

A cosmic background featuring a large, detailed moon in the upper right, a smaller blue planet in the upper left, and a ringed planet (Saturn) in the center. The background is a dark starfield.

*36th Annual International*

# **NUCLEAR AND SPACE RADIATION EFFECTS CONFERENCE**

*NORFOLK, VIRGINIA*

*JULY 12 - 16, 1999*



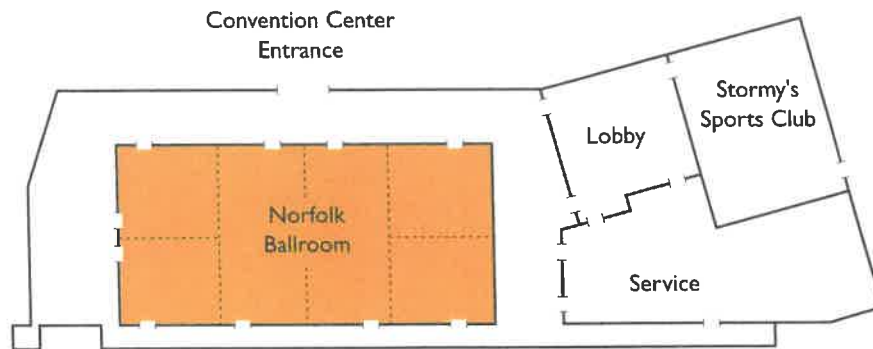
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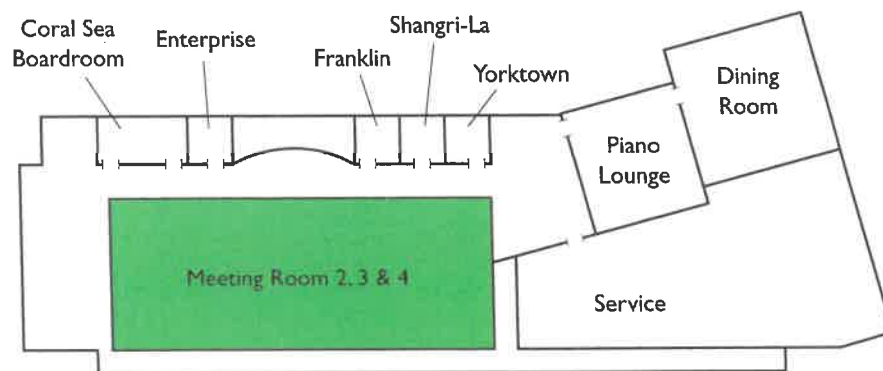


# Norfolk Waterside Marriott

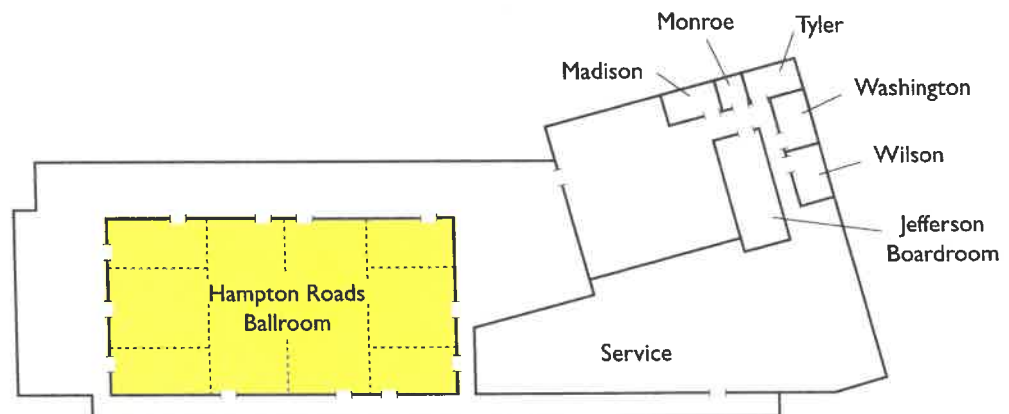
## First Floor



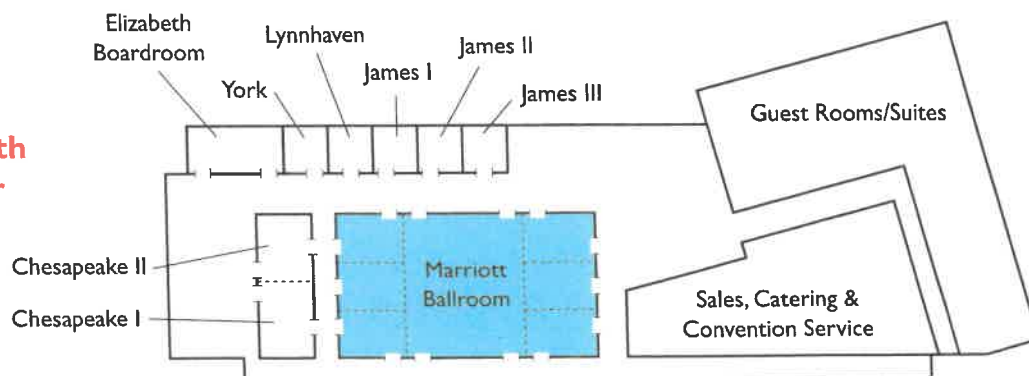
## Second Floor



## Third Floor



## Fourth Floor



# Schedule

Time	Monday July 12	Tuesday July 13	Wednesday July 14	Thursday July 15	Friday July 16
7:30	[7:30] Continental Breakfast	[7:30] Continental Breakfast	[7:30] Continental Breakfast	[7:30] Continental Breakfast	[7:30] Continental Breakfast
8:15	[8:15] <b>Short Course Introduction</b> Daniel M. Fleetwood Hampton Roads Ballroom	[8:15] <b>Conference Opening</b> Awards Presentation Hampton Roads Ballroom	[8:15] <b>Invited Talk Life and Times of Gen. Douglas MacArthur</b> Col. William J. Davis	[8:15] <b>Invited Talk The Challenges and Benefits of Scientific Experimentation on the International Space Station</b> Mr. Frank Culbertson	[8:15] <b>Invited Talk Atlantic Hurricane "Business": An Operational Perspective</b> Capt. Tom Bosse
8:30	[8:30] <b>Basic Mechanisms for Single-Event Effects</b> Paul E. Dodd				
9:00		[9:10] <b>Session A</b> SEE Mechanisms & Modeling			
9:30			[9:15] <b>Session E</b> Basic Mechanisms	[9:15] <b>Session G</b> Devices & ICs	[9:15] <b>Session I</b> Photonic Devices & ICs
10:00	[10:00] Break	[10:00] Break	[10:05] Break	[9:50] Break	[9:50] Break
10:30	[10:30] <b>Total Dose Effects: Modeling for Present and Future</b> Jean-Luc Leray	[10:30] <b>Session A</b> (continued)	[10:35] <b>Session E</b> (continued)	[10:20] <b>Session G</b> (continued)	[10:10] <b>Session I</b> (continued)
11:00					[10:55] <b>Session J</b> Isolation Technologies
11:30			[11:30] Lunch	[11:35] Lunch	
12:00	[12:00] Short Course Luncheon	[12:00] Lunch			[12:00] End of Conference
12:30					
1:00			[1:00] <b>Session F</b> Hardness Assurance	[1:05] <b>Session H</b> Dosimetry & Facilities	
1:30	[1:15] <b>Proton Effects &amp; Test Issues for Satellite Designers</b> Paul W. Marshall Cheryl J. Marshall	[1:30] <b>Session B</b> SEE in Devices & ICs			
2:00					
2:30			[2:30] <b>Poster Session</b> Poster Presentation Marriott Ballroom	[2:30] <b>Data Workshop</b> Poster Presentation Marriott Ballroom	
3:00	[2:45] Break	[2:40] Break			
3:30	[3:15] <b>System Level Mitigation Strategies</b> William F. Heidergott	[3:10] <b>Session C</b> Space & Terrestrial Environments			
4:00					
4:30		[4:20] <b>Session D</b> Commercial Space Systems			
	[4:45] Wrap-up				
5:00	[5:00] Exam (only for students requesting CEU credit)	[4:55] End of Session	[5:00] End of Session	[5:00] End of Session	
5:30	[5:30] End of short course			[5:30] Radiation Effects Committee Open Meeting Hampton Roads Ballroom	
6:00	[6:00 to 10:00] Conference Reception <b>The Tidewater Experience</b> Norfolk Ballroom		[6:00 to 10:30] Conference Social <b>Louisiana Tricentennial at Nauticus</b>		
6:30					
7:00		[7:00 to 10:00] Industrial Exhibit Reception Norfolk Ballroom			

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# Chairman's Invitation



*"Welcome to NSREC 1999 and Norfolk. The short course, technical programs and industrial exhibits will offer you the latest information on radiation effects. The social venue will enhance the week's activities. Have a great NSREC!"*

*Ron Schrimpf  
Vanderbilt University  
General Chairman*

On behalf of the NPSS Radiation Effects Committee, it is my pleasure to invite you to attend the 36th Annual International Conference on Nuclear and Space Radiation Effects, to be held July 12-16, 1999 at the Norfolk Waterside Convention Center in Norfolk, Virginia. This conference is one of the premier international symposia on radiation effects in electronic materials, devices, circuits, and systems. The 1999 Conference will continue the tradition of previous NSRE Conferences by offering an outstanding technical program, a one-day Short Course preceding the technical program, a Radiation Effects Data Workshop, and an Industrial Exhibit. We expect attendance by engineers, scientists, managers, and other interested persons from many nations. Highlights of the conference are given below and more complete details are provided in this booklet. Additional conference information can be obtained from the World Wide Web at [www.nsrec.com](http://www.nsrec.com).

Norfolk is located about 200 miles south of Washington, D.C. in the historic Hampton Roads area. The city is located along the Elizabeth River, just a few miles from the beautiful Atlantic beaches. The Norfolk area offers a fascinating variety of recreational opportunities, including theme parks, museums, harbor tours, and historical sites.

The Technical Program Chairman, Fred Sexton (Sandia National Laboratories), and his program committee, have assembled a very strong program of contributed papers. These papers have been organized into ten sessions of oral presentations, a poster session, and a Radiation Effects Data Workshop. In addition, there will be three invited talks.

The theme of this year's Short Course, organized by Dan Fleetwood (Sandia National Laboratories), is Radiation Effects in the Space Telecom Environment. The Short Course will span topics that range from device-level effects to system design, including basic mechanisms for single-event effects, total-dose effects (with an emphasis on emerging issues), proton effects and test issues for satellite applications, and system-level mitigation strategies. It is particularly exciting that this year all Short Course attendees will receive a special CD-ROM that contains the complete notes from all previous NSREC Short Courses (1980-1998). The notes are electronically searchable and include all figures and text. The Short Course is scheduled for Monday, July 12.

Thursday afternoon will feature a Radiation Effects Data Workshop consisting of papers emphasizing radiation-effects data from electronic devices and systems and descriptions of new simulation and radiation-test facilities. An Industrial Exhibit on Tuesday and Wednesday will provide an opportunity for discussions between conference attendees and exhibitors on the latest in radiation-hardened electronic devices, radiation analysis and testing services, simulation tools, and radiation test facilities and test equipment.

A variety of entertaining social events have been planned by Ken LaBel (NASA Goddard), the Local Arrangements Chairman. The highlight of the social program will be the Wednesday evening social, which will be held at Nauticus, the National Maritime Center. All of the Nauticus attractions will be open for attendees and the party will include Cajun food and the band Zydeco Crayz. The Companion Events will be highlighted by the Tall Ship Cruise on Tuesday. There also will be a special tour of the Norfolk Naval Base (the largest in the world) on Friday afternoon following the conference.

The 1999 NSREC Conference Committee looks forward to seeing you in Norfolk. The technical activities will be outstanding and the social opportunities will be unsurpassed.

# Short Course Program

## RADIATION EFFECTS IN THE SPACE TELECOM ENVIRONMENT

### HAMPTON ROADS BALLROOM - MONDAY, JULY 12

- 7:30 AM     **REGISTRATION/CONTINENTAL BREAKFAST**
- 8:15 AM     **SHORT COURSE INTRODUCTION**  
Daniel M. Fleetwood  
*Sandia National Laboratories*
- 8:30 AM     **BASIC MECHANISMS FOR SINGLE-EVENT EFFECTS**  
Paul E. Dodd  
*Sandia National Laboratories*
- 10:00 AM    **BREAK**
- 10:30 AM    **TOTAL DOSE EFFECTS: MODELING  
FOR PRESENT AND FUTURE**  
Jean-Luc Leray  
*CEA/DAM Ile-de-France*
- 12:00 PM    **SHORT COURSE LUNCHEON**
- 1:15 PM     **PROTON EFFECTS & TEST ISSUES  
FOR SATELLITE DESIGNERS**  
Paul W. Marshall  
*Consultant*  
Cheryl J. Marshall  
*NASA Goddard Space Flight Center*
- 2:45 PM     **BREAK**
- 3:15 PM     **SYSTEM LEVEL MITIGATION STRATEGIES**  
William F. Heidergott  
*Motorola, Inc., Satellite Communications Group*
- 4:45 PM     **WRAP-UP**
- 5:00 PM     **EXAM** (only for students requesting CEU credit)
- 5:30 PM     **END OF SHORT COURSE**

**NOTE:** All short course attendees will receive a special CD-ROM containing the complete notes from all previous NSREC short courses (1980-1998). The notes will be electronically searchable and will include all figures and text.

# Short Course

## COURSE DESCRIPTION

In their 40-year history, satellites have revolutionized how we communicate, how we are informed, and how we are entertained. In the next century, they will continue to do so in ways we can only imagine. Electronic and photonic devices and integrated circuits are the hearts and minds of space based telecommunications systems. Surviving the space radiation environment is a significant challenge to these systems. The passage of a single high-energy particle through the sensitive volume of a critical device or integrated circuit can mean sudden device or system failure, and total dose degradation can significantly reduce mission lifetimes from those planned. The challenge to the spacecraft designer is to maximize system performance in this difficult environment at a low enough cost that still allows the mission to be accomplished. The topics covered in the 1999 Short Course will aid system designers and parts engineers in this task.

Dan Fleetwood is the 1999 NSREC Short Course Chairman, and has assembled a team of experienced instructors who are recognized authorities in their respective fields. Instructors for this year's Short Course are Paul Dodd of Sandia National Laboratories, Jean-Luc Leray of CEA/DAM Ile-de-France, Paul Marshall, Consultant, Cheryl Marshall, NASA Goddard Space Flight Center, and Bill Heidergott, Motorola Satellite Communications Group. The four Short Course segments will be one hour and fifteen minutes each, with a fifteen minute question-and-answer period following each session. A Short Course Luncheon will be served to all registered attendees.

## CONTINUING EDUCATION UNITS (CEUS)

As in previous courses, 0.6 CEUs endorsed by the IEEE and the International Association for Continuing Education and Training (IACET) will be made available to qualified students. The IEEE is an Authorized CEU Sponsor member of the IACET. IEEE guidelines for offering CEU credit will be followed. To qualify, a student must be a registered attendee of the Short Course and pass a written exam with a score of 75% or greater. The exam will be given immediately after the last segment of the Short Course (5:00 PM), will be open book, and will consist of approximately 20 multiple-choice questions covering the presented material. No CEU credit will be offered to students who have not taken and passed the written exam. A certificate of completion will be mailed to all qualified students.

## SHORT COURSE CHAIRMAN



*Daniel M. Fleetwood*

**Daniel M. Fleetwood** received his B.S. in Physics and Applied Mathematics from Purdue University in 1980, and his M.S. and Ph.D. in Physics from Purdue in 1981 and 1984. He is a Distinguished Member of the Technical Staff in the Radiation Technology and Assurance Department at Sandia National Laboratories. He has been active in the field of radiation effects in microelectronics since joining Sandia in 1984, is the author or co-author of more than 170 publications, and holds two patents. In 1997 and 1998 he received R&D 100, Industry Week, and Discover Magazine awards for co-invention of a nonvolatile memory based on hydrogen-annealed SiO<sub>2</sub>. Dr. Fleetwood has served the radiation effects community as a guest editor of the December 1988-1990 and April 1996 special issues of the *IEEE Transactions on Nuclear Science*, as technical program chair and short course instructor for the IEEE NSREC, and as vice-chair/publications on the Radiation Effects Steering Group. He has received Outstanding Paper Awards for the 1985, 1988, and 1995-1998 IEEE NSREC's and 1988, 1990, and 1995 HEART Conferences. He was awarded the International Correspondence Chess Master title in 1997, and is a member of The American Physical Society, Phi Beta Kappa, Sigma Pi Sigma, and a Fellow of IEEE.



**Paul E. Dodd** received his B.S. and M.S. in Electrical Engineering from Purdue University in 1988 and 1989. He received his Ph.D. from Purdue in 1993 for research on novel cryogenic InAs bipolar transistors and experimental and theoretical studies of GaAs-based heterojunction bipolar transistors. He joined Sandia National Laboratories in 1993, and is a Senior Member of the Technical Staff in the Radiation Technology and Assurance Department. He is actively involved in the development of Sandia's 0.5- $\mu\text{m}$  and 0.35- $\mu\text{m}$  bulk and SOI CMOS technologies, and the computer simulation of single-event, total-dose, and transient radiation effects on microelectronics. Paul has served the radiation effects community as publicity chairman and session chairman for the IEEE NSREC, and has been a session chairman for the Single-Event Effects Symposium. He has also served the IEEE International Electron Devices Meeting as a member of the Modeling and Simulation technical subcommittee and session chairman. Paul is the author or co-author of more than 30 publications and is a member of the IEEE.

