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CENTER FOR APPLIED RADIATION RESEARCH (CARR)

Annual Report

July 1996 - June 1997

Prairie View A&M University

CENTER FOR APPLIED RADIATION RESEARCH

ANNUAL REPORT
JULY 1, 1996 PROJECTED THROUGH JUNE 30, 1997

EXECUTIVE SUMMARY
(Overview)

Principal Investigator: Thomas N. Fogarty, Ph.D., P.E.

INTRODUCTION

Prairie View A&M University (PVAMU) Center for Applied Radiation Research (CARR) was established in 1995 to address the tasks, missions and technological needs of NASA. CARR is built on a tradition of radiation research at Prairie View A&M started in 1984 with NASA funding. This continuing program has lead to:

- A more fundamental and practical understanding of radiation effects on electronics and materials
- A dialog between space, military and commercial electronics manufacturers
- Innovative electronic circuit designs
- Development of state-of-the-art research facilities at PVAMU
- Expanded faculty and staff to mentor student research
- Most importantly, increased flow in the pipeline leading to expanded participation of African-Americans and other minorities in science and technological fields of interest to NASA.

MISSION OF CARR

CARR's mission is to establish and maintain a comprehensive research center with the capability of seeking an understanding of space radiation effects on electronics and biosystems. CARR seeks to answer essential questions concerning various projects within the NASA strategic enterprises and explores means to use this knowledge to increase the nation's economic competitiveness. A unique quality of CARR is that its research spans from the atomic level to integrated systems.

CARR Paradigm Shift

Since last year, NASA has changed its strategic plan to distribute the former Space Technology Enterprise to the various other strategic enterprises within NASA. While CARR's mission has not changed, CARR has reassessed its goals and focus. With the CARR funding shift from NASA Headquarters to Johnson Space Center (JSC), and keeping with JSC's principal association with the Human Exploration and Development of Space (HEDS) Enterprise, CARR will emphasize research work applicable to the International Space Station (ISS) and Mars Mission.

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TABLE OF CONTENTS

Specific task summaries have been chosen in conjunction with Space Environments and Effects Office Roadmap 1997 and personnel at JSC that will focus CARR's primary research goals for the coming year on problems related to the ISS. These task summaries are presented in the renewal proposal.

In developing these task summaries, CARR management was pleased to note that our existing research program was already addressing many of the aspects in the summaries that express the needs of HEDS Office of Space Flight. Therefore, while CARR has adjusted its research focus, the primary research mission as expressed in the original proposal remains vital and valid.

Mainstreaming:
The expressed desire of the HEDS Office of Space Flight is that minority university research centers should have strong collaborations with major universities and industry to increase efficiency and move research to the mainstream.

CARR has maintained strong relationships with several major university subcontractors and affiliates that started before CARR was established. As evidenced by the membership of our Technical Advisory Panel (TAP), we also have longstanding and active interactions with industry at all levels. In addition to enhancing CARR research, these relationships have resulted in leveraged funding from both government and industrial sources (See Technical Accomplishments and Plan.) CARR has directed this complementary research into our major research areas.

This crosscutting research has applications to other NASA strategic enterprises such as Aeronautics (Avionics on the High Speed Civil Transport) and Space Science (Deep space probes, orbital science satellites). In fact some radiation effects, such as single event effects (SEE), are now a concern to modern complementary metal-oxide-semiconductor (CMOS) technology (found in most state-of-the-art integrated circuits) on earth. We believe this will create a community of interest between space avionics and commercial integrated circuit manufacturers.

Implementation of the CARR mission is based on four components: Research, Human Resource Development and Outreach, Service and Commercialization/Technology Transfer.

Research:
The breadth of CARR research allows crosscutting contributions to various NASA strategic enterprises yet practical expertise allows focused work in areas of priority to ISS and Mars Mission. The research areas where CARR has developed its core competencies are (See Figure 1):

- Total Dose and SEE Radiation Testing
- Process and Radiation Induced Defects
- Life Science
- Circuit Innovations
- Emerging Technologies

The first three areas concentrate on the immediate needs of space avionics and human space flight, while the last two focus on the future needs of the ISS and other NASA missions. The technical section of this document details CARR capabilities.

Human Resource Development & Outreach:

CARR is committed to increasing the number of African-American and other minorities in the following areas:

- The advanced degree pipeline
- The workplace of companies, government research institutions and academic institutions of interest to NASA

CARR works toward these goals with a vigorous outreach program that extends from pre-kindergarten and K-12 through terminal degrees and professional internships. Our success in this area is outlined in the Student Participation section of this document.

Service:

CARR faculty, staff and students participate in a number of ways to improve the university, community, state and nation through advisory boards, support for student organizations and participating in science and technology programs of local high schools.

Commercialization/Technology Transfer:

The successful conclusion of the RADSCON'96 conference last April gave CARR and PVAMU an international spotlight. Through this conference, many collaborative relationships were established or strengthened, resulting in productive efforts extending throughout Year 2.

CARR also organized a tutorial given at the NASA MURC Technical Conference, developed an Internet Delphi Forecast Survey on space and commercial electronics, will act as facilitator in co-operative work between other NASA MURC's in the area of electronic and photonic materials and devices, posted a homepage on the World Wide Web and is exploring its first patent for a circuit innovation.

ORGANIZATION AND MANAGEMENT STRUCTURE

The Center has an effective organizational structure with advisory inputs from various boards and panels. Dr. Charles A. Hines, President of PVAMU, is the

Executive Director for the Center. The Center's activities are governed by the Office of the Director (OoD).:

1. Dr. T. N. Fogarty, Center Director
2. Dr. J. O. Attia, Associate Director
3. Dr. Fred Wang, Managing Director; Mr. Kelvin Kirby, Managing Director Intern
4. Dr. R. Wilkins, Senior Research Scientist
5. Dr. A. A. Kumar, Technical & Outreach Director

An Administrative Assistant, Ms. Carolyn Wedeking assists all the CARR personnel in day-to-day activities. The Key Investigators are empowered to commit resources to their individual tasks.

Investigators and Subcontractors are reviewed on a monthly basis and integrated into CARR goals. Meetings of the CARR faculty, staff and students are held monthly to review the overall state of the Center. Relevant information is fed into these meetings from individual research projects groups, investigators and the OoD.

The Center is forming and Executive Advisory Board which provides assistance to the Executive Director concerning CARR's relation to the strategic plan of the university. The Internal Advisory Board consists of the Deans of participating PVAMU colleges and has proven effective at facilitating matters concerning space and allocating resources. A Technical Advisory Panel (TAP) works with the Office of Director to give technical support and assistance to CARR. Sections of TAP render guidance electronically to the specific task areas. The NASA Technical Review Committee (TRC) has assisted in developing a vision, focusing CARR work toward a primary enterprise (Human Exploration and Development of Space) while allowing CARR to meet the specific radiation effect needs of various NASA missions associated with other enterprises.

SIGNIFICANCE OF THE CARR TO PVAMU

CARR has a major impact on the opportunities for both undergraduate and graduate students to participate in research related to various science and technological fields. CARR funds have been used to purchase state-of-the-art, industrial grade equipment, giving students hands-on experience with instruments they may meet in their careers. CARR investigators provide the expertise needed to expand the university curriculum in a variety of science and engineering departments. In addition, facilities and personnel infrastructure related to CARR provide the basis for future Ph.D. (e.g. electrical engineering) and M.S. (e.g. physics) programs at PVAMU. CARR continues to serve as the model for multidisciplinary research at PVAMU.

SIGNIFICANCE OF THE CARR TO NASA

NASA's goals of exploring the origins of the universe, the origins of life within the universe and make humans part of the exploration of the universe (at a price the nation can afford) will demand that NASA rely on advanced technology that is "faster, better, cheaper." CARR research impacts all these goals. CARR's strong ties to both the radiation hardened and commercial semiconductor industry provides a vital and unique liaison for NASA to new Ulta-Large Scale Integration (ULSI) and nanoscale technologies. At the same time, these ties will answer the industrial needs concerning terrestrial device stability (i.e. as device dimensions shrink, radiation susceptibility increase on earth as well as space). This strengthens NASA's capabilities while enhancing the competitiveness of the U.S. economy .

CARR's core competencies in total dose and single event effects (SEE); life sciences, and process and radiation induced defects have immediate applications to NASA forefront projects (e.g. ISS and High Speed Civil Transport). In addition, our expertise in circuit innovation and emerging technology will meet future needs. For example, we anticipate that our advances in materials and system modeling will be a key path to this future. We are fortifying our systems study through visiting scholars and subcontractors (Texas A&M University-Kingsville) in the area of error correction techniques. Dr. Parag Lala of North Carolina A&T University will give a short course on the subject sponsored by CARR in June 1997. Besides CARR researchers, we hope to attract the participation of area NASA contractors and NASA staff at this course. In the life science area, we are enhancing the study of radiation effect on the immune and reproductive system so that valid human risk assessment can be related to specific high risk environments, such risks include solar flares for space station personnel and extended exposure of High Speed Civil Transport (HSCT) crew. In addition, PVAMU will also cooperate with the University of Texas Health Science Center in regards to the proposed Life Science Institute.

SIGNIFICANCE OF CARR TO INDUSTRY

A convergence of needs is taking place between space and terrestrial electronics applications (see Figure 2). NASA's desire for cheaper yet more versatile and self sufficient spacecraft will come, in part, through advances in integrated circuit technology and software. The driving force in the commercial electronics industry has always been to make components faster and cheaper yet more reliable and versatile. Therefore, the electronics requirements of both NASA and the commercial market will be met through ultra-large scale integration (ULSI) in integrated circuits. Ongoing work in industry and universities indicates that as the device sizes shrink and become more densely packed, circuit susceptibility to radiation effects increases. In the near future, and perhaps even in the current generation of integrated circuits (IC), radiation

effects such as SEE will become a significant problem on earth-based systems. CARR is poised to meet this potentially high economic impact challenge. Evidence for industrial concern is given by the high level of semiconductor industry representation on the CARR Technical Advisory Panel (TAP). In addition, CARR is currently running a Delphi Forecast Survey over the Internet to top level industrial, government and university executives, engineers and scientist to assess the level of concern of the terrestrial radiation effects and potential steps to address the issue. The recently completed upgrade of CARR's Hewlett-Packard 82000 test set at the Texas A&M Cyclotron will enhance the ability to do radiation testing of advanced commercial off-the-shelf (COTS) circuits and future ULSI technology.

UNIVERSITY COMMITMENT

PVAMU is committed to the continued enhancement and growth of CARR. Interviews for two new tenure track faculty appointments in electrical engineering (to strengthen CARR research potential) proceeded in the 1996-97 academic year, with anticipated start dates of Fall 1997. Two additional appointments in other fields of interest to CARR are committed for the future. The university continues to provide 25% release time to CARR senior personnel and a full time administrative assistant. In addition, the university reaffirmed its commitment to provide appropriate laboratory space for the CARR gamma cell (expected purchase: Fall 1997) and material and electronic device characterization facilities. The extent of the university's commitment to CARR is summarized in a letter from the president in the renewal proposal for Year 3.

CARR ACHIEVEMENT HIGHLIGHTS

- Student involvement exceeds second year goal:

Undergraduate	Goal: 10	Actual: 29
Graduate	Goal: 10	Actual: 16

- Three undergraduate student interns at NASA Dryden.
- One graduate summer intern at Motorola, Austin, TX.
- Kelvin Kirby, instructor electrical engineering department, serves internship for Doctor of Engineering (TAMU) as managing director intern; this increases African-American representation in the Office of Director.
- Conducted interviews for two new tenure track faculty positions in electrical engineering in support of CARR research (expected start dates Fall 1997).
- CARR design of switched capacitor SRAM was fabricated and is being tested.
- Hewlett Packard HP82000 automatic test set upgraded for enhanced integrated circuit radiation testing.
- Installed three major materials and device characterization tools.

- Processes for deep UV photolithography, oxidation, diffusion and thin film measurements have been developed and are used on a routine basis in the CARR cleanroom.
- Completed round robin testing of charged pumping experiments on MOS structures with outside collaborators.
- CARR is the MURC facilitator for centers with research in electronic and photonic materials devices.
- CARR is meeting or has exceeded all goals and milestone set up for Year 2 in the original CARR proposal (see Table 1).
- CARR has taken direct action on all NASA Technical Review Committee (TRC) recommendations from the June 1996 TRC report (see Table 2).

