Research and Technology Report

1998

Acknowledgments

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On the Cover: School children visiting the Tuskegee University Center for Food and Environmental Systems for Human Exploration of Space get a taste of NASA-sponsored research at minority universities. Reflected on the wall of a plant growth chamber is the image of the late Dr. Phil Loretan, outstanding project coordinator of the Tuskegee Center from 1986 to October 1998.

Foreword

Nothing compares to the excitement of a world seen through the eyes of a child. The students on the cover of this volume are seeing a world completely unlike that seen by their parents and grandparents. They are seeing a world in which human beings will soon be living and working in space every day of the year. They are seeing a world in which caring for the Earth has become an international concern. They are seeing a world from which we are viewing the very beginnings of the universe itself. It is a world in which science and technology, carried out in the realms of air and space, are making today's realities out of yesterday's dreams.

Imagine the excitement when children who would have been excluded from these events in previous times discover that in today's world they can be full participants. Imagine their excitement when they discover far-reaching science and technology research work being carried out at colleges and universities that cater to their own very human needs. Imagine their excitement when they meet college professors and students who look just like themselves engaged in exploring the frontiers of air and space.

It is for the sake of these children that NASA, through its Minority University Research and Education Program (MUREP), sponsors the programs chronicled in this report. Within these pages, you will find highlights from major multidisciplinary research efforts conducted under the University Research Centers and Institutional Research Awards programs, and reports from individual principal investigator efforts conducted under the Faculty Awards for Research programs. For the first time, you will also find reports from the Partnership Award grants, initiated in FY 1997 in response to a directive from Congress. In total, the work reported encompasses contributions from 1,084 students and 561 professional researchers at institutions eligible to compete for MUREP funding, including Historically Black Colleges and Universities (HBCU), Hispanic-Serving Institutions (HSI), and Tribal Colleges and Universities (TCU). This work is the cornerstone of NASA's response to Executive Orders 12876, 12900, and 13021, which mandate increased Federal support to these classes of institutions. We firmly believe that maintaining America's leadership in air and space depends on fully developing the talents and interests of students served by the Nation's minority universities.

It is a pleasure to thank the NASA Offices of Aero-Space Technology, Life and Microgravity Sciences and Applications, Earth Science, Space Flight, and Space Science, as well as the NASA Field Centers and Jet Propulsion Laboratory (JPL), for their continued strong support of the projects chronicled here.

George E. Reese
Associate Administrator for
Equal Opportunity Programs

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University Research Centers

The University Research Centers (URC) at Minority Institutions program seeks to achieve a broad-based, mainstream, competitive aerospace research capability among the Nation's Historically Black Colleges and Universities (HBCU's) and other minority universities (OMU's).

The goals of the program are to:

- foster new science and technology concepts;
- expand the Nation's base for aerospace research and development;
- develop mechanisms for increased participation by faculty and students of HBCUs and OMU's in mainstream research; and
- increase the production of disadvantaged students who are U.S. citizens and who have been historically underrepresented with advanced degrees in NASA-related fields.

Now entering its eighth year, the URC program funds research centers at 11 HBCU's and 3 OMU's. This report summarizes the activities of the URC's during the academic year September 1997 through August 1998 reporting period. During this period, 245 professional-level investigators were involved in research projects at the URC's, including 185 faculty members, 45 research associates, and 15 postdoctoral fellows. A total of 458 students—255 undergraduate and 203 graduate—participated in these research activities.

The research accomplishments were documented in 352 refereed papers or book chapters published during this time period. Significantly, 193 students were authors or co-authors of these publications. An additional 163 papers or book chapters, including 91 student authors or co-authors, were accepted for publication during this period. The broader research community was informed of this work through 812 technical presentations, including 300 presentations given by students.

During the reporting period, the URC's were able to leverage their NASA MUREP expenditures ($14.3 million, not including $3.4 million of student support) to an additional $20 million in new research support, $4.6 million from other NASA programs, and $15.4 million from other agencies.

A major goal of the URC program is to increase the number of disadvantaged and underrepresented minority and disabled students receiving advanced degrees and entering into careers in NASA-related fields. Of the 458 students involved in the research projects at the 14 URC's during the reporting period, 255 (56 percent) participated at the bachelor degree level, 144 (31 percent) participated at the master degree level, and 59 (13 percent) participated at the doctoral degree level. Of the participating students, 93 percent were members of an underrepresented ethnic minority group. Perhaps most importantly, 183 degrees, including 107 bachelor's degrees, 64 master's degrees, and 12 doctoral degrees were awarded to URC students.

The URC's perform scientific and/or engineering research relevant to the four NASA Strategic Enterprises: Aero-Space Technology, Human Exploration and Development of Space, Earth Science, and Space Science. The reports from each of the URC's, arranged according to the primary Strategic Enterprise that they support, follow.

Aero-Space Technology

High Performance Polymers and Composites Research Center

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Date of Original Award: 1992

INTRODUCTION

The High Performance Polymers and Composites (HiPPAC) Research Center utilizes a team approach where interdisciplinary teams of chemists, material scientists, and engineers work together to conduct research on a number of areas. This research focuses on the synthesis and characterization of polymeric nonlinear optical (NLO), photorefractive, photoluminescent (PL), electroluminescent (EL), and piezoelectric materials; characterization and engineering applications of induced strain smart materials, processable polyimides, and additives to enhance polyimide processing for composite applications; and the fabrication and mechanical characterization of polymer-based composites. These research areas span the range of synthesis, processing, and characterization on new materials to meet the Nation's aerospace needs.

RESEARCH ACCOMPLISHMENTS

Preparation and Characterization of Non-Linear Optical (NLO), Photorefractive, Photoluminescent (PL), and Electroluminescent (EL) Polymers
Polyimide-based photorefractive materials, which are compatible with existing semiconductor processing technology, are the principal candidates for applications such as high-density optical data storage and image processing. We have prepared and characterized new NLO polyimides that contain either main chain embedded or side chain NLO chromophores. Differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) evaluated the thermal properties of these NLO polyimides. New polymers have been prepared which exhibit sufficient thermal stability to meet processing requirements. New photorefractive materials that incorporate stable NLO chromophores, charge transporting agents, and photo sensitizers have been prepared.

Photoluminescent (PL) and electroluminescent (EL) polymers are key components of low energy usage display devices such as Light Emitting Diodes (LEDs) and computer screens. New processable polymers with very high photoluminescence and electroluminescence have been designed and synthesized. The quantum efficiencies of the photoluminescence and electroluminescence of these new materials are some the highest ever reported.

Synthesis, Characterization, and Processing Properties of Polyimides
Polyimides are advanced materials that possess the thermal stability, dimensional stability, and mechanical properties necessary for use in aeronautics applications. However, the use of polyimides in aeronautics programs has been limited by the requirement of extreme processing conditions. These conditions are caused by very high glass transition temperatures and high melt viscosities.

HiPPAC investigators have synthesized and incorporated a series of new bicycooctylene/alkyl aniline additives to improve the processability of polyimides to extend their use in composite applications. These processing routes have been examined in conjunction with NASA Langley Research Center's phenylethynyl terminated imide Langley Research Center-PETI-5™, and Dupont's Avimide® KIII polymer K3B. These processing additives significantly lowered the glass transition temperatures, flow temperatures, and melt viscosities, thus allowing for easier processing.

Smart Material Systems
Smart material systems are material systems and structures that can rearrange themselves to their optimum functional capabilities or to adapt to external stimuli by using inherent or integral functional elements such as sensors, actuators, and controllers. Smart material systems can be implemented in aerospace applications such as health monitoring, active damage control, and active vibration control of aerospace structures.

A new actuator/sensor layout and structural excitation scheme has been developed to study the effectiveness of using piezo-ceramic actuators and sensors to detect de-bonding in structural adhesive joints, such as those used in aerospace applications. The new actuator/sensor layout consists of an aluminum beam lap joint with one pair of surface-bonded actuators on one side of the joint and one pair of sensors symmetrically surface-bonded on the other side of the joint. The finite element method has been used to analyze this new actuator/sensor configuration.

Steady-state analysis has been performed on both undamaged and damaged joints. The actuators

were excited in-phase with a sinusoidal potential. The induced electrical potentials on the surfaces of the sensors were then obtained and recorded. The sensor signal response of the damaged joint is significantly different in terms of both amplitude and phases relative to the undamaged joint. This work has applications in assessing the health of aging aircraft.

Fabrication and Mechanical Characterization of Polymer-Based Composites
HiPPAC Center investigators are working on the design, fabrication, processing, testing, and modeling of the mechanical properties, durability, aging, and life-time prediction of Polymer Matrix Composites (PMCs) and Hybrid Metal Composite Laminates (HMCLs). An example of an HMCL is the Hybrid Titanium Composite Laminate (HTCL), a material system in which thin plies of titanium are laminated together using a high-temperature polyimide resin with high modulus fibers included in the bondline.

Research has been carried out to identify the mechanisms of damage in tension-tension fatigue of unidirectional T650-35 carbon fiber /AMB-21 polyimide (an environmentally friendly polyimide developed by NASA Glenn Research Center) laminates under both ambient and elevated temperatures. A study was conducted to investigate the mechanical behavior of the unidirectional T650-35/ AMB-21 polymer composite system. Accomplishments included successful fatigue testing with tabbed dog-bone shaped specimens in which failure occurred away from the tabs. The data obtained will help in assessing replacement of PMR-15 with AMB-21 as a matrix for high-temperature applications.

Experimental studies were undertaken to investigate the compressive buckling and tensile response of HTCL. The HTCL was prepared using a graphite fiber-reinforced thermoplastic polyimide as the adhesive in a unidirectional pre-peg to determine if these systems will be useful in the next generation of high-speed aircraft. Overall, the HTCL systems tested proved stronger than their corresponding monolithic metals.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Polymeric NLO and photorefractive materials have applications in optical computing, information storage, and the development of "flight by light" systems. High efficiency photorefractive photoluminescent (PL) and electroluminescent (EL) polymers are key materials for the fabrication of low energy usage display devices. Smart materials systems can be utilized for the health monitoring, vibration control, and damage control of aerospace structures. Polymer matrix composites and hybrid metal composite laminates have applications in lightweight structural materials. These materials possess superior strength/weight and modulus/weight characteristics as well as superior impact resistance for applications in future aerospace applications including aircraft, missiles, and spacecraft.

BENEFITS TO SOCIETY

The research and technology under development in the HiPPAC Center will play a vital role in ensuring the safety, environmental compatibility, and productivity of air transportation and space systems as well as enhancing the security and economic health of the Nation.

STUDENT ACHIEVEMENTS

Undergraduate and graduate students have been an integral part of the research programs described above. These students have carried out research, coauthored papers, and made presentations at regional, national, and international professional meetings, while earning undergraduate and graduate degrees in science and engineering.

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Center for Nonlinear and Nonequilibrium Aeroscience

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Date of Original Award:1992

INTRODUCTION

Research at the Center for Nonlinear and Nonequilibrium Aeroscience (CeNNAs) at Florida A&M University (FAMU) focuses on plasma-based

hypersonic drag reduction, jet noise reduction and high speed noise velocimetry, turbulent free shear layers with vortex shedding manipulation, and advanced aerospace materials characterizations. As a result of this research, we expect to develop cooperative initiatives between academic and industrial partners. This will help to support our NASA-related interests and to contribute to the overall quality of NASA research activities through mutually beneficial interactions with NASA Field Centers. Furthermore, we expect to develop new physical insights and new methodologies that will have an impact on current and future aeronautics and space transportation technologies. We also intend to provide a broad-based aerospace research capability at FAMU. This research capacity will be accompanied by the identification and training of potential NASA scientists and engineers who otherwise might have been missed.

RESEARCH ACCOMPLISHMENTS

Vorticity Production in Dissipation-Free Compressible Turbulent Supersonic Flow
Using Direct Estimation Velocimetry on the supersonic free shear layer in our Mach 2 Ludwieg Tube, measurements at a 2 MHz rate have been made for the first time of all three components of the flow vorticity. With these data, a direct measurement has been made of the evolution in time of the energy dissipation rate. The energy dissipation rate was found to be zero. This method has the advantage of avoiding use of the exact local viscosity, which is difficult to determine.

New Diagnostic and Optical Implications from Turbulent Ionized Gases
Using an arc-driven shock tube to provide a stationary turbulent ionized gas, fluorescence, and emission, optical diagnostics simultaneously keep track of the state of turbulence in both the neutral and the ionized components. This environment allows us to study the origins of turbulence in ways that can be implicitly limited to molecular effects while we look for the possible coupling of microscopic optical effects with macroscopic turbulence. Evidence was found of a general shift in the spectral line associated with the history of turbulence in the system. There was also evidence of a turbulence-related evolution of signal strength and width in the neutral spectra of the sort that may be influenced by a local concentration of ions. Finally, evidence was found of the evolution or "onset" of turbulence in the molecular data.

Jet Noise Suppression Through Water Injection
Using a Mach Number 1.44 ideally expanded jet, a minimal amount of water injected at the nozzle exit produced a decrease in the near-field noise level. The narrow band frequency spectra show that both the shock-associated noise and the mixing noise were reduced by the injection of water. In our shock tunnel facility, it was observed that the dominant mixing noise sources are located at the end of the potential core. The dominant radiation angle of the far field mixing noise was found to correspond to the Mach wave radiation angle at the potential core region of the jet. We expect that the results obtained so far can be extended to a broad class of jets by careful measurements using particle image velocimetry and laser speckle density measurements in our new Mach 1.5 nozzle.

Texture and In-Situ Characterization of Crystalline Polymer and Carbon Composite Materials
In a study with NASA Langley Research Center, a high-temperature polymer composite material was studied for its high-temperature properties and the effect of moisture on mechanical properties. The in-situ study was conducted using an Environmental Scanning Electron Microscope equipped with a high temperature furnace. The results show that the composite behaves in a very heat-resistant manner up to a temperature of 370K. However, a large amount of degradation was observed at the fiber matrix interface at a temperature of approximately 400K.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The result on vorticity production provides support for new theoretical speculations on the inherently non-dissipative nature of "pure" turbulent systems. This will help to motivate a fundamental reevaluation of the relationship between classical mechanics and quantum mechanics for turbulent flow. The results on optical spectra provide new opportunities as high data-rate unobtrusive diagnostics for turbulent systems with reliable optical signatures. The use of the new rectangular nozzle will afford detailed distinctions between the sonic core, the potential core, and the flow associated with the water injection nozzles and the applicability of water injection for jet noise manipulation.

BENEFITS TO SOCIETY

A next generation of high data-rate flow diagnostics is needed for wind tunnel simulations and aircraft design. With this in mind, our research on the implications from molecular phenomena in turbulent flow promises new techniques for making megahertz velocity measurements in air without a

need for artificial seed particulates or seed molecular subspecies. Commercial hypersonic flight has highly desirable potential economic and social benefits. Therefore, the research on shockwave interactions with weakly ionized plasmas allows us to hope for acceptable fuel efficiency in flight at four times the speed of sound. Our research on jet noise suppression can lead to quieter airplanes and to reduced separations for aircraft during takeoff. Our research on the correlation of targeted surfaces and their associated temperature and longevity requirements can provide substantial savings in airframe manufacturing costs with no loss of airframe reliability.

STUDENT ACHIEVEMENTS

The CeNNAs program's student successes drive our research program. Our students continue to win national awards. Our students have been awarded National Science Foundation (NSF) Student Fellowships and have made presentations on their work at major national and international meetings. Our students also continue to move with great success into the aerospace technology impacted workforce, academia, and NASA Field Centers. Some private sector employers of CeNNAs students include Hughes Aircraft, Boeing, General Electric, and Caterpillar.

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The NASA Center for Aerospace Research (NASA-CAR)

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Date of Original Award: 1992

INTRODUCTION

One of the goals of North Carolina A&T State University (NCA&TSU) is that its students attain a level of scientific literacy that will enable them to excel in the technological society of the 21st century. The Center for Aerospace Research (CAR) is one of many centers in the College of Engineering dedicated towards realizing this goal. CAR has facilitated innovative research breakthroughs in the areas of Computational Fluid Dynamics (CFD), Autonomous Control Engineering (ACE), Structural Health Monitoring (SHM), and Human Machine Systems Engineering (HMSE). CAR is providing leadership and inspiration to our students, our faculty, and our community.

RESEARCH ACCOMPLISHMENTS

During the 1997 academic year, CAR has invested in its laboratories to maintain their state-of-the-art capabilities. The Aerospace Structures Laboratory has acquired a scanning laser doppler vibrometer, illustrated in Figure 1, to boost its capabilities in structural health monitoring. A new laser reflection technique developed at NCA&TSU maps the vibration response of a point on the structure to lines on a flat surface. This method will be investigated as an alternative to experimental modal analysis and to detect damage in structures. The laser research is being conducted in collaboration with Raytheon Systems and United Technologies. A new control technique is also being developed using an alpha DEC controller with a high processor speed and a new control scheme using vibration measurements from a scanning laser.

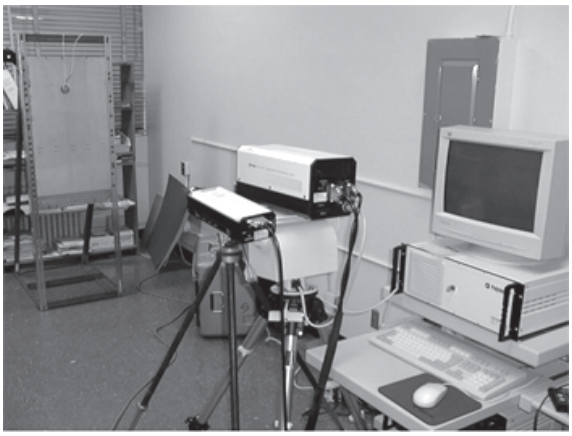

Figure 1. Scanning laser doppler vibrometer

In the area of HMSE, significant progress was made in the development of mathematical models that quantify the relationship between perceptual and pilot control gain during different task conditions. In our study, we have developed such a relationship based on the concept of decision theory. An application of this theory to a low-altitude flight control task is illustrated in Figure 2.

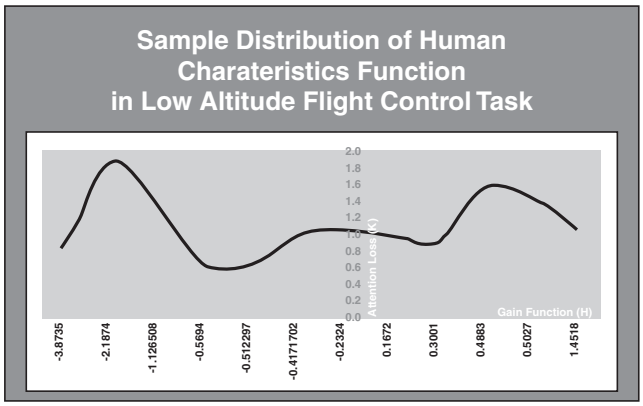

Figure 2.

The CFD laboratory has acquired licenses for GASP, a grid generation package (ICEM-CFD) and the data visualization tool TECPLOT. The CFD group is engaged in a wide variety of research efforts, one of which is a numerical simulation of the interaction between a normal sonic jet and a laminar hypersonic crossflow. Numerical results compared well with the experimental data generated at Southampton University, England. This study of a two-dimensional case (slot-jet) was part of the master's thesis of Mr. Damon Jeffries. Other research efforts include a numerical study of duct-strut interactions in advanced propulsors and a numerical simulation of plume-induced flow separation on launch vehicles.

In the area of vibration control of flexible structures, extensive research is being done. The objective of this study is to actively reduce the level of vibration in plates. It also provides an excellent reference for comparing many existing control strategies. These strategies include rate-feedback, GA-designed PD control, LQG/LTR, and H_2/H_∞. In our study, the model is described with some degree of uncertainty. During simulation, our hierarchical hybrid fuzzy proportional integral derivative (HHFPID) controllers have demonstrated excellent robustness despite these uncertainties. The experimental set-up is shown in Figure 3.

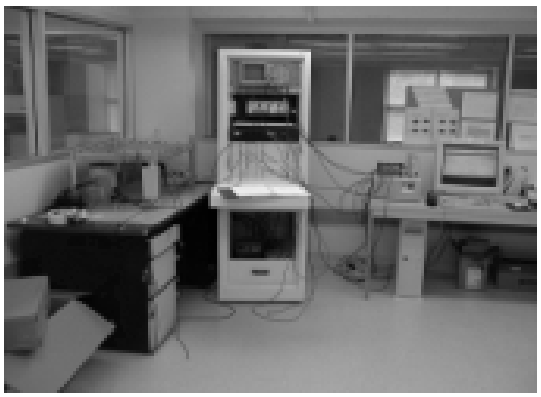

Figure 3. Experimental set-up for flexible structure control.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The primary mission of CAR is to conduct high-quality research in aeronautics and astronautics in a safe and cost-effective manner. CAR is one of the few NASA-supported academic research centers that performs critical research that contributes to the technology necessary to support the development of NASA's High Speed Civil Transport (HSCT) programs. Technology development geared towards the improvement of the Single and Two Stage to Orbit (SSTO, TSTO) missions is also being conducted. Under development are research efforts geared towards the support of NASA's exploration of space and the long-term human presence in space, as well as enhancing life on Earth by applying the resultant advances in human knowledge and technology. Researchers at CAR are actively developing capabilities in the areas of space station design, space station project management, and microgravity materials research.

BENEFITS TO SOCIETY

Presently, our scientists are conducting joint research with NASA Field Centers, including Glenn Research Center, Langley Research Center, Marshall Space Flight Center, and Dryden Flight Research Center. CAR is also collaborating with private aerospace industries, such as Lockheed Martin and Raytheon Systems. Over the 1997 academic year, our researchers have submitted and won research proposals to aerospace companies, including Rockwell International and Lockheed Martin. Joint investigative proposals with universities such as the Virginia Polytechnic Institute and North Carolina State University were submitted to the National Science Foundation, the Ballistic Missle Defense Organization, the Army Research Office, and Wright Patterson Air Force Base. All projects received funding from NASA and associated industrial partners to meet the following program goals:

- increase the number of U.S. citizens trained in NASA-related disciplines, placing special emphasis on diversity by recruiting women, underrepresented minorities, and persons with disabilities;
- encourage collaborations among faculty, colleges, universities, businesses, and industries and continue to strengthen the national network of faculty, colleges, and universities with interests and capabilities in aeronautics, astronautics and space science technology; and

- encourage interdisciplinary research programs that are relevant to the U.S. aerospace industry and promote programs in aeronautics, astronautics, and space science for research, education, and public service.

STUDENT ACHIEVEMENTS

During the 1997 academic year, special emphasis was placed on collaborative relationships with NASA's industrial partners and the strengthening of the problem-solving skills of our student researchers. This has lead to success in CAR's research endeavors, an increase in leveraged research funding, and an increase in CAR's ability to attract quality students. At the annual 1997 URC conference, CAR students delivered two of the best eight selected conference papers. CAR's faculty and students assisted in the planning and organization of the International Conference for Composite Materials Research, ICCE 98, in Las Vegas, Nevada. They organized the 1998 Human Machine Systems Engineering Symposium in Greensboro, North Carolina. During the 1997 academic year, CAR has contributed to the graduation of over 14 undergraduate students and over 9 Masters students. The faculty and students have published over 50 journal and conference papers. Several of our graduates are planning to pursue Ph.D. studies in the Mechanical and Electronics Engineering Departments at NCA&TSU. In addition, a few are planning careers in teaching and research. However, the majority of our Masters graduates have opted to join the private sector, including companies such as IBM, Boeing, Lucent Technologies, Motorola, Hamilton Technologies, and Allied Signal. Our graduates have shown a 100 percent success rate in obtaining jobs immediately upon graduation.

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The Center for Autonomous Control Engineering

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INTRODUCTION

The main theme and thrust of the NASA Center for Autonomous Control Engineering (ACE) at the University of New Mexico (UNM) continues to be soft computing (fuzzy logic, neurocomputing, and evolutionary computation) and its applications to NASA's mission and U.S. industrial needs. The Center is based at UNM, with two main partners: North Carolina A&T State University and New Mexico Highlands University. The Center is internationally recognized for intelligent techniques and their applications to control systems, signal processing, and image processing. This new technology will allow fault-tolerance fail-safe paradigms to be implemented on NASA's planetary and deep space missions. Technologies being established at ACE will allow remote devices to be controlled in spite of faulty sensors or actuators.

RESEARCH ACCOMPLISHMENTS

The cooperative robotics project has allowed intelligent control paradigms and communication protocols among robots for a given mission. Multi-agent robotic systems are now becoming a reality at ACE. Someday, these systems will allow NASA to implement projects such as multiple pathfinders working together on the planet Mars or multiple nano-satellites working in groups (i.e., "formation flying") to conduct either deep space exploration or the continued study of Earth. ACE has had fuzzy logic chips designed and fabricated for a better implementation of intelligent controllers.

ACE's virtual collaborative environment technology will allow remote devices like the Pathfinder to operate through the Internet and remote sites. This virtual collaborative testbed has been very cost effective and robust for remote-controlled experiments involving industrial robots.

ACE's smart image processing and SmartPhoto Technology Group's advances may allow for a better understanding of deep space images from sources such as the Hubble Telescope or a better understanding of Earth resources and disasters from satellite imagery.

ACE's biomedicine group is working on the broken bone healing process and how this is affected by microgravity.

ACE research results were published in 3 books, 8 journal papers and 50 conference papers in 1998.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Every NASA Strategic Enterprise can benefit from ACE's research results. Deep-space Exploration, Earth Sciences, Aeronautics, and Human Factors all stand to benefit from the work being done here. The micro-rover fuzzy logic behavior control strategy is already impacting the Pathfinder team's work at the NASA Jet Propulsion Laboratory, and will make future remote missions more productive. The work in progress by the biomedicine group will improve medical care on future manned space missions. The SmartPhoto Technology group's work has implications both for the study of space and the study of Earth.

BENEFITS TO SOCIETY

ACE strives to make its research dollars go a long way towards helping the national economy by emphasizing commercialization of its patents and innovative ideas. Presently, one hardware product and three software products are being prepared for commercial applications. These are as follows:

- CoMeT® (Computational Mechanics Toolbox)—a software environment for the modeling and identification of mechanical bodies with applications in aeronautics and space exploration;
- SmartPhotoLab®—a fuzzy logic software environment for enhancement of images from all sources, including the Internet, video, satellite, TV, VCR, etc. For example, SmartPhotoLab is being used at Johnson Space Center and City of Houston's Police Department for image content interpretation;
- SoftLab®—a soft computing software environment for the modeling, identification, synthesis, and real-time implementation of intelligent control systems; and
- PhotoCard®, a fuzzy micro-controller board to get error-proof color prints from one-hour photo machines and to produce better photos in high-end photo studios.

STUDENT ACHIEVEMENTS

In 1998, ACE students had an excellent year with respect to realizing research and educational goals. Two ACE-UNM students received $1,000 2nd place Best Paper awards at the 1997 symposium of the Mexican American Engineering and Science (MAES) meeting in San Diego, California; five ACE student papers were among the final eight for Best Paper Awards at URC-TC '98 in Huntsville, Alabama; an ACE-UNM student, Ms. Denise Padilla, received a $2,500 National Hispanic Heritage Scholarship in 1998; and an ACE student at NMHU has received a fellowship at Los Alamos National Laboratory.

ACE Centers at all three locations and fellowship posts have 55 minority students enrolled at various levels. These include 10 Ph.D. students (4 African-American, 2 Hispanic, 3 Native American and 1 Pacific Islander), 12 M.S. students (4 African-American, 7 Hispanic, and 1 Native American), and 33 undergraduate students (10 African-American, 18 Hispanic and 5 Native American). These students work primarily in teams with other students, including foreign students and students of European descent. These student groups are led by a doctoral student, and each team contains both graduate and undergraduate students at all levels, and may even contain some high school students.

ACE is proud to announce that so far 30 students have graduated from ACE Center locations and its Fellowship programs. Of these 30, 22 received M.S. degrees and 8 received doctoral degrees. In 1998, ACE had 4 Ph.D. graduates (2 African-American Americans and 2 Hispanic Americans) and 13 M.S. graduates (5 African-American Americans, 7 Hispanic Americans, and 1 Native American). The main reason for this has been vertical integration of students in groups where retainment, motivation, mentorship, and recruitment are all built into the structure.

ACE has several partnerships with other institutions. Aside from close cooperation with the main partners, North Carolina A&T State University and New Mexico Highlands University, ACE has built close cooperation with the Southwest Indian Polytechnic Institute (SIPI) and the Technical Vocational Institute (TVI) here in Albuquerque, New Mexico. ACE's doctoral students are now teaching as a matter of normal practice at SIPI and are helping revise its curriculum. A Department of Energy funded project allowed ACE students to establish new robotics courses at SIPI. In addition, ACE once again hosted a group of high school students from outside of New Mexico for 10 weeks during the summer of 1998. These students joined ACE research teams in learning many fundamental issues in technology areas and made significant contributions to their host teams at ACE.

ACE students and Director Mo Jamshidi at the robot soccer testbed.

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Human Exploration and Development of Space

NASA/FISK University Center for Photonic Materials and Devices

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Date of Original Award: 1992

INTRODUCTION

The NASA/Fisk University Center for Photonic Materials and Devices aims at performing research and developing technologies relevant to NASA's mission, focusing on the field of photonics. Research in photonics has led to the development of new technologies in this area; this has produced revolutionary changes in communications, computing, robotics, medicine, environmental control, and many industrial processes. In particular, the Center has focused its research on one of the most promising branches of photonics—one that produces new materials or improves the production of known materials. This is the initial stage of the development of the latest advanced technologies. As a result, the potential reputation of the Center will attract an increased number of disadvantaged and underrepresented students, both graduate and undergraduate, and will motivate them to pursue careers relevant to the NASA mission.

The accomplishments in research and education during 1998 were communicated in 41 refereed papers and 46 presentations at NASA installations, national laboratories, universities, and national and international conferences. Abstracts of these accomplishments and their significance are listed in the following paragraphs.

RESEARCH ACCOMPLISHMENTS

The Nanophase Materials research group uses recently developed nanotechnology methods to produce new materials that contain inclusions of single atoms, clusters of atoms, or molecules. These nanophase materials are beginning to contribute to extraordinary advances in research, development, and industrial applications. The miniature quantum well lasers, cascade IR lasers, quantum wire lasers, and high bit-rate micro-cavity LEDs are a few devices that have emerged from quantum confinement effects in semiconductor materials.

The three-dimensional confined metals and alloys are found in many significant applications in industries, including the tungsten-carbide-colbalt nanocomposite material. This material can be as hard as diamond and can be used to make cutting tools, drill bits, armor plate, and jet engine parts. The combination of nano-sized metal and magnetic materials led to the discovery of the giant magnetoresistance effect. This made it possible to achieve ultra high-density data storage. Nano-sized spherical noble metals are highly desired catalysts in the synthetic chemical and pharmaceutical industries, and nanostructured transparent coatings have been adopted for the cathode ray tubes used in televisions.

In 1998, a model was developed describing the interaction of F_n centers with gold nanocrystals embedded in magnesium oxide in term of their Fermi levels. When F_n centers are created, they act as electron donors to the gold nanocrystals. This causes the surface plasma to blue-shift. When the F_n centers are annihilated, the surface plasma red-shifts by 30 nm. This process was found to be completely reversible, and it represents the first observation of the interaction of nanocrystal with a defect.

An ultra-high vacuum chamber was constructed for fabricating quantum dots by laser ablation. The chamber was fitted with a rotating target stage, a

substrate stage which can be heated to 900° C and can be rotated 270°, an electron beam gun with three crucibles, and a quartz thickness monitor.

The objectives of the Semiconductor and Films group are to increase knowledge of properties, structures, and processing relationships in wide bandgap semiconductors, and the way they affect the performance of radiation detectors. In particular, we are attempting to evaluate Earth- and micro-gravity-grown crystals and determine their relative contributions to defect incorporation. In order to assess that contribution, highly sensitive analytical tools were developed, and compositional non-uniformities, micro-structural defects, and native point defects that limit the device performance were investigated.

NASA has identified the use of wide bandgap, semiconductor detector technology as a promising technology for x-ray and gamma-ray astronomy. Room-temperature detectors fabricated from these materials have broader applications of clear benefit to the society. These benefits include the early detection of breast cancer, brain and heart nuclear medical imaging, nuclear waste monitoring, nuclear non-proliferation, oil logging, and so forth. During the last year, we have developed novel surface treatments and electrical contact applications that lead to improved performance detectors. The crystals were investigated for their defect content using optical and electron microscopy and by low-temperature photoluminescence to determine the presence of point defects. The effects of gravity on the distribution of dopants during the crystal growth of zinc selenide by the physical vapor transport technique were also investigated.

A device based on cadmium zinc telluride crystals that detects and analyzes x-rays and gamma-rays, designed by a group formed by the Fisk Center, Sandia National Laboratory, Radiation Safety Engineering Inc., and Ludlum Measurements Inc., won one of the 100 best 1998 Research and Development Awards for innovative excellence. The award was presented on September 24, 1998, at the Museum of Science and Industry, Chicago, IL.

A third group is working with glasses and other optical materials that can be used to make new laser sources. Glasses have the advantage of easily being formed into whatever shape is required and in particular can be drawn into very thin optical fibers. With the appropriate heat treatment, certain glasses can also be transformed into ceramic materials (glass-ceramics). Some of the glasses being studied at Fisk can be used to make optical fiber lasers, which provide compact, rugged sources of near-infrared laser radiation. This group has produced and is continuing to develop a new glass (rare-earth-doped lead-tellurium-germanate), which shows great promise as a fiber laser material. New glass-ceramic materials doped with rare-earth elements are also being developed for use as selective emitters in thermophotovoltaic energy systems.

These materials, when heated, emit light in wavelength regions that can be efficiently utilized by solar cells, and can thus form part of a compact system that can convert heat energy into electrical energy. These materials have wide applications for space technology due to use in compact, rugged, lightweight systems for light generation and energy conversion. Potential applications of these materials which can benefit the general public include, for example, compact, reliable laser systems to be used on board civil aircraft for windshear detection and thermal-to-electrical energy systems which can be used to provide electricity in remote areas.

Finally, a fourth group possesses the most modern equipment for studying the physical structure and chemical composition of solid surfaces, as well as the modifications introduced to those surfaces by the usual methods used to prepare them for practical applications.

Studies are being conducted on silicon carbide (SiC), a new semiconductor with superior characteristics. The SiC-based electrical/optical devices can result in greatly enhanced performance and reliability under severe operational environments. They can be operated at high temperature, in high radiation fields, and at high power levels. The studies of metal thin film/SiC contacts have wide applications in chemical sensors, photodiodes, power switching devices, and interconnections in microelectronics.

Our studies of the electrical properties and interfacial compositions of palladium and gold ultra-thin films on 6H-SiC and 4H-SiC at high temperatures have demonstrated for the first time the effects of SiC surface structural factors to Pd ultra-thin film mechanical properties. The study of Ce/SiC contact properties also was started. A collaboration agreement with NASA/MSFC in sol-gel composite optical materials has been established. The development of a sol-gel materials fabrication laboratory has been started.

We continue to increase our research capability; an ultra high vacuum electron beam evaporation thin film fabrication with *in situ* characterization system

has been designed and the Plasma Sciences Laboratory was fully established this year. Experimental studies were performed using three independent plasma sources: DPX (Dusty Plasma eXperiment), FPS (Fisk Plasma Source), and PHLUX (Plasma Hybrid Linear University eXperiment). The Laboratory focuses on investigations of plasma-material interactions and dusty plasmas, which are important in astrophysics and the industrial processes performed in semiconductors and other photonic devices.

STUDENT ACHIEVEMENTS

Graduate and undergraduate students from the physics and chemistry departments at Fisk were pursuing research in all components of the Center using state-of-the-art scientific facilities. During the 1997-98 academic year, 30 undergraduate students and 15 graduate students participated in the research activities. The highlight of our student training activities was the Summer Research Program, an intensive 9-week, full-time program of study and research, during which 14 undergraduate students (from 7 minority universities and 5 states; 10 females and 4 males) participated in the research activities of the Center. As a result of their summer experiences, all four seniors who participated in the program applied were accepted by Fisk University for graduate studies.

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Space Medicine and Life Sciences Research Center

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Date of Original Award: 1995

INTRODUCTION

The overall strategic goals of the NASA Space Medicine and Life Sciences Research Center (SMLSRC) at Morehouse School of Medicine are to answer important questions in life sciences and biomedicine that are of relevance to the mission of NASA; increase the number of minority students and postdoctorates trained in space medicine and life sciences research and embarking on careers in that area; and foster the development of faculty members engaged in space-related biomedical research by providing scientific advisors, research funds, and opportunities for collaboration.

The Center is divided into three research teams. These teams specialize in cardiovascular, cell, and musculoskeletal biology, and are comprised of eleven faculty members. The cardiovascular team examines hemodynamic responses of salt-sensitive rats and humans to simulated microgravity. This team uses the hind-limb suspended method for rats and the head-down-tilt bed rest model for humans. The musculoskeletal team is determining whether the drug Clenbuterol may be used as a countermeasure for the muscle wasting and bone loss that is observed in rats under simulated microgravity conditions (hind-limb suspension). The cell biology team examines the differentiation, development, and function of vascular, skeletal, and neuronal cells and tissues in a NASA bioreactor, which simulates aspects of a microgravity environment.

RESEARCH ACCOMPLISHMENTS

Cardiovascular
Space flight results in reduced body fluid volume and orthostatic hypotension upon reentry to Earth. Dietary salt is a contributing factor to the development of hypertension in individuals who are salt-sensitive. Studies with human subjects show that salt-sensitive individuals have higher peripheral vascular tone and are less likely to develop a drop in blood pressure after short-term bed rest. Post-suspension hypotension is observed in rats as well and salt-sensitivity/salt-loading may serve as a partial countermeasure. Calcium loss into urine in response to high salt intake was found to be unaffected by salt-sensitivity, but blood levels of two vitamin D metabolites were reduced in salt-sensitive rats in response to high salt intake.

Musculoskeletal
The musculoskeletal team is involved in a study to determine whether the drug Clenbuterol can reduce the muscular atrophy caused by hind-limb unloading in mature rats. The drug prevented loss of both wet weight and total protein in muscles composed largely of fast fibers. Clenbuterol did not protect against wet weight loss in slow muscles, but it did help to maintain total protein content of these muscles.

Vascular
Endothelial and smooth muscle cells from blood vessels have been cultured in a horizontally rotating bioreactor (simulated microgravity). This environment allows for three-dimensional vascular cell growth with the spontaneous formation of capillary-like structures. These three-dimensional aggregates form best under slowly rotating conditions. The aggregates will allow the team to focus on the function of vascular cells under simulated microgravity conditions. This is the first time that tube-like structures have been formed without a required three-dimensional scaffolding.

Retinal
Co-culturing of retinal and endothelial cells in the bioreactor caused early induction of capillary-like structures and the enhancement of photoreceptor differentiation in retinal cells.

Skeletal
Experiments with bone tissue cultured in the bioreactor suggest that bone tissue is sensitive to simulated microgravity at the earliest developmental stages, resulting in the prevention or retardation of differentiation and mineralization. If the initial development takes place prior to placement in the bioreactor, however, development proceeds to almost normal levels.

RELEVANCE TO NASA STRATEGIC ENTERPRISE

These studies will lead to the development of countermeasures for the cardiovascular changes and the bone loss and muscle wasting experienced by astronauts during space flight.

BENEFITS TO SOCIETY

The SMLSRC is contributing information on salt-induced hypertension. There is a potential that blood levels of the liver metabolite of vitamin D may be used to distinguish salt-induced hypertension from other forms. This would improve the treatment outcome for salt-induced hypertension. This project has particular relevance to the black American population, because of the higher rate of hypertension and salt-sensitivity in that population compared with the white American population.

The use of the horizontally rotating bioreactor should prove valuable in generating three-dimensional tissues for scientific research projects.

The SMLSRC will also benefit society by providing information that may be used toward the treatment and prevention of skeletal problems, such as osteoporosis, and the bone loss and muscle wasting experienced by patients that must undergo extensive bed rest.

STUDENT ACHIEVEMENTS

The SMLSRC supported 7 graduate and 14 undergraduate students this year. One student received the Hypertension Award at the 1998 Western Regional Meeting of the American Federation for Medical Research.

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Center for Applied Radiation Research (CARR)

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Date of Original Award: 1995

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 led to a more fundamental and practical understanding of radiation effects on electronics, materials and bio-systems; a dialog between space, military and commercial electronics manufacturers; innovative electronic circuit designs; the development of state-of-the-art research facilities at PVAMU; recognition of CARR as a resource for radiation testing for industry, academia, and government agencies; expanded faculty and staff to mentor student research; and, most importantly, an increased flow in the pipeline leading to the enhanced participation of African-Americans and other minorities in science and technological fields of interest to NASA.

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 bio-systems. CARR seeks to

answer essential questions concerning various projects within the NASA Strategic Enterprises and explores the 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.

RESEARCH ACCOMPLISHMENTS

During the past year, CARR technical efforts concentrated on research and activities directly related to stated NASA needs. We especially focused on the needs of the Human Exploration and Development of Space (HEDS) Strategic Enterprise, Office of Space Flight, emphasizing work applicable to the International Space Station (ISS) and a possible future Mars Mission. This research included proton tests conducted on International Space Station opto-electronic parts, proton tests conducted on commercial-off-the-shelf (COTS) and radiation-tolerant memory circuits, and total dose tests conducted on COTS field-programmable gate arrays (FPGAs). CARR also accelerated the development and enhancement of experimental facilities that greatly increase CARR's ability to perform research in its core competencies. A comprehensive test program on COTS memory circuits has been initiated. This program includes the development of a versatile, compact, portable radiation testbed. This testbed is designed to be easily transportable to remote ground-based radiation sources and to be light enough for practical in situ testing. A prototype of the testbed has already flown on two high-altitude balloon flights and is scheduled to fly onboard the NASA ER-2 high-altitude research aircraft and the space shuttle.

These efforts have allowed CARR to attract additional funding from within NASA, industry, and other funding agencies. For example, CARR's HP82000 test facility at the Texas A&M Cyclotron Institute attracted its first commercial customers this year.

CARR maintains strong relationships with several major university subcontractors and affiliates. Many of these affiliates were started before CARR was established. We also have longstanding interaction with industry at all levels. In addition to enhancing CARR research, these relationships have resulted in leveraged funding from both government and industrial sources. This complementary research has been directed into CARR's major technical research areas.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This crosscutting research has applications in other NASA strategic enterprises such as Aero-Space Technology (avionics on the High-Speed Civil Transport and Single Stage to Orbit Vehicles) and Space Science (deep space probes, orbital science satellites). In fact, some radiation effects that CARR explores, such as single event effects (SEE), are now a concern to Earth-bound technologies, such as the modern complementary metal-oxide-semiconductor (CMOS) technology found in most state-of-the-art integrated circuits. We are examining this convergence of need between space avionics and commercial integrated circuit manufacturers.
Our efforts to understand space radiation effects on biosystems continued this year. Our focus is on the human reproductive system. CARR's research is applicable to female astronauts on long duration missions such as ISS or a Mars Mission as well as to female crewmembers working onboard a future High-Speed Civil Transport.

STUDENT ACHIEVEMENTS

CARR emphasizes student involvement in all its efforts. During the past year, 38 undergraduate and 14 graduate students have participated in CARR research and activities. This participation includes a student intern at NASA/Dryden and student presentations at NASA/Wallops. In addition, eight CARR students presented research results at the 1998 University Research Centers Technical Conference in Huntsville, Alabama.

CARR students have been very successful in obtaining jobs in the science, math, engineering and technology (SMET) fields. Many hold positions in the semiconductor and communication industries. Those who go on to graduate school stay in a SMET area. Of the graduate students working with CARR who finished their degree last year, all have found employment with high-technology organizations or gone on to professional school.

CARR's outreach programs span the range from preschool to graduate school. CARR faculty and staff participate in a variety of activities intended to attract students to the SMET fields. During the past year, this included (among other things) giving talks at local high schools; creating a picture story of a stuffed bear that visited NASA Dryden Flight Research Center; attending student organization conferences; hosting summer students; activities with a local Boy Scout Post; awarding scholarships to engineering students; and providing support for

university engineering design labs and competitions.

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Center for Food and Environmental Systems for Human Exploration of Space

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Date of Original Award: 1992

INTRODUCTION

The Center for Food and Environmental Systems for Human Exploration of Space (CFESH) focuses on the development and refinement of information, technology, and systems for the production and utilization of sweet potato and peanut bio-mass that meet the design plans of NASA's Advanced Life Support program (ALS). The Center's overall objectives are to determine the optimal conditions for sweet potato and peanut production through cultivation, evaluation, improvement, and assessment of nutritional requirements, environmental factors, cultural practices, processing, recipe development and testing, nutritive analyses, and resource recovery while primarily utilizing biological agents. These objectives are being accomplished through the integrated efforts of CFESH's four research groups: Crop Production and Environmental Systems, Food Technology and Utilization, Germplasm Development and Improvement, and Waste Management and Resource Recycling.

RESEARCH ACCOMPLISHMENTS

Two of the more notable research findings of the past year are highlighted here. The first is the progress that has been made in refining a crop-growing protocol for peanuts, one of the baseline crops for ALS. A number of temperature and relative humidity (RH) studies were conducted on peanuts. A 28/24 C temperature regime coupled with an RH of 85 percent was found to be optimal and has been recommended for use in ALS. The second is a follow-up to our 1997 report of the increase in protein content in sweet potatoes and peanuts through biotechnology. This past year, we identified the source of that protein increase. After successfully introducing the synthetic *asp*-1 protein gene into sweet potatoes, we conducted two positive field tests for growth comparisons with conventionally grown sweet potatoes. The high protein gains in our transgenic sweet potatoes have been shown to be due to increased sporamin in two separate laboratory tests.

The Crop Production and Environmental Systems Research Unit emphasized peanut and sweet potato environmental/physiological factors, nutrition, and plant modeling. Findings from temperature studies with peanuts indicated that total biomass increased with temperature. At the same time, the time to the appearance of the first flower was delayed. Leaf temperatures averaged 1.5 C below air temperature. Studies showed that the interaction of CO_2 and light intensity increased total biomass. Edible yield increased with CO_2 enrichment under both high and low light intensities. However, the magnitude of increase was higher under high light intensity.

Sweet potato plants grown with metal halide lamps had shorter vines than plants grown with high-pressure sodium lamps. Storage root biomass was not adversely affected by lamp type. Studies on sweet potato with critical nitrogen levels indicated an inverse relationship between storage root and vine growth.

The Food Technology and Utilization Research Unit has been working on processing, recipe development, nutritive quality, and composition of peanut and sweet potato products. An aqueous method was used to extract peanut oil. The peanut residue left after oil extraction was high in protein (48 percent) and exhibited high water and oil binding functional properties. The addition of oil and plasticizer improved the flexibility and extensibility of edible film prepared from defatted peanut protein. This film can be used as a biodegradable food packaging material.

Enzymatic hydrolysis was used to produce sweet potato syrup. Analysis of high-protein transgenic sweet potatoes revealed a lower starch content and higher ash content than controls, indicating that genetic manipulation may cause changes in nutrient composition. Animal feed experiments indicated that transgenic sweet potatoes had no toxicity effect and lowered serum cholesterol levels of test animals.

Studies characterizing paper-like products prepared from sweet potato stems, peanut shells, and soybean pods found the highest tensile strength in the sweet potato stem products.

The Waste Management and Resource Recycling Unit has been involved in evaluating effluent and sludge from aerobic biodegradation of sweet potato biomass. An Oxymax-C Chamber (Columbus Instruments) was modified for use as a continuous stirred tank reactor by incorporating in-line pH monitoring and control and temperature and electrical conductivity monitoring. Preliminary results from composting sweet potato biomass indicated increased macronutrient concentration in the effluent during the first two weeks. Activities in the area of protein characterization yielded an operating protocol.

The Germplasm Development and Improvement Research Unit has recommended three high-yielding sweet potato cultivars to be released for growth in controlled environments using the nutrient film technique. A three-year successive yield stability test of several sweet potato breeding lines in three varied environments (field, greenhouse, and growth chambers) showed one high yielding line to be very stable. The variety is expected to perform well under either favorable or adverse conditions. An animal feeding study using *asp*-1 transgenic sweet potato plants whose protein content was increased by the introduction of the *asp*-1 gene showed that animals fed transgenic sweet potatoes weighed 56 percent more at the end of 28 days than animals fed with control sweet potatoes whose protein content had not been altered. Based on this study, we estimate that there is a 30 percent increase in protein efficiency in the *asp*-1 transgenic sweet potato. Transgenic sweet potato lines with the *asp*-1 gene are being tested under tropical field conditions in the U. S. Virgin Islands. A new storage protein gene *DNP-2* has been introduced into two sweet potato cultivars (Beauregard and Jewel) and one peanut cultivar (New Mexico).

RELEVANCE TO NASA STRATEGIC ENTERPRISES

As part of the Human Exploration and Development of Space Enterprise's objective to expand the human experience into the far reaches of space, CFESH specifically provides information to NASA on critical issues pertaining to bio-regenerative life support systems as a component of the Advanced Life Support program. Plants, a principal ingredient in a bio-regenerative life support system, can serve as a food source, as air and water purifiers, and to enhance the aesthetics of the human habitat. NASA has identified baseline crops for future planetary food systems. Information on production in controlled environments, food processing, and resource recovery for the baseline crops is needed as input to NASA's decision making. CFESH provides this information to NASA for sweet potatoes and peanuts.

