technologies focusing on hardness-by-design. He retired from Boeing in 2008.

SINGLE EVENT EFFECTS IN DIGITAL AND LINEAR ICS

Mark P. Baze
Boeing (retired)

Mark Baze will present and discuss concepts and challenges of single event effects in digital and linear integrated circuits (IC's). The presentation will begin with an overview of the basic mechanisms of single event effects (SEE) reviewing the particles and their relevant properties, basic physics of charge deposition in IC materials, and charge collection dynamics in simple circuit structures. This will include a discussion of the relative scale of charge deposition and collection effects in deep sub-micron technologies. The array of resulting circuit effects such as single event transients (SET), upsets (SEU), functional interrupts (SEFI), latchup (SEL) etc., will be described within the context of the more vulnerable circuit types for each effect. A discussion of testing will begin with a description of various test facility capabilities/limitations and the implications these have for device evaluation. A brief description of evaluation techniques will be given in the context of their chronologic development and application. Test challenges resulting from specific device characteristics such as overburden, circuit speed, test vector coverage, small signal analog circuits, advanced packaging, total dose vulnerability, and possible solutions will be reviewed. Finally, there will be a short discussion of SEE mitigation techniques.

Basic Mechanisms of Single Event Effects

- Charge deposition, collection, circuit response

Effects on Device Performance

- SET, SEU, MBU, SEFI, SEL, SEGR, SEB

Test and Evaluation of Devices for SEE Effects

- Ideal test facility
- Concepts of Cross-Section and Threshold
- Real test facilities and implications - Proton, Heavy Ion
- Evaluation techniques for real test data
- Circuit Testability
- Test Planning

Circuit/Device Mitigation Techniques

- SET Filtering
- Redundancy/EDAC

ON-ORBIT ANOMALIES: INVESTIGATIONS AND ROOT CAUSE DETERMINATION

Robert Ecoffet
CNES

Robert Ecoffet received his degree in electrical engineering from the Ecole Supérieure d'Electricité engineering school, Paris, France, in 1987 and a MS degree in electronic properties of materials from the University of Paris-VI, Paris, France, in 1987. After one year of teaching electronics in the French Marines, he joined the Centre National d'Etudes Spatiales (CNES), French space agency, Centre Spatial de Toulouse, Toulouse, France, in 1989. He worked for ten years in radiation testing, radiation effects R&D, development of radiation facilities, and development of in-flight radiation monitors and technology experiments. In 1999 he became head of the radiation effects department at CNES. Since 2003, he is currently a senior expert in space environment and effects at CNES, where he coordinates the space environment (radiation, charging, materials, contamination, debris) R&D axis, gives training courses, participates in European working groups and international collaborations, and he is called in for spacecraft anomaly working groups. He has co-authored over 100 papers in radiation effects and on the radiation environment. He is also currently secretary of the RADECS association steering group.

Robert Ecoffet, CNES, will discuss on-orbit anomalies, investigations, and root cause determination. Spacecraft anomalies due to radiation effects on electronic devices have been known since the very beginning of the space era. Today they represent a major part of on-board anomalies, mission outages, and create an unexpected workload on ground controllers of operational systems. This talk will first describe a sample of known cases of cumulated or transient effects in Earth or planetary environments. Then, it will discuss investigation methodology, and issues such as the statistical aspects of probabilistic anomalies in the assessment of cause to effects relationships, and the necessity of multi-field experts group root cause analysis, from radiation effects to satellite fault determination, identification, and reconfiguration strategy. A focus on some practical cases of anomaly analyses will be made. Finally, brief considerations on the benefit of on-board environment and radiation effects monitoring will be discussed.

- **Introduction**
- **Overview of Radiation Effects**
- **In-flight Anomalies and the Space Environment**
- **Cumulated Effects**
- **Single Event Effects**
- **The Particular Case of Sensors**
- **Investigation Methodology of Root Causes**
- **Dedicated Instruments and Experiments**
- **Conclusions**