YEAR 2 WORK PLAN/MAJOR TASK - DELIVERABLES (From Original Proposal)	
WORK PLAN/MAJOR TASK	**CURRENT STATUS**
Initiate design architectures of memories	Ongoing - 1 design fabricated for testing
Perform initial simulations of the memory circuits	Achieved: Result of ongoing simulation of switched capacitor SRAM in hand
Perform surface, sub-surface, electrical characterizations	Ongoing; AFM/STM, probe/parameter test system, resistivity setup, DLTS operational
Enhance existing sputtering equipment to grow films	Equipment in hand, being installed in renovated vacuum system
Prepare space for gamma source	Final plans for facility in hand; construction imminent
Upgrade clean room wet chemical process	Achieved
Expand ATE system to 128 channels	Task changed: Upgraded to faster channels with more memory to enhance SEE testing; expansion in process
Identify factors controlling prostaglandin secretion	Achieved: Paper in preparation
DELIVERABLES	**CURRENT STATUS**
Initial designs of rad hard memories	Achieved
Enhanced database of material properties	Ongoing
Initial software codes for CSPIFF	Emphasis placed on error correction codes during Year 2
Complete preliminary evaluation of rad effects on epithelial cells	Achieved
5 undergraduate Senior Project Reports	Deliverable changed; individual undergraduate reserachers report directly to graduate mentors and investigators
3 M.S. Thesis	Achieved
Center's Newsletter (half-yearly)	Expected 4/97
Second Annual Report	Expected complete 4/97
≥ 10 papers at the E&A '97	Actual # 8; emphasis shifted to MURC Technical Conference, 6 papers presented 2/97
8 Undergrads for SMET track	Achieved
8 Grads for M.S./Ph.D.	Achieved
2 new courses created	Electronic Materials & Communications Lab

TABLE 1

NASA TRC RECOMMENDATIONS, JUNE 1996

RECOMMENDATIONS	ACTION TAKEN
Acquire knowledge of current environment data analysis models & new developments in models	Acquired Severn Communication Space Radiation Software for modeling, will be upgraded as new information is available, NASA has supplied Space Environment Data at ISS, Geosynchronous and L2
Research new techniques to minimize risk from SEU's including error correcting codes	Sponsoring short course on Error Correction Code for June 1997; TAMU @ Kingsville ECC Rad Hard Memory
Diversification and trends analysis studies conducted to understand where the field is going and produce toward the end	Internet Delphi Forecast Survey of convergence of space & terrestrial electronic needs
Increase the number of African American faculty	TAMU doctorate student and PVAMU instructor, Kelvin Kirby, interns with CARR; C. Akujuobi interviews for EE tenure track position
PI to prepare and make available to the TRC a detailed milestone for each project of the program	Complete project timelines prepared in Year 1 Annual Report; HEDS task summary sheets prepared with milestones indicated included in Year 3 Renewal Proposal
Work on future challenges in radiation research and concentrate on areas that have not been worked on	Commenced work on radiation effects on quantum devices; starting work on radiation effects on electro-optical and photonic devices
Hold periodic meetings to inform all PI's and staff of the status of research projects and activities	Monthly comprehensive meetings have been held along with individual group meetings at various intervals

TABLE 2

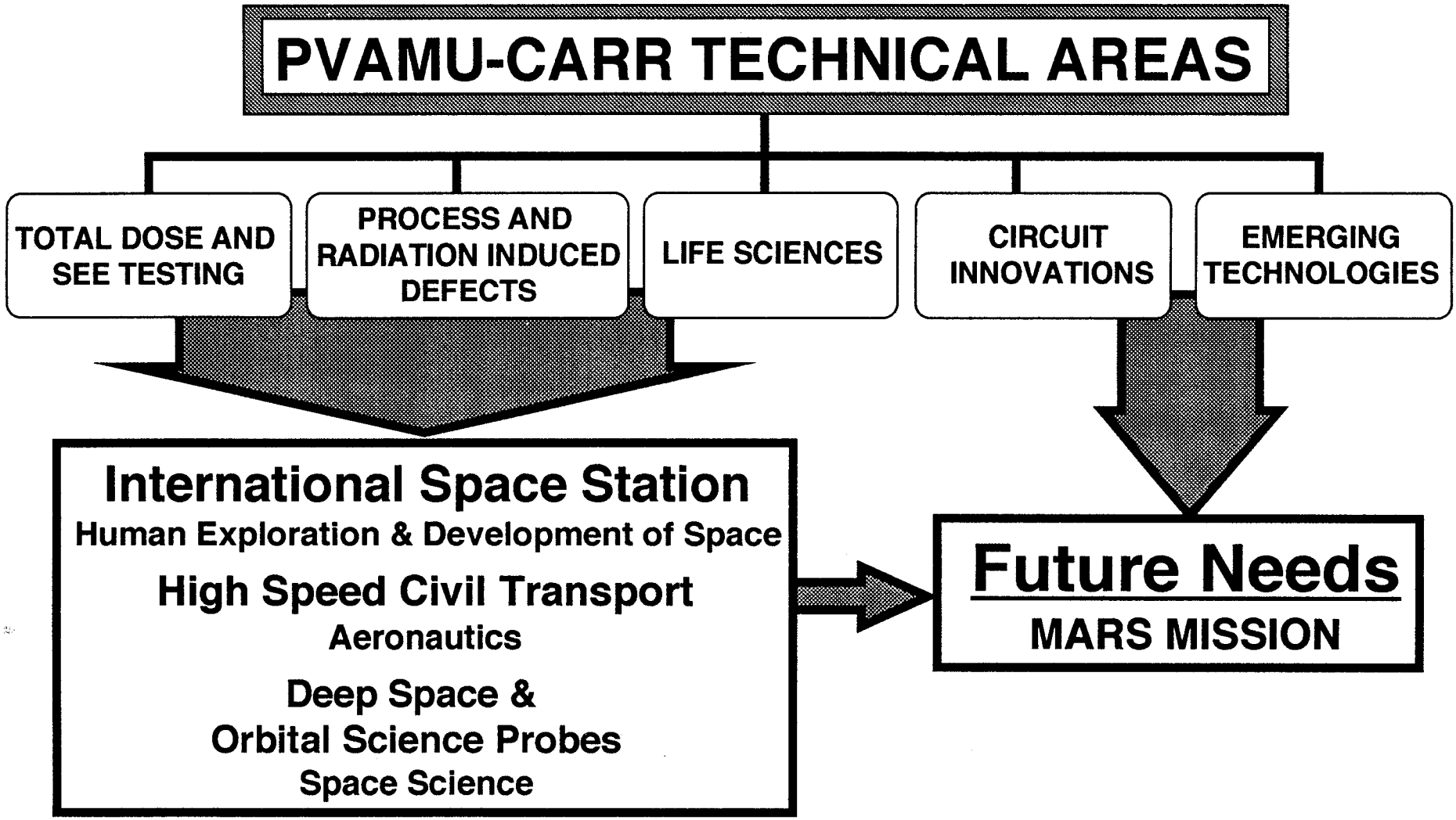

PVAMU-CARR TECHNICAL AREAS
TOTAL DOSE AND SEE TESTING
PROCESS AND RADIATION INDUCED DEFECTS
LIFE SCIENCES
CIRCUIT INNOVATIONS
EMERGING TECHNOLOGIES
International Space Station
Human Exploration & Development of Space
High Speed Civil Transport
Aeronautics
Deep Space &
Orbital Science Probes
Space Science
Future Needs
MARS MISSION

FIGURE 1

CONVERGENCE OF TECHNOLOGICAL NEEDS

CARR

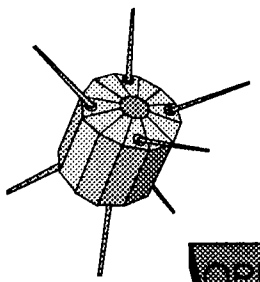
Center for Applied Radiation Research

CM^3

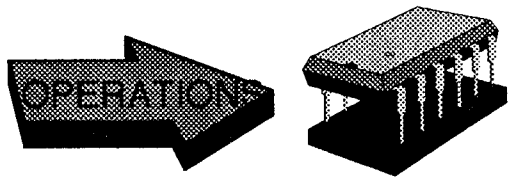
Center for Materials, Microdesign and Microfabrication

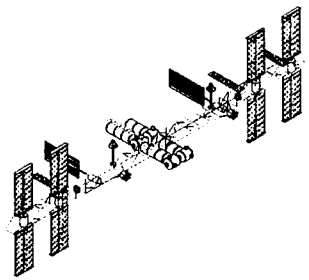
Space Applications

Terrestrial Applications

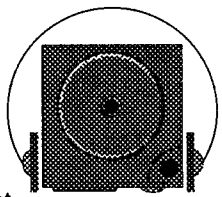


NEED RADIATION IMMUNITY IN SPACE





NEED RADIATION IMMUNITY ON EARTH!



- C. Lage, et. al., 1993 IEDM Technical Digest, pg. 821 ff. (Motorola)
- S. Krishnan, S. Aur, G. Wilhite and R. Rajgopal, 1995 IEDM Technical Digest, pg. 315 ff. (Texas Instruments, PVAMU).
- IBM Journal of Research and Development, January 1996.

FIGURE 2

PROGRAM MANAGEMENT

CARR's organizational and management structure, consisting of the Office of Director (OoD) and associated advisory boards and panels, has proven to be an efficient and productive system of Center management. The organizational structure of CARR is shown on Figure 3. Each member of the OoD is also responsible for, or involved in, one or more of the key technical areas of CARR. The OoD meets once a week, or as needed, to discuss and act upon Center business, including review of subcontractor activity. Monthly comprehensive meetings help the OoD assess the status of the Center's activities and feeds back relevant information to CARR faculty, staff and students. Members of individual research groups meet regularly and report to the OoD.

CARR PERSONNEL

The Center Executive Director - Dr. Charles A. Hines: Dr. Hines is President of the University and provides program oversight and review. His extensive experience in the Army as a Major General and as the Director of Protection & Health Services for the Smithsonian uniquely qualifies him as the senior commander concerning the direction and development of the Center.

The Center Director - Dr. Thomas N. Fogarty: Dr. Fogarty heads the overall Center and defines the Center's direction. Dr. Fogarty, a former Distinguished Member of the Technical Staff of AT&T Bell Laboratories, is the AT&T Endowed Chaired Professor of Engineering. He has extensive experience in the areas of materials, devices, systems and radiation testing. His principal interest is in process- and radiation-induced defects and their effect on parametric shifts in microelectronic devices.

The Center Associate Director - Dr. John O. Attia: Dr. Attia assists Dr. Fogarty in the overall administration of the Center's activities. Dr. Attia works in the area of radiation effects on electronic circuits and circuit innovations. Dr. Attia chaired and organized the RADSCON'96 Conference held at PVAMU, April 22-23, 1996.

The Center Managing Director - Dr. Fa-Chung (Fred) Wang: Dr. Wang is the Associate Director of the Center for Materials, Microdesign and Microfabrication (CM^3) and is managing director of CARR. Dr, Wang has expertly handled personnel choices and hiring, budget details is of immense value to the Center.

The Center Technical & Outreach Director - Dr. A. Anil Kumar: Dr. Kumar's national network of collaborators, colleagues and associates has been beneficial to the successful commencement of CARR. His experience as a researcher, writer of a large number of funded proposals, and manager of several budgets, is an important element of the Center's management.

PVAMU-NASA

CENTER FOR APPLIED RADIATION RESEARCH (CARR)

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L. Peddicord, TAMU
H. A. Lindsay, GTE
C. Dongean, UT-Austin
W. T. Greer, Motorola

Center Executive Director
Dr. Charles A. Hines
President

NASA Technical Review Committee
Kumar Krishen, Chair

Dr. E. J. Thomas-Smith
Provost & Vice President

Prairie View A&M
Research Foundation
(Contracts & Grants Administration)

Technical Advisory Panel

Office of the Director

Center Director
Thomas N. Fogarty ▲
Associate Director
John O. Attia ◆
Senior Research Scientist
Richard T. Wilkins ■
Managing Director
Dr. Fa-Chung (Fred) Wang ●
Managing Director Intern
Kelvin Kirby ◆
Technical & Outreach Director
A. Anil Kumar ■
Technical Director-Bio-Systems
Gary Newton ★

Internal Advisory Board

Dean W. F. Trotty, Chair
Research & Graduate School

Interim Dean Mylton Bryant
Engineering & Architecture

Dean Edward Martin
Arts & Sciences

Dean Elizabeth Noel
Agriculture & Human Sciences

Dean Jewel Prestage
Banneker Honors College

● **Total Dose & SEE Testing**
- Total Dose Gamma
- SEE Test Anomaly
  - E, ±θ, Z
- Other Radiation Types

▲ **Process and Radiation Induced Defects**
- Si/SiO_2 Interface States
- Bias Dependent Parameter Shift
- Measurement Round Robin

★ **Life Sciences**
- Bio-systems
  - Immune
  - Reproductive

◆ **Circuit Innovations**
- Resistive Hardening Alternatives
- Radiation Hard
  - DMOS
  - FPGA

■ **Emerging Technologies**
- Advanced Electronic & Photonic Materials and Devices
- Advanced System and Codes
- EMI/EMC

FIGURE 3

The Center Senior Research Scientist - Dr. Richard T. Wilkins: Dr. Wilkins is responsible for reduction to practice of the experimental fabrication and characterization of materials and devices. Dr. Wilkins is working in conjunction with other CARR investigators to establish a materials characterization facility on par with any in the country.