## BASIC MECHANISMS FOR SINGLE-EVENT EFFECTS

Paul E. Dodd

*Sandia National Laboratories*

Paul Dodd will present an overview of the mechanisms responsible for single-event effects (SEE), with a particular eye toward the use of physics-based modeling and simulation to shed light on the fundamental processes involved. After a brief review of the space radiation environment responsible for SEE, nondestructive and destructive SEE failure modes will be discussed. Techniques for mitigating SEE will be reviewed, as well as newer topics such as particle energy effects and gate rupture in thin oxides. Future trends in SEE susceptibility will be addressed, including growing concerns for SEE in terrestrial microelectronics.

## BASIC MECHANISMS FOR SINGLE-EVENT EFFECTS

### Introduction

#### Brief Overview of Environments

- Trapped Particles
- Transient Particles
- Secondary Particles

#### Basic Mechanisms for Non-Destructive Single-Event Effects

- Charge Deposition
- Charge Collection
- Single-Event Upset Mechanisms in DRAMs
- Single-Event Upset Mechanisms in SRAMs
- Single-Event Upset in Other Circuit Types
- Single-Event Multiple-Bit Upset
- Particle Energy Effects
- Mitigation Techniques

#### Basic Mechanisms for Destructive Single-Event Effects

- Single-Event Latchup
- Single-Event Gate Rupture
- Single-Event Burnout

#### Modeling and Simulation of Single-Event Mechanisms

- Interaction Models
- Physics-Based Device Models

#### Future Trends

- Technology Drivers Impacting Single-Event Effects
- Hardening Strategies
- Terrestrial and High-Altitude Single-Event Effects

#### Conclusions





**Jean-Luc Leray** received his Engineering Degree from the "Ecole Centrale des Arts et Manufactures de Paris" in 1978, and the "Docteur d'État es Sciences Physiques" Degree from the University of Orsay, Paris, in 1989. Meanwhile, he was successively research engineer, project leader, and group leader at "Commissariat A l'Energie Atomique" (CEA), the French Agency for Atomic Energy. In 1992, he became head of the Radiation Hardening Section at CEA. In 1994, Dr. Leray was awarded "Grand Prix de l'Electronique Général Ferrié" by SEE (Société des Electriciens et des Electroniciens, Paris) and FIEE (French Federation of the Electronic Industries) for works in design and hardening of integrated technologies for military, space, and high-energy physics applications. Dr. Leray has served as Session Chair for the IEEE NSREC, and as Short Course Instructor and Technical Program Chair for RADECS. He is the author or co-author of more than 110 publications and 4 book chapters, and holds one patent. In 1998, he was awarded the medal "Chevalier des Palmes Académiques" by the Ministry of Education and Research. Dr. Leray is now a scientific assistant and program advisor to the director of the department in charge of hardening matters at CEA. He is a "Membre Senior" of SEE and a Senior Member of the IEEE.

## **TOTAL DOSE EFFECTS: MODELING FOR PRESENT AND FUTURE**

Jean-Luc Leray  
*CEA/DAM Ile-de-France*

Jean-Luc Leray will review the basic mechanisms of total ionizing dose effects on semiconductor devices in the natural space environment. Time dependent effects on radiation response will be discussed, as will new issues of special interest to commercial off-the-shelf (COTS) parts. Examples will be presented that incorporate numerical modeling of total dose effects where it is possible.

## **TOTAL DOSE EFFECTS: MODELING FOR PRESENT AND FUTURE**

### **Introduction**

#### **The Total-Dose Environment in Space**

- Origin of Particles
- Effects on Electronics

#### **Ionizing Radiation Effects in MOS and Bipolar Transistors**

- Charge Generation and Transport
- Oxide Traps and Interface States
- Visible and Hidden Transistors
- Measurement Techniques

#### **Fundamentals of Charge Trapping**

- Low Dose Limit
- High Dose Limit

#### **Hardness Assurance and Testing Issues**

- Time Dependent Effects
- Isochronal and Isothermal Annealing

#### **Modeling Total-Dose Effects**

- Status of Past and Current Codes
- Modeling in 1D, 2D, and 3D
- Parasitic MOS Leakage

#### **Hardening Issues**

- Causes of Physical Defects in SiO<sub>2</sub>
- SOI

#### **Technologies and Products**

- Hardened
- Commercial Off-the-Shelf

### **Conclusions**



**Paul W. Marshall** received his B.S. in Physics from James Madison University in 1980, his M.S. in Radiation Biophysics from the Medical College of Virginia in 1982, and his Ph.D. from the Department of Nuclear Engineering and Engineering Physics at the University of Virginia in 1985. Since 1985, he has been employed by SFA, Incorporated, under contracts supporting the Naval Research Laboratory's Radiation Effects Branch. His activities there have included development of proton test capabilities for microelectronic and photonic components of interest to satellite developers. Basic mechanisms of proton interactions have been a major emphasis in his studies of displacement damage and single event effects from protons. Since 1991 Dr. Marshall has been engaged, first as a collaborator and more recently as a consultant, with the NASA Goddard Space Flight Center's Radiation Effects Group where he supports component and subsystem evaluations for numerous flight projects and continues investigations into basic mechanisms of proton and other radiation effects in emerging technologies. Dr. Marshall has chaired sessions and served on several committees for the NSREC, and he is a member of the IEEE and NPSS with over 80 published papers.

## **PROTON EFFECTS & TEST ISSUES FOR SATELLITE DESIGNERS**

**Paul W. Marshall**

*Consultant*

Paul Marshall will briefly review the proton environments, and discuss single event and total ionizing dose issues specific to proton effects in space. Case studies will illustrate typical applications of single event rate predictions. Current issues pertaining to emerging technologies, on-orbit predictions, and test fidelity will also be discussed.

## **PROTON EFFECTS & TEST ISSUES FOR SATELLITE DESIGNERS**

### **Part I: Ionization Effects**

#### **Introduction**

#### **Proton Environments within Satellites**

- General Description and Example Requirements
- Current Issues with Environment Models

#### **Total Ionizing Dose and Protons**

- Where is Proton Dose Important?
- Is a rad always a rad?

#### **Proton-Induced Single Event Effects**

- Special Cases and Test Issues
  - High Speed Technologies
  - Small Probability Events
- Destructive Failures
  - Latch-Up (and COTS)
  - Burnout
  - Stuck bits
- Direct Ionization and SEEs
  - Case Studies: CCD's, Optocouplers, Optical Link Photodetectors
  - Rate Predictions

#### **Conclusions**



**Cheryl J. Marshall** received her B.S. degrees in Physics and Chemistry from Georgetown University in 1979, and her Ph.D. in Physics from the University of North Carolina at Chapel Hill in 1986. From 1986 until 1998, she worked as a research physicist for the Naval Research Laboratory, investigating basic mechanisms of radiation damage in microelectronic and optoelectronic technologies critical to satellite imaging and communications. She also served as Section Head of the Emerging Technologies Section in the Radiation Effects Branch at NRL, and provided flight program support. Dr. Marshall has served as the Defense Threat Reduction Agency's Program Area Reviewer for Single Event Effects, and chaired the 10th and 11th Single Event Effects Symposia. Since 1998, Dr. Marshall has worked for the NASA Goddard Space Flight Center evaluating radiation effects in emerging technologies and providing flight program support. She has participated in the IEEE NSREC on several committees and chaired sessions (including the Poster Session in 1998). She is a member of the IEEE and NPSS with over 80 published papers.

## **PROTON EFFECTS & TEST ISSUES FOR SATELLITE DESIGNERS**

Cheryl J. Marshall

*NASA Goddard Space Flight Center*

Cheryl Marshall will discuss displacement damage issues specific to proton effects in space. Case studies will illustrate typical applications of displacement damage analysis tools. Current issues pertaining to emerging technologies, on-orbit predictions, and test fidelity will also be discussed.

## **PROTON EFFECTS & TEST ISSUES FOR SATELLITE DESIGNERS Part 2: Displacement Effects**

### **Introduction**

#### **Proton-Induced Displacement Damage Mechanisms and Tools**

- Formation of Displacement Damage
- Device Response to Displacement Damage
  - Materials and Device Effects
  - Damage Constants and Damage Factors
- Non-Ionizing Energy Loss Rate (NIEL) Concept
  - Concept of "Displacement Damage Dose"
  - Limitations in Usage of NIEL
  - Calculation of Displacement Damage Equivalent Fluences
- On-Orbit Performance Predictions

#### **Proton Displacement Damage Case Studies**

- Introduction
  - Ground Test Issues
  - On-Orbit Prediction Issues for Devices and Subsystems
- Case Studies
  - Bipolar Transistors
  - Charge Injection Devices and Charge-Coupled Devices
  - Photo-detectors
  - Lasers and Light Emitting Diodes (LEDs)
  - Optocouplers
  - Solar Cells
  - Other Photonic Components (e.g. fibers, polymers,...)

### **Conclusions**



**William F. Heidergott** received his B.S. in Electrical Engineering from the University of Arizona in 1974. Since joining Motorola, Inc., he has worked in the design and development of CMOS custom devices, application specific integrated circuits and standard products, and subsystem design and system development for numerous DoD, NASA, and commercial space programs. Mr. Heidergott's recent assignments include program engineering support in design for radiation environment compatibility and management of technology for commercial space programs. In 1998 he chaired the inaugural NSREC session on radiation effects in commercial electronics and space systems.

## **SYSTEM LEVEL MITIGATION STRATEGIES**

**William F. Heidergott**

*Motorola, Inc., Satellite Communications Group*

Bill Heidergott will address the commercial space telecommunications industry and satellite systems, space environment effects on spacecraft payloads and design for radiation environment compatibility. The presentation will include very brief discussion of the environment, models, and effects on devices; primary focus will be upon single event upset and transient effects and fault tolerance techniques for mitigating their impact to system operations.

## **SYSTEM LEVEL MITIGATION STRATEGIES**

### **Introduction**

#### **Commercial Space Telecommunications Industry**

- Historical Perspective, Systems Presently in Development or Deployment and Projections for Future Telecommunications Systems

#### **Satellite Telecommunications Systems**

- Geostationary Telecommunications Systems; Big LEO, Little Leo, MEO and Hybrid Systems; and Bent-Pipe vs Intersatellite Linked Systems

#### **The Space Environment**

- Launch Phase, Vacuum, Micrometeoroid, Orbit Debris, Atomic Oxygen, Neutral and Energetic Charged Particle Environments

#### **Space Radiation Effects on Devices and Technologies**

- Mission Integrated Effects, Destructive Single Event Effects and Single Event Upset and Transients

#### **Systems Engineering for Space Radiation Environment Compatibility**

- Radiation Environment Severity in System Architecture Trade Studies
- Spatial and Temporal Variation in the Charged Particle Environment
- Tolerance to Mission Integrated Effects
- Mitigation of Destructive Single Event Effects

#### **Management of Single Event Upset and Transients**

- Effectiveness of Shielding, Semiconductor Technology and Process Techniques, Integrated Circuit Design Techniques, IC Application Techniques and System Fault Tolerance
- Single Event Effects Rate Prediction

#### **Fault Tolerant Systems**

- System Reliability and Availability
- Fault Masking Techniques
- Fault Avoidance, Detection, and Recovery
- Validation and Verification Methods

### **Conclusions**

# Technical Program

## TECHNICAL INFORMATION



"NSREC 1999 will provide you with an informative and educational technical program. On behalf of the technical chairs and myself, we'd like to thank all authors for their efforts."

Fred Sexton

The NSREC technical program will consist of contributed oral and poster papers, three invited papers, and a data workshop. All oral sessions will be held in the Hampton Roads Ballroom. Oral papers will be 12 minutes in length with an additional three minutes for questions. The Technical Sessions and chairpersons are:

- **SEE Mechanisms & Modeling**  
*Chairpersons: Robert Reed, NASA/GSFC and Marie-Catherine Calvet, Aerospatiale*
- **SEE in Devices & ICs**  
*Chairman: Dennis Oberg, Boeing Defense and Space*
- **Space & Terrestrial Environments**  
*Chairman: Allan Tylka, Naval Research Laboratory*
- **Commercial Space Systems**  
*Chairman: Hugh O'Donnell, Lockheed Martin Missiles and Space*
- **Basic Mechanisms**  
*Session Chairpersons: Steve Witczak, The Aerospace Corp, and Olivier Flament, CEA/DAM Ile-de-France*
- **Hardness Assurance**  
*Chairman: Lewis Cohn, Defense Threat Reduction Agency*
- **Devices & ICs**  
*Chairman: Joe Benedetto, UTMC Microelectronic Systems*
- **Dosimetry & Facilities**  
*Chairman: Charles Foster, Indiana University Cyclotron Facility*
- **Photonic Devices & ICs**  
*Session Chairman: Shyam Khanna, Defence Research Establishment Ottawa*
- **Isolation Technologies**  
*Chairman: Michael Liu, Honeywell Solid State Electronics Center*

## POSTER SESSION

Papers that are most effectively presented visually with group discussion will be displayed from 12:00 PM Tuesday through 5:00 PM Thursday in the Marriott Ballroom. Authors will be available to discuss their work during the Poster Session from 2:30 to 5:00 PM on Wednesday. The poster chairman is Eugene Normand, Boeing Defense and Space.

## RADIATION EFFECTS DATA WORKSHOP

Papers in the workshop 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. Workshop posters can be previewed from 12:00 PM Tuesday through 5:00 PM Thursday in the Marriott Ballroom. The Data Workshop will be held from 2:30 - 5:00 PM Thursday, at which time the authors will be available to discuss their work. A copy of the Workshop Record will be mailed to all registered attendees after the conference. The workshop chairperson is Michele M. Foster, NASA Headquarters.

## INVITED SPEAKERS

Col. William J. Davis, Director MacArthur Memorial, will discuss the *Life and Times of Gen. Douglas MacArthur* on Wednesday. Mr. Frank Culbertson, NASA/JSC, will discuss *The Challenges and Benefits of Scientific Experimentation on the International Space Station* on Thursday. Capt. Tom Bosse, USN, NAVLANT METOC CEN will discuss *Atlantic Hurricane "Business": An Operational Perspective* on Friday.

## LATE-NEWS PAPERS

A limited number of late-news papers will be accepted and included in the poster session. The deadline for submitting late-news papers is June 3, 1999. Please submit late-news papers using the 4-page summary and 35-word abstract format to the Technical Program Chairman, Fred Sexton, Sandia National Laboratories, 1515 Eubank SE, Bldg 891, Room 3062B, MS 0527, Albuquerque, NM 87123, 505-844-3927. For further information, please see the NSREC Conference web site at [www.nsrec.com](http://www.nsrec.com).



# Technical Program Tuesday

8:15 AM      **OPENING REMARKS**  
*Ron Schrimpf, Vanderbilt University*

8:25 AM      **AWARDS PRESENTATION**  
*Klaus Kerris, Radiation Effects Steering Group Chairman*

9:00 AM      **TECHNICAL SESSION OPENING REMARKS**  
*Fred Sexton, Sandia National Laboratories*

## **SESSION A      SEE MECHANISMS & MODELING**

9:10 AM      **SESSION INTRODUCTION**  
*Chairpersons: Robert Reed, NASA/GSFC; and Marie-Catherine Calvet, Aerospatiale*

**A-1**  
9:15 AM      **Angular and Energy Dependence of Proton Upset in Optocouplers**  
*A. H. Johnston, T. Miyahira, G. M. Swift, G. Guertin, and L. D. Edmonds, Jet Propulsion Laboratory*

Direct ionization is investigated for proton upset in optocouplers. The upset cross section with 30-MeV protons starts to increase for angles less than 60° and is two orders of magnitude higher at large angles than at normal incidence.

**A-2**  
9:30 AM      **Differences in Critical Charge with Particle Species**  
*P. J. McNulty, M. W. Savage, Clemson University; D. R. Roth, The Johns Hopkins University APL; and C. C. Foster, Indiana University Cyclotron Facility*

Charge collection experiments on one COTS device compare device response to a flux of neutron vs. protons. Results show that the critical charge necessary to induce an upset is species specific.

**A-3**  
9:45 AM      **Determination of Key Parameters for SEU Occurrence Using 3-D Full Cell SRAM Simulations**  
*P. Roche, J. M. Palau, G. Bruguier, C. Tavernier, J. Gasiot, CEM<sup>2</sup> Université Montpellier II; and R. Ecoffet, CNES*

3-D simulations of a 0.35- $\mu\text{m}$  CMOS SRAM cell are used to predict the shape of the current transient for various LETs. A definition of the critical charge related to SEU occurrence is also proposed.

10:00 - 10:30 AM      **BREAK**

**A-4**  
10:30 AM      **Analysis of the Influence of MOS Device Geometry on Predicted SEU Cross Sections**  
*K. Warren, L. Massengill, R. Schrimpf, and H. Barnaby, Vanderbilt University*

Single event sensitive-area geometry and its influence on SOI upset cross sections have been investigated using a novel analysis technique. Results support the influence of both intra- and inter-cell variations on the cross section curve.

**A-5**  
10:45 AM      **Charge Deposition Modeling of Terrestrial Ions in Scaled MOS Devices**  
*X. W. Zhu, L. W. Massengill, C. R. Cirba, and H. J. Barnaby, Vanderbilt University*

Neutron reaction products are an important terrestrial SEE concern for modern scaled technologies. We discuss the applicability and limitations of conventional ion-track models for neutron effects and show a unique need for a temporal track description.