BENEFITS TO SOCIETY

Recent benefits resulting from the efforts of CFESH scientists and students are the development of new products and methodologies, identification/verification of a significant health benefit of sweet potatoes, and improvement of the nutritional value of sweet potatoes. Center scientists have developed an edible film from peanut protein that has potential applications as a food packaging material. Paper-like products have been developed from non-edible parts. Omega-3 fatty acid (α- linolenic acid) found in sweet potato leaves reduces high cholesterol in humans. Thus, Omega-3 fatty acid can potentially reduce the incidence of stroke and heart disease. CFESH's biotechnology-induced protein increase in sweet potatoes has potential significance for developing regions of the world where food security in general and protein deficits in particular are major concerns. Sweet potatoes are produced in most of these areas. The technology is potentially transferable to other crops as well. This technology has the potential to be an important spin-off of NASA research with significant benefits to humankind.

STUDENT ACHIEVEMENTS

Jacquelyn Jackson, a first year graduate student, received special recognition from Johnson Space Center following her summer internship for her contributions to the evaluation of organic wicks in lettuce seed germination and plant growth. Casey Hamilton, a first year graduate student, won first place in the Graduate Student Paper Competition at the NASA URC Technical Conference, February, 1998, in Huntsville, AL.

Kamau Crawford, a senior in Environmental Science now pursuing graduate study in the same area, spent the summer at the Institute of Ecosystem Studies researching denitrification in urban/rural riparian wetlands. Michon Walker, a first year graduate student, applied N-terminal sequencing techniques for protein characterization to transgenic sweet potatoes during a summer research opportunity at Iowa State University.

Craig Battle, Lakisha Odom, and Ronald Grider, summer interns at Kennedy Space Center, worked

on concentrating solid organics in nutrient solution, development of a nitrification reactor, and evaluating the ecological effects of elevated CO_2 on a scrub oak community.

Hurann Walton, a graduate student at Tuskegee University in environmental science, stands next to a 40-liter Oxymax-Csystem reservoir which she uses in her study of degrading biomass by composting.

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Earth Science

Center for Hydrology, Soil Climatology, and Remote Sensing

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INTRODUCTION

The research thrust of the Center for Hydrology, Soil Climatology, and Remote Sensing (HSCaRS) is developing a comprehensive research program that investigates hydrologic processes, with emphasis on remote sensing measurements and modeling of soil moisture. The objectives are threefold: first, to develop a measurement/modeling strategy from low-resolution microwave data to derive soil moisture profile information and to determine its variability on a range of spatial scales; second, to develop a precise, inexpensive, in situ technique for measuring soil moisture to facilitate ground truth of remotely sensed data and validation of global and regional climate change models; and third, to take knowledge from hydrologic modeling, coupled with evolutionary computing techniques, to model and visualize soil moisture, soil erosion, and contaminant transport through soils and within water bodies.

RESEARCH ACCOMPLISHMENTS

The Center's activities are grouped into four major research areas: Hydrology/Hydrologic Modeling (H/HM), Remote Sensing/Geographic Information Systems (RS/GIS), Evolutionary Computing (EC), and Sensor Development (SD). There is also an Educational Outreach (EO) component.

Our research accomplishments during this academic year included the publication of 18 refereed manuscripts, 36 non-refereed manuscripts in conference proceedings, and 88 scientific presentations at national and international professional conferences.

Hydrology/Hydrologic Modeling
The Hydrology/Hydrologic Modeling (H/HM) team developed a soil dielectric mixing (SDM) model, using the FORTRAN language and a vegetation correction factor, to estimate soil moisture using microwave brightness temperature data. The SDM model was designed using the theories proposed in the Dobson et al. (1985) publication in the *IEEE Transactions on Geoscience and Remote Sensing, GE-23* (No. 1, pp. 35-46). The vegetation correction factor was obtained from the Jackson and Schmugge (1991) publication in *Remote Sensing of Environment* (Vol. 36; pp. 203-212). The SDM is very sensitive to bulk density and soil temperature, but does not appear to be affected by changes in soil texture. These results have significant implications for remote sensing of soil moisture from aircraft and space platforms (see Figures 1 and 2).

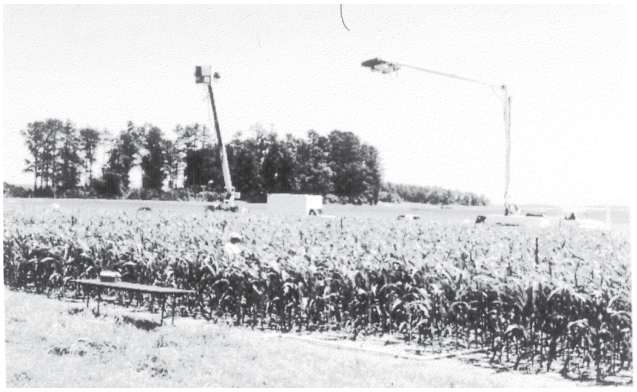

Figure 1. Collection of microwave remote sensing data using active and passive sensor systems during HSCaRS 1998 summer field experiments.

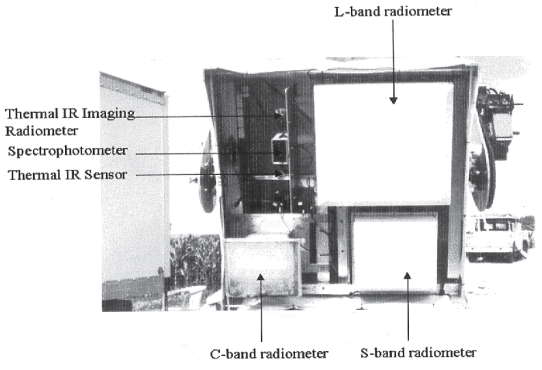

Figure 2. Close-up of the S and L band microwave radiometer (SLMR), the C band radiometer, the Spectrophotometer, the Thermal IR Sensor, and the Thermal IR Imaging Radiometer.

A stochastic model (see Equation 1) was developed to predict soil moisture content within the top 10 cm. The model was developed using a Decatur silt loam soil under alfalfa (cultivation). It was tested using data collected during the HSCaRS 1996 Summer Field Experiment. The results showed a good agreement between the observed and predicted soil moisture in the 10 cm layer of soil.

$$\Theta = 28.87 + 0.44P_d - 0.24P_{d-1} + 0.04P_{d-2} + 0.04T_a \quad [R^2 = 0.65]$$

Where: P_d = Current day precipitation (mm); P_{d-1} = Previous day Precipitation (mm); P_{d-2} = Previous two day precipitation (mm); T_a = Average temperature (°C)

Equation 1

A forward radiative transfer model has also been developed, which estimates microwave brightness temperature from known soil moisture and temperature profiles. This model includes the effects of surface roughness and vegetation. An inverse model was also developed to invert the microwave brightness temperature for soil moisture.

Remote Sensing/Geographic Information Systems

The Remote Sensing/Geographic Information Systems (RS/GIS) team developed a model to determine the vegetation attenuation effect on microwave energy transmission using the HSCaRS 1996 data set. The model is being used to study the effect of vegetation on microwave remote sensing of soil moisture and hydrologic models.

All of these models were tested using the microwave data collected during the HSCaRS 1996 summer field experiments and validated using gravimetric soil moisture measurements. Further testing and refinement of the models will be done using data collected during the HSCaRS 1998 summer field experiments, which took place during the period of June 14-28, 1998 (Figures 3a, 3b, and 3c).

Figure 3a. Ms. Akilah Martin and Mr. Keith Pullum are positioning absorbing panels on the L, S, and C band microwave radiometers.

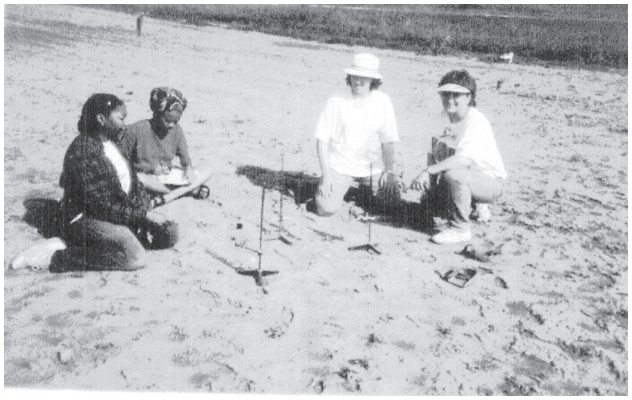

Figure 3b. HSCaRS Summer Enrichment Program students performing infiltration studies during HSCaRS summer 1998 field experiments (from left to right: Ms. Eboni Crayton, Ms. Elissa Palmer, Ms. Christine Bowman, and Ms. Janet Martinez).

Figure 3c. Mr. Frank Archer III and Dr. Andrew Manu collecting soil moisture samples for validating microwave remote sensing algorithms.

Evolutionary Computing

The Evolutionary Computing (EC) team developed a Quantum Indeterministic Parallel Genetic Algorithm for sensor data disaggregation. This system simulates an optical processor with a photon counting camera. It has the property of a monotonically increasing or decreasing figure of merit, which speeds the convergence to an optimal solution. Additionally, the team developed Pulse Coupled Neural Network (PCNN) modeling software using the Java programming language. This model was adapted for a novel type of multispectral/ hyperspectral sensor fusion. The preliminary results are promising, and may prove to be very beneficial in extracting features from hyper-spectral data.

Sensor Development

The Sensor Development (SD) team developed and tested three portable soil moisture sensors during this past year. The sensor that showed the most promise was developed using a fiber-optic sensor based on the total internal reflection of light, and is sensitive to ± 0.01 percent. The major drawback of the sensor is that it must remain stationary in the soil (Figures 4a, 4b, and 4c).

Figure 4a. Field testing of the Fiber Optic Sensor during HSCaRS 1998 summer field experiments; the sensor is located by the white bucket at the far left. The light source, light detector, and the chart recorder are stored in the small house. Optical fiber extends from the house to the sensor and from the sensor to the house under the wooden board.

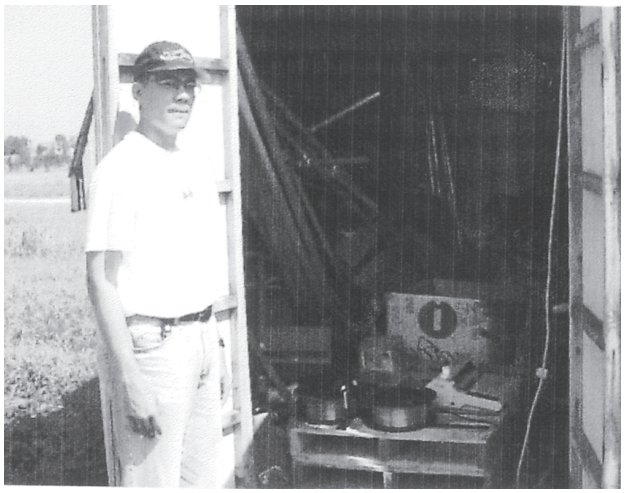

Figure 4b. A close-up of the equipment inside the small house: light source, light detector, chart recorder, and two 250-meter bundles of optical fiber.

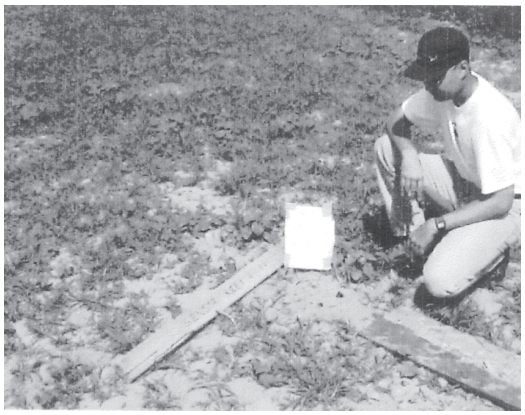

Figure 4c. A close-up of the sensor location in the ground showing the wooden board under which the optical fiber is placed.

Educational Outreach

The Educational Outreach component once again sponsored the HSCaRS Summer Enrichment Program. This year, there were 17 new and 1 returning undergraduate students who participated in the program. The students worked with mentors from Alabama A&M University and the Global Hydrology and Climate Center for a total of eight weeks. These students also participated in the HSCaRS 1998 Summer Field Experiments and presented their findings at the student symposium during the last week of the program (Figure 5).

Figure 5. HSCaRS Summer Enrichment Program students during the Huntsville 1998 field experiments (from left to right, front row: Mr. Jay Wiggins, Ms. Ebony Gaston, Mr. Quincy Wilson, Ms. Sarah Bowmen, and Ms. Shelbi Hostler; back row: Ms. Oyin Williams, Ms. Eboni Crayton, Ms. Elissa Palmer, Mr. Lawrence Ferguson, Ms. Vonda Little, Ms. Amy Apprill, Ms. Dierdre Teeter, and Mr. Samuel Santana).

The Center also sponsored a one-week workshop entitled "Integration of Remote Sensing, GIS, and GPS Technology," for Historically Black Colleges and Universities (HBCUs) faculty members to enhance their knowledge in the applications of these technologies. The workshop had 17 participants and took place August 10-15, 1998, in the HSCaRS facilities on Alabama A&M University campus (Figure 6).

Figure 6. Participants in the HSCaRS HBCU Workshop, August 10-15, 1998 (from left to right, front row: Dr. Shobha Sriharan, Dr. George DaBai, Dr. Lisa Mueller, Dr. Katherine Milla, Dr. Francisco San Juan, and Dr. Vernon Jones; middle row: Mr. Wubishet Tadesse, Mr. Fesseha Gevremikael, Dr. Chukudi Izeogu, Dr. John Meister, Dr. Alfredo Lorenzo, Dr. Stacy White, Dr. Pauline Lindo, and Ms. Sylvia Long; back row: Dr. Eric Rahimian, Dr. Teferi Tsegaye, Dr. Alton Johnson, Dr. Dale Loberger, Dr. D. Chongo Mundende, Dr. Phil Loretan, Dr. Tommy Coleman, Dr. Ravi Malik, and Dr. Ahmed Fahsi).

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The research and educational outreach activities of HSCaRS are well grounded in the Strategic Plan of NASA's Earth Science Enterprise (ESE). The overall goals of HSCaRS fit within three of the stated goals of ESE, which are to increase understanding of the Earth as an integrated system; to observe and characterize the Earth system using satellite, aircraft, and associated research systems; and to characterize and understand natural and human-induced changes on global and regional scales with emphasis on climate change.

BENEFITS TO SOCIETY

The research activities being conducted in HSCaRS will enable the average citizen to better understand hydrology and the role of soil moisture in our ecological system.

STUDENT ACHIEVEMENTS

Our students co-authored two refereed manuscripts and presented 38 scientific papers at national and international professional conferences. Of those presentations, 17 non-refereed manuscripts were published in Conference Proceedings.

Twenty-one of the undergraduates affiliated with HSCaRS earned their B.S. degrees during the 1997-98 academic year. Three students, Mr. Johnny L. Boggs, Mr. Tabarius Gay, and Mr. Donvilla Williams, received M.S. degrees, and Reginald S. Fletcher earned a Ph.D. All four individuals are now working in a NASA-related science field.

One of our undergraduate students in physics, Mr. Ryan Swain, was named to the 1998 All-U.S.A College Academic Team. This is a 60-member team chosen from a field of 1,194 students nominated by their schools from around the U.S. The criteria include grades, academic awards, leadership roles, and public service. Ryan was one of 11 men and 9 women who made up the First Team Winners. They received a cash award of $2,500.

Mr. Johnny Boggs received the School of Agricultural and Environmental Sciences Outstanding Graduate Student Award for 1997-98.

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Research Center for Optical Physics

Director: Dr. Doyle Temple
Department of Physics
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Date of Original Award: 1992

INTRODUCTION

The mission of the Research Center for Optical Physics (RCOP) is to promote world-class leadership in selected areas of optical sciences and technologies and to develop under-utilized human resources to meet the Nation's science and engineering labor needs in the 21st century. The vision of RCOP is to establish Hampton University as a premier institution for optical scientific advancement and education in the Mid-Atlantic United States. There are three areas of research that form the core of the RCOP's strategic focus:

- Atmospheric Sciences and Optical Remote Sensing Technology;
- Optical Materials (including laser, nonlinear optical, and smart materials development); and
- Non-Intrusive Diagnostics.

RESEARCH ACCOMPLISHMENTS

During the past year, RCOP researchers have developed a variety of new technologies and made a number of significant scientific discoveries. In the area of atmospheric sciences and remote sensing RCOP researchers have developed new laser light sources that are used to study ozone molecules in the upper atmosphere; a new tunable infrared laser for use in measurement of greenhouse gases for the study of global warming; and new laser technology that is used to assist NASA scientists in their study of aircraft wake vortices, a major factor in airline safety.

In the area of optical materials, the RCOP has developed a new patented method of calibrating fiber optic sensors for use in monitoring structures such as bridges or airplane wing surfaces; made discoveries about the physical properties of new holographic data storage materials that have potential to dramatically increase data storage capacity above that of CD-ROMs; successfully fabricated new organic thin films for use as low-current LEDs, thresholdless laser devices and photonic band gap materials; and developed new technology for the testing of mid-infrared laser materials for use in eye-safe lasers for remote sensing.

In the area of non-intrusive spectroscopy, the RCOP has developed new technology to detail the flow analysis of the High-Speed Flow Generator (HFG) at NASA's Langley Research Center for use in aerodynamic measurements; new techniques to measure the flow velocity at the nozzle exit of the Solar Thermal-Electric Propulsion (STEP) systems for use in low- to high-orbit transfer vehicles; and a new, very high sensitivity, focusing Schlieren system for a fast flow visualization of low-density flow fields.

The RCOP has also established numerous research and educational collaborations with private industries, NASA and other government agencies, and universities. Some of include: Brimrose Corporation of America; Spire Corporation; Hughes Research Laboratories; Northrop-Grumman; NASA Langley Research Center; NASA Glenn Research Center; Clark Atlanta University; Florida A&M University; the

University of Rochester; the University of Hamburg; Fisk University; Norfolk State University; the University of Florida; California State University, Sacramento; the Virginia Polytechnic Institute; Virginia State University; and the AF Loffe Physicotechnical Institute of the Academy of Sciences in St. Petersburg, Russia.

This year the Center completed development of six, state-of-the-art research laboratories:

- The Optical Remote Sensing Technology Laboratory is developing lasers for lidar remote sensing of the atmosphere (especially those of significant value to the mission of NASA), field measurements with lidar systems, interpretations of lidar data in conjunction with other atmospheric data in order to understand atmospheric chemistry and physics, and laser diagnostic techniques for other applications.

- The Ultra-Fast Laser Spectroscopy Laboratory has developed a state-of-the-art wave-mixing spectroscopy laboratory for the study of nonlinear properties of new materials, such as single crystal oxides, polymers, organic thin films, and multiple quantum well devices.

- The Organic Thin Film Laboratory has developed the technology for fabricating organic thin film devices for use as low-current LEDs, threshold-less laser devices, and photonic band gap materials.

- The Fiber Optics Sensors and Smart Materials Laboratory is fabricating discrete stress, strain, temperature, and acoustic fiber-optic sensors along with their readout interfaces for NASA-oriented uses. Also under development in this lab are high-definition distributed Bragg grating fiber-optic sensors as well as systems that can address the particular needs of NASA's Earth Science Enterprise.

- The Laser Materials Development Laboratory has established a state-of-the-art laser spectroscopy laboratory for the characterization and device testing of new optical materials developed by NASA Centers, universities, and industry.

- The Non-Intrusive Diagnostics Laboratory has established a high-resolution spectroscopy facility that allows complete visualization of aerodynamic flows; developed an advanced global flow visualization system; and developed new optical diagnostic techniques for the detailed analysis of the flows for validating models of physical and chemical processes in aerothermodynamics and propulsion research.

STUDENT ACHIEVEMENTS

During the past year, there were 43 students who participated in RCOP research and education programs, including 8 African-American high school students, 19 African-American undergraduate students, and 16 African-American graduate students. One African-American student earned a Ph.D. and two African-American students earned masters degrees. In addition, 3 students passed the doctoral qualifying examination in Physics, bringing the total number of doctoral candidates to 10, 7 of whom are African-American.

The Center hosted several very successful outreach programs. These included The Advanced Undergraduate Research Using Optical Radiation in the Atmosphere (AURORA) program, a six-week program in atmospheric sciences for undergraduate students; the Undergraduate Institute in Physics (UnIPhy), a research training program for undergraduate students in optics; the "Adopt a Class" elementary school program, in which a third grade class was introduced to various science activities including building and launching model rockets; and a mentorship program in the local area schools. RCOP faculty and students also undertook a host of other outreach and recruiting activities in the local elementary, middle, and high schools.

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Center for the Study of Terrestrial and Extraterrestrial Atmospheres

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Date of Original Award: 1992

INTRODUCTION

The Center for the Study of Terrestrial and Extraterrestrial Atmospheres (CSTEA) is an interdisciplinary research unit with 17 participating faculty members from the departments of chemistry, physics, mechanical engineering, and electrical engineering. The primary focus of CSTEA is to establish a world-class facility for the study of atmospheres, with special emphasis on the training of underrepresented minorities in the space-based sciences and engineering. Specific research topics are varied and range from in-situ aerosol detection and chemical sensor development to laser spectroscopic studies of free radicals and the analysis of remote sensing data obtained from the recent Tropical Rainforest Measurement Mission (TRMM) satellite. CSTEA has strong research ties to the Laboratory for Atmospheres at NASA's Goddard Space Flight Center, Penn State University, the University of Colorado at Boulder, and NASA's Langley Research Center.

RESEARCH ACCOMPLISHMENTS

CSTEA research is divided into three basic areas: atmospheric chemistry, theory and computation, and field experiments and remote sensing. The division for atmospheric chemistry is focused on laboratory studies of photochemistry, kinetics, chemical dynamics, and spectroscopy of free radicals and aerosols of importance in planetary atmospheres. Current studies are centered on tropospheric chemistry, reactions in cometary atmospheres, and the atmospheres of Titan, Venus, and interstellar molecular clouds. Other research in this division involves the development of chemical sensors, especially those that can be incorporated into field instrumentation.

The theory and computation group has diverse research interests which range from numerical modeling of turbulent flows, dispersion modeling of flows over complex terrain, gravity wave dynamics in planetary atmospheres, molecular modeling of chemical reactivity, and kinetic modeling. Computational resources include an assortment of Silicon Graphics, Sun Microsystems, IBM RS6000, and DEC workstations. A new computer lab is under renovation; when completed, it will house two additional Silicon Graphics and DEC workstations, as well as several Power PCs. Although it will primarily serve as the student computer lab, it will also be available for principal investigators and collaborative research.

The field experiments and remote sensing group is involved in the analysis of satellite data pertaining to NO distributions in the mesosphere, lightning development in thunderstorms, tropical lightning climatology, and atmospheric aerosols. Several investigators in this group also work collaboratively on instrument development.

In addition to the satellite remote sensing efforts, CSTEA sponsors three major field campaigns: the Stratospheric Particulate and Aerosol Measurements, the CSTEA Howard Oxidants and Air Quality Experiment (CHOAQE), and the Colorado High Plains Study.

Stratospheric Particulate and Aerosol Measurements
The aerosol measurement experiments evolved from an earlier set of flight experiments aboard the NASA ER-2 research aircraft (1994-1996). These studies were known as the Stratospheric Wakes Analysis Project (SWAP), and their main purpose was to characterize the chemical and vortex breakdown in the far field region of stratospheric aircraft wakes. These experiments also led to spin-off research in optimizing the performance of the quartz crystal microbalance cascade impactor, the instrument used to take in-flight measurements. CSTEA has now developed individual sampling and detection modules for atmospheric aerosol and trace gases. Recent flights have included stratospheric measurements over the West Coast, Nevada, and the eastern Pacific Ocean.

CSTEA Howard Oxidants and Air Quality Experiment (CHOAQE)
CHOAQE began in summer 1997 with a 12-week monitoring period of ozone, particulate, and meteorological parameters in northwest Washington, D.C. The suite of instrumentation was expanded in summer 1998 to include NO_x and SO_x. This project will ultimately involve Eulerian and Lagrangian field studies, dispersion modeling of the region, and closure studies to investigate the major factors depressing the air quality in D.C.

Colorado High Plains Study
The Colorado High Plains Study is a new collaborative venture led by CSTEA whose main purpose is the characterization of surface fluxes of trace gases and aerosols from agricultural fields as a function of crop type, fertilization patterns, meteorological conditions, and soil type. The ultimate goal is to determine the impacts of agricultural practices on regional tropospheric chemistry and to quantify exchange fluxes of key species that may affect the ozone balance in the non-urban, continental boundary layer. This effort began in June 1998 with the establishment of the field site and measurement protocols. CSTEA and CHARC (CSTEA-HBCU Aca-

demic and Research Consortium) students participated in this experiment.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The research program at CSTEA is focused primarily on the terrestrial atmosphere, and consequently the lead Strategic Enterprise for this Center is Earth Science. Other research projects at CSTEA involve studies related to AeroSpace Technology and to Space Sciences.

BENEFITS TO SOCIETY

The benefits of CSTEA's research to the public come from the enhanced ability to monitor and predict chemical and physical changes in our environment. An additional benefit is the alternative uses of the QCM instrument. This device and its associated chemical sensors can potentially be used for detecting chemical leaks, hazardous materials, and even airborne viruses; the instrument is sensitive enough to do so before lethal levels of exposure are reached.

STUDENT ACHIEVEMENTS

Bachelor degrees were awarded to six undergraduates in the fields of physics, chemistry, computer science, and business. The master of science degree was awarded to one student in physics and one student in chemistry. Of these latter two students, one is continuing on for a Ph.D. in chemistry. There was one Ph.D. awarded from the electrical engineering department; the student is presently working for Motorola. For fall 1998, CSTEA is totally or partially supporting 10 undergraduate students and 20 graduate students. Throughout the entire reporting period, CSTEA has sponsored 22 undergraduates and 23 graduate students. The Howard University Program in Atmospheric Sciences has five students enrolled directly in this program. One student is pursuing a Ph.D., and the other four are working toward their masters' degrees.

The CSTEA-HBCU Academic and Research Consortium (CHARC) sponsored their Summer Program from June 8 through July 31, 1998. CHARC's report will be separate from CSTEA. However, 19 students participated from the 5 partnership schools.

CSTEA has participated in and/or sponsored several community events. These events included "Holiday Weather Briefings" by television meteorologist and Goddard Space Flight Center (GSFC) scientists for Thanksgiving (November 25, 1997); a science & technology fair for middle/high school students (April 4, 1998); an exhibit for "Futurefest III '98—A Celebration of Children, Teens, & Family," sponsored by the District of Columbia Government; and an exhibit for "Celebrate Goddard Day" on the mall at NASA GSFC in Greenbelt, Maryland (September 10, 1998).

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Tropical Center for Earth and Space Studies

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Date of Original Award: 1995

INTRODUCTION

The Tropical Center for Earth and Space Studies (TCESS) comprises a multidisciplinary effort in several components, including UV Radiation Effects, Crustal Deformations of the Lesser Antillean Arc, Advanced Automated Image Analysis, Semiconductor Materials and Electronics for Space Applications, the Space Information Laboratory, and a small Education and Outreach effort. The Space Information Laboratory (SIL) is charged with receiving data from satellites and making it available to the user components within TCESS.

RESEARCH ACCOMPLISHMENTS

Semiconductor Materials and Electronics for Space Applications (SMESA)
SMESA researchers used ultra-fast nonlinear laser spectroscopy to study newly engineered materials, particularly ferroelectric-paraelectric ($KNbO_3$-$KTaO_3$) multi-layers in which individual layer thickness have widths of a few atomic mono-layers. These structures have novel properties, compared to their constituents, and could lead to nonlinear optical device applications. One material being studied is porous silicon. In contrast to its better known and

more common embodiment, porous silicon is a luminescent material. The discovery of this material in recent years has aroused much interest for enhanced opto-electronic applications for silicon. The latest developments by SMESA group researchers in this field include the accomplishment of increased ultraviolet sensitivity for porous silicon thin films. After these studies, an improved silicon-based UV photo-detector appears feasible.

Advanced Automated Image Analysis (AAIA) Project
Research conducted at the AAIA Project reached several milestones in the course of the past year. A neural network-based algorithm for subpixel phytoplankton estimation using Sea-viewing Wide Field-of-view Sensor (SeaWifs) data was developed by Dr. Shawn Hunt from Electrical and Computer Engineering and Dr. Fernando Gilbes from Marine Sciences. Work on image compression for multi-spectral imagery continues. A loss-less compression algorithm developed by Dr. Hunt reached a 2.8 compression ratio for Advanced Very High-Resolution Radiometer (AVHRR) data. Dr. Hamed Parsiani has developed a fractal based compression algorithm that achieves compression ratios of 10 to 13 with near loss-less quality from the point of view of the results of a classification algorithm. Dr. Domingo Rodriguez developed a new implementation suitable for parallel processing architectures of the Fast Fourier Transform (FFT) algorithm based on $N=R^2M$ parameterization. This algorithm is particularly efficient for data sets of lengths not in powers of 2. Dr. Luis Jimenez has developed prototypes on the MATrix LABoratory (MATLAB) program of a toolbox for Pattern Recognition. Dr. Miguel Velez-Reyes has developed prototypes of algorithms for nonlinear retrievals using regularization methods.

On November 3, 1997, Dr. Miguel Vélez-Reyes, who heads the AAIA group, received the highest honor bestowed by the United States government on outstanding scientists and engineers at the outset of their independent research careers: the Presidential Early Career Award for Scientists and Engineers (PECASE).

Ultraviolet (UV) Radiation Effects
The UV Radiation Effects component reports that data from the UV monitoring established in 1997 at La Parguera, Puerto Rico, is providing critical information on incident UV fluxes. These data are being used by another NASA-funded research project on the effects of UV on public health in Puerto Rico. This research complements NASA's studies of stratospheric ozone depletion by relating data from the Total Ozone Mapping Spectrometer (TOMS) to surface UV irradiant measurements from our permanent monitoring station. Stratospheric ozone depletions and the corresponding increases in surface UV radiation are important components of NASA's Earth Science Enterprise.

Crystal Deformations of the Lesser Antillean Arc
The primary focus of the research performed by the Crystal Deformations component is to use a wide variety of geological and geophysical techniques to study the current characteristics and geologic behavioral past of the active volcanoes of the Lesser Antilles. In particular, we are using state of the art Global Positioning System (GPS) geodetic techniques in concert with Interferometric Synthetic Aperture Radar (InSAR) to measure how the surface of several volcanoes is changing.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The tiny surface changes that can be detected by GPS and InSAR technologies can be used to deduce in part at what depth below the surface magma may reside, whether the magma is moving toward the surface, and the rate of its ascent. All of these factors are important in controlling the style and magnitude of any volcanic eruption. The knowledge gained from this research answers some of the questions at the core of NASA's Earth Science Studies.

The University of Puerto Rico at Mayagüez (UPRM) is partnering with The Johns Hopkins University to host the primary Ground Station for their Far Ultraviolet Spectroscopic Explorer. This implies tasking as well as receiving telemetry. In addition, UPRM is partnering with Caltech/JPL to serve as the primary downlink for the Galaxy Evolution Explorer (GALEX). Both of these missions are crucial to NASA's Earth Systems Science missions.

As the amount of data from Earth observing systems increases, advanced information extraction and data processing algorithms are necessary in order for Earth scientists to optimize the use of Earth Observing System (EOS) platforms. Algorithms developed by our research will help NASA and other Earth scientists achieve these goals.

BENEFITS TO SOCIETY

Increases in UV radiation can have important public health implications. The data from our UV monitoring station is readily available to researchers, health officials, and students.

During the first three years of our project, UPRM Geology concentrated its efforts on the 1995 to 1998 eruption sequence of Soufriere Hills volcano on the island of Montserrat. Our GPS data, along with observations from other scientists from the British Geological Survey and the Montserrat Volcano Observatory, were important in providing the Government of Montserrat scientific rationale for decisions regarding the evacuation of citizens living within several kilometers of the summit lava dome.

Recent highlights of the SMESA group's research activity include development of new phosphor materials of interest for lighting and display applications. For example, Eu^{3+} -doped sol-gel glasses emit bright red light at about 610 NM. This is very attractive, and fulfills the chromatic requirements for most red-emitting phosphors, including lamp and cathode ray phosphorescent materials. Extensive studies have been done in order to obtain more efficient and stable phosphors.

Nitride semiconductor materials offer one of the most exciting approaches to tomorrow's electronic and Electro-optic devices. Of particular interest for both NASA and industry are the direct-transition binary nitrides (AlN, GaN, and InN) which are building materials for efficient light emission and detection in the range from the green to the ultraviolet. Faculty and students in the SMESA group recently completed an initial round of studies in which they attained good quality thin films of all three direct-transition nitrides by a novel approach based on Pulsed Laser Deposition. An advantage of the method is that growth temperatures are lower than those required for customary techniques. This is important because it could lead to cost reduction in manufacturing and enabling of technologies which are incompatible with high temperatures currently required (over 1,000° C).

STUDENT ACHIEVEMENTS

Three underrepresented minority graduate students are currently supported by the UV component of TCESS. Dr. Roy Armstrong-Pacheco and the students Yasmín Detrés and Xana Connelly Pagán presented a special seminar at NASA's Ames Research Center on June 18, 1998 entitled "The Effects of Ultraviolet Radiation on Tropical Marine Organisms." Yasmín Detrés and Ana Navarro presented a poster at the 10th Annual EPSCoR Meeting entitled "Monitoring Ultraviolet Radiation in Puerto Rico: A Long-Term Database for Global Change in the Tropics."

The research activities of the Crustal Deformations component have included the participation of several M.S. students from the Department of Geology, including Lorna Jaramillo, Jamie Camacho (now deceased), Lizzette Rodriguez, Audeliz Matias, and Alberto Lopez. All of the above named have spent days to weeks in residence on Montserrat working closely with the Montserrat Volcano Observatory (MVO) staff. The UPRM team originally deployed two continuous Global Positioning Satellite (GPS) systems to automatically record and transmit geodetic observations on Soufriere Hills. During the course of the eruption, these original sites were destroyed. With the help of the MVO and our students, these sites have been rebuilt and our network improved to include additional sites in the far north of Montserrat and Antigua. As the activity in Montserrat began to wane during the spring of 1998, we extended our GPS campaigns to include the islands of Saba and St. Eustatius of the Netherlands Antilles, and St. Kitts and Nevis. Government disaster management and mitigation agencies from these islands have agreed to allow NASA-UPRM to install additional GPS sites on the flanks of these volcanoes. We hope to have these new sites installed by the end of 1998, thereby increasing our capability to provide the people and local governments of the northern Lesser Antilles volcanic islands with timely and useful geodetic data to aid in their ongoing assessment of their currently dormant, but potentially active, volcanoes.

AAIA supported 16 graduate and 12 undergraduate students. Mr. Francisco Pagán received the award for best student of the ECE class of 1998. He also received a Graduate Degrees for Minorities in Engineering and Science (GEM) fellowship and is continuing graduate studies at Purdue University, where he is interested in continuing research in signal processing applications in remote sensing. Fabian Gonzalez finished his M.S. degree and in working at Lucent Technologies. Jose Miguel Ortiz finished his M.S. and accepted an instructor position at the Interamerican University in Puerto Rico. Engel Sanchez and Gianna Fernandez finished their B.S. and are working for Raytheon in Massachusetts. Ricardo Garcia finished his B.S. in Electrical Engineering and is working for Hewlett Packard.

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Pan American Center for Earth and Environmental Studies

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Date of Original Award: 1995

INTRODUCTION

The Pan American Center for Earth and Environmental Studies (PACES) has a mission with dual goals. These goals are to contribute research to support NASA's Earth Science Strategic Enterprise and to contribute to the education of the next generation of scientists and engineers, many of whom will be underrepresented minorities. PACES has established a major database of remote sensing, geophysical and geological, and environmental information generated by NASA and other agencies and institutions for a region comprising the southwestern United States and Mexico.

RESEARCH ACCOMPLISHMENTS

Since its inception, PACES has become a fully functional center with intensive computational facilities to support remote sensing and geographical information systems applications. PACES researchers have been involved in the investigation of the Rio Grande rift as well as the many practical problems that can be studied within the context of rift zones. As a consequence of a grant from the National Science Foundation Continental Dynamics program, a major interdisciplinary, multi-institutional investigation of the Rocky Mountain region of Wyoming, Colorado, and New Mexico has emerged. This program has leveraged PACES support and facilities, and is a logical outgrowth of PACES research in the Rio Grande region on the evolution of North America during the Precambrian age.

In March of 1998, PACES hosted a major three-day conference, "Tilting the Balance: Climate Variability and Water Resource Management in the Southwest," which was sponsored by NASA, National Oceanographic and Atmospheric Administration (NOAA), Environmental Protection Agency (EPA), United States Department of Agriculture (U.S.DA), and United States Geological Survey (U.S.GS). This conference focused on the response of arid and semiarid basins in the Southwest to short-term variations in climate represented by droughts and El Niño effects, as well as the longer term changes driven by broader elements of global climate change.

PACES research in computer science has focused upon the major problems that are often encountered when agencies acquire, store, and process geographically based data. In particular, PACES researchers are working to develop a computer language, SequenceL, which will ease the burdens related to exploratory programming tasks related to extracting information of interest from raw data. In addition, PACES researchers have made significant strides toward addressing problems associated with the interaction of a multiplicity of high-level software tools used to manipulate geographically based data.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

PACES research is relevant to NASA's Earth Science Strategic Enterprise. The resources of PACES provide a unique opportunity to analyze the Rio-Grande Rift corridor region, a major rift zone, in a comprehensive fashion. Rifting has played a major role in the evolution of continents and the terrestrial planets. Consequently, understanding the evolution, structure, and dynamic processes that form rift zones is an important topic for NASA-sponsored research. Rift zones have substantial impact on the environment; in particular, they form grabens, fault-bounded troughs, which localize water resources such as rivers, lakes, and ground water. As rift zones evolve, they can produce by-products such as volcanism and earthquake activity that are the source of geological hazards. PACES faculty, staff, and students are researching these phenomena.

BENEFITS TO SOCIETY

As rifts extend the Earth's upper crust, large areas subside as a result of movement along faults. In the Rio Grande rift zone, this process has led to the development of a series of large sedimentary basins. These basins contain a significant portion of the region's scarce water supply. PACES investigators are seeking to gain a better understanding of the structural framework of these basins. The goal is to evaluate the extent of the water resources and the potential for ground water pollution, particularly in and along the border with Mexico, where the population is rapidly increasing. PACES are working with the U.S. Geological Survey to generate a new basin-wide study of the Albuquerque basin. In addition, findings are being extended to the west Texas, southern New Mexico, and Chihuahua regions. The goal is to eventually provide a full analysis of each major basin in the region. This comprehensive analysis will form a basis for resource management and urban planning.

Regional analysis of the Rio Grande rift provides a framework for more focused local studies such as the Hueco Bolson, the Mesilla Bolson, the NASA test facility near Las Cruces, and the Valles Caldera. Additionally, PACES investigators are studying the region south of El Paso extending to Ciudad Chihuahua. Special attention is being paid to water resource issues.

PACES is working with the Texas Natural Resources Conservation Commission and other agency partners in the U.S. and Mexico to study critical land-use/land-cover changes affecting surface water quality and quantity in the Rio Conchos and Pecos River basins. In another collaborative effort, PACES investigators have initiated a comprehensive inventory and evaluation of the Rio Grande riparian habitat between Elephant Butte Reservoir in New Mexico and Big Bend National Park in Texas. PACES technology also supports a Center for Education and Research on Macromolecules (CERM) CERM/U.S.-Mexico Foundation for Science cooperative research program on desalination of surface and ground waters for use in agriculture and public water supplies. A major focus of this project is an inventory of sources of saline irrigation return flow from irrigated land along the Rio Grande. This is being accomplished by accurately differentiating and mapping soils on the basis of their salinity.

As the largest landholder in the U.S. Army Training and Doctrine Command, El Paso-based Ft. Bliss is uniquely situated to apply spatial analysis technologies to the problems of ecosystem management. The synthesis of remote sensing and geographical information systems technology in addressing problems of land management has helped form the basis for collaboration between PACES and Ft. Bliss. Additionally, PACES is participating in the development of a border-area regional airshed model to be used as the pilot project for a continental airshed model. The emphasis in the modeling effort is on the transpiration and dispersion of health-related atmospheric pollutants on a continental scale.

STUDENT ACHIEVEMENTS

PACES seek to engage both graduate and undergraduate students in its research projects and to foster peer interactions in which graduate students help to mentor undergraduate students. During the annual reporting period, PACES provided research assistantships to 18 undergraduates, 5 masters' students, and 3 doctoral students. Of the four undergraduates who earned bachelors degrees, three accepted positions in NASA-related careers and the other elected to continue studies in Graduate School. Three PACES students received masters' degrees and one received a doctoral degree. Another 27 students received support through research assistantships from aligned funding sources.

During the past academic year, PACES researchers published 52 refereed papers and book chapters; 16 if these were either authored or co-authored by students. Another 36 papers authored by PACES investigators were accepted for publication in refereed journals; 17 of these were also authored or co-authored by students. PACES researchers made 91 presentations at national and international conferences during the past year. Students gave 42 presentations.

Through a collaboration with the Arctic Region Supercomputing Center, the Geophysical Institute of the University of Alaska, and the Alaska Space Grant Consortium, seven UTEP undergraduates participated as summer interns at the University of Alaska, Fairbanks.

To help promote science and environmental awareness among K-12 students, PACES outreach specialists are working with colleagues in UTEP's College of Education to devise ways to improve preservice teacher training through the use of NASA's Earth Science resource materials. Recently, PACES hosted a series of GLOBE (Global Learning and Observations to Benefit the Environment) training workshops for area teachers.

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Space Science

Center for Automated Space Science

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Date of Original Award: 1995

INTRODUCTION

The objective of the Center for Automated Space Science (CASS) at Tennessee State University (TSU) is to achieve a broad-based aerospace research capability that will foster new science and technol-

ogy concepts featuring autonomous space systems, expand the nation's research base for aerospace research, increase participation by faculty and students at TSU and its partners at Western Kentucky University and South Carolina State University, and; increase the production of underrepresented minorities who are U.S. citizens with advanced degrees in NASA-related fields.

RESEARCH ACCOMPLISHMENTS

Automated Astronomy Group
The four CASS automatic photometric telescopes (APT's) were moved during the summer of 1996 from their original observing site at Whipple Observatory on Mt. Hopkins in southern Arizona to a nearby site on private land at 5,700 feet in the Patagonia Mountains. The new location allows for expansion of the automated observatory as well as better management of operations. The new site will house the CASS 24-inch automatic imaging telescope (AIT), three new 32-inch APT's, and a new 2-meter automatic spectroscopic telescope (AST) when these are completed. The four existing 10- to 32-inch APT's continued their long-term observing programs monitoring semi-regular variable stars, chromospherically active single and binary stars, and Sun-like stars. The APT's have been operating now for as long as 12 years and have collected over 250,000 precise measurements of the changing brightness of their target stars, far more data than could have been collected with manually operated telescopes.

Measurements with the APT's have, for the first time, shown that it is possible to measure subtle, long-term brightness changes in stars that are twins of our own Sun. This requires a measurement precision of 0.01 percent, since the Sun's brightness varies by only 0.1 percent in concert with the 11-year sunspot cycle. This level of precision has not been achieved before with ground-based telescopes. These observations will place the Sun's behavior in context with that of other similar stars and allow greater insight into the Sun's long-term brightness variations and their effect on Earth's climate.

The APT's have also participated in the search for extrasolar planets (i.e. planets beyond our own solar system). An exciting new development in astronomy has been the recent detection of such planets (albeit by indirect means) around several of the Sun-like stars being monitored by the APT's. CASS data on these stars have been crucial in confirming or refuting the existence of these planets. In special cases, these new planets might move in front of their stars, thus blocking some of the star's light from reaching the Earth. The APT's are searching for these events, known as planetary transits, in order to measure the sizes, masses, and mean densities of the new planets.

Advanced Control Systems Group
The existing robust and optimal control system design methodologies unintentionally assume that the controller can be implemented with infinite precision. Based on testing, controllers obtained by these methods provide absolutely no freedom to further adjust controller parameters. This is a severe problem in practice, since further tuning of controller parameters is common in real-world situations. Many related issues, such as the relationships between controller parameters, plant robustness, and optimality of the closed loop system, are currently under investigation.

A robust parametric control approach has been applied to the problem of controlling large space structures against potential structural damage. It has been shown that this method, in conjunction with interval system identification, can be effectively used to suppress structural vibration despite various structural failures.

A new scheduling algorithm to support multi-tasking, multi-user automatic telescopes has been developed.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

CASS accomplishments support the specific needs of NASA's Space Science Enterprise. More specifically, research is being conducted which is relevant to the Sun-Earth Connection and the Astronomical Search for Origins and Planetary Systems themes. The completion and operation of the TSU completely automated astronomical observatory will be utilized for obtaining ancillary and/or back up observations made with NASA satellite observatories. The CASS research results relating to the confirmation of the existence of extra-solar planets is relevant to the Origins Program in the Office of Space Science. A better understanding of Sun-climate links is being obtained from luminosity cycle APT data of solar-type stars which is relevant to the Sun-Earth Connection theme.

BENEFITS TO SOCIETY

The origin and distribution of life in the universe has intrigued civilizations since earliest times. The question "Are we alone?" continues to fascinate the average citizen. CASS's role in the search for other

solar systems will help to provide answers to this question. Additionally, global environmental change affects all humans, whether the primary driver has anthropogenic or solar origins. The CASS research on luminosity cycles in solar duplicates will aid in determining the relative importance of this possible climate driver.

STUDENT ACHIEVEMENTS

This year, 40 students (33 undergraduate and 7 graduate) participated in the CASS program; 45 students (23 undergraduate and graduate and 22 secondary students), along with five of their teachers, attended and presented 18 papers at the 1998 University Research Centers Conference in Huntsville, Alabama. CASS researchers and students reported their research findings in 64 separate publications, 25 of which were refereed journals.

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Institutional Research Awards

One purpose of the Institutional Research Awards (IRA) program is to strengthen the capacity of minority institutions to provide a quality learning and research environment for students traditionally underrepresented in science and engineering fields. Another purpose is to increase these students' opportunities to participate in and benefit from NASA and Federal research and education programs. Through IRA funding, minority institutions and researchers are given the opportunity to enhance their research and educational capabilities in NASA-related fields, providing the additional benefit of increasing their ability to enter the mainstream competitive research process. Now in its fourth year, the IRA program is enhancing research and education capabilities at five Hispanic-Serving Institutions (HSI's).

This report summarizes the activities of these IRA's during the academic year September 1997 through August 1998 reporting period. During this period, 60 professional-level investigators were involved in research projects at the IRA's, including 27 faculty members, 28 research associates, and 5 postdoctoral fellows. A total of 105 students—64 undergraduate and 41 graduate—participated in these research activities.

The research accomplishments were documented in 106 refereed papers or book chapters published during this time period. Significantly, 62 students were authors or co-authors of these publications. An additional 52 papers or book chapters, including 42 student authors or co-authors, were accepted for publication during this period. The broader research community was informed of this work through 139 technical presentations, including 114 presentations given by students.

During the reporting period, the five developing IRA's were able to leverage their NASA MUREP expenditures ($3.2 million, not including $0.9 million of student support) to an additional $1.7 million in new research support, $1.0 million from other NASA programs, and $0.7 million from other agencies.

A major goal of the IRA program is to increase the number of underrepresented minorities and students with disabilities receiving advanced degrees and entering careers in NASA-related fields. Of the 105 students, 64 (61 percent) participated at the bachelor's degree level, 16 (15 percent) participated at the master's-degree level, and 25 (24 percent) participated at the doctoral degree level. Of the participating students, 79 percent were members of an underrepresented ethnic minority group. Perhaps most importantly, 14 degrees, including 9 bachelor's degrees, 3 master's degrees, and 2 doctoral degrees, were awarded to IRA students. The reports for the five programs currently receiving IRA funding follow.

Earth Science

Tunable Solid-State Lasers and Optical Imaging

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Date of Original Award: 1994

INTRODUCTION

The research goals of the Tunable Solid-State Lasers & Optical Imaging program are to develop new and improved laser materials and devices, develop LEDs and laser diodes which emit throughout the visible range, characterize and study NASA-relevant materials using atomic-scale microscopes, improve image quality through enhancement techniques, especially through turbid media, and enhance person-machine interfacing for improved system utilization.

We also work to meet the agency's diversity goals for NASA-supported research by recruiting undergraduate and graduate students to participate in research and to acquire valuable experiences with state-of-the-art facilities, focusing on opportunities for minorities.

RESEARCH ACCOMPLISHMENTS

Major research accomplishments in the past year were made in laser development, imaging and medical diagnostics, and materials development and characterization.

Laser Development
Several new developments in lasers were made this year. We demonstrated continuous- wave tunable laser operation of direct diode-pumped Cr:forsterite and Cr:cunyite, the operation of all-solid-state double-clad fiber laser-pumped cunyite, and pulsed laser operation of $LiScGeO_4$ in the near-infrared region. All lasers were tunable in the desired near-infrared region. Chromium-doped forsterite and newly developed cunyite (a chromium-doped germinate) were pioneered at City College. New potential laser crystals were identified, and we began material development of the promising Cr^{4+}:$LiInGeO_4$; crystals of up to 1 cm in length have been grown. We discovered the source of the large timing jitter in passively Q-switched lasers that is an obstacle to laser miniaturization, and succeeded in reducing it from 1 ms to less than 10 ns.

Imaging and Medical Diagnostics
We developed an inverse algorithm that uses Fourier transforms to obtain 3-D images of objects hidden in a highly scattering media. We also continued to refine algorithms and ultra-fast time-gated techniques to improve spatial resolution in the optical imaging of objects in turbid media. Development was continued on real-time fluorescence intensity- ratio imaging to detect cancer. We tested the system, which uses the difference in fluorescence signatures between normal and cancerous tissue, on in-vitro human tissue. Preliminary imaging data were obtained, detecting the structure of pre-cancerous regions not visible to the naked eye. This system, the CD Map, can be coupled to another instrument (such as an endoscope) to obtain spectroscopic measurements during examinations. We also formulated an algorithm to obtain jet-spray drop shape and distribution from ultra-fast experimental data and continued testing pseudo-color to improve the person-machine interface.