The day-to-day administration is performed under the direction of the CARR Director with the assistance of the Associate Director and the other administrative personnel. Our Administrative Assistant (AA), Carolyn Wedeking, performs clerical functions, maintains records, prepare budget and expenditure reports, processes requisitions, assists in technical typing and preparation of manuscripts for Center members. The Prairie View A&M Research Foundation supports the Director with cost and schedule tracking, contract management, publications administration, and other administrative functions so as to allow the technical personnel to focus on technical issues.

The other Faculty Researchers - Dwivedi, Gabitto, Lin, Li, McWhinney, Newton, and Zhou work closely with the Office of the Director in carrying out the research in their areas of specialization pertaining to the Center. Table 3 summarizes their areas of specialization and academic backgrounds. These researchers are empowered to commit resources necessary for their studies. The OoD reviews all actions of key investigators and subcontractors monthly. The activities of individual subcontractors will be discussed in their relevant technical areas. Mr. Harold Huff, research engineer, renders technical assistance to all investigators.

Mr. Kelvin Kirby, a Doctor of Engineering candidate at Texas A&M University and instructor in the electrical engineering department at PVAMU, is serving his internship for his degree at CARR. Under the mentorship of Dr. Fred Wang and Dr. Thomas N. Fogarty, Mr. Kirby has skillfully managed the organizational, financial and student affairs aspects of CARR. Upon receiving his degree it is expected that Mr. Kirby will assume full management responsibilities and become a faculty investigator of CARR.

CARR BOARDS, PANELS AND COMMITTEES

An Internal Advisory Board (IAB) consisting of the deans from the College of Engineering and Architecture, College of Arts and Sciences, College of Agriculture and Human Sciences, is chaired by Dr. Willie F. Trotty, Director of Research & Sponsored Projects and Dean of Graduate School. The IAB provides the means of correlating our research programs with the academic strategies of the colleges and vice versa.

The Center has formed a Technical Advisory Panel (TAP) consisting of academic, government and industrial personnel (see Appendix A). The primary purpose of the Technical Advisory Panel is to review the Center's technical and outreach activities, make recommendations as to the future directions of the

Key Investigator Information
Center for Applied Radiation Research
Prairie View A&M University

Key Investigator	Research Interests	Phone, e-mail
Dr. John. O. Attia, Associate Director (EE)	Design and simulation of radiation hard VLSI circuits, and communication.	409-857-4423 jattia@pvcea.pvamu.edu
Mr. Ramesh C. Dwivedi P. E. (Eng. Tech.)	Development of IC microfabrication.	409-857-4606
Dr. Thomas. N. Fogarty, Director (EE)	Radiation and process induced defects and SEE testing, IC design, and failure analysis.	409-857-2344 tfogarty@carr.pvamu.edu
Dr. J. Gabitto (Chem. E.)	Modeling of plasma processes for microelectronics	409-857-2427 jgabitto@pvcea.pvamu.edu
Dr. A. Anil. Kumar, Technical and Outreach Director (EE)	Simulation of fault tolerant systems, electromagnetic interference, communications & signal processing, and disordered systems	409-857-2591 akumar@pvcea.pvamu.edu
Dr. Joy Li (EE)	Simulation of electromagnetic interference effects	409-857-4423 jli@pvcea.pvamu.edu
Dr. S. Lin (Chem. E.)	Plasma deposition, combustion synthesis of electronic and photonic substrate materials	409-857-2427 slin@pvcea.pvamu.edu
Dr. Hylton McWhinney (Chemistry)	Surface science of radiation shielding and tolerant electronic materials	409-857-2616
Dr. Gary Newton (Agricultural Research)	Radiation effects on reproductive and immune systems	409-857-4061 gnewton@pvcea.pvamu.edu
Dr. F.-C (Fred) Wang, Managing Director (Physics)	Space radiation environment, radiation testing	409-857-4510
Dr. Richard Wilkins, Senior Research Scientist (CARR)	Materials processing, characterization, and surface science of radiation tolerant electronic & photonic materials, radiation testing and mesoscopic systems	409-857-4606 rwilkins@pvcea.pvamu.edu
Dr. Jianren Zhou (Mech. Eng.)	Materials processing and characterization of thin film sensor materials	409-857-4023 jzhou@pvcea.pvamu.edu

Fax: 409-857-4608
Completed March 11, 1997

TABLE 3

Center, and foster interaction between the Center and academic, government and industrial affiliates. An Executive Advisory Board (EAB), selected by the President, will advise him on the Center and collegiate strategies pertaining to the Center in meeting the overall strategic goals of the university. In addition, the EAB will be a high level liaison between majority university collaborators and minority university consortium. Key participants have been identified and have agreed to serve.

A NASA Technical Review Committee has been established consisting of NASA experts from the various NASA Centers (see Appendix A). This committee will review and provide guidance for the Center's cooperative agreement with NASA.

UNIVERSITY FACILITIES

The cleanroom in the Gilcreast Engineering Building has been provided to CARR to establish a microfabrication capability for test devices. Additional adjacent space has been provided as a workshop area. The CARR scanning electron microscope is housed in mechanical engineering laboratories. A new facility is currently being renovated for a gamma cell facility, surface and interface laboratory, electrical characterization equipment, instrumentation development laboratory, X-ray diffraction facility and machine shop. These facilities will be housed in the CARR-AG building. The floor plan for this facility is given in Figure 4.

CARR Subcontractors: Table 4 lists the CARR subcontractors and their contribution to CARR research:

Subcontractor (Principal Investigator)	Contribution
University of Houston (L. Trombetta)	Complementary electrical measurements of radiation induced defects
Pennsylvania State University (P. Lenahan)	Electron Spin Resonance Characterization of radiation induced defects
Texas A&M University School of Veterinary Medicine (R. Burghardt)	Radiation effects on the reproductive system
University of Texas Health Science Center (G. Castro)	Radiation effects on the immune system
Tennessee State University (M. Awipi)	Electromagnetic Pulse for SEE Tests
Vanderbilt University (K. Galloway)	Radiation Effects on Electronic Devices and Circuits

TABLE 4

NASA-CARR/CM & AG-ENGINEERING LABORATORY & WORKSHOP

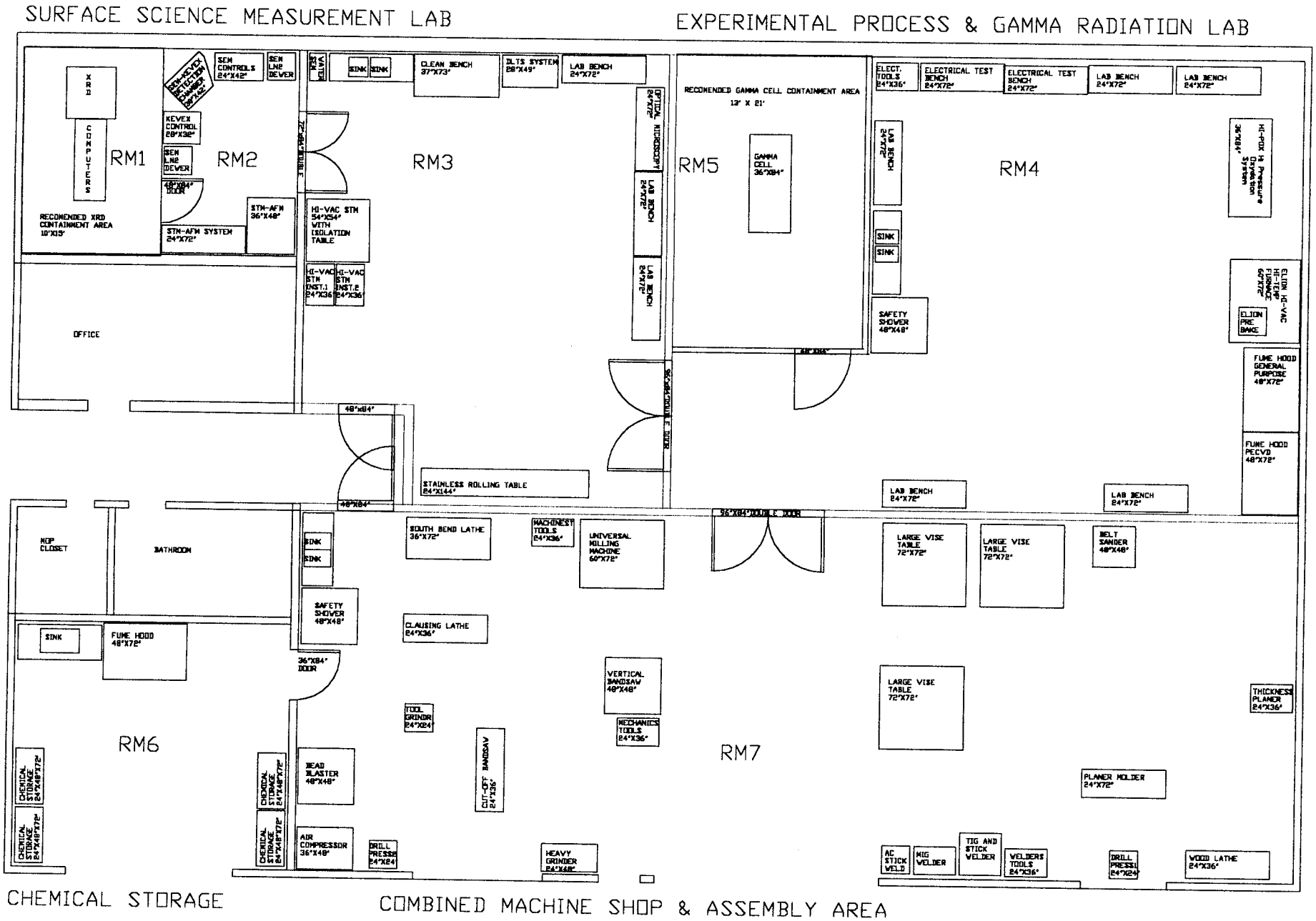


FIGURE 4

NEW CARR RELATIONSHIPS

New relationships have recently been established between the NASA MURC to facilitate collaboration, cooperation and information interchange between the MURC's. CARR is participating in two such groups. CARR is acting as the facilitator in the group of MURC's where there is mutual interest in electronic and photonic materials and devices. The CARR Life Science effort will participate in the MURC group with interests in the life science areas. These associations are shown schematically in Figure 5.

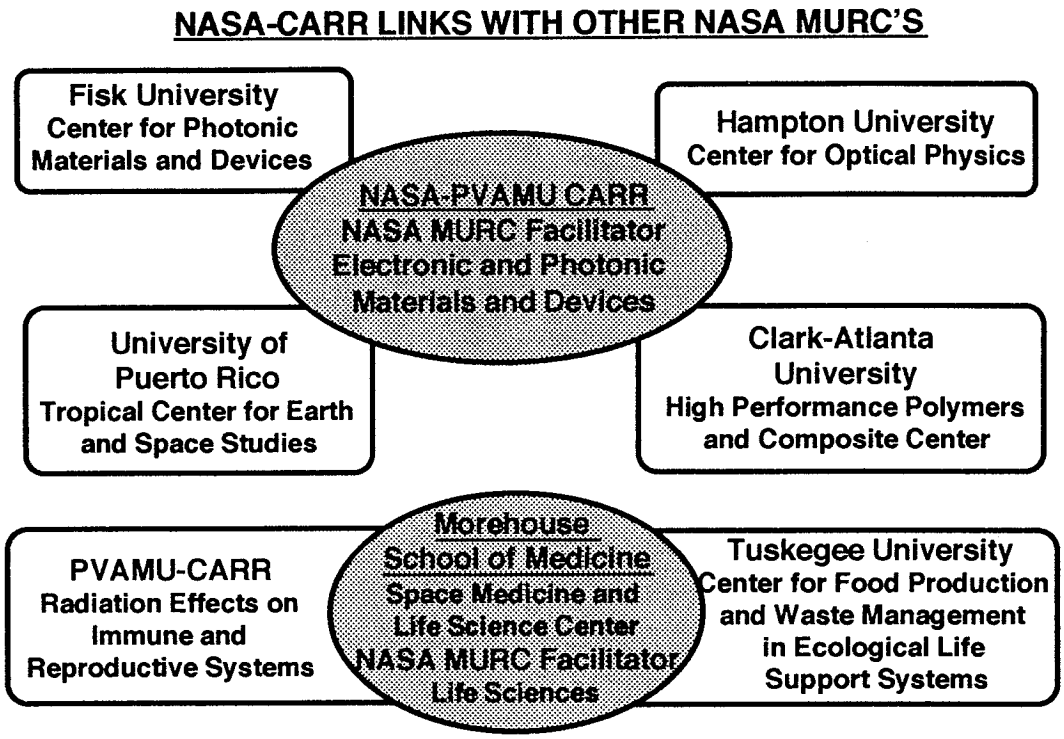


FIGURE 5

Outreach

The following are brief discussions of the diversified outreach activities the Center has performed or is projected to perform during Year 2.

Development of Outreach Materials: A comprehensive outreach material package has been developed. An internal CARR newsletter "The Radiator" will be published in April 1997. A CARR homepage is now available at www.carr.pvamu.edu.