# Technical Program Tuesday

**A-6**  
11:00 AM

## **Single Event Burnout Sensitivity of Embedded Field Effect Transistors**

*R. Koga, S. Crain, K. Crawford, The Aerospace Corporation;  
and M. Gordon, Lockheed Martin*

Single event burnouts (SEBs) of field effect transistors (FETs) embedded in MOS integrated circuits are observed. Unlike SEBs in power FETs, these catastrophic upsets appear to be initiated by lateral parasitic bipolar transistors.

**A-7**  
11:15 AM

## **The Role of Energy Deposition in the Epitaxial Layer in Triggering SEGR in Power MOSFETs**

*L. E. Selva, G. M. Swift, W. A. Taylor, and L. Edmonds, Jet Propulsion Laboratory*

In these SEGR experiments, three identical-oxide MOSFETs were irradiated by six ions with significantly different ranges. Results show the prime importance of energy deposited in the epitaxial layer.

**A-8**  
11:30 AM

## **Cell Design Modifications to Harden a N-channel Power IGBT Against Single Event Latchup**

*E. Lorfèvre, B. Sagnes, G. Bruguier, J. M. Palau, J. Gasiot, Université Montpellier II;  
M. C. Calvet, Aerospatiale; and R. Ecoffet, CNES*

A device simulator is used to analyze the heavy-ion induced failure mechanism in IGBTs and to investigate hardening solutions. Modifications of the p+ plug are proposed and validated by simulations on a n-channel IGBT structure.

**A-9**  
11:45 AM

## **High Energy Heavy Ion SEB Imaging in Power MOSFETs**

*O. Musseau, A. Torres, CEA/DAM Ile-de-France; A. B. Campbell, Naval Research Laboratory; A. R. Knudson, S. Buchner, SFA; B. Fischer, M. Schlogl, GSI;  
and D. Gaudin, ST Microelectronics*

We present the first experimental determination of SEB sensitive area in a power MOSFET irradiated with a high LET heavy-ion microbeam. Nondestructive charge collection measurements illustrate the complex 3-dimensional behavior of a real structure.

## **POSTER PAPERS**

**PA-1**

## **Single Event Upsets Calculated from New ENDF/B-VI Proton and Neutron Data Up to 150 MeV**

*M. B. Chadwick, Los Alamos National Laboratory;  
and E. Normand, Boeing Defense and Space*

Single-event upsets (SEU) in microelectronics are calculated from newly developed silicon nuclear reaction recoil data that extend up to 150 MeV for incident protons and neutrons. Calculated SEU cross sections are compared with measured data.

**PA-2**

## **Scaling of SEU Mapping and Cross Section at Reduced Supply Voltages**

*J. Barak, J. Levinson, E. Adler, A. Zentner, D. David, Y. Lifshitz, Soreq NRC; M. Hass, Weizmann Institute; B. E. Fischer, and M. Schlogl, GSI*

The scaling parameters which govern SEU microprobe-mapping and cross section of a SRAM as a function of supply voltage and LET are shown to be the effective charge collection depth and the reduced LET.

# Technical Program Tuesday

12:00 - 1:30 PM LUNCH

**SESSION B**  
1:30 PM

**SEE in DEVICES & ICS**  
**SESSION INTRODUCTION**

*Chairman: Dennis Oberg, Boeing Defense and Space*

**B-1**  
1:35 PM

**Single Event Upset Immunity of Strontium Bismuth Tantalate Ferroelectric Memories**

*J. M. Benedetto, UTMC Microelectronic Systems; G. F. Derbenwick, Celis Semiconductor; and J. D. Cuchiaro, Symetrix Corp.*

An embedded 1K-bit nonvolatile serial memory manufactured with strontium bismuth tantalate ferroelectric technology was shown to be SEU and SEGR immune to a LET of 128 MeV-cm<sup>2</sup>/mg with a maximum ion exposure of 1.5x10<sup>7</sup> ions/cm<sup>2</sup>.

**B-2**  
1:50 PM

**Single Event Effects in Static and Dynamic Registers in a 0.25  $\mu$ m CMOS Technology**

*F. Faccio, K. Kloukinas, A. Marchioro, CERN; T. Calin, J. Cosculluela, R. Velazco, and M. Nicolaidis, TIMA/INPG Laboratory*

We study SEE in 0.25  $\mu$ m CMOS static and dynamic cells. Use of edgeless transistors for total dose tolerance increases the SEU threshold. A novel SEU-hardened storage cell is proposed with LET<sub>th</sub> close to 89 MeV-cm<sup>2</sup>/mg.

**B-3**  
2:05 PM

**Single Event Effects in Resolver-to-Digital Converters**

*S. Buchner, L. Tran, SFA; J. Mann, NRL; T. Turflinger, NSW Crane; D. McMorrow, A. B. Campbell, and C. Dozier, NRL*

The SET and SEL responses of two resolver-to-digital converters have been measured with heavy ions. The important role played by a pulsed laser in understanding the nature of the SETs is discussed.

**B-4**  
2:20 PM

**Single Event Upset Characterization of the Pentium<sup>®</sup> MMX and Pentium<sup>®</sup> II Microprocessors Using Proton Irradiation**

*D. M. Hiemstra and A. Baril, SPAR Space Systems*

Experimental single event upset characterization of the Pentium MMX and Pentium II microprocessors using proton irradiation is presented. Results show the Pentium II processor core cross-section is ten times that of the MMX.

## POSTER PAPERS

**PB-1**

**The Impact of Software and CAE Tools on SEU in Field Programmable Gate Arrays**

*R. B. Katz, NASA/GSFC; J. Wang, A. Jeong, J. McCollum B. Cronquist, Actel Corp; and K. Jobe, Hughes Aircraft Co.*

COTS computer aided engineering tools can produce unreliable FPGA circuit designs when the device is used in a radiation environment. Software can be used to improve the SEU performance of FPGA flip-flops.

**PB-2**

**SEU Testing of a Novel Hardened Register Implemented Using Standard CMOS Technology**

*T. Monnier, F. M. Roche, J. Cosculluela, and R. Velazco, Université Montpellier II*

# Technical Program Tuesday

A novel SEU-tolerant memory structure has been implemented in full standard sub-micron non-radiation hardened CMOS without performance or area penalties. An improvement in SEU-robustness is seen in heavy-ion tests.

## **PB-3 Neutron-Induced Single-Word Multiple-Bit Upset in SRAMs**

*K. Johansson, M. Ohlsson, Ericsson Saab Avionics AB; N. Ohlsson, J. Blomgren, and P-U Renberg, Uppsala University*

The Single-Word Multiple-bit Upset frequency for SRAM with different neutron energies has been measured. Also, the supply voltage influence on the SMU rate has been studied. The SMU frequency vs. altitude is estimated.

## **2:35 PM OVERVIEW OF SESSION G — DEVICES & ICS**

*Chairman: Joe Benedetto, UTMC Microelectronic Systems*

## **2:40 - 3:10 PM BREAK**

## **SESSION C SPACE & TERRESTRIAL ENVIRONMENTS**

### **3:10 PM SESSION INTRODUCTION**

*Chairman: Allan Tylka, Naval Research Laboratory*

## **C-1 Long Term Study of Spacecraft Charging at Geosynchronous Altitude**

*3:15 PM B. K. Dichter, K. P. Ray, M. S. Gussenhoven, Air Force Research Laboratory; E. G. Mullen, Assurance Technology Corp; and D. E. Delorey, Boston College*

We present results of experimental charging studies for a geosynchronous spacecraft. Charging is related to local electron and ion populations, geomagnetic activity and solar EUV flux. Efficacy of active spacecraft discharge technique is also described.

## **C-2 Observations of the Radiation Belts with REM**

*3:30 PM P. Buhler, L. Desorgher, A. Zehnder, Paul Scherrer Institute; and E. Daly, European Space Agency*

Radiation Environment Monitor results from the STRV-1 (GTO) spacecraft are presented. STRV data show electron belt variability and a hard proton radiation belt feature. Models and simulations are discussed.

## **C-3 Microdosimetry Code Simulation of Charge-Deposition Spectra, Single Event Upsets and Multiple Bit Upsets**

*3:45 PM C. S. Dyer, P. R. Truscott, C. Sanderson, DERA; C. Comber, EDS Defense Limited; C. Underwood, M. Oldfield, University of Surrey; A. Campbell, S. Buchner, and T. Meehan, NRL*

A microdosimetry extension to HETC has been applied to model charge-deposition spectra in PIN diodes caused by monoenergetic and atmospheric neutron spectra, as well as upsets in DRAMs from ground and space irradiation.

## **C-4 Probability Model for Worst Case Solar Proton Event Fluences**

*4:00 PM M. A. Xapsos, G. P. Summers, Naval Research Laboratory; J. L. Barth, and E. G. Stassinopoulos, NASA/GSFC*

A model of worst-case solar-proton event fluences is presented for time periods corresponding to space missions and for confidence levels up to and including 1.0.

# Technical Program Tuesday

## POSTER PAPERS

- PC-1 A New Low Altitude Trapped Proton Model for Solar Minimum Conditions Based on SAMPEX/PET Data**  
*D. Heynderickx, M. Kruglanski, V. Pierrard, J. Lemaire, Belgisch Instituut voor Ruimte-Aeronomie; M. D. Looper, and J. B. Blake, The Aerospace Corp.*

We present a low altitude trapped proton model for solar minimum, based on measurements made by the Proton/Electron Telescope on board the SAMPEX satellite. This model may replace the low altitude part of AP-8 MIN.

- 4:15 PM **OVERVIEW OF SESSION H — DOSIMETRY & FACILITIES**  
*Chairman: Charles Foster, Indiana University Cyclotron Facility*

- SESSION D COMMERCIAL SPACE SYSTEMS**  
4:20 PM **SESSION INTRODUCTION**  
*Chairman: Hugh O'Donnell, Lockheed Martin Missiles and Space*

- D-1 Design Guidelines for the Use of COTS in Military and Space Systems**  
4:25 PM *P. S. Winokur, M. R. Shaneyfelt, F. W. Sexton, Sandia National Laboratories; G. K. Lum, and L. Scott, Lockheed Martin Missiles and Space*

A set of guidelines is provided for the cost-effective use of COTS microelectronics in radiation environments that enable the designers to manage risks and ensure mission success.

- D-2 On the Figure of Merit Model for SEU Rate Calculations**  
4:40 PM *J. Barak, R. A. Reed, and K. A. LaBel, NASA/GSFC*

The Figure of Merit model of Peterson for SEU rates in orbit is analyzed for its merits and its limitations. The FOM for protons is compared with other empirical models for calculating proton-SEU from heavy ion measurements.

## POSTER PAPERS

- PD-1 Single Event Effects Design Methodology for Commercial Communications Satellites**  
*A. Bogorad, R. Herschitz, S. Moyer, S. Seehra, and R. Kong, Lockheed Martin Missiles and Space*

Spacecraft level methodology to mitigate the SEE effects on commercial communications satellites is presented along with the SEU test data for 37 typical devices used in satellite systems.

- PD-2 Radiation Effects on ISOCAM On Board the Infrared Space Observatory**  
*A. Claret and H. Dzitko, CEA-Saclay*

The sensitivity of the ISOCAM infrared camera is limited by glitches caused by charged particle impacts. Temporal and spatial properties of glitches led to a classification into 3 distinct families related to the particle LET.

- 4:55 PM **END TUESDAY SESSIONS**



# Technical Program Wednesday

**INVITED TALK**  
8:15 - 9:15 AM

**Life and Times of Gen. Douglas MacArthur**  
*Col. William J. Davis, Director MacArthur Memorial*

**SESSION E**  
9:15 AM

**BASIC MECHANISMS**  
**SESSION INTRODUCTION**

*Session Chairpersons: Steve Witczak, The Aerospace Corp;  
and Olivier Flament, CEA/DAM Ile-de-France*

**E-1**  
9:20 AM

**The Role of Electron Transport and Trapping  
in MOS Total-Dose Modeling**

*D. M. Fleetwood, P. S. Winokur, L. C. Riewe, Sandia National Laboratories; O. Flament, P. Paillet, and J. L. Leray, CEA/DAM Ile-de-France*

Deep and shallow electron traps form in irradiated thermal SiO<sub>2</sub> as a natural response to hole transport and trapping. The density and stability of these defects are discussed, as are their implications for total-dose modeling.

**E-2**  
9:35 AM

**Consideration on Isochronal Anneal Technique:  
From Measurement to Physics**

*O. Flament, P. Paillet, J. L. Leray, CEA/DAM Ile-de-France;  
and D. M. Fleetwood, Sandia National Laboratories*

The isochronal anneal technique used to predict isothermal anneal behavior of MOS devices is analyzed as a function of experimental parameters. The effects of detrapping of trapped holes and compensating electrons are discussed.

**E-3**  
9:50 AM

**New Fundamental Defects in a-SiO<sub>2</sub>**

*S. P. Karna, W. M. Shedd, R. D. Pugh, B. K. Singaraju, Air Force Research Laboratory;  
and H. A. Kurtz, University of Memphis*

The atomic structure of the X center in a-SiO<sub>2</sub> has been characterized by first-principles quantum mechanical calculations to be O<sub>2</sub>Si=Si<sup>↑</sup>. A new defect center, named Y, with OSi<sub>2</sub>=Si<sup>↑</sup> atomic structure is identified in Si-rich oxide.

10:05 - 10:35 AM

**BREAK**

**E-4**  
10:35 AM

**Ab Initio Calculations of H<sup>+</sup> Energetics in SiO<sub>2</sub>: Implications for Transport**

*P. E. Bunson, R. D. Schrimpf, K. F. Galloway, M. Di Ventra, and S. T. Pantelides,  
Vanderbilt University*

Stable bonding sites, migration pathways, and barrier heights of H<sup>+</sup> in SiO<sub>2</sub> are studied using first-principles density-functional theory. New binding sites have been found and possible reaction modes are under investigation.

**E-5**  
10:50 AM

**Proton Mobility in a-SiO<sub>2</sub>**

*H. A. Kurtz, University of Memphis; and S. P. Karna, Air Force Research Laboratory*

A model for proton mobility in a-SiO<sub>2</sub> is developed. Theoretical first-principles calculations are performed to test this model by obtaining pathways and activation energies for proton motion.

# Technical Program Wednesday

- E-6**  
11:05 AM **Nonionizing Energy Loss (NIEL) for Heavy Ions**  
*S. R. Messenger, E. A. Burke, E. M. Jackson, SFA, Inc.; G. P. Summers, M. A. Xapsos, R. J. Walters, and B. D. Weaver, Naval Research Laboratory*

In this paper, we describe the methodology used to extract NIEL from SRIM for a number of materials and particles. We will also provide general rules of thumb for predicting NIEL values for any condition.

## POSTER PAPERS

- PE-1**  
**Effects of Radiation on the Transport and Trapping of  $H^+$  in  $SiO_2$**   
*R. E. Stahlbush, Naval Research Laboratory*

Radiation-induced defects slow the transit time of  $H^+$  in hydrogen-annealed oxides. This effect is examined in a variety of SOI buried oxides and thermal oxide.

- PE-2**  
**Radiation-Induced Trapped Charge in Metal-Nitride-Oxide-Semiconductor Structures**  
*Y. Takahashi, K. Ohnishi, T. Fujimaki, and M. Yoshikawa, Nihon University*

The charge trapping mechanism of metal-nitride-oxide-semiconductor structures under irradiation has been discussed. The charge depth profile was evaluated by varying insulator thickness. The suitable insulator thickness for radiation hardened devices have also been estimated.

- PE-3**  
**Trapped Charge in Dual-Dielectric CCDs and MOSFETs**  
*A. Holmes-Siedle, K. Egan, and S. Watts, Brunel University of West London*

The interface between dual dielectric layers strongly affects the response of CCD02 imagers to radiation. The shift and photoanneal of flatband voltage and dark current as a function of dose are measured and modelled up to megarad levels.

- PE-4**  
**Analysis of Anomalous TDE Data On-Board the KITSAT-1**  
*Y-H. Shin, K-W Min, J. G. Rhee, and D-H Lee, Satellite Technology Research Center, KAIST*

Anomalies in the radiation response of RADFETs on board the KITSAT-1 are observed. The cause is identified as annealing of oxide-trapped charge during thermal cycles associated with changes in the satellite eclipse rate.

- PE-5**  
**Photoluminescence Study of Gallium Arsenide Irradiated with 15-MeV Alpha Particles**  
*L. Sellami, M. Aubin, C. Aktik, C. Carlone, A. Houdayer, and P. Hinrichsen, Université de Sherbrooke*

The experimental gallium vacancy introduction rate in gallium arsenide films irradiated with 15-MeV alpha particles is estimated to be  $2500 \pm 800 \text{ cm}^{-1}$ . The theoretical elastic scattering contribution is  $270.1 \text{ cm}^{-1}$ . The discrepancy is discussed.

- 11:20 AM **OVERVIEW OF SESSION I — PHOTONIC DEVICES & ICS**  
*Session Chairman: Shyam Khanna, Defence Research Establishment Ottawa*

- 11:30 - 1:00 PM **LUNCH**

# Technical Program Wednesday

## **SESSION F      HARDNESS ASSURANCE**

### **1:00 PM      SESSION INTRODUCTION**

*Chairman: Lewis Cohn, Defense Threat Reduction Agency*

### **F-1      Enhanced Low Dose Rate (ELDRS) Response of Bipolar Transistors 1:05 PM      and Linear Circuits in a Space Environment**

*J. L. Titus, T. Turflinger, J. F. Krieg, D. Emily, NSWC - Crane; R. L. Pease, RLP Research; and A. Campbell, Naval Research Laboratory*

The total dose responses of bipolar transistors and linear circuits are recorded in a real space environment. These data clearly demonstrate that enhanced low dose rate sensitivities (ELDRS) do exist in space.

