Electrical & Computer Engineering Research Projects 2009-2010

GaN II-EBIC (Year-2), FREEDM Core Project
B. Jayant Baliga
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
07/01/09 - 08/31/10
This is a newly formed project for FREEDM that is funded from the Industry Pool Project 529737 - see attached documents

GaN Impact Ionization Characterization for Generation 2 Power Devices
B. Jayant Baliga
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
09/01/08 - 08/31/09
To obtain accurate Impact Ionization Coefficients for GaN to allow precise design of Generation 2 GaN Power Devices.

PSD-Y1-04 Generation 2 SST and FID SiC Power Devices
B. Jayant Baliga, Alex Q. Huang
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
09/01/08 - 08/31/10
See attached supporting documents. This is a continuation of Project 529669 from the prime FREEDM project 529598

Development of FREEDM System Control and Digital Testbed, Center Core Project
Mesut E. Baran
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
07/01/09 - 08/31/10
See supporting documents - this is a NEW FREEDM project that will be funded from research funds from FREEDM Industry pool 529737.
The project objective is to test the effectiveness using Branch Current State Estimation (BCSE) program for allocating feeder loads by phase, using information from Automated Metering Infrastructure (AMI) and Distribution Supervisory Data Acquisition and Control devices. Load allocation is one aspect of the larger load and state estimation problem for distribution systems. Distribution automation and AMI projects offer the promise of improved state estimation on distribution systems.

Effective management of distribution systems requires analysis tools that can estimate the state of the system (the operating condition). This project aims at development of two new analysis tools for this purpose. The main tool is the state estimator that will use the historical data and the real-time data to estimate the state of the system which is the voltages at all the nodes of a distribution feeder. The second tool will be a load estimator which will characterize the loads based on limited customer load data to be obtained from automated meter readers.
This project has two objectives. The main objective is to develop a notional Freedm system simulation model. The system will be realistic enough to capture the system dynamics and component interactions that will occur on an actual 12kV distribution system. This notional system will be used as a common system for many of the studies for Freedm, especially during the early stages of development, such as system level simulation, component design, and control applications. The notional system will be delivered to the other teams who will need it to develop other applications for it. The second goal is to study functional performance of the notional system and demonstrate its proposed capabilities.

100A, 300 to 1200 V GaN Power Device Development
Alex Q. Huang, Douglas W. Barlage
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
09/01/08 - 08/31/09
To develop high current (up to 100A) and low voltage (300V to 1200V) GaN power switches for secondary side of the solid state transformer. The initial goal is to achieve 100A/300V for Gen-2 SST.

CAREER: Low Dimension Column III-Nitride (III-N) Metal Oxide Semiconductor (MOS) Structures for Terahertz and Gigascale Electronics
Douglas W. Barlage
National Science Foundation
$400,112
04/01/06 - 03/31/11
The focus of this supplementary effort is to focus on small-signal parameter extraction for novel MOS devices and support the ongoing process development efforts that are the central focus of this proposal. Measurement in the 1 to 10 GHz range requires the low-frequency FET model to be modified such that it includes additional components that describe leakage, transconductance delay, and dispersion, if necessary. Due to the frequency range and geometry of the devices measured, S-parameters are the means of characterization. While GaN transistors have already been modeled and are currently sold commercially, this work investigates parameter temperature dependence and dispersion phenomena. Dispersion is an undesirable feature that reduces gain by reducing output resistance. It is more common to heterogeneous structures and devices that suffer from trapping effects. By understanding the origin and form of the dispersion phenomena better devices can be fabricated and more useful circuits designed.

GaN-Based Schottky Diodes For Power Converters in X-band Radar Power Supplies
Mark A. Johnson, Douglas W. Barlage
Kyma Technologies, Inc (formerly Carolina Sputter Solutions)
Investigation of the Metal Organic Chemical Vapor Deposition (MOCVD) epitaxial growth of Gallium Nitride based Schottky diode test structures on company supplied substrates for device fabrication. Subsequent diode test structures will be fabricated by company into diode structures for testing. Correlation between crystal defects in Gallium Nitride epitaxial layers and Schottky diode electrical characteristics are an intended area for investigation.