Visits to Colleges and Universities: Dr. Kumar visited Houston-Tillotson College, Austin for recruiting faculty and student interns for CARR. Dr. Kumar also visited Tennessee State University for expanding on existing collaboration.

Tribal College Interns: The intent is to facilitate a one month research experience for a faculty and student from a JSC affiliated Tribal College.

NASA SHARP Plus Program: CARR hosted five Summer High School Apprentice Research Program (SHARP) Plus students if efforts to provide a mentoring relationship between students and active researchers. CARR investigators involved the students in research activities associated with space flight simulations and possible radiation effects on reproductive and immune systems.

Summer Intern: CARR sponsored one summer intern from Talladega College, Tammie Nichols, as a research assistant. Result: The summer student has transferred to Prairie View A&M University majoring in electrical engineering and is currently an student intern at NASA Dryden.

Pre-School: Dr. Wilkins made an interactive presentation to his daughter's pre-school class involving a model rocket demonstration and other space flight concepts. This will be developed into an outreach tool for pre-school and elementary school.

Boy Scouts of America Charter Post 1141: CARR established an Explorer Post with a Science Club of a local High School. The Post activities provide science and engineering enrichment experiences for students, as well as, selected social activities within the college environment. Recent activities included hands on exercises within the logic and digital design labs, with the design of a simple alarm system. In addition, students were introduced to communication activities of reproductive cells in mammals and how radiation induced effects may alter the cell reproductive processes.

Explorer Post Expansion: Experiences currently provided to the Explorer Post will be extended to the Engineer's Club, at Waller High School and to other Technical High Schools.

Scholarships: CARR has awarded $20,500.00 in scholarships in engineering and science majors. Scholarship recipients will naturally seek research opportunities within CARR as a learning enrichment activity.

Contributions: Used Indirect Dollars to support the following: $1,000.00 - fees for university membership with the Texas Space Grant Consortium. $1,000.00 - contribution to Annual Student Paper Competition sponsored by Sigma Xi, the Scientific Research Society.

Summer Outreach Faculty Intern: Dr. Leary O. Myers from the University of West Indies, Mona Campus in Jamaica, served for two weeks with CARR for

collaborations in surface analysis of a fluorinated amorphous silicon for photovoltaic device application.

Visiting Scholars: Dr. Parag Lala, will conduct a one week workshop/seminar on fault tolerant systems and error correction codes in June 1997. Starting June 1997, Dr. Jan Gryko, a theoretical physical chemist from University of Eastern Utah, will begin a summer faculty intern with CARR. Dr. Gryko will perform theoretical interface analysis in support of our work in concerning radiation effects on photonic and quantum devices.

Technical Program

Accomplishments and Plans

In order to focus our research efforts toward the immediate concerns of NASA, (particularly HEDS ISS) yet permitting long range, fundamental research to address future needs (Mars Mission), CARR research areas have been organized into core technical competencies (See Figure 1):

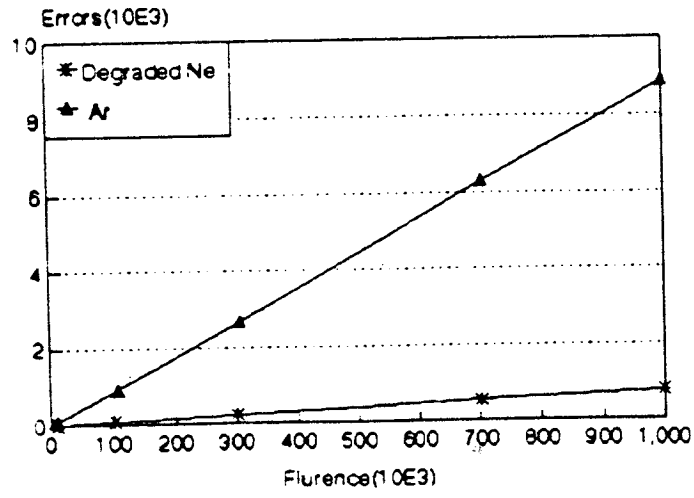
- Total Dose and Single Event Radiation Testing
- Process and Radiation Induced Defects
- Life Sciences
- Circuit Innovations
- Emerging Technologies

The goal of the first three is to obtain solutions to problems that will allow sustained progress in NASA's current projects. The last two will attempt to anticipate problems and provide solutions to problems for future NASA missions. This paradigm shift represents a reassessment of resource distribution and a re-evaluation of research projects done by the key investigators. The result is a change in emphasis in individual research projects. The research and technical progress for each of the core technical competencies is discussed in detail below. Each area is illustrated schematically; showing the pertinent external inputs to CARR in each area, key CARR personnel, and specific research topics within each area.

Total Dose and Single Event Effects (SEE) Radiation Testing:
At the present time, CARR uses the gamma cell located at the University of Houston for relatively high dose applications and the one at Texas A&M School of Veterinary Medicine for dose rates as low as 1.5 rad/sec. We are currently modifying a space for the installation of a gamma cell at PVAMU with dose rates over a broader range and the capability of operating cryogenically and at elevated temperatures. This will certainly enhance our capabilities. We are also at present examining proton, electron and neutron radiation sources. In fact, Kalu Diogu (while a masters candidate at PVAMU during the first NASA supported charged particle radiation study) demonstrated clearly that even with 1 MeV protons, secondary characteristic radiation was an important component in causing device parameter shift. John Wilson, NASA Langley, theoretically studied X-ray production in low energy proton stopping in materials. Ten years later, the problems of secondary radiation and nuclear fragmentation have increased in importance because of the requirements for ISS and Mars Mission. We have recently demonstrated 30-50 MeV proton beam at the TAMU Cyclotron for proton SEE testing, and we are currently exploring the possibilities of a 10 MeV proton beam degraded to 1-2 MeV for solar cell, electro-optic and electron device testing to help simulate the radiation environment for ISS. Other possible proton sources are at University of Indiana, University of California - Davis, and University of North Texas.

Earlier we have shown that pre-total dose proton and gamma radiation cause imprinting and may lower the Linear Energy Transfer (LET) threshold for SEE.

Z. You, a PVAMU NASA LRS Masters graduate is continuing his work as a CEMDAS research assistant and is currently a Ph.D. candidate at TAMU. He and Dr. Fogarty have been evaluating SEE in Rad-Hard and commercial SRAM technology. At the same time we are investigating test anomaly as a function of Z (atomic number), θ (arrival angle) and LET in relation to Brag Peak. Perhaps our most important finding is the experimental verification that LET_{eff}=LET/cos may not be valid especially in the area of critical LET. The error rates shown in the figure below are for equivalent LET obtained by Ar at normal incidence and degraded Ne at 49^0 ; a much higher upset rate is observed for normal incidence.



In fact, in the area of critical LET, the reduced SEE cross section may be more pronounced than one would assume from Woodruff's simulation results for mirror imaged SRAM cells. This invalidity of the effective LET assumption has been demonstrated in both Rad-Hard and commercial six transistor cells. This discovery is extremely important in evaluating CMOS devices for application in ISS and Mars Mission.

With the great emphasis on use of Commercial Off the Shelf (COTS) technology, it should be noted that we are currently about to evaluate commercial FPGA for total dose and dose rate effects. Dr. Fogarty served as committee member and Mr. You assisted in the experimental procedure of Coy Kouba's (Thesis advisor Dr. Choi) master thesis on evaluating of 486DX4 microprocessors for SEU. The important finding of the thesis was the strong vendor dependency of single event latchup (SEL). This work was sponsored by NASA/JSC where Mr. Kouba is currently employed.

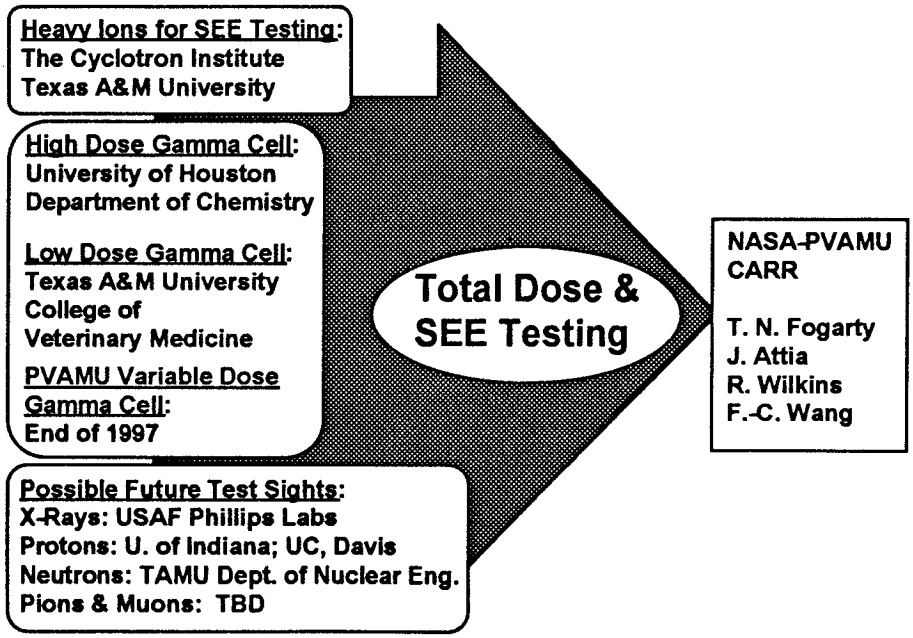
REFERENCES:

[1] Proceedings of National Space Radiation and VLSI Technology Conference, January 1987, NASA CP-10023

[2] J. W. Wilson, G. S. Khandelval, T. N. Fogarty, "X-ray Production in Low Energy Proton Stopping", NASA Technical Memorandum, Ap ril 1988

[3] D. Ngo, J. Wilson, W. Buck and T. N. Fogarty, "Nuclear Fragmentation Effects on Electron Devices", IEEE Trans. N. S. 38, Vol. 1 P. 2, 1991

[4] T. N. Fogarty, "Process and Radiation Induced Defects in Electronic Materials and Devices", Invited paper ACerS, May 1995, published in Crystal Growth of Novel Electronic Materials, Ceramic Transactions, Vol. 60, 1996



Schematic of the Total Dose & SEE Testing Effort

PROCESS AND RADIATION INDUCED DEFECTS:
These defects located at Si-SiO_2 interface affect important CMOS device parameters such as threshold voltage and transconductance. Interface states and border traps are amphoteric (causing either negative or positive charge accumulation depending on bias condition and Fermi level position). We have found the charge pumping technique to be superior to sub-threshold current and C-V methods. Recently we have completed round-robin tests of charge pumping experiments on the same devices with Dr. Bob Stahlbush, Naval Research Laboratory, using independent charge pumping techniques confirming the validity of our test. Complementing our efforts in this area are major university sub-contractors. Dr. Len Trombetta, The University of Houston, has complementary electronic defect measuring capabilities. Dr. Trombetta is internationally known as discoverer of anomalous positive charge, the first border trap. The second university collaborator, Dr. Pat Lenahan, Pennsylvania State University, is known for his work on Electron Spin Resonance (ESR) and Spin Dependent Recombination (SDR) which yield the quantum level atomic structure of defects.

For some time we have been studying the increase in interface state density and the surprising decrease of electron-hole pair capture cross section as a function of increasing proton or gamma radiation. After a series of hypothesis and critical experiments we have become confident that reduction of capture cross section is due to a change in the atomic structure of the interface state. This may involve a switch between P_{b0} and P_{b1} defects, which may involve a change in the degree of SP hybridization as suggested by Lenahan. Most of our work has been on Rad-Hard NMOS structures. Recently Ms. Tania Thomas* has extended this work to liquid nitrogen temperature where interface state density is not increased. However we still observed the decrease in capture cross section. Her work also shows a slower phenomena causing threshold voltage shift which we believe may demonstrate for the first time a negatively charged border trap. Mr. Danzhi Lin* extended this work to commercial process devices and found reduction of capture cross section was significantly lower than that observed with Rad-Hard devices. However it should be noted that pre-radiation capture cross section was an order magnitude less than that of Rad-Hard devices.

Our intent is to combine the electronic measurements such as charge pumping and AC conductance vs. voltage (G-V) with the Electron Spin Resonance and Spin Recombination technique to further our understanding of this important phenomena to stabilize the device parameters. Dr. Pat Lenahan has performed some hot electron experiments which are similar to radiation damage and found a E' center which is close enough to the interface to act as an interface state but has the same missing oxygen structure of a deep oxide trap. Dr. Kalu Diogu, (Motorola) has found this reduction of capture cross section phenomena in thin gate oxide commercial devices. The combined resources of this industrial commercial group will focus on this problem which is important to ISS utilization of both Rad-Hard and COTS devices.

* LRS/CM3 supported students.