### **F-2      Hardness Assurance Implications of Bimodal Irradiation Response 1:20 PM      in a Bipolar Linear Voltage Comparator**

*J. F. Krieg, J. Titus, M. Gehlhausen, D. Emily, T. Turflinger, NSWC - Crane; R. L. Pease, RLP Research; H. Barnaby, R. Schrimpf, Vanderbilt University; and M. C. Maher, National Semiconductor*

The total dose response of transistors and circuits from a single wafer lot is measured at high and low dose rates and elevated temperature. A bimodal irradiation response is observed. Hardness Assurance implications are examined.

### **F-3      Use of the Radiation-Induced Charge Neutralization Mechanism 1:35 PM      to Achieve Annealing of Complex Electronic Devices**

*O. Quittard, F. Joffre, LETI (CEA - Advanced Technologies); C. Oudea, Aerospatiale; F. Saigne, L. Dusseau, J. Fesquet, and J. Gasiot, CEM<sup>2</sup> Université Montpellier II*

Annealing of commercial SRAMs and CMOS inverters was achieved during irradiation using the RICN mechanism. This was the first time that such a result was obtained by switching the supply voltage.

### **F-4      Anomalous Low Dose Rate Effects in Gamma Irradiated 1:50 PM      SiGe Heterojunction Bipolar Transistors**

*G. Banerjee, G. Niu, J. D. Cressler, M. J. Palmer, Auburn University; S. D. Clark, NSWC - Crane; and D. C. Ahlgren, IBM Microelectronics*

We present the first investigation of ELDR effects in gamma-irradiated SiGe HBTs. We find an anomalous decrease in base current at doses up to 20 krad(Si) in these devices.

## **POSTER PAPERS**

### **PF-1      Prediction of Early Lethal SEGR Failures of VDMOSFETs for Commercial Space Systems**

*C. F. Wheatley, T. H. Wheatley, Consultant; J. L. Titus, NSWC - Crane; K. M. VanTyne, W. A. Levinson, D. I. Burton, Harris Semiconductor; J. L. Barth, and R. A. Reed, NASA/GSFC*

Any system of satellites contains many power MOSFETs exposed to heavy ion destruction. Failures are examined with normalized Monte Carlo and statistical analysis. An empirical expression is developed. The lethal ion rate is also discussed.

# Technical Program Wednesday

- PF-2 Enhanced Low Dose Rate Sensitivity (ELDRS) in a Voltage Comparator Which Only Utilizes Complimentary Vertical NPN and PNP Transistors**  
*J. F. Krieg, D. Emily, M. Gehlhausen, J. L. Titus, T. Turflinger, NSWC - Crane; J. Swonger, and C. Tabbert, Harris Semiconductor*

For the first time, ELDRS is reported in an all-vertical bipolar circuit. The proposed ELDRS RHA method was successfully demonstrated. High, low and elevated temperature data for HS139RH and associated transistors are presented.

- PF-3 ELDRS of COTS Linear Bipolar and BiCMOS Integrated Circuits, at Very Low Dose Rates**

*L. Bonora and J. P. David, ONERA DESP*

Very low dose rate irradiations may be a useful tool to estimate the design margins, necessary for the COTS ICs subject to ELDRS, without requiring a high total dose.

- PF-4 Single Event Effects on 1300 nm Laser Diode for Satellite Optical Data Link**

*E. Pailharey, J. Baggio, C. D'hose, and O. Musseau, CEA/DIF*

We measured the sensitivity to transient irradiation of a laser diode used for a digital optical link. Bit error rate evaluation is correlated with the response of the diode under pulsed laser and heavy-ion irradiation.

- 2:05 PM OVERVIEW OF SESSION J — ISOLATION TECHNOLOGIES**

*Chairman: Michael Liu, Honeywell Solid State Electronics Center*

- 2:30 - 5:00 PM POSTER SESSION**

*Chairman: Eugene Normand, Boeing Defense and Space*



- 5:00 PM END OF WEDNESDAY SESSIONS**

# Technical Program Thursday

## **INVITED TALK** 8:15 - 9:15 AM

### **The Challenges and Benefits of Scientific Experimentation on the International Space Station**

*Mr. Frank Culbertson, NASA Johnson Space Center*

Mr. Frank Culbertson, US Program Manager for the International Space Station, will describe the International Space Station program, and the possibilities and challenges of conducting scientific research in space. The Space Shuttle and two types of Russian rockets will conduct 45 missions to launch and assemble the more than 100 elements which will comprise the completed International Space Station. In all, 460 tons of structures, modules, equipment and supplies will be placed in orbit by the year 2004. But the difficulties of such an undertaking pale in comparison to the potential benefits of scientific research in the microgravity environment of space. This unique laboratory enables research into a wide range of disciplines including: the life sciences, such as human health, biosystems, and agriculture; materials science, crystallography, and electronic and non-electronic materials. Knowledge gained from focused space research will lead to new insights and understanding that will be the basis for man's future exploration of space, and the creation of new products and processes that will create new jobs and improve the quality of life.

## **SESSION G** 9:15 AM

### **DEVICES & ICS** **SESSION INTRODUCTION**

*Chairman: Joe Benedetto, UTMC Microelectronic Systems*

#### **G-1** 9:20 AM

### **Identification of Degradation Mechanisms in a Bipolar Linear Voltage Comparator Through Correlation of Transistor and Circuit Response**

*H. J. Barnaby, R. Schrimpf, Vanderbilt University; J. Krieg, J. Titus, M. Gehlhausen, P. Cole, D. Emily, T. Turflinger, NSWCC - Crane; R. Pease, RLP Research; S. C. Witczak, The Aerospace Corp.; and M. C. Maher, National Semiconductor*

The total dose response of circuit transistors and voltage comparators is measured at high and low dose rates and elevated temperature. Input bias current is shown to correlate to the degradation of the test transistors.

#### **G-2** 9:35 AM

### **The Effects of Gate Bias on Defect Generation and Surface Recombination in Gate Controlled Lateral PNP Bipolar Junction Transistors**

*H. J. Barnaby, C. Cirba, R. D. Schrimpf, Vanderbilt University; S. Kosier, VTC Inc.; P. Fouillat, and X. Montagner, University of Bordeaux 1*

Gate potentials that deplete the base during radiation exposure and accumulate the base during operation suppress gain degradation in gate controlled lateral PNP transistors. Results suggest dynamic control of gate potential improves radiation hardness.

#### 9:50 - 10:20 AM

### **BREAK**

#### **G-3** 10:20 AM

### **Overcoming Scaling Concerns in a Radiation-Hardened CMOS Technology**

*J. Maimon and N. Haddad, Lockheed Martin Federal Systems*

Scaling efforts to develop an advanced radiation-hardened CMOS process to support a 4M SRAM are described. Transistor data, total dose radiation results, and the performance of novel SEU resistors across temperature are presented.



# Technical Program Thursday

**G-4**  
10:35 AM

## **Ionization and Displacement Damage Irradiation Studies of Quantum Devices: Resonant Tunneling Diodes and Two-dimensional Electron Gas Transistors**

*R. Wilkins, S. Shojah-Ardalan, T. N. Fogarty, Prairie View A&M University; W. P. Kirk, G. F. Spencer, R. T. Bate, University of Texas at Dallas; A. C. Seabaugh, R. Lake, Raytheon Systems Co.; P. Stelmazyk, and A. D. Wieck, Ruhr-Universität Bochum*

Irradiation experiments on two different types of quantum devices, resonant tunneling diodes (RTD) and two-dimensional electron gas transistors (2-DEGT), are discussed. The data indicate that RTDs have high radiation tolerance.

**G-5**  
10:50 AM

## **Displacement Damage in Bipolar Linear Integrated Circuits**

*B. G. Rax, A. H. Johnston, and T. Miyahira, Jet Propulsion Laboratory*

Displacement damage from protons is investigated for several types of integrated circuits. Commercial voltage regulators fail catastrophically below 35 krad(Si) when irradiated with protons, but function with moderate degradation to 100 krad(Si) gamma irradiation.

**G-6**  
11:05 AM

## **Study of Dose Effects on IGBT-Type Devices Subjected to Gamma Irradiation**

*M. Marceau, C. Brisset, LETI (CEA - Advanced Technologies); and M. Da Costa, IRESTE*

This paper describes characterization tests performed on insulated gate bipolar transistors. A possible explanation for the observed phenomena is obtained using an electrical model and a PSPICE simulator.

**G-7**  
11:20 AM

## **Radiation Tolerant VLSI Circuits in Standard Deep Submicron CMOS Technologies for the LHC Experiments: Practical Design Aspects**

*G. Anelli, M. Campbell, F. Faccio, E. Heijne, P. Jarron, K. Kloukinas, A. Marchioro, P. Moreira, W. Snoeys, A. Giraldo, CERN; and M. Delmastro, University of Padova & INFN;*

We discuss design issues related to the use of edgeless devices in deep submicron technologies in order to achieve improved radiation tolerance. We present novel aspects related to the use of this design approach.

## **POSTER PAPERS**

**PG-1**

## **Dose Rate Dependence of the Current Noise Performance of an Ultra-Low Noise Precision Bipolar Operational Amplifier**

*D. M. Hiemstra, SPAR Space Systems*

Dose rate dependence of the current noise of a bipolar operational amplifier is presented. Total current noise performance degrades linearly with increasing dose rate. Generation-recombination, white and 1/f spectral components contribute to the degradation.

**PG-2**

## **Techniques for Dose-Rate-Hardening of Crystal Controlled Clocks**

*R. J. Williams, K. O. Wessendorf, and J. A. Dye, Sandia National Laboratories*

A gated Pierce oscillator was dose rate hardened to  $7.5 \times 10^{11}$  rad(Si)/s using innovative circuit design techniques. These concepts can be used in conjunction with other hardening methods to further increase the upset threshold.

# Technical Program Thursday

**PG-3 Electron Irradiation Effects on Polyimide Passivated InP/InGaAs Single Heterojunction Bipolar Transistors**

*A. Shatalov, S. Subramanian, Oregon State University; S. Chandrasekhar, A. Dentai, Lucent Technologies; and S. M. Goodnick, Arizona State University*

Total dose electron and neutron irradiation effects on polyimide passivated InP/InGaAs Single Heterojunction Bipolar Transistors (SHBTs) are presented. The devices are shown to have excellent radiation performance.

**PG-4 The Effects of Proton Irradiation on the RF Performance of SiGe HBTs**

*S. Zhang, G. Niu, J. D. Cressler, Auburn University; S. D. Clark, NSWC - Crane; and D. C. Ahlgren, IBM Microelectronics*

The effects of proton irradiation on the RF performance of SiGe HBTs are reported for the first time. Frequency response and broadband noise properties are investigated in SiGe HBTs for proton fluences up to  $5 \times 10^{13} \text{ p/cm}^2$ .

**PG-5 Electron Irradiation Effects on Photoconductive Semiconductor Switches (PCSS) Used in Sub-nanosecond Transient Generators**

*N. E. Islam, E. Schamiloglu, B. Shipley, T. H. Kirby, University of New Mexico; W. T. Kemp, and J. S. H. Schoenberg, Air Force Research Laboratory*

Filamentary conduction is a characteristic response of photoconductive semiconductor switches used in ultra wideband (UWB) high power microwave (HPM) generation. Homogeneous, defect free devices and shielding may ensure their survivability.

**PG-6 Reprogrammable FPGA for Space Applications**

*J.-J. Wang, B. Cronquist, J. McCollum, T. Speers, Actel Corp.; and R. Katz, NASA/GSFC*

An SRAM-based re-programmable FPGA is assessed for its potential use for space applications. A new commercial device is used as an example.

**PG-7 The Effects of Architecture and Process on the Hardness of Programmable Technologies**

*R. B. Katz, R. Reed, NASA/GSFC; J. Wang, J. McCollum, B. Cronquist, Actel Corp.; I. Kleyner, J. Howard, Jackson and Tull; and M. D'Ordine, Ball Aerospace and Technologies Corp.*

This paper demonstrates that architecture and process, combined, significantly affect the hardness of programmable technologies.

**PG-8 Radiation Effects on Advanced Flash Memories**

*D. N. Nguyen, S. Guertin, G. M. Swift, and A. H. Johnston, Jet Propulsion Laboratory*

Tests of advanced flash memories are compared with results from previous generations, with similar total dose results. Small numbers of hard errors were observed in single-event testing of the multi-level devices.

# Technical Program Thursday

## **PG-9 Neutron Radiation Hardness Studies of Spectrometric Natural Diamond Detector**

*Y. Kaschuck, A. Alekseyev, V. Amosov, A. Krasilnikov, and D. Portnov, Troitsk Institute for Innovative and Fusion Research*

Degradation of alpha spectra measured in-situ by a Natural Diamond Detector under intense fast neutron irradiation has been studied in the active zone of a fission reactor. High radiation resistance of the NDD has been demonstrated up to the neutron fluence  $3 \times 10^{16} \text{ cm}^{-2}$ .

11:35 - 1:05 PM LUNCH

## **SESSION H DOSIMETRY & FACILITIES**

1:05 PM SESSION INTRODUCTION

*Chairman: Charles Foster, Indiana University Cyclotron Facility*

### **H-1 SEU and Microdose Measurement Based on FAMOS Transistors**

1:10 PM *P. J. McNulty, L. Z. Scheick, Clemson University; and D. R. Roth, Johns Hopkins University APL*

A new method using a FAMOS transistor array and an appropriately programmed UVPROM for measuring microdose absorbed from ionizing radiation is described. Measured change in erasure time determines bit flip and first flip event distributions.

### **H-2 High Energy Electron Dose-Mapping Using Optically Stimulated Luminescent Films**

1:25 PM *L. Dusseau, G. Ranchoux, G. Polge, D. Plattard, Y. Magnac, F. Saigne, J. Fesquet, J. Gasiot, CEM<sup>2</sup> Université Montpellier II; J. C. Bessiere, CORAD*

High energy electron dose mapping is a complex work. Experiments using Optically Stimulated Luminescent films behind various shielding structures and dual inline packages are presented. These results are compared with PENELOPE transport code calculations.

### **H-3 Comparison of Indiana University Cyclotron Facility Faraday Cup Proton Dosimetry with Radiochromic Films, A Calorimeter, and a Calibrated Ion Chamber**

1:40 PM *A. Z. Jones, C. D. Bloch, E. R. Hall, R. Hashemian, S. B. Klein, C. C. Foster, Indiana University Cyclotron Facility; and K. M. Murray, KM Sciences*

Accuracy and utility of the IUCF dosimetry system used for radiation effects research with high energy protons has been confirmed by comparison with a calibrated Markus ion chamber, a Shultz water calorimeter and GAFCHROMIC™ films.

### **H-4 A System for Radiation Damage Monitoring**

1:55 PM *A. Rosenfeld, M. Reinhard, D. Marinaro, P. Ihnat, N. Freeman, University of Wollongong; G. Taylor, University of Melbourne; L. Peak, University of Sydney; and A. Holmes-Siedle, REM Oxford*

An automatic system, based on MOSFETs and P-I-N diodes, for measurement of integral ionizing and non-ionizing losses in silicon in terms of dose in  $\text{SiO}_2$  and 1-MeV(Si) equivalent neutron fluence, has been developed and tested.

# Technical Program Thursday

## POSTER PAPERS

### PH-1 MOSFET Dosimetry of X-ray Microbeams

*A. Rosenfeld, G. Kaplan, B. Allen, University of Wollongong; A. Dilmanian, Brookhaven National Laboratories; and A. Holmes-Siedle, REM Oxford*

The topology of a MOSFET gate limits its suitability when mapping synchrotron microbeams on micron scale. The edge-on MOSFET, however, has outstanding spatial resolution of approximately one micron and is much better than existing detectors/dosimeters.

2:30 - 5:00 PM

### DATA WORKSHOP

*Chairperson: Michele M. Foster, NASA Headquarters*



### W-1 Recent Radiation Damage and Single Event Effect Results for Microelectronics

*M. V. O'Bryan, J. Howard, H. Kim, Jackson and Tull Chartered Engineers; K. A. LaBel, R. A. Reed, J. L. Barth, C. Marshall, D. Hawkins, R. B. Katz, NASA/GSFC; C. M. Seidleck, Raytheon Systems Corp.; P. Marshall, and M. Carts, SFA*

We present heavy ion and proton single event effect (SEE) as well as radiation damage ground test results for candidate spacecraft electronics. Microelectronics tested include digital, analog, and hybrid devices.

### W-2 Device SEE Susceptibility Update: 1996-1998

*J. R. Coss, T. F. Miyahira, and G. M. Swift, Jet Propulsion Laboratory*

This eighth Compendium continues the previous work of Nichols, et al, on single event effects (SEE) first published in 1985. Because the Compendium has grown so voluminous, this update only presents data not published in previous compendia.

### W-3 Components Total Dose and Single Event Testing for the HESSI RAS and SAS Modules

*J. Bialkowski, A. Mchedlishvili, W. Hajdas, R. Henneck, K. Thomsen, and A. Zehnder, PSI Paul Scherrer Institute*

COTS devices dominate HESSI satellite electronic board population. Mission oriented component qualification for total dose and single event phenomena were performed using proton beams. First results are reported for a variety of low power parts.

# Technical Program Thursday

## **W-4 Total-Dose Tolerance of Chartered Semiconductor 0.35- $\mu$ m CMOS Process**

*R. C. Laco, J. V. Osborn, D. C. Mayer, S. Witczak, S. Brown, R. Robertson, The Aerospace Corporation; and D. R. Hunt, USAF System Engineering Div.*

MOSFET transistors fabricated in the commercial Chartered Semiconductor 0.35- $\mu$ m CMOS process show negligible threshold shifts to 300 krad(Si). NMOS field leakage currents begin to increase at 50 krad and become excessive at 300 krad.