Materials Development and Characterization
We demonstrated n- and p-type doping in ZnCdMgSe alloys for fabrication of p-n junction devices to be used in developing full-color displays. Laser emission across the entire visible spectrum was achieved. We were also able to significantly reduce material defect densities. We used scanning probe and near field scanning optical microscopes to characterize and study materials relevant to NASA; scanning thermal microscopy was used to evaluate the absolute thermal conductivity of amorphous "diamond-like" nanocomposite films for the first time. We also investigated photon migration in highly dense and absorbing ceramic suspensions.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The Tunable Solid-State Lasers and Optical Imaging program is mainly applicable to NASA's Earth Science Enterprise. Tunable near-infrared solid-state lasers are of interest for applications such as eye-safe remote sensing (as in satellites), aerosol and molecular lidar, differential absorption lidar, wind measurements, cloud penetration, and altimetry and ranging measurements.

Our light emitting diodes research and person-machine interface studies have applications in various military, commercial and spacecraft displays. Scanning Thermal Microscopy studies have applications in the characterization of materials used in the production of NASA spacecraft.

Our researchers have discussed specific needs of the agency with NASA scientists; current collaborations exist with the NASA Lewis Research Center on jet spray droplet distributions and the NASA Langley Research Center on telemammography.

BENEFITS TO SOCIETY

Our laser studies have a variety of technological, commercial, medical, and military applications, including optical communications, environmental sensing, and medical diagnostics.

Imaging studies, particularly medical diagnostics, are of great interest to health-related concerns of society. New optical-based diagnostics tools, such as those being developed at City College, can be used to safely and effectively screen for breast, prostate, aerodigestive tract, and gastrointestinal tract tumors.

Scanning Thermal Microscopy studies have industrial and manufacturing uses, such as the characterization of materials. The red-blue-green Light Emitting Diode (LED) research has home and commercial display applications. Person-machine interface studies aim to improve the visual processing of displays. This research is applicable to any situation in which complex graphic material must be presented to a human observer. Recent work has centered on the use of pseudo-color to improve the comprehension of information from image displays.

STUDENT ACHIEVEMENTS

This year, 23 supported students participated in CCNY's NASA IRA research projects. There were 7 doctoral students (2 Hispanic, 2 African-American, and 3 other), 2 master's students (1 Hispanic and 1 other) and 14 undergraduate students (4 Hispanic, 2 African-American, and 8 other). NASA-supported research has resulted in 18 papers being published in journals, 6 additional papers accepted, and 16 presentations at conferences. Of these, 22 were co-authored and 8 were co-presented by NASA-supported students.

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High-Performance Database Management With Application to Earth Sciences

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Date of Original Award: 1994

INTRODUCTION

In performance of this project, we are developing a highly parallel database system based on the semantic/object-oriented approach. Our research aims to significantly improve the usability and efficiency of highly parallel database computers and system clusters (tightly networked groups of systems). We are developing algorithms and a database management system that will have substantial advantages over current database systems. Our object-oriented system is based on the Semantic Binary Model of databases. Recent results in database theory and applications show considerable advantages of the Semantic Binary Model in comparison to the Relational Data Model. A semantic database system will have better logical properties, as follows:

- friendlier and more intelligent user interfaces based on the stored meaning of the data;
- comprehensive enforcement of integrity constraints;
- greater flexibility;
- spatial data;
- scientific data; and
- substantially shorter application programs.

Our system will also provide higher efficiency for both small and massive numbers of processors, and better exploitation of parallelism for data storage and processing.

We also conduct research on such theoretical and applied issues as database design methodology,

database design tools, information analysis, multimedia databases, distributed databases, database languages, data compression, and spatial databases.

RESEARCH ACCOMPLISHMENTS

Query and Indexing Algorithms

We have developed algorithms to provide very efficient full indexing, allowing fast access to every single fact in the database. Further, our algorithm guarantees optimality of the basic queries defined in our semantic algebra.

Concurrency Control and Load Balancing

We have also developed a semantic optimistic concurrency control algorithm, supporting theoretically maximal granularity without the overhead that such precision would normally require.

Multi-user Database Engine

A multi-user semantic database engine has been developed and is being tested. A user interface to this engine has also been developed using C++. A Java interface is nearing completion.

Adaptation of SQL

We have adapted Structured Query Language (SQL), which is the standard language for relational databases to semantic databases. It has turned out that the size of a typical SQL program for a semantic database is many times smaller than for an equivalent relational database.

Spatial Databases

Semantic databases containing significant quantities of spatial data have been assembled for testing in the following areas: ocean temperature, ozone layer thickness, reflectivity, simulated Sea-viewing Wide Field of View Sensor (SeaWiFs) data, aerial photography, and Landsat. We have also developed a very large semantic schema (over 2000 relations and attributes) for environmental research activities at the South Florida (Everglades) Research Center of the National Park Service. National Oceanographic and Atmospheric Administration (NOAA) is using our semantic database to manage wind data.

Storage and Visualization of Spatial Data

We are investigating better techniques for the efficient storage of spatial data to allow random access to the data, along with associated textual data. A self-contained terrestrial data browser with an elegant graphical interface has been developed and named "TerraFly." In this project, the spatial data (images) that are of interest to the user community is partitioned into tiles and stored in a semantic database after compression. The database, the semantic DBMS, and an image browser are stored on a single CD-ROM for client distribution. The versatile browser enables the user to fly over the terrestrial data (LandSat, etc.) in real-time (with the support of the semantic DBMS) with audio and video effects on any standard PC. The browser forms the basis of an educational/entertainment CD-ROM, which is being developed under support from the NASA Small Business Technology Transfer (STTR) program for schools, database customers, and other interested parties.

Compression

We have implemented compression of facts and spatial data in the database. We are investigating further improvement in compression of spatial data sets, the storage of substantial volumes of such data on immediate access devices, and the bulk storage or data warehousing of huge volumes of spatial data.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Our Center's research aims to support NASA's need for efficient access to the vast quantities of data that are being collected by satellites. An example of the type of data access our system will enable is embodied in the ozone data mentioned above.

NASA Goddard Space Flight Center (GSFC) and Florida International University (FIU) have established a Regional Applications Center (RAC) at FIU. This collaborative effort is expanding the practical applications of NASA satellite sensor readings, combined with other physical or logical data, to the benefit of the southeast U.S. region and beyond. This program also will strengthen the bond between NASA and FIU's High Performance Database Research Center (HPDRC) for the purpose of developing and implementing advanced new database technology. The mission of the RAC at FIU is to

collaborate with GSFC to serve public and business needs for remote sensing data obtained by NASA, primarily from orbiting satellites, as well as from other local and global sources.

BENEFITS TO SOCIETY

Our research indirectly benefits the average citizen by allowing scientific researchers to perform their work more efficiently. In the future, the database technology that is being developed at our Center will be able to provide more efficient information access for everyone.

STUDENT ACHIEVEMENTS

During the reporting period, four NASA-supported undergraduate students received their B.S. degrees in computer science from Florida International University. One of them has chosen to begin his graduate studies at FIU; the other three have taken positions in the industry. One NASA-supported graduate student received an M.S. degree in computer science and another received a Ph.D. in computer science; both have gone on to work in the industry. NASA-supported students have continued to co-author papers and to present these papers at conferences.

Additional NASA Enterprise Areas: Aero-Space Technology, Human Exploration and Development of Space, and Space Science

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Land Management in the Tropics and Its Effects on the Global Environment

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Date of Original Award: 1995

INTRODUCTION

The primary focus of the project is to examine how land-use changes in Puerto Rico over the last 50 years have affected plant and animal communities, stream flow and water quality, soil and water microbiology, and greenhouse gas emissions to the atmosphere. This information can then be used to better understand how changing land use in the tropics may affect biological diversity. In addition, subgroups have studied variability in land-use in Puerto Rico, and the regeneration of native forested ecosystems following human disturbance. During the past year, the project has been expanded to include regions of the Dominican Republic and Costa Rica.

ACCOMPLISHMENTS

The recovery of forested ecosystems in six areas in Puerto Rico representing the 5 main life zone/geology classes in Puerto Rico has been described. Among the major accomplishments of the research effort to date are: the identification of plant successional sequences for a range of sites following pasture, sugar cane, tobacco and other crops; established linkages between soil microbes, earthworms and greenhouse gas emissions; preparation of a Geographic Information System (GIS) database for landscape scale studies of land use in Puerto Rico; creation of island-wide databases for geology, hydrology land use, elevation, watersheds and life zones; and the expansion of this research effort to other locales, including the Dominican Republic, Costa Rica, the Republic of Palau and Colombia.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

We contribute to NASA's Earth Science Strategic Enterprise by identifying specific changes in climate, hydrology, soils, and greenhouse gas fluxes that occur during land use changes in tropical areas. Our work attempts to relate social practices to environmental impacts, and to examine the capacity of native ecosystems to restore themselves. Changes in land cover, as areas are converted to human use and then abandoned, are readily interpreted from satellite information. This research is particularly relevant to the land use and land cover (LU/LC) components of the Earth Science Strategic Enterprise. We provide baseline LU/LC data to allow project researchers and others to address changes in biophysical, biogeochemical, and hydrological states, as well as ecological goods and services. Our variability studies will improve our models of the environmental effects of future land use changes.

BENEFITS TO SOCIETY

Land-use changes in the tropics are occurring at unprecedented rates. We are identifying results—ocal and global, positive or negative—of particular land-use decisions in the tropics. This should contribute to making better-informed decisions about land uses in the future. This research will lead to management schemes designed to enhance the recovery process. These management schemes are important to Puerto Rico and other tropical countries because of the services that forested ecosystems provide: watershed protection, renewable resources (timber), and carbon sequestration, and because of the interconnections between land-use practices and global climate. Society will also benefit from the next generation of environmental scientists being trained by this project.

Our program also continues to impact formal education efforts at the University of Puerto Rico, with new course offerings in environmental sciences and the training of students in the use of remotely-sensed imagery. A monthly seminar series was initiated during the past year to stimulate greater interaction among the faculty researchers of the project and to promote more visibility and an influx of new ideas from the outside.

STUDENT ACHIEVEMENTS

Student training and research participation is a central goal of our project. We continue a large scale training effort with 2 postdoctoral, 7 graduate and 14 undergraduate students directly funded by this program. In the past project year alone, 29 students have co-authored 31 peer-reviewed publications. Project-trained undergraduates and master's students have pursued advanced studies at major stateside universities.

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Space Science

The Use of Decentralized Control in Design of a Large Segmented Space Reflector

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Date of Original Award: 1994

INTRODUCTION

The Control and Structures Research Laboratory (CSRL) at California State University at Los Angeles (CSULA) was established for the design and fabrication/assembly of a testbed resembling the complex dynamic behavior of a space segmented reflector telescope. Advanced technologies for decentralization, precision pointing, vibration attenuation, fault identification, controller reconfiguration, adaptive/robust control, neuro-fuzzy control, system identification, and reflector shape control have been developed and experimentally validated on the testbed. These new technologies are of immediate interest to NASA, the aerospace industry, and the commercial sector.

RESEARCH ACCOMPLISHMENTS

Sixty-two articles have been published in technical journals and national and international conference proceedings.

A major goal of the program is to expose minority students to a NASA research and development environment, to prepare them for future employment, and to motivate them towards graduate studies. To accomplish this, we have formed a coalition with two major Ph.D. granting universities (the University of Southern California, and the University of California at Berkeley), a primarily undergraduate comprehensive university (California State University at Long Beach), the Jet Propulsion Laboratory, Southern California Edison, TRW, Boeing, Schobers Machine, and Lockheed Martin.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Control architectures developed at CSRL are applicable to NASA astronomical missions and other applications that employ segmented reflectors (e.g. the SELenological and ENgineering Explorer (SELENE) and the Next Generation Space Telescope (NGST). The decentralized control results, in particular, can be extended to enable missions such as multi-spacecraft formation flying. The decentralized

results obtained can also be applied in the control of the Department of Energy's Long Arm Manipulator and to intelligent highways and vehicles. Decentralization techniques are also well suited for microspacecraft attitude control using multiple miniaturized sensors distributed on the vehicle.

BENEFITS TO SOCIETY

Adaptive control and neural network-based vibration attenuation and shape control results can be extended to acoustic disturbance isolation, which is of interest to the Department of Defense (DoD) for the control of hypersonic vehicles and to the automotive industry. Adaptive control results are directly applicable to advanced urban traffic control systems such as intelligent highways and vehicles. Failure detection and reconfigurable control will present a direct benefit to autonomous spacecraft control Research and Development currently under way at NASA and DoD.

STUDENT ACHIEVEMENTS

Thirty-five undergraduate and graduate students from the participating universities have received support to conduct research of interest to CSRL. Over 20 undergraduate and graduate students have been involved with CSRL and have completed undergraduate senior design projects, theses, and independent studies. Five graduate students are currently working on their Ph.D. theses on topics related to the research performed at CSRL. One, after receiving his Ph.D. degree, has assumed employment at an aerospace firm. A total of 16 graduates of the program are employed with Hughes Aircraft, Boeing, Phillips Electronics, TRW, JPL, and Hewlett Packard. Additionally, the program has sponsored six high school NASA Summer Fellows (three females and three males).

CSRL Segmented Reflector

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Alliance for Nonlinear Optics

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Date of Original Award: 1994

INTRODUCTION

The Alliance for Nonlinear Optics originally consisted of seven faculty members at five universities: Alabama A & M University, New Mexico Highlands University, Spelman College, the University of Alabama in Huntsville, and the University of Puerto Rico at Mayagüez. Since that time, faculty at Grambling University and the University of Texas at El Paso have been added, one person left the group this year, and one died. The purpose of the project is to develop new nonlinear optical materials that may be employed in the electronics industry in the 21st century. Emphasis has been on performance, stability, and processability.

During the past year, several things have occurred that have had a positive impact on the Alliance. In the area of technical accomplishments, Dr. Leyderman obtained the first patent to be issued based on Alliance work. This patent (5,746,823) covers the plate-guided thin-film formation technique developed by Dr. Leyderman. The technique has proven to be valuable in his studies of crystal behavior of nonlinear optical materials.

A general strategy for the molecular design and crystal engineering of new Nonlinear Optical (NLO) active compounds has been developed. This strategy includes prior calculation of the molecular nonlinear optical characteristics and crystal structure of new hypothetical compounds having large values of second- and third-order susceptibilities, chemical synthesis of the compounds of interest, and the experimental x-ray structural and non-linear optical studies of these components both in solution

and the solid state, preparation of thin films and bulk single crystals of NLO compounds, optimization of the chemical and crystal structure of the compounds studied to obtain their higher NLO characteristics, and preparation of different electronic devices based on these compounds.

A large series of new and some well-known NLO active compounds has been prepared and studied, including numerous derivatives of substituted dicyanovinylaromatics and their analogs, phthalocyanines, oligomer, and polymers containing NLO active materials. In addition, NLO properties of a few hundred hypothetical organic chromophores have been calculated. More than 30 new crystal structures have been studied. Several compounds that exhibit high prospective NLO characteristics in the solid state may be recommended for further study.

Phthalocyanines are of a particular interest to the research group. A series of octaalkoxy-substituted phthalocyanines has been prepared that have shown unusual solvent and pH effects. As a consequence, these materials may have applications as sensors. These same materials have also been studied for possible use in photorefractive devices.

Progress continues on the Fabry-Perot Electro-optic Modulator designed by Dr. Duerksen. Vapor deposition of a thin film surface for the device is scheduled for a Space Shuttle flight during the coming year.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This research is relevant to the NASA mission in general, and to the area of microgravity research in particular, because these materials will be used in telecommunications and high-speed computers in the future. Some of the materials that have been studied may have applications as sensor materials. These are all areas that are needed for space travel and research. Improvements in these areas will be relevant to all areas of modern life; faster telecommunications, for example, will clearly be of benefit to all people.

STUDENT ACHIEVEMENTS

The students in the Alliance continue to be one of its greatest assets. The number of students who have been involved in the project now exceeds 70. Of these, there have now been 4 Ph.D. degrees, 10 master's degrees, and 12 bachelor's degrees awarded to Alliance students. Three students have been admitted to medical school. One student received a bachelor's degree from one Alliance school and a master's degree from another, and is now enrolled in a Ph.D. program at still another (non-Alliance) school. Over 36 student poster presentations have been made by Alliance students at various regional, national, and international meetings.

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Faculty Awards for Research

NASA's Faculty Awards for Research (FAR) program seeks to provide the Agency with those resources necessary for mission completion while developing a diverse NASA-sponsored research community consisting of institutions with significant underrepresented minority enrollments. The FAR program supports faculty-driven research at HBCU's and OMU's that is relevant to the NASA Strategic Enterprises as described in the NASA Strategic Plan. Participation in FAR is currently open to tenure-track faculty of HBCU's and OMU's that offer degrees in engineering, mathematics, or science disciplines. As a result of participating in this program, principal investigators contribute directly to NASA research and support the development of disadvantaged and/or disabled student researchers. Opportunities for participation in the agency's mainstream research expand as recipients' research capabilities are enhanced through interaction with NASA researchers and facilities. In addition, the pool of disadvantaged and/or disabled students with research experience and interest in pursuing advanced degrees in the fields of science, engineering, and mathematics increases through faculty support.

During its sixth year, the FAR program funded 81 research projects (including 38 new projects) at 26 institutions—17 HBCU's and 9 OMU's. The data that follow were obtained from 60 of the projects. These reports summarize the activities of the FAR projects during the Academic year September 1997 through August 1998 reporting period. During this period, 91 professional-level investigators were involved in the 60 research projects—61 faculty members, 25 research associates, and 5 postdoctoral fellows. A total of 228 students—141 undergraduate and 87 graduate—participated in these research activities.

The research accomplishments were documented in 45 refereed papers or book chapters that were published during this period. Significantly, 24 students were authors or co-authors of these publications. An additional 16 papers or book chapters, involving 16 student authors or co-authors, were accepted for publication during this period. The broader research community was informed of this work through 161 technical presentations, including 45 presentations given by students.

During the academic year September 1997 through August 1998, the 60 reporting FAR projects were able to leverage their NASA MUREP expenditures ($2.2 million, not including $1.2 million of student support) to an additional $3.2 million in new research support, $0.9 million from other NASA programs, and $2.3 million from other agencies.

A major goal of the FAR program is to increase the number of disadvantaged and/or disabled students receiving mathematics, science, engineering, and technology research experience and entering careers in NASA-related fields. Of the 228 students, 141 (62 percent) participated at the bachelor's degree level, 70 (31 percent) participated at the master's degree level, and 17 (7 percent) participated at the doctoral degree level. Of the participating students, 79 percent were members of an underrepresented minority group. Perhaps most importantly, 61 degrees, including 37 bachelor's degrees, 20 master's degrees, and 4 doctoral degrees, were awarded to FAR students.

Brief reports from each of the FAR projects, along with abstracts of the newly funded projects, follow.

Ames Research Center (Reports)

Monitoring Software Through Integrity Constraint

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Date of Original Award: 1995

INTRODUCTION

The rapid advancement of technology has created a demand for more complex software systems that integrate knowledge from varied domain experts. This causes several concerns, including the management of conflicts that may exist in the requirements, communication of specialized knowledge to members of the development team, and verification of programs. This research addresses these issues through an approach that uses integrity constraints to monitor program behavior. Integrity constraints reflect knowledge elicited from domain experts, properties gleaned from software requirements, limitations imposed by the design, and assumptions made by programmers. This approach keeps the constraints separate from the program and embeds constraint-checking code at compilation. The goals of this research are as follows: to develop a methodology for eliciting integrity constraints, to define a language for specifying constraints, and to create a monitoring mechanism that verifies the enforcement of constraints during program execution.

RESEARCH ACCOMPLISHMENTS

The definition of a first-order logic language for specifying constraints has been published; the paper provides the basis for defining a classification of integrity constraints. The methodology for eliciting constraints, which is critical for the effectiveness of this approach, lays the groundwork for the identification of constraints from domain experts, customers, and users. During the reporting period, the project focused on completing a study that analyzes the methodology used to elicit constraints, the language used to specify these constraints, the process of manually inserting the constraints into the application code, and the effectiveness of the constraints. The study involved identifying and inserting constraints into 10 different programs written by 10 different students (~100 programs) in an independent-study course entitled "Intensive Problem Solving." Based on the results of the study, the initial classification of constraints was extended, and the constraint specification was augmented to provide the knowledge needed to direct the automatic instrumentation of constraint-checking code.

Work continued on the development of a tracing tool that provides the ability to link constraints and artifacts. This tool improves the current approaches to tracing by reducing the physical links that must be maintained. In addition, it facilitates the detection of potential conflicts among constraints, and displays relevant information when a constraint violation occurs. The interface for the prototype tracing tool is being validated.

An algorithm was developed for inserting constraint-checking code during compilation at appropriate locations in a program (written in a subset of Pascal) for a large class of constraints. This work is significant because it is a proof-of-concept for a monitoring mechanism that verifies the enforcement of the constraints during the program's execution. The algorithm provides the foundation for meeting one of the biggest challenges of this project—the embedding of constraint-checking code without knowledge of the implementation.

RELEVANCE TO NASA STRATEGIC ENTERPRISES AND BENEFITS TO SOCIETY

This research is aimed at developing tools that will improve the reliability and integrity of software. These tools can be used to detect errors in NASA's mission-critical applications during runtime and to trigger graceful degradation of software when appropriate. The work is applicable to any critical software and provides an approach that can prevent the loss of equipment and/or life.

STUDENT ACHIEVEMENTS

Eight students have worked on the project over the three years; four of these students have been funded directly through NASA. One of the undergraduate students has graduated and is currently employed in a NASA-related field. Of the six other undergraduate students who graduated, five have continued on to graduate school. An undergraduate student who started with the project in the first year continued on to graduate school on an NSA fellowship, received his master's degree in Spring 1998, and was named the Outstanding Graduate Computer Science Student for 1998. An undergraduate student that was involved in the project in the second year was named the Outstanding Undergraduate Computer Science Student for 1998.

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Identification of Isolation of Microgravity Responsive cDNAs

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INTRODUCTION

The Cell and Molecular Biology Research Laboratory focuses on understanding eukaryotic differential gene expression under various laboratory and environmental conditions. The general strategy of this research focuses on using a messenger ribonucleic acid (mRNA) differential display polymerase chain reaction (PCR) known as RT-PCR to synthesize and amplify partial complementary DNA (cDNA) sequences from subsets of mRNA of the adult rat slow-twitch soleus muscle when it is exposed to the atrophy of microgravity.

RESEARCH ACCOMPLISHMENTS

To simulate the effects of microgravity, the hind-limb suspension method was used. Initially, total lactate dehydrogenase (LDH) expression patterns in the left soleus muscle were examined after seven days of hind-limb suspension followed by six hours of recovery using eight-week-old male rats and their parallel controls. All animals were used in accordance with NASA Ames Research Center AHB 7180-1 guidelines and National Institutes of Health regulations. LDH-specific activity in the seven-day suspended/no recovery rats was 690 units/liter as compared to 160 units/liter in the seven-day suspended/six hour recovery rats. These results reflect a four-fold increase in total LDH activity in the soleus muscle of the seven-day suspended/no recovery rats. LDH-specific activity in the parallel control rats ranged from 60 to 100 units/liter. However, suspended rats did show a loss of mass in their left soleus muscle when compared to their parallel controls. The exact nature of this expression pattern in suspended soleus muscle is yet to be determined. Hopefully, these studies will provide some insight into this NASA concern.

Higher organisms contain about 100,000 different genes, of which only about 15 percent (15,000) are expressed in any individual cell. Experiments are now underway to determine if any of the 15,000 and other individual mRNA species are uniquely expressed in microgravity-exposed soleus muscle in the suspended rats compared to their parallel controls. The key element is to use a set of oligonucleotide primers, one (3"-oligo-dT, 5"-TMN) being anchored to the polyadenylate tail of a subset of mRNA, the other (5'-10mer) being short and arbitrary in sequence so that it anneals at different positions relative to the first primer. This primer set permits the initiation of reverse transcription of a specific mRNA sub-population. Unique PCR-amplified cDNA from the soleus muscles of rats both exposed and not exposed to simulated microgravity will be characterized by dideoxy DNA sequence analysis after cloning them into a suitable vector. The sequence data will then be compared to known DNA sequences using the GeneBank and European Molecular Biology Laboratory (EMBLE) DNA protein databases. This unique PCR-amplified cDNA will also be used as probes to verify that it is differentially expressed in soleus muscles that have been exposed to microgravity as compared to soleus muscles that have not been exposed.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Extended exposure of humans and other animals to space flight produces a progressive loss of skeletal muscle mass and strength. This atrophy has been well documented by NASA. This process must be understood in order to design effective countermeasures. In the complex of hind limb muscles, the greatest atrophic effects have been seen in slow-twitch muscles such as soleus muscle.

This research relates to NASA's interest in outer space exploration missions and investigations of musculoskeletal changes that occur during space flight as specified in NASA's publication "Research and Technology Objective and Plans (RTOP) Summary" (RTOP, NASA TM-105441, and W/92-70279) and to NIH's interest in musculoskeletal protein structure, genetic, and connective tissue diseases. Although the tail-suspension model of microgravity has long been available and has had a significant impact on our knowledge of space flight-induced skeletal

muscle atrophy, we still know little about adult muscle repair and maintenance in the presence of normal (ground-based) muscular tensions such as household and occupational injuries.

STUDENT ACHIEVEMENTS

LaTanya Garvin and Rawlings Clark IV, two second-year biology undergraduate students, completed their first 10-week summer research residency (summer 1998), learning reverse transcription-PCR protocols, DNA sequence gel electrophoresis, and DNA gel sequence analysis under the direct supervision of Dr. Larry L. Lowe. They also attended the 9th Annual NASA University Joint Venture Program (JOVE) Retreat in Cocoa Beach, Florida and Kennedy Space Center, where they met NASA research students and scientists from other colleges and universities. LaTanya is currently developing her DNA sequencing skills using the Stratagene Eagle Eye II DNA Imaging and Sequence Analysis System; Rawlings is currently learning to purify total RNA to be used in trial reverse transcription-PCR reactions. LaTanya and Rawlings will be presenting the results of their summer research findings at the South Carolina Academy of Science in the Spring of 1999.

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Theoretical and Observational Studies of Solar and Extra-Solar Planetary Atmospheres

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Date of Original Award: 1996

INTRODUCTION

This research program focuses on the atmospheres of giant planets, both those orbiting our sun and the newly discovered planets orbiting nearby stars.

RESEARCH ACCOMPLISHMENTS

Uranus orbits the sun tipped on its side. Its large obliquity means that one pole receives almost constant sunlight for half of its 84-year orbit and sits in almost constant darkness for the other half. Uranus' north pole is now emerging from almost 40 years of darkness, and we have been monitoring the planet's atmosphere for changes. Data has been obtained both from the Apache Point Observatory's 3.5-meter telescope and the Hubble Space Telescope. The images now show many new bright clouds on the planet. These clouds were not seen during the Voyager flyby in 1986, and may indicate large changes in Uranus' weather. NMSU students Kerry Forsythe, a graduate student in astronomy and Stephanie Salas, an undergraduate in physics, participate in the observations, reduce the data, and search for clouds. This group will continue to monitor the atmosphere of the planet and work to interpret the changes that have been seen so far.

Before it is possible to directly detect the extra-solar planets, there must be some knowledge of how bright the planets appear at various wavelengths. Our main modeling effort is to predict the spectra of the currently known extra-solar giant planets. With NMSU undergraduate Sergio Mendoza and graduate students Chris Gelino and Denise Stephens, a great many models of the atmospheres of extra-solar giant planets have been computed. In a paper to be published in the *Astrophysical Journal*, it is demonstrated that the reflected spectra of these objects depend on the details of their clouds. This is good news, since it means that once the spectra of extra-solar giant planets has been observed, it will be possible to learn a great deal about cloud formation and behavior in a great variety of atmospheres.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The detection and characterization of extra-solar planetary systems is one of the highest priority goals of the NASA Origins program. The construction of a database of both the emitted and reflected spectra of extra-solar Jovian planets will facilitate both the direct detection of these objects and the interpretation of such spectra as they become available. Monitoring changes in the atmosphere of Uranus is directly relevant to the NASA goal of understanding the origin and evolution of planetary atmospheres.

BENEFITS TO SOCIETY

This work to better understand the atmospheres of planets, both within and beyond our solar system, will help to improve our understanding of atmospheric processes in general. Gaining a better appreciation of the behavior of clouds in a variety atmospheres may help to achieve a better understanding of the role that clouds play in Earth's weather.

STUDENT ACHIEVEMENTS

Sergio Mendoza, an NMSU engineering undergraduate student, was supported by this program to spend his summer break at NASA Ames Research Center, where he assisted in the design of a prototype rover for Mars exploration. Graduate student Denise Stephens presented the results of her research at an international conference in Lisbon, Portugal.

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Development of a Transdermal Delivery Device for Melatonin in Vivo

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INTRODUCTION

The primary objective of this study is to develop a novel transdermal delivery system (skin patches) of melatonin that can eliminate the problems associated with oral administration. Melatonin is a drug of choice in the Space Adaptation Syndrome that occurs in space scientists and airline pilots. However, after oral administration, melatonin has a very short half-life (45 minutes) and is very rapidly metabolized to 6-sulphatoxy melatonin (6-STMT). Due to the first pass metabolism of melatonin, it is not bioavailable in significant amounts to cross the blood-brain barrier, which is necessary if it is to show its desired effect. Transdermal delivery of melatonin will overcome the above shortcomings associated with this drug. Melatonin transdermal monolithic systems will be prepared by dissolving the drug and the polymer together, casting them as a matrix, and then drying the matrix. Various polymer combinations along with penetration enhancers will be used. The gelled melatonin matrix will be cut into individual units. The percutaneous absorption of melatonin patches through rat skin will be studied using the Franz diffusion cell apparatus. The formulation with the best characteristics for penetrability across rat skin will be selected for further in vivo study. The efficiency of the patch to deliver and maintain melatonin levels in vivo will be assessed using hairless rats under various lighting conditions. The concentration of melatonin and 6-STMT in the urine, blood, serum, pineal gland, and cerebrospinal fluid will be studied and compared to the results when melatonin is delivered intraperitoneally.

In addition, the behavioral circadian rhythm changes after administration of the transdermal melatonin patch will also be investigated in hairless rats. The transdermal formulation will be further tested in hairless rats in centrifugation studies to simulate the effect of hyper-gravity. These studies will help in understanding the implications of light and hypo-gravity (gravity vector) in the administration of melatonin via different delivery systems for space scientists in the future.

RESEARCH ACCOMPLISHMENTS

The first objective in these studies was to ascertain the appropriate formulation to deliver melatonin transdermally. Various solvent vehicles like ethanol, water, and propylene glycol were used. The best vehicle for melatonin delivery was found to be a mixture of water and ethanol in a 40:60 ratio. This formulation showed a high lag-time when used with rat skin. Various penetration enhancers were then used to improve the delivery of melatonin across the rat skin. The experiments were conducted with both rat and pig ear skin. Pig ear skin was used as a model for human skin because several studies have proposed that pig ear skin is the closest to human skin.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

One of the needs for NASA scientists and astronauts in outer space is to maintain the normal circadian rhythm. Since there are rapid day and night cycles in outer space, it becomes difficult to have normal sleep patterns. Furthermore, NASA is also interested in the changes in the pharmacokinetics profiles of various transdermal formulations in outer space. The knowledge obtained from this project will help to determine the feasibility of using transdermal formulations of other drugs in outer space.

STUDENT ACHIEVEMENTS

Several minority students have been working on this research. One student graduated with an M.S. in pharmaceutics with a thesis titled "Transdermal Delivery of Melatonin." Shishei Andega, an African-American female, is also pursuing an M.S. in pharmaceutics with research in the same area. Three

undergraduate students are being trained in the broad area of drug delivery. Valerie Turnage and Kisha Hortman presented their results at the Minority Biomedical Research Support (MBRS) Symposium in New York in November 1998. Additionally, two papers were presented at the American Association of Pharmaceutical Scientists Meeting in San Francisco in November 1998.

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Ames Research Center (Abstracts)

Neural Network Analysis of Leaf Multispectral Reflectance for Detection and Discrimination of Nutrient Deficiencies

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ABSTRACT OF PROPOSED RESEARCH

NASA's strategic plan for Human Exploration and the Development of Space (HEDS) will require reliable crop production in space. Nutrient solution-based cropping methods coupled with close nutrient monitoring are likely. Total replacement of nutrient solution is prohibitive due to mass constraints. Using a neural network analysis of leaf multi-spectral reflectance for detection and then discrimination of specific nutrients should enable precision nutrient supplementation.

In research recently funded for one year by NASA Ames Research Center, the relationship between in vivo leaf reflection spectra over a series of discrete wavelengths and the actual nutrient analysis of those leaves is being investigated. In this preliminary work, single nutrient deficiencies are imposed and then leaves of lettuce are scanned using a leaf spectroreflectometer. By using the fiber-optic cable attachment, specific locations on young, old, and fully expanded leaves can be isolated. Data thus obtained will determine the best method of analysis and will allow several input and back propagation cycles for training the neural network.

In the proposed research, we will investigate how the trained neural network, developed under the first-year funding, responds to multiple deficiencies and other Controlled Ecological Life Support System (CELSS) crops, and will determine if alterations in environmental conditions change the accuracy of the neural network model. The neural network model will be evaluated in a ground-based pilot test conducted in the growth modules located at the Ames Research Center at Moffett Field to verify its utility.

A minority M.S. level graduate student will focus on the multiple nutrient deficiency aspect, while a minority doctoral student will examine the robustness of the model under conditions of environmental stress. The undergraduate students will conduct experiments on the alternate crops. This work will acquaint minority students with opportunities available for professional development at NASA and in the space-based industries.

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Mechanisms of UV-B Induced Free Radical Oxidative Damage in Bovine Lenses and Human Fibroblasts

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ABSTRACT OF PROPOSED RESEARCH

Global atmospheric changes may become an increasingly important factor in determining the health status of human populations in the 21st century. Increasing levels of ultraviolet (UV) radiation could have serious implications for human health in terms of the onset of diseases such as skin cancer and cataracts.

UV-B radiation is known to induce the production of oxygen free radicals (OFR's), which cause oxidative damage. It is necessary to understand biochemical and molecular mechanisms by which UV-B causes oxidative damage in order to develop preventive measures and to implement effective clinical therapies. Despite the potential effects on human health, we have a limited understanding of the mecha-

nisms by which UV-B induces oxidative damage in nucleic acids, lipids, and proteins in bovine lens, lens epithelial cells, and fibroblasts.

In this study, three markers of damage to DNA (7, B-dihydro 8-oxo-21-deoxyguanosine), to lipids (thiobarbituric acid-reactive substances) and protein (oxidation or carbonyl and thio groups) will be utilized to measure the extent of UV-B-induced damage and apoptosis by OFR's to bovine lenses, lens epithelial cells, and human skin fibroblasts. In addition, the concentrations of these markers will be measured in mitochondria isolated from bovine lenses, lens epithelial cells, and fibroblasts that have been irradiated with biologically revelant fluxes of UV-B. (Mitochondria are important producers of OFR's, and mitochondrial damage promotes aging and is involved in several clinical pathologies.) The usefulness of these three biochemical markers of UV-B induced oxidative damage will be evaluated. These may provide the basis for correlation with cellular health and functional status, as well as their suitability as sensitive diagnostic tools of risk associated with UV-B exposure.

Finally, a well-defined plan is presented for increasing the participation in scientific research of Hispanic graduate and undergraduate students, which have been underrepresented in the NASA community.

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Dryden Flight Research Center (Reports)

Multidisciplinary Modeling and Simulation of Aerospace Vehicle Systems

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INTRODUCTION

With the increasing use of lightweight flexible structural elements in the design of modern flight vehicles, the use of multidisciplinary tools in modeling and predicting the flight characteristics of such vehicles has assumed greater importance. The flexible structural elements are subject to large deformations and vibrations at high speeds, leading to potential constraints on dynamic stability and controls performance margins for flight safety. For example, due to the presence and movement of shock waves in the transonic range, undesirable aeroelastic behavior may occur. In another example, a highly swept wing of an aircraft might experience vortex-induced aeroelastic oscillations. The design of such vehicles demands a thorough understanding of the interactions between aerothermodynamic loads, structural response, and control.

The advent of more powerful computers and highly efficient algorithms has resulted in significant advances in both computational fluid dynamics (CFD) and computational structural dynamics (CSD). These advances have played a major role in improving the modeling prediction of the aeroelastic response of aerospace vehicles. In developing a suitable integrated tool for predicting flight-critical dynamic stability and control performance characteristics, the methodologies of CSD and CFD need to be combined in a seamless manner. NASA Dryden Flight Research Center has developed a multidisciplinary finite-element code, Structural Analysis RoutineS (STARS), which couples fluid equations with structural equations and uses an unstructured mesh in the solution.

The overall objectives of the proposal include introducing graduate students to multidisciplinary research using STARS code as the computational tool and conducting and expanding research in the multidisciplinary area of the NASA Center for Aerospace Research (NASA-CAR).

RESEARCH ACCOMPLISHMENTS

In the first year, we plan to use the STARS code and its different modules to become familiar with its capabilities and limitations. To date, we have acquired the latest version of the code and the necessary hardware. The hardware is networked, which allows the students and faculty involved to hook up with remote sites. A graduate student has been recruited to work on the project while working towards his M.S. degree. We have made arrangements with NASA Dryden Flight Research Center to

conduct a training session in October 1998. We will conduct the research in close consultation with Dr. Gupta of NASA Dryden Flight Research Center.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

One of the competing design parameters in the development of supersonic and hypersonic aircraft is the gross weight of the vehicle. As the flight Mach number approaches supersonic and hypersonic speeds, as happens with the High Speed Civil Transport (HSCT) and other Mach 4-8 aircraft of interest, it becomes increasingly important to employ lightweight flexible structures to minimize the total weight of the aircraft. However, such flexible structures may undergo large deformations and vibrations due to aerothermodynamic loads at supersonic and hypersonic speeds. Consequently, nonlinear structural analysis and the design and control of flexible structures subjected to aerothermodynamic loads are necessary in order to validate high-speed aircraft at supersonic and hypersonic speeds.

BENEFITS TO SOCIETY

NASA-CAR has two main objectives: student education and conducting forefront aerospace research to establish a strong aerospace research capability and to enhance opportunities for socially and economically disadvantaged persons in the aerospace engineering and technologies professions.

STUDENT ACHIEVEMENTS

A socially and economically and disadvantaged graduate student will be identified to work on the desired topics. The progress of the graduate student will be closely followed both through academic advisement and research supervision and guidance.

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Hybrid Motion Planning With Multiple Destinations

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Study of Control Structure Interaction in Large Flexible Space Structures

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INTRODUCTION

The objective of this project is to conduct research on large, flexible structures that could have applications in future NASA missions. In particular, inflatable structures are being investigated.

These structures behave very differently from the conventional rigid structures. The mechanics of inflatable structures are far more complicated and difficult than those of rigid structures. To understand the behavior of stretchable materials and the mechanics behind it so that we can accurately model their performance is a real challenge. In this research, we will conduct theoretical investigations as well as computer modeling to develop useful design tools for these types of structures.

RESEARCH ACCOMPLISHMENTS

The initial effort for the research is focused on gaining a better understanding of the properties and mechanics of stretchable materials such as nylon, kapton, and aluminum sheets. A laboratory has been set up to conduct static tests to determine the mechanical properties of these materials. The research team has been working in close collaboration with engineers from the Jet Propulsion Laboratory to obtain samples for testing. In parallel with the testing effort, finite element computer models have been built using IDEAS (ISM's Disciplines for Engineering Application Software) and STARS (Structural Analysis Routines) software. Experimental results have been used to validate these models.

Once validated, they can be used as design tools for the accurate prediction of the behavior of inflatable structures. The current work is focused on structures of relatively simple shape, which are the building blocks for more complex structures. After the static testing and modeling are completed, the same approach will be taken to model the dynamic behavior of the inflatable structures.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The inflatable structures being investigated in this project are of great interest to NASA for use in future missions. Among different types of flexible structures, the inflatable structures appear to be particularly attractive because of the light launch weight, ease of deployment, and lack of size limitation. They have been increasingly found to be ideally suited for use in large antennas, sun shields for telescopes, synthetic aperture radars, solar sails for space travel and human habitation, and inflatable living modules. There are also potential applications in the fields of aeronautics and astronautics such as wings, tail cones, reentry vehicles, and impact airbags.

STUDENT ACHIEVEMENTS

The research team is composed of two undergraduate mechanical engineering students, one graduate mechanical engineering student, one industry consultant, and the principal investigator. Since the project began, the undergraduate students have been learning about setting up the test apparatus, running the tests, and doing data reduction. The graduate student is working on writing a thesis from this work.

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Thermo-Mechanical Characteristics of Composite Materials

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Date of Original Award: 1998

INTRODUCTION

Composite materials are steadily replacing more conventional materials used in the aircraft industry because of their high stiffness/density and strength/density ratios. The most commonly identified thermo-mechanical properties of composites are thermal conductivity, tensile strength, shear strength, and elastic modulus. Composites used in space applications are subjected to extreme operating conditions. The purpose of this research is to expand the knowledge base for the behavior of these materials.

The research is being carried out in three phases. The main objective of the first phase is to design and develop a laboratory facility for high-temperature testing of composite coupons. The secondary objective is to study and understand the use of the Structural Analysis Routines-Finite Element Analysis (STARS-FEA) software provided by NASA Dryden Flight Research Center (DFRC).

ACCOMPLISHMENTS

The major accomplishment of phase I is the design and development of the high-temperature test facility, which is capable of testing coupons up to 1200° F. Modifications of the existing machine were made in such a way that the unit could still be used for normal materials lab work as well as for the high-temperature composite research. LabVIEW V4.1, a graphical programming language, is being used to control the servo-hydraulic system and to measure stress, strain, and temperatures of the test specimens.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

By conducting studies on composite materials, the knowledge base for the behavior of these materials at high temperatures will be expanded. For example, NASA Dryden Flight Research Center (DFRC) is looking into the use of composites in the manufacture of the X-33 and Hyper–X vehicles. The research conducted in the area of composite materials subjected to high temperatures will contribute to the research efforts at NASA–DFRC.

BENEFITS TO SOCIETY

The obvious advantage of using composites in aircraft and space vehicle applications is the reduction in the weight of the vehicle, resulting in a greater payload per unit cost of the fuel used in the operation of the vehicle.

STUDENT ACCOMPLISHMENTS

The students involved in this research have achieved considerable experience in using and applying STARS for the analysis of coupon testing. In addition, they are conversant in the use of LabVIEW software for the acquisition of experimental data and control of the MTS high-temperature tensile testing machine. One of the students has become proficient in the operation and use of the MTS machine.

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An Imaging Framework for Aerodynamic, Fluid Mechanic, and Heat Transfer Scientific Grade Measurements

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INTRODUCTION

Researchers at the NASA Imaging Laboratory at the University of Texas at El Paso (UTEP) are investigating the instantaneous structure of a fuel spray using flow visualization and digital particle image velocimetry (DPIV). The applications of these experiments are in spray combustion. For the experiments, a quartz research cylinder is placed between a pair of aluminum plates, providing optical access around the cylinder's circumference. A fuel injector injects fuel into one end of the research cylinder and an air purge circuit removes the fuel after injection. The developed DPIV system consists of the research cylinder located on an optical table, a Nd:YAG (neodymium linear amplifier) laser, optics, a double-triggered high resolution digital camera, a pulse generator for synchronization, a digital image acquisition board, and a computer.

RESEARCH ACCOMPLISHMENTS

The necessary equipment for the experiments has been acquired, the experiment has been designed and constructed, and preliminary fuel spray research has been performed. The UTEP team has collaborated with a DPIV expert, Professor Jun Sakakibara from Tsukuba University in Japan, in the development of the DPIV system. Figure 1 presents an instantaneous image of the fuel spray taken 0.5 ms after injection. The DPIV system uses two acquired images at known intervals to determine the instantaneous velocity. Figure 2 presents velocity vectors determined using the DPIV system superimposed on a spray image.

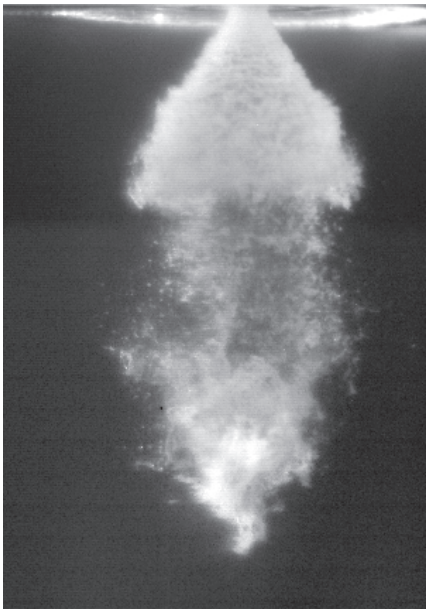

Figure 1.

Figure 2.

RELEVANCE TO NASA ENTERPRISES

The optical measurement techniques developed in the course of this research can be applied to numerous fluid mechanic and combustion applications. An improved understanding of the instantaneous behavior of sprays, particle dynamics, and particle-fluid interactions and the developed optical measurement techniques will benefit both the Aero-Space Technology and Earth Science Strategic Enterprises.

BENEFITS TO SOCIETY

This research will benefit various spray applications and future spray research. For example, the fuel spray research could have a direct impact on spark ignition (SI) engines where the current emphasis is on direct injection (DI) of fuel into the cylinder. If DISI technology proves successful, a measurable global decrease in gasoline fuel consumption will result, promoting U.S. energy independence from foreign oil sources and a reduction in air pollution. Other examples of benefits include improved medical inhaler designs and improved models for the atmospheric transport of pollutants.

STUDENT ACHIEVEMENTS

The two undergraduate research assistants, shown in Figure 3, have become familiar with optical measurement techniques, experimental fluid mechanics, and DPIV. Prior to the development of the DPIV system, the students developed a fluid mechanics experiment in which the instantaneous velocity of a single falling object was determined optically. This is a simple experiment that can be incorporated at various levels within the mechanical engineering curriculum. A description of the experiment and the results is included in a paper titled "Optical Velocity Measurement Using LabVIEW (a graphical programming language) and IMAQ Vision (a library of image processing virtual instruments designed for use with LabVIEW)" by H. Loya, D. Regalado, and R. Wicker. This paper was presented at the 1998 National Instruments Week conference in Austin, Texas and can be found in the conference proceedings.

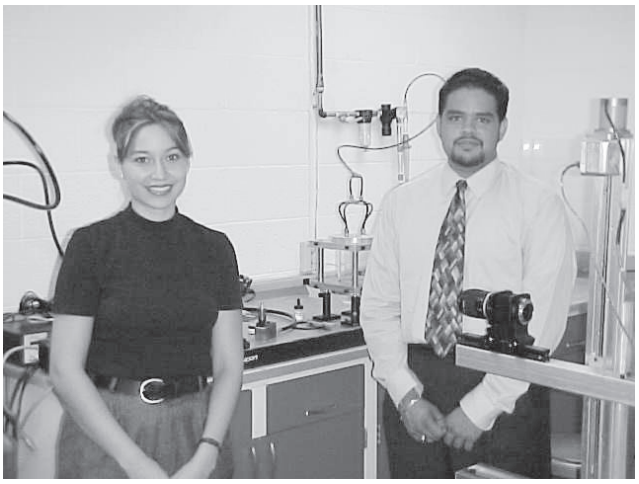

Figure 3.

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Radiation Effects on Electronic Materials and Devices at High Atmospheric and Low Earth Orbital Altitudes

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Date of Original Award: 1998

INTRODUCTION

In order to make future flight vehicles faster, better, and cheaper, engineers will rely heavily on sophisticated electronic devices for flight operations. As the integrated circuits used in these flight systems become more advanced, their susceptibility to effects from natural radiation may increase. This project is designed to assess this scenario, provide NASA with the means to test devices of interest in situ, and create a database for the engineering of future high-performance aircraft and reusable launch vehicles.

RESEARCH ACCOMPLISHMENTS

To facilitate these goals, an electronic testbed designed to evaluate static random access memory (SRAM) integrated circuits has been built and tested. SRAM was chosen as the first device because it is

straightforward to test for errors (called single event upsets) caused by radiation effects. The prototype of the testbed has already been flown on two high-altitude balloon flights (at altitudes of 107,000 ft. and 130,000 ft.) and ground tested at the Texas A&M Cyclotron Institute under proton irradiation and Los Alamos National Laboratory under neutron irradiation. Preliminary analysis of the balloon data shows no upsets of the devices tested during the two six hour flights. Comparison with expected radiation intensities at these altitudes and the performance of these devices observed during independent ground tests agree with this outcome. Attallah Lewis, a graduate student supported by the FAR grant, is currently analyzing the data from the proton and neutron tests, where upset events were observed.

The work performed by the prototype testbed will provide information for future improvements and modifications. In addition, a version of the testbed is currently being constructed to be integrated aboard a NASA/Dryden ER-2 high-altitude aircraft. The testbed will also be flown "piggyback" with a Dryden Project APEX balloon payload sometime early next year.