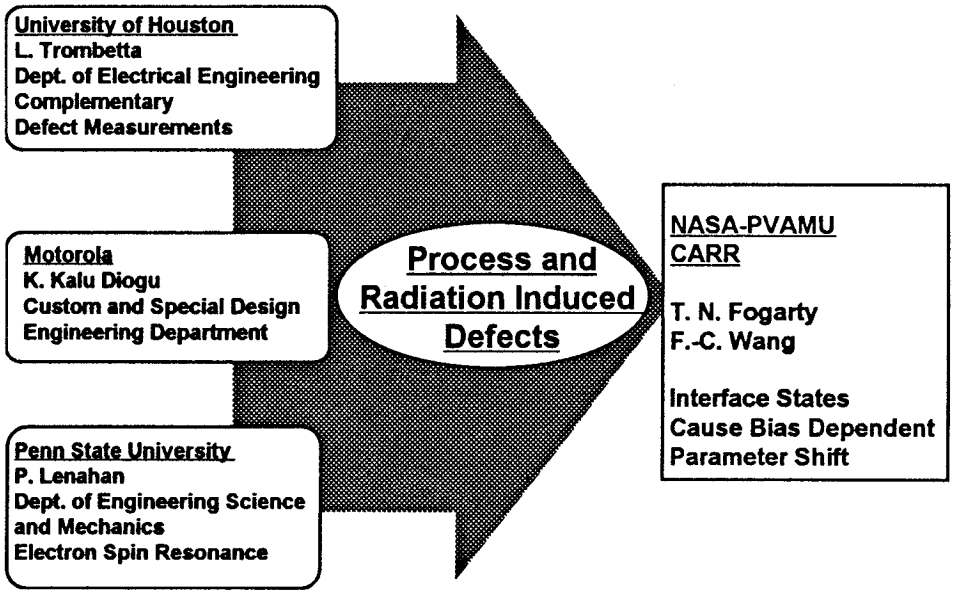
REFERENCES:

[1] T. N. Fogarty "Process and Radiation Induced Defects in Electronic Materials and Devices", Invited paper ACerS May '95, Crystal Growth of Novel Electronic Materials, Ceramic Transactions, Volume 60, 1996

[2] T. N. Fogarty, J. O. Attia, A. A. Kumar, T. S. Tang, and J. S. Linder "Modeling and Experimental Verification of Single Event Upsets" Selected Topics in Robotics for Space Exploration, (Ed. R. C. Montgomery) NASA LaRC, Dec. 1993

[3] T. A. Thomas, T. N. Fogarty, D. Lin, K. J. Kloesel, "Detection of Process and Radiation Induced Defects in MOS Devices", PVAMU-NASA/JSC Conference on Materials, Devices, and Circuits and Bio-systems, November 22 & 23, 1993, Page 22 ff.

[4] A. B. Hillman, P. M. Lenahan, W. Weber, "Identification of the Microscopic Structure of New Hot carrier Damage Centers in Short Channel MOSFETs", accepted for publication in Microelectronics



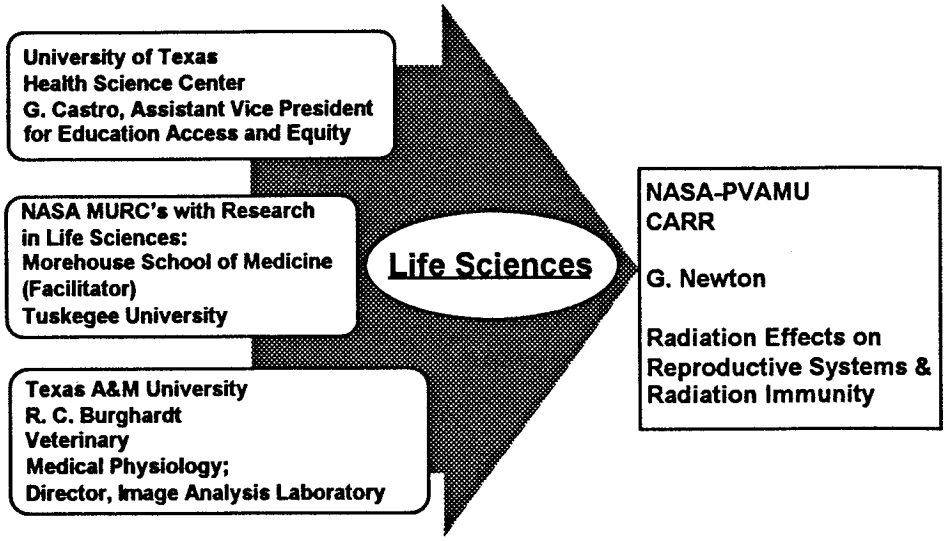
Schematic of the Process and Radiation Induced Defects Effort

Life Sciences:

The initial attachment of trophoblast to uterine epithelial cells may be medicated by protein - carbohydrate interactions and subsequently stabilized by protein - protein interactions involving integrins. To test this hypothesis we are utilizing a battery of monoclonal antibodies to screen uterine tissues and polarized uterine epithelial cells grown on Matrigel coated filters for reactivity to specific fucosylated epitopes. We are especially interested in uterine epithelial cell apical surface glycoproteins containing lacto-N-fucopentanose 1 (LNF-1) sugars since this epitope has been implicated in the initial attachment of trophoblast to uterine spithelial cells in the rodent. We have submitted an abstract to the Society for the Study of Reproduction for presentation at this summers meeting (see page 3) outlining our findings in the pregnant animal. We are currently

extending these observations using tissues obtained on various days of the estrous cycle. This work will be used by Mr. Powell for his M.S. Thesis.

We have also obtained two human cell lines for use in similar studies: JAR trophoblast cells and UL95 endometrial carcinoma cells. CARR student Ms. Manley will be learning cell culture and immunocytochemistry and will test whether these cell lines express integrins.



Schematic of the Life Science Effort

Circuit Innovations:

The standard static random access memory (SRAM) integrated circuit is very susceptible to single event effects (SEE). These effects are due to energy dissipation by a cosmic ray in the active region of an individual memory cell in the IC. The resulting creation of electron-hole pairs and collection of this charge can "flip" a bit of memory.

One way (and the standard technique) of hardening SRAM against single event upsets is the use of a feedback resistance. However this technique has its disadvantage and can significantly slow down circuit operation. The switched capacitor SRAM (SC SRAM) has been proposed as an alternative method for hardening CMOS SRAM against radiation effects.

The SC SRAM has been designed to consume very low power and use one less transistor than some previous versions of the SRAM cell circuit. The switched capacitor networks provide the resistance and capacitance needed to increase the time constant of the cell feedback paths of the standard SRAM cell; thus making the SC SRAM less susceptible to SEE.

The SC SRAM concept was developed at PVAMU and cell designs were studied. A four kilobyte SC SRAM circuit has been designed using MAGIC CAD tool. The memory circuit design has undergone extensive simulations to evaluate its potential performance. In general, the SC SRAM has similar or

better switching times than SRAM with feedback resistors. Simulation results also indicate that the SC SRAM, with clock pulse on, has a lower write time than SRAM with the feedback resistors. However, the write time for the SC SRAM is high when the clock pulse is off. The critical charge, the most important parameter for radiation hardening, has also been determined. When the clock of the SC SRAM is off, the critical charge of the SC SRAM is extremely large.

The 4kB SC SRAM integrated circuit has been fabricated by MOSIS using 2um scaleable CMOS technology. The device is undergoing test and will soon be tested for radiation hardness performance. The possibility of patenting the SC SRAM is currently being explored.

REFERENCE:

[1] J. L. Andrews, J. E. Schroeder, B. Gingerrich, W. A. Kolansinski, R. Koga and S.E. Diehl "Single Event Error Immune CMOS RAM"; IEEE Trans. Nucl. Sci., Vol. NS-29, No. 6, December 1982.

[2] M. N. Liu, S. Whitaker, "Low Power SEU Immune CMOS Memory Circuits", IEEE Trans. Nucl. Sci., Vol. NS-39, No. 6, Dec. 1992, pp. 1679 - 1684.

[3] L. R. Rockett, "Simulated SEU Hardened scaled CMOS SRAM cell using gated resistors", IEEE Trans. Nucl. Sci., Vol. 39, pp. 1532 - 1540, 1992.

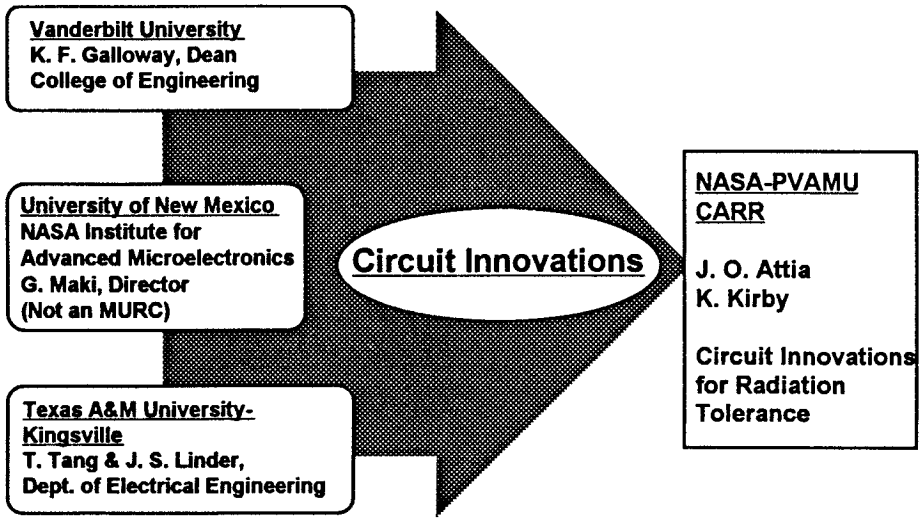
[4] J. K. Ousterhout, MAGIC Manual, 1990

[5] MOSIS Manual, Information Science Institute, Marina Del Rey, CA, 1996

Subcontracts:

University of Arizona/Vanderbilt University: High power MOS transistors have important application in space systems. Time and costs associated with irradiation of devices and evaluation of results make computer simulation of such experiments attractive. In this work, a SPICE model that included ionizing radiation effects on power MOSFETS was evaluated. Results from SPICE simulations show that the power MOS subcircuit can be adjusted to accurately predict the behavior of the irradiated transistors when placed in switching power converters. This work is summarized in a paper, co-authored by J. O. Attia, to be submitted for publication to the IEEE Transaction on Nuclear Science. Dr. K. F. Galloway, leader of this subcontract, is immediate past chairman of the IEEE Steering Committee on radiation effects and the 1996 Program Chair of the International Electron Device Meeting.

Texas A&M University - Kingsville: This work involves the design of an SEU tolerant CMOS SRAM using a commercial VLSI process. The techniques used for the design are on-chip error correction and active resistance SEE hardening. The system has been simulated and is currently being prepared for fabrication.



Schematic of the Circuit Innovations Effort

Emerging Technologies:

This is the competency area of CARR where the answers to fundamental questions are sought, exploration of new technologies takes place and assessments are made as to the importance of the resulting information is to NASA's mission.

Within emerging technologies some research topics have been an active area for radiation research at PVAMU for some time, while other areas are new.

Materials: Advanced and novel materials for radiation tolerant electronics and photonics is a very active research area for CARR investigators. The goal of the work is to provide a basis for improving existing materials and processing, modeling the processes of material fabrication, and characterizing materials to assess their usefulness in radiation tolerant applications. Work is progressing on the following materials considered strategic to future CARR research:

- Wide Bandgap Semiconductors: The electronic and surface properties of Ilmenite ($FeTiO_3$) are being evaluated. This work is done in close collaboration with the NSF Center for Electronic Materials, Devices and Systems (CEMDAS) at Texas A&M University. A new project is producing precursor materials for a lattice matched substrate material (a Cd-Ga-In-O compound) for gallium nitride, a very important photonic material.
- Amorphous Silicon: One project is studying the effects of stabilizing amorphous silicon against radiation damage by incorporating fluorine into the material matrix by the chemical vapor deposition process. A related project seeks to model the deposition process itself to help optimize material processing.
- Ferroelectrics: High dielectric constant ferroelectrics (e.g.: Barium strontium titinate) is being evaluated for dynamic random access memory (DRAM) applications. Other materials are also under consideration; this work is also done in collaboration with CEMDAS.

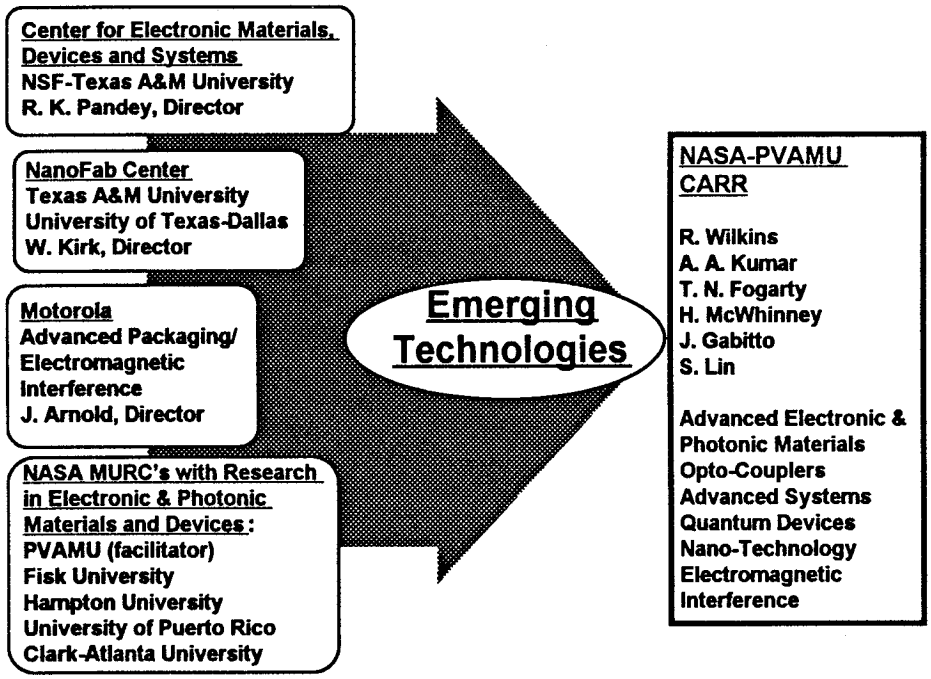
- High Tc Superconductors: There are indications in the literature that Josephson junction devices are radiation tolerant. These materials may be important for future space applications.