## **W-5 The Effects of Space Radiation and Burn-In on Plastic Encapsulated Semiconductors**

*J. J. Wall, Defence Evaluation and Research Agency;  
R. E. Sharp, and S. L. Pater, AEA Technology PLC*

Variability is established in radiation induced degradation caused by differences in packaging technology and whether burn-in is applied. This work adds an investigation of the effects of different dose rates.

## **W-6 Radiation Evaluation of Plastic Encapsulated Transistors and Microcircuits for Use in Space Applications**

*J. L. Gorelick, S. McClure, and C. Swink, Hughes Space and Communications*

Radiation test results demonstrate the viability of selected PEMs devices for space use. Most devices presented are commercial equivalents of devices currently used on satellites. Material evaluations and bulk charging experiments were also run.

## **W-7 SDRAM Space Radiation Effects Measurements and Analysis**

*B. G. Henson, P. T. McDonald, and W. J. Stapor, Innovative Concepts Inc.*

Energetic proton and high energy heavy ion measurements were performed on state of the art Samsung SDRAMs. Analysis addresses typical space radiation effects as well as observed anomalous functional failure and comparisons with the PROFIT model.

## **W-8 Total Ionizing Dose Effects in a SRAM-Based FPGAs**

*N. J. Buchanan, D. M. Gingrich, D. M. MacQueen, University of Alberta;  
and P. W. Green, TRIUMF;*

Total ionizing dose effects of XL4036XL FPGAs were measured. An average total dose of  $41 \pm 1$  krad(Si) was absorbed before the power supply current began to increase and  $60 \pm 4$  krad(Si) before the first error occurred.

## **W-9 Single Event Upset Characteristics of Some Digital Integrated Frequency Synthesizers**

*L. Dayaratna, S. S. Sehra, M. Moser, and A. Bogorad, Lockheed Martin*

Single Event Upset characteristics of digital frequency synthesizers from National, Peregrine, and GEC Plessey are presented.



# Technical Program Thursday

## **W-10      Radiation Effects in a Fixed-Point Digital Signal Processor**

*S. H. Crain, A. Bofill, P. Yu, R. Koga, The Aerospace Corporation;  
and R. Velazco, TIMA Laboratory;*

Radiation effects in a fixed-point digital signal processor (DSP) from Texas Instruments were studied. Single event upset, single event snapback and total ionizing dose effects were observed and comparisons to previous studies are made.

## **W-11      A Radiation-Hardened Cold Sparing Input/Output Buffer Manufactured on a Commercial Process Line**

*J. M. Benedetto and A. Jordan, UTMC Microelectronic Systems*

The radiation hardness of a cold sparing buffer manufactured on a commercial process line is demonstrated. The buffer is resistant to total dose ionizing radiation and immune ( $>128 \text{ MeV-cm}^2/\text{mg}$ ) to effects from heavy ions.

## **W-12      The Irradiation Facilities for the Radiation Tolerance Testing of Semiconductor Devices for Space Use in Japan**

*M. Saidoh, M. Fukuda, K. Arakawa, S. Tajima, H. Sunaga, K. Yotsumoto, T. Kamiya, R. Tanaka, T. Hirao, I. Nashiyama, T. Ohshima, H. Itoh, S. Okada, Japan Atomic Energy Research Institute; N. Nemoto, S. Kuboyama, and S. Matsuda, National Space Development Agency of Japan*

We present facilities in Japan for the radiation testing of semiconductor devices for space use. We emphasize single event phenomena testing using an ion beam with large LET range and a  $1 \mu\text{m}$  diameter microbeam.

## **W-13      A New Proton Irradiation Facility at the Northeast Proton Therapy Center**

*J. M. Sisterson and J. Flanz, Massachusetts General Hospital*

The outside user's program at the Harvard Cyclotron Laboratory will be transferred to the Northeast Proton Therapy Center (NPTC) in 1999. Continuous proton beam, 230-MeV protons and custom defined emittance are available at NPTC.

5:00 PM      END THURSDAY SESSIONS

5:30 PM      **RADIATION EFFECTS COMMITTEE OPEN MEETING**  
HAMPTON ROADS BALLROOM

# Technical Program Friday

## INVITED TALK 8:15 - 9:05 AM

### Atlantic Hurricane "Business": An Operational Perspective

*Capt. Tom Bosse, USN Commander, Naval Atlantic Meteorology and Oceanography Center, Norfolk, VA*

Each year from May through November, local tropical depressions in the eastern Atlantic Ocean near the coast of Africa begin a meandering westward path, absorbing energy along the way and growing into the immense and extremely destructive weather systems known as hurricanes. The US Naval Meteorology and Oceanography Command is the military parallel to the National Hurricane Center and is dedicated to providing environmental support to the Atlantic Fleet. This talk will provide an overview of the data gathering, computer modeling, forecast process and interagency (NOAA/DOD) coordination/cooperation exercised on a routine basis to construct the best tropical cyclone forecasts and warnings available for civil and military use. It will highlight aircraft reconnaissance; use of satellite, doppler radar, ship/buoy and land station data; and how all of this information is integrated in the computer modeling and tropical forecasting process. The discussion will also include a review of the different NOAA and DOD activities involved in the warning process and interaction with their respective customers (local emergency managers, ships, aircraft, etc). Finally, using the results of the 1998 season, the Navy perspective of hurricane forecast and warning impact on operations (movement of people, ships, aircraft) will be presented.

**Captain Thomas E. Bosse** attended the U.S. Naval Academy where he earned a Bachelor of Science degree in Physics (Oceanography) in 1976. His early Navy assignments included Communications Officer and Navigator, Surface Warfare Officer and Nuclear Officer Program recruiter. Capt. Bosse then attended the Naval Postgraduate School in Monterey where he was awarded a Master of Science in Meteorology and Oceanography in 1984. Upon completion of assignment to the Commander, Amphibious Group ONE, Okinawa, he was assigned to the Naval Eastern Oceanography Center, Norfolk. Transferring to USS Coral Sea in 1989, Capt. Bosse served as Oceanographer through a final deployment. He was then transferred to the NAVOCEANCOMCEN/Joint Typhoon Warning Center, Guam. Prior to his current assignment as Commander, Naval Atlantic Meteorology and Oceanography Center, he served as Executive Officer and CINCLANTFLT Oceanographer, Fleet Numerical METOC Center, Monterey, in April 1998. Capt. Bosse is authorized to wear the Meritorious Service Medal (two gold stars), Navy Commendation Medal (two gold stars), Navy Achievement Medal and National Defense Medal.

## SESSION I 9:15 AM

### PHOTONIC DEVICES & ICS

#### SESSION INTRODUCTION

*Session Chairman: Shyam Khanna, Defence Research Establishment Ottawa*

## I-1 9:10 AM

### Proton Degradation of Light-Emitting Diodes

*A. H. Johnston, B. G. Rax, and L. Selva, Jet Propulsion Laboratory*

Proton degradation is investigated for several LED technologies. AlGaAs LEDs and some double heterojunction LEDs at low forward current degrade severely at low levels, but unit-to-unit variations appear to correlate with wavelength.

# Technical Program Friday

**I-2**  
9:25 AM **Avalanche Breakdown Light Emission in GaAs Diodes and Neutron Radiation Effects**

*S. Aboujja, C. Carlone, Université de Sherbrooke; J-P Charles, Université de Metz; and S. M. Khanna, Defence Research Establishment Ottawa*

Optical emission due to avalanche breakdown in reverse biased GaAs LEDs is susceptible to nuclear radiations. This differs dramatically from the emission in Si LEDs which are rad-hard.

9:50 - 10:10 AM **BREAK**

**I-3**  
10:10 AM **Proton Damage Effects on P-Channel CCDs**

*G. R. Hopkinson, Sira Electro-optics Limited*

An experimental batch of p-buried channel CCDs has been characterized for proton-induced radiation damage. Dark current effects are similar to conventional n-channel CCDs, but charge transfer inefficiency effects were reduced by a factor of 3.

**I-4**  
10:25 AM **Energy Dependence of Proton Damage Effects on Multi-Quantum Well (MQW) GaAs/GaAlAs Laser Diodes**

*S. C. Lee, Y. F. Zhao, R. D. Schrimpf, K. F. Galloway, Vanderbilt University; and M. A. Neifeld, University of Arizona*

Proton damage effects on MQW GaAs/GaAlAs laser diodes are studied for 70-200 MeV protons. The threshold current damage factor is essentially constant up to 150 MeV and decreases slightly at 200 MeV.

**I-5**  
10:40 AM **VLSI Compatible X-Ray Radiation Tolerant Planar Ni-Si-Ni (MSM) Photodetector**

*A. K. Sharma, Air Force Research Laboratory*

Effects of x-ray radiation exposure on the performance of Ni-Si-Ni MSM photodetectors are reported. Devices fabricated on bulk Si and SIMOX show excellent tolerance to X-ray radiation up to a total dose of 2 Mrad(Si).

## POSTER PAPERS

**PI-1** **Degradation and Recovery of 1.3  $\mu$ m InGaAsP Laser Diodes Irradiated by 1-MeV Fast Neutrons**

*H. Ohyama, Kumamoto National College of Technology; E. Simoen, C. Claeys, IMEC; Y. Takami, Rikkyo University; T. Kudou, M. Yoneoka, Kumamoto National College of Technology; and H. Sunaga, Takasaki JAERI*

The degradation of 1.3  $\mu$ m InGaAsP laser diodes by 1-MeV neutron irradiation and their recovery by subsequent isochronal annealing are investigated and compared with results obtained after 1-MeV electron irradiation.

**PI-2** **Radiation-Induced Effects in InGaAs Photodiodes**

*A. H. Paxton, H. Schone, and A. D. Sanchez, AFRL/VSSE*

The degradation of two photodiodes as a function of displacement-damage dose induced by 12-MeV carbon ions is presented. Collected charge after transits of 4.5-MeV protons is also given, and the results discussed.

# Technical Program Friday

## **PI-3 Total Dose and Hot Carrier Effects on Silicon Light Emitting Devices**

*D. Jiang, M. de la Bardonnie, H. Barnaby, S. Kerns, D. V. Kerns, R. D. Schrimpf, B. L. Bhuva, Vanderbilt University; P. Mialhe, Université de Perpignan; A. Hoffmann, and J.-P. Charles, Centre Lorrain d'Optique et d'Electronique des Solides*

Electrical characteristics of Si LEDs are changed in similar ways by x-irradiation and hot carrier stresses. Extended hot carrier stress alone causes coalescence of light emission consistent with junction-localized boron passivation by liberated hydrogen.

## **SESSION J ISOLATION TECHNOLOGIES**

### **10:55 AM SESSION INTRODUCTION**

*Chairman: Michael Liu, Honeywell Solid State Electronics Center*

## **J-1 BUSFET - A Novel Radiation-Hardened SOI Transistor**

*J. R. Schwank, M. R. Shaneyfelt, B. L. Draper, and P. E. Dodd, Sandia National Laboratories*

We have designed a partially-depleted SOI transistor that does not require the use of hardened buried oxides for total-dose hardness and maintains the intrinsic SEU and dose rate hardness advantages of SOI technology.

## **J-2 Radiation-Enhanced Short Channel Effects Due to Multi-Dimensional Influence from Charges at Trench Isolation Oxides**

**11:15 AM**

*G. U. Youk, P. S. Khare, R. D. Schrimpf, L. W. Massengill, and K. F. Galloway, Vanderbilt University*

Radiation-enhanced drain-induced-barrier-lowering (DIBL) was experimentally observed and verified by 3-D simulations for submicron devices with trench isolation oxides. Radiation-induced charge may decrease the effectiveness of short-channel engineering.

## **J-3 A Scaleable, Radiation Hardened Shallow Trench Isolation**

**11:30 AM**

*F. T. Brady, J. Maimon, and M. Hurt, Lockheed Martin Federal Systems*

A LOCOS-based hardening approach is successfully applied to shallow trench isolation (STI). Key issues for implementing and controlling a hardened STI process are discussed. Hardening is successfully demonstrated for NFETs as narrow as 0.7  $\mu\text{m}$ .

## **J-4 Radiation-Induced Back-channel Leakage in SiGe CMOS on Silicon-on-Sapphire (SOS) Technology**

**11:45 AM**

*S. J. Mathew, G. Niu, J. D. Cressler, M. J. Palmer, Auburn University; S. D. Clark, NSWC - Crane; and W. B. Dubbelday, SPAWAR Systems Center*

First results of gamma irradiation effects in SiGe CMOS on SOS technology show a significant leakage in pFETs and a reduction in nFETs. We attribute this to negative charge trapping at the Si-sapphire interface.

# Technical Program Friday

## POSTER PAPERS

**PJ-1      Total Dose Effects on the Shallow-Trench Isolation Leakage Current Characteristics in a 0.35  $\mu\text{m}$  SiGe BiCMOS Technology**

*G. Niu, S. J. Mathew, G. Banerjee, J. D. Cressler, M. Palmer, Auburn University; S. D. Clark, NSWC - Crane; and S. Subbanna, IBM Microelectronics*

Effects of gamma irradiation on Shallow-Trench Isolation (STI) leakage currents in a SiGe BiCMOS technology are investigated for the first time and shown to be strongly dependent on the irradiation bias.

**PJ-2      Worst Case Total Dose Radiation Response of 0.35  $\mu\text{m}$  SOI NMOSFETs**

*S. T. Liu, S. Balster, Honeywell Solid State Electronics Center; and W. C. Jenkins, Naval Research Laboratory*

Correlation of experiments and TSUPREM4/MEDICI simulations for the worst case total dose radiation response of 0.35  $\mu\text{m}$  back channel SOI NMOS transistors is investigated. Good agreement between experimental results and simulations is demonstrated.

12:00 PM      END OF CONFERENCE



## NEWS FROM THE RADIATION EFFECTS STEERING GROUP (RESG)

The RESG welcomes Jim Kinnison of Applied Physics Laboratory as its newly elected Member-at-Large. A complete listing of RESG members appears in the brochure.

The Radiation Effects Steering Group held its annual Fall meeting on October 29 and 30, 1998, at the Sheraton Norfolk (VA) Waterside Hotel, one of the two conference hotels for the 1999 Nuclear and Space Radiation Effects Conference (NSREC). The meeting agenda included reports and plans from the chairmen of the 1997 through 2001 NSRECs, as well as discussions of conference guidelines and policies.



*Klaus G. Kerris  
Chairman*

Jim Schwank of the Sandia National Laboratories, 1998 Conference General Chairman, reported on the 35th annual International IEEE Nuclear and Space Radiation Effects Conference which was held July 21-25, 1998, at Newport Beach, California. An excellent technical program was organized by the Short Course Chairman, Jim Pickel of Maxwell Laboratories, and the Technical Program Chairman, Lloyd Massengill of Vanderbilt University. Papers presented at the conference have been published in the December 1998 issue of IEEE Transactions on Nuclear Science. The 599 attendees and 332 companions were able to enjoy the beauty and charm of the Southern California beach communities and attractions because of the outstanding work of Local Arrangements Chairman Gary Lum and his committee. Certainly the high point of the social events was the boat cruise to Catalina Island with the barbecue and dancing on the beach at Catalina. The attendance at the 1998 conference was 7 percent higher than the previous year's attendance and represents a seven-year high. The Industrial Exhibit also increased dramatically this year with 32 exhibitors using 38 booths—an all-time high.



*Dale G. Platteter  
Executive Vice Chairman*

Ron Pease, 2000 Conference General Chairman, reported that the Millennium Nuclear and Space Radiation Effects Conference will be held July 24-28, 2000, at the Silver Legacy Resort and Casino in Reno, Nevada. Lew Cohn of the Defense Threat Reduction Agency is planning a tutorial Short Course. The Technical Program Chairman will be Art Campbell of the Naval Research Laboratory. Once again there will be a Radiation Effects Data Workshop and an Industrial Exhibit. An excellent social program is being planned by Local Arrangements Chairman Steve Clark of the Air Force Research Laboratory.

Marty Shaneyfelt of Sandia National Laboratories, the 2001 Conference General Chairman, reported that he is still researching possible venues for the 2001 NSREC. Sites that he is considering include San Francisco, California, Washington, DC, and Vancouver, British Columbia.

For the most current information on the Nuclear and Space Radiation Effects Conference and the Radiation Effects Steering Group, please visit our web site at [www.nsrec.com](http://www.nsrec.com). As always, the Radiation Effects Steering Group is committed to maintaining the highest technical standards for the Nuclear and Space Radiation Effects Conference so that we may continue to provide you with the latest in radiation effects research, as well as an opportunity for informal technical exchange.

# Awards

## **1998 OUTSTANDING PAPER AWARD**

### **Space Charge Limited Degradation of Bipolar Oxides at Low Electric Fields**

*S. C. Witczak, R. C. Lacoe, D. C. Mayer, The Aerospace Corporation,  
D. M. Fleetwood, Sandia National Laboratories, R. D. Schrimpf, and  
K. F. Galloway, Vanderbilt University.*

## **1998 MERITORIOUS PAPER AWARDS**

### **Damage Mechanisms in Radiation-Tolerant Amorphous Silicon Solar Cells**

*J. R. Srouf, G. J. Vendura, D. H. Lo, C. M. C. Toporow, M. Dooley, R. P. Nakano,  
TRW Space and Electronics Group, and E. E. King, The Aerospace Corporation.*

## **1998 DATA WORKSHOP PAPER AWARD**

### **Single Event Effects on Commercial SRAMS and Power MOSFETs: Final Results on the CRUX Flight Experiment on APEX**

*J. L. Barth, NASA/GSFC, J. W. Adolphsen, Unisys, and G. B. Gee, SES, Inc.*

## **IEEE FELLOW**

One member of the radiation effects community was elected to the grade of IEEE Fellow on January 1, 1999.