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Glenn Research Center (Reports)

Research to Significantly Enhance Composite Survivability at 550°F in Oxidative Environments

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Development of Synchronously Scanned Optical Parametric Oscillator (OPO) Coherent Antistokes Ramen Spectroscopy (CARS) as a New Probe for Hostile Environments

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Study of Electrical Contacts and Devices in Advanced Semiconductors

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INTRODUCTION

This research project involves a study of contacts and devices on heteroepitaxial Si/Ge (Silicon/Germanium) and GaN (Gallium/Nitrogen) films. These semiconductors are materials of interest to various NASA communication technology projects because they have the potential for supporting high frequency and high-speed solid-state devices for advanced communications applications. The primary objective of the project is to obtain stable low specific contact resistance ohmic contacts for these semiconductors to enhance device performance. The first two years will be devoted to a study of contacts for Si/Ge devices. Since heterojunction transistors with Si/Ge bases are beginning to be important in communications applications, an in-depth study of the contact metallization system was considered necessary for further performance improvement. Following the recent trend in very

large-scale integrated circuit (VLSI) metallization, Ti/Cu/Ti/Al (Titanium/Copper/Titanium/Aluminum), a copper-based system, has been employed in the initial study.

RESEARCH ACCOMPLISHMENTS

Test patterns have been designed and fabricated on Si/Ge wafers. For the fabrication of the contacts, as-grown doped layers were further implanted with BF_2 and As ions for the p-type base and the emitters layers, respectively, in order to produce a low sheet resistance surface layer. Contacts were metallized using an electron-beam deposited multi-layer structure of Ti/Cu/Ti/Al. Specific contact resistances on the order of 10^{-7} $\Omega \cdot cm^2$ and lower have been achieved. These results are comparable to the lowest reported contact resistances for conventional Si integrated circuit devices.

RELEVANCE TO NASA STRATEGIC ENTERPRISES AND BENEFITS TO SOCIETY

The Electron Device Technology Branch within the Communications Technology Division of NASA Glenn Research Center is developing Si/Ge-based RF integrated circuits for communications applications in the frequency bands through 32 GHz to cover the NASA Deep Space Network (DSN), the new Low Earth Orbit (LEO) commercial satellite communications network, and the recently FCC-approved terrestrial Local Multipoint Distribution Service (LMDS). The Si/Ge-based microwave integrated circuits will be less expensive in comparison to the conventional circuits. The lower power consumption of the Si/Ge chips and the possibility of producing single chip communication systems will accelerate the growth of portable communication equipment for the average citizen. The research conducted at Tuskegee directly complements the NASA research in this area.

STUDENT ACHIEVEMENTS

Fourteen undergraduate students are participating in this research program. They are receiving training in Si-integrated circuit process technology and electrical measurements on solid-state electronic devices. Some of these students are developing the motivation to continue on to graduate study and research programs at Tuskegee and other universities, while others will enter the electronics industry. These student researchers are currently preparing presentations to be made at regional and national conferences and writing papers for publication in professional journals.

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Cubic Boron Nitride Alphavoltaic Devices

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INTRODUCTION

The primary goal of this project is to grow cubic phase boron nitride compound semiconductor material in the form of thin films for use in alphavoltaic energy conversion devices, a recently proposed concept for space power applications. The growth of this particular material has proved challenging largely due to problems associated with obtaining large quantities of active nitrogen species. We proposed a modification to the conventional pulsed laser deposition technique for growing thin films where the laser provides the boron atoms and a relatively new type of inductively coupled RF plasma source is used to crack molecular nitrogen into atomic nitrogen (see Figure 1).

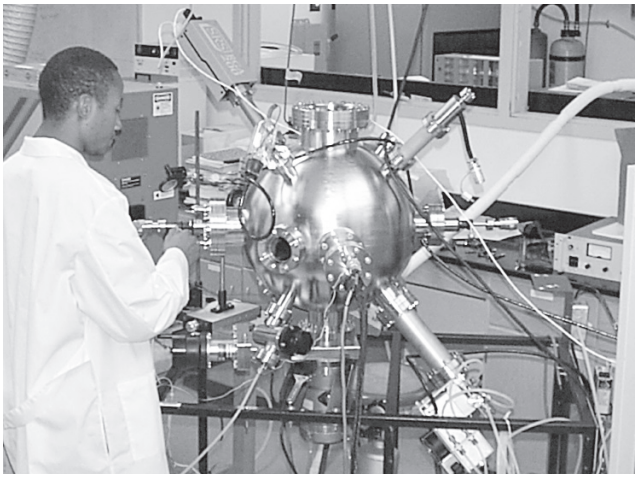

Figure 1: The new pulsed laser deposition system. The KrF excimer laser is on the left, and a student is adjusting the substrate position prior to film growth. The Radio Frequency (RF) plasma source is mounted on the bottom right of the spherical vacuum chamber.

RESEARCH ACCOMPLISHMENTS

A new custom-built vacuum chamber was delivered in January 1998, and was further customized in-house to provide greater flexibility during the film deposition process, as well as to permit a variety of in-situ characterizations, including quadrupole mass spectrometry (QMS) and reflection high-energy electron diffraction (RHEED). The new system is uniquely suited to permit the growth of nitrogen-containing compound thin films on a variety of substrates, and has been used to grow up to three separate films in a single day.

A detailed analysis of the inductively-coupled RF plasma source, which was installed in the system using QMS, indicates a cracking efficiency on the order of 5 percent in the range of 250 to 500 watts. Further studies are nearly completed to determine the optimum operating parameters and to maximize the production of atomic nitrogen. We have already demonstrated that this type of nitrogen plasma source can be used to produce stoichiometrically correct thin films of boron nitride (as verified by x-ray photoelectron spectroscopy) in conjunction with the ablation of an elemental boron target by a KrF excimer laser. To date, both silicon and polycrystalline diamond substrates have been employed, typically at temperatures in excess of 500° C. Analyses of the films using Fourier transform infrared spectroscopy, Raman spectroscopy, and x-ray diffraction to determine the crystal structure are in progress.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The fabrication of radiation-resistant semiconductor materials will permit the development of low-current on-chip power supplies for deep-space missions where photovoltaic and battery-based technologies are not optimal. In addition, the cubic phase of boron nitride is known to be second in hardness only to diamond, which makes it attractive for non-electronic applications such as wear-resistant ceramic coatings, especially in high-temperature environments.

BENEFITS TO SOCIETY

The material under investigation has a number of unique properties that make it ideal for devices other than those suited for space power applications. For example, the material has potential for both Light Emitting Diodes (LED's) and photodetectors for operation in the blue and near-ultraviolet region of the spectrum. It is a good candidate for high-temperature environments, such as those found in airplane and automobile engines. Because it is a very hard, low-reactivity material, it is also of interest as a wear-resistant coating. Further, the specific variation of pulsed laser deposition being developed to realize the cubic phase of boron nitride is expected to also provide the means to investigate other novel nitrogen-based composite thin films that may prove useful for a variety of applications.

STUDENT ACHIEVEMENTS

During the course of the second year of the project, several new graduate and undergraduate students were recruited. Gregory Triplett, the first student recruited for the project, received his M.S.E.E. in December 1997, and subsequently enrolled in the Ph.D. program. The bulk of his thesis work was presented at the NASA Glenn Research Center in March and at the International Conference on Metallurgical Coatings and Thin Films in April.

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Picosecond Gated Optical Imaging of Dense Fuel Sprays

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INTRODUCTION

This research uses picosecond time-resolved optical parametric amplification (TOPA) gates to image the spatial distribution of atomized dense fuel sprays from a jet nozzle system. The fuel sprays are simulated with water. Ultra-fast time gated imaging can "freeze" the motion of the droplets and provide information on the size and shape of each droplet from 3D reconstruction. TOPA has the advantages of simultaneously amplifying and slicing optical images on the picosecond time scale. Ultra-fast time-resolved optical imaging, using the earlier arrival photons, provides a superior approach to obtaining direct image information through the dense spray region by removing later arrival scattered photons.

From multiple time-resolved 2D images obtained from different illumination angles, a 3D image of the spatial distribution of the atomization of dense spray can be reconstructed. The time-resolved optical imaging to study atomization from fuel sprays is based on differences in optical radiation transmitted through dense jet sprays observed from different illumination angles using early (picosecond) light images; the development of the TOPA gate to isolate and amplify earlier arriving photons; and the 3D image reconstruction from two or more forward ballistic images.

We plan to extract information from early arrived ballistic and snake photons from dense fuel sprays using both single and double jet nozzles. The transmitted signal through this TOPA will not only be spatial- and temporal-gated but also amplified. The signal-to-noise ratio of the output signal will be enhanced with a TOPA gate. Diffusive noise will be separated from the early arrival image. 3D imaging under different illumination directions to determine the spatial distribution of atomization and the image processing and analysis of fuel sprays will be collaborated with other City College of New York (CCNY) faculty in order to develop a 3D reconstruction algorithm.

RESEARCH ACCOMPLISHMENTS

During this period, a femtosecond Ti:sapphire laser with a regenerative amplifier system has been tested as the laser source for the TOPA, a TOPA gated imaging system has been designed and parts have been ordered to be assembled and tested, a model system with stationary droplets situated in a host medium has been designed and tested to simulate the fast moving jet spray as a reference system, an improved jet has been designed and assembled, and one graduate student and three undergraduate students have been recruited and trained in photonic research.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The source of the atomization of fuel droplets is generated from a sub-scale prototype rocket injector (single or double water/air nozzles) to simulate jet nozzles in turbine engines and rockets. NASA researchers K. Breisacher and L. Liou from NASA Glenn Research Center (LeRC) are providing us with the necessary expertise in engine nozzle designs. Modeled fuel spray systems, such as a model for an impinging jet with two nozzles in series, will be designed and built at NASA LeRC and tested at CCNY. Water will be used to simulate the liquid fuel and high-pressure nitrogen gas will be used to break up the spray into droplets. This research can potentially lead to information on the fuel/oxidizer jet geometry and dynamics and the size, shape, and velocity of droplets from single and multiple jets. The outcome of this research will provide information for future engine design with improved efficiency and stability of fuel combustion.

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Polymerizable Monomer Reactants-Synthesis of Aryl Ethers

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Date of Original Award: 1996

INTRODUCTION

The primary focus of this investigation is to prepare durable, high-melting-point materials made from a class of chemical macromolecules known as polyamides. The polyamides will be used to form polymeric composites that have found significant application in the aeropropulsion industry.

RESEARCH ACCOMPLISHMENTS

Current studies are underway to measure the rheological properties of the polymer disks that have been formed using the aryl ether polyamides prepared during this research. The results listed in Table 1 show that neat resin disks have lower glass transition temperatures than those of PMR-15 (Polymerizable Monomer Reactant) polymers. Evaluation of the data presented in Table 1 shows that neat resin disks prepared from 25 percent pPDA and 75 percent BPAB are potential candidates for composite formulations. The major advantages of the polymers used in this study are that they consume less energy to process and provide similar durability to that of PMR-15 polymers.

Table 1. Modified Cure Cycle During Processing

Run No.	%pPDA/ %BPAB	Soak Time (min) Soak Temp (°F)	T_g (°C)	Description of Neat Resin Disk
1	25/75	30 450	242.03	No flow during heating; smooth; (Ideal)
2	25/75	60 488	249.33	No flow during heating; smooth; shiny
3	25/75	30 525	256.88	No flow during heating; smooth; shiny
4	25/75	90 450	242.08	No flow during heating; smooth; shiny
5	25/75	90 525	245.30	No flow during heating; smooth; shiny; minimal flash
6	60/40	30 488	254.72	Partial Consolidation

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The primary application of PMR technology is in the aeropropulsion industry. Both military and commercial vehicle engines can benefit from PMR technology; the use of PMR polyamides as components of commercial or military engines has shown that similar polyamides are durable to well over 100 hours of continuous use. We also expect that other uses of these materials are on the horizon. For example, when an electropositive metal such as chromium or cesium is deposited on the surface of pyromellitic dianhydride-oxydianiline (PMDA-ODA) polyamides, holographic properties have been observed.

BENEFITS TO SOCIETY

As noted above, PMR polyamides have potential applications in commercial vehicle engines. They also have numerous other possible applications.

STUDENT ACHIEVEMENTS

Ms. Jameelah Salim presented the synthesis and characterization work at the Department of Energy EPSCoR (Experimental Program to Stimulate Competitive Research) Research Conference in Baton Rouge, Lousiana. Ms. Salim received a cash award for the technical soundness and quality of her presentation. Mr. Jaimal Williamson is now a graduate student in the material science and engineering department at the Georgia Institute of Technology. He is also a GEM fellowship recipient and a scholarship recipient of the Semiconductor Research Corporation.

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Using Surfactants to Enhance Thermocapillary Migration of Bubbles and Drops and Facilitate Drop Spreading on Hydrophobic Surfaces

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INTRODUCTION

This project studies how to use surfactant molecules to enhance two processes that are crucial to microgravity technologies: the thermocapillary migration of bubbles and drops, and the spreading of aqueous drops onto hydrophobic surfaces. The scope and objectives of these processes are described separately below.

Thermocapillary migration is a method for moving fluid particles in the absence of buoyancy through a continuous liquid phase by applying a temperature gradient to the phase. When a bubble or drop contacts the gradient, one pole of the particle becomes warmer than the opposing pole. As the surface tension between the fluid particle and the continuous phase decreases with temperature, the cooler pole is of higher tension then the warmer pole. The interface is tugged in the direction of the cooler pole, and this causes a fluid streaming which propels the particle in the direction of the warmer fluid. Surfactant impurities present in the continuous phase adsorb on the surface and are convected to the trailing or cooler pole where they lower the tension. This decreases the thermocapillary driving force, and the particle velocity is reduced. The overall objective is to remove this retardation. A theory for inertialess flows for buoyancy-driven motion has previously been constructed which demonstrated that when a surfactant which kinetically exchanges quickly between the sub-layer and the surface is dissolved in the continuous phase at a high surface concentration, the surfactant does not

allow the impurity onto the surface. In addition, because of the high concentration and the rapid kinetic exchange, the surface concentration of surfactant is uniform, and this remobilizing surfactant does not exert any retarding stresses. The specific theoretical objectives of the study are to extend the model to higher migration velocities in which inertial effects (as measured by the Reynolds number) are important, and include thermocapillary effects and finite kinetic exchange. The experimental objectives are to conduct experiments to verify this remobilization.

Aqueous solutions do not normally spread on hydrophobic surfaces because the high aqueous/hydrophobic solid tension ($\gamma_{s/l}$) leads to a large contact angle, and the aqueous phase beads up as a drop. The overall goal of this research is to find surfactants that reduce this tension and thereby enable spreading. It is suggested that surfactants with long hydrocarbon chains and small polar groups adsorb strongly on the surface, with the chains cohered together, and with the polar groups in contact with the aqueous phase. This configuration presents a hydrophobic surface to the aqueous phase, which should significantly reduce $\gamma_{s/l}$. To study this idea, a series of model polyethoxylated surfactants, CH_3 $(CH_2)i(-OCH_2CH_2)j$-OH, in which the chain length and polar group can be varied and model surfaces which are reproducibly hydrophobic will be used. The specific objectives are twofold. The first is to measure the adsorption of surfactant onto the aqueous/solid surface by using Fourier Transform Infrared Spectroscopy as a function of chain length i and polar group size j. From these measurements, it should be possible to prove that long-chain small-polar-group surfactants adsorb at high density. The second is to measure contact angles and correlate the extent of adsorption to the reduction in angle. From these measurements, surfactants which optimally reduce the tension should be identified.

RESEARCH ACCOMPLISHMENTS

The research on remobilizing thermocapillary migration has obtained numerical simulations of the flow pattern and drag on a bubble at a first order Reynolds number, where Re is $Ua\rho/\mu$ and U is the particle velocity, μ and ρ are the viscosity and density of the continuous phase, and a is the radius. Results are presented here for bubble motion driven by buoyancy with rapid kinetic exchange. The bulk concentration is characterized by the nondimensional parameter k ($=\beta C_b/\alpha$ where β and α are the adsorption and desorption rate coefficients and C_b is the bulk concentration); bulk diffusion by the Peclet number Pe (Ua/D, where D is the bulk diffusion coefficient); interfacial forces by a Marangoni number ($RT\Gamma_\infty/\mu U$, where RT is the thermal energy and Γ_∞ is the maximum packing concentration); and adsorption by the parameter $\chi(=a\alpha/\beta\Gamma)$. All simulations are for Ma=5, Pe=100 and χ=1. For a fixed bulk concentration (k=1), as Re increases, a vortex develops at the back end of the bubble due to the reduction in interfacial mobility caused by the surfactant adsorption. As the bulk concentration increases, the surface becomes remobilized, the vortex disappears (Re=50) and the drag (nondimensionalized by $\pi\rho a^2U^2$) is reduced (Re=50). This verifies the theory for remobilization at high velocities.

The research on enhancing the spreading of aqueous drops on hydrophobic surfaces has focused first on synthesizing model hydrophobic surfaces to be used for the FTIR (a type of spectroanalysis) measurements. Octadecyl trichlorosilane (OTS) has been reacted on oxidized silicon surfaces by dissolving OTS in a nonpolar solvent and placing a wafer of the oxidized silicon surface in the solution. The OTS adsorbs on the surface with the hydrocarbon chain towards the nonpolar solvent, and the time of reaction determines the coverage. Atomic force microscopy (AFM) has been used to study the coverage as a function of adsorption time to identify the time necessary for complete coverage and maximum hydrophobicity. The AFM images of height and lateral friction demonstrate a primary fractal growth of islands of OTS for short times (a-c) followed by a secondary growth (d-e) which fills the regions between the islands until a uniform coverage is reached. Contact angle measurements given in the figure correlate the coverage to the surface hydrophobicity.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

NASA is currently involved in developing material manufacturing processes in space where the microgravity manufacturing environment enhances the properties of the final product (such as containerless crystal and glass manufacture). These material processes involve the generation of bubbles, which must be removed from the final product. On earth, buoyancy effects this removal. While thermocapillary migration has been suggested as a means to remove these bubbles, the presence of surfactant contaminants has reduced thermocapillary migration velocities, and this approach has not been very effective. The use of remobilizing surfactants to remove this retarding

effect, as studied here, promises to increase thermocapillary velocity and thereby enhance the viability of this method of bubble removal.

Many processes vital to mechanical system performance in microgravity require aqueous solutions to spread completely over surfaces that are partially hydrophobic or "dirty." An important example is contact film cooling. In space, without gravity to force spreading, small contact angles are necessary to force liquids to move over dirty surfaces. This research on finding surfactants that reduce water contact angles on hydrophobic surfaces by adsorbing strongly on the surface and enhance spreading will be vital to mechanical systems requiring complete spreading.

BENEFITS TO SOCIETY

The surfactant systems developed here, which enhance spreading on hydrophobic surfaces, can be used to increase the efficiency by which insecticides are sprayed from aqueous preparations onto leaf surfaces. Presently, as drops are sprayed onto foliage, they tend to bead up because of the waxy nature of the leaf surface, and then bounce or roll off. Surfactants that enhance spreading will increase the retention on the foliate surface, and will allow for less preparation to be applied.

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Controlling Chaos in Josephson Junction

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INTRODUCTION

At present, digital communication is carried out mainly by transmitters and receivers operating in the so-called linear regime. The technology used by these transmitters and receivers is based almost exclusively on linear theory. The option of creating digital communication systems based on transmitters and receivers operating in the nonlinear regime has been investigated by a number of researchers recently. The type of nonlinear behavior on which these transmitters and receivers will be based is known as "chaos." Chaos designates the deterministic but complicated behavior of systems of equations in which arbitrarily small changes in the input produce large changes in the output. Recent advances have uncovered fundamental principles that make nonlinear digital communication possible. It is now known that chaos can be controlled. Various control techniques have been implemented in prototype devices that generate, transmit, and receive nonlinear digital signals.

In this project, we are attempting to investigate a variety of very high-frequency new devices, design and analyze physical and mathematical models of the devices, investigate the dynamic and chaotic process in these models, and investigate techniques for the control of chaos.

During the past two decades, the Josephson Junction (JJ) has served as a powerful paradigm in understanding low-dimensional chaos in nonlinear systems. This is mainly because the equation modeling the dynamics of the junction represents a minimal system for the observation of chaos and it is isomorphic to a variety of physically interesting situations such as the forced pendulum, pinned charged density waves, and phased locked loops. A thorough study on high-frequency devices such as a superconducting JJ will be conducted in light of the above issues.

RESEARCH ACCOMPLISHMENTS

The principal investigator and a research associate spent the summer working on techniques for controlling chaos. A feedback control process, which is applicable to stabilizing some well-known non-linear systems, is in progress.

BENEFITS TO SOCIETY

The need for digital communication devices with lower power consumption, greater carrying capacity, increased flexibility, and enhanced security is ubiquitous in today's economy. Mobile and satellite space communication networks, business transactions, and health monitoring will benefit from such devices.

STUDENT ACHIEVEMENTS

Three students were involved during Summer 1998 for eight weeks. They worked on a project called the "chaotic pendulum." The students developed several mathematical programs to study IRC (inductor, resistor, capacitor) circuits, the Vander Pol equation, and the simple and forced pendulum. They observed the periodic and chaotic behavior of the forced pendulum. They will continue to work on a method of controlling the chaotic pendulum. The students' work was presented at two international conferences.

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Growth and Characterization of m-v Semiconductors for Device Applications

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Turbulent Premixed Methane-Air Combustion: Emissions, Characteristics, and Modeling

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INTRODUCTION

The objective of this study is to enhance the understanding of the premixed combustion of methane and air under normal gravity conditions. In particular, the effects of flow rate, equivalence ratio, and the presence of chlorinated hydrocarbons on emissions and flame structure (shape, velocity, streamlines, and vorticities) are to be established and explained.

RESEARCH ACCOMPLISHMENTS

In the past year, point flow velocities were measured using a TSI 3-D Laser Doppler Velocimeter (LDV), and the whole (sheet) flow velocity distribution, streamlines, and vorticities were measured using a Dantec Dual Cavity Particle Image Velocimeter (PIV) for both cold (no flame) and hot (with flame) premixed jets. Seeding was found to be essential for both the LDV and PIV measurements, but the LDV was more sensitive to the seeding because it took minutes and sometimes hours for the LDV to map one full-sized image. During that time, the particle concentration and flow rate could vary. On the other hand, one full image could be obtained from the PIV in mini-seconds, minimizing the influence of particle concentration and flow rate variation. A cold airflow at 1.4 m/s jet penetrated 7 D above the nozzle without many disturbances. In the region of 7.5 to 16 D above the nozzle, vortices were formed on both sides of the main flow-stream. On each side of the main stream, there was a 3-mm region where the stationary gases mixed with the main stream, which made the streamlines of the flow appear about twice as wide as the nozzle.

With the flame, the flow jet quickly expanded several times in volume and the flow speed significantly increased from its corresponding cold flow value. Some of the flame packets were entrained into the reverse flowing stream of the large stationary vortex and were transported upstream. Just before an active period of vortex shedding, the rotational velocity around the stationary vortex center increased. As the shed vortex rotated, it picked up the flame packets around the combustor, thus making the shed vortex visible in the image picture. These results represent some of the first published PIV data for premixed flames. The numerical modeling results were compared and used to explain the experimental results.

With respect to emission measurements, in the fuel-lean region, the CO concentrations quickly jumped to thousands of ppm or more as the equivalence ratio, Φ, increased. CO_2 reached its maximum value of about 10 percent at $\Phi = 1$, where complete combustion occurred. NOx formation was also strongly dependent on the equivalence ratio at which the burner was operated. It reached its maximum of 58 ppm at $\Phi \approx 1$, and decreased

significantly as the operation moved away from stoichiometric. The total flow rate was found to have a significant effect on the combustion characteristics of the premixed burner. As the total flow rate increased, the O_2 concentration decreased, but the UHC (unburnt hydrocarbons), CO, CO_2 and NO_x concentrations increased, and the NO_x curve shifted to the fuel-lean region.

The nozzle material and size were found to be critical for the premixed combustion. High thermal conductivity materials (such as aluminum) led to low temperatures (<100° C) at the nozzle, resulting in unstable flames. Low thermal conductivity nozzles (such as marble) produced higher CO_2 concentrations because of the high combustion temperature. As the width of the nozzle increased, the curve of the CO_2 concentration became broader and less sensitive to the fuel-air ratio, and the curve of the NO_x concentration increased and shifted toward the fuel-lean region.

STUDENT ACHIEVEMENTS

During this academic year, a total of five students (one graduate and four undergraduate) received research support and training at various times during the year as student research assistants. Most of these students will graduate in the 1998-1999 academic year. Three technical papers and one poster presentation on the project were presented at the American Institute of Chemical Engineers (AIChE), American Society of Mechanical Engineers (ASME), and 27th International Combustion conferences, and two papers have been accepted for 1999 conferences.

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Glenn Research Center (Abstracts)

High Resolution Measurements in Compressible Turbulence Interacting With Shock and Expansion Waves

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ABSTRACT OF PROPOSED RESEARCH

Supersonic combustion systems of future aircraft may take advantage of the presence of shock waves in the flow to enhance mixing properties down to small scales of turbulence. Manipulation of supersonic jets and free shear layers by impinging shocks or expansion waves may provide a new technology for combustion applications. The phenomenon of relaminatization of compressible turbulent flows through a nonlinear interaction with expansion waves and the phenomenon of turbulence amplification through interactions with shock waves have not been explored adequately. In the very few previous investigations of these phenomena, the interaction of turbulence with shock or expansion waves was accompanied by the destabilizing or stabilizing effects of streamline curvature.

In the present work, three experiments are proposed that are designed to investigate the interactions of shock and expansion waves with turbulence. These experiments include the interaction of shock waves with a circular jet, the interaction of planar expansion waves with a turbulent jet, and the interaction of planar expansion waves with grid-generated turbulence. The experimental configurations will eliminate the effect of streamline curvature. This approach will provide a direct assessment of the effects of the interaction on turbulence and of the possibility of suppressing turbulence inside the flow over long distances.

The experiments will be carried out in a one-foot diameter shock tube facility with high-resolution instrumentation. Measurements of velocity, vorticity, temperature, density, and pressure at various locations of the flow field, combined with UV-laser diagnostics, will provide the required information. A jet flow facility has been designed with an exit tube diameter of 1/4 inch. This facility, which is under construction, will use an independent pressure tank and will allow for sub-micron particles to enter and mix with the flow before they exit the tube and the interaction region.

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Robust Fault Detection and Isolation for NASA Launch Vehicles

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ABSTRACT OF PROPOSED RESEARCH

Health monitoring and supervision of space vehicles is essential for the improvement of system reliability, safety, and dependability. This entails continuously checking the system for faults and failures and taking appropriate actions to maintain the operation of the vehicle in such situations. A space vehicle is a complex technical system that involves the extensive use of multiple sensors, actuators, and other system components, any one of which could fail or deteriorate. One of the primary approaches to model-based fault detection and isolation (FDI) uses residuals from a bank of state estimators.
The proposed research will improve the performance of estimator-based FDI by using the power and non-conservativeness of recently developed mixed-structure singular-value theory to develop estimators that are robust with respect to errors in the system model. These robust estimators will be used to improve the performance of existing FDI algorithms. The resulting robust FDI algorithms will be applied to the health monitoring of the Space Shuttle Main Engine and a NASA Expendable Launch Vehicle.

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Goddard Space Flight Center (Reports)

Exploitation of Properties of Aggregated Molecules for Optical Device Applications

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Date of Original Award: 1996

INTRODUCTION

The two main research goals of this FAR award are the following: first, the expansion of basic research investigations pursued in the principal investigator's (PI) laboratories dealing with fundamental molecular information about aggregated molecules. Second, the exploitation of properties of aggregated molecules to develop superradiant nanoscale light sources for near-field scanning optical microscopy (NSOM); to formulate coatings composed of aggregated molecules that allow remote detection through luminescence that is monochromatic and superradiant; and to develop so-called fluorescence lifetime variation sensors.

RESEARCH ACCOMPLISHMENTS

Raman Probing of Porphyrins on Electrode Surfaces

We have acquired Raman spectra of meso-tetra(p-sulfonatophenyl)porphyrin (TSPP) and its metal complexes in thin films adsorbed onto electrode surfaces in electrolytic solution.

The Raman spectra of adsorbed TSPP obtained by microscopic (~ 1-10 μm) probing indicates a dependence on the surface pH, described in a recent publication from the PI's laboratory accepted in the *Journal of Physical Chemistry*.

A most important deduction derived from studying the dependence of the Raman spectrum on applied potential Raman is that the pH of the surrounding environment is a key determinant of spectral change. As a spin-off, the possibility of exploiting the spectral change to formulate molecular optoelectronic devices is evident. In particular, nanostructural ultrafast molecular switches and magnets have been proposed that are based on the potential-controlled protonation and aggregation of porphyrins.

Superradiance and Spectral Dynamics of Adsorbed Cyanine Dyes

The cyanine dye 3,3'-bis-(3-sulfopropyl)-1,1'-diethyl-5,5',6,6'-tetrachlorobenzimidazolo-carbocyanine (BIC) adsorbed onto colloidal silver particles shows lasing at a phenomenally low threshold, enabling

the nanostructural system to function as a mirrorless laser. Since the last report, continued study has led to conditions under which a threshold for laser can be attained that is substantially lower than that measured earlier, and has led to a paper that has been accepted for publication in *Applied Physics Letters*.

Two other dyes that have been found to exhibit superradiance, lasing, and dynamic Stokes's shifts of excitation bands, upon formation of aggregates, are DDPT (3,3'-diethyl-5,5'-dichloro-9-phenylthiacarbocyanine) and NTC (3,3'-dimethyl-9-phenyl-4,4',5,5'-dinaphthothiacarbocyanine).

RELEVANCE TO NASA STRATEGIC ENTERPRISES

These research efforts fall under the Strategic Enterprise thrust of Earth Science, with overlap to efforts aimed at using optical techniques for remote sensing and search-and-rescue.

BENEFITS TO SOCIETY

Applications envisaged for the systems discussed above, include mirrorless lasers; laser gain materials with ultralow thresholds for lasing; materials for flat-panel display devices; superradiant coating materials for search-and-rescue (and robotic vision) applications, as opposed to the "LaserPaint" approach; materials for optical switches in optical/optoelectronic devices; and high-intensity light sources in NSOM.

STUDENT ACHIEVEMENTS

Two graduate students are presently conducting research under this project.

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The Development of a New Generation Trapped Radiation Database

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INTRODUCTION

Electrons and protons stream from the sun in a plasma called the solar wind. That portion of the solar wind which approaches Earth alters the Earth's magnetosphere—the region around the Earth affected by the Earth's magnetic field—distorting, squeezing, pushing, and elongating it in a complex of only partially understood ways. Meanwhile, energetic electrons and protons within the Earth's magnetosphere bounce back and forth along the Earth's magnetic field lines between its poles, drifting in well-understood ways even as they move. This radiation, called trapped radiation, is a central feature of space physics; it plays an important role in both theoretical and practical applications. Empirical models developed at NASA provide the best available quantitative information about this radiation, and its intensity at different locations, by providing averages of the results of many satellite missions. But for many purposes, such summaries are not adequate; more detailed information is needed that reflects the actual state (shape) of the magnetosphere. This project is developing and implementing new tools to provide a prototype of a new generation trapped radiation database, which is sensitive to varying magnetospheric conditions.

RESEARCH ACCOMPLISHMENTS

The key to our approach is to characterize the state of the magnetosphere in terms of solar wind (input) parameters and magnetospheric responses (using geomagnetic indices as surrogate output parameters). To do so, it is first necessary to determine the nominal time delays between these various parameters. Two methods are being used: the classical method of linear prediction filters and an independent method based on two-dimensional histogram analysis. Together, these methods will provide convincing evidence for the delay conclusions. In addition, energetic particle data from the 1985 Japanese satellite Ohzora has been transformed into a standard archival format (CDF) as a step in the creation of a prototype database. Software has been written to similarly archive energetic particle data from the 1993 Combined Release and Radiation Effects Satellite (CRRES) mission, though some apparent discrepancies were discovered in the original data, causing a temporary delay in the actual archiving process.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Satellites pass through regions in which there is the possibility of radiation damage to telemetry, electri-

cal systems, cargo, and animals or humans on board. Shielding requirements in mission planning stages use radiation estimates based on the best available models. Long-term averages available from current energetic particle models often do not adequately predict radiation dosages. This work will provide a major step towards the creation of a far more accurate and comprehensive database.

BENEFITS TO SOCIETY

Increased satellite safety and cost effectiveness will result from providing only the shielding needed to protect against radiation doses likely to be encountered.

STUDENT ACHIEVEMENTS

Three students have become proficient C programmers and IDL users and three have become sufficiently familiar with the project that they began making useful research suggestions. Three are continuing work on the project during its second year.

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Formal Foundations of Agents

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Boundary Layer Processes Affecting Tropical Cyclone Intensity Change

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INTRODUCTION

The objectives of this research are to develop the most extensive database of the tropical cyclone boundary layer to date and to investigate thermodynamic cooling of the eyewall region. A rigorous theoretical treatment of how the eyewall structure is maintained with this cooling is being developed and is supported by numerical models.

RESEARCH ACCOMPLISHMENTS

A database for the Atlantic and western Pacific Ocean has been assembled, containing several thousand occurrences when a tropical cyclone passed within 555 km of buoys maintained by the National Data Buoy Center, ships, and/or land. The data is currently being processed from the Australian Climatology Centre and the Japanese Meteorological Agency based on buoy, ship, and island atoll observations in those respective ocean basins. This is already the largest database of its kind, and will be quite extensive once the Australian and Japanese data is included.

Analysis of the data shows that cooling is almost always observed in the boundary layer. However, once an eyewall forms, this cooling occurs at a lesser rate since sensible heat fluxes and warm eye air begin to compensate. Calculations show that this cooling is due to adiabatic expansion, sea spray evaporation, and precipitation evaporation. We have begun to model these results using a Cray C90 supercomputer. Seminars have presented at the Hurricane Research Division, Colorado State University, Texas A&M University, and the Intergovernmental Hurricane Conference.

RELEVANCE TO NASA STRATEGIC ENTERPRISES AND BENEFITS TO SOCIETY

Many university and NASA researchers who are conducting research on tropical cyclone genesis and development will find this data useful. The analysis

will yield a better understanding of the tropical cyclone boundary layer and tropical cyclone intensification. In addition, a better understanding of the hurricane boundary layer, which is where hurricanes derive their energy, will translate into better hurricane intensification forecasts.

STUDENT ACHIEVEMENTS

Seven students have been involved in all facets of this research, including programming, spreadsheets, graphics, conference papers, and conference attendance. Two have graduated, one entered graduate school, and the other obtained civilian Navy employment with future plans for graduate school.

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Basic Research in Atomic, Molecular, and Optical Physics in Support of NASA Strategic Enterprises

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High-Density Solid-State Memories

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INTRODUCTION

Solid-state memory is defined as systems that store electronic data using no mechanical motion. It is nonvolatile and rewritable. This type of memory offers the advantages of small size, light weight, high access speed, and ruggedness compared to conventional memory such as magnetic or optical disks and tapes. These unique features of solid-state memory have the potential to profoundly impact every business from entertainment to medicine.

There are two main existing technologies for nonvolatile memory. One is the floating gate technology that produces electrically erasable programmable read only memory (EEPROM) and flash memory (FM). The other is the ferroelectric capacitor-based technology that yields ferroelectric random access memory (FRAM). The proposed nonvolatile memory cell in this project relies on a unique combination of a Schottky junction with a tunable barrier height and an adjacent electron potential well. It can be integrated with high electron mobility InP[AHO6]- or GaAs-(Gallium/Arsenic) transistors and possibly with silicon transistors. The objective of this project is to pursue realistic approaches in the development of new types of high-density solid-state memory along the preliminary lines already demonstrated by recent work.

RESEARCH ACCOMPLISHMENTS

Since the initiation of this project in March 1998, significant research progress has been made. A new apparatus has been set up to test the endurance of the memory devices. The most significant feature for this set-up is the ability to study how the device being tested evolves under various testing conditions. Information gathered from the testing process is used to modify the device structure and the growth conditions for semiconductor layers. Using this apparatus, a maximum number of 72 was obtained for on-off and off-on cycling. This number is more than an order of magnitude improvement over the initial published result. It should be possible to dramatically improve this cycling number up to the number commercially required.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This project is important for the development of the next generation of space instruments that require very large-scale integrated circuits and high-density solid-state memory.

BENEFITS TO SOCIETY

Applications of the proposed memory include sub-notebook computers and video and audio recordings.

STUDENT ACHIVEMENTS

One graduate student has been recruited to be involved in every aspect of this project.

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Development of a Balloon-borne X-ray/Gamma-ray Detector for Studies of High Energy Astrophysical Sources and Related Space- and Ground-based Multiwavelength Observations

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Date of Original Award: 1998

INTRODUCTION

The goal of this program is to perform multi-faceted research in the area of high-energy astrophysics. The two major research efforts are the laboratory development of a new balloon-borne x-ray/gamma-ray detector designed to precisely fix the location and study the properties of high-energy cosmic sources, and the analysis and interpretation of an extensive multi-wavelength database to address questions related to the origin of the broadband emissions observed from active galaxies and similar objects.

RESEARCH ACCOMPLISHMENTS

The principal investigator has completed the first year of a joint faculty appointment between the department of physics at Southern University and the department of physics and astronomy at Louisiana State University, where he is also a member of the Space Science and Particle Astrophysics research group. During the first months of this project, he has initiated an active research program in the area of astronomy and astrophysics involving both undergraduate and graduate students and is in the process of establishing a laboratory for the design, fabrication, assembly, and testing of components for photon and particle detectors intended for space science applications. In collaboration with colleagues elsewhere, he also maintains an active multi-wavelength observation program, with associated publications and presentations at professional meetings.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The objectives of this research program are directly relevant to the goals of NASA's Space Science Strategic Enterprise. Published results from this project will contribute to our fundamental understanding of the universe, especially the role that energetic processes play in its ongoing evolution. Further, innovative and novel concepts in detector design are being investigated in the laboratory, some with potential commercial applications.

BENEFITS TO SOCIETY

This program will increase our fundamental understanding of the universe and our place within it. An immediate and practical benefit may result from the development of a new type of electronic component, a bi-directional charge-coupled device for fast timing that may find future applications in the area of medical imaging and related fields. From a human resource perspective, students involved in this program will acquire a solid grounding in the current methods of astrophysical research, including instrumentation, laboratory, and computer skills, and will be well prepared to pursue further education or careers in a wide range of technical fields.

STUDENT ACHIEVEMENTS

Over the first months of active funding for this research program, one undergraduate Physics major was employed for the summer to work on public outreach and educational projects at a newly established public observatory. For the 1998-99 academic year, two undergraduate senior honors theses in the areas of astronomy and astrophysics are being supervised. Additionally, an incoming first year graduate student has begun work on a research topic in astrophysics that will eventually lead to a master's thesis. Most of these projects will likely involve student presentations at professional meetings and student co-authorship on research publications.

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The Accuracy of Earth Observing System Measurements of Middle Atmosphere Dynamics

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Effects of Aerosols and Cloud Interactions on UV, PAR, and Crop Yields

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Goddard Space Flight Center (Abstracts)

Characterization and Simulation of Gallium Nitride Ultraviolet Photodetectors

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ABSTRACT OF PROPOSED RESEARCH

This research is directed at understanding the fundamentals of high-performance ultraviolet photodetector arrays. The performance of these arrays will be investigated as they relate to materials properties, device topology, and manufacturability. This project will be implemented using the latest computational techniques based on physical models and scientific visualization. The models will be verified using state-of-the-art experimental characterization techniques involving carrier transport measurements and high-speed testing. The uniqueness of this approach is highlighted through the combined use of electron beam testing methods and computational visualization to convey the experimental and simulation results.

This program will directly support and enhance ongoing solid-state ultraviolet photodetector technology development at NASA, which is primarily headed by the Solid-State Device Development Group at NASA Goddard Space Flight Center. The combination of materials measurements and computational electronics will augment the design and fabrication of wide band-gap detectors being used in this application.

As a benefit to Morgan State University, this program will afford underrepresented students and faculty with research opportunities that will help shape the future as it relates to the mission of NASA.

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Simulation Support for the Development of GLAST 2

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ABSTRACT OF PROPOSED RESEARCH

The Gamma-ray Large Space Telescope (GLAST) is a next generation high-energy gamma ray observatory intended as the successor to the Energetic Gamma Ray Experiment Telescope (EGRET) instrument on the Compton Gamma Ray Observatory. It has been under development since 1995, when it

was selected as part of NASA's "New Mission Concepts for Astrophysics" Program. This mission concept study resulted in additional NASA support for the project. Heavy use of simulations was critical to the success of this study. These simulations helped determine the response characteristics of the telescope, and guided the subsequent research and development program.

The principal investigator of this proposal joined the GLAST simulation team as an American Society for Engineering Education Summer Faculty Fellow working at the Naval Research Laboratory (NRL) in the summer of 1995. He is the primary simulation expert for the NRL, and helps maintain the Gismo simulation code used by GLAST.

This grant will provide the academic release time, undergraduate salary, and computer equipment necessary to continue the GLAST simulation effort during the academic year. It supports NASA's interests by increasing the level of simulation support provided to GLAST, which is currently in the pre-A program phase with an anticipated launch in 2005. In particular, simulations will be conducted to:

- study the response of the hodoscopic[LG7] calorimeter being constructed by NRL; these studies will result in a finalized design for the calorimeter section of GLAST;
- study different tracker/converter designs; and
- test the data acquisition and data reduction electronics being designed by NRL; this will result in a detailed design of the data acquisition (DAQ) system on GLAST.

Since the principal investigator works at a Hispanic-Serving Institution, this project provides a unique opportunity for the participation of an economically or socially disadvantaged student in a major ongoing NASA project.

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Self-Timed Synchronous Digital System Design

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ABSTRACT OF PROPOSED RESEARCH

The maximum throughput of a computer system that uses a global fixed-period clock to control its circuits/systems timing is not realized for a given bulk CMOS/BiCMOS (Complementary Metal Oxide Semiconductor/Bi-Complementary Metal Oxide Semiconductor) VLSI (very large scale integration) technology. Because the period of the global clock is determined by the worst case propagation delay of the computational logic used to realize the functional unit, the peak throughput of the unit is determined by the slowest stage critical path propagation delay. If a computer/digital system is implemented with a global clock that has a variable period determined by the propagation delay of the slowest computational logic blocks for a given input, the throughput of the system would approach the maximum possible for the selected technology and system architecture. Circuits with this property are called self-timed circuits. The goal of the proposed research is to design and develop a synchronous self-timed superscalar processor architecture. This investigation will consist of the following three tasks.

The first task will be to develop the synchronous self-timed functional units of a superscalar microprocessor, such as integers and floating point execution units, bus interface units, cache architecture and controller, and so forth. This task includes the physical design of the VLSI circuits and high-level simulation of the functional units to identify the optimum scalar pipeline architecture and number stages. This task will be completed within twelve months.

The second task will focus on architectural and performance issues that are associated with a variable global/local clock processor architecture. The issues included in this investigation will be data and procedural dependency, resource conflicts, instruction parallelism, and machine parallelism in a self-timed synchronous superscalar computer architecture. The main objective of this architectural- and performance-level research is to determine the optimal processor architecture and system/processor-level clock control hierarchy.

The final task will concentrate on the on-chip and off-chip memory and bus timing and performance issues associated with a variable processor cycle architecture. The goal of this work is to determine the optimal memory architecture and interface realization for a self-timed synchronous superscalar processor.

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Robust Algorithms for Image Registration

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ABSTRACT OF PROPOSED RESEARCH

Image registration refers to the problem of aligning a set of images. The images may be taken at different times, by different sensors, or from different viewpoints. There exists a fundamental problem in establishing correspondence among the images, placing them into a single spatial reference. This problem is of practical importance in many fields, including remote sensing, medical imaging, and computer vision. Registration is often necessary for integrating information taken from different sensors (i.e., multi-sensor data fusion), finding changes in images taken at different times or under different conditions, inferring three-dimensional information from images in which either the camera or the objects in the scene have moved, and for model-based object recognition. NASA-related tasks associated with image registration include satellite remote sensing, planetary data mapping, generating large panoramic images (mosaics) from several overlapping images, producing super-resolution images from multiple images of the same scene, and multi-sensor image fusion.

We propose to develop robust techniques for establishing the precise geometric relationship between tactically acquired imagery. The system will be flexible enough to position imagery derived from electro-optical, infrared, and synthetic aperture radar sensors. In addition, digital elevation maps resulting from digital terrain elevation data will be accommodated and utilized when available. Performance bounds for achieving the image-to-image registration with and without knowledge of the local terrain elevations will be investigated. We will demonstrate the ability to ortho-rectify the imagery and register forward-looking with downward-looking imagery. This will involve handling data containing a significant amount of perspective distortion, such as that in imagery collected by a low altitude tactical unmanned aerial vehicle over mountainous regions.

This project will build upon our preliminary work in parameter estimation and logpolar registration. In that work, we have achieved subpixel accuracy in registering images subjected to large-scale distortions. We plan to exploit those results to provide flexible solutions to many problems in surveillance, targeting, data fusion, and multi-sensor data exploitation. The developed algorithms will provide capabilities to assemble, update, and maintain geographical information databases using imagery collated from different sensor types and platforms. Given such a system, new imagery can be quickly integrated into the database so that site monitoring change detection tasks may be performed.

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Jet Propulsion Laboratory (Reports)

A Prototype Object-Oriented GIS

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Multilayer Thin Film Capacitors for High Performance Power Applications

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Fault-Tolerant and Self-Checking Logic System Design

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Low Complexity, Refigurable Circuits for Data Compression

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INTRODUCTION

NASA continues to receive pressure to design spacecraft in a more cost-effective manner. Building electronic hardware to fulfill this mandate is especially difficult, since space missions require low volumes of specialized circuits. A recent development in circuit design, field programmable gate arrays (FPGA's), offers a solution to this problem. FPGA's are reconfigurable digital logic circuits whose operation depends on how they are programmed. The reprogrammability of FPGA's means that circuits can be prototyped and tested very quickly and inexpensively, since the delays and expense of custom fabrication are bypassed. Being reprogrammable makes FPGA's especially cost-effective in low-quantity applications, which is the typical case for NASA missions. This research project is using FPGA's to design data compression circuits. The objectives of this project are to produce working circuits that can be used in NASA missions, to create a library of reusable data compression modules that can be connected to form compression circuits, to evaluate the viability of using reconfigurable circuits in NASA missions, to train students in reconfigurable circuit design, and to research data compression algorithms. Reconfigurable design is still a new research area, and more work is needed to improve both design methods and applications. This project will help to determine where reconfigurable circuits can benefit both space and commercial applications.

RESEARCH ACCOMPLISHMENTS

Two data compression circuits have been designed. The first is a fixed-point, one-dimensional symmetric wavelet transform and its corresponding inverse wavelet transform. The second is a multiplier-free binary arithmetic encoder and its corresponding decoder. Both designs have been tested through computer simulation and synthesized down to the chip level. Currently, FPGA's and hardware are being purchased to verify the actual programmed circuits. In addition to these circuits, a simple data scrambling circuit has been completed, from the computer description down to the tested hardware. This verified that complete design capability was in place.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

There are two main reasons for NASA to be interested in reconfigurable circuit design. First, designing and fabricating custom circuits is very expensive. In commercial applications, this cost can be amortized over many thousands of units. However, in space applications, where typically only a few units are required, the cost of custom circuits can be prohibitively expensive. Using reconfigurable circuits is a way for NASA to obtain performance approaching that of custom circuits, while still maintaining low cost. The data compression circuits currently being designed by this project can be used to build complete data compression systems. A second reason for considering reconfigurable circuits is their potential for reducing volume and weight requirements in space missions. Since FPGA's can be reprogrammed, one FPGA can replace multiple

custom circuits, so long as these circuits are not used at the same time. The results of this project provide more data to determine whether replacing custom circuits with reconfigurable circuits is a practical design trade-off.

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Jet Propulsion Laboratory (Abstracts)

Formation and Characterization of Metal-Diamond Interfaces

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Date of Original Award: 1998

ABSTRACT OF PROPOSED RESEARCH

A comprehensive research project is proposed to study the growth and morphology of metal films on diamond. The objective of the proposed research is to gain an understanding of how ultra-thin metal films can be grown on diamond—a technologically important wide-gap semi-conductor. Diamond's extraordinary properties, such as high thermal conductivity and high-temperature stability, make it a candidate for a variety of direct applications that are key to NASA's future. These include electronic device technology, weight- and space-saving flat panel displays for use in flight, small packaged high-current switches, magnetic overlayers, and novel multi-layer structures. All of these applications hinge on the ability to produce high quality metal-diamond interfaces.

In this project, we plan to incorporate structural analysis with sufficient spatial resolution, specifically Spot Profile Analyzing-Low Energy Electron Diffraction (SPA-LEED) and Scanning Tunneling Microscopy (STM), so that we can begin to address the problems of how defects influence the growth and electronic properties of metal-diamond interfaces. SPA-LEED is a powerful technique for measuring defect types, defect densities, and defect distributions during growth. STM is very well suited for detecting local defects, and will be used to determine the surface structure and the growth modes of the metal overlayers after the films are grown. By using a four-point contact probe to measure characteristics of the metal-diamond interfaces, we will be able to correlate structural properties of the films with their electrical properties. The proposed research will be the first study of diamond or metal-diamond interfaces that will have sufficient resolution to study diamond substrate perfection and the role of defects in film growth and interface characteristics.

The proposed effort will not only enhance the research capability of Clark Atlanta University, an Historically Black College and University (HBCU) institution, but will also impact the training of minority undergraduate and graduate students in experimental surface physics and chemistry. The students will receive a thorough exposure to state-of-the-art surface techniques and will have major responsibilities in conducting the proposed research. The experience and degrees that they gain will provide them with employment opportunities in both government and industry.