Advanced Devices and Systems: Electro-optical systems are beginning to play an important role in spacecraft. The radiation effects on the devices that constitute these systems are not well known or understood. This is an area that is becoming an important part of CARR. In the near future, the radiation effects of commercial and space avionics opto-couplers will be investigated.

Novel devices that rely on quantum mechanics or their shear smallness for their operation will also be studied for their future applications in radiation tolerant systems. CARR investigators have already embarked on a project funded by the Air Force Office of Scientific Research on radiation effects on quantum devices.

Along with advanced hardware systems, CARR will initiate a project to study the utility of error correcting software codes. Dr. Parag Lala of North Carolina A&T University, an expert in error correcting software will teach a week-long course hosted by CARR during June 1997.

Electromagnetic Interference/Electro-static Discharge: Investigators in this area concentrate on packaging of advanced IC (partially funded by Motorola) and modeling of systems for electromagnetic interference studies.



Schematic of the Emerging Technologies Effort

LEVERAGING OF CARR FUNDING

CARR has excellent potential for growth and new funding. Programs from both within NASA and other agencies have been forthcoming as a result of CARR activities. In addition, CARR should provide the basis for future research centers at PVAMU in fields related to CARR research. In fact, The Center for Materials, Microdesign and Microfabrication (CM^3), created by the Texas A&M University System Board of Regents, serves as an umbrella organization for terrestrial applications utilizing the same facilities and investigator expertise as CARR. For example, a project entitled "Radiation Effects in Quantum Devices" started during the reporting period. This project is funded by the Air Force Office of Scientific Research in collaboration with Texas A&M University and the University of Texas at Dallas. A complete summary of leveraged funds is given in Table 5.

In addition, CARR has sought out opportunities within NASA for additional research opportunities and funding:

- Memorandum of agreement with NASA-Langley to use ER-2 flights for high altitude atmospheric radiation testing
- Competing for the student launch program (proposal was selected)
- Design and fabrication of TID and SEE test devices for commercialization with Martin Bueler, Jet Propulsion Laboratories
- Solar Cell Radiation Evaluation with NASA-Lewis (Pending)

Collaborations with major universities, government laboratories and industry strengthen the technical competencies and research:

- Total Dose and SEE testing: Texas A&M University, University of Houston, USAF Phillips Laboratories

- Life Sciences: University of Texas Health Science Center, Texas A&M University School of Veterinary Medicine

- Process and Radiation Induced Defects: University of Houston, Pennsylvania State University, Motorola

- Circuit Innovations: Vanderbilt University, Texas A&M University-Kingsville, University of New Mexico

- Emerging Technologies: Texas A&M University, University of Texas-Dallas, Motorola

Other Collaborators and Affiliates (contributing to one or more of the these areas): Sandia National Laboratory, Los Alamos Laboratory, Tennessee State University, University of North Carolina-Charlotte, Texas Instruments, Lockheed-Martin, Boeing, MEMC Southwest, GB Tech.

RESEARCH AND INFRASTRUCTURE FUNDS LEVERAGED VIA RADIATION RESEARCH AT PVAMU ('95-'99) (*LEVERAGED VIA CARR)

PROJECT TITLE (STATUS)	FUNDING SOURCE	AMOUNT/PERIOD	TYPE
Instrumentation Infrastructure, XRD & AFM/STM (Ongoing)	Office of Naval Research & Advanced Research Projects Agency	$274,000/1year	Minority Directed
Intelligent Processing of Novel Wide Bandgap Semiconductor (Ongoing)*	Texas Higher Education Coordinating Board, Texas Instruments MEMC Southwest	$400,000/2 years	Mainstream
Electromagnetic Interference and Microelectronic Packaging (Ongoing)*	Motorola	$50,000/1 year	Mainstream
Radiation Effects in Quantum Devices (New)*	Air Force Office of Scientific Research	$400,000/3 years	Mainstream
Student Launch Program (funded)*	NASA	$34,000/2 years	Mainstream
Space -Based Microelectronic Testbed* - CARR/GB Tech Alliance	NASA	to be determined	Mainstream

TABLE 5

PAPERS AND PRESENTATIONS:

Refereed Papers

C. A. Billman, P. M. Lenahan and W. Weber, "Identification of the Microscopic Structure of New Hot Carrier Damage Centers in Short Channel MOSFETs", accepted for publication in Microelectronics, 1997.

J. A. Bowen, G. R. Newton, D. W. Weise, F. W. Bazer and R. C. Burghardt, "Characterization of a Polarized Porcine Uterine Epithelial Model System"; Biol Reprod. 55:613-619, 1996

R. C. Burghardt, J. A. Bowen, W. E. Day, R. Barhoumi, F. W. Bazer, S. R. Glasser and G. R. Newton, "Comparative Analysis of Gap Junction Protein Expression in Porcine, Equine and Caprine Endometrium"; Biol. Reprod. 54 (Suppl. 1):174, 1996.

S. Lin and D. Luss, "A Continuous Synthesis of $YBa_2Cu_3O_{6+x}$ by Thermal Explosion in a Rotary Kiln", Physica C, pp.321-326, 260, 1996.

G. R. Newton, T. L. Ott, S. Woldesenbet, A. H. Shelton, and F. W. Bazer; "Biochemical and Immunological Properties of Related Small Ruminant Trophoblast Interferons"; Theriogenology:46:703 - 716, 1996.

D. W. Weise, S. Woldesenbet and G. R. Newton, "Influence of Gonadal Steroids, Oxytocin and Interferon Tau on Protaglandin E_2 and Prostaglandin $F_2 \alpha$ Secretion by Caprine Uterine Epithelial Cells in Vitro.", Biol. Reprod. 54 (Suppl. 1):79, 1996.

Submitted or in Progress:
C. Canty*, S. Lin, and J. F. Gabitto; "A Simplified Plasma Model for Design Applications" submitted for publication J. Vac. Sci. Tech., 1997

S. Lin, and J. F. Gabitto; "Temperature Influence on Reaction Mechanisms in Photo-CVD Reactor" to be submitted for publication J. Electrochem Soc, 1997.

Sy-Chyi Lin, Richard Wilkins, and Dan Luss; "Self-Propagating High-Temperature Synthesis (SHS) of Cd-In-Ga-O Powder for Novel Substrate for Gallium Nitride Based Thin Film Growth" to be submitted to The American Ceramic Society Transactions; May 1997.

T. H. Ma, J. E. Pizano, J. O. Attia, R. D. Schrimpf and K. F. Galloway, "Modeling Low-Dose Rate Total Dose Effects in Power MOSFETs for Circuit Analysis", to be submitted to IEEE Trans. On Nuclear Science.

Hylton G. McWhinney - "The Role of Flourine in Oxygen Uptake in Amorphous Silicon Films" in progress.

G. R. Newton, D. W. Weise, J. A. Bowen, S. Woldesenbet and R. C. Burghardt; "Structural and Functional Properties of Caprine Uterine Epithelial Cells in Vitro" In Vitro Cell. Develop. Biol. - Animal: Submitted, 1996

M. Williams*, S. Lin and J. F. Gabitto; "Simulation of Photo-CVD Reactor"; submitted for publication Industrial and Engineering Research, 1997.

G. Yao, S. Lin, and J. F. Gabitto; "Simulation of Plasma-Enhanced Chemical Vapor Deposition of Si Thin Films"; submitted for publication J. Electrochem. Soc., 1997.

Conference Papers

J. Alexander* and J. O. Attia; "Performance of Logic Gates Under Radiation and Post-Radiation Environments", Proc of NASA URC Technical Conference, Feb. 16-19, 1997.

S. Binzaid*, J. O. Attia and T. N. Fogarty; "VLSI Design of 4K Switched Capacitor SRAM", Proc. Of 6th NASA Symposium on VLSI Design, Albuquerque, New Mexico, March 5-6, 1997.

T. N. Fogarty, Z You, K. Washington*, F. Brown*, T. Nichols*, "Radiation Tolerance of Integrated Circuits in Space and the Terrestrial Environment", NASA URC Technical Conference Proceedings, pp 261, Feb. 16-19, 1997.

H. Huff; "Energy Conservation and Monitoring Measures and Methods"; PVAMU E&A '97 Symposium Proceedings, PVAMU, February 1997.

S. Lin, and J. F. Gabitto; "Modeling and Simulation of Photo-CVD Reactors"; Proceedings of AICHE96 Annual Meeting Symposium, Chicago, Illinois, November 1996.

J. K. Powell*, F. Limar, S. R. Glasser, R. D. Burghardt, and G. R. Newton; "Expression of Carbohydrate Antigens in the Early Pregnant Goat Uterus and Steroid Treated Polarized Uterine Ephithelial Cell Cultures"; PVAMU and Center for Animal Biotechnology, Texas A&M University.

Tian Shen Tang and John S. Linder, "Single Event Upset Immune CMOS SRAM by Circuit Design" NASA URC Technical Conference Proceedings, pp717, Feb. 16-19, 1997.

R. Wilkins and Kirk Powell*, "Characterizing Surfaces of the Wide Bandgap Semiconductor Ilmenite with Scanning probe Microscopies", NASA URC Technical Conference Proceedings, pp 797, February 16-19, 1997.

G. Yao, S. Lin and J. G. Gabitto; "Modeling of Plasma Enhanced CVD Reactors"; Proceedings of AICHE96 Annual Meeting Symposium, Chicago, Illinois, November 1996.

Presentations & Tutorial/Workshops

J. O. Attia, "Latchup in CMOS" - Concerning Radiation Tolerance Requirements in Future Generation Commercial Integrated Circuit Technology and Space Avionics, Tutorial 2 of NASA URC Technical Conference, Feb. 16, 1997.

Mohammad Hashem & Jianren Zhou; "Effect of Particle Monitoring and Reduction on Microelectronic Processes"; Institute for Mechanics and Materials Coupled Property Issues in Integrated Microstructures; ACTA/SCRIPTA MATERIALIA Workshop; April 4-7, 1997.

Hylton G. McWhinney - Naval Research Solid State & Organometallic Chemistry Workshop, February 1996.

Jiaren Zhou, "Effect of Particle Monitoring and reduction on Microelectronic Processes", Coupled Property Issues in Integrated Microstructures, ACTA/SCRIPTA MATERIALIA Workshop, April 4-7, 1997, Monterey, CA.

Invited Talks

T. N. Fogarty, "Converging Needs of Commercial Integrated Circuits and Space Avionics", International Conference on Agile Manufacturing (ICAM'97), Feb. 23-25, 1997.

Gary Newton, "Regulation of Implantation in Ruminants", Texas Agricultural Experiment Station Annual Staff Conference - Physiology of Reproduction Minisymposium, January 7, 1997, Texas A&M University.

R. Wilkins, " Characterizatin of the Wide Bandgap Semiconductor Ilminite for Radiation Tolerant Applications", Los Alamos National Laboratory, August 19, 1996.