### **Harold L. Hughes**

*Naval Research Lab*

A certificate will be presented to Mr. Hughes during the conference opening on Tuesday, July 13.

## **1998 RADIATION EFFECTS AWARD**

The 1998 NPSS Radiation Effects Award was presented to Edward L. Petersen for pioneering contributions to the understanding of upset rate calculations for micro-electronics in space environments.

## **RADIATION EFFECTS AWARD**

Nominations are currently being accepted for the 2000 IEEE Nuclear and Plasma Sciences Society (NPSS) Radiation Effects Award. The purpose of the 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 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.

A cash award and plaque will be presented at the IEEE NSREC at Reno, Nevada in July 2000. Nomination forms are available electronically in PDF Format or in Microsoft Word97 format at <http://www.nsrec.com/nominate.htm>. Additional information can be obtained from Nick van Vonno, Member-at-Large for the Radiation Effects Steering Group. Nick van Vonno can be contacted at 407-724-7546.

# Industrial Exhibits



*"NSREC's Industrial Exhibit is the premier exhibit for radiation-hardened products and services. The exhibitors listed here look forward to meeting you."*

Ruth Merchey

This year's Industrial Exhibit will feature the leading suppliers of radiation-hardened products, related materials and services. The Industrial Exhibits will be held in the Norfolk Ballroom of the Norfolk Waterside Marriott.

The exhibits will be open Tuesday from 12:00 to 5:00 PM with the afternoon break being held in the exhibit area. The Industrial Exhibit Reception starts at 7:00 to 10:00 PM where a sumptuous feast of Virginia favorites, libations and incredible desserts will be served to conference attendees and their guests.

The exhibits will open again Wednesday, July 14 during the 7:30 AM Continental Breakfast and continue until 12:00 PM. Another food and beverage mid-morning break will be served in the exhibit area.

If you are interested in exhibiting, please contact:

Ruth Merchey  
IEEE/NSREC Industrial Exhibits Chairperson  
representing Space Electronics, Inc.  
619-565-7224 fax: 619-278-0553  
rmerchey@rsft.com

## EXHIBITORS

Check our website at [www.nsrec.com](http://www.nsrec.com) Industrial Exhibits for more exhibitor information and the latest listing of those companies who will be exhibiting.

**Actel**  
[www.actel.com](http://www.actel.com)

**Allied Signal**  
[www.alliedsignal.com](http://www.alliedsignal.com)

**Amptek, Inc.**  
[www.amptek.com](http://www.amptek.com)

**Army Pulse Radiation Facility**  
[www.atc.army.mil/brochures/aprf/html](http://www.atc.army.mil/brochures/aprf/html)

**Babcock, Inc.**  
[www.babcockinc.com](http://www.babcockinc.com)

**Boeing Radiation Effects Laboratory**  
[www.boeing.com/asocproducts/radiationlab](http://www.boeing.com/asocproducts/radiationlab)

**Boeing Solid State Electronics**  
[www.boeing.com/defense-space/infoelect/elecdev](http://www.boeing.com/defense-space/infoelect/elecdev)

**Data Devices Corp.**  
[www.ilcddc.com](http://www.ilcddc.com)

**EMP Consultants**  
301-869-2317

**Harris Semiconductor**  
[www.semi.harris.com](http://www.semi.harris.com)



# Industrial Exhibits

## EXHIBITORS

**Honeywell**  
[www.honeywell.com](http://www.honeywell.com)

**Innovative Concepts**  
[www.innocon.com](http://www.innocon.com)

**Integrated Systems Design**  
[www.ise.com](http://www.ise.com)

**International Rectifier**  
[www.irf.com](http://www.irf.com)

**Lambda Advanced Analog**  
[www.lambdaa.com](http://www.lambdaa.com)

**Lockheed Martin Space Electronics and Communications**  
[www.lmco.com/manassas](http://www.lmco.com/manassas)

**Maxwell Technologies**  
[www.maxwell.com](http://www.maxwell.com)

**Mitsubishi Heavy Industries**  
[www.mhi.co.jp](http://www.mhi.co.jp)

**NASA/Marshall Space Flight Center**  
[www1.msfc.nasa.gov](http://www1.msfc.nasa.gov)

**Radiation Tolerance Assured Supply and Support Center**  
505-678-1165

**Sandia National Laboratories**  
[www.sandia.gov](http://www.sandia.gov)

**Space Electronics Inc.**  
[www.spaceelectronics.com](http://www.spaceelectronics.com)

**J. L. Shepherd & Associates**  
818-898-2361

**Silvaco**  
[www.silvaco.com](http://www.silvaco.com)

**Synova, Inc.**  
[www.synova.com](http://www.synova.com)

**TEMIC Semiconductors**  
[www.temic-semi.com](http://www.temic-semi.com)

**Thomson & Nielsen Electronics LTD**  
[www.magna.ca/~tnelec/](http://www.magna.ca/~tnelec/)

**UTMC Microelectronic Systems**  
[www.utmc.com](http://www.utmc.com)

# Conference Information

## **ROOMS FOR SIDE MEETINGS**

Several meeting rooms are available for use by NSREC attendees during the conference week at Norfolk Waterside Marriott Hotel. Arrangements for audiovisual equipment, refreshments, etc., are made through the hotel and are the responsibility of the attendee. Contact ETC Services, Inc. at 303-770-2055 or send an e-mail message to [ETCSVC@aol.com](mailto:ETCSVC@aol.com) to make a meeting reservation in advance of the conference. To make a meeting room reservation during the conference, see the NSREC reservation desk.

## **MESSAGES**

**757-626-4200**  
**FAX: 757-628-6466**

A message board will be located in the lobby area outside the Hampton Roads Ballroom for all incoming messages during the NSREC Short Course and Technical Sessions. Faxes can be sent and received through the hotel. Costs associated with faxes are the responsibility of the attendee.

## **CONTINENTAL BREAKFAST AND COFFEE BREAKS**

The 1999 NSREC will provide continental breakfast and refreshments at breaks during the NSREC Short Course and Technical Sessions for registered short course and technical attendees *only*. Continental breakfasts will begin at 7:30 AM Monday through Friday just outside of the Hampton Roads Ballroom.

## **RADIATION EFFECTS COMMITTEE OPEN MEETING**

The IEEE NSREC Radiation Effects Committee will hold its Open Meeting in the Hampton Roads Ballroom from 5:30 PM to 7:00 PM on Thursday, July 15. All conference attendees are encouraged to attend the Open Meeting to discuss this and future IEEE Nuclear and Space Radiation Effects Conferences. There will be an election for a Junior Member-at-Large on the Radiation Effects Committee. Nominations will be taken from the floor. All NPSS members present are eligible to vote. Refreshments will be provided.

## **BUSINESS CENTER**

**757-628-6492**  
**FAX: 757-628-6466**

The Norfolk Waterside Marriott Hotel has a Business Center located on the lobby level adjacent to the Front Desk. The Business Center's hours of operation are Monday to Friday, 8 AM to 7 PM. Should conference participants have faxing and/or copying needs beyond those hours, the Norfolk Waterside Marriott Front Desk associates would be happy to be of assistance. Other services available from the Business Center include printing, modem connection, secretarial services, shipping (FedEx, UPS, and U.S. Postal Service), computer rentals, and office supplies. Costs associated with Business Center services are the responsibility of the attendee.

# Registration and Travel

## CONFERENCE REGISTRATION

**ETC SERVICES, INC.  
7731 SOUTH COVE CIRCLE  
LITTLETON, CO 80122**

**303-770-2055  
FAX: 303-741-5890**

To pre-register for NSREC, complete the conference registration form enclosed in this booklet. Please note that the registration fees are higher if payment is received after June 11, 1999.

Mail the Conference registration form with your remittance to ETC Services, Inc. Faxed registrations will be accepted with credit card payment. The registration form, **with payment**, should be mailed to arrive no later than seven days prior to the Conference, or arrangements should be made to hand carry fees for on-site registration. Telephone registrations will not be accepted.

**Registration fees should be made payable to the "1999 IEEE NSREC" and must be in U. S. funds only.** Advance payment of registration and activity fees should be by one of the following: (1) check made out in U. S. dollars and drawn on a domestically-located bank, (2) U. S. Money Order, or (3) Mastercard, VISA, or American Express credit card. Please note that there is no longer an additional charge for credit card payments.

On-site registration for the Conference will be conducted at the Registration Office in the Marriott's Madison Room, third floor, on the following schedule:

<b>Sunday, July 11</b>	<b>5:00 PM – 9:00 PM</b>
<b>Monday, July 12</b>	<b>7:30 AM – 4:00 PM 6:00 PM – 9:00 PM</b>
<b>Tuesday, July 13</b>	<b>7:30 AM – 5:30 PM</b>
<b>Wednesday, July 14</b>	<b>7:30 AM – 3:00 PM</b>
<b>Thursday, July 15</b>	<b>7:30 AM – 3:00 PM</b>
<b>Friday, July 16</b>	<b>7:30 AM – 10:00 AM</b>

## REGISTRATION CANCELLATION POLICY

A \$25 processing fee will be withheld from all refunds. Due to advance financial commitments, refunds of registration fees requested after June 11, 1999, cannot be guaranteed. Consideration of requests for refunds will be processed after the conference. To request a refund, you must notify ETC Services by FAX at 303-741-5890.

# Registration and Travel

## HOTEL RESERVATIONS

### **NORFOLK WATERSIDE MARRIOTT NORFOLK, VIRGINIA**

**800-228-9290  
FAX: 757-628-6466**

NSREC technical and social events will be held at the Norfolk Convention Center adjacent to the Norfolk Waterside Marriott. The conference room rate is \$112.00 per night plus tax. A block of rooms is available at the Government per diem rate for U.S. government attendees. *Proof of Government employment is required.* The Marriott is extending conference rates from July 8 through July 19.

Please call the Marriott and ask for the "IEEE NSREC" block of rooms. Reservations must be guaranteed. The cut-off date for room reservations is June 11, 1999. After that date, room accommodations will be confirmed on a space-available basis and the conference rate will not be guaranteed. PLEASE BOOK EARLY!!

### **SHERATON NORFOLK WATERSIDE NORFOLK, VIRGINIA**

**757-622-6664  
FAX: 757-625-8271**

NSREC has also selected as a conference hotel the Sheraton Norfolk Waterside, located a few minutes walk to the Marriott. The conference room rate is \$110.00 per night plus tax. A block of rooms is available at the Government per diem rate for U.S. government attendees. *Proof of Government employment is required.* The Sheraton Norfolk Waterside is extending conference rates from July 8 through July 19.

Please call the Sheraton and ask for the "IEEE NSREC" block of rooms. Reservations must be guaranteed. The cut-off date for room reservations is June 11, 1999. After that date, room accommodations will be confirmed on a space-available basis and the conference rate will not be guaranteed. PLEASE BOOK EARLY!!

## AIRPORT INFORMATION

The most convenient airport to Norfolk is the Norfolk International Airport, which is located nine miles east of the Norfolk Waterside Marriott and Sheraton Norfolk Waterside Hotels. Norfolk International airport is currently served by seven commercial air carriers and six commuter air carriers. Approximately 100 daily departures provide non-stop service to 22 U.S. destinations, most of which are major airline hubs providing easy one stop connecting service to hundreds of other major cities. These services, along with convenient ground access, make Norfolk International a handy choice for conference participants. More information about services and flight schedules can be found on their website at <http://www.norfolkairport.com>. Another travel option is Newport News/Williamsburg International Airport which is located 28 miles northeast of Norfolk.

## TRANSPORTATION AND DIRECTIONS

The Norfolk International Airport is located nine minutes by car from the Norfolk Waterside Marriott and Sheraton Norfolk Waterside Hotels. Shuttle service is available from the airport to both hotels. Groome Transportation shuttle service is located on the baggage side of the airport; exit the doors in front of the escalator, cross over on the cross-walk to the booth on the left. Shuttle costs are the responsibility of the traveler; there is no free shuttle service. Shuttle fees are \$13.50 one way or \$24.00 round trip. The shuttle service may be charged to your hotel room at a discounted rate of \$11.50 one way or \$23.00 round trip. Ask for the "IEEE NSREC" discount.

# Registration and Travel

## **Directions from the airports to the Norfolk Waterside Marriott and Sheraton Norfolk Waterside Hotels:**

Norfolk International Airport – ORF (9 mi E). Take airport Exit to Norview. Norview Boulevard to I-64 East. I-64 East to 264 (Norfolk Downtown). Take 264 West to Waterside Drive-Downtown Exit. The Sheraton will be on the left. Turn right on Atlantic Street to the Marriott.

Newport News/Williamsburg International Airport – PHF (28 mi NE). Take I-64 East across and through Hampton Roads Bridge Tunnel, into Norfolk I-264 West to Waterside Dr. Exit. The Sheraton will be on the left. Turn right on Atlantic Street to the Marriott.

## **Simple directions from the Baltimore-Washington DC area:**

*From anywhere in the Baltimore-Washington area, take I-95 South towards Richmond, VA. Take 295 South outside of Richmond. Take I-64 East towards Norfolk, to Route 264 West (Norfolk) and follow as if coming from the Norfolk International Airport.*

## **The Local Arrangements recommended way from the Baltimore-Washington DC area:**

*From Baltimore Washington International Airport, take Route 195 West to 295 South. Take Exit for I-95 South (Richmond). Take Route 5 South off the DC Beltway. Take Route 301 South. Take Route 17 East. Exit just past Yorktown at Ft. Eustis Blvd. (towards I-64). Take I-64 East towards Norfolk. Take 664 South towards the Outer Banks. Exit onto 264 East. Follow to Exit for Waterside Drive to hotels.*

*From Ronald Reagan National Airport, follow signs for 395 South. Take 395 South to I-95 South. Exit at Route 17 East. Exit just past Yorktown at Ft. Eustis Blvd. (towards I-64). Take I-64 East towards Norfolk. Take 664 South towards the Outer Banks. Exit onto 264 East. Follow to Exit for Waterside Drive to hotels.*

*From Dulles International Airport, take Dulles Access Road to DC Beltway (495 South). Exit onto 95 South. Exit at Route 17 East. Exit just past Yorktown at Ft. Eustis Blvd. (towards I-64). Take I-64 East towards Norfolk. Take 664 South towards the Outer Banks. Exit onto 264 East. Follow to Exit for Waterside Drive to hotels.*

Two driving notes: Traffic on the DC beltway near the I-95 South split with 395 (the “mixing bowl”) can be rather fierce. Traffic in the Hampton Roads area can be heavy on the bridges and tunnels off of I-64. This is especially true on weekends in the summer and during rush hour time periods during the week. Delays can be expected.

## **PARKING**

The parking is limited in downtown Norfolk. At the Norfolk Waterside Marriott hotel, the cost of parking is \$10.00 per day (\$12.00 valet). Parking fees may be charged to your hotel room. At the Sheraton Norfolk Waterside the parking costs are \$3.00 per day for self-parking (the garage is approximately 200 yards from the hotel, estimate a three minute walk). Valet parking at the Sheraton Norfolk Waterside costs \$7.00 per day (\$10.50 over night).

# Registration and Travel

## AIRLINE DISCOUNT

US Airways is the sole official airline for the 1999 NSREC and is offering special discounted fares for conference attendees. Fares can be purchased for US Airways, US Airways Express, US Airways Shuttle and MetroJet.

- Travel dates are between July 9-19, 1999.  
Destination is Norfolk, Virginia only.
- Discounts are from all points on US Airways Route System.  
NOTE: Additional restrictions may apply on international travel.
- A 10% discount off unrestricted applicable coach fares with seven days advance reservations/ticketing required.
- A 15% discount off unrestricted applicable coach fares with 60 day advance reservations/ticketing required.
- A 5% discount off First/Envoy Class or lowest applicable published fares with seven days advance reservations/ticketing required.
- A 10% discount off First/Envoy Class or lowest applicable published fares with 60 days advance reservations/ticketing required.
- These discounts are valid provided all rules and restrictions are met and are applicable for travel from all points on US Airways' route system. These discounts are not combinable with other discounts or promotions.

To take advantage of these discounts, call US Airways Meeting and Convention Reservation Office, or have your travel agent call 800-334-8644 between 8:00 AM and 9:00 PM EST. Select "1" when making the call. **Reference Gold File # 99630130.**

## RENTAL CAR DISCOUNT

Hertz has been selected as the official rental car agency for the 1999 NSREC. Special discounted rates will apply from one week before through one week after the conference. For reservations and information call Hertz at 800-654-2240 and mention Meeting #40897.

<u>Rental Car Class</u>	<u>Daily Per Day</u>	<u>Weekend Per Day</u>	<u>Weekly (5-7 days) Per Week</u>
A Economy 2DR	\$35.99	\$26.99	\$165.99
B Compact 4DR	\$38.99	\$27.99	\$180.99
C Midsize 2/4DR	\$41.99	\$28.99	\$195.99
D Sporty 2DR	\$44.99	\$29.99	\$210.99
F Fullsize 4DR	\$47.99	\$30.99	\$225.99
I Luxury	\$57.99	\$62.99	\$266.99
L 4-Wheel Drive*	\$57.99	\$62.99	\$266.99

\* Rental Car Class L 4-Wheel Drive is available only from Richmond, Virginia.