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Wave Profiles in Gravitational Radiation Astronomy

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ABSTRACT OF PROPOSED RESEARCH

The purpose of this research program is to study aspects of gravitational wave astronomy. The central aspect of this program is the creation of accurate templates representing wave profiles that account for the signal-to-noise ratio of laser interferometer detectors. The project is a collaboration with an interdisciplinary team of astronomers and physicists at the Pennsylvania State University. The work at the University of Texas at Brownsville will be part of a comprehensive study of the gravitational radiation emitted by binaries consisting of a rotating black hole and a stellar-mass object (which could be a main-sequence star, a white dwarf, or a neutron

star). The study concentrates on binary systems for which the black hole provides the dominant contribution to the curvature of the spacetime and finite size effects of the black hole's companion are relevant.

Studies of this kind are of direct relevance to the NASA Orbiting Medium Explorer for Gravitational Astrophysics (OMEGA) mission and the projected European Laser Interference Space Antenna (LISA) mission, which propose to set up interferometric gravitational wave detectors in space.

The work will train two physics undergraduate students per year in the associated techniques and will be instrumental in the development of the recently-created physics program at UTB, one of the Hispanic-Serving Institutions (HSI) with the highest percentage of minority and/or disadvantaged students in the country.

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Hydrogen Production and Separation in a Novel Membrane-Reactor-Separator for Use in Fuel Cell Systems

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ABSTRACT OF PROPOSED RESEARCH

Fuel processors are a major subsystem of fuel cell power systems. Fuel processing depends on both the raw fuel and the fuel cell technology. The fuel cell technology determines what constituents are desirable and acceptable in the processed fuel. Since gaseous hydrogen (nearly pure) is considered to be the fuel of choice in all fuel cells, hydrogen needs to be generated from other fuels and processed to meet various system requirements. From economical and practical considerations, hydrocarbon reforming and hydrogen purification processes for an integrated fuel cell system need to meet several key criteria. They must produce high-purity hydrogen, must be modular compact units in size and weight, must have low parasitic power requirements, must be economic and affordable, and must exhibit rapid-load-following capability.

To meet these requirements, we propose to use a membrane-based technology for hydrocarbon reforming and hydrogen separation. In our laboratory, we have developed a new class of palladium-ceramic composite membranes by depositing thin-film palladium on microporous ceramic substrates. Laboratory tests at elevated temperature and pressure indicated that the new membrane has both high permeability and selectivity for hydrogen. For applications in fuel cell systems, we propose to use this membrane in a membrane-reactor configuration in a single unit for hydrocarbon reforming and hydrogen separation. This will have several technological advantages over other hydrogen-purification methods that include the following:

- The reforming reaction is not limited by chemical equilibrium. As soon as product hydrogen is formed, it is transported across the membrane.
- Reforming and separation will be carried out in a single unit, thereby eliminating the need of hydrogen separation and recovery units.
- The membrane reactor-separator (fuel processor) is modular and compact in size.

The proposed research will be performed within the facilities of the chemical engineering department and the Center for Composite Materials Research (CCMR) at NC A&T State University. The principal investigator will work with the mentor at the Jet Propulsion Laboratory (JPL) to meet the project goals. In this work, the membrane will be fabricated by electrolysis deposition of palladium (Pd) on ceramic substrates. Based on JPL's interest, this method may be modified to use Pd-Ag (palladium-silver) alloys or other noble metal alloys for better stability and integrity of the membrane film. The possibility of using vacuum techniques for film deposition may also be considered.

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New Directions for Reliable and Cost-Effective Deep Space Microelectronics

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ABSTRACT OF PROPOSED RESEARCH

The proposed program will lead to a world-class effort in cost-driven integrated space microelectronics design with special emphasis on reliability, fault tolerance, and testability technologies. Critical mass within the premier Electronic Design Automation and Application Specific Integrated Circuit (EDA/ASIC) Design Laboratory at California State University at Northridge (CSUN) will be oriented to address fundamental issues impacting the design of the next generation of reliable, low-power space microelectronics. CSUN's proposed plan is to leverage university and graduate student resources to research and direct high-risk design issues identified by focused mission studies within NASA Jet Propulsion Laboratory's (JPL) Center for Space Microelectronics Technology (CSMT) and Center for Integrated Space Microsystems (CISM). To impact fabrication and mission insertion downstream, a close collaboration is planned between CSUN, JPL/CSMT, JPL/CISM, JPL/EDBAT (Electronic Design, Build, and Test) [AHO8]and CSUN's industrial partners, namely Hughes Aircraft Company, Boeing Rocketdyne, Insyte Corporation, Synopsys, a leading supplier of EDA tools, and Xilinx, a leading Field programmable gate array (FPGA) toolmaker.

NASA's interest in unmanned spacecraft is focused on astronomical and astrophysics missions. The nature of these missions is increasingly diverted by programs such as the New Millennium technology development effort. These programs must have a strong grip on the relationships of cost, reliability, and risk. A key technology area requiring this knowledge is microelectronics, where one of the primary unknowns is reliability. Exploring the relationship of fault tolerance, high-speed computing, and low-cost space electronics is a key ingredient of this research. Characterization of low-cost EDA tools for NASA's needs in many areas of design and analysis is useful for both decreasing the cost of NASA's smaller spacecraft electronics and improving their reliability. FPGA's are very popular devices in current spacecraft design. This research addresses how FPGA's can be used in traditional spacecraft architectural approaches such as fault tolerance design. Efficient tools and techniques are needed for testing FPGA's with such approaches as constant cardinality test sets and embedded structures. These can be used for both fault coverage testing and built-in testing.

NASA's JPL facility and CSUN's industrial partners, with their leadership in aerospace, telecommunications' and high-reliability electronics-related research, development, and manufacturing will be a major asset to this program. The proposed research will also benefit from the PI's recent activities such as the Teledyne Systems Company's Design Clinics, fault-tolerant avionics for unmanned air vehicles (UAV's) in collaboration with Lockheed Martin Skunk Works, his two NASA fellowships in testability, and design of FPGA's/ASIC's.

Specific tasks to be performed under this three-year proposed program are:

- application of ASIC test methodology to FPGA design;
- development of a low-power, fault-tolerant FPGA ASIC-based very large-scale integration (VLSI) system and Multi-Chip Module (MCM) design methodologies;
- identification of low-cost electronic design automation tools for space applications, specifically, the study of Synopsys' behavioral compiler to identify whether it is cost-effective for mode-based design; and
- identification of differences between the approaches to reliability for $20 to $50M 2nd generation small spacecraft programs and $100 to 600M spacecraft programs.

Through the efforts of this coalition between CSUN, JPL and industry we will be able to combine our strengths to develop at CSUN a strong research program that challenges minority students to participate in NASA's missions for the next century.

NASA's benefit from this research includes EDA process improvement for lower cost mode-based design, fast turn-around time, and ASIC-based systems. The results of this research are also directly applicable to spacecraft system 632-10 and NASA Code SM Technology Development Program.

CSUN's benefits from the results of this project include the following:

- Under-represented minority students who are US citizens will be exposed to NASA and other high-technology related research and development environments, becoming prepared for future employment and graduate studies.
- Faculty and their students will have the opportunity to publish technical papers in cutting-edge areas related to the project. Some of the technical problems arising during this study will become

the subjects of new research activities. Activities related to the proposed research will also play a key role in curriculum development.
- Award of this grant will substantially enrich laboratory facilities at CSUN College of Engineering, thus making the college a stronger candidate for future grant awards.
- The EDA/ASIC Lab will be used as a recruitment tool to attract more minority students to pursue their studies in science and engineering at CSUN. During and after the three-year period, EDA/ASIC Laboratory will serve as an advanced laboratory facility at which universities, as well as industry, can conduct experiments to validate relevant technologies.

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Consortium for Undergraduate Research Experience-Solar System Astronomy Program

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ABSTRACT OF PROPOSED RESEARCH

A unique consortium of a minority-serving four-year university and two minority-serving community colleges is proposing to combine with a national laboratory to provide research opportunities to underrepresented minority and female students. The student researchers will conduct observations of Mars, Pluto/Triton, Jupiter, globular clusters, circumstellar disks, and DS-1 (deep space one) asteroids. All of these projects are of direct interest to NASA's Office of Space Science.

A connected set of seven astronomical projects is presented which further the NASA Space Sciences Strategic Enterprise. They include astrometry and photometry of solar system objects (planets and comets) extra-solar planetary systems (circumstellar disks) and observations of globular clusters. These projects assist and complement spacecraft missions (Mars Global Surveyor and DS1) with ground-based observations and data analysis. They also assist and complement NASA's ground-based efforts in cometary and asteroid studies, astrophysics, and cosmology.

Teams of student researchers from Los Angeles City College (LACC) and Los Angeles Southwest College (LASWC) will be responsible for gathering, reducing, analyzing and presenting data from the projects described under the mentorship of Jet Propulsion Laboratory (JPL) staff and faculty from California State University at Los Angeles (CSLA), LACC, and LASWC. Photometric, astrometric, polarimetric, and seismological methods will be used to gather the data. The objectives of the projects are to better understand the objects being studied, to support the NASA Space Sciences Strategic Enterprise, and to provide the participating student researchers with real-world research experience that will encourage them to continue in higher education.

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Johnson Space Center (Reports)

Simulated Microgravity: A Model for Human Neural Cell Plasticity and Angiogenesis

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Report not submitted.

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Basic Studies of CdTe Solar Cells

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INTRODUCTION

CdTe/CdS solar cells have a great potential for impacting photovoltaic energy production, both terrestrial and in space applications, because they are inexpensive to produce, can be lightweight if on metal foil substrates, and should be radiation-hard. However, CdTe/CdS large area cell efficiencies remain near 10 percent, well below their potential as indicated by laboratory efficiencies of 15 percent and theoretical efficiencies of over 25 percent. To boost device performance, a concerted effort of basic studies into the mechanisms of CdTe solar cells, identifying the major sources of loss so that proper design and processing adjustments can be made to suppress loss is needed. The objectives of this project are to extend characterization techniques that have been established for crystalline cells to polycrystalline cells by incorporating spatial resolution for the non-uniformity of thin-film cell performance.

RESEARCH ACCOMPLISHMENTS

We are establishing a process for building the cells that incorporates testing and characterization at each step of device fabrication, so that the process step that causes the non-uniformities can be identified. This characterization is done using a Charge Coupled Device (CCD) camera that images the thin films at each step using a variety of excitation sources.

We have presented an invited paper at an international conference in Cancun, Mexico on the deposition of CdTe films on flexible metal foils by close-spaced sublimation, and that paper will soon be published in *Solar Energy Materials and Solar Cells*. We have also had an abstract accepted to the Electronic Imaging Conference in 1999; this paper will detail the image processing aspect of our project.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Eliminating the non-uniform performance of these devices will significantly increase overall conversion efficiencies so that industry can make the cells at lower cost per watt. Achieving such advances on flexible substrates makes CdTe solar cells viable for space applications where thin film cells are expected to be less susceptible to radiation damage, opening up new orbits to satellites.

BENEFITS TO SOCIETY

Significant increases in conversion efficiencies for these inexpensive thin film solar cells will open up a wide variety of terrestrial markets for photovoltaic energy systems, which offer a clean and renewable alternative to fossil fuel sources. Opening up new orbits for satellites can result in advances in communications and other satellite functions.

STUDENT ACHIEVEMENTS

More than fifteen students have worked on various aspects of the project. Students were the first authors for all of the publications mentioned above. Student have built and tested complex deposition systems, established and tested characterization tools and software for studying these devices, and are poised to share their results with the scientific community. A surge of results and presentations is expected during the upcoming year.

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Assessing the Putative Mechanisms of Gravity-Induced Cellular Changes

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Date of Original Award: 1995

INTRODUCTION

The goal of these studies is to provide an understanding of the impact of microgravity on wound healing. The objectives of the research are to evaluate whether changes in vascular cell proliferation and migration induced by different gravitational fields are coupled to the expression of autocrine growth and migration factors; assess whether simulated microgravity and/or hyper-gravity alters the expression of these autocrine growth and migration factors; and investigate possible signal transduction mechanisms that may be involved in gravity-induced cellular changes.

RESEARCH ACCOMPLISHMENTS

We examined gene expression by vascular smooth muscle cells (SMC) following injury under simulated microgravity using the horizontal clinostat model. Cells were retarded in the rate of wound closure under microgravity compared to controls; treated cells did not close the wound by 24 hours, where controls completely closed by 16 hours. SMC, maintained under microgravity, showed a time-dependent increase in heat shock proteins HSP72/73 and HSP90; this was seen by immunolabeling cells and by Western Blotting. Growth and migration factors that showed increased expression under hyper-gravity were found to have no change or a decrease in expression under microgravity. There was no change in the expression of galectin-1, c-myc, or TGFß1 but a decrease in c-fos [LG9]expression after 48 hours compared to controls. These findings indicate that factors that may mediate the cellular changes are clearly different for microgravity compared to hyper-gravity.
Further studies to address whether microgravity treatment affects endothelial cell expression of c-myc and c-fos were done during this period. Previously, we reported that antisense oligonucleotides to c-myc and c-fos prevented the microgravity-induced inhibition of endothelial cell wound closure and alteration in the organizations of vimentin and f-action. However, we had not established that microgravity induced the expression of c-myc and c-fos in these cells. In recent experiments, we found that c-myc expression was elevated after 48 hours and remained elevated after 72 hours under microgravity compared to control cells. C-fos expression was elevated after 72 hours compared to controls. In this case, control cells showed a decrease in c-fos expression at 72 hours, but microgravity-treated cells remained elevated. These findings strengthen our previous suggestion that the influence of microgravity is mediated through changes in the expression of early response and growth regulatory genes, which in turn modulate the expression and distribution of cytoskeletal elements.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

These studies are related to NASA's Human Exploration of Space Strategic Enterprise. As astronauts spend longer periods of time in space, the possibility increases that they could receive a variety of injuries, including fractures, deep punctures, and cuts. The microgravity environment of space will affect the treatment of these wounds and may complicate the wound healing process. Understanding the underlying cellular mechanism(s) responsible for changes in the way vascular and other cells respond to a wound under altered gravity environments (e.g., during space flights) is a primary goal of the life sciences program of NASA. Achieving this goal is a necessity for the development of interventions that will allow for continued and long-term manned space flights.

BENEFITS TO SOCIETY

These studies will provide insight into the mechanisms underlying how cells and tissues respond to a wound. Specifically, an understanding of the cellular and molecular events involved in blood vessel wound healing will be achieved.

STUDENT ACHIEVEMENTS

Felicia Love presented at the NASA University Research Centers Technical Conference in Huntsville, Alabama in February 1998. A manuscript was published in the proceedings of this conference. Ms. Love also applied for and was awarded an American Heart Association Student Scholarship in Cardiovascular Disease and Stroke. This is a short-term student research award. Ms. Love will develop reverse transcriptase polymerase chain reaction methodologies for measuring the expression of nitric oxide synthase, endothelin, and angiotensin converting enzyme in endothelial cells isolated from salt-induced hypertensive rats.

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Design and Development of Intelligent Biomimetic Robots Powered by Ionic Polymeric Artificial Muscles for NASA Applications

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Date of Original Award: 1998

INTRODUCTION

The goal of this research has been to develop the building blocks for materials characterization and optimization in applications involving an assembly of ionic polymeric platinum composite (IPPC) artificial muscles. The objective has been to develop the fundamental building blocks necessary for deploying a family of biomimetic robotic structures and bodies. In particular, artificial agile swimming robotic structures equipped with appropriate sensors and fin actuators made with ionic polymeric platinum composite (IPPC) artificial muscles have been studied.

RESEARCH ACCOMPLISHMENTS

Two minority students (F. Carter Hughes and German Chamorro) were hired to perform the proposed research and development on this project. The first year of activities has concentrated on materials research and development. A series of potential ionic polymers such as perfluorinated sulfonic polymers were thoroughly analyzed to gain a better understanding of parameters controlling muscle force and deformation characteristics in an electric field. A series of intelligent materials characterization and optimization experiments to determine the best set of parameters for the manufacturing of ultimate ionic polymeric solid-state sensors and actuators for applications relevant to NASA has been performed. A typical graph displaying the variation of displacement of artificial muscles with voltage for a frequency of 0.5 Hz is shown below.

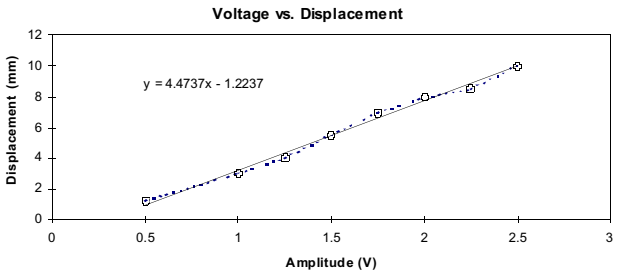

Figure 1. Experimental results showing displacement versus voltage amplitude for a biomimetic robotic swimmer.

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Gravity-Induced Changes on the Steroidalgenesis by Luteal Cells of the Pregnant Rat

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Johnson Space Center (Abstracts)

Smart-Sensor Design Incorporating Signal Processing for Data-Compression and Feature Enhancement

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ABSTRACT OF PROPOSED RESEARCH

There is currently a need for more sensitive, non-invasive sensors and instrumentation to monitor human physiological functions. These sensors are required to respond to various inputs including mechanical, electrical, and chemical. The proposed work is directed towards researching new sensor implementations and architectures, and extending the functionality of present sensors through applicable signal processing methods. The computational power inherent in current digital signal processing (DSP) chips makes smart sensors a possibility. It is possible to design sensor(s) to do onboard data preprocessing in order to reduce or parameterize the data, retaining only the most salient features. This parameterization has the additional benefit of making more efficient use of available data storage requirements.

Presently, there are several sensors of interest to NASA Johnson Space Center (JSC) that can benefit from signal processing algorithms that perform noise reduction, detection, feature enhancement, and feature extraction. These include an interaural probe designed to non-invasively measure cardiac and respiratory function and an impedance probe designed to measure tumor/tissue characteristics.

In this research, hardware and software digital signal processing (DSP) methodologies will be examined to configure smart sensors, or to implement distributed sensor processing. Initially, the applicable sensors will be examined in their current state. Research will then be undertaken to increase sensor sensitivity, data capture, interpretation, and reduction, either in their current state or through new architectures as warranted by the research findings.

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Kennedy Space Center (Reports)

Mission Planning and Risk Analyses

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Date of Original Award: 1998

INTRODUCTION

In this project, the issue of human errors in the Space Shuttle and other flight programs is being investigated. The availability of probabilistic models of the processing workflow might offer the opportunity to analyze contributing factors to such errors and to reduce or eliminate these events. The objectives of this project are to establish probabilistic models substantiated by sound mathematical foundations to address the occurrence of human errors in the Space Shuttle processing flow. These mathematical models will incorporate different types of causes and influencing factors such as the learning curve, training, poor instructions, and fatigue. The parameters in each model will be estimated based on history and available data. The different models will be analyzed to see if any factors can be isolated for control of human errors.

RESEARCH ACCOMPLISHMENTS

There are two main components to this project: the research and student involvement. The project started in early summer; since May 1998, several graduate and undergraduate students have been selected to work on the project. Students started their work in September.

The principal investigator has constructed several probabilistic models describing different types of human error. Using the mathematical theory of Poisson Processes, both stationary and non-stationary, several stochastic models have been developed. These models can be used to analyze and predict human error caused by such problems as fatigue. Some of the developed models take into account the improvement in performance from learning.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Human errors persist in the processing of the Space Shuttle and other flight programs. Such events as sending the wrong command or assembling the wrong parts tend to recur despite efforts at prevention. The availability of probabilistic models would help to predict these errors, provide the opportunity to analyze contributing factors, and test process improvements that could reduce or eliminate these events. Therefore, this project supports the Aero-Space Technology and Human Exploration and the Development of Space Strategic Enterprises.

BENEFITS TO SOCIETY

One of today's challenges is to deliver more for less. To meet these challenges, methods and techniques must be developed to enhance productivity and performance. This project supports efforts to enhance processing efficiency, safety, and cost-effectiveness.

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A Continuous Hazard Tracking and Failure Prediction Methodology

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Date of Original Award: 1997

INTRODUCTION

Utilizing the principles of work sampling and control charting, a proactive methodology for accident prevention called Continuous Hazard Tracking and Failure Prediction Methodology (CHTFPM) has been developed. Sampling is performed to observe the occurrence of conditions that may become hazardous in a given system. These conditions, known as dendritics, may become hazards and could result in an accident or unacceptable risk. The collected data is then used to generate a control chart. Based on the pattern of the control chart, a system "under control" is not disturbed, whereas a system "out of control" is investigated for potentially hazardous conditions. Appropriate steps are then taken to eliminate or control these conditions in order to maintain a safe system.

RESEARCH ACCOMPLISHMENTS

The uniqueness of the CHTFPM lies in its ability to track dendritics, the building blocks of hazards. The principal advantage of using the CHTFPM is that conditions leading to critical system hazards can be tracked in order to predict when the system will fail, an accident will occur, or conditions will deteriorate to a point where risks become unacceptable. This will alert systems personnel to conditions that need to be changed in a system before problems occur. New conceptual problems have been identified, such as the need for further development of the building blocks of hazards through the use of neural networks and cinematography.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Within NASA, there are many critical systems. The hazards in these systems should be tracked in order to predict when problems will arise. At present, NASA does not have a mathematical model to predict the failure of systems. The CHTFPM will aid in predicting failures, accidents, and unacceptable risk conditions. This will in turn alert systems personnel to take action ahead of time to avoid or minimize the risk of failures or accidents by design modification, maintenance, or other procedural controls.

BENEFITS TO SOCIETY

This methodology has universal application in all kinds of industries, including, but not limited to, the computer, chemical, space, medical, electrical, automotive, heavy equipment, information technology, and robotics industries. It will improve safety and reliability in all of these industries, and it will aid in reducing costs and improving efficiency.

STUDENT ACHIEVEMENTS

The students who participated in this project are Michael Camet, B.S.M.E., who was the graduate project leader; Lorinda Braun, an undergraduate industrial engineering student who was the operations analyst; and Nathaniel Robinson, an undergraduate electrical engineering student who was the systems analyst. These students helped to develop the dendritics in the Space Shuttle's hypergol system at Kennedy Space Center and a testing laboratory at Marshall Space Flight Center. They performed statistical analysis, developed control charts and Pareto analysis for this project, and helped to develop the documentation. Their technical writing and computer skills were enhanced as a result of this project. They also became quite adept at time management, and at working both individually and in a team setting. These skills will make them quite valuable to industry upon graduation.

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Control and Calibration of an Automatic Radiator Inspection Device (ARID)

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Date of Original Award: 1997

INTRODUCTION

Prior to and after each mission, the Space Shuttle orbiter's payload bay radiator panels must be inspected for damage. Defects must be carefully documented and cataloged. The goal of this project is the automation of the radiator inspection of the Space Shuttle orbiter. The relevant issues considered include kinematics, dynamics, statics, stiffness, and fault tolerance.

RESEARCH ACCOMPLISHMENTS

Software for analyzing and addressing design issues for the automated radiator inspection device was provided to Kennedy Space Center. The kinematics, dynamics, statics, stiffness, and fault tolerance of cable-suspended robots were studied in detail. The results of this work were recognized through publications in one journal and at three conferences.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Automating this process will eliminate the use of overhead buckets for inspection, reduce the coordination effort and paperwork required, reduce inspection time, increase personnel and equipment safety, and reduce cost.

BENEFITS TO SOCIETY

The technology developed in this project has significant potential for several important applications. Examples of potential technology transfer to the private sector include construction applications, painting, window cleaning, and visual inspection. These results are applicable to a large class of cable-suspended robots and will hopefully provide a basis for other researchers interested in this new area of robotics.

STUDENT ACHIEVEMENTS

Three undergraduate students and three graduate students assisted the principal investigator on this project. One graduate student, Marcus Spells, completed his M.S.E.E. in August 1998 and is now working for IBM. The other two graduate students plan to complete their M.S.E.E. programs in May 1999 and August 1999.

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Surfactant/Supercritical Fluid Cleaning of Contaminated Substrates

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Report not submitted.

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Langley Research Center (Reports)

Structure-Function Relationships of Impact-Modified Cyanate Ester Resins

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INTRODUCTION

Researchers in the chemistry department at Howard University have perfected new reaction schemes to produce siloxane-modified cyanate ester resins (CER's). These schemes are new and useful because they minimize the incorporation of aliphatic linking groups, thereby reducing flammability. Researchers on this project have succeeded in siloxane-modifying a cyanated novolac from Lonza. The schemes vary the substitution of polysiloxanes that we are characterizing with gel permeation chromatography, Fourier Transform infrared spectroscopy, and proton NMR spectroscopy. In phase one, Ciba-Geigy's AroCy® resins will be reacted with these siloxanes to produce rubber-modified CER's.

The first phase of our research is well under way. This phase modifies CER's with siloxanes and characterizes them. The base resins that have been selected for cyanate ester systems in this project are two AroCy® resins: a bisphenol A dicyanate, B-10, and a methylated version, L-10. Methylated L-10 will be siloxane-modified and compared to siloxane-modified B-10. Methylation influences the compatibility of the polycyanurate and siloxane domains to influence properties and phase separation. Modifying CER's with a siloxane rubber holds promise for applications in space structures. For example, the siloxane is not as susceptible to UV (ultraviolet) or ozone degradation as polybutadiene-polystyrene. This project will also siloxane-modify and characterize a cyanated novolac in phase two.

The chemistry to incorporate siloxanes typically into the cyanate esters being used is well known. They are reacted with aromatic hydroxyl-containing compounds possessing more than one siloxane moiety catalyzed with cyanogen halide or *in situ* from cyanogen halide typically catalyzed with triethylamine. The reaction best proceeds for 30-240 min at -20 to 20 ° C. Popular solvents are toluene, methylene chloride, dimethoxy diglycol ether, or acetonitrile. Siloxane-modified cyanate synthesis can include backbone aliphatics using a reaction scheme of hydrosilylation.

Phase separation of siloxane-modified cyanate ester resins occurs during curing. Cured rubber-modified resins consist of finely dispersed rubber-rich domains bonded to the cyanate ester matrix. Improvement of fracture energy depends on the domain size, volume fraction, and size distribution of the dispersed rubber phase. A CPU-controlled hot stage is currently being used to compare the influence of precise curing cycles on the mechanical properties of the impact-modified B-10 and L-10. Curing will proceed at 150-250 ° C, expanding our curing range to enhance performance. Different compositions of siloxane, curing agent, and unmodified resin are under investigation in order to ascertain optimum compositions for each resin.

In phase one, the primary criterion for optimum composition will be performance in impact and tensile testing. Differential scanning calorimetry (DSC) will later appraise the curing behavior, heat resistance, and flame-retardant properties of siloxane-modified cyanate ester resins. DSC will be combined with thermogravimetric analysis to assess their flammability and combustion. As proposed, two students have been brought on to support the initial phase of this project. Two additional undergraduates provided assistance during the summer.

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Phenylethynyl Containing Polyarylene Ethers/Polyimides Resin Infiltration of Composites

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INTRODUCTION

The objective of this research is to make composites by the resin transfer molding method (RTM). The resin of interest is newly developed at NASA Langley Research Center by Dr. Brian Jensen. This resin is specially formulated to be used in composites at high temperatures of about 300°C, while having a relatively low and stable melt viscosity before cure, enabling RTM processing. The resin studied is easy and simple to synthesize which should prove effective in reducing costs, and has good low viscosity flow characteristics. However, the porosity of first-generation panels was higher than acceptable by a factor of ten.

RESEARCH ACCOMPLISHMENTS

The following work was completed during the second year: synthesis of the resin at North Carolina A&T State University (NCA&TSU); neat resin cure studies; neat resin specific gravity determinations under varying time, vacuum, pressure, and temperature conditions; creation and use of a flat panel RTM molding apparatus; flat panel compression molding; uniaxial compression testing; fiber volume testing; and microscopic sample preparation and examination. For the initial panels created, the void content was too high—being around 20 percent. The void content needs to be reduced to 2 percent or less in order to produce a useful composite.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

High-temperature material applications are of importance to NASA's ongoing support of techno-

logical developments in the aerospace industry. An example is the High Speed Civil Transport (HSCT), which requires structural materials capable of withstanding 300°C temperatures for sustained periods of time. High-temperature materials will also allow aircraft to be more efficient and faster while carrying bigger payloads. The RTM process for making composites is inexpensive compared to other methods, because a complex shape can be made as one part and because the RTM process is capable of producing near-net-shape composites, which reduces and/or eliminates machining. Composite aerospace structures also permit weight savings. The resin synthesis technique employed proved to be straight-forward. The simple synthesis used could prove beneficial in manufacturing the resin if the void content of composites constructed from it can be significantly reduced.

BENEFITS TO SOCIETY

The use of high-temperature composites in aerospace applications will maintain and improve current air transportation standards while avoiding a consumer cost increase. The use of composites also avoids dependence on metals made with expensive elements, which are scarce and available from only a few sources worldwide. By using high-temperature composites for aerospace structures, aircraft can be made faster (such as the HSCT), comparably lighter (allowing higher fuel efficiency and a larger payload) and more durable (enabling less maintenance), all of which will help to moderate costs. The use of RTM processing for aerospace structural composites will help to hold down the cost of aircraft construction by enabling a reduction in the number of structural parts, the amount of machining, and the amount of labor involved.

STUDENT ACHIEVEMENTS

Six students were involved in research activities during the reporting period. There were two graduate students, three undergraduate students, and one summer high school intern. One student was a chemical engineering major, four were mechanical engineering majors, and one was a rising high school senior. Valerie McLaughlin, a graduate student in chemical engineering, is preparing to defend her M.S. thesis, which was supported by the project. She is currently in residence at Tuskegee University, where she is enrolled in the doctoral program in materials science and engineering. Cordell Charleston, a master's student in mechanical engineering, is currently continuing the research started by Valerie. Katrina Butler received her B.S. degree in mechanical engineering at NCA&TSU in December 1997 while supported by the project and participating in the research. Two other undergraduate students in mechanical engineering, Malcolm Boney and Sonya Williamson, each presented oral papers entitled "Study of a Wet Prepregging Technique" and "Study of a Dry Prepregging Technique," respectively, at the Second Annual NCAMP Undergraduate Research Conference at the University of North Carolina-Charlotte in April 1998. Mr. Malcolm Boney received his B.S. degree in mechanical engineering at NCA&TSU in May 1998. Lucinda Hickey, a high school research intern from Florida, participated in research supported by the project. Lucinda was a Summer 1998 NASA-Sharps+ intern, whose mentor was this project's principal investigator.

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Micromechanical Characterization and Texture Analysis of Direct Cast Titanium Alloy Strips

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INTRODUCTION

This report summarizes the major accomplishments of research efforts on the texture analysis of the Titanium Aluminide materials produced using the Ribbon Technology (RibTech) process. This project focused on specifically on Ti_3A1 (alpha2), which is an ordered hexagonal close-packed DO_{19} that has two phases α_2 and β(B2)). The as received material exhibited a Widmanstatten structure due to the rapid cooling of the Melt Overflow Rapid Solidification Technology (MORST) process. Ti_3A1 contains five independent slip systems. Three systems account for dislocation motion on the basal {0001}; prism {1010}, and pyramidal {0221} planes and two systems satisfy the Von Mises criterion for uniform deformation. At room temperature alpha-2 is ductile, but at elevated temperatures it becomes unstable. The addition of Nb stabilizes the high temperature

body-centered crystal (bcc) phase. The alloy being studied is Ti-24Al-llNb (percentages by weight). The compositional stability of this material ranges in aluminum content from 22 to 39 percent.

RESEARCH ACCOMPLISHMENTS

The production of titanium foils by conventional ingot metallurgy involves casting ingots, hot forging the ingots into billets, and several sequences of hot rolling, heat treating, and surface grinding to produce plates and strips that are later cold-rolled to foil gauge. Among titanium alloys, processing losses can be 50 percent or more. As a result, titanium foils are expensive to produce commercially and often require long lead times for delivery. In a NASA-funded project, a new technique has been developed which produces cast titanium strips with up to a 0.020-inch thickness. The technique used by Ribtech to cast titanium strips is called the Plasma Melt Overflow Process because it combines transferred plasma arc skull melting in a water-cooled copper crucible with MORST. This technique can potentially replace all of the hot working operations used to produce conventional wrought strips. The advantage of producing cold-rolled foils from near-net-shape cast titanium strips is lower-cost processing resulting in higher-performance foils. The cast strips may be appropriate for applications that do not require high strength or those involving thermal treatments that affect the microstructure. Examples include turbine engine nozzles and flaps or low-cost titanium matrix composites (TMC's) processed by vacuum hot-pressing or hot isostatic pressing (HIP) for less demanding applications. The cast materials exhibited high surface roughness and variations in thickness across the width and length of the strips. There have also been reports of cast strips twisting and buckling after the cold-rolling process.

To improve the properties of the cast material, a few changes have been implemented in the MORST technique. This involved the investigation of casting surfaces, optimizing the melting and casting parameters for each alloy, and collecting the cast strips on a mesh belt conveyor. These parameters were optimized for each alloy system and improvement was observed in the thickness, uniformity, and flatness by collecting the strips on a conveyor belt. Fully dense foils were produced with a bright surface finish and low average surface roughness. The feasibility of wet grinding and hot pack-rolling cast strips into foil materials were demonstrated. Hot pack-rolling resulted in foils with more conventionally wrought microstructures; however, this process was considered expensive. The direct cast and cold-rolled foils exhibited finer, more uniform microstructures, higher strength, lower ductility, and higher modulus of elasticity than the comparable ingot metallurgy foils. The surface roughness of the cast strips was generally eliminated by cold-rolling. Cold-rolling direct cast strips was considered the most economical way to produce foils.

The objective of the present work is to characterize the microstructure and crystallographic texture of alpha-2 (Ti-24A1-llNb) produced via the MORST process. The pole figures were measured using the X-ray Diffractometer and the microstructure was analyzed using the environmental scanning electron microscope (ESEM).

Ribtech processed the material via the Rapid Solidification Melt Overflow Process. Samples of as-received alpha-2 were cut and mounted for texture and microstructure tests. Hot pressure mounting was performed first, but epoxy mounting worked better for sample preparation. Each sample was prepared by first grinding, and then polishing. Polishing started with 3 microns, 1 micron, then .05 micron (collodial silica). After the texture and microstructure tests, samples were heat-treated at 900°C and 1000°C, respectively, for thirty minutes in argon gas. The texture and microstructure of the heat-treated samples were analyzed, then the samples were cold-rolled until failure and analyzed again.

Before viewing the microstructure, the post-processed samples were etched using Kroll's Reagent solution (1-3mL HF, 2-6mL HNO_3, 100mL H_2O). The microstructure was first examined under the optical microscope, and then looked at with the ESEM. The grains were found to be too small to see using the optical microscope. The magnification used to see the microstructure was on the order of 1200 times (l0μm) or better.

The texture was analyzed via the X-ray Diffractometer. Each sample was tested as received, during processing, and post-processing. Orientation distribution functions (ODF's) were calculated by spherical harmonics using Roe's approach. The pole figures were recalculated using the ODF's. The planes used to calculate the pole figures were as follows: <002>, <100>, <101>, <102>, <103>, <110>, and <112>. Only the ϕ = 0, 20, 30, and 40 angles were used from the pole figure calculations for texture analysis.

The as-received Ti-24A1-1lNb microstructure and texture analysis was compared to the results from previous studies. The cast Ti aluminide exhibited a Widmanstatten microstructure, but was weak as a result of the rapid cooling of the MORST process[5].

After heat-treating at 900°C, the sample was yellowish in color, which indicated oxidation. Although there was oxidation during heat treatment, the microstructure was recovered, but still exhibited a Widmanstatten microstructure. The sample had a rainbow-like coloring after heat-treating at 1000°C, which indicated less oxidation than at 900°C.

After heat-treating the materials for 30 minutes, the samples were cold-rolled. The sample heat-treated at 900°C reduced approximately 40 percent before cracking. The sample treated at 1000°C allowed for only a 24 percent reduction before failure. Recrystallization of the material was the main objective of heat-treating. The apparent decrease in ductility indicated different results than those expected. The reasons for the results will be investigated further. One reason for the results may be that the material was overheated. Overheating can cause deformation in the microstructure, which may decrease ductility. Another reason for the results could be a phase change. The alloy Ti-24Al-1lNb has $\alpha_2+\beta$ phase at 900°C but it has a phase of α_2+B2 (ordered b phase) at 1000°C. The results of the microstructure at both temperatures show that recrystallization may have started, yet the majority of the microstructure remained unchanged.

X-ray Diffractometer 2Θ scans performed showed dual-phase beta and alpha-2 phases. The alpha-2 phases were very close to the pure Ti 2Θ scan. The texture of as-received alpha-2 exhibited a fiber texture in the $\phi = 30$ plane (-2 1 1 0). At $\phi = 0$ there was a uniform texture. At $\phi = 20$ and 40 the texture was 2x random.

The experiments detailed in this paper show that heat-treating Ti-24AL-llNb at 900°C recovers the material and increases the ductility. Heat treatment at 1000°C decreases ductility, but the material shows some recrystallization.

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Investigation of Optical Phase Distortions in Solid-State Pulsed Laser Amplifiers

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INTRODUCTION

The main objective of this research is to design and implement the first ultraviolet laser system with the high-energy output and the high spectral quality required to take measurements from space. The research will be conducted in close collaboration with Dr. James Barnes, head of the Remote Sensing Technology branch at NASA Langley Research Center.

RESEARCH ACCOMPLISHMENTS

Since the award of the grant to pursue this research in May 1998, we have been focusing on two main approaches to yield laser pulses at 305 nm with 500 mJ pulse energies. In one possible scheme, a 915 nm pulsed laser diode is used as a seed and amplified in a medium, such as a Titanium:Sapphire crystal, by pumping it with a pulsed 532 nm Nd:YAG (Neodymium linear amplifier) laser. Frequency tripling of the amplified 915 nm pulses yields third-harmonic pulses at 305 nm. In another approach, pulses from a 610 nm pulsed laser diode are amplified in a gain medium by pumping with a pulsed 532 nm Nd:YAG laser. The amplified 610 nm pulses are then frequency doubled in a crystal, such as KTP, to yield second-harmonic pulses at 305 nm.

To conduct initial feasibility studies on the set-ups listed above, a Nd:YAG laser has been ordered and will be installed at Delaware State University (DSU). This laser will provide a pulsed laser source with 5-8 ns pulses delivering 200 mJ at 532 nm at a 10 Hz repetition rate, and will serve as the pump for the laser amplification schemes.

The seed to be amplified is a 905 ± 10 nm pulsed laser source (Hamamatsu L2376). This is a 1 kHz repetition rate pulsed diode laser with a 150 ns pulse width. A diagram of proposed experiments for the generation of 305 nm laser pulses is below (Figure 1). This laser has been ordered and is expected shortly.

The large difference in the repetition rate between the pump and the seed means that some form of external triggering will be necessary to synchronize the firing of the pump and the seed laser sources. This problem is currently being worked on at DSU.

Modeling the timing between the seed and the pump pulses will be conducted using MathCAD. The Numerical Recipes Extension Pack for MathCAD has been ordered to allow numerical solutions to partial differential equations related to the modeling of the timing problem.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This study will contribute to NASA's Earth Science Strategic Enterprise and more specifically to the Differential Absorption Lidar (DIAL) transmitter technology for the atmospheric remote sensing of ozone, water vapor, and aerosols by providing a better understanding of the basic physics and dynamics of solid-state lasers and laser amplifiers.

STUDENT ACHIEVEMENTS

The DSU student working on this project, Mr. Claude Tameze, has been going through the literature on laser amplification and is becoming proficient in the use of packages such as MathCAD for numerical modeling. He is also being trained in the use of lasers and laser test and detection instrumentation.

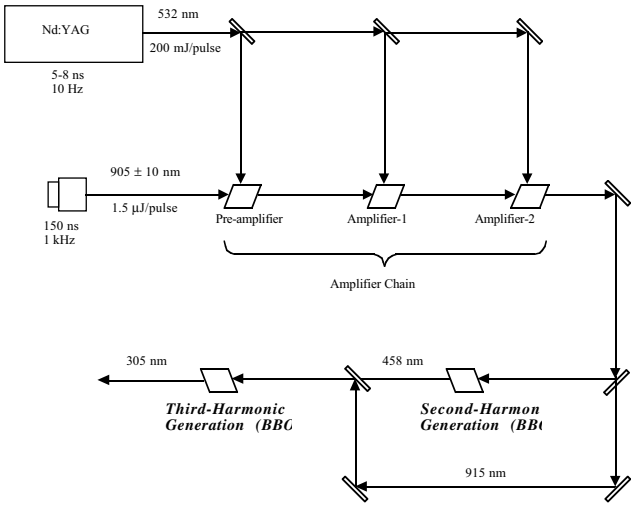

Figure 1. Schematic diagram of the proposed experiment

915nm pulses from a pulsed diode laser are amplified using an amplifier chain using Titanium:Sapphire crystals as the gain medium. These amplified pulses are then frequency doubled in a second-harmonic generation crystal, such as BBO, to produce 458 nm pulses. The second-harmonic is mixed with the fundamental 915 nm in another crystal (BBO) to produce the third-harmonic at 305 nm.

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Active Control of Aerodynamic Noise Sources

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Visualization of Atmospheric Water Vapor Data for SAGE

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INTRODUCTION

Water vapor plays a major role in short-term weather patterns, long-term global climate changes, and atmospheric chemistry. The main goal of the Visualization of Atmospheric Water Vapor Data for Sage (ViSAGE) project is to study long- and short-term atmospheric water vapor dynamics and their impact on climate changes. To facilitate this study, multi-dimensional scientific visualization procedures for the analysis and interpretation of the Stratospheric Aerosol and Gas Experiment II and III (SAGE II and III) water vapor data are being developed.

The objectives of this project are threefold. First, middle- and long-term dynamics of global atmo-

spheric water vapor will be studied in order to establish the correlation of water vapor dynamics with high and low Atlantic tropical storm activity years and with the El Niño—Southern Oscillation years. Second, an effort will be made to enhance scientific visualization procedures for the analysis and interpretation of solar occultation data in order to fully exploit the scientific capabilities of the SAGE II and SAGE III instruments. This multi-dimensional scientific visualization procedure will facilitate the accomplishment of objective 1. Finally, training and research opportunities in Earth System Science will be provided to students who are underrepresented in Earth Science Engineering programs and the use of on-line NASA resources will be encouraged.

RESEARCH ACCOMPLISHMENTS

ViSAGE's first year efforts were concentrated on producing scientific visualization procedures to fully exploit the excellent spatial coverage and resolution of SAGE II and SAGE III. These procedures attempt to streamline the process of analysis and interpretation of SAGE II and SAGE III water vapor data by conditioning the raw data through the use of grids, interpolation, and smoothing and providing various visualization perspectives such as 3D and 4D animations. These images and animations were utilized to study long-term water vapor dynamics. The images, animations, and interpretations are being disseminated to the public via the Internet, presentations, and publications.

RELEVANCE TO NASA STRATEGIC ENTERPRISES and BENEFITS TO SOCIETY

The goal of the NASA Earth Science Enterprise has been to understand the Earth as an intricately coupled system and to understand the variables that influence climate changes. Water is one of the most important variables in understanding atmospheric processes and climate change. Currently, the SAGE II is providing large amounts of global atmospheric water vapor mixing ratio data; after 1999, SAGE III missions will also provide this data.

Multi-dimensional visualization is necessary to fully exploit the excellent spatial resolution of the data from SAGE. Multi-dimensional, real-time, or quasi-real-time data visualization, analysis, and interpretation will permit scientists to observe and predict short- and long-term climate changes. The tools developed in the course of this project will be a positive step towards real-time data visualization and interpretation. Additionally, these tools could easily be modified to study data from other NASA satellite instruments.

STUDENT ACHIEVEMENTS

Seven students—Eyad Youssef, Cyntrica N. Eaton, Lou Youssef, Jasper Lewis, Cheuvront G. Henderson, John Ippolito, and Andre Stevenson—have been directly involved and very enthusiastic about this project. Two of them have presented papers at conferences and three have been directly involved with web page development. Two more papers are currently under way.

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Identification of Surface and Near Surface Defects and Damage Evaluation by Laser Speckle Techniques

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INTRODUCTION

The purpose of this research is to develop and demonstrate a novel, automated, non-destructive evaluation technique called laser speckle shearing interferometry (Digital Shearography), which is capable of determining flaws and the initial development of micro-cracking and its subsequent propagation in aluminum-, titanium-, and nickel-based super alloys and composite materials. This includes the characterization and space-time evolution of material properties in an aggressive dynamic and tribological environment (fatigue, flaw initiation and propagation, friction, etc.). The four significant factors in final failure—the number and character of the flaws, the load environment, the residual stress level, and the mechanism of failure for the material—will be investigated. The technique will be enhanced with other techniques, such as Dual Beam Digital Shearography and the phase shift method. The results obtained from this approach will be compared to and coupled with results from other techniques such as Moire Interferometry and Laser Speckle Photography. This will help in establishing a better understanding of the behavior of the materials under such conditions.

RESEARCH ACCOMPLISHMENTS

The effects of various loads have been investigated on specimens with different crack angles. Moreover,

this study investigates the processing and post-processing of shearographic imagery (image filtering). A methodology was developed for filtering the shearographic images for clarity. The fringes obtained gave a good quantitative and qualitative representation of material properties in scrutinized specimens. An analytical procedure has been developed to calculate the strain component. From the calculated strain component, the out-of-plane deformation can be calculated and constructed. This work shows that electronic shearography is useful in the detection of micro-cracks and weak spots due to internal pressure. This technique is becoming more promising with the continuous developments in electronics associated with recording, analysis, and filtering the signals obtained.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

One of the highest priorities within the NASA logistics community is to obtain sufficient information about material degradation through the nondestructive evaluation (NDE) of aircraft structures and components. The recent drive to enhance performance by incorporating ceramic components into turbine engines has led to an increased demand for the creation of new flight-line instrumentation capable of detecting invisible subsurface damage.

BENEFITS TO SOCIETY

Proper maintenance of existing aerospace structures and mechanical components depends mainly on accurate predictions and understanding of the severity of flaws due to fatigue, corrosion, wear, plastic deformation, and other factors. By allowing fundamental real-time measurements to be made in situ, fast detection of defects such as disbonds and micro-cracking can be achieved. In addition, the development of engineering models can be attained, which will contribute to improved basic studies of super alloys and composite materials under various operational conditions. The current technique possesses several advantages with respect to simplicity, accessibility, and versatility. Moreover, the technique is viable and suitable for operation in a manufacturing environment or repair facility as well as in the field.

STUDENT ACHIEVEMENTS

The project has increased the number of student participants in NASA-related fields. Two master's theses have been completed. Four undergraduates have been exposed to this research; two of them are currently continuing their master's programs on this project.

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Eigenstructure Assignment for Fault Tolerant Flight Control Design

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INTRODUCTON

Aircraft flight control systems are designed with extensive redundancy to ensure a low probability of failure. During recent years, however, several aircraft have experienced major control system failures. The objective of a fault-tolerant control system is to control and safely land an airplane with severely damaged or inoperative control surfaces. In addition to safety, the passengers of a civilian aircraft may require gust alleviation characteristics.

RESEARCH ACCOMPLISHMENTS

An eigenstructure assignment controller has been designed for the longitudinal axis of the Total In Flight Simulator (TIFS) aircraft. This design is different from previous designs because it considers the phugoid dynamics in addition to the short period dynamics. A MATLAB (a MathWorks product) program has been written which computes an optimal stochastic output feedback gain. Current work involves combining the two programs to achieve gust alleviation subject to eigenstructure constraints. Work is progressing on writing a MATLAB program that uses multi-model eigenstructure assignment to achieve a fault-tolerant flight control design.

STUDENT ACHIEVEMENTS

Zoila Cabrera, an undergraduate female Hispanic student, has joined the American Institute of Aeronautics and Astronautics; has attended the 1998 Guidance, Navigation, and Control Conference; and has begun work on a six-credit senior thesis. Herby Dallard, an undergraduate African-American stu-

dent, was a summer intern at IBM and completed an advanced control systems course during the summer session at Binghamton University.

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Feasibility Study of Piezoelectric Materials Actuator Driven by a Microwave

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INTRODUCTION

The goal of this research is to conduct a feasibility study of a piezoelectric materials actuator system driven by a microwave. A proof-of-concept experiment has been set up and demonstrated in cooperation with NASA Langley Research Center. The feasibility of such a system is being considered for the application of the Next Generation Space Telescope (NGST) fragmented optics control.

RESEARCH ACCOMPLISHMENTS

The preliminary experimental set-up for the research was completed under a cooperative agreement between NASA Langley Research Center and Norfolk State University. The voltage outputs in a frequency-modulated condition for a 3 x 3 array rectenna were measured at three different locations, as shown in the figure. The peak voltage of 32.0 V from the rectenna was obtained at 8.5 GHz with a 13 W microwave power at 38 cm. The output peak implies a 2.6 μm displacement of the material used based on the result obtained. The results are very promising for the practical applications.

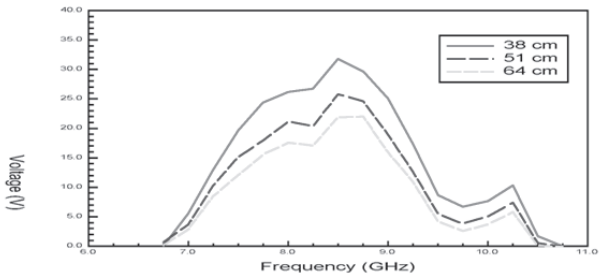

Figure. Frequency effect on DC voltage output of JPL 3x3 rectenna at various distances from feed horn.

RELEVANCE TO NASA STRATEGIC ENTERPRISES AND BENEFITS TO SOCIETY

Remotely powered and wireless controlled actuators offer tremendous advantages over wired actuators, especially for space applications such as the NGST. The advantage of this concept is that it alleviates the need for hard-wired connections to thousands of distributed actuators, resulting in significantly simpler system designs, lower system mass, and remote control capability in the NGST program. Other applications of the proposed concept include microwave-driven smart strings and smart membranes in micro-robots for commercial uses.