Dilute Magnetic Semiconductor Devices Based on Fermi Level Engineering
Nadia A. El-Masry, Salah M. Bedair
Army Research Office
$481,305
10/01/07 - 09/30/10
The objectives of proposed research are to investigate the effects of the built-in polarization field upon the FM and optical properties of GaN crystals doped with a magnetic dopant such as manganese or a rare earth element. Two main tasks are involved in this effort: (a) diffusion of magnetic dopants into polar and non-polar GaN surfaces, and (b) in situ magnetic doping during growth of III-nitride thin films on non-polar GaN surfaces. Following incorporation of the dopant, magnetic and optical properties of the GaN samples are to be characterized and assessed for spintronic device application.

Improved LED Performances by Sidewall Epitaxy on M-Plane Oriented GaN (STIR)
Salah M. Bedair, Nadia A. El-Masry
Army Research Office
$50,000
06/01/09 - 02/28/10
The current state of m-plane GaN bulk substrate is presently limited by tiny, very expensive substrates. We avoid the use of small a-plane and m-plane substrates. We propose to investigate sidewall epitaxy on the etched m-plane facet of GaN/Sapphire. The sidewall epitaxy approach is less traditional than previous LED device structures; it provides the following distinct device advantages such as: 1. High quality, low defect materials due to the advantages of lateral growth. 2. Elimination of detrimental piezoelectric field effects. The current activities will be focused on LED structures to demonstrate the validity of the proposed concept. Future activities can then be extended to laser diodes.

Tunable Narrow Band Gap Absorbers for Ultra High Efficiency Multi Junction Solar Cells
Salah M. Bedair, Nadia A. El-Masry
US Dept. of Energy (DOE)
$1,147,814
05/01/08 - 04/30/11
The four junction cell requires materials system with band gap $E_g$: 1.9 eV/1.5 eV/1.0 eV/0.67 eV (Ge). Material system with $E_g > 1.43$ eV and lattice matched to GaAs (or Ge) are readily available such as InGaP (Al), GaInAsP and AlGaInAs. However, material system that collects photons in the 1.42 eV to 1.0 eV range and lattice matched to GaAs (or Ge) had proven to be very difficult to achieve. We propose a new sub cell structure to collect photons in the energy range 1.4 - 1 eV. This sub cell will be part of four junction cascade structure. The projected practical efficiency is in the range from 35% to 40% at one sun AM1.5 and efficiency = 45% - 50% at higher solar concentration. NCSU will develop the new sub cell and Spectra Lab will integrate the developed sub cell into their four junction structures.

**Compact Power Conversion Technologies**
Subhashish Bhattacharya, Alex Q. Huang
DRS Power Technology Inc
$85,136
05/01/10 - 07/15/10
Modular Bi-directional Power Converter Modules based on SiC power semiconductor devices Silicon Carbide (SiC) is promising with the potential for major improvements in the power density of power converters, high temperature and high frequency operation, and higher breakdown voltage devices suitable for medium voltage applications. Compared to Si based power semiconductor devices, SiC based devices offer the ability of high switching frequency at high voltage. This project will investigate design and loss evaluations of modular Bi-directional Power Converters based on SiC 10kV MOSFETs and 10kV JBS Diodes.

**Development and Integration of Advanced Lithium-Ion Battery into Power Management System of Small Satellites**
Xiangwu Zhang, Subhashish Bhattacharya
University of Florida
$52,000
02/09/09 - 02/08/11
This proposed work focuses on i) the development and deployment of advanced lithium-ion batteries that outperform the state-of-art batteries and ii) the design of a flexible & scalable digital power management system that integrate advanced batteries and solar cells into small satellites.