Presentations at NASA Installations

T. N. Fogarty and J. O. Attia, "Convergence of Need: Commercial Off the Shelf Devices", NASA Goddard, January 1997.

R. Wilkins, "Research Capabilities at Prairie View A&M University", NASA Ames Research Center, January 23, 1997

MEMBERSHIP OF PANELS/BOARDS:

T. N. Fogarty:
Tutorial Chair, NASA URC-TC '97
Sessions Chair, NASA URC-TC '97
Reviewer, National Science Foundation

A. Anil Kumar :
Member, External Advisory Board, NASA Center of Excellence on High Performance Polymers and Composites (HiPPAC), Clark Atlanta University ('93 - present)
Member IEEE National EMI/EMC Education Committee ('93 - present)
Member, National Steering Committee, Science & Engineering Alliance ('95 - present)
Member, Technical Advisory Panel, Texas Department of Transportation ('96 - present)
Member, NSF Advisory Panel ('96 - present)
Nominee, Fermilab Board of Overseers (January '97)

Harold Huff:
PVAMU Energy Advisory Council
Texas State Agencies Energy Advisory Group (SAEAG) Committee on Legislation and Implementation

Gary Newton:
National Institutes of Health, Cell and Molecular Biology Review Panel - Minority Biomedical Research Support Program
National Institutes of Health, Special Emphasis Panel - Minority Biomedical Research Support Program Supplemental Instrumentation Grant Applications.
National Institutes of Health, Cell and Molecular Biology Review Panel - Minority Biomedical Research Support Program
National Institutes of Health, Special Emphasis Panel - Minority Biomedical Research Support and Minority Access to Research Careers Programs

Jiang Li:
Consultant for Motorola, semiconductor product sector, Austin, TX, on integrity analysis for VLSI interconnects, Summer 1996.
Continuing education course "Electrical modeling, simulation, and design of electronic packages", Oct. 23-25, 1996, San Jose, CA

R. Wilkins: NSF-Center for Electronic Materials, Devices and Systems, Industrial Advisory Board, Spring 1996 & 1997.

Commercialization & Technology Transfer

CARR industrial collaborators and associates and other collaborators provide many opportunities for transfer of knowledge to a broader audience. A summary is provided below:

Tutorial at the 1997 NASA MURC Technical Conference: CARR organized a tutorial entitled "Concerning Radiation Tolerance Requirements in Future Generation Commercial Integrated Circuit Technology and Space Avionics." Participants in the tutorial included academic, industrial and NASA personnel. A round-table discussion focused on industries concern, or lack of concern, for terrestrial single event effects in commercial integrated circuits. It was also pointed out that industries' most immediate radiation problems deal with the actual processing steps in fabricating an integrated circuit.

Internet Delphi Forecast Survey: This survey is designed to gauge the level of importance currently placed on terrestrial radiation effects and chart the converging needs of NASA and the commercial electronics industry. This survey (See Appendix B) was e-mailed to over 70 executives, engineers and scientists in industry, government and academic firms and institutions in January 1997. The responses to the survey are currently coming back and the result tabulated. It is hoped that an assessment of this convergence will be published.

CARR Homepage: The homepage is currently available and will soon be updated to include a summary of information found in this document. The address is www.carr.pvamu.edu.

Facilities of PVAMU CARR

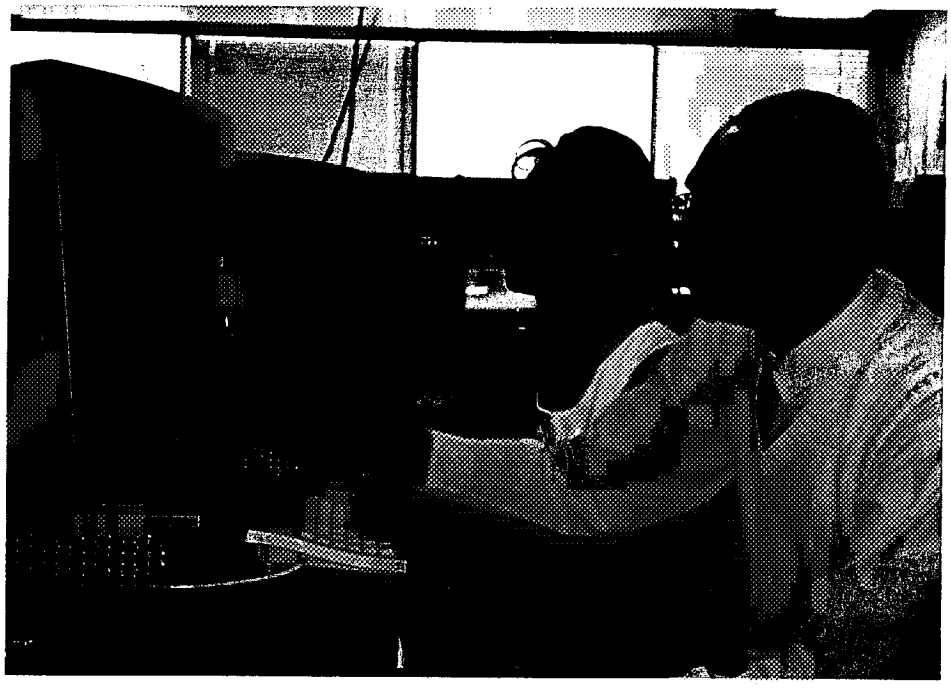
- Radiation Testing:
  1. Radiation Sources
     - -Alpha Particle Test System
     - -Gamma Source (UH, TAMU Veterinary School, PVAMU 1997)
     - -Cosmic Ray Simulation (TAMU Cyclotron Institute)
  2. Hewlett-Packard System 82000 Integrated Circuit Test Set (operated by CARR at the TAMU Cyclotron)
- Device Characterization:
  1. Hewlett-Packard 4145 Parametric Analyzer System
  2. Kiethley System 83 Variable Temperature Probe Station with C-V & I-V Measurements
  3. Charge Pumping System

- Device Fabrication & Design:
  1. Fully Equipped 500ft.^{2} Clean Room for 5m design rules MOS devices and circuits (March 1996)
  2. SEM modified for e-beam lithography for submicron test devices
  3. Workstations with design and simulation software & plotters.

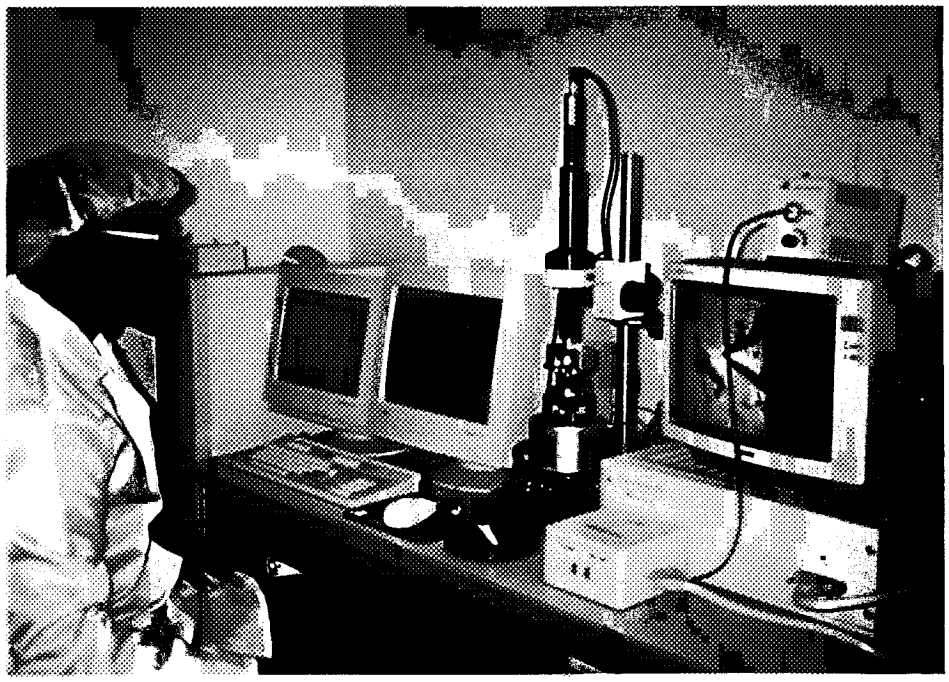
- Device Design and Simulation Software:
  1. VLSI CAD tools: LEDIT, MAGIC, OCTOOLS, LAGER, VIEWLOGIC, Mentor Graphics
  2. Simulation tools: PICES, MINIMOS, SUPREM, PSPICE, IS_SPICE, RADSPICE

- Space Radiation Environment Simulation:
  Severen Communication Space Radiation Software

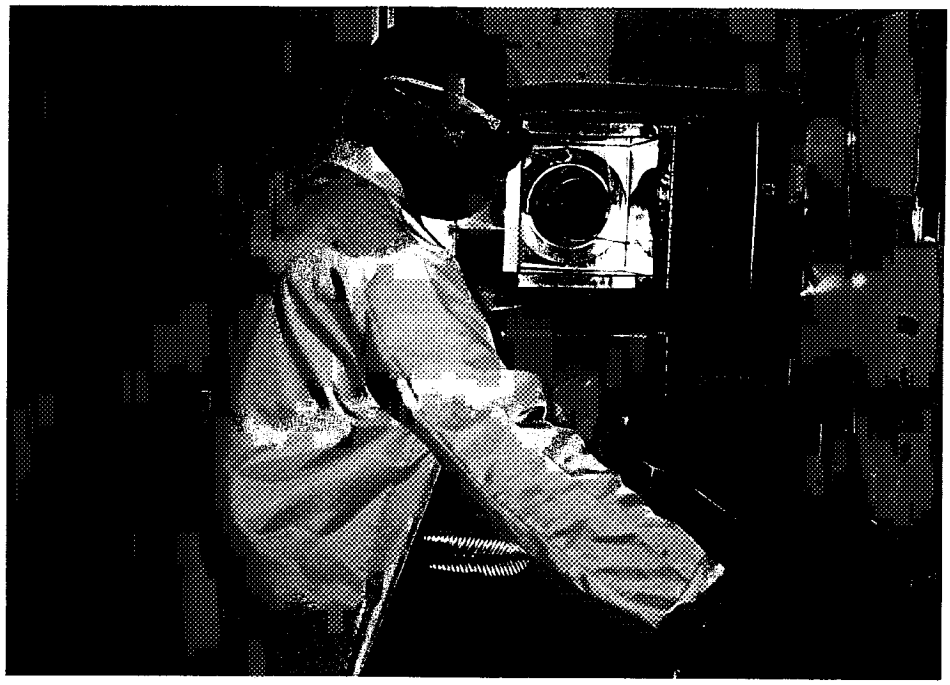
- Materials Characterization:
  1. X-Ray Photoelectron Spectroscopy
     - -Chemical Mapping (30m resolution)
     - -Back sputtering
  2. Ion Scattering Spectroscopy
  3. Scanning Electron Microscopy/Energy Dispersive Spectroscopy
  4. X-Ray Diffractometer (Purchased, installed Summer 1997)
     - -Single Crystal
     - -Thin Films
     - -Powder
  5. Scanning Tunneling Microscopy
     - -Ambient
     - -Ultra-high Vacuum (1997-98)
     - -Cryogenic (1997)
  6. Ambient Atomic Force Microscopy
     - -Lateral Force Microscopy
  7. Deep Level Transient Spectroscopy
  8. Scanning Auger Spectroscopy (End of 1997)



Attalah Lewis and Dr. John Attia discuss the design layout of SRAM circuit

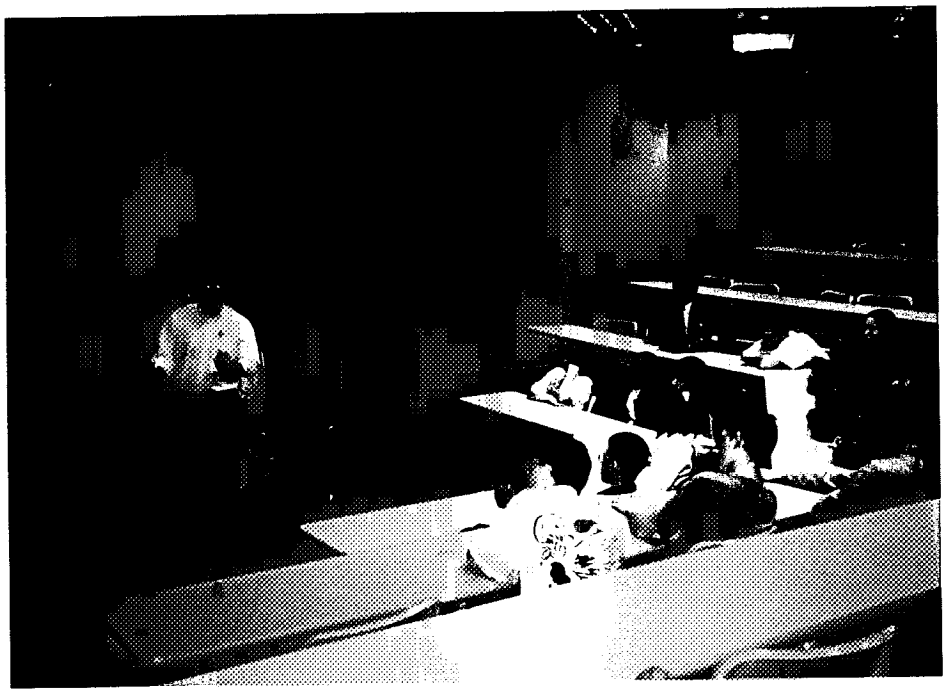


Kirk Powell studies the surface of a wide bandgap semiconductor with an atomic force microscope



Johnny Devereaux operates the diffusion furnace in the CARR microfabrication cleanroom

B. J. Jackson and Mr. Ramesh Dwivedi examine the results of a photolithographic resist application on a silicon wafer



Dr. Gary Newton talks to Hempstead (TX) High School Explorer Post about radiation effects on reproductive cells.