STUDENT ACHIEVEMENTS

Five undergraduate students were involved in research activities during the reporting period. Their majors were electronic engineering, mechanical design technology, electronics technology and computer science. They are all working at NASA Langley Research Center for the Summer and Fall semesters in the area of materials research, especially in piezoelectric materials. They presented a poster session titled "Smart Materials Driven by a Microwave" at the opening ceremony of the ARC [AHO11]building for the public on May 4, 1998.

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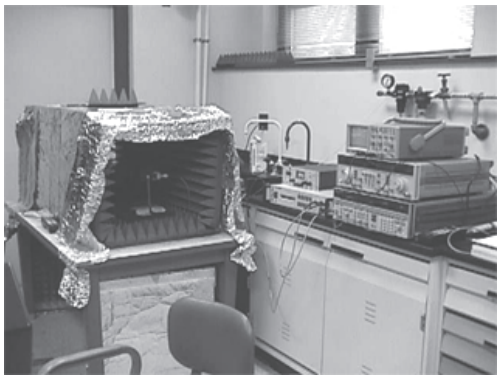

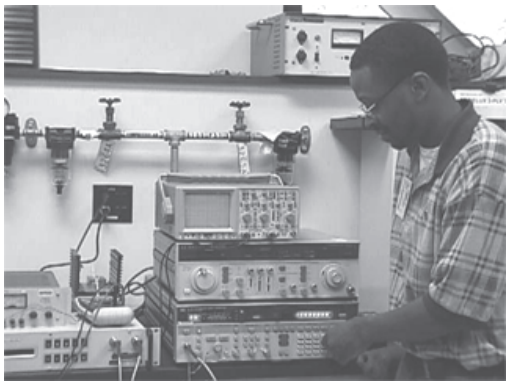

Figure 2. A student working on microwave driven actuator-Rectenna coupling experiment.

Simulation of Flow Control Using Deformable Surfaces

Principal Investigator:
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Date of Original Award: 1998

INTRODUCTION

Recent advances in materials suitable for flow control devices have made it possible to seek significant improvements in aircraft performance through active control of the flow field upon airfoils or within engines. Besides the well-known silicon-based MEMS (Micro-electromechanical Systems) devices, these materials include ionic polymer-metal composites that are electrically activated. These "artificial muscles" (M. Shahinpoor, "Micro-Electro-Mechanics of Ionic Polymeric Gels As Electrically-Controllable Artificial Muscles," *International Journal of Intelligent Material Systems*, v. 6, no. 3, pp. 307-314, 1995) provide the promise of a deformable surface that can be readily controlled to provide specified dynamic motions in response to flow conditions. Computational tools are being developed as part of this project to predict the response of flow fields on realistic aircraft surfaces and bodies to such surface manipulation.

Flow control seeks to prevent separation, delay transition, or augment lift. Predicting such flows, including their response to surface manipulation, requires accurate simulation of the unsteady flow fields. Parallel computing will be employed for the large computational problems resulting from realistic flow fields using the resources of the Albuquerque and Maui High-Performance Computing Centers. Many questions, including robustness and frequency response, remain for materials and devices proposed for flow control applications. This work can be used to predict requirements for these composite materials or other types of devices that manipulate the flow field through dynamic boundary deformation.

RESEARCH ACCOMPLISHMENTS

Most of the effort so far has focused on introducing the students who are working on the project to the concepts of computational fluid dynamics (CFD) and turbulence modeling. The two-dimensional version of the unsteady Navier-Stokes code (OSC2D) has been converted for compilation and execution on the Mechanical Engineering workstations. Some simple test cases have been run to familiarize the students with grid generation, turbulence model parameters, and graphical display of the results. The plan is to move on to the dynamic motion of rigid surfaces (e.g., pitching airfoils) and then to deforming surfaces.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This research is a part of the Aero-Space Technology Enterprise, in collaboration with the Flow Control group led by Dr. Ronald Joslin at NASA Langley Research Center. Prof. Truman met with Dr. Joslin in August to discuss the planned test cases and future collaboration.

BENEFITS TO SOCIETY

The successful design of flow control devices and strategies will enable aircraft designers to reduce structural weight and lead to improved efficiency and safety. The computational tools developed in this research will lead to improved design methodologies.

STUDENT ACHIEVEMENTS

In the five months that this project has been underway, two undergraduate students have been employed. One of these students will complete his bachelor of science in mechanical engineering in December and become a graduate research assistant on this project.

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Characterization of Molecular Interactions at Polymer/Metal Surfaces and Interphases

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Date of Original Award: 1997

INTRODUCTION

This research project is concerned with the preparation, characterization, and adhesion behavior of polymers on metals to form composite materials. The performance of a composite material is dependent on the integrity of the metal/polymer interface, which is greatly influenced by the type of surface treatment applied to the metal substrate. Thus, in order to design a composite with optimal properties, a better understanding of the interactions, whether physical or chemical, is necessary. Modern spectroscopy and microscopy techniques can play an important role in developing superior composites by characterizing the interface of these systems. Such techniques have significantly increased the understanding of interfaces, specifically their structure-property relationships. In so doing, specific tailoring of the interface can produce a high-performance composite material.

RESEARCH ACCOMPLISHMENTS

During the past year, research has focused on characterizing various surface treatments for enhancing adhesion properties of titanium metal alloy/polymer composite materials to be used in high-performance structural materials for aerospace and aeronautics applications. We have utilized x-ray photoelectron spectroscopy (XPS), auger electron spectroscopy (AES), scanning electron microscopy (SEM), and atomic force microscopy (AFM) to elucidate the compositional and topographical differences in two different types of surface treatments being evaluated by NASA Langley Research Center (LaRC). One type is trade-named Pasa-Jell 107, and has been previously used with noted limitations. The other is a type of Sol-Gel process, which is hoped to be an improvement.

XPS results on untreated, Pasa-Jell 107 treated, and Sol-Gel treated titanium alloy showed significant differences in the atomic composition of the surfaces (~5 nm depth), particularly carbon, oxygen, nitrogen, silicon, and aluminum. This has been interpreted as evidence that Pasa-Jell 107 treatment yields a greater amount of oxygen on the surface due to oxide buildup, whereas Sol-Gel treatment yields enhanced amounts of carbon, nitrogen, and silicon on the surface due to the alkyl-saline chemistry.

AES results on the above samples showed atomic compositional changes with depth of penetration and allowed for the determination of the thickness of surface to bulk material region, namely the interface. Pasa-Jell 107 showed a substantially thicker oxygen layer than Sol-Gel. SEM and AFM results both reveal that the Pasa-Jell surface consisted of large hills and valleys, whereas the Sol-Gel surface showed cavities due to chemical etching of the surface.

These research studies have established a protocol for evaluating surface treatments for adhesive bonding to form composite materials.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This research project is contributing to NASA's mission by helping to identify the structural nature of these materials on the molecular level and relating these findings to a better understanding and control of the macroscopic behavior of composite materials.

BENEFITS TO SOCIETY

The benefits of this research project to society are improvements in the development of aerospace, military, and civil high-speed aircraft.

STUDENT ACHIEVEMENTS

One African-American female graduate student completed sufficient research for her M.S. degree in chemistry and has presented research findings at two national conferences. An African-American female undergraduate (sophomore year) has received introductory exposure to research in chemistry and is continuing to pursue a career in science.

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Langley Research Center (Abstracts)

Active Isolation Techniques for Mitigating Earthquake Effects on Civil Structures

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ABSTRACT OF PROPOSED RESEARCH

The proposed program will use the NASA-supported Control and Structures Research Laboratory (CSRL) facility at the California State University, Los Angeles (CSULA) at no cost to develop methods and technologies for structural control of civil structures. Advanced technologies for analysis, design, instrumentation, active isolation, modeling, and control will be developed and tested experimentally. The proposed technologies will offer protection of civil structures such as bridges, commercial and residential buildings, schools, and so forth against earthquake-induced damages. Moreover, the technologies to be developed may have other commercial applications in industries such as the automotive industry, the medical field, and the manufacturing sector.

The proposed project will make full use of the CSRL facility and the methodologies developed for the CSRL testbed. CSRL has been sponsored by NASA under an IRA (Institutional Research Award) program. The project will use the high-speed data acquisition systems, sensors, and control computers employed for the CSRL testbed, and it will also apply the control technologies developed for the CSRL testbed to the control of civil structures. The project will investigate the concept of active isolation, which combines the traditional passive isolation method for civil structures with active controllers. The project involves the analysis, design, modeling, dynamic analysis, development of control algorithms, and experimental testing of active isolation systems on experimental scale models of civil structures subjected to earthquake excitations.

A major goal of the proposed program is to train minority students, expose them to state-of-the-art research, prepare them for future employment, and motivate them towards higher degrees in engineering and science.

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Marshall Space Flight Center (Reports)

A Study of the Relationships Between Structure, and Magnetic and Electron Transport Properties in $R1-_xA_xMnO_3$ Alloys

Principal Investigator:
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Date of Original Award: 1998

INTRODUCTION

The main objective of the project is to enhance understanding of the electron transport properties of some ceramic materials that exhibit colossal magneto-resistance (CMR). These properties have potential applications in magnetic sensor device technology. The project will accomplish this objective by studying some $R1-_xA_xMnO_3$ alloy samples (*R* is a rare earth, *A* is an alkaline earth, and the value of *x* is in the range 0-1). After the samples are fabricated, the magnetic and electron transport properties will be examined using laboratory techniques involving magnetic and current-voltage (I-V) measurements. Interpretation of the results will yield information to enhance understanding of CMR in these materials.

RESEARCH ACCOMPLISHMENTS

Equipment has been acquired, including a high-temperature furnace capable of temperatures up to 1700°C, precision resistance measuring equipment, and other supplies. Preliminary sample fabrication of $LaMnO_3$ and some $R1\text{-}_xA_xMnO_3$ combinations has begun.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This research is relevant to the Aero-Space Technology Strategic Enterprise, which utilizes various types of sensor devices. The project will extend the current understanding of properties of some materials that can be used for magnetic sensor devices. Increased understanding of the mechanisms that drive the magnetic and transport behaviors of these materials will provide information to tailor them to specific engineering applications.

BENEFITS TO SOCIETY

Magnetic sensors also impact the lives of the average citizen, since applications of these devices are ubiquitous in everyday consumer items. For example, they are used in automobiles, home video equipment, and computers. Again, an understanding of the mechanisms that cause the materials to exhibit the properties that they do will provide information to engineer devices to fit specific applications.

STUDENT ACHIEVEMENTS

Currently, two African-American students (Mr. Jeremy Jackson, a master's-level physics student, and Mr. Jeremiah Gray, an undergraduate physics major) are working on this project. The student involvement to date has included making the samples; as the project progresses, student involvement will extend to all facets of it.

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Atomization in Impinging-Jet Injectors of Liquid-Propellant Rocket Engines

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Date of Original Award: 1996

INTRODUCTION

The impinging-jet atomizer affords a convenient means of controlling the drop size and spatial distribution of a spray and has found widespread applications. It is particularly suited to liquid-propellant rocket engines where intimate mixing of reactants may be easily achieved by the impingement of fuel and oxidant jets. The main objective of this project is to develop a theoretical model that accurately characterizes the physical mechanisms responsible for the atomization phenomenon. The model will be used to effect predictions of the penetration depth, breakup time, drop size, and orientation of the spray produced by the impinging jets.

RESEARCH ACCOMPLISHMENTS

The research effort during the past year was focused on the application of nonlinear instability theory to predict the spray characteristics in the impinging jet injector. It is well known that the impingement of two cylindrical co-planar jets of equal diameters and momentum (like-on-like doublet) produces an expanding sheet in the plane at right angles to the plane containing their axes. The processes of instability and the subsequent breakup of the sheet dictate the outcome of atomization. A second order perturbation analysis was employed to investigate the growth of the asymmetrical disturbances that lead to the disintegration of an attenuating liquid sheet similar to the sheet produced by impinging injectors. It was found that the sheet breaks up into ligaments of half-wavelength size. The breakup length, breakup time, and resulting drop size decrease as the Weber number is increased. Raising the Weber number causes the breakup thickness to increase. Favorable agreement was observed between the present computations and existing experimental data. The present approach yields more accurate predictions compared to existing procedures.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The theory and predictions of the present work are imperative to allow for accurate numerical simulations of the combustion processes that take place in liquid-propellant rocket engines. The characteristics of the instability and atomization in the impinging jet atomizer are also of importance for the design of fan spray nozzles, which operate on a closely similar principle.

BENEFITS TO SOCIETY

The present work contributes to a better understanding of fuel injection and atomization processes, which may lead to improving combustion efficiency and hence a reduction in fuel consumption and pollutant emissions.

STUDENT ACHIEVEMENTS

Eight minority students, two graduate and six undergraduate, are involved in this project. Shawn Marshall and Emmanuel Isong are expected to complete their master of science in mechanical engineering requirements in December, 1998 and August 1999, respectively, and to continue their graduate studies towards a Ph.D. Ivan Morrison, Jennifer Twyman, and Kimberic Windham have received bachelor of science in mechanical engineering (BSME) degrees and are employed in industry. Caryn Chappell, Marcus Chatman, and Wykeisha Ross are working toward their BSME degrees. Most of the research conducted in this project has been performed by the students and has resulted in two presentations and two journal papers.

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3-D Multiphase-Flow Modeling of Oxygen Flow Systems

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Date of Original Award: 1996

INTRODUCTION

The major research objective of this project was to continue the development of a fully 3D fluid mechanical model of the supersonic velocity impact nozzle used at the Johnson Space Center White Sands Test Facility. This tester is used in determining what materials can be safely employed in high-pressure, high-temperature oxygen systems. The systems of particular interest are shuttle main engines and life support for astronauts. The model developed includes the effects of compressibility, turbulence, and entrained particles. The results of the fluid mechanical model will be used as inputs to an impact model. This impact model will help determine under what conditions particle ignition can occur.

RESEARCH ACCOMPLISHMENTS

A commercial code was applied to the modeling of the tester. Calculations were continued for inlet pressures of 28 MPa and inlet temperatures of 700°K. The relationship between target position and flow separation was studied in detail. First year results indicated that separation would occur, but it was not known if such separation could be eliminated. The latest results suggest that if the target diameter is reduced to 60 percent of its current size, no separation will occur. The elimination of separation might allow the use of optical diagnostics for measuring particle impact velocities. In addition, the full conjugate heat transfer problem was solved for a limited number of cases. The conclusion from these calculations is that the flow is insensitive to the details of the wall thermal boundary conditions. Preliminary experimental measurements show good agreement with model predictions.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The successful modeling of the supersonic tester directly supports efforts at the White Sands Test Facility. To date, testing has been primarily comparative, determining which materials are more or less prone to burning. With the model now available, modifications are being investigated to better characterize the particles at impact. The availability of such data can be used to improve the understanding of the ignition process and the potential danger from fire.

BENEFITS TO SOCIETY

The present efforts are specific to NASA work, but could be applied in the public arena. For example,

oxygen systems are used in both industry and medicine. Wherever high-pressure oxygen is used, there have been accidents involving fire. The present model could be adapted to the design of safer oxygen systems.

STUDENT ACHIEVEMENTS

One undergraduate and two graduate students were involved with the project. One of the students earned his master's degree and is now employed by a major technology company. A paper with this student as a co-author was presented at the International Symposium on Computational Technologies for Fluid/Thermal/Chemical Systems with Industrial Applications, a joint ASME/JSME (American Society/ Japanese Society of Mechanical Engineers) meeting held in San Diego in July 1998. The other graduate student is working toward her doctoral degree, while the undergraduate student is gaining valuable experience in applied fluid mechanics not available through the usual classroom setting.

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Object-Oriented Software Control Architecture for Robotic Vehicles

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Original Date of Award: 1996

INTRODUCTION

The Strategic-Tactical-Execution Software Control Architecture (STESCA) is being developed under this project. STESCA is intended to be a general control approach that can be used on any type of robotic vehicle. The initial testbed vehicle was the Phoenix Autonomous Underwater Vehicle (AUV) at the Naval Postgraduate School (NPS) in Monterey, California. STESCA is currently being developed for use with the simulator for the Pioneer AT, a land-based wheeled robotic vehicle.

RESEARCH ACCOMPLISHMENTS

A prototype graphical user interface (GUI) was developed for mission specifications. The development of "worlds" (i.e., maps of the UTPA campus and Engineering Building) for the Pioneer AT robotic simulator were begun. The two-dimensional path planning system developed during the first year was expanded into a three-dimensional system. Various solutions to failure path planning (i.e., what to do if a portion of the mission is unobtainable) have also been investigated.

Two papers, "An Object-Oriented Approach to Autonomous Underwater Vehicle Control" and "Overview of Path Planning Algorithms for Autonomous Vehicles," were presented at the 10th International Symposium on Unmanned Untethered Submersible Technology (UUST) in September 1997. A paper titled "A Software Control Architecture for Autonomous Vehicles" was presented at the 31st Annual Hawaii International Conference on System Sciences (HICSS-31) in January 1998; this paper was named the Best Paper in the Emerging Technologies Track. A paper titled "Teaching C++ / Teaching Object-Oriented Programming" was presented at the Texas Computer Education Association Conference (TCEA'98) in February 1998. A position paper titled "Scalability of Autonomous Vehicle Control Systems" was included in the Scalability Workshop of the 4th Conference on Object-Oriented Technologies and Systems (COOTS). A paper titled "The Path Planning Component of an Architecture for Autonomous Vehicles" was presented at the 11th International Florida Artificial Intelligence Research Society (FLAIRS) in May 1998. A technical report titled "STESCA: The Strategic-Tactical-Execution Software Control Architecture" was published in November 1997.

STUDENT ACHIEVEMENTS

Two students gave presentations at the 4th Annual Student Research Conference in November 1997. One student completed his honors proposal ("STESCA: Land Ho!") and is currently working on his honors thesis.

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Health Monitoring of Composite Material Structures Using a Vibrometry Technique

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INTRODUCTION

Non-destructive evaluation (NDE) methods for quantifying and locating damage are essential for inspecting structures to ensure safety and reliability. Transmittance function (TF) monitoring is a potential new NDE technique being tested as a tool to detect, quantify, and locate damage on flexible structures. The technique has a large spatial range that is practical for detecting damage on large composite material structures such as a Reusable Launch Vehicle (RLV). The TF theory is based on structural dynamics principles that define how vibration at one point in a structure is related to a force at another point. This relationship is called the Frequency Response Function (FRF). A TF is derived as the ratio of FRF's, and can detect damage to structures because the FRF's are changed due to damage. In the damage detection procedure, the structure is subjected to wide-band vibration and TF's are computed between different sensors to detect any changes in the structure, presumably due to damage. An advantage of the TF method is that if one excitation is used for the testing, the force does not need to be measured.

RESEARCH ACCOMPLISHMENTS

In the first year of the project, the TF method was tested on a bolted panel, a curved panel, and beams, all made of fiberglass. It was shown that damage could be detected using low-frequency vibrations of 250 to 1,250 Hz. The technique is sensitive to damage, but it requires storage of historical or pre-damage TF's for the healthy structure. This would become a large data storage requirement for large structures. Consequently, one objective for the second year of the project was to eliminate the need to store historical data. This was accomplished by using clipping of lower magnitude data and by defining a variance TF. The new technique requires storing only one data point per sensor, but the trade-off is slightly reduced sensitivity as compared to storing all of the healthy data. Further testing of panel structures was also done.

RELEVENCE TO NASA STRATEGIC ENTERPRISES

Research in health monitoring is important for the development of an RLV that can replace the Space Shuttle, reducing launch and maintenance costs while increasing the payload. Lockheed Martin and NASA Marshall Space Flight Center are developing an RLV known as the X-33. This structure will use a large percentage of composite materials and will incorporate a Vehicle Health Management (VHM) system. The algorithms developed in this project might become part of this VHM system. The work in this project is also applicable to VHM systems under development for future high-speed civil transport aircraft, rotorcraft, and space vehicles developed by NASA.

BENEFITS TO SOCIETY

Health monitoring technology can make flight vehicles, bridges, buildings, and other mechanical and structural systems more reliable, less expensive, and safer. A miniature sensor-processor system installed on a structure can monitor its condition. When a problem begins, the system will alert the operator and the problem will be corrected in the initial stage before becoming dangerous. This approach can increase safety by avoiding catastrophic problems and reduce costs by eliminating unnecessary maintenance.

STUDENT ACHIEVEMENTS

Students working on the project have learned to use the most advanced vibration testing equipment available, including high speed data acquisition systems, smart materials, and a scanning laser Doppler vibrometer. Students graduating from working in the Structural Dynamics and Control Laboratory are getting employment offers because they have an experimental background to supplement their classroom knowledge.

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NLO Polymers That Have Enhanced Thermal Stability and Low Alignment Decay and the Use of Microgravity to Optimize NLO Properties

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Date of Original Award: 1997

INTRODUCTION

The aim of this project is to design nonlinear optical (NLO) polymers that have excellent thermal stability and low alignment decay. NASA's main interest in NLO research is in materials that can be used in laser communications with satellites deployed in space. Another interest NASA has is the use of the microgravity environment to optimize NLO properties. In this project, a microgravity environment will be used to obtain polymer films that are free of defects. This should result in the polymer being a more efficient NLO material.

RESEARCH ACCOMPLISHMENTS

The first year of the grant was spent setting up the laboratory and optimizing the reaction conditions for the synthesis of the polymer precursors. A method was found that selectively reduced 2,7-dinitrofluorenone to yield target compound I, 2-amino-7-nitro-9-fluorenone. This method involved a reaction between sodium hydrosulfide, which was generated in situ, and 2,7-dinitrofluorenone. The structure of compound I was confirmed using infrared and nuclear magnetic resonance spectroscopy. Target compound II, 2-[N,N-diethyl]amino-7-nitro-9-fluorenone, was synthesized by a reaction between the amine and triethylphosphate. The next step will be to convert compound II into a monomer that can be incorporated into a polymer structure.

STUDENT ACHIEVEMENTS

Nine undergraduate students were involved in this project. Seven of these students were directly involved in the synthesis of the intermediates. The other two students were used as clerical support. The students received training in giving an effective presentation and the importance of attending scientific meetings. All of the students who were involved in this project attended the Louisiana Academy of Science meeting that was held in February in Hammond, Louisiana. Two of these students gave oral presentations. It was the first time that one student had given an oral presentation at a scientific meeting, and he was clearly unnerved. He had the opportunity to present again in March at a Department of Energy's EpSCoR (Experimental Program to Stimulate Competitive Research) conference that was held in Baton Rouge, Louisiana. At this meeting, it was evident that he was becoming quite confident in his ability to give presentations. Another student attended the spring national meeting of the National Organization for the Advancement of Black Chemists and Chemical Engineers and gave a poster presentation. Another student gave a presentation at the Phillip E. Young Symposium that was held on the Grambling State University campus. Two students attended the spring national meeting of the American Chemical Society that was held in Dallas, Texas.

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Marshall Space Flight Center (Abstracts)

Modeling and Analysis of Heat-Activated Thermal Coupling for Joining Composite to Composite/ Alloy Structures

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ABSTRACT OF PROPOSED RESEARCH

In order for advanced composite structures to receive acceptance for many applications, reliable joining methods must be developed to compete with heavy, often expensive, alloys. The development of a predictable composite joining method would allow for the use of advanced composite systems in situations where weight reduction is of concern. This proposal, submitted by Southern

University in collaboration with Louisiana State University, expands on the established benefits of composites, namely their light weight and corrosion resistance.

The objective of this project is to develop a joining process for composite-to-composite or composite-to-alloy structures using pre-impregnated (prepreg) fibers which can be directly used in engineering design and performance assessment. It is proposed that a prepreg laminate containing heat-set resins and fiber reinforcements (glass, carbon, etc.) be used to couple composite-to-composite or composite-to-alloy structures. The main barrier to the effective use of this technology is the non-uniform heating that may occur due to the thickness of the laminate and to the vastly different thermal conductivities of composite and alloy materials. Emphasis will be placed on the performance of the joint as it experiences various loading conditions such as pressure changes and thermal stress due to temperature changes. Mechanical performance will also be evaluated.

This project will combine theoretical analysis, finite element analysis, and experimentation. Both finite element analysis and experimental results will be used to verify the developed models. Great effort will be devoted to experimental investigation during the three-year research period.

The research group for this project will include the principal investigator, an academic mentor, graduate students, and undergraduate students. The potential contributions of this project will be significant not only to the enhancement of research and development capabilities and infrastructure for NASA-related research, but also to the education of future scientists and engineers in disciplines critical to the NASA mission.

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Stennis Space Center (Reports)

Analysis of the Inherent and Apparent Optical Properties in Case 1 and Case 2 Waters of the Caribbean Sea

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Date of Original Award: 1997

INTRODUCTION

Remote sensing of ocean color provides the capability of performing large-scale phytoplankton studies. However, at local and regional scales, the variability of water optical properties makes the interpretation of remote sensing data very difficult. Our goal is to assess the spatial and temporal variability of the inherent and apparent water optical properties and their relationship to the satellite's spectral signal.

RESEARCH ACCOMPLISHMENTS

A serial station in oceanic waters south of Puerto Rico (Caribbean Time Series-CaTS) has been routinely sampled since 1994. In western Puerto Rico, Mayagüez Bay has also been sampled every month since February 1997. We operate a high-resolution picture transmission antenna (HRPT) for real-time data reception from the National Oceanographic and Atmospheric Administration Advanced Very High Resolution Radiometer (AVHRR) and the NASA Sea-viewing Wide Field-of-view Sensor (SeaWiFs). Since October 1997, we have processed daily L1A SeaWiFs data and sent it to NASA for archiving.

In addition to the field sampling effort, we process SeaWiFS data to derive Chl-a in order to determine its temporal and spatial variability in the eastern Caribbean. Preliminary analyses show a large variability in the inherent and apparent optical properties in Caribbean waters. We suggest the use of several bio-optical algorithms in this region for better estimation of Chl-a with SeaWiFS.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This project is providing necessary data for the development of more accurate bio-optical algorithms for the estimation of phytoplankton chlorophyll. This will provide a better understanding of the ocean's carbon cycle, which is a key element of NASA's Earth Science Enterprise.

STUDENT ACHIEVEMENTS

Dr. Fernando Gilbes is a post-doctoral researcher in charge of the application aspects of the HRPT station

and the field work and laboratory analysis. The following undergraduate and graduate students have received training in bio-optical and satellite data processing: Marcos Rosado, Eugenio Lomba, José Hernández, Natacha Carlo, and Ricardo Figueroa.

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Labile and Stable Soil Organic Carbon Pools Revealed by ^{14}C and ^{13}C Signatures

Principal Investigator: Dr. Yuch Ping Hsieh
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Date of Original Award: 1996

Report not submitted.

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Seeing the Earth: Using Remote Sensing Technologies to Stir the Imagination of Science Students

Principal Investigator: Dr. Sally O'Connor
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Xavier University of Louisiana
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Date of Original Award: 1998

INTRODUCTION

The goals of this project include the development and distribution of multimedia instructional materials on environmental science topics and the incorporation of remotely-sensed data and geographic information systems (GIS) in the instructional materials.

RESEARCH ACCOMPLISHMENTS

A university committee formed to help guide the development of the instructional materials met numerous times to finalize recommendations on software platforms, topic priorities, and design strategies. Members included faculty from the Chemistry, Biology, Computer Science, and Education departments.

An annotated bibliographic database using ProCite software was used to input web sites and other gathered information. The database currently includes data on approximately 65 web sites. Any user can search the database using any of the codes included with each entry.

Content materials for several modules have been gathered and packaged in HTML format. These materials will be incorporated in a multimedia format using Macromedia Director. Materials include text, images, and video clips. Exercises are being developed for each topical area. A workshop on the use of Director was offered in June 1998 to familiarize those involved in the project with the software. At present, two environmental scholars (both African-American) are learning Macromedia Director in order to assist in future production efforts.

A draft version of the introduction to the CD-ROM product was made. Changes in format were recommended and the draft copy will be revised.

Students and project researchers made several visits to NASA Stennis Space Center (SSC) in Mississippi. During these visits, Dr. Armond Joyce provided an overview of educational materials produced with NASA funding and other resources available to aid in the development of Xavier's modules, including remotely-sensed data. Resources available at the SSC's Educator Resource Center were also discussed.

Project staff attended several workshops and conferences to become more informed on topics related to the subject matter included in the project. These conferences and workshops included the following: the University Research Centers Technical Conference '98, February 22, 1998, in Huntsville, Alabama (including a workshop on NASA's Earth Science Enterprise); a Wetlands Workshop, April 27-29, 1998, in Corpus Christi, Texas; and the Coastal Wetlands Summit, October 2, 1998, in Thibodaux, Louisiana.

STUDENT ACCOMPLISHMENTS

Five African-American students were hired to work on the project. They were given instructions on navigating the Internet, searching for appropriate web sites, and summarizing the contents. The web sites were entered into a database and coded with the site name, access date, educational level of content, type of media contained in the web site (audio, video, remotely-sensed data, etc.), key words reflecting content, and a short abstract describing the web site content. Students also accessed information available in the library.

One student, Shanda Mobley, attended a lecture given by Dr. Peter Vitousek, an ecologist and global change scientist from Stanford University, on March 26, 1998. This lecture, held at Tulane University, was on the topic of tropical forests and global climate change.

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Stennis Space Center (Abstracts)

Pre-construction Thermal, Hydraulics and Materials Analysis of the Second Generation Space Shuttle Engine Test Diffusor

Principal Investigator: Dr. Sam M. Aceil
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Date of Original Award: 1998

ABSTRACT OF PROPOSED RESEARCH

The available literature indicates that the design and analysis of the second-generation Space Shuttle Main Engine test facility is underway at NASA Stennis Space Center (SCC). The 25 years of experience with the first generation diffusers, such as the A and B series at SSC, raised many questions; some still await concrete answers. The objective of this proposal is to investigate the statics, dynamics, and thermal responses of the testbed diffuser for various conditions using some of the finite element numerical technique simulation codes available. The proposal will use simulation code such as ALGOR (a finite element analysis software package) or COSMOS (similar to ALGOR) to simulate some of the thermal, hydraulic, and material responses of the diffuser under real conditions. These codes are capable of simulating the statics, dynamics, and thermal effects of real conditions on the performance of the diffuser.

Graduate students' theses and undergraduate final projects will be assigned in this area. Students who show aptitude and interest in the areas of mathematics, science, engineering, and technology will be recruited and encouraged to join this project.

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Noise Removal, Deconvolution, and Vibrational Relation Studies to Enhance Exhaust Plume Diagnostic Technology

Principal Investigator:
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Date of Original Award: 1998

ABSTRACT OF PROPOSED RESEARCH

Some of the material atoms and product molecules such as oxides and hydrides present in exhaust plumes are in the excited state due to the high temperature, while most are still in the ground state. Emission and absorption spectroscopy methods are employed to study the presence of metallic species in the exhaust plume. The data acquired by these methods and electric field (EF) measurements of the plume can be used for engine health monitoring, enhancement of post-test inspections, and certification of engine readiness for reuse.

Remote sensing is another area where the Point Spread Function distorts the input data. This distortion is in the form of blurring of the images obtained. In the first two years of the project, it is proposed to apply the Morrison's and always-convergent iterative smoothing and restoration algorithms along with an appropriate deconvolution method to the Plume Diagnostics Project data for enhancement and improved reliability. Spectral deconvolution will also be performed in order to eliminate the small peaks adjacent to the larger peaks for the EF data.

The last year of this project will be devoted entirely to theoretical calculations of the plume emission spectra as well as initiating a plan to study various physical and chemical processes that take place in the plume. As part of the proposed plan, the principal investigator will train a graduate student and two undergraduate students. The students will be selected from the socially underrepresented student body of the College of Sciences or Engineering of Southern University.

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Response of Leaf and Canopy Spectral Reflectance to Drought Stress in Soybean

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Date of Original Award: 1998

ABSTRACT OF PROPOSED RESEARCH

The basis of existence of life in the biosphere on planet Earth is the capture of solar radiation in the visible spectrum to provide organic and biochemical energy to vegetation. Photosynthesis is a unique process in green plants. The chlorophyll pigment in the leaves and the availability of water are the key elements needed for the process of photosynthesis and the growth and development of plants.

To assess the growth and development of forests and economic plants like soybean on a larger scale by remote sensing, efficient and reliable tools are needed to predict the potential damage to plants due to lack of water and/or efficient use of light energy. NASA scientists have determined that near 700 nm narrow-band reflectance and its ratio to near infrared to be an optimum basis for remote sensing of chlorosis and drought-stressed growth in plants. Thus, the objectives of this study are to determine the leaf and canopy reflectances between 400-800 nm wavelengths with a spectroradiometer in order to predict the growth and development of soybean plants subjected to drought stress and grown in the greenhouse and in the field.

Data collected in a research study establishing leaf and canopy spectral reflectances in relation to leaf chlorophyll content and degree of plant stress will help in the production of prototype airborne and spaceborne spectroradiometers. Research data generated with the use of ground-based spectroradiometers and the response of drought-stressed plants will also provide a basis for preparing models to predict potential crop-damaging events.

The active participation in this study of one graduate and two undergraduate students is required in collecting the research data. It is expected during the course of this study that three students will have acquired training and experience in the latest technology and NASA- and aerospace industry-related topics.

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Partnership Awards

Partnerships between the NASA Installations and minority universities have great potential to further the ongoing mission of NASA and to assist in developing a diverse community of research institutions with a significant percentage of socially and economically disadvantaged students. The Partnership Award is designed to create and strengthen such partnerships. Projects supported are unique and innovative, and they fall outside of NASA's usual competitive programs. These projects show evidence of having high potential for long-term support from other sources. Special efforts are made to include outreach to individuals with disabilities and to public schools with enrollments of predominately socially and economically disadvantaged students.

Partnership Awards are funded for no more than two years, at a maximum of $200,000 per year for each participating minority institution. Second-year funds are contingent on the successful completion of the first year's activities. The NASA Installations and minority institutions' partners are expected to leverage the impact of the award with other funding. Awards are made in three categories: education, research, and a combination of education and research. Education Awards are made in support of such endeavors as pre-college projects, bridge projects, course and curriculum development projects, and/or projects that expand the understanding and use of education technology. Research Awards are made to cover a wide spectrum of research that is of interest to NASA. Combination Awards are made to projects that skillfully combine activities in both the research and education areas.

These reports summarize the activities of 16 research and 12 combined research and education Partnership Awards during the academic year September 1997 through August 1998 reporting period. During this period, 104 professional-level investigators were involved in these projects—76 faculty members, 19 research associates, and 9 postdoctoral fellows. A total of 190 students—133 undergraduate and 57 graduate—participated in these research activities.

The research accomplishments were documented in 34 refereed papers or book chapters that were published during this period. Significantly, 26 students were authors or co-authors of these publications. An additional 21 papers or book chapters, involving 24 student authors or co-authors, were accepted for publication during this period. The broader research community was informed of this work through 143 technical presentations, including 27 presentations given by students.

During the academic year September 1997 through August 1998, the 28 reporting Partnership projects were able to leverage their NASA MUREP expenditures ($3.0 million, not including $0.7 million of student support) to an additional $2.6 million in new research support, $0.5 million from other NASA programs, and $2.1 million from other agencies.

A major goal of the Partnership program is to increase the number of disadvantaged and/or disabled students receiving mathematics, science, engineering, and technology research experience and entering careers in NASA-related fields. Of the 190 students, 133 (70 percent) participated at the bachelor's degree level, 42 (22 percent) participated at the master's degree level, and 15 (8 percent) participated at the doctoral degree level. Of the participating students, 87 percent were members of an underrepresented minority group. Perhaps most importantly, 53 degrees, including 40 bachelor's degrees, 11 master's degrees, and 2 doctoral degrees, were awarded to Partnership students.

Brief reports from each of the projects follow. Reports on the Education Partnership Awards can be found in a companion report titled *Education and Training Report—1998*, published by the NASA Office of Equal Opportunity Programs/Minority University Research and Education Division.

Ames Research Center

Solar Ultraviolet-R Radiation and Public Health in Puerto Rico

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Report not submitted.

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Verification of NASA Mission-Critical Software Without Sacrificing Performance

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Date of Original Award: 1997

INTRODUCTION

Because the verification and validation of large, complex systems are difficult, a monitoring facility that checks for software failure during the execution of a program is needed. Many of the existing approaches require the programmer to insert checks at appropriate places in the code. The promotion of these approaches has been hampered by the detrimental effect of monitoring on performance. Our approach, called Dynamic Monitoring with Integrity Constraints (DynaMICs), proposes to keep the constraints separate from the program, initiate the execution of constraint-checking code dynamically, and minimize performance degradation due to integrity constraint monitoring. The goals of the project are to design various methods of constraint checking, including compiler-embedded constraint-checking code; to design and evaluate a performance-friendly system that incorporates these different methods; and to design and implement methods that provide graceful degradation of NASA mission-critical applications.

RESEARCH ACCOMPLISHMENTS

A comprehensive literature review has been completed and a survey paper is in progress. Currently, four complementary approaches are being investigated: local and remote procedure calls to constraint-checking code; insertion of constraints through the editing of an executable file; initiation of constraint-checks by software that monitors the execution of the application code, which resides in the address space of the monitoring software; and the design and simulation of a DynaMICs snoopy coprocessor-based system. The approach that is based on remote procedure calls is being implemented on a multiprocessor system, using MPI (Message Passing Interface). These four approaches are complementary because the insights and facilities provided by one can be used by another. For example, the initiation of constraint checks by monitoring software can be used to develop a fast prototype (proof-of-concept) of a methodology for checking a specific type of constraint, and an edited executable file can be used as input to a simulation of a DynaMICs snoopy coprocessor-based system. Investigation of the various approaches has led to new insights with respect to the types of errors that are detectable by integrity constraints (a paper has been published on this topic), the requirements of a constraint-specification language (a paper is in progress on this topic), compiler-directed embedding of constraint-checking code, and tracing from constraints to supporting documentation and the application code. A paper that describes a preliminary design of a DynaMICs snoopy coprocessor-based system has been submitted for publication. Collaboration with Sandia National Laboratories' High Integrity Software System Engineering Department is underway with respect to a DynaMICs snoopy coprocessor-based system. The application of DynaMICs systems to survivable information systems was included in an National Science Foundation Science and Technology Center Proposal submitted by the University of Virginia.

RELEVANCE TO NASA STRATEGIC ENTERPRISES AND BENEFITS TO SOCIETY

The research is aimed at developing software tools that will improve the reliability and integrity of software. A DynaMICs system can be used to detect errors in NASA mission-critical applications during runtime and to trigger graceful degradation of software when appropriate. The work is also applicable to any critical software and provides an approach that can prevent the loss of equipment and/or life.

STUDENT ACHIEVEMENTS

Five students, three of them undergraduates, have been working on the project over the past year. Three of the students are funded directly through NASA. One student, who started as an undergraduate, continued to graduate school. One graduate student has co-authored a refereed conference paper. An undergraduate student has co-authored a conference paper that is under review. One student has presented a paper at a regional conference.

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Dryden Flight Research Center

Computer Simulation of Multidisciplinary Engineering

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Report not submitted.

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Glenn Research Center

Ultra-Sensitive Optical Strain Gauges for Plume Impingement Studies

Principal Investigator: Dr. Donald Lyons
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Date of Original Award: 1997

INTRODUCTION

The general objective of this research effort is a proposed demonstration involving the fabrication of fiber-optic interferometric sensors for high-temperature environments. The interest in these devices lies in their high sensitivities and their ability to allow a greater understanding and possible characterization of plume impacts on spacecraft systems. If these impact conditions can be obtained, then it follows that these same sensor types could be configured to measure such parameters as momentum transfer, electromotive forces, and temperature, since each of these field-related phenomena can be addressed either directly or indirectly by strain.

RESEARCH ACCOMPLISHMENTS

We have designed and fabricated compact, stable, low-temperature analog devices that function in a similar manner to that of the high-temperature version. Typical optical strain sensors consist of single material compositions, namely fused silica. In contrast, the high-temperature device is a composite of three materials (Macor, Super Invar, and fused silica).

An approximate gap spacing of 10 microns has been chosen in conjunction with a Super Invar stability element to taper the sensitivity, since we have assumed a fairly harsh and strain-rich environment. Due to the insulating nature of the Macor and the slow linear thermal response of the Super Invar, we have designed the sensor such that strain information will be efficiently transferred to the sensor while the optical fiber will be shielded from the heat.

We are nearing completion of a prototype for multiple sensor fabrication. This prototype consists of a high-resolution automated writing system containing a double interferometer setup (one visible and the other UV). This device, based on a simple transimpedance JFET (Junction Field Effect Transistor) for its fringe counting detection circuitry, will be used to register evenly-spaced gratings in samples such as our distributed Bragg sensors, which are planned for several NASA-related projects.

Finally, we are developing compact, stable readouts for directly-correlated strain, plume impingement, and momentum-transfer measurements and adapting the same technology for linearly scaled-down high-temperature measurements in harsh environments.

Two patents and one presentation have resulted from this work so far. D.R. Lyons and S.R. Bullock filed the patent disclosure "Non-Intrusive Fiber-Optic Sensor for Detection of Lead in Environmental and Biological Systems" on September 20, 1997. D.R. Lyons and J.V. Lindesay filed the patent disclosure "High Temperature Fiber-Optic Sensor" on March 20, 1997. The paper "Preliminary Fringe-Counting Verification for a Bragg Grating Wavelength Standard," by K. Samuel and D.R. Lyons, was presented at the 5th Annual HBCU Research Conference in April 1998.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The work illustrated here has an essential application in the area of Aero-Space Technology, where temperature cycling and high fatigue due to plume impacts is a problem. This NASA Enterprise encompasses aerospace structures, which can make use of characterization elements such as these. Although this technology is primarily geared towards space-bound structures, its spin-offs have potential applications in many areas both inside and outside of NASA. These include process monitoring, telecommunications, and medicine.

BENEFITS TO SOCIETY

The development of certain materials for microelectronics, medical, and other applications necessitates a microgravity manufacturing environment. The overall integrity and stability of such an arrangement depends heavily upon the ability to characterize rocket plume interactions with space structures.

STUDENT ACHIEVEMENTS

During the course of this grant, 11 students have been involved either part-time or full-time with the research efforts. These students have given numerous presentations associated with this work.

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Aerothermo Structural Analysis of Low Cost Composite Nozzle/Inlet Components

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Date of Original Award: 1997

INTRODUCTION

This research is a cooperative effort among the Turbomachinery and Propulsion divisions of NASA Glenn Research Center (GRC), the Center of Composite Materials Research (CCMR) of [LG1]North Carolina A&T State University, and Tuskegee University. North Carolina A&T is the lead center and Tuskegee University is the participating institution. The objectives of the research are to develop an integrated aerodynamic, thermal, and structural analysis code for the design of aircraft engine components, such as nozzles and inlets, made of textile composites; to conduct design studies on typical inlets for hypersonic transportation vehicles and set up standard test examples; and to manufacture a scaled-down composite inlet.

RESEARCH ACCOMPLISHMENTS

These objectives are being accomplished through the following seven tasks: 1) identify the relevant public domain code for all three types of analyses; 2) evaluate the code for the accuracy of results and computational efficiency; 3) develop aero-thermal and thermal-structural mapping algorithms; 4) integrate all of the codes into one single code; 5) write a graphical user interface (GUI) to improve the user-friendliness of the code; 6) conduct test studies for a rocket-based combined-cycle engine inlet; and 7) fabricate a demonstration inlet model using textile preform composites.

During the current year, task numbers one, two, and six were initiated and are being continued. We selected and evaluated NPARC for flow field analysis, CSTEM for in-depth thermal analysis of inlets and nozzles, and FRAC3D for stress analysis. These codes have been independently verified for accuracy and performance. A rocket-based combined-cycle engine was selected for test studies. Flow field analyses of various inlet geometries are being studied. The other tasks will be initiated during the remaining part of this year and continued in the next year. The

code developed is being applied to a candidate example of a trailblazer engine proposed for space transportation.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The successful development of the code will provide a simpler, faster, and more user-friendly tool for conducting design studies of aircraft and spacecraft engines, which will be applicable to the high-speed civil transport and space missions.

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Radiation Effects on DC-DC Converters

Principal Investigator: Dr. John O. Attia
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Date of Original Award: 1997

INTRODUCTION

DC-DC converters are circuits that can be used to convert a DC voltage from one value to another. The market for DC-DC converters is growing because of increasing application of the converter in the areas of telecommunication, instrumentation, automation, and control systems. DC-DC converters are found in the Space Shuttle, the Space Station, and communication satellites. DC-DC converters that use power MOSFET's can experience single event burnout (SEB), single event gate rupture (SEGR) and single event latchup (SEL). This work investigates the effects of high-energy particles on DC-DC converters found in spacecraft and communication satellites. The objective of this work is to design a radiation-hardened DC-DC converter.

RESEARCH ACCOMPLISHMENTS

Of all the converters that were simulated with regard to total dose radiation, the performance of the Buck-Boost converter significantly degraded under a radiation-intensive environment. Although, there were some effects of total ionizing dose radiation on Buck, Boost, Cuk, and Flyback converters, the effects were insignificant. The full bridge-zero voltage switching (FB-ZVS) DC-DC converter was simulated. It was found that the output voltage of the converter increases with phase shift and pulse period. The FB-ZVS converter was also simulated under the worst case Single Event Burnout (SEB), Single Event Gate Rupture (SEGR), and Single Event Latchup (SEL) conditions. It was found that as a number of power MOSFET's become short-circuited, the output voltage of the converter decreases. In the special case where two power MOSFET's in either the "upside" or "downside" of the FB-ZVS converter become short-circuited, the output voltage of the converter is zero. This situation makes the converter inoperable.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This work is developing space models for power MOSFET DC-DC converters. The circuit innovation techniques that are being explored to make radiation-hardened DC-DC converters will be especially useful to NASA. The characteristics of power MOSFET DC-DC converters under high-energy radiation environments will be invaluable to NASA in qualifying small feature-sized commercial-off-the shelf DC-DC converters for future NASA missions. The result of this work will be useful to the Aero-Space Technology and Human Exploration and Development of Space NASA Strategic Enterprises.

BENEFITS TO SOCIETY

The operational characteristics of power MOSFET DC-DC converters under high-energy radiation environments will be valuable in the reliable design of communication satellites and the high-speed civilian transport.

STUDENT ACHIEVEMENTS

We are developing the human and technical potential of students. The students are working in the forefront of research in DC-DC converters and MOSFET device modeling. The students are also gaining experience in circuit simulation and radiation testing.

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Experimental Evaluation of Motor Drive Technologies for Future Aerospace Applications

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Report not submitted.

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Goddard Space Flight Center

Novel Methods of Fabrication and Evaluation of Room Temperature X-ray and Gamma Ray CdZnTe Detectors

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Date of Original Award: 1997

INTRODUCTION

CdZnTe (Cadmium/Zinc/Tellurium) crystals are the basis for novel radiation detectors that combine high efficiency with room temperature operation, making CdZnTe an excellent technology for imaging and spectroscopy from 10-200 keV. The surface preparation during the detector fabrication plays a vital role in determining the contact characteristics and the surface leakage current, determining the ultimate performance of a $Cd_{1-x}Zn_xTe$ detector. The objectives of the project are to establish the effects of the surface preparation steps prior to contacting (polishing, chemical etching), the choice of the metal, and the contact deposition technique and to reduce surface defects by surface oxidation.

RESEARCH ACCOMPLISHMENTS

We have discovered that one of the reasons for the high electronic noise of detectors is the presence of chemical residues (telurium rich layers) that can be oxidized using atomic oxygen and therefore transformed into an insulator that will actually protect the device. We have developed a photoconductivity mapping technique that will be useful to study the effect of surface oxidation on the electronic properties of the radiation detector. The best procedures were used to fabricate detectors exhibiting a significantly lower surface leakage current and improved energy resolution. Future implementation of these procedures will lead to improved sensitivity detectors.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Our project is in line with the NASA Space Science Enterprise, in support of the Low Energy Gamma-Ray Astronomy Program, which aims at a better understanding of the Universe. CdZnTe detectors are specifically suitable for the ~5-600 keV energy range, providing the high sensitivity needed to study a critically important region of the astrophysical spectrum where an unusually rich range of astrophysical processes occur, including gamma-ray bursts, emissions from black holes, neutron stars, active galactic nuclei, and supernovae.

BENEFITS TO SOCIETY

The CdZnTe technology has multiple applications. The CdZnTe device can be used to detect and identify x- and gamma-rays emitted by radioactive materials in order to characterize, monitor, and safeguard them. In addition to its benefits in the realm of national security and space applications, the technology will improve health care by providing better medical diagnosis of cancerous tumors, heart disease, and osteoporosis. Because it does so with lower radiation levels, it is safer for patients.

STUDENT ACHIEVEMENTS

One of the graduate students working in the project, Mr. Miguel Hayes, has studied the oxidation process using hydrogen peroxide solutions. Mr. Hayes went further and discovered that using an aqueous solution of potassium hydroxide to treat the surface prior to the deposition of the electrical contacts has the effect of increasing the lifetime of carriers in the subsurface region. This procedure may be effective in restoring the stoichiometry of the surface and therefore may act as an alternative to

the oxidation process. Mr. Hayes presented his findings at the NASA University Research Centers Conference in Alabama, February 1998.

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Laboratory Study of the Behavior of Saturated Sedimentary Material

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Date of Original Award: 1997

Report not submitted.