All rates include free mileage. Taxes, permitted reimbursement for property taxes, title, and license fees (including, as applicable, California or Hawaii vehicle licensing fees) and optional items, such as refueling, are extra. Standard rental qualifications apply. Return car to same rental location or additional charges may apply. Advance reservations are recommended, but not required. Rental locations are Norfolk and Richmond, Virginia.

# 1999 IEEE NSREC and Short Course Registration Form



Name \_\_\_\_\_  
Last Name First Name Middle Initial

Name to  
appear on badge \_\_\_\_\_

Company/Agency \_\_\_\_\_

Mailing Address \_\_\_\_\_  
 \_\_\_\_\_

City \_\_\_\_\_

State \_\_\_\_\_ Zip Code \_\_\_\_\_

Country \_\_\_\_\_

Telephone Number \_\_\_\_\_

FAX Number \_\_\_\_\_

E-mail Address \_\_\_\_\_

## IEEE MEMBERSHIP

☐ I am an IEEE Member. \_\_\_\_\_  
Membership Number

☐ I am not a Member, but I wish to join the IEEE.

**Nonmembers must register at the nonmember rate**, but if you join during the conference, you will receive a complimentary half-year membership in IEEE and in the IEEE Nuclear and Plasma Sciences Society.

## CANCELLATIONS

A \$25 processing fee will be withheld from all refunds. Due to advance financial commitments, refunds of registration fees requested after June 11, 1999, cannot be guaranteed. Consideration of requests for refunds will be processed after the conference.

**Mail or FAX this form and your remittance  
(payable to 1999 IEEE NSREC) to:**

**ETC Services, Inc.  
7731 South Cove Circle  
Littleton, CO 80122**

**303-770-2055 FAX: 303-741-5890**

## REGISTRATION FEES

Late fee REQUIRED if payment received after June 11, 1999.

	Early	Late	
<b>IEEE Member</b>			
Short Course*	\$280	\$310	\$ _____
Technical Sessions	\$285	\$360	\$ _____
<b>Non-IEEE Member</b>			
Short Course*	\$335	\$360	\$ _____
Technical Sessions	\$385	\$465	\$ _____
<b>Full-Time Students who are IEEE Members</b>			
Short Course*	\$155	\$155	\$ _____
Technical Sessions	\$105	\$105	\$ _____

**TOTAL AMOUNT ENCLOSED:** \$ \_\_\_\_\_

## PAYMENT OF FEES

☐ Enclosed is a check or money order in **U.S. DOLLARS ONLY**, drawn on or payable through a U.S. bank. Payable To: **1999 IEEE NSREC**.

☐ Charge registration fees to my credit card:

☐ American Express ☐ Master Card ☐ Visa

Card No. \_\_\_\_\_

Expiration Date \_\_\_\_\_

Signature \_\_\_\_\_

If your company or agency is going to pay by check at a later date, **please do not complete the credit card portion of this form.**

\* All short course attendees will receive a special CD-ROM containing the complete notes from all previous NSREC short courses (1980-1998). The notes will be electronically searchable and will include all figures and text.





# 1999 IEEE NSREC Activities Registration Form



Conference  
Participant \_\_\_\_\_

Company/Agency \_\_\_\_\_

Address \_\_\_\_\_

City \_\_\_\_\_

State \_\_\_\_\_ Zip Code \_\_\_\_\_

Country \_\_\_\_\_

Telephone Number \_\_\_\_\_

FAX Number \_\_\_\_\_

Accompanying  
Persons \_\_\_\_\_  
Name

Please list ages for children under age 21 only

Name \_\_\_\_\_ Age \_\_\_\_\_

Name \_\_\_\_\_ Age \_\_\_\_\_

Name \_\_\_\_\_ Age \_\_\_\_\_

**Child care** will be provided only during the Monday night Conference Reception. Child care will be available at no charge for those who pre-register their children by June 11, 1999 (names and ages must be included on this registration form). If you do not pre-register, we cannot guarantee there will be space for your child. For those who wish to arrange for child care at other times during the Conference, contact Clarice Johnson at Baysitter Tidewater Inc. 757-489-1622.

## CANCELLATIONS

To encourage advanced registration for conference activities, we will refund all activity fees for conference attendees and/or their family members who for any reason are unable to attend the conference. If your plans change after this form is submitted, notify ETC Services by FAX at 303-741-5890 (do not FAX changes after Thursday, July 8) or notify the conference registration desk when picking up your registration materials (but no later than 24 hours before the scheduled activity).

Mail or FAX this form and your remittance  
(payable to 1999 IEEE NSREC) to:

**ETC Services, Inc.**  
**7731 South Cove Circle**  
**Littleton, CO 80122**

**303-770-2055 FAX: 303-741-5890**

## ACTIVITY FEES

Late fee REQUIRED if payment received after June 11, 1999. We strongly encourage early registration; note that the number of tickets available for each event is limited. Children must be accompanied by an adult during all tours and social events.

	Early	Late	Number Attending	Total Cost
<b>Conference Reception: Monday, July 12</b>				
Adult/child	\$0	\$0	_____	_____
Child care (age 0-10)	\$0	\$0	_____	_____
<b>Tall Ships Cruise Luncheon: Tuesday, July 13</b>				
Adult/child (age 3-13)	\$32	\$42	_____	\$ _____
Child (age 0-2)	\$0	\$0	_____	_____
<b>Portsmouth: Wednesday, July 14</b> No advance sign up				
<b>Louisiana Tricentennial at Nauticus: Wednesday, July 14</b>				
Adult	\$30	\$42	_____	\$ _____
Child (age 3-13)	\$15	\$21	_____	\$ _____
Child (age 0-2)	\$0	\$0	_____	_____
<b>Botanical Garden Tour: Thursday, July 15</b>				
Adult/child (age 3-13)	\$14	\$20	_____	\$ _____
Child (age 0-2)	\$0	\$0	_____	_____
<b>Norfolk Naval Base Tour: Friday, July 16</b>				
Adult/child (age 3-13)	\$10	\$15	_____	\$ _____
Child (age 0-2)	\$0	\$0	_____	_____

**TOTAL AMOUNT ENCLOSED:** \$ \_\_\_\_\_

## PAYMENT OF FEES

- ☐ Enclosed is a check or money order in **U.S. DOLLARS ONLY**, drawn on or payable through a U.S. bank. Payable To: **1999 IEEE NSREC**.
- ☐ Charge registration fees to my credit card:
- ☐ American Express ☐ Master Card ☐ Visa
- Card No. \_\_\_\_\_
- Expiration Date \_\_\_\_\_
- Signature \_\_\_\_\_



# Social Program

The 1999 NSREC Committee has arranged for a social program that gives you and your companions a taste of the history, natural beauty, and entertainment found in the Norfolk area. We strongly encourage early registration for the social events; note that the number of tickets available for each event is limited. Late fees apply if payment is received after June 11, 1999. Children must be accompanied by an adult during all tours and social events.

## **SUNDAY JULY 11 6:00 TO 9:00 PM**

### **Short Course Reception**

Please join us for light refreshments in the Marriott Ballroom IV. Refreshments will be served from 6:00 to 9:00 PM. The registration desk will be open from 5:00 to 9:00 PM so take advantage of this opportunity to register early. Feel free to explore portions of the conference area.

## **MONDAY, JULY 12 6:00 TO 10:00 PM THE TIDEWATER EXPERIENCE**

### **Conference Reception**

In the Norfolk Ballroom, conference attendees and their families and guests are invited to get together, renew acquaintances and enjoy the Tidewater Experience. From 6:00 to 10:00 PM enjoy a complimentary buffet of a variety of Chesapeake delights. Dress is casual.

### **CHILD CARE**

Child care will be available at no charge for those who pre-register their children by June 11, 1999 (names and ages must be included on the Conference registration form). If you do not pre-register, we cannot guarantee there will be space for your child. For those who wish to arrange for child care at other times during the Conference, contact Clarice Johnson at Baysitter Tidewater Inc. 757-489-1622.



*Ken LaBel  
Local Arrangements Chairman*



*Martha O'Bryan  
Assistant Local Arrangements*

*"We hope you enjoy the social and companion events of historic Norfolk."*

# Social Program

**WEDNESDAY, JULY 14  
6:00 TO 10:30 PM  
LOUISIANA  
TRICENTENNIAL  
AT NAUTICUS**

## **Conference Social**

On Mardi Gras Day in 1699, Pierre le Moyne, Sieur d'Iberville, set up camp on the Mississippi River and named it Point Mardi Gras. The State of Louisiana has been celebrating ever since. In remembrance of this event, this year's conference social will celebrate Louisiana's founding by the French. The event will be held at Nauticus, the National Maritime center, a hands-on family attraction that delivers scores of ingenious exhibits and entertaining shows for all ages. We will have access to all attractions including: the first-ever group virtual reality experience, a subma-



Photograph courtesy of Nauticus

rine ride; the Aegis Theater, a multi-media naval battle show; the NAUTICUS Theater, showing giant films on a screen that opens to reveal the working harbor outside; exotic aquaria; touch pools, even shark petting! One-of-a-kind computer and video interactives including navigation, sonar sub hunt, time travel, reef diving, "virtual reality" flight simulators, Hampton Naval Museum, and much more. All Nauticus attractions will be open to conference attendees during the Conference Social. Other entertainment includes the rhythm and blues duo Naked Blue during cocktails and dance lessons from the band Zydeco Crayz after dinner. Hors d'oeuvres will be served from 6:00 to 8:00 PM. The dinner buffet will start at 7:30 PM. Dinner selections emphasize the spices and variety that can be found in Louisiana. From hot to mild, you will enjoy the range of tastes. Located on the waterfront, this event is a two block walk from the Norfolk Waterside Marriott Hotel and a three block walk from the Sheraton Norfolk Waterside Hotel. Bus service will be provided for those needing transportation or in case of inclement weather. *Note this event is limited to 500 attendees.* Tickets will be sold on a first come, first served basis. Adults/children two years and older: \$30.00 (early)/\$42.00 (late). Children zero to two years old are free.

## **ACTIVITIES CANCELLATION POLICY**

To encourage advance registration for conference social activities, we will refund all activity fees for conference attendees and/or their companions who for any reason are unable to attend the conference. If your plans change after your activities registration form is submitted, to receive a refund you must notify ETC Services by FAX at 303-741-5890 but no later than July 8 (do not FAX changes after Thursday, July 8).

# Companion Events

**TUESDAY, JULY 13  
10:30 AM TO 2:30 PM  
TALL SHIPS CRUISE**

Come aboard the American Rover for a wonderful day of history and exploration. This graceful sailing ship is the largest, three-masted, passenger-carrying topsail schooner under the U.S. flag. Modeled after the Chesapeake Bay cargo schooners



*Photograph courtesy of American Rover*

of the past century, the American Rover departs from the Waterside marina for a three-hour sail-powered cruise along the Elizabeth River. The crew assures us that there is always smooth sailing on the Elizabeth River and that sea sickness is not an issue on this vessel. An elegant luncheon will be served onboard the American Rover. Meet at the American Rover, Waterside harbor to board at 10:30 AM. Adults/children two years and older: \$32.00 (early)/\$42.00 (late). Children zero to two years old are free. Dress is casual.

**WEDNESDAY, JULY 14  
10:00 AM TO ?  
PORTSMOUTH**

Be on your own to explore historic Portsmouth. Olde Towne Portsmouth's waterfront is a five-minute ferry ride from Norfolk's Waterside Festival Marketplace. From the High Street Landing visitors can enjoy a variety of restaurants, shops, and five museums. Portside, as the waterfront complex is called, includes the Olde Harbour Market, which features 12 open-air shops with offerings from ice cream to seafood. A trolley tour of Olde Towne highlights one of the largest collections of antique houses on the East Coast. The Children's Museum of Virginia, expanded and reopened in 1994, offers more than 60 creative and interactive exhibits for kids to enjoy. Visitors call 757-393-5327. Lunch is available at many fine Portsmouth restaurants. Meet at the Waterside harbor to board the Elizabeth River Ferry at 10:00 AM and receive your complimentary ferry tickets. This is a limited time offer; ferry tickets are available on a first come, first served basis.

**THURSDAY, JULY 15  
9:30 AM TO 1:00 PM  
BOTANICAL GARDEN**

Bordered on three sides by the waters of Lake Whitehurst, Norfolk Botanical Garden represents an oasis of many gardens covering 155 beautiful acres. The Garden dates back to 1938, when 200 workers from the Works Progress Administration cleared the dense, native vegetation and planted 4,000 azaleas. Today, the Garden features one of the largest and most diverse collections of azaleas, camellias, roses and rhododendrons on the east coast. The nation's only botanical garden that can be toured by tram and by canal boat. Norfolk Botanical Garden displays more than 20 themed gardens, including the 3.5-acre Bicentennial Rose Garden and the Fragrance Garden for the visually impaired. Year-round color is provided by winter-blooming, hardy plants and by tropical plants found in the climate-controlled Tropical Pavilion. Lakes and fountains add to the garden's pleasing landscape. The garden hosts the International Azalea Festival Queen's Coronation Ceremony and NATO Fest each

# Companion Events

April. The NSREC 99 Botanical Gardens Tour package includes admission to the gardens and a ride on the tram. After the tram ride you will be on your own to enjoy the many footpaths through the gardens, eat at the garden cafe or enjoy an optional 45-



*Photograph courtesy of Adrian Corton*

minute boat tour of the gardens for an additional \$2.50 charge (payable at the Botanical Gardens). Buses leave the Convention Center entrance at 9:30 AM sharp and return about 1:00 PM. Adults/children two years and older: \$14.00 (early)/\$20.00 (late). Children zero to two years old are free. Dress is casual.

## **FRIDAY, JULY 16 1:30 TO 4:00 PM NORFOLK NAVAL BASE TOUR**

Home port to more than 100 ships of the Atlantic Fleet, Norfolk Naval Base is the world's largest naval installation. Guided bus tours of the base, which are narrated by naval personnel, pass by Atlantic Fleet training centers, awe-inspiring aircraft carriers and sleek submarines. A strip of restored historic homes from the 1907 Jamestown Exposition is included on this one-hour tour. Buses leave the Convention Center adjacent to the Norfolk Waterside Marriott at 1:30 PM sharp. Sodas will be provided for your touring pleasure. Adults/children two years and older: \$10.00 (early)/\$15.00 (late). Children zero to two years old are free. Dress is casual.

## **AEROBICS, LAND AND WATER**

Start your mornings off on a high. Join Dave Bushmire on Tuesday and Thursday mornings at 6:30 AM, Marriott Health Club for an hour of low impact land aerobics (we suggest a good quality exercise shoe). On Wednesday morning at 6:30 join Dave for an hour of water aerobics in the Marriott pool. Enjoy the opportunity for improving the quality of your life and learn about the latest findings concerning the value of land and water exercise.

## **ACTIVITIES CANCELLATION POLICY**

To encourage advance registration for conference social activities, we will refund all activity fees for conference attendees and/or their companions who for any reason are unable to attend the conference. If your plans change after your activities registration form is submitted, to receive a refund you must notify ETC Services by FAX at 303-741-5890 but no later than July 8 (do not FAX changes after Thursday, July 8).



*Kathy Schrimpf  
Companion Event Coordinator*

# Local Activities

## GENERAL INFORMATION

Founded in 1682, Norfolk is a city with a proud history. You can feel the grandeur of the past in the city's graceful architecture. More importantly, you can feel the spirit of its future. Over the years, the downtown skyline has evolved into something spectacular, featuring a festival marketplace, high-rise office buildings, a major hotel-convention center complex, a national maritime center and a Triple A league baseball stadium. Known as Tidewater and The Virginia Waterfront, this region is also called Hampton Roads by mariners across the world — all due to the community's essential connection to the water. The conference hotels, the Norfolk Waterside Marriott and the Sheraton Norfolk Waterside, are located adjacent to the Waterside area, just a few minutes walk from several major city attractions and nine minutes from the airport.



## CHRYSLER MUSEUM

The Chrysler Museum, in downtown Norfolk, is widely considered one of the top 20 art museums in the country. Over the years, the museum's collection has grown to include over 30,000 objects spanning almost 4,000 years of art history. Examples from nearly every period and school of European and American paintings, sculpture and drawings are represented, including works by such acclaimed artists as Gianlorenzo Bernini, Henri Matisse, Pierre Auguste Renoir, and Paul Gauguin. The museum also incorporates pieces of art from African, Egyptian, Pre-Columbian, Islamic and Asian cultures. Located at 245 West Olney Rd. 757-664-6200. Admission is free.

## D'ART CENTER

This working studio center for the visual arts allows 30 artists to create, display and sell original art. Visitors are welcome and invited to see sculptors, painters, jewelry makers, and potters as they work. Located at 125 College Place in the Freemason neighborhood of Norfolk. 757-625-4211. Open Tue - Sat, 10:00 AM - 6:00 PM; Sun, 12:00 - 5:00 PM. Closed Monday year-round. Admission is free.