**Investigation of Dual Active Bridge DC-DC Power Conversion with SiC MOSFET and SiC JBS Diodes**
Subhashish Bhattacharya
Cree, Inc.
$25,000
11/20/09 - 10/25/10
The goal of this project is to design, develop and test a power converter using the SiC 1200V MOSFET and 1200V JBS Diode to demonstrate weight and size reduction. This project will
design, develop and test a dc-dc power converter based on Dual Active Bridge (DAB) isolated topology with 800V input and 400V output operating at 20 kHz switching frequency. The DAB will be based on SiC 1200V, 20A MOSFET and JBS Diode. A second design and DAB power converter will attempt to increase the switching frequency to 100 kHz. The following tasks and deliverable are planned for this project.

Power Conversion Technologies for Storage Integration
Subhashish Bhattacharya
ABB, Inc
Unfunded
05/17/10 - 05/16/11
This project is to investigate power conversion technologies suitable for storage integration.

SSTGEN1: Design and Development of Isolated Bidirectional DC-to-DC Converter For SST, Verification of SST Controller, and Testing of Gen1 SST System
Subhashish Bhattacharya, Alex Q. Huang, Richard D. Gould
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
09/01/08 - 08/31/10
See attached supporting documents - this is a continuation of FREEDM project 529666 from the prime FREEDM project 529598

Fast and Robust Target Tracking
Griff L. Bilbro
Army Research Office
$50,000
01/01/09 - 10/31/09
We propose to apply our recent SKS technique for matching regions in image pairs to the problem of tracking objects in video sequences. The new tracking technique is expected to inherit the strengths of the underlying SKS technique, including computational efficiency as well as insensitivity to partial occlusion, rotation, translation, zoom, and brightness.

Architectures and Applications for Three-Dimensional Chip Multiprocessors
Gregory T. Byrd, William R. Davis
National Science Foundation
$300,000
05/15/07 - 04/30/11
This project will investigate multi-core architectures, advanced design tools, and highly-parallel applications to exploit three-dimensional integrated circuits (3D ICs) for significantly higher performance and reduced power, compared to traditional two-dimensional multi-core chips. The use of emerging 3D IC technology has primarily focused on shrinking existing designs,
achieving shorter wire delays and lower power dissipation without scaling transistor size. This work concentrates on the next-higher level of abstraction: the best mechanisms to integrate multiple processing cores into a powerful parallel computing engine.

**Energy-Efficient Multicore Processing For Mobile Platforms**  
Gregory T. Byrd  
Qualcomm  
$41,438  
09/01/08 - 09/01/09  
Energy consumption is a paramount concern in mobile consumer devices, such as cell phones. This project will investigate and prescribe ways to use emerging multicore architectures to reduce energy consumption for applications running on the mobile device, such as web browsers, media players, and so forth.

**Exploiting Multicore Parallelism in the Control Plane, CACC Core project**  
Gregory T. Byrd  
NCSU Center for Advanced Computing & Communication  
Unfunded  
07/01/09 - 06/30/10  
While much networking research is geared toward increasing throughput in the data plane, recent routers have experienced scalability problems in the control plane. The number of logical and physical interfaces is increasing, as is the complexity of router protocols and management services. This proposal aims to explore ways in which multicore and many-core processors can be used to address the scalability problems, in terms of both performance and programmer productivity. First, we will select some open-source codes that are representative of interesting control-plane applications. Then, we will evaluate the concurrency present in those codes, determining which can benefit from a multicore approach. Finally, we will evaluate various architectural mechanisms (e.g., transactional memory, cache hierarchies and protocols, speculative memory accesses) that can improve scalability and performance, and/or make the parallel codes easier to write and maintain.

**IPA Agreement with Asian Office of Aerospace Research & Development**  
Jim C Chang  
US Air Force (USAF)  