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The Magnetic Transport and Structural Properties of Pulsed Laser Deposited Magnetic Oxide Films

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Date of Original Award: 1997

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Jet Propulsion Laboratory

Real-Time Prototyping Project

Principal Investigator: Dr. John S. Hurley
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Date of Original Award: 1997

INTRODUCTION

The Real-Time Prototyping Project aims to integrate state-of-the-art multi-computer technology with real-time microkernel support to directly address the needs of embedded applications. This integration will be achieved through basic research in multi-computer systems and real-time concurrent programming. The project will provide an applications testbed for exploring the emerging Message Passing Interface/Real-Time (MPI/RT) standard on NASA applications. Proposed network configurations are shown in Figures 1-3.

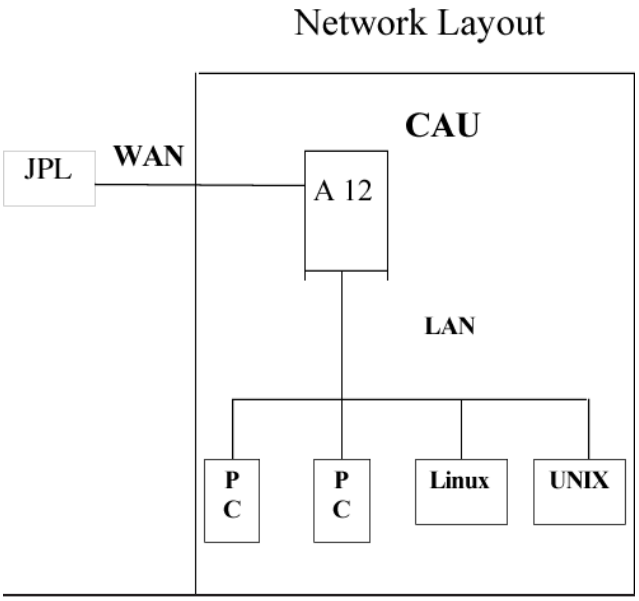

Figure 1. Overall Network (LAN + WAN) Configuration

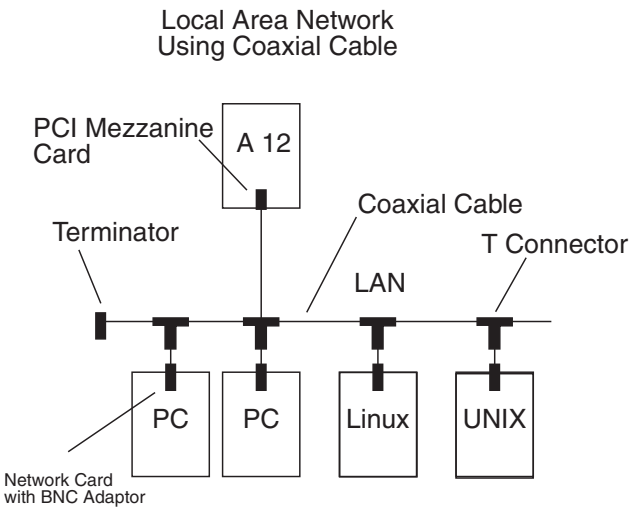

Figure 2. LAN Using Coaxial Cable

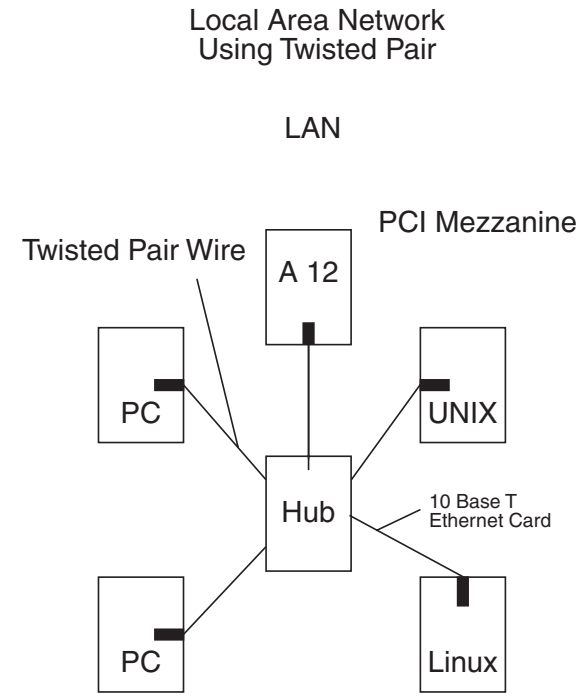

Figure 3. LAN Using Twisted Pair

The specific research objectives are to develop real-time microkernel technology to support the emerging MPI/RT standard, construct prototype real-time software systems, actively explore real-time applications and the utility of these new technologies,' and construct a testbed system for industrial partners and applications experiments.

RESEARCH ACCOMPLISHMENTS

This year, the program was nominated for listing in the International Who's Who in Information Technology. An abstract was accepted at the Institute of Electrical and Electronics Engineers (IEEE) Applied Superconductivity Conference in September 1998. A paper entitled "Large Scale Numerical Simulations of Flux-Line Lattice Using Parallel Computing Techniques," by J. S Hurley of Clark Atlanta University and Zhi-Xiong Cai of the Brookhaven National Laboratory was submitted in October 1998 to *IEEE Transactions on Applied Superconductivity*. A paper entitled "Large Scale Numerical Simulations of Flux-Line Lattice Using Parallel Computing Techniques-Flux Pinning" by J.S Hurley of Clark Atlanta University and Zhi-Xiong Cai of the Brookhaven National Laboratory was submitted to *IEEE Transaction on Magnetics* in October 1998, and was presented at the Materials Research Society (MRS) Fall 1998 meeting in November 1998.

RELEVANCE TO NASA STRATEGIC ENTERPRISES AND BENEFITS TO SOCIETY

By actively exploring real-time NASA applications and the utility of these new technologies, we can determine the relevance of existing MPI/RT libraries and protocols in applications for NASA and its industrial partners and the need to modify software and hardware. These efforts can enhance the real-time communications and sensing capabilities of NASA, Defense agencies, and industrial partners to better serve society.

STUDENT ACHIEVEMENTS

Lanier Watkins, a second-year graduate student in Computer Science, submitted a paper entitled "Simulation Design of a Wavelet Transform Image Compression Prototype" to *IEEE Electronic Devices* in January 1999, and is completing the layout design of the Image Compression prototype.

Real-Time Prototyping Project.

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Johnson Space Center

Caffeine Metabolism: The Pharmacokinetics of Space Flight

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Kennedy Space Center

Sweet Potato Stem Cuttings Database in Preparation for Flight

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Langley Research Center

Mixing, Noise, and Thrust Benefits Using Corrugated Designs

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Date of Original Award: 1997

INTRODUCTION

The purpose of this project is to support research, training, and teaching of Hampton University students in fluid mechanics and acoustics. The work is organized and implemented by the new Fluid Mechanics and Acoustics Laboratory (FM&AL), which was established at Hampton University in the School of Engineering and Technology in 1996 under another NASA grant. In addition, FM&AL, in cooperation with NASA Langley Research Center (LaRC), jointly conducts research with the Central AeroHydrodynamics Institute (TsAGI) in Moscow under a 2-year Civilian Research and Development Foundation (CRDF) grant.

It is well known that reducing aircraft engine noise and improving aeroperformance are significant drivers in the success of the NASA Advaned Subsonic Technology (AST) and High Speed Research (HSR) programs in their attempt to meet new stringent international environmental regulations on noise, as well as to increase flight speed and endurance for commercial aircraft. The research at the FM&AL supports reduction schemes associated with the emission of engine pollutants for commercial aircraft and concepts for reduction of observable pollutants for military aircraft.

RESEARCH ACCOMPLISHMENTS

The main achievements for this reporting period are as follows.

- Predictive theoretical models and numerical simulations were created for several complicated 2D and 3D nozzle designs using NASA codes based on full Euler and Navier-Stokes solvers, including CFL3D, CRAFT, GODUNOV, and others. Theoretical expectations were compared with experimental results, and theoretical approaches, models, grids, etc. were modified based on the results.
- Experimental acoustic tests at the NASA LaRC Jet

Noise Laboratory with both small and large scale Bluebell nozzles were conducted with promising results for subsonic and supersonic regimes.
- Meetings and joint experimental tests were conducted with Russian scientists at the TsAGI. Joint reports were prepared.
- Dr. John M. Seiner, the permanent NASA LaRC monitor and an active participant in all FM&AL projects, received the American Institute of Aeronautics and Astronautics (AIAA) Aeroacoustics Award for 1998. He and the Co-PI of this project, Dr. Mikhail Gilinsky, were awarded eight Certifications of Recognition for their joint patent applications to NASA.
- Six undergraduate and two graduate students have been brought on as assistants in current research projects.
- Four papers were presented at AIAA Conferences and Congresses and two were published in the AIAA Journal.

RELEVANCE TO NASA STRATEGIG ENTERPRISES

This research attempts to satisfy the goals of the NASA Aero-Space Technology Enterprise concerning the development of environmentally acceptable aircraft. The corrugated nozzle concept including several innovative designs is an important item in the HSCT and AST programs, which the NASA LaRC Jet Noise Laboratory implements jointly with well-known aviation companies.

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Marshall Space Flight Center

An Unconventional Three-Dimensional Computation of Transition Aerodynamics for RLV

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INTRODUCTION

For a Single Stage to Orbit (SSTO) Reusable Launch Vehicle (RLV) maneuvering at altitudes above 75 km, the flow field around the RLV is in the transitional to rarefied regimes, where the flow is characterized by a low Reynolds number and a high Mach number. Because of the extreme difficulties in obtaining flight-testing and ground testing data, the RLV transitional aerodynamics above 75 km is still poorly understood. Therefore, it is imperative to obtain aerodynamic data through numerical simulation. For this reason, flight tests of the current X-33 advanced demonstrator would only involve speeds of up to Mach 15 and altitudes of up to approximately 75 km.

The objectives of this research are to develop an analytical tool to investigate the nose-to-tail hypersonic flow characteristics around the RLV at altitudes above 75 km, to foster research and development activities which contribute substantially to NASA's mission at Alabama A&M University (AAMU), and to prepare faculty and students at AAMU to successfully participate in competitive research.

RESEARCH ACCOMPLISHMENTS

Four tasks were completed in the past year:

- A grid system was generated using 3DGRAPE to simulate flow around a hypersonic flight vehicle. Figure 1 shows the volume grids generated by 3DGRAPE for flow over a cone-cylinder body geometry.

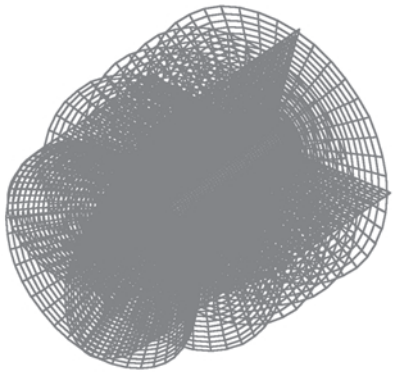

Figure 1. Volume grid around cone-cylinder body, generated by 3DGRAPE.

- The Beam-Warming implicit algorithm was implemented to solve the three-dimensional Burnett equations.
- A modified Direct Simulation Monte Carlo (DSMC) code was developed to simulate flow past a two-dimensional vertical plate and a sphere. Results of the flow over a sphere, with the Mach number 6 and the Knudsen number 0.01, are plotted in Figure 2. An AIAA paper, entitled "The Prediction of the Blunt Body Near-Wake Flows by a Modified Direct Simulation Monte Carlo Method," was presented and published at the 7th AIAA/ASME Thermophysics and Heat Transfer Conference in Albuquerque in June 1998.

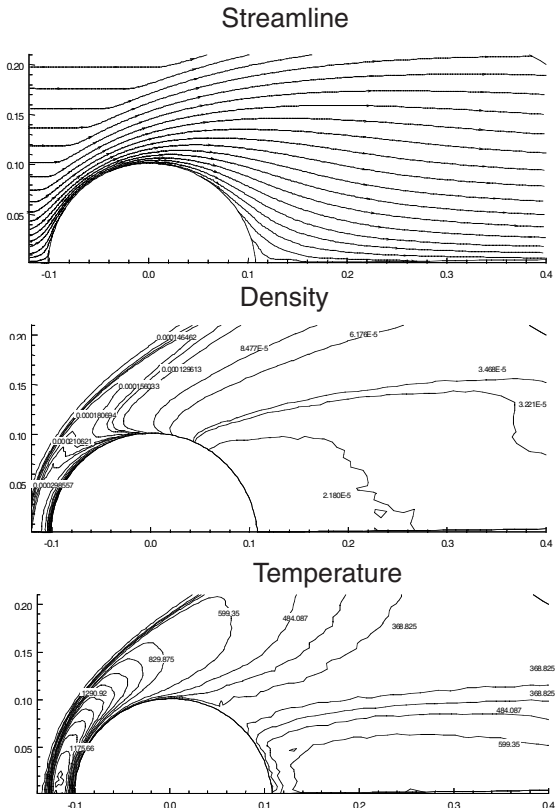

Figure 2. Streamlines, density, and temperature contours of flow past a sphere at M=6, Kn=0.01.

- A small-scale experimental high performance parallel-computing network was established. Three Pentium II PCs were purchased. Each PC has a 300 MHz Pentium II CPU with MMX technology, 128 MB SDRAM memory, a 7 GB hard disk, and a 10/100 Base-T Ethernet card installed. In addition, an eight-port 100 Base-TX Fast Ethernet hub and a switch were purchased to connect all three PCs together as a local area network (LAN). This LAN was established and is now functioning normally.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The successful completion of this project will enable the generation of accurate predictions of aerodynamic and thermal loads on RLVs, which will not only benefit NASA's RLV technology program, but will also provide an analytical tool to the aerospace community for space vehicle design.

STUDENT ACHIEVEMENTS

Alabama A&M University is a land grant historically black university. The proposed research will strengthen the computational fluid dynamics (CFD) [LG5]and propulsion research capability at AAMU. Students will benefit from this cutting-edge research project. In this period, two graduate students and one undergraduate student were involved in this project. Specifically, they help the senior investigators to visualize scientific data from our CFD simulation.

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Novel Method for Evaluation of Uniformity and Structural Homogeneity of Ternary Wide Gap Semiconductors

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Telemedicine and Rapid Identification of Microorganisms by Fourier Transform Infrared Spectroscopy

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Composite Truss Design Optimization

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Date of Original Award: 1997

INTRODUCTION

This project focuses on the minimum weight design for the truss structure used in space launch vehicles. Minimizing the weight of a space truss structure or a payload support structure is very important for a space launch vehicle because it can save the total launching weight and increase the payload capacity. Traditionally, high-strength alloy materials, such as aluminum and Inconel, are employed in such structures. However, composite materials are attracting aerospace engineers' attention and efforts, despite the high cost compared with alloy materials, because of their low density and high strength. Moreover, a composite member can be designed to sustain some specific loading conditions while isotropic materials can not. The objective and final goal of this investigation is to develop a computer code, using the Gradient method, to optimize the truss design in weight and cost for composite tube members.

RESEARCH ACCOMPLISHMENTS

The current research is divided into two levels: the truss level and the member level. First, for a given structural design, the initial values of design parameters such as tube wall thickness, ply orientation, and tube diameter are input along with loading conditions. Then a linear static analysis is conducted on the global truss level using the stiffness method. At this stage, an approximation for the weight function is formed. At the same time, in the member level, a detailed analysis of each truss member is performed to find stress and strain, a failure analysis is performed to evaluate the strength, and a buckling analysis (due to axial compression and/or torsion) is performed to determine the critical load. The strength and buckling load serve as the behavior constraints in the optimization process. As a result of this analysis, a new set of design variables is generated. Using these as input and conducting a new round of analysis, the gradient of the objective function, as well as behavioral constraints, can be found. The convergence is checked based on the user-defined criteria. The iteration is repeated until convergence is achieved.

A program used to optimize a composite tube in 3D space with fixed ends in the member level by the conventional optimization method, the method of feasible directions (MFD), is ready to incorporate with the results of truss structural analysis. The tube weight is chosen as the objective function in this level. The constraints are geometrical condition, material strength, adhesive strength of end joints, column buckling failure, and torsion-related buckling. The loads include end forces, end moments, and distributed loads, as well as the specific displacements. Given inputs such as composite material properties, initial tube dimension, and joint end condition, the calculation determines the optimum tube dimension and the minimum weight. Additionally, for the purpose of comparison, this program can also be applied to optimize a tube made of isotropic materials with fixed-fixed ends.

Investigations have shown that composite materials are much better than alloy aluminum in almost all cases. For example, in the single loading cases such as torsion, bending, compression, and tension, T300/4211 [$V_f = (60 \pm 3)\%$] performs 5 to 10 times better than the aluminum alloy 17ST. The influence of the fiber angle is a very important factor; the

optimum fiber angle varies case by case. The smaller the fiber angle, the larger the strength in the axial direction, which is favorable to the optimum design in most loading cases. Under a given compression load, the tube length determines whether Euler buckling happens during the optimization. The strength constraint is most active with respect to relatively short tubes, while the Euler buckling constraint is most active with respect to the longer ones. The torsional buckling load is related to the tube length, tube diameter, tube thickness, ply number, and ply orientation. The longer the tube length, and the thinner the tube wall, the lower the critical load is. Under a given load condition, the ratio of the tube length to the tube diameter is determined by the Euler buckling constraint. The tube wall thickness and tube diameter are optimized under these conditions. Generally, the torsional buckling load is 2 to 3 times higher than the applied torsion load. Therefore, torsional buckling seldom happens.

These results show that the composite material has a potential advantage in composite truss design because of its high strength and low density. It is especially advantageous because the ply orientation can be changed to satisfy a loading condition. Moreover, different ply combinations can be redesigned for combined loading cases. In the truss level design, these kinds of combinations will become a very important factor in reducing the total truss weight.

The method of feasible directions (MFD) is successful at exploitation because it focuses on the intermediate area around the current design point, using the local gradient calculations to move to a better design. Since no attempt is made to explore all regions of the parameter space, one more different initial point is recommended in order to insure that the design is the global optimum.

STUDENT ACHIEVEMENTS

Six minority undergraduate students and one graduate student are currently involved in this project. Each student has been assigned different tasks based on his or her major subject. Through the project, each student gains both research experience and financial support. Two senior mechanical engineering students have been motivated to go to graduate school in aerospace engineering after their graduation.

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Integrated Approach to the Prediction of Hyperpolarizabilities of Organic Crystals

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INTRODUCTION

The goal of this research is to understand, and thus to be able to predict, the nonlinear optical (NLO) properties of organic molecules in the crystal state. A good organic crystal may be used as a device in photonics. In the present project, important progress on the development of an integrated approach utilizing x-ray crystallographic data and computational methods has been achieved.

RESEARCH ACCOMPLISHMENTS

The designed procedure was applied to a series of monosubstituted derivatives of dicyanovinylbenzene. These compounds were selected because of previous experience by the investigators with ortho methoxydicyanovinylbenzene (DIVA), and because this series constituted a good model to provide information regarding the relationship between substituent positions and the formation of centrosymmetric or acentric crystals. The theoretical work was complemented with an experimental investigation, which was funded through other sources. As a result, and based on powder and solution measurements, two new compounds were found to be NLO-active in the crystal state.

STUDENT ACHIEVEMENTS

Seven students from Spelman College and New Mexico Highlands University have been partially supported by this grant. Work has been performed in three different areas. An investigation has been conducted on monosubstituted derivatives of dicyanovinylbenzene; the derivation of force field and potential energy parameters for molecular mechanics has been calculated on borane and carborane; and several studies have been carried out on biomolecules. The project investigators and

one graduate student performed the first and second investigations; five undergraduate students under the direction of one of the project investigators performed the third set of studies.

The outcomes of the work are two almost-completed manuscripts to be submitted to the *Journal of Physical Chemistry* and the *Journal of Molecular Structure*, and three student publications in the Proceedings of the 12th National Conference of Undergraduate Research in Salisbury, Maryland, in April 1998. In addition, the undergraduate students gave five poster presentations during the February 1998 NASA URC Conference in Huntsville, Alabama, and three oral presentations at the 12th National Conference of Undergraduate Research.

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Analysis of Friction Stir Welding

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INTRODUCTION

The goal of this project is to measure the temperature and stress field of Friction Stir Welds (FSWs). This is a new technique for welding that has already proved capable of welding alloys that in the past were thought to be impossible to join. Welds between different grades of, for example, aluminum can be performed readily with relatively inexpensive equipment and minimal operator training. Briefly, a cylindrical pin or nib is inserted along the mating surfaces of plates to be welded. The nib rotates and is advanced along the seam. As material ahead of the nib heats, it is forced around the nib and closes up the seam behind it.

RESEARCH ACCOMPLISHMENTS

We have published several papers including information about the temperature fields and the very interesting and complex microstructures obtained during FSW. Our most interesting findings have been that the temperature does not vary greatly through the thickness of our 0.25 inch-thick samples and within the shoulder region of the pin, there is also minimal temperature variation. The temperature never exceeds 0.8 times the melting point for aluminum. It appears that the shoulder rather than the nib itself contributes most of the heating which is necessary for the fine-grained dynamically recrystallized weld zone to form.

Perhaps the most interesting findings have been from welds between copper and aluminum or different grades of aluminum. Very striking vortices of metal were observed even though the metal never melted. The scale of the vortices seems to decrease at higher nib rotational speeds.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

It is hoped that NASA can use FSW to weld its new super lightweight aluminum-Li external tanks. The first such tank was launched early last summer, and it is believed that FSW can replace the fusion welding that was used on the tank. There will be considerable cost savings if FSW can be used reliably. FSW is, of course, a new technique and must be used carefully, but this work will help to build the necessary understanding of the technique before it is used in space.

BENEFITS TO SOCIETY

If FSW can become a standard welding technique (like, for example, gas or arc welding), industry will benefit considerably by using a safe, inexpensive, and easy-to-learn welding technique. At the same time, Friction Stir Welds are typically stronger than fusion welds, so product reliability can be improved.

STUDENT ACHIEVEMENTS

The following minority or female students are working on the project: Lola Norton (Hispanic descent), Ric Flores, Manny Cabral, Brooke Nowak, and Roscio Avalos. Each student is responsible for a phase of the overall project and they are learning not only technical skills, but must report on their work at bi-weekly research meetings.

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Research and Education Partnerships

Ames Research Center

Motion Planning in a Society of Intelligent Mobile Agents

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Training Under-Represented Students in Biological Research at Fisk University

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Air Traffic Control Using Neural Networks: A Proposal for Research and Educational Enhancement

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Dryden Flight Research Center

Artificial Potential Field-Based Motion Planning/Navigation in Two and Three Dimensional Dynamic Environments

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Report not submitted.

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Glenn Research Center

Consortium for Advancing Renewable Energy Technology

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Date of Original Award: 1997

INTRODUCTION

The Consortium for Advancing Renewable Energy (CARET) is a consortium of four universities and NASA Glenn Research Center working together to

promote science education and research to minority students using the theme of renewable energy. The consortium membership includes Kent State University and NASA Glenn Research Center, as well as the Historically Black Colleges and Universities (HBCUs) Fisk, Wilberforce, and Central State. The various stages of this pipeline provide participating students with a variety of experiences, each with a different emphasis. Some emphasize building enthusiasm for the classroom study of science and technology while others emphasize the nature of research in these disciplines. Still others focus on relating a practical application to science and technology. Of great importance to the success of the program are the interfaces between the various stages. Successfully managing these transitions is a requirement for producing trained scientists, engineers, and technologists.

An important feature of this consortium is its structure, in which a coordinator is solely dedicated to promoting and facilitating interactions among the members of the consortium. This has resulted in the maintenance of an active interaction among the consortium members, and has enabled us to guide students through the pipeline, causing Wilberforce and Central State students to share a class, having a Central State student attend a summer program at Fisk, and having both Wilberforce and Central State students participate in a Kent State summer internship. A Wilberforce graduate is attending graduate school in the School of Technology at Kent State University. This student received encouragement from many consortium participants, not just from those at Wilberforce and Kent State. This interaction has also resulted in a very real and beneficial research collaboration, where one group can focus on materials preparation, another on materials characterization and laser ablation, and a third on radiation effects on these materials.

RESEARCH AND EDUCATIONAL ACCOMPLISHMENTS

An ultra-high vacuum chamber was designed and constructed for fabricating nanocrystals that have potential for being developed into space solar energy cells with high collection efficiencies. A conceptual design was developed of such a solar energy cell based on the idea of a device constructed from an assembly of size-graded quantum dots. The collection efficiency of this type of solar energy cell was estimated to be ~80 percent when operating in a space environment.

The ultra-high vacuum chamber was first evaluated by ablating gold onto three substrates: Silicone (Si), Silicone dioxide (SiO_2) and Muscovite mica. (Mica is a generic term applied to a group of complex aluminosilicate minerals having a sheet or plate like structure with different composition and physical properties.) Unique doughnut-shaped particles were observed on the Si substrate (see image), but pancake-shaped particles were observed on SiO_2 and Muscovite mica. Strategies were developed for fabricating gold nanowires by fixing the substrate to a target angle at near grazing incidence. These nanowires can be used as contact elements in miniaturized electronic devices.

Neutron and electron irradiation of gold nanocrystals embedded in single crystal MgO (Magnesium oxide) matrices were studied as means to modify the optical response of composite materials that have potential for ultra-fast all-optical switches.

Thin films of the photovoltaic material $CuInS_2$ (Copper Indium Disulfide) were characterized by electrical and optical measurements. These studies demonstrated that the majority carriers are holes and the band gap is 1.35 eV. A manuscript entitled "A Comprehensive Characterization of Copper Indium Disulfide Thin Films" has been written based on these investigations and will be submitted to the *Journal of Applied Physics*.

In addition, the following was accomplished this year:

- Don Henderson presented an invited talk entitled "Silicon Quantum Dots Embedded in Fused Silica" at the Fall Materials Research Society meeting in Symposium JJ: Materials in Space-Science, Technology and Exploration in Boston, Massachusetts, November 30-December 4, 1998.

- Elena Bryant, a new graduate student, has joined the Chemical Physics Laboratory and will do her thesis work on interfacial effects between metal nanocrystals and dielectric media.

- A new course called "Applied Renewable Energy Technology" was offered to four Wilberforce and four Central State students, in which the students learned about renewable energy by participating in the design and installation of two renewable energy systems.

- Central State collaborated with Wilberforce to present the "1998 Renewable Energy Summer Enrichment Program" to 25 secondary school students. Twenty-three of these students were

minorities and 10 were females.

- A small lab at Wilberforce was renovated into the NASA Renewable Energy Center. This is a renewable energy-powered facility utilized as a tutoring and student study area.

- The installation of two of the demonstration projects that are a part of the CARET project is nearly complete.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This project supports NASA's Space Science Enterprise by carrying out fundamental research on photovoltaic materials, whose understanding can lead to the development of space solar cells with superior performance over those currently available.

BENEFITS TO SOCIETY

CARET benefits society in two ways. First, by advancing scientific understanding of areas with potential technological applications, it is contributing to the technological advances that help make ours an advanced society. Second, by promoting science and technology education, it is both enhancing technical literacy and helping to ensure a racially diverse supply of scientists and technologists.

STUDENT ACHIEVEMENTS

Dennis Denmark, a first year graduate student at Fisk in 1997-98, gave an oral presentation entitled "Indium Phosphide Nanocrystals Formed by Sequential Ion Implantation into Fused Silica" at the 45th annual American Vacuum Society meeting in the Nanoscale Patterning and Modification Session in Baltimore, Maryland, November 2-6, 1998.

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Research and Education in Probabilistic Structural Analysis and Reliability

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Date of Original Award: 1997

INTRODUCTION

The goal of this project is to advance innovative research and education objectives in theoretical and computational probabilistic structural analysis, reliability, and life prediction for improved reliability and safety of structural components of aerospace and aircraft propulsion systems. The project includes primarily research but also educational objectives and accomplishments as listed below.

RESEARCH ACCOMPLISHMENTS

Probabilistic structural analysis, reliability, and life prediction methods are supported or facilitated by NESSUS (Numerical Evaluation of Stochastic Structures Under Stress), a stochastic finite element program developed by NASA Glenn Research Center (LeRC) with the Southwest Research Institute (SwRI). A review and evaluation of probabilistic methods, including time-variant probabilistic analysis models, was undertaken; a review of the probabilistic capabilities of NESSUS was carried out; and a review and evaluation of probabilistic material models to extend NESSUS through interfaces or built-in models was conducted. Furthermore, the NESSUS code was enhanced by the implementation of a probabilistic material strength degradation model in the form of a multi-factor equation. Finally, the resulting enhanced NESSUS code was exercised to verify correct results.

EDUCATIONAL ACCOMPLISHMENTS

The introduction of undergraduate students to deterministic analysis methods utilizing the finite element method was achieved through a UTSA summer course, *Introduction to the Theory of Finite Elements*. The creation of a NESSUS Student User's Manual was initiated.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Probabilistic structural analysis and reliability methods support the specific needs within the Aero-Space Technology Enterprise by contributing to the development of a next-generation design tool that promises to improve the safety and reliability of both civil aviation and reusable space launch vehicles. For example, the enhanced NESSUS code is now able to assist in the design of the reusable Space Shuttle Main Engine (SSME) through reliability calculations of turboprop blades. Thus, it is now possible to consider future engine designs based upon target reliabilities through a practical next-generation design tool.

BENEFITS TO SOCIETY

New probabilistic approaches to engineering analysis and design utilizing modern computational methods are critical to society in reshaping engineering failure theories from traditional factor-of-safety approaches (little understood by the public) to a target reliability approach (a concept far more easily understood by the public). NESSUS is a groundbreaking finite element tool that makes a significant contribution in this area. It allows the probability of failure and/or reliability to be quantitatively evaluated and judgments by non-engineers, non-scientists, and society at large to be made reflecting the degree of risk they are willing to tolerate in complex engineered systems.

STUDENT ACHIEVEMENTS

One undergraduate student, Mr. Cody Godines, has made significant progress towards obtaining his bachelor's degree in mechanical engineering. Through this project, he has become interested in going to graduate school and plans to enroll in UTSA's graduate program for the Spring 1999 semester. Mr. Godines has also been made aware of an opportunity to attend a NASA LeRC-sponsored HBCUs/HSIs (Historically Black Colleges and Universities/Hispanic-Serving Institutions) Research Conference in April 1999, and plans to present a project that he completed during the UTSA summer course. A graduate student, Mr. Mark Jurena, has also been recruited to complete a master's degree in Mechanical Engineering. His thesis topic will directly relate to research objectives outlined for the proposed second-year continuation of this Partnership Award.

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Goddard Space Flight Center

Partnership for Space Telecommunications Education

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Date of Original Award: 1997

INTRODUCTION

The principal partners in the Partnership for Space Telecommunications Education are Goddard Space Flight Center (GSFC) and the Electrical and Computer Engineering (ECE) Department at the University of Puerto Rico at Mayagüez (UPRM). GSFC and UPRM will collaborate on a program for the mentoring of students in radio frequency (RF), microwaves, and space telecommunications design through the master's level. UPRM will install a ground station for synthetic aperture radar satellites and for such high-data rate platforms as LANDSAT 7, utilizing NASA funds from the NASA University Research Center (URC) Tropical Center for Earth and Space Studies grant and additional moneys from the University of Puerto Rico. The ECE Department and the Far Ultraviolet Spectroscopic Explorer (FUSE) at The Johns Hopkins University will also partner in the installation and operation of a Ground Station for FUSE at a site within UPRM, and will also promote educational and research opportunities.

STUDENT ACHIEVEMENTS

For two summers, beginning master's-level students from the ECE Department at UPRM have been collaborating with GSFC personnel in the development of future Tracking and Data Relay Satellite System (TDRSS) communications systems. During the summer of 1998, Javier Díaz-Serrano worked on a TDRSS and Shuttle PN Code Generator, while Eliud Bonilla-Gonzalez designed a Channel Combiner for the International Space Station S-Band Single Access Port. Both Javier and Eliud received mentoring from David Israel. Nelson Rodriguez-Rosario worked on an S-Band Array Antenna 3-Bit Phase Shifter, and Kelvin Cabrera Cuevas developed an S-Band Phased Array Wilkinson Power Divider. Both students were mentored by Ken Hersey. Eladio Rodriguez-Rivera worked on the implementation of the Cordic Algorithm on Field-Programmable Gate Arrays supervised by Richard Katz, and David Pérez simulated a Squaring Loop using MATLAB (an integrated technical computing environment that combines numeric computation, advanced graphics and visualization, and a high-level programming language).

STUDENT OUTCOMES

All of the students who have joined the Partnership for Space Telecommunications Education are pursuing graduate degrees at present. A total of 10

master's degrees are expected to be awarded due to this NASA Partnership. The mentoring organizations at GSFC have praised the student work and have expressed their wish that actions be taken to further the collaboration between GSFC and UPRM.

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Medgar Evers College Ocean and Environmental Science Research Program

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INTRODUCTION

This project is a partnership between the Department of Physical Sciences and Computer Science (PS&CS) at Medgar Evers College (MEC) and the NASA Goddard Institute for Space Studies (GISS). A campus research center based primarily on ocean/atmospheric and environmental science has been created at MEC so that underrepresented undergraduate students, graduate students, college faculty, high school students and teachers can be involved in the NASA Earth Science Program. Research teams are based on the GISS Institute on Climate and Planets (ICP) model. The goals are to have a pipeline of research activities from high school through graduate school; to integrate research and research-related activities into the fabric of the undergraduate programs; and to increase the number of underrepresented students in the science, mathematics, engineering, and technology (SMET) pipeline who wish to enter teaching or continue on to graduate school or to take positions in research institutions or industry.

RESEARCH PROGRAMS AND ACCOMPLISHMENTS

"Ocean General Circulation Model (OGCM) Studies of Turbulent Mixing Mechanisms and the Significance of Ocean Turbulence on Global Climate" is being conducted by Dr. Wilson Obi. RAM in the SUN Ultra Workstation has been expanded to 256K, a size deemed sufficient for ocean modeling. A 4.2 GB internal hard disk and a 9 GB external hard disk have been added. Compilers and utilities are being installed and tested.

"Studies On Ambient Particles in The Brooklyn Environment: The Focus of Environmental Measurements and Instrumentation" is being conducted by Dr. Wilbert Hope. Students collected more than fifteen indoor and ambient samples of particulate matter from Brooklyn neighborhoods and analyzed them for lead, cadmium, copper, and water-soluble ions. Micro-analytical techniques for the determination of volatile and semi-volatile organic compounds were also investigated.

Systems and methods developed for sampling and analysis of ambient and indoor air are being incorporated into the laboratory sections of the Environmental Measurements and Instrumentation course. A multi-filter rotating shadow band radiometer obtained for MEC was installed on the roof of GISS. Data from this instrument was matched with data from the existing sun photometer at GISS in order to standardize and synchronize operating parameters. The NASA/GISS scientists are Dr. V. Canuto, Dr. B. Carlson, Dr. B. Cairns, and Dr. A. Howard. The high school faculty are Ms. K. Vick of Middle College High School, Ms. C. Johnson and Ms. S. Thomas of Far Rockaway High School, and Mr. K. Brathwaite of Manhattan Transition High School.

The collaboration of MEC faculty with faculty from other colleges has led to the partial support of other research projects. "Towards a Better Understanding of Remotely-Sensed Light Winds: Verifying Results of Satellite Data" is being conducted by Dr. W. Sylvester and Dr. S. Austin of City College NY. "Magnetic Resonance Studies of Materials for Advanced Batteries and Fuel Cells" is being conducted by Dr. S. Greenbaum of Hunter College and Prof. S. Bajue and Dr. J. Flowers of MEC. "Photometry of Variable and Binary Stars" is being conducted by Prof. I. Robbins of College of Staten Island, Dr. C. Damas of Long Island University, and Dr. L. Johnson of MEC. "Developing an Information Infrastructure and Advanced Computing Research Laboratory" is being conducted by Mr. D. Davis of IBM Global Services and Prof. W. Harris of MEC.

The closing ceremony of the Summer program was held on July 30; all participants gave poster presentations. Eight students gave poster presentations at national or CUNY-wide conferences.

ENROLLMENT DATA

During the academic year, 12 undergraduates and 4 high school students were actively engaged in research. The Summer research program had 14 undergraduate students, 14 high school students, and 3 junior high school students. Five graduate students (3 from the City University of New York (CUNY) and 2 from Pennsylvania State University) assisted in mentoring the students. Fifty percent of the student participants were female and 94 percent were minorities.

Medgar Evers College Ocean and Environmental Science Research Program

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Preservation of the Environment Through Education and Research on Remote Sensing of the Atmosphere and of Land Use/Land Cover Changes

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Anacostia River Institute for Remote Sensing (AIRS)

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INTRODUCTION

The Anacostia River Institute for Remote Sensing (AIRS) is a partnership between the University of the District of Columbia (UDC), NASA Goodard Space Flight Center, and Anacostia High School. It is designed to foster a collaborative and working partnership between UDC, the Anacostia High School and NASA. Focus will be placed on improvement and possible restoration of the Anacostia River. The primary objective of the program is to bridge the transition from high school to college in science and mathematics. This program has established field laboratory stations for water monitoring and assessment of the Anacostia River.

The program was designed to introduce and involve high school students in the latest methodology, techniques, and technology used in water monitor-

ing and water quality assessment. Our aim is to follow these students through graduation and college entrance applications. Our goal is to provide exposure to the types of science and mathematics necessary to ensure acceptance to an institution of higher education for the majority of the students. We are providing opportunities for students to learn about techniques used in remote sensing, career opportunities in remote sensing, and other careers in the sciences and mathematics.

Program Objectives include:

- identify the target population of the Freshman Academy of Anacostia High School and bring students to UDC for hands-on exercises;
- conduct field experiments at the experimental research sites;
- introduce student partners to the basic research methodology and statistics necessary;
- simulate our program with that of Dr. Robert Perry of Jersey City, NJ;
- have student partners in D.C. and NJ who will interact and share their research;
- introduce the students to basic satellite remote sensing and how it can be used in environmental monitoring; and
- monitor and evaluate the programs through formative and summative evaluation.

EDUCATIONAL ACCOMPLISHMENTS

At present, 15 10th grade Anacostia High School students from Washington, D.C. are enrolled in the AIRS program. Students were selected from incoming 9th graders in the summer of 1997. Most live in walking distance or a short commute to the high school. Initially, student capabilities and motivation for science and mathematics ranged from moderate to high. Science teachers at Anacostia High School monitor performance of AIRS students during the school year.

Twenty, four-hour Saturday sessions of the AIRS science program were held during the 1997-1998 school year. The first meeting of the AIRS Program, held on the UDC campus on Saturday, October 11, 1997, was devoted to introductions of faculty to students and students to each other. The next meeting introduced AIRS students to the scientific method and involved them in several hands-on activities. The third meeting, October 25, 1997, selected students from Pre-CAP (Pre-College Academic Program) at St. Peter's College, visited the AIRS Program on the UDC campus. Students from both programs collaborated in performing an experiment involving empirical data collection. The experiment was one in which students working in groups made and flew different kinds of paper airplanes, recording the distance the paper airplanes flew and comparing different kinds of paper airplanes. On November 22, 1997 the meeting took place at the Anacostia River, where students took water samples. On December 13, 1997, the students were taken to New York/New Jersey where they attended a performance of the Alvin Ailey Dance Theater and visited the Pre-CAP Program at St. Peter's College, offering the parallel science program to AIRS.

This summer, AIRS students participated in a 6-week summer science institute. They received intensive instruction in science, mathematics, computer programming, remote sensing, and water quality.

The majority of the AIRS sessions have been held at the UDC campus; other sessions have involved field trips. Virtually all AIRS faculty attend each session and team teach a curriculum designed in part during the summer of 1997 and subsequently modified in minor ways as the academic year unfolded.

These sessions are introducing students to the scientific method, the metric system, the techniques they will use to measure water quality by direct water sampling with Hach Kits and by remote sensing, and statistical measurement including central tendency, variability, water resampling techniques similar to those use to measure properties of water samples by EPA, and correlation (e.g., correlation between water samples measured by direct water sampling and by remote sensing). Students use hand-held calculators and computers to do computations so that they develop an understanding of the principles and methods involved. Graphing is done using computers.

The class sessions held at the UDC campus have been divided into a science presentation and a question/answer session by an AIRS faculty member, followed by a laboratory exercise. For the laboratory exercise, students have been divided into three teams; each led by a college undergraduate mentor. Students work together on the laboratory exercise and report their results.

Students and other participants of the AIRS program walked along the Anacostia River (behind Anacostia Senior High School) and were given a description of the hydrology of the Anacostia River and it's connection to the Potomac River and Chesapeake Bay. The purpose of this trip was to establish sampling locations for the summer science field studies. It was

decided that samples would be taken from the upper part of the watershed (NE/NW branches), at Bladensburg, at storm water outfalls, at combined sewer outfalls, at Benning Road Bridge, at the Washington Navy Yard, and at the mouth of the Potomac River. This trip was also taken after a rainstorm and trash was observed below storm water outfalls. The connection between storm drains and the river was established and observed firsthand.

UDC UNDERGRADUATE STUDENT PARTICIPATION

- Present at all sessions (classroom and field trips)
- Working closely with AIRS faculty and participants, providing invaluable assistance in both the classroom and in the field
- Serving as mentors to the AIRS students
- Conducting research projects with scientists who have sponsored programs at the University
- Trained on the 1408 Imaging and software instrument

ENROLLMENT DATA

Listed below are the enrollment data for the 1998-99 school year. Males and females are evenly represented; however, 100 percent are African-American. The students have participated in many science and computer-related activities before. All of the students use computers for a variety of purposes, although only 3 out of 15 report owning a home computer. Nearly one-third of both boys and girls reported sending e-mail over the computer.

	Male	Female	Total
Sex	7	8	15
Race			
Black	7	8	15
White	0	0	0
Hispanic	0	0	0
Other	0	0	0
School District			Anacostia High School
Age	14 yrs - 2 15 yrs - 3 16 yrs - 2	14 yrs - 3 15 yrs - 4 16 yrs - 1	
Grade	10	10	

At present, 10th grade AIRS students are planning to enroll in science and math courses throughout their high school careers. AIRS students are more likely than their peers to report that they would enroll in the most challenging and specialized courses, such as physics, zoology and AP (advance placement) sciences. AIRS students participate in four to six hours of science each time the program convenes. Although virtually all AIRS students are planning to attend college, they have not yet identified the institutions they would like to attend.

OUTCOMES

Both quantitative and qualitative process evaluations are being used to track student performance and provide participating faculty with feedback that will enable them to fine-tune the program as needed to ensure success. Outcome evaluations were used to measure the impact of the program on student motivation and achievement. Process evaluation was begun, at the outset of the program, by asking students to describe their course and career plans. They also evaluated the sessions held on October 18, 1997 (introduction to the scientific method) and October 25, 1997 (empirical data collection), describing what they liked best and least about these sessions.

Quantitative and qualitative evaluation data have been gathered from 13 pre-college students from Anacostia High School, attending parents and godparents, and 3 UDC undergraduates serving as mentors. Process evaluation in Fall 1997-Spring 1998 semesters has encompassed several different activities:

- Student course and career choices have been measured once to date and will be measured periodically again.
- Students have been asked to report on their prior science and computer experiences, in general and in the Fall 1997 semester, to assess interest and readiness to participate in the AIRS program activities as well as readiness and interest in using the computer.
- Students have been specifically asked to react to different aspects of the AIRS program. They have responded on 5-point attitude scales as well as to open-ended questions answered both in writing and orally.
- Student attendance at AIRS sessions has been monitored.
- Students have been given a math achievement test to assess readiness for the AIRS program.

Anacostia High School students participating in AIRS were observed to be highly motivated and to have high achievement potential in science and mathematics as evidenced by the perceptions and evaluation of students by Anacostia High School science teachers; student performance on a math pre-test; and student attendance at AIRS sessions.

Quantitative data indicate that boys in AIRS have come into the program with somewhat more science-related experience than girls have. They were more likely to report visiting the Air and Space Museum, the Museum of Natural History, or the Washington Children's Museum; reading science books; watching science programs on TV; participating in science fairs and science clubs; and using a computer to play video games, to do math and to make graphs, though they were not more likely to report using a computer.

Both girls and boys from the AIRS Program plan to enroll in many science and math courses, with the girls, if anything, outnumbering the boys in terms of the numbers of different courses in which they indicate they plan to enroll. Boys from the AIRS Program were more likely to report that they were planning to enroll in most of the physical sciences than girls were. However, more girls than boys reported that they would take regular physics and engineering, and more AIRS girls than boys planned to enroll in all of the life sciences except marine science, in which no girls but 37.5 percent of boys planned to enroll. More girls than boys plan to enroll in all but two of the math courses (in Algebra and Algebra 2, boys outnumber girls). Substantial numbers of both boys and girls plan to take academic courses throughout all four years of high school.

To measure the students' career interests, they were given a survey and were invited to check off as many careers as they were considering as well as writing in potential choices not shown on the survey form. A career in science, engineering, or medicine was selected only four times by the boys, in marked contrast to the girls, who expressed some interest in all of the science careers identified, except marine scientist.

Generally, AIRS students look as if they are entering the program with comparable levels reported of prior science and computer experience. AIRS students have been generally very satisfied with the program to date. There have been other benefits as well, including a science prize awarded to one student and his peers in a D.C.-wide science fair competition.

PARTNERSHIPS

Mr. Mark Irish and Mr. James Harrington (Director, Minority University-Space Interdisciplinary Network [MU-SPIN]) have provided assistance with computer training and technology.

A parallel hands-on science program, conducted by St. Peter's College Pre-College Admissions Program (Pre-CAP), was launched in Jersey City, New Jersey. Students selected to participate in the AIRS program were 15 ninth graders at Anacostia High School in Washington, D.C., primarily drawn from Kramer Middle School. Twenty 9th grade students, drawn from Lincoln High School in Jersey City, NJ, participated in the Pre-CAP program.

A site visit was paid to the St. Peter's Program on March 21, 1998 to see the science program in action. Students in Pre-CAP met in a college science laboratory, listened to a class presentation on bacteria (friendly and unfriendly) and conducted an experiment. They took mouth cultures before and after brushing their teeth with different brands of toothpaste and grew the bacteria on agar in petri dishes. The laboratory exercise was intended to introduce the students to the different kinds of bacteria they would later see in water sampling via direct measurement and measurement by remote sensing.

Mr. Steve Syphax, of the National Park Service, joined the group on one of the field trips to the Anacostia River. He discussed some of the pollution-related causes and effects on the Anacostia River. He also provided hands-on demonstrations and water sampling techniques. He will join the group periodically throughout the academic year.

Ms. Beverly Baker, Environmental Scientist and Anacostia Liaison from the U.S. Environmental Protection Agency Chesapeake Bay Program Office (CBPO), has volunteered her time and expertise to assist in this program. She served as the moderator and guide on several field trips along the Anacostia River and Chesapeake Bay.

OBSERVATIONS

Student attendance is high and the students' evaluation of the program is uniformly positive. As the program continues, students are learning about the importance of self-discipline and how to behave on a college campus in addition to learning the specifics of a hands-on science program. Available evidence strongly suggests that participation is having a positive effect on students' science and

mathematics courses and career choices.

Students were ready to benefit from the intensive summer experience that included water sampling in the field, measurement and data analysis, and peer mentoring by high school students who have completed a first year with new entrants into the program. Several students may also be mature and capable enough to take on an internship of a few weeks, should it be possible to make one available to them.

Students were questioned periodically as the AIRS Program progressed, to see how course and career aspirations change with involvement in the program and how course and career aspirations correspond with what students actually do in school.

Participants in the Anacostia River Institute for Remote Sensing (AIRS) through the University of the District of Columbia.

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Jet Propulsion Laboratory

Electromagnetic Wave Scattering From Volumes and Surfaces—The Aerosols and Ice Surfaces Electromagnetic Scattering

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Studies on Neptunion and Uranian Magnetospheres

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Johnson Space Center

Effect of Microgravity on the Disposition and Biotransformation of Therapeutic Agents Used in Space Flight: Clenbuterol as a Model

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INTRODUCTION

This research is founded on the hypothesis that the pharmacokinetics (how the body acts on the drug) of clenbuterol are altered significantly when the drug is administered under conditions of microgravity. The specific aims of this research are to assess the disposition (clearance, tissue levels) of clenbuterol when administered in an animal model of simulated microgravity (hind-limb suspension); to

determine if the bio-transformation of clenbuterol by hepatocytes is altered by simulated microgravity; and to stimulate interest in space medicine research by developing curricular opportunities that blend the study of microgravity-induced changes in bodily function and pharmacology.

RESEARCH ACCOMPLISHMENTS

The majority of progress made during the first year of the grant was related to assessing the disposition of clenbuterol when administered in an animal model of simulated microgravity and to stimulating interest in space medicine research. Abstracts were presented at the national meetings of the American Society for Gravitational and Space Biology [ASGSB] and the American Society of Experimental Biology, one manuscript was submitted for publication, and two additional abstracts will be presented this year at the meetings of the ASGSB in Houston and the Society of Forensic Toxicology in Albuquerque.

Two methods, gas chromatography-mass spectrometry (GC-MS) and enzyme immunoassay (EIA), were developed and utilized at Morehouse School of Medicine (MSM) for the detection of clenbuterol in biological fluids and tissues. The GC-MS method has been used to detect clenbuterol in plasma over the concentration range of 5-200 mg/ml. In addition to established research collaborations with scientists (Drs. Catherine White and Stuart Feldman) at the University of Georgia (UGA) School of Pharmacy, the MSM group established collaborative research arrangements with Dr. Stephen Liggett at the University of Cincinnati School of Medicine and Dr. Hassan Y. Aboul-Enein at the King Faisal Research Centre. Dr. Liggett is an expert on the molecular biology of beta adrenoceptors and their use as a bioassay system for the detection of the cellular effects of clenbuterol. Dr. Aboul-Enein is an expert on the enantioselective separation of clenbuterol enantiomers. These collaborative arrangements will be continued into the second year.