Mr. Kelvin Kirby demonstrates a digital logics lab to the Hempstead High School Explorer Post

Student Participation

The principal goal of CARR is to increase the participation of African-American and other minorities in science and technology fields of interest to NASA. Year 2 has been very successful in making progress towards this goal. Three CARR undergraduates have or are serving internships at NASA Dryden. Student participation in CARR research has exceeded the goals set forth in the original proposal each year of the contract thus far. This year, CARR had 29 undergraduates from six different disciplines (see Table 6) and 16 graduates from five different disciplines (see Table 7) participate in CARR related research and activities. The post-degree plans of our Master's students (as they have been determined) are all in high technology areas of interest to NASA (see Table 8).

UNDERGRAD STUDENTS AND FUNDING SOURCE

NAME	MAJOR	U. S. CITIZENSHIP	ETHNIC ORIGIN	FUNDING SOURCE
1. Brim, Daryl	Electrical Engineering	yes	African American	CM^3
2. Brown, Frederick	Electrical Engineering	yes	African American	CARR
3. Canty, Chantay	Chemical Engineering	yes	African American	CARR
4. Cherry, Holly	Chemical Engineering	yes	African American	CARR
5. Dangerfield, Shawn	Mechanical Engineering	yes	African American	CARR
6. Harris, Monika	Chemical Engineering	yes	African American	CARR
7. Hervey, Patrick	Electrical Engineering	yes	African American	CARR
8. Hoskins, Lola	Electrical Engineering	yes	African American	CARR
9. Houston, James	Mechanical Engineering	yes	African American	CARR
10. Jackson, Billy J.	Electrical Engineering	yes	African American	CARR
11. Jackson, Eric	Electrical Engineering	yes	African American	CM^3
12. Jones, Alexander	Mechanical Engineering	yes	African American	CARR
13. Lacy, Christeveous	Electrical Engineering	yes	African American	CARR
14. Ledet, Elonda	Architecture	yes	African American	CARR
15. Lewis, Attalah	Electrical Engineering	yes	African American	CARR
16. Pierrot, Charles	Electrical Engineering Technology	yes	African American	CARR
17. McFerren, Tommy	Mechanical Engineering	yes	African American	CARR
18. Manley, Keisha	Agriculture	yes	African American	CARR
19. Martin, Detrick	Electrical Engineering	yes	African American	CM^3
20. Mohammad, Khan	Electrical Engineering	yes	Asian	CARR
21. Nichols, Tammie	Electrical Engineering	yes	African American	CARR
22. Powell, Kirk	Electrical Engineering	no	Jamaican	CM^3
23. Reed, Jonathon	Electrical Engineering	yes	African American	CM^3
24. Tucker, Calvin	Electrical Engineering	yes	African American	CM^3
25. Schmidt, Christopher	Electrical Engineering Technology	yes	Anglo	CARR
26. Sturns, Kenya	Electrical Engineering	yes	African American	CARR
27. Walker, Oveal	Electrical Engineering	yes	African American	CARR
28. Williams, Clarence	Agriculture	yes	African American	CARR
29. Williams, Erskine	Electrical Engineering	yes	African American	CARR
30. Williams, Melanie	Chemical Engineering	yes	African American	CARR

TABLE 6

GRADUATE STUDENTS AND FUNDING SOURCE

NAME	MAJOR	U. S. CITIZEN	ETHNIC ORIGIN	FUNDING SOURCE
S. Binzaid	Electrical Engineering	yes	Asian	NASA/CARR
Johnny Devereaux	Electrical Engineering	yes	African American	NASA/CARR
Junious Powell	Biology	yes	African American	NASA/CARR
Kenneth Washington	Electrical Engineering	yes	African American	NASA/CARR
William Reynolds	Electrical Engineering	yes	African American	NASA/CARR
Dawn Burton	Chemistry	yes	African American	NASA/CARR
Felicia Lindor	Electrical Engineering	yes	African American	NASA/CARR
Ajay Sehgal	Chemical Engineering	yes	Asian	NASA/CARR
Kofi Burney	Mechanical Engineering	yes	African American	NASA/CARR
Lynette Drayton	Chemical Engineering	yes	African American	NASA/CARR
Ali Huneiti	Electrical Engineering	yes	Asian	NASA/CARR
John Wara	Electrical Engineering	yes	African	NASA/CARR
Xinya Yu	Electrical Engineering	no	Asian	CM^3
Shojah Ardalan	Electrical Engineering	no	Asian	CM^3
Faizul Islam	Electrical Engineering	yes	Asian	(TAMU Ph.D. student)
Lisa Calloway	Electrical Engineering	yes	African American	DOE/TAMU*

* National Need Program Fellowship

TABLE 7

GRADUATE STUDENTS POST DEGREE PLANS

NAME	EXPECTED GRADUATION DATE	THESIS/PROJECT TITLE	POST DEGREE PLANS
S. Binzaid	Completed all requirements for M. S.	Development & Verification of a Computer Controlled CV MOS Measurement System	Position with Motorola
Johnny Devereaux	May 1997	Development of NMOS Transistor Microfabrication Process for PVAMU Clean Room	Position with Motorola
Kenneth Washington	Completed all requirements for M. S.	Study of Stabilized High Dialectrics Constant MIS Gate Insulators	Employment in High Tech Industry
William Reynolds	May 1997	Quantitative comparison of thickness measurement techniques for thin film electronic materials	undetermined
Felicia Lindor	May 1997	Project Planning and Review of Complementary Metal Oxide Semiconductor Microfabricaton Process	Position with Lockheed-Martin
Lisa Calloway	Completed all requirements for M. S.	Characterization of Amphorous SiThin Film Deposition by Plasma Enhanced Chemical Vapor Deposits	Position with Texas Instruments
Junious Powell	Completed all requirements for M. S.	Expression of carbohydrate antigens in the early pregnant goat uterus and steroid treated polarized uterine epithelial cell cultures	undetermined

TABLE 8

APPENDICES

Appendix A:

1. Technical Review Committee
2. Technical Advisory Panel

Appendix B:

Internet Delphi Forecast

APPENDIX A-1

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Prairie View, TX

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revised 3/21/97

APPENDIX A-2
CARR/CM^3 TECHNICAL ADVISORY PANEL (TAP)

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revised 3/22/97

APPENDIX B

DELPHI FORECAST
CONVERGING NEEDS OF SPACE AVIONICS AND COMMERCIAL VLSI

As feature size continues to shrink in commercial VLSI, specific capacitance and critical charge necessary to cause single event upsets (SEU) also decreases. Therefore, it is expected that cosmic ray induced SEU soft errors will be significant problem in the next generation of VLSI in a terrestrial environment. The reduction of operation voltage from 5 volts to 3 volts and so on will reduce noise margins and compound this problem. At the same time, the small market for radiation tolerant devices in SPACE and DEFENSE AVIONICS has escalated the cost and shrunk the availability of radiation hardened parts. For example many experiments on International Space Station desire to use commercial off-the-shelf (COTS) integrated circuits to reduce cost and utilize state-of-the-art technology. Since the demise of the Cold War, Total Ionizing Dose requirements for Space Avionics have moderated considerably. Modern VLSI fabrication technology utilizes processes such as Reactive Ion Etching , Plasma Etching, Plasma Deposition and Sputtering as well as Deep UV, Electron Beam and X-Ray Lithography. All of these processes are capable of inducing some degree of radiation damage in MOS structures.

As these needs converge, we at the Prairie View A&M / NASA Center for Applied Radiation Research (CARR) believe that an electronic dialogue would further cooperation and may lead to more reliable parts. We ask you to please return this query as soon as possible and feel free to add a query topic if you desire. We plan to establish a use net under our Home Page to facilitate further electronic dialogue.

T.N. Fogarty
Director, CARR

J.O. Attia
Associate Director, CARR

Query: Please place X in appropriate box and return by e-mail

1. My effort may be categorized as follows:
   ___ Academic Research ___ Space Avionics
   ___ Commercial Semiconductors ___ National Laboratories

2. SEU Prevention (soft errors) in the terrestrial environment will be necessary by:
   ___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

3. RAD hardening achieved with standard commercial CMOS via circuit inovation techniques will reach application equivalence with specialized Rad Hard processing by:
   ___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

4. Circuit innovation (such as resistive hardening of SRAM) will usually increase DIE ACTIVE area. The following percentage increase would be economically feasible:
___ 10% ___ 20% ___ 30% ___ None ___ No Opinion

5. Standard EPI CMOS processes and designs will be modified to prevent latch-up by:
___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

6. SOI will be widely utilized by commercial manufacturers to alleviate the above mentioned problems by:
___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

7. A high dielectric constant material such as Ta_2O_5 will be highly utilized in the capacitor of the standard transistor capacitor cell of DRAM by:
___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

8. A ferroelectric material will be highly utilized capacitor of the standard transistor capacitor cell of DRAM by:
___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

9. As TID radiation, SEU and latch-up resistance depend on scaling, process and design COTS such as 4 Mbyte SRAM and 486 DX CPU show varying degrees of immunity. Commercial suppliers would be willing to supply NASA, DOD and DOE scaling level gate oxide thickness, BiCMOS or CMOS of changes that might affect qualified components at a nominal differential cost by:
___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

10. Particle beam accelerators are used to simulate proton and heavy ion charge particle-induced SEU. Woodruff has shown that he critical linear energy transfer may depend on the sense of the arrival angle of the particle beam. Thus the assumption that $LET_{effective} = LET / \cos \phi$ is called into question. Therefore, particle beam accelerators will use normal incidence in determining critical LET for SEU by:
___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

11. Prior Total Dose, Secondary Radiation and Fragmentation will impact SEE by:
___ 1998 ___2000 ___ 2005 ___ Never ___ No Opinion

12. Micro Dose and Ion Triggered Channeling will impact SEE by:
___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

13. R.J. Jaccodine and T.P.MA shown that fluorine doped oxide increased tolerance for TID radiation in MOS structures. In addition, fluorine accelerates the oxide growth rate suggesting it might be a good candidate for field oxidation by:
___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

14. The University of Illinois and Lucent Technologies are studying the effect of the replacement of Hydrogen by Deuterium in processes such as the post metal anneal to form a more stable silicon to silicon dioxide interface. The first application of this technology to commercial manufacturing is expected by:
___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

15. As gate oxide thickness is reduced, gate oxide rupture will replace oxide and interface trapping as a principal failure concern by:
___ 1998 ___ 2000 ___ 2005 ___ Never ___ No Opinion

16. Specialized design rules to alleviate leakage at the field oxide gate-oxide boundary will be transferred from RAD HARD to commercial VLSI by:
___ 1998 ___2000 ___2005 ___ Never ___ No Opinion

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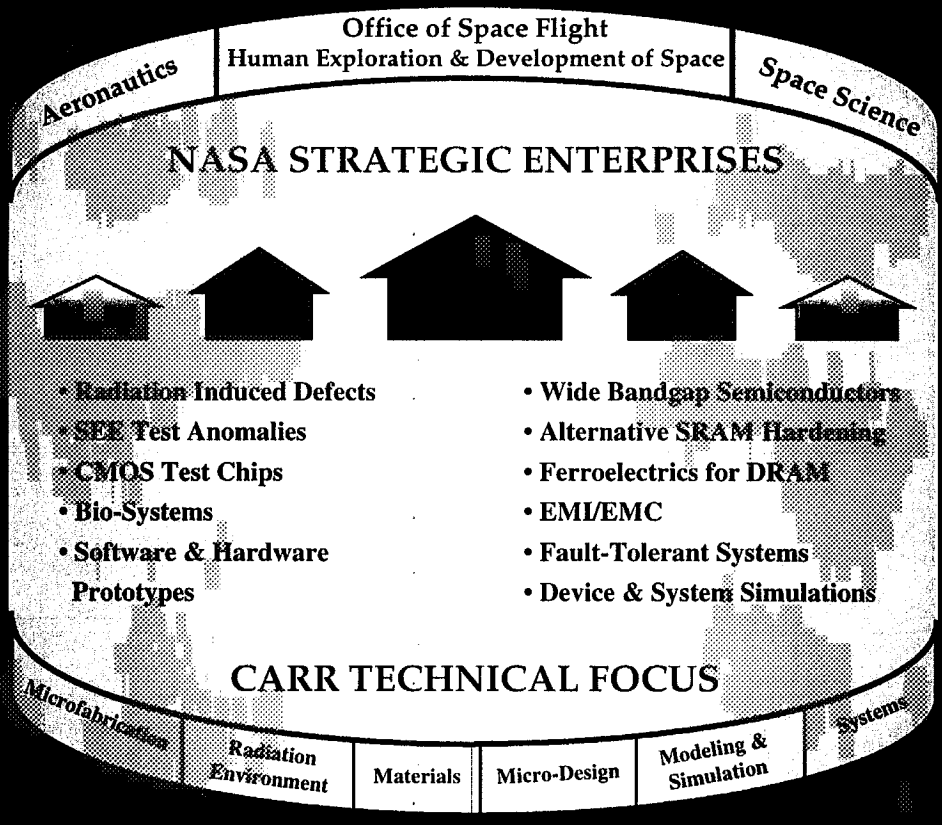

Radiation Research through Vertical Integration from Materials to Systems