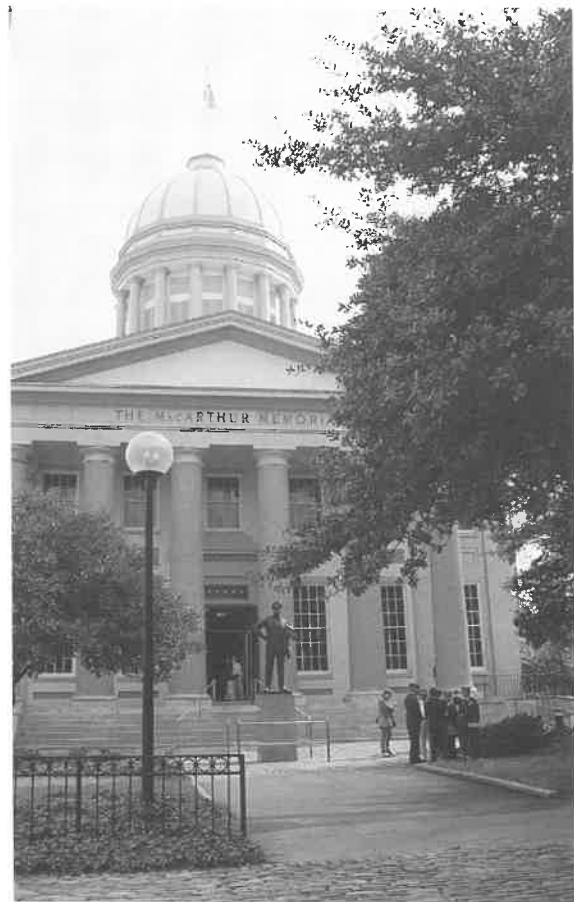
## FORT NORFOLK

Called "one of the best preserved and most original War of 1812 sites in America" by John Quarstern, director of the War Memorial Museum of Virginia, Fort Norfolk is one of the oldest forts in Hampton Roads. It is one of the surviving forts that George Washington commissioned to be built in 1794. The fort is the site of special events during the year which usually include military battle re-enactments and tours of the buildings. The Norfolk Historical Society spearheaded the renovation of Fort Norfolk and its office is housed in one of the fort's main buildings. Located on the banks of the Elizabeth River near historic Ghent, at 810 Front Street, the grounds at Fort Norfolk are open to the public on weekdays, but tours must be prearranged. Visitors call: 757-625-1720.

# Local Activities

## **DOUGLAS MACARTHUR MEMORIAL**

Located in Norfolk's restored 1850 city hall, the museum traces the life and military career of the late Gen. Douglas MacArthur, the controversial war hero who chose Norfolk as his final resting place. Highlights include World War II artifacts, photographs, documents, paintings, memorabilia, the general's trademark cap, sunglasses and corncob pipe, plus his 1950 Chrysler Crown Imperial limousine, which is on display in the adjacent gift shop. A separate theater, featuring a 24-minute film on MacArthur's life, is also on site. Located downtown, in MacArthur Square at Bank Street and City Hall Avenue. Donations requested. Visitors call 757-441-2965.



*Photograph courtesy of Community Link*

## **WILLOUGHBY-BAYLOR HOUSE**

A classic example of Georgian and Federal architecture, the Willoughby-Baylor House was built in 1794 by Captain William Willoughby, one of the members of a wealthy merchant class that evolved after the Revolutionary War. It is furnished with authentic 18-century pieces and its grounds include a charming 18th century style garden. Located downtown Norfolk at 601 E. Freemason Street near St. Paul's Church and the Moses Myers House. Open by appointment only. Admission fee. 757-664-6283.

## **ADAM THOROUGHGOOD HOUSE**

Built c.1680, the Adam Thoroughgood Plantation House is one of the oldest brick homes in America. It is furnished with late 17th century and early 18th century furniture and adjoins a charming English-style garden. Located at 1636 Parish Road, Virginia Beach. Admission fee. Visitors call 757-664-6200.

## **MOSES MYERS HOUSE**

One of America's first millionaires and Norfolk's first permanent Jewish settler built this elegant Federal Period home in 1792. Seventy percent of the current collection of furnishings is original to the first generation of Myers and reflects the French influences prevalent during the period. The collection also boasts artwork by Gilbert Stuart, Thomas Sully, John Welsley Jarvis and many other noted American artists. The family hosted such luminaries as Henry Clay, President James Monroe, Daniel Webster and Commodore Stephen Decatur in the house. The Moses Myers House is the only historic house in the U.S. interpreting the traditions of early Jewish immigrants. Located downtown Norfolk at 331 Bank Street. Admission fee. 757-664-6283



# Local Activities

## **CARRIE B**

Tour Norfolk's inner harbor and shipyards aboard the Carrie B, a reproduction of a Mississippi-style paddle wheeler. The open-air top deck provides an unobstructed view for visitors as they pass by Navy aircraft carriers, nuclear submarines, the nation's oldest dry dock and historic Fort Norfolk. The Carrie B departs from The Waterside. Admission fee. 757-393-4735.

## **MACARTHUR CENTER**

MacArthur Center, opening March 1999, will bring first-class fashion, film and fun to the largest market between Washington D.C. and Atlanta. Located in Norfolk's beautifully revitalized rapidly growing region whose residents and millions of tourists are poised to make MacArthur Center a five-star shopping center. It's located two blocks from the conference hotels.

## **HISTORIC GHENT**

Only a mile from downtown Norfolk, the Historic Ghent area has intriguing cafes and boutiques, especially along Colley Avenue and 21st Street. Some of the area's finest women's clothing shops, marvelous antiques stores, shops selling art items and jewelry and a host of tasty restaurants dot the streets. On a typical night, you might enjoy a jazz act at a restaurant or watch a foreign film at the Naro, a hip, renovated repertory movie theater. Antiques auctions are sometimes held in the early evenings at shops on 21st street. Rowena's, a gourmet food manufacturer of famous almond pound cakes, jams and sauces, offers tours of the factory at 758 W. 22nd St. Visitors call 757-664-6620.

## **THE WATERSIDE**

Festival marketplace overlooking the Elizabeth River houses more than 100 shops, restaurants and an information center. Located on the downtown Norfolk waterfront at 333 Waterside Drive next door to the Sheraton. Included in The Waterside Festival Marketplace are five full-service restaurants specializing in seafood, American and international cuisine; dozens of specialty food shops; craft and gifts shops; the Virginia Shop; unusual clothing stores; a music store; a book store; and pushcarts, where independent merchants vend jewelry, handcrafts and specialty items; entertainment centers and an information center. Live entertainment, including singers and dancers, is featured on the center stage throughout the week. On the water's edge, an outdoor amphitheater and brick promenade provide the staging area for spring and summer concerts.

## **OCEAN VIEW PARK**

Walk through the six-acre, bay front Ocean View Park located at the southern end of the Hampton Roads Bridge-Tunnel. Ocean View is a clean, uncrowded beach on the Chesapeake Bay. This Chesapeake Bay beach has a gentle surf with no undertow. There's excellent surf fishing right on the beach, but it can be even more fun to cast a line from a 1,600-foot fishing pier. The bay's calm surface is a great place for water-sports, from jet skis and sailboats to johnboats and wave-skimming windsurfers.

## **HAMPTON**

Hampton, the oldest continuously English-speaking settlement in America, was also the first site of NASA (the National Aeronautics and Space Administration) and the first training ground for U.S. astronauts. Today, Hampton is home to more than 15 attractions including the exciting \$30-million Virginia Air & Space Center. Visitors call 800-487-8778.

## **THE GREAT DISMAL SWAMP**

Home to black bear, bobcat, river otter and dramatic cypress trees, the 106,000-acre Great Dismal Swamp has been attracting the interest of visitors since the 1700s when Col. William Byrd called it a "very large bogg." Today, visitors may stop at the visitors center on Route 17 in South Mills, N. C., or visit the trails built by the U.S. Fish & Wildlife Service on the Virginia side of the swamp in Suffolk.

# Local Activities

## **COLONIAL WILLIAMSBURG**

Colonial Williamsburg is the re-created capital of colonial Virginia. The daily routine of a bustling 18th-century city is brought to life by shopkeepers, slaves, visiting dignitaries, outspoken patriots and other "people of the past." Visitors can stroll throughout 90 acres of landscaped gardens and courtyards. Admission fee. Visitors call 800-HISTORY.

## **BUSCH GARDENS**

A theme park with 17th-century flair, Busch Gardens Williamsburg boasts more than 30 thrilling rides, dazzling shows, shops and European cuisine. The world's tallest and fastest inverted roller coaster, Alpengeist, debuted in 1997. Admission fee.

## **JAMESTOWN SETTLEMENT AND YORKTOWN VICTORY CENTER**

Visitors can view the first permanent English colony and the drama of the American Revolution through fascinating exhibits and outdoor living history. Costumed historical interpreters bring history to life at Jamestown's re-created fort, Indian village, and replica ships, and at Yorktown's re-created army encampment and farm. Jamestown Settlement visitors call 757-229-1607. Yorktown Victory Center visitors call 757-887-1776.

## **OUTER BANKS OF NORTH CAROLINA**

The Atlantic Ocean beaches of Kitty Hawk, Nags Head and Duck, North Carolina lie one-and-a-half hours south of Norfolk, by car. One of the main routes to North Carolina, I-64, is just five miles from downtown Norfolk.

## **NEWPORT NEWS**

Home to the 8,000-acre Newport News Park, the largest municipal park east of the Mississippi River, Newport News is also the site of Civil War battles and 1812 campgrounds. Children in particular will enjoy the Virginia Living Museum, while history and military buffs will find one-of-a-kind exhibits at the U.S. Army Transportation Museum and the Virginia War Museum. Other attractions include The Japanese Tea House in Virginia, The Mariners' Museum, the Matthew Jones House, and Newport News Harbor Cruise. Visitors call 757-886-7777.

## **VIRGINIA'S EASTERN SHORE**

Linked to Norfolk by the Chesapeake Bay Bridge-Tunnel, the eastern shore of Virginia gives visitors a glimpse of the Tidewater area from days gone by. From the beautiful wooden boats of the shore's watermen, to hand-crafted duck decoys created here, to the exciting wild pony penning at Chincoteague and Assateague Island, the eastern shore provides coastal beauty and an individual culture for visitors to enjoy.

## **VIRGINIA BEACH**

Located just 18 miles from downtown Norfolk, Virginia Beach features more than 28 miles of seacoast beaches and a renovated resort strip. Other attractions include the First Landing Cross and historic lighthouse at Cape Henry, First Landing/Seashore State Park, the Christian Broadcasting Network (CBN), the newly expanded Virginia Marine Science Museum, the Lynnhaven House, Francis Land House (open year-round) and Adam Thoroughgood House and the new GTE Virginia Beach Amphitheater. Visitors call 757-437-4888.

## **THE VIRGINIA ZOO**

Virginia's largest zoo, nestled on 53 acres along the Lafayette River, the Virginia Zoological Park is home to some 350 animals, ranging from rare Siberian tigers and elephants to reptiles and nocturnal animals. A beautiful new habitat for the Siberian tiger twins, Shere Khan and Shaka Khan, opened in the 1995. The Virginia Zoo is the largest facility in the state accredited by the American Zoo and Aquarium Association. The zoo has ambitious plans to expand in the next ten years. The Virginia Zoo is located at 3500 Granby Street adjacent to Lafayette Park, in Norfolk. By car, take I-264 west to downtown Norfolk. Take the Waterside Drive exit and turn right onto St. Paul's Boulevard. Follow St. Paul's Boulevard until it merges with

# Local Activities

Monticello Avenue. Follow Monticello Avenue until it merges with Granby Street. The Zoo's entrance is on the right immediately past St. Mary's Cemetery. Open 10:00 AM until 5:00 PM, 7 days a week. Admission fee. Visitors call: 757-441-2706.

## GOLF COURSES

Ocean View Municipal Golf Course: 9610 Norfolk Ave., Norfolk, Virginia. Situated across from Chesapeake Bay this 18 hole golf course, established in the 1930s, is one of the oldest and most scenic in the area, with beautiful mature trees, bentgrass greens and Bermuda fairways. Voted Norfolk's best golf course 1994-95-96. 757-480-2094.

Lake Wright Golf Course: North Hampton Blvd., Norfolk, Virginia. Silky, smooth putting greens are combined with tough sand traps, water hazards and roughs to challenge even the best golfer on this Lake Wright championship course. Set around the Lake with picturesque par 3 holes, the greens are bent grass. There's also a driving range and two putting greens. 804-461-2246. Convenient to the interstate highway.

Sewells Point Golf Course-Military: Naval Station Bldg CA 99, Norfolk Virginia. This golf course features 6280 yards, 18 holes, and has Par of 71. 804-444-5572.

## WEATHER AND CLOTHING

South of the normal path of winter storms originating in the higher latitudes and north of the usual track of hurricanes and other tropical storms, Norfolk's climate is considered one of the most desirable by the National Weather Service. The area has a mild climate and year-round ice-free ports area. July is the warmest and most humid month, the low is typically around 70°F (21°C) and the high is around 87°F (31°C). Comfortable and casual best describes the appropriate attire for Norfolk. A sweater or light jacket is suggested for the evenings and remember to bring comfortable shoes for exploring the area's fine attractions.

## CHILD CARE

Child care will be provided only during the Tidewater Experience (the Monday night Conference Reception). Child care will be available at no charge for those who pre-register their children by June 11, 1999 (names and ages must be included on the Conference registration form). If you do not pre-register, we cannot guarantee there will be space for your child. For those who wish to arrange for child care at other times during the Conference, contact Clarice Johnson at Baysitter Tidewater Inc. 757-489-1622.

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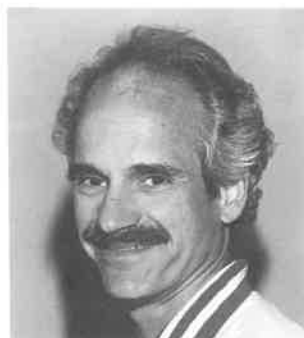
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**July 24 - 28, 2000**

**Silver Legacy Resort Hotel — Reno, Nevada**

The 2000 IEEE International Nuclear and Space Radiation Effects Conference will be held July 24-28 in Reno, Nevada at the Silver Legacy Resort Hotel. The Conference features a technical program consisting of eight to ten sessions of contributed papers describing the latest observations in radiation effects, an up-to-date Short Course on radiation effects offered on July 24, a Radiation Effects Data Workshop, and an Industrial Exhibit. The technical program includes oral and poster sessions.

Papers describing nuclear and space radiation effects on electronic and photonic materials, devices, circuits, sensors, and systems, as well as semiconductor processing technology and 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

- Ionizing Radiation
- Displacement Damage
- Materials and Device Phenomena
- Single Event Phenomena
- Dosimetry, Energy Deposition in Small Volumes, Radiation Transport

#### Radiation Effects in Electronic and Photonic Devices and Circuits

- MOS, Bipolar and Advanced Technologies including MEMS
- Isolation Technologies
- Optoelectronic and Optical Devices and Systems
- Hardness Assurance Methods
- Radiation Tolerant Technologies
- Modeling Device and Circuit Response
- Testing Facilities and Procedures
- Single Event Effects and Permanent Damage

#### Space and Terrestrial Radiation Environments

- Effects in the Atmosphere - Avionics
- Transient and Permanent Damage Effects in Space
- Spacecraft Charging
- Modeling the Space Environment and Effects

#### Recent Developments in Radiation Effects

**PAPER SUMMARY DEADLINE: FEBRUARY 4, 2000**

## PROCEDURE FOR SUBMITTING SUMMARIES

**Summaries (12 copies)  
must be received by  
February 4, 2000**

*Address them to:*

Art Campbell  
IEEE/NSREC  
Technical Chairman

Naval Research Laboratory  
Code 6610  
Washington, DC 20375  
202-767-9043

Authors must conform to the following requirements:

1. Submit 12 copies of (a) an abstract no longer than 35 words attached to (b) an informative summary (appropriate for a 12-minute presentation). The summary must furnish sufficient details to permit a meaningful review and clearly indicate (a) the purpose of your work, (b) significant results, and (c) how your work advances the state of the art.
2. The summary should be no less than two nor 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.
3. Type your summary using 11 point or greater type on either U. S. Standard, 8.5 in. (21.6 cm) x 11 in. (27.9 cm), or A4, 21 cm x 29.7 cm, white paper, with 1 in. (2.5 cm) margins on all four sides. Please include title, names and company affiliations of the authors, and company address (city and state). Underline the name of the author presenting the paper.
4. Obtain all corporate, sponsor, and government approvals and releases necessary for presenting your paper at an open-attendance international meeting.
5. Include a cover letter giving (a) the names, complete addresses, telephone and FAX numbers, and e-mail addresses of all authors, and (b) the session that you prefer for presentation (if you have a preference). *Authors are also encouraged to state their preference for an oral or poster presentation in the conference, or a poster at the data workshop.* However, 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 Conference will be eligible for publication in the Conference issue of the *IEEE Transactions on Nuclear Science* (December 2000), based on a separate submission of a complete paper, and subject to an independent review after the Conference. 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 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*.

## RENO, NEVADA



Reno and the surrounding area are full of indoor and outdoor activities. Of course, there are the casinos where one can chance a fortune. But there are also museums, art galleries, golf courses, amusement parks, wildlife sanctuaries, hiking and backpacking, cruises on Lake Tahoe, and train trips to Truckee and Donner Pass.

The conference hotel, the Silver Legacy, was opened in July 1995, and has over 1700 rooms. In all it encompasses six square city blocks of Downtown Reno. It is connected via spacious skywalks to the El Dorado Hotel/Casino to the South and the Circus Circus Hotel/Casino to the North. It is equipped with conference rooms, outdoor swimming pool and hot tub, state of the art health club and workout room, separate male/female spa areas with massage therapy or personal trainers, saunas, steam rooms, and whirlpools. The hotel is only 3.5 miles from the airport, and there is complementary shuttle service from the airport every half hour 7:00 AM to midnight, or if you wish a taxi, the cost is about \$6.00 one way. There are ten above ground levels of self-parking and valet service parking facilities with approximately 2,000 spaces for vehicles or rental cars. There is more tourist information available at <http://www.reno-sparkschamber.org/visitor.html> on the World Wide Web.



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