In addition to the work with clenbuterol, the effect of simulated microgravity on the biliary and renal excretion of an antibiotic, ampicillin was evaluated. Preliminary data indicate that simulated weightlessness decreased the renal and biliary excretion of ampicillin in hind limb-suspended rats. This latter observation will be expanded to the study of other drugs in the second year of the grant.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This grant has strengthened the partnership between NASA and the Atlanta University Center through research and educational activities that are responsive to the Agency's strategic initiatives. Moreover, it addresses specific solutions to the important scientific problems of how space travel can affect the body's ability to eliminate endogenous chemicals as well as exogenous xenobiotics that may be used as countermeasures for flight-induced changes in bodily function or as therapies for diseases/conditions encountered during excursions in space.

STUDENT ACHIEVEMENTS

During this period of the grant, a number of graduate and undergraduate students at MSM and UGA were trained in setting up and managing the hind-limb suspension animal model and in conducting analytical techniques (GC-MS and EIA) used in the clenbuterol study.

An undergraduate course in pharmacology has been developed and discussed with chairpersons and professors at Morehouse College, Spelman College, Clark-Atlanta University, and Morris Brown College. Approval of the course as an elective by the Atlanta University Center schools is being sought currently for implementation in 1999.

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Intelligent Agents-based Scheduling

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Kennedy Space Center

Applied Research in Industrial and Systems Engineering (ARISE) Center

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Research and Education Experiences for Minority Undergraduates in Composite Materials

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NASA Minority Institution Entrepreneurial Partnership

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Date of Original Award: 1997

INTRODUCTION

The objective of this two-year partnership with NASA is to provide minority students and the faculty teaching at minority institutions with real-world experiences with high-tech entrepreneurial opportunities. Historically, minority groups have been poorly represented among the legions of high-tech companies, due in part to a lack of exposure to the environments that promote these activities. Very few colleges and universities include entrepreneurship in existing course curricula. By providing first-hand knowledge of the practices and challenges facing small businesses, the participants from these institutions are better prepared to disseminate information about, and embark on, high-tech small business ventures. Bethune-Cookman College (B-CC) of Daytona Beach is the lead consortium member of the partnership, which includes Florida International University (FIU) and Florida Memorial College (FMC) both in Miami, and Edward Waters College (EWC) in Jacksonville. Through the NASA Commercialization Office at the Kennedy Space Center (KSC), and companies and local organizations involved in the established technology transfer programs, participants gain insight into the challenges faced by high-tech small businesses. The students and faculty have become educated in NASA technologies available for commercialization, market research, technical problem solving, and the processes involved in bringing a high-tech product or service to market. Support for the Commercialization Office was given to the NASA-KSC/State of Florida Technology Outreach Program, the Florida/NASA Business Incubation Center, the Technology Development Program and the Small Business Innovative Research program.

Over 100 students with a varied mix of ethnic backgrounds have participated in the program. Between the four institutions, there is a combination of African-American, Pacific Islander, and Hispanic participants. Florida International University has a graduate program, while the others have undergraduate programs. During the first year, the total number of faculty involved was 13 and this continues to grow. The participants have, as a result of this program, diligently and effectively guided these students into experiences and opportunities they feel to be very beneficial to the paths they choose.

The intended program roles of the institutions for the period June 27, 1997 through June 26, 1998 are as follows.

Bethune-Cookman College (B-CC) is the lead in the consortium, and Dr. Ann Taylor is the principal

investigator there. Faculty and students from the college will work to assist the NASA-KSC Technology Transfer and Commercialization Office with business assistance, will assist the Technology Outreach Program through the local Economic Development Commission, and will provide a faculty member for a two-week summer workshop at NASA-KSC.

Edward Waters College (EWC), Ms. Doris Brown—principal investigator
Faculty and students from the college will provide assistance to companies responding to Small Business Innovative Research (SBIR) solicitations with support from the Southern Technology Applications Center, will assist the Technology Outreach Program through the local Economic Development Commission, and will provide a faculty member for a two-week summer workshop at NASA-KSC.

Florida Memorial College (FMC), Dr. Abbass Entessari—principal investigator
Faculty and students from the college will provide assistance and work with the NASA/Florida Small Business Incubation Center, will assist the Technology Outreach Program through the local Economic Development Commission, and will provide a faculty member for a two-week summer workshop at NASA-KSC.

Florida International University (FIU), Dr. Irma Fernandez—principal investigator
Faculty and students from the college will provide support for the Commercialization Office in the areas of Technology Commercialization and Licensing and the Technology Development Program, and will provide a faculty member for a two-week summer workshop at NASA-KSC.

The Technological Research and Development Authority (TRDA) The TRDA, as KSC's state partner in NASA's technology transfer, has assisted B-CC with program administration to ensure that the defined objectives are maximized. TRDA has acted in a support role to B-CC and all other schools to assist faculty and project coordinators with all program coordination. TRDA staff time was dedicated to working with the schools in facilitating the required relationships with NASA personnel; coordinating activities to ensure that tasks and deliverables were completed according to project specifications; and acting as the liaison between the colleges and the local economic development organizations and the Technology Outreach Program Office.

This multi-faceted program has proven beneficial to many different entities. Students and faculty have gained knowledge and insight, the growth of economic development in Florida has been assisted, and valuable information in the area of space research has been provided to Kennedy Space Center. The outcomes for each of the institutions are as follows:

Florida International University has completed comprehensive assessment reports for 11 NASA/KSC technologies. Included in their findings were 668 leads for potential commercialization partners and 110 new potential uses for these technologies.

Florida Memorial College submitted a marketing plan for the Florida/NASA Business Incubation Center. This plan was used to secure a $216,000 enhancement grant for the incubator program. FMC is also providing individual assistance according to the incubator tenant's specific needs. During the first year, a competitive analysis was provided to a tenant and the tenant was assisted in developing a marketing plan to help get the business off the ground.

Edward Waters College has been instrumental with their SBIR efforts. During this past year, EWC has worked hard to bring an awareness program to Florida companies about the NASA/SBIR program. They have created a clearinghouse-style web site, which publicizes SBIR related information for state businesses. The site's location (URL) is *www.ewc.edu/sbir*. The students have created a unique acronym designed to facilitate recognition of EWC and NASA/SBIR: "We are your Florida Business ASSET (Auxiliary Services for Small Enterprises)." In order to recruit companies for the SBIR program, a search was conducted and mailers were sent to prospective submitters. Interest meetings and seminars were developed and hosted by EWC. Out of the 78 Florida companies submitting SBIR proposals, 17 were Edward Waters' clients. Support included interpretation of solicitation contract language, data gathering, market research, proposal word processing, assistance in finding experts, references for partnering opportunities, assistance in funding searches for Phase II and III, and basic tutoring in computer file maintenance and the use of Windows 95. An "SBIR How-To Handbook" was also submitted by EWC for KSC's review; contents include relevant information for minority businesses.

Bethune-Cookman College provided assistance to market the Technology Transfer and Commercialization Office. They developed and provided 4 alternative commercialization plans, 20 examples of booth display materials, and 3 sample brochures to KSC for their marketing efforts. They also compiled and provided a comprehensive list of 1,969 Florida

media sources. State-of-the-art capabilities were utilized in creating three complete KSC homepages.

B-CC, EWC, and FMC worked together to provide assistance in marketing the Technology Outreach Program (TOP), which provides businesses with free technical assistance. Cable-TAP 36 taped a program of FMC's Business Administration Division that incorporated a segment on their TOP efforts. Another show aired in February on the NASA/FMIEP (Model Institution Entrepreneurial Partnership) featuring Project Coordinator Joe Heimbuch and two students. Each Institution completed a comprehensive listing of area companies, an assessment report on the current promotional program (including recommendations for improvement), and an analysis of their local Economic Development Organization's (EDO) promotional program. To work closely with their local EDO's, the faculty and students at the institutions participate and network in various business conferences around the state. Students made a total of 783 company visits on behalf of the Technology Outreach Program. The NASA/FMIEP consortium has successfully attained its objectives and has produced remarkable results in its first year. The confidence level of the students has escalated greatly and their interests in pursuing careers in the science, engineering, and business arenas have increased. The benefits of the NASA/FMIEP program include an enhanced relationship between NASA-KSC and minority institutions, thereby broadening the potential for future joint programs and contributing talent and resources to existing outreach programs.

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Langley Research Center

Development of a Portable Ground-Based Ozone LIDAR Instrument for Tropospheric Ozone Research and Educational Training

Principal Investigator: Dr. Thomas Chyba
Department of Physics
Hampton University
Hampton, VA 23668
Date of Original Award: 1997

INTRODUCTION

The objective of this project is to develop a portable, eye-safe, ground-based ozone lidar instrument specialized for ozone differential absorption lidar (DIAL) measurements in the troposphere. This prototype instrument is intended to operate at remote field sites and to serve as the basic unit for monitoring projects requiring multi-instrument networks, such as those discussed in the science plan for the Global Tropospheric Ozone Project (GTOP).

This instrument will be based at Hampton University for student training in lidar technology as well as atmospheric ozone data analysis and interpretation. It will also be available for off-site measurement campaigns and will serve as a test bed for further instrument development. Students are involved in all aspects of this effort.

RESEARCH ACCOMPLISHMENTS

Hampton University students and faculty have investigated several candidate solid-state laser technologies in collaboration with scientists at ITT Systems and Sciences and NASA Langley Research Center. An optical parametric oscillator design has been chosen for the first-generation system. ITT has designed an optical receiver in a compact, lightweight composite structure. Hampton University students are writing LabVIEW software for data acquisition, processing, and display. A complete mathematical model of the laser, atmosphere, optical receiver, and detection electronics has been developed. This model is being used to study the impact of different technologies upon the capabilities of the system. In this manner, the most reliable and cost-effective technologies can be used and still allow useful scientific data to be obtained.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This project directly supports the priority of NASA's Earth Science Enterprise to improve its capability to continuously monitor atmospheric ozone. The technologies developed could contribute to future ground-, air-, and space-based lidar systems.

BENEFITS TO SOCIETY

In addition to promoting NASA's goal of understanding global ozone distributions, this system enhances the ability of the Environmental Protection Agency (EPA) and National Oceanographic and Atmospheric Administration (NOAA) to study local or regional

ozone pollution. The ability to hourly monitor urban ozone pollution with high spatial resolution in a cost-effective manner will contribute to the protection of the health of U.S. citizens, as well as that of the agriculture, forests, and animals upon which the nation depends.

STUDENT ACHIEVEMENTS

Mr. Christopher McCray presented papers at the 1998 Advanced Solid State Laser Conference and the 1998 NASA University Research Center Technical Conference concerning his laser research. Ms. Brandi Thomas and Mr. Roosevelt Elivert presented a poster paper at the Hampton University Third Annual Student Research Symposium in 1998 concerning their LabVIEW-based data acquisition system. Ms. Crystal Toppin, Ms. Brandi Thomas, Mr. David Larson, and Mr. Jason McNeil developed LabVIEW software for data acquisition and display as part of the AURORA (Advanced Undergraduate Research Using Optical Radiation in the Atmosphere) and UNIPhy-REU (Undergraduate Institute in Physics-Research Experiences for Undergraduates) summer programs at Hampton University.

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Concepts for Atmospheric Science Education (CASE)

Principal Investigator: Dr. M.P. McCormick
Center for Atmospheric Sciences
Hampton University
23 Tyler St
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Date of Original Award: 1997

INTRODUCTION

The goal of the CASE (Concepts for Atmospheric Science Education) project is to take an initial step in establishing a center of excellence in atmospheric and Earth radiation sciences at Hampton University (HU). Objectives of the project are as follows: to begin to develop the HU faculty, curriculum, and programs leading to advanced degrees concentrating in atmospheric and Earth radiation sciences; to conduct fundamental research in atmospheric and Earth radiation sciences; and to conduct educational outreach to the non-science students at HU, other universities, K-12 students and teachers, and the general public.

ENROLLMENT DATA

The first three graduate students in the HU program in atmospheric sciences were enrolled in the Fall term of 1998. The first graduate course, "An Introduction to Atmospheric Chemistry," is being taught; two new graduate students and two African-American students from the Chemistry department are enrolled. A new female faculty member partially funded under the CASE grant is teaching this course. Another new member of the faculty funded under CASE is teaching an undergraduate course in Astronomy to reach the non-science population of HU. Five African-American students are enrolled in this course.

OUTCOMES IN THE FIRST YEAR

Three PhD students who have a strong desire to teach as well as to perform research were recruited from Florida State University, the University of Colorado, and the University of Illinois. These new faculty funded under CASE are teaching two courses now and will offer two more courses in the Winter term. One will be a graduate course in atmospheric physics and the other an undergraduate course titled "Introduction to Atmospheric Phenomena." New faculty members also served as advisors/mentors to junior and senior level minority students in our six-week summer program in atmospheric sciences, AURORA. They are also essential to the implementation of an HU atmospheric science rocket study program funded by the Department of Defense Ballistic Missile Defense Options (DOD/BMDO). One new faculty member took two students (including one African-American undergraduate Engineering student) on a summer rocket campaign to Colorado.

Two new faculty members played key roles in the submission of two major satellite experiment proposals, one to the Office of Space Science (OSS) and the other to the Office of Earth Science (OES), which are presently under review. These proposals have significant outreach and education elements for minority and other students. One faculty member funded by CASE, an African who is soon to become a U.S. citizen, is leading graduate student recruitment, and is an excellent role model for incoming students.

Key contacts have been made with the University of North Carolina Center for Mathematics and Science

Education, the head of the National Center for Atmospheric Research (NCAR) Significant Opportunities in Atmospheric Research and Science (SOARS) program, and an National Science Foundation (NSF) educational representative. CASE has provided the vehicle for synergistic interactions among the faculty in the various activities listed and in other HU programs, including the Research Center for Optical Physics.

PARTNERSHIPS

The Langley Research Center, with Dr. Lamont Poole as our technical partner, has provided satellite data and ground-based lidar data which has aided our educational efforts. An HU undergraduate student in physics is working directly with Dr. Poole on the analysis of lidar data.

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Marshall Space Flight Center

Curriculum Adjustments in Mathematics for Science and Engineering Programs

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Alabama A&M University
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Normal, AL 35762
Date of Original Award: 1997

Report not submitted.

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Stennis Space Center

JSU-NASA Partnerships for Research and Educational Programs

Principal Investigator:
Dr. Paul B. Tchounwou
P.O. Box 18540
Jackson State University
Jackson, MS 39217- 0940
Date of Original Award: 1997

INTRODUCTION

This project is designed to develop and strengthen a collaboration and partnership between faculty of the School of Science and Technology at Jackson State University (JSU) and scientists from three main offices/laboratories [Commercial Remote Sensing (CRSP), Earth System Science (ESS), and University Programs (EUP)] at NASA-Stennis Space Center (SSC)]. The project embodies a set of activities including both a research component and an education component, which focus on NASA's Earth Observation theme. The three main elements of the research component include commercial remote sensing, with a focus on satellite data acquisition, data analysis, and product development and generation and with applications in urban planning, pollution monitoring, and environmental assessment; Earth system science, with a focus on coastal processes and an emphasis on the development of a GIS (Geographic Information System) database for the lower Pearl River, the examination of the cause and effect of hypoxia in the Gulf of Mexico, the investigation of the effects of natural and anthropogenic factors on coastal vegetation stress, and the assessment of meteorological events on land-sea-air interfaces in coastal regions; and data handling/image analysis, with a focus on system development for satellite data management and the examination of current technology for performing image analysis. The education component also involves three elements, including curriculum support document development, focusing on the development of learning exercises based on Earth observation data for the purpose of enhancing biological and physical science curricula; community college faculty development, with a focus on training faculty in the use of Earth observation data and in finding and downloading Earth observation data from the Internet; and summer internship programs to provide opportunities for students to acquire practical training in specific areas of Earth observation and Earth system sciences.

SUMMARY OF ACCOMPLISHMENTS

Exchange Programs:
Activities carried out during the first year of this partnership focused on the establishment and development of active collaborations and interfaces between the faculty of the JSU School of Science and Technology and scientists from the three main offices/laboratories at SSC.

For the purpose of achieving this major goal, four visits have been made by JSU faculty to SSC, while four other such visits were made by SSC scientists and managers to Jackson State University. So far, a total of eight JSU faculty have undertaken formal visits to SSC to interact with relevant groups and personalities.

SSC personnel have made four visits to JSU. These visits provided opportunities to JSU faculty to know the exact nature of professional activities implemented by relevant programs at SSC, and to open doors for long term collaborations with NASA scientists. These visits also increased the awareness of SSC scientists and managers of the JSU facilities and the capabilities and expertise of the School of Science and Technology faculty.

Faculty Training
A faculty training workshop, "Applications of GIS and Remote Sensing Technologies to Earth System Science Research," was organized at Jackson State University. Instructors at this workshop included Drs. Armond Joyce and Lloyd McGregor of SSC and Mr. Julius Baham of JSU. In addition to these three instructors, eight JSU faculty and staff participated in this workshop.

Student Training
Four JSU students (Robin Bridges, an Atmospheric Sciences major; and Aliu Adesuwa, Alfred Vann, and Wesley Powe, all biology majors) were identified to participate in the summer internship program at Stennis Space Center in 1998. These students were selected based on their interest in NASA programs and their academic performance. They were assigned individual mentors, and arrangements made for all of them to participate in a preliminary training program at JSU to insure a successful completion of their internship at SSC during the summer. All of these students successfully completed their seven-week internship programs in specific laboratories or offices at Stennis Space Center.

In addition, three Coahoma Community College students (Jessie Readus, Antonio Collins and Tameka Lampkin) and three Hinds-Utica Community College students (Karen Sanders, Michael McIntosh and Felisha Irving) came to Jackson State University this summer and participated in a six-week training session on NASA-related programs.

Development of Curriculum Support Materials
Efforts in developing curriculum support materials have been made in an integrated fashion through the Office of University Programs at Stennis Space Center. So far, this office has produced two CDs, *The Earth Sciences* and *The Earth from a Distance*, containing a significant number of learning exercises. The purpose of these efforts is to enhance biological and physical science curricula through the development and use of observation data in classrooms of community colleges in order to stimulate students' interests in Earth system science.

Research
Research equipment has been purchased. This equipment includes computers and printers, which are currently being used for training and research and in the investigation of physiographic influences (fog, sea breeze, convective initiation, and attendant wind circulation) on weather systems using GIS/RS (Geographic Information System/Remote Sensing) techniques, and a GER 1500 Spectroradiometer, which is currently being used by JSU researchers in greenhouse experiments to monitor leaf spectral reflectance characteristics of a non-stressed and drought-stressed plant (*Brassica sp.*). It is expected that the results of this research will help to determine if a correlation exists between spectral signatures and important physiological endpoints in plants. A Global Positioning System (GPS) unit has also been acquired for the purpose of geo-referencing and identifying field research sites. In addition, a dissolved oxygen meter, a DR/2000 spectrophotometer, and a pH meter have been bought for field use in acquiring data on selected chemical characteristics of surface waters.

PLANNED ACTIVITIES

The following activities are planned for the 2nd year of the project:

- Organize a five-day faculty training for JSU and Coahoma and Utica Community College faculty.
- Identify four additional students to participate in NASA-related activities at JSU during the next academic year.
- Organize a 6-8 week internship program for JSU students at Stennis Space Center.
- Organize a 4-6 week internship program for Coahoma and Utica students at Jackson State University.
- Strengthen collaborations by organizing additional exchange visits and encourage collaboration in relevant research projects by JSU faculty and NASA-SSC scientists.
- Develop and implement research initiatives in relevant areas of interest to NASA as indicated in the project summary.

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Other Awards

Other Awards

In addition to the awards made under the solicited award programs described in the previous sections of

this report, a number of other proposals from HBCU's and OMU's are also funded each year by NASA Field Installations and MUREP. The annual reports submitted by 12 of these awardees follow.

Ames Research Center

Iron Ion Induced Low Dose Mutagenesis

Principal Investigator: Dr. Purushuttam Kale
Department of Biology
Alabama A&M University
P.O. Box 610
Normal, AL 35762
Date of Original Award:

RESEARCH ACCOMPLISHMENTS
This project consists of three specific aims. In this project period, the first of the three aims was investigated. The Drosophila cultures were carried to the Brookhaven National Laboratory two days before the scheduled date of irradiation. The newly emerged males ((6 hours) of Canton-S stock were collected in the laboratory. The males were divided into two groups and kept in gelatin capsules, which were taken to the Alternating Gradient Sychrotron (AGS)[AHO1]. The capsules were kept at the target in the cave and were irradiated with 40 and 400 R (rads) of a GeV (Germanium/Vanadium) iron ion beam.

The irradiated males were then carried to Alabama A&M University where further experimentation continued. The males were mated to six sets of virgins every two days and six broods were cultured to obtain the lethal mutation frequencies for all four germ cell shapes at 40R and at 400R. The main purpose of using these doses was to establish lower and higher limits of the dose response relation to be investigated. The findings showed that even at 40R, a significant number of mutations were induced. The spontaneous mutation rate in Drosophila is 0.1 percent, and 40R induced more than 10 times this rate in spermatocytes and spermatids. Therefore, doses as low as 10R can be tried. The purpose of using 400R was to see if this dose induced complete sterility in irradiated males. Although this dose induced significant cell killing, there were more mutations than at the lower dose. These data now allow lower than 40R as a low limit and higher than 400R as a high limit for obtaining the proposed dose frequency response, where it will still be possible to obtain a measurable mutation frequency.

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Study of Radiation Effects on Infrared Detectors and Materials for Space-Based Astronomy Applications

Principal Investigator: Dr. Richard Wilkins
Department of Electrical Engineering
Prairie View A&M University
P.O. Box 4209
Prairie View, TX 77446
Date of Original Award:

This project supports NASA Ames Research Center's efforts to explore the universe in the infrared spectrum by studying radiation effects on infrared detectors and read-out electronics. This is part of a continuing program that seeks to place infrared astronomy instruments deeper into space to maximize their scientific potential.

The goal of this research is to place detectors and read-out electronics in radiation environments where their performance may be affected. We are building the infrastructure needed to test infrared detectors under a variety of radiation types. To this end, we are developing a compact, self-contained test unit outfitted with a helium cryostat and infrared light source. This will allow radiation tests to be conducted while the detectors are active, simulating as closely as possible their operation in space. Testing of actual devices will begin soon.

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Dryden Flight Research Center

Team Training and Retention of Skills Acquired in Above Real Time Training on a Flight Simulator

Principal Investigator: Dr. Syed Firasat Ali
Aerospace Science Engineering Department
Tuskegee University
Tuskegee, AL 36088
Date of Original Award:

INTRODUCTION

Above Real Time Training (ARTT) is the training acquired on a real time simulator when it is modified to present events at a faster pace than normal. The experiments related to training of pilots performed by NASA engineers and others have shown that in comparison with the real time training (RTT), ARTT provides the following benefits: increased rate of skill acquisition, reduced simulator and aircraft training time, and more effective training for emergency procedures. The objectives of the present effort have been to design and perform an experiment to study the retention of skills acquired under ARTT at 1.5 times real time and to design an experiment to evaluate the effectiveness of ARTT in team training. The work is completed and a paper has been written on the retention study, while the team training design is in progress.

RESEARCH ACCOMPLISHMENTS
Thirty-two university students received real time training (RTT) or above real time training (ARTT) for an aerial gunnery task on a simulator. Some of the trainees were tested immediately after the training, and the others were tested two days later. Results of the experiment show that the effects of ARTT did not decrease over a two-day retention interval and that ARTT was more efficient than RTT in that equal test performance could be achieved with less clock time spent on the simulator.

RELEVANCE TO NASA STRATEGIC ENTERPRISES
The primary benefit of this research is to the Aero-Space Technology Enterprise. The work on flight simulation systems in the Research Facilities Division of NASA Dryden Flight Research Center (DFRC) will benefit especially.

BENEFITS TO SOCIETY
The ARTT would result in appreciable savings in simulator-based training of high-performance skills.

STUDENT ACHIEVEMENTS
The students on this project obtained valuable experience on flight simulation through their own work and by staying in direct contact with the faculty and the expert consultants. Dennis Ezell obtained a brief training on the Universal Distributed Interactive Simulation (UDIS), and he contributed to the design of pilot stations and equipment selection. Jason Williams worked and provided leadership to other students in using UDIS software for generating flight scenarios. Kongolo Mulumba and Rodriques Walker demonstrated exceptional ingenuity and patience in generating flight scenarios for training on gunnery tasks. Traron Moore, Don Angelo Bivens, Mayard Williams, Allison Foster, Quionna Caldwell, and Kwame Royal participated in recruiting subjects for the study, randomization of events, and conduct of the experiments. Two of these are now graduate students. Two others are now working as engineers.

ACKNOWLEDGEMENTS
The research project has been supported by the NASA DFRC. On the above real time training with emphases on training of pilots, the most recent work of substantial value has been published by Dr. Dutch Guckenberger, an expert on simulation and by Dr. Peter Crane, a research psychologist in the Air Force. The availability of Dr. Guckenberger and Dr. Crane as consultants has been a blessing for everyone working on the project. Dr. Marcia Rossi, associate professor of psychology at Tuskegee University and her students have been very helpful through their continued association with the project. Mr. Matt Archer of ECC International Corporation (Orlando, FL) remained available to respond to any special software needs.

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Non-Intrusive Airspeed Indicator for Transonic Aircraft Applications

Principal Investigator: J.P. Clark
Dept. of Engineering
New Mexico Highlands University
Las Vegas, NM 87701
Date of Original Award:

INTRODUCTION:
When an object is immersed in a flowing fluid, the effects of friction between the surface and the fluid are manifest in thin boundary layers that grow on the body. These boundary layers may be described as laminar or turbulent, and usually they undergo a transition from the former state to the latter. When a boundary layer undergoes such a transition, spots of turbulence form and convect downstream. The goal of this project is to create a device that measures the speed of these turbulent spots and infers the true flow speed from the result.

RESEARCH ACCOMPLISHMENTS
A study to assess the feasibility of a transducer that derives airspeed from a measurement of turbulent-spot convection rates was conducted. The opera-

tion of the sensor in a low-speed wind tunnel was demonstrated with commercial-off-the-shelf hardware and software (See Figures 1 and 2 on the following pages). A prototype of the transducer was also partially constructed using the Texas Instruments DSK31 Digital Signal Processor starter kit and a simple multiplexing circuit. In addition, a parametric design analysis was performed using a boundary-layer transition simulation to assess the use of the sensor in the transonic regime. Finally, additional means of deriving airspeed from turbulent-spot propagation characteristics were studied and deemed plausible.

RELEVANCE TO NASA STRATEGIC ENTERPRISES
As part of its mission in the field of aeronautics, NASA may investigate alternate methods for determining the speed at which an aircraft travels. The turbulent-spot flow meter described above is one such technology.

BENEFITS TO SOCIETY
The turbulent-spot flow meter provides an estimate of airspeed that is independent of the altitude at which an aircraft flies. This makes it ideal for use by pilots of aircraft for general aviation. It also does not interfere with the flow the way most airspeed indicators do; its use translates directly to fuel savings.

Figure 1- Unsteady voltage traces from a pair of thin-film gauges offset in the streamwise direction along the centerline of a flat plate in a low-speed wind tunnel.

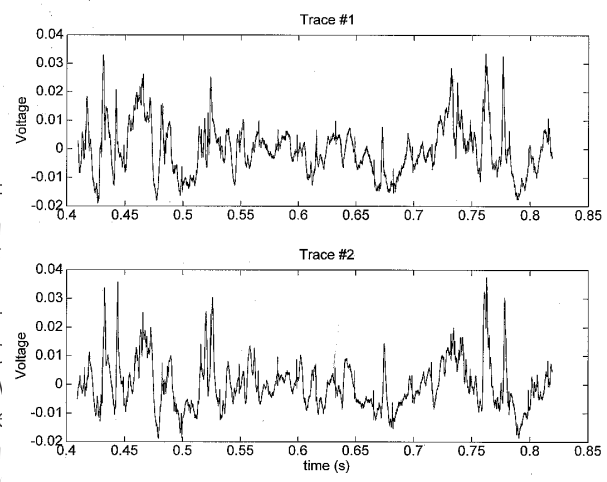

Figure 1. Unsteady voltage traces from a pair of thin-film gauges offset in the streamwise direction along the centerline of a flat plate in a low-speed wind tunnel.

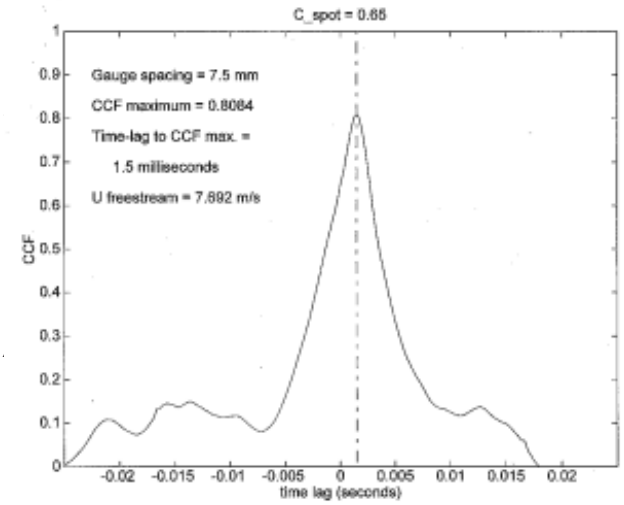

Figure 2. The results of crosscorrelation analysis performed on the signals from Figure 1 in order to determine airspeed.

The goal of this project was the continued development of a prototype test bed for in situ radiation testing of integrated circuits. The test bed was designed to be carried aloft by both high altitude aircraft based at NASA Dryden Flight Research Center (DFRC)—for example, the ER-2(tm)) and high altitude balloons—and is designed to be as light and self-sufficient as possible.

A working relationship has been established with the DFRC Project APEX (a high-altitude flight experiment) that would allow the test bed to ride "piggyback" on their balloon payload. In addition, preliminary talks with the NASA ER-2(tm) contractor (Lockheed Martin Corp.) on test bed flight integration took place.

Students working on the project included an intern at DFRC who helped determine appropriate batteries for the test bed operation. Another student accompanied the principal investigator on a visit to DFRC to inspect possible locations for the test bed onboard the DFRC ER-2(tm) aircraft. Work on this project is continuing under a Faculty Award for Research.

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summer, Jolene worked at Hewlett-Packard in Colorado, while Amy was an engineering intern with Sandia National Laboratories in Albuquerque,

Kennedy Space Center

Assist in Development of New Automated Web-based Change Tracking System for the (LPS-CM) Paper Trail

Principal Investigator: Dr. Satinderpaul Sing Devgan
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Nashville, TN 37209-1561
Date of Original Award: 1997

INTRODUCTION
The present manual update and approval process for keeping track of changes to the Launch Processing Systems-Configuration Management (LPS-CM) system is time consuming and cumbersome. The proposed web-based automated system using Oracle 8 and Java Applets will facilitate economic tracking, storage, and authentication of Engineering Change Request (ECR) information.

RESEARCH ACCOMPLISHMENTS
A sample change tracking and approval recording process was developed and demonstrated using an Oracle 8 DBMS (database management section) and a Java JDBC(tm) interface for a simulated employee database. Researchers and students working on this project gained experience in the use of HyperText Markup Language (HTML) and Java Applets in the development of dynamic web pages. One undergraduate student completed a capstone design project in this area and is now pursuing graduate studies.

RLELVANCE TO NASA STRATEGIC ENTERPRISES
Keeping track and records of hundreds of engineering changes to the LPS-CM is extremely important to NASA, and implementing modern technologies will automate the process and result in significant savings. In addition, NASA needs a trained workforce including minorities and women with experience in information systems and object-oriented programming.

BENEFITS TO SOCIETY
There is great demand for engineers with experience in information systems. This research project will help meet the need for qualified systems analysts and computer engineers. These high-paying positions will improve the standard of living of the socially and economically disadvantaged students working on the project.

STUDENT ACHIEVEMENTS
Two graduate and six undergraduate students gained extensive experience in the use of HTML and Java Applets in the development of dynamic web pages for the department and the college. Three students won awards for their presentations at a university-wide Research Symposium.

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Fuzzy Logic Controller for Controlled Ecological Life Support Systems

Principal Investigator: Dr. William Taylor
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Date of Original Award:

INTRODUCTION
The objective of this research has been to develop a fuzzy logic controller for advanced life support systems. Traditional control system technology depends upon the ability to develop a mathematical model that captures the entire dynamic behavior of the system to be regulated. However, systems containing living and growing components are non-linear and generally change dramatically over time. Therefore, this research investigated the use of fuzzy logic controllers capable of adapting to changing conditions in life support systems that contain plant growth chambers.

RESEARCH ACCOMPLISHMENTS
First, a successful fuzzy control algorithm able to regulate the temperature and humidity of sealed environments containing plant growth chambers, illumination systems and atmospheric controls was developed. Next, the fuzzy logic algorithm was successfully implemented on a single-chip microcontroller with the help of the Fuzzy Inference System Translator (FIST) program.

RELEVANCE TO NASA STRATEGIC ENTERPRISES
This project contributes to the human exploration and development of space. Autonomous fuzzy logic controllers could play an important role in life support systems for deep space missions that require the regeneration of food, oxygen, and water.

BENEFITS TO SOCIETY
The technology developed can be used immediately in the agriculture industry to regulate the temperature and humidity of greenhouses. The single-chip controllers are inexpensive and could easily be used in the expanding home greenhouse market to regulate heating and ventilation systems.

STUDENT ACHIEVEMENTS
Four students have co-authored an important paper on this project. One student is now completing a co-operative program at Dryden Flight Research Center and another has graduated and is now employed in the aerospace industry. A third student has successfully completed a co-operative program with the Federal Aviation Administration. Three student researchers presented the results of this work to the technical monitors at the Kennedy Space Center.

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Langley Research Center

Solar Eagle III Project

Principal Investigator: Dr. Raymond Landis
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Los Angeles, CA 90032
Date of Original Award:

INTRODUCTION
The Solar Eagle III Project at California State University, Los Angeles received a two-year grant from the NASA Minority University Research and Education Division (MURED) for the period July 1996 through September 1998. The first phase of this project (July 1996 through September 1997) involved a team of students, faculty, and staff from the School of Engineering and Technology coming together to design, build, and race the school's third solar-powered electric race car, the Solar Eagle III. The grant provided the funding for the design and fabrication of the solar panel and the development of the telemetry system for the vehicle.

During the second phase of the project (July 1997 through September 1998), the School of Engineering and Technology conducted an outreach/public awareness campaign for the vehicle and our school, using the Solar Eagle III as the centerpiece of the campaign.

There were four overall objectives for this project, as follows:
* to provide a practical, "real-world" engineering design and fabrication project for our students, not otherwise provided in a classroom setting;
* to gain further knowledge in technologies related to ground vehicle aerodynamics, power electronics associated with electric vehicles, energy conversion efficiency, solar energy, composite materials, and environmentally safe transportation and contribute those results to others;
* to use the success of this project to stimulate young students to want to study engineering and technology at California State University at Los Angeles (CSLA); and
* to increase the public awareness of the need for environmentally clean transportation systems.

RESEARCH ACCOMPLISHMENTS
The Solar Eagle III competed in the major collegiate solar-powered electric car race, Sunrayce 97, which was sponsored by the U.S. Department of Energy in June, 1997. This 1200-mile race was held from Indianapolis, Indiana to Colorado Springs, Colorado. CSLA competed against a field of thirty-six other vehicles from universities from across the United States and Canada. The Solar Eagle III captured a first place finish in the race, beating several top institutions, including Massachusetts Institute of Technology, Stanford/University of California at Berkeley, University of Michigan, and Texas Tech. The Solar Eagle III also set a new Sunrayce speed record with an average speed of 43.29 mph, which was six mph faster than the previous speed record.

From July 1997 to September 1998, our national championship vehicle, the Solar Eagle III, has been the centerpiece of a comprehensive outreach and public relations campaign. Through this grant a student team member has been hired from the project to accompany the vehicle to hundreds of off-campus events and celebrations and to serve as

spokesperson for the project. Throughout the year, the Solar Eagle III has visited dozens of junior and senior high schools, ride-share fairs, environmental and transportation related events, and corporate and legislative recognition events. In addition, through this grant hundreds of posters, buttons, flyers, and a Mattel Hot Wheels version of the Solar Eagle III were designed and distributed to high school teachers, counselors, and students along with other important constituents of the school. In addition, it was possible to cover a portion of the costs to produce a 20-minute video that chronicles the Solar Eagle III Project and its exciting story.

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Potential Use of Halogenated Tetraphenylporphyrins in Nonlinear Optical Materials

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Date of Original Award:

INTRODUCTION
Organic materials have hyperpolarizabilities that are orders of magnitude larger than inorganic compounds, and thus offer greater second- and third-harmonic generation capabilities. Furthermore, organic molecules may be incorporated into polymeric materials with specific chemical and mechanical properties, which may be made suitable for data storage or communications devices. Porphyrins are an important class of cyclic conjugated tetrapyrrole molecules, essential constituents of a number of important biological systems.

RESEARCH ACCOMPLISHMENTS
The effect that fluorine and chlorine substitution has on the nonlinear optical properties of porphyrin, tetramethylporphyrin, and tetraphenylporphyrin has been theoretically studied. The calculations of nonlinear optical properties have been obtained by performing finite-field calculations on structures determined by semiempirical methods. In addition, tetra (p-chlorophenyl)porphyrin and tetra(p-bromophenyl)porphyrin were synthesized by the condensation of pyrrole and the appropriate aldehyde. Thin films of polymethylmethacrylate containing these materials were obtained by spin coating onto glass substrates. The films were characterized by third-harmonic generation. It was determined that the experimental conditions enhanced the third-order polarizability of the tetraphenyl porphyrins by a factor of about 1.6.

STUDENT ACHIEVEMENTS
Two students from Spelman College, Celeste Roney and Shani DuMaurier, have been partially supported by this grant during the Fall of 1998. The results of this investigation were presented at the NASA University Research Centers Conference in Huntsville, Alabama in February 1998, and at the NSF-NARCE Conference in Mayagüez, Puerto Rico in February 1998.

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Plastic Optical Fibers for Electro-optical, All-Optic and Optical Sensing Applications

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INTRODUCTION
Electro-optical (EO) modulator technology based on nonlinear processes has the potential to increase the speed of optical communications by a factor of up to 10,000 over existing technology. Plastic Optical Fiber (POF) technology will likely be the best approach to bring optical communications to the general public through the use of distributed POF local area networks. The goal of this project is to marry both technologies into one device system, potentially simplifying the overall initial implementation of broad bandwidth optical modulator technology. This research attempts to incorporate metal electrodes (such as Indium) into optical fibers, blending a combination of metallurgy and plastics technology into a composite material system.

The main thrust of the project at this time is the development of a plastic optical fiber capable of in-line electro-optical modulation. Such a device, outlined in the original proposal, consists of at least one wave-guiding core, preferably single-mode,

and two electrodes capable of supporting a sufficient voltage drop to enable modulation using the linear electro-optical effect. The electro-optical effect is enabled by including a polar dye in the region between the electrodes.

Two approaches can be utilized to create the wave-guiding cores. The cladding around the core can be polymerized, or the cladding around a Teflon-coated wire can be polymerized; this is then withdrawn, a core fiber is inserted, and the core and cladding are squeezed together.

RESEARCH ACCOMPLISHMENTS

Unfortunately, the first procedure involves polymerizing around a core that is soluble in the monomer that makes up the cladding. Consequently, the core dissolves while the cladding is polymerized. An attempt has been made to slow the dissolution of the core by either esterifying cross-linking groups to the surface of the fiber, impregnating the fiber with long chain alcohols (which are non-solvents for the monomer of the cladding), or coating the fiber with silicone oils and grease (also non-solvents for the monomer of the cladding). The impregnation with long chain alcohols works best, and enhances the lifetime of the core in the monomer of the cladding by at least an order of magnitude, though still short of the time necessary to assure polymerization of the cladding. This endeavor is ongoing, though success has been limited; it appears that the first EO fibers will not contain a core and will be crude multi-mode device structures until this procedure is worked out.

Incorporation of metal electrodes has been tricky. Indium was chosen because it is malleable and has a low melting temperature that corresponds reasonably well with the softening temperature of the polymer. The preform indium wire size must be at least 2mm, or the electrodes do not draw well with the polymer. There has been significant bubbling around the electrodes as well as fracturing of the preform prior to releasing it from the polymerization apparatus. The bubbling problem has been solved by freeze-pump-thaw degassing, while fracturing has been largely eliminated by using thinner-walled glass reaction vessels.

At present, an EO dye, Disperse Red 1 (DR1), is being incorporated in preforms containing Indium electrodes which are then drawn into fibers. However, this dye is being switched to a nitroaniline electro-optical dye, since initial wave-guiding measurements have shown that the orange-red DR1 is too absorptive at the HeNe laser wavelengths preferred for system characterization.

The electro-optical effect requires poling. Poling while pulling the fiber has not yet been demonstrated, but will be attempted shortly. However, multi-mode modulation can still be demonstrated using the quadratic electro-optical effect (QEO). QEO does not require poling, but will still allow the demonstration of simultaneous modulation and wave guiding, and will be the first set of tests on the EO fibers.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Eventually, all signal-processing technologies will shift from electronic to optical. The major reason for this shift is the vast increase in processing speed and bandwidth anticipated for optical components. This project explores the development of one of those technologies. The relevance to NASA is manifold. First, NASA depends on information and data processing; such tasks as orbital trajectory processing and mission analysis and support will involve the need for increased speed and bandwidths. In the long term, deep space missions will require equipment that minimizes power consumption and, more importantly, minimizes component failure. Advanced-generation optical components will likely last many times longer than electronic and magnetic components. For instance, it is thought that CD-ROM optical storage of digital data will last at least 30-50 years, while magnetic storage might at best be good for only a few years before significant defects spoil the media.

BENEFITS TO SOCIETY

The development of optical signal processing technology and the underlying materials that enable the necessary devices and systems to function is both inevitable and desirable because of the vast increases in anticipated speed and bandwidth. As communication technologies require the high-speed transmission of large amounts of data, faster systems will become vital. This is already evident in the case of the Internet, where there is an ever-increasing demand for faster communications. High-speed optical modulators are under development throughout the world. This project addresses an overlap of some of the niche areas of these devices, exploring POFs (likely to be the choice for local area networks in the future), nonlinear electro-optical modulation, and hybrid device structures integrating both.

STUDENT ACHIEVEMENTS

One student, Mr. Albert Paralez, has completed his

undergraduate chemistry degree and is matriculating to our graduate program to continue on the project as the subject for his master's thesis. Mr. Paralez also presented this work at a NASA Alliance for Nonlinear Optics Meeting at New Mexico Highlands University in July of 1998.

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Electro-optical Effect on Thin Organic Films of 3-Nitroaniline and 2-Cyclo-octylamino-5-nitropyridine

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SUMMARY
During the last year, efforts were concentrated on studies of nonlinear properties of organic materials. The goal of these studies was to investigate and explore possible application of organic materials for device fabrication. The above-mentioned materials, 3-nitroaniline and 2-cyclo-octylamino-5-nitropyridine, were chosen because they posses very high coefficients of nonlinear hyperpolarizability and susceptibility. This makes them good candidates for applications in nonlinear devices where low electromagnetic energy density is sufficient. One of the very successful projects that was started with unique results was an electro-optical effect on thin organic crystals. The uniqueness of these results is in the observation of the electro-optical effect using longitudinal geometry, and a high magnitude for the figure of merits of the compounds that were studied. A cell-double frequency generator and linear (Pockels) and quadratic (Kerr) electro-optical devices were fabricated for light intensity modulation. In addition to very high optical susceptibility due to the material properties, these devices are very simple in shape and miniature in size. The device fabricated has a shape that allows one to very easily orient the device with respect to the incident beam, thus achieving the highest efficiency of performance. The size of the device is approximately 15 mm, which is much smaller than that one based on KDP (potassium dihydrogen phosphate) crystal. The thickness of the film (on the order of a few microns) allows one to obtain an electro-optical effect of the same magnitude applying low voltage (not exceeding 10 V), while the inorganic-based Pockels cells require the application of at least 5,000 V. This approach opens a new avenue towards studies and applications of this method to the fabrication of diffraction and electro-luminescence devices.

INTRODUCTION
Electro-optical (EO) devices are important as high speed, reliable, and cost-effective components for many applications, such as communications, analog and digital signal processing, information processing, optical computing, and sensing. Inventing modulators, multiplexers, couplers, and so forth has made significant contributions. Among the materials that have attracted attention as candidates for fabrication of these devices during the last decades, the organic ones are the most promising because some of them revealed an extremely large nonlinear optical activity as compared with inorganic materials. Organic materials have also been proposed for electro-optical device fabrication as having high natural birefringes.

In contrast to inorganic material based EO devices, the nonlinear phenomena in organics are due to the electronic properties; therefore contribution from the lattice vibrations is negligible. This property raises the possibility of producing very high-rate signal processing devices, exceeding inorganic-based devices by at least 3-4 orders of magnitude. However, organic materials are fragile with respect to chemical and mechanical damage. To prevent decomposition of an organic material-based device is a real challenge. Our approach to thin crystalline film growth and device fabrication was based on an invented plate-guided (PG) method. The PG method is a variation of the known Bridgman method using a fused quartz cell with a thickness from 0.5 to 500 microns. The crystal thus grown is protected from chemical and mechanical damages, and could be used to envelop the cell.

The objectives were to study the electro-optical effects, linear and quadratic, on thin organic films of meta-nitroaniline (mNA) and 2-cyclo-octylamino-5-nitropyridine (COANP), using longitudinal geometry, collinear light propagation, and application of an electrical field and to assemble the indium-tin oxide (ITO) deposition system for electro-optical cell fabrication. COANP and mNA have been chosen as showing high nonlinear activity.

RESEARCH ACCOMPLISHMENTS
During the last year, a cell was designed for electro-optical measurements, thin crystals of mNA and COANP were grown, the electrooptical effects (Pockel and Kerr) were measured, and efforts continued in assembling a new ITO deposition system. For fabrication of the EO, the cells previ-

ously invented for the second harmonic generation (SHG) studies on thin organic films were used. The cell was modified by carving a radial groove on both the cell and the lid, with a length of 3 mm from the edge of the cell. Then a 250 nm thick transparent and conducting ITO layer was deposited on the inner surfaces of the cell and the lid. Golden terminals were attached to the ITO surface via the radial groove. Then a microscopic dose of either mNA or COANP was placed on the cell, covered with the lid, fused on a hot plate for crystallization, then transferred into a heat exchange chamber on a polarizing microscope. The compound has been recrystallized a few times to obtain a good quality seed, from which the crystal was grown.

The Pockels effect was characterized by an AC modulation method, which is similar to, but more practical than that reported by Yoshimura. A 632.8 nm He-Ne laser was employed as the light source. Two Glan-Thompson polarizers were used as a polarizer and an analyzer, and a Fresnel double rhomb (FDR) was used to rotate the plane of polarization. After passing through the polarizer and the FDR, the light beam was incident on the cell, then through the analyzer, and finally detected by a silicon photo detector. An oscilloscope monitored the beam intensity. A sinusoidal modulated voltage with a frequency of (=1 kHz and amplitude up to 10 V was applied to the quartz plates through a function generator. Pockel's effect was examined when the output signal was sent to a lock-in amplifier and compared with the reference signal at 1 kHz. The Kerr effect was analyzed in a similar way.

The Pockels effect of the COANP crystal in the cell was examined with the AC modulation method. External voltage, both DC and AC, were applied to the crystal through two ITO electrodes. The DC bias was always set at zero for linear Electro-optical measurement (Pockel's effect) because there was no significant change when the DC bias changed from 0 to a few volts. It was necessary to ensure that a measured signal was linear with the electric field applied. For arbitrary angles of the Fresnel double rhomb (FDR) and the analyzer, without an external field, the output light was a DC signal. However, when an AC voltage was applied and increased from 0 to 9V, with an interval of 0.5 V, then reversed, the output light was modified correspondingly. A small AC signal, which was the same as that of the DC voltage, was added to the DC signal. The output-modulated intensity depended on the applied amplitude of AC voltage.

The Pockels effect of the COANP and mNA cell depended on the orientation of the cell to the light beam. The phase shift (0 and angle between FDR and analyzer (were estimated to be 90(and 38(, respectively. The experimental results can be well fitted with the theoretical calculations. ((was estimated as 2.5(10-4 and the figure of merit was estimated as 4.2(10-12 m/V. These values did not change significantly within 10 months.

Four papers on the Electro-optical effect were published. Additionally, two patents were applied for.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The achievements on thin crystal growth and Electro-optical effects are of importance for NASA activity as well as for other agencies and industry. First, it was possible to show and fabricate miniature devices for nonlinear optical performance such as second harmonic generation (SHG) and Electro-optical Pockels and Kerr cells. The threshold of the cells for the SHG is very low, and allows one to observe the frequency doubling at a very low fundamental beam intensity. Second, the Electro-optical cell operates at a very low driven voltage, not exceeding 5-6 V. To our knowledge, this is the first device fabricated and operating at such a low voltage. Third, all of the devices are very miniature, and will allow significant space to be saved in applications such as the Space Shuttle. Finally, these cells will be useful in studying the processes of crystallization in micro-gravity.

BENEFITS TO SOCIETY

The benefits of our achievements to the society and to the average citizen are the potential for advanced devices for applications in communications, optical computing, the laser industry, and so forth.

STUDENT ACHIEVEMENTS

More than 10 undergraduate and graduate students participated in these projects. In addition to taking theoretical courses on optics and spectroscopy, they also conducted experiments on the topics described above. These included crystal growth, assembling experimental set-ups, conducting measurements, analyzing data, writing reports and papers, and delivering talks at national and international conferences. Some of the students are co-authors in papers published in peer-reviewed journals and in patents.

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[AHO1] Unknown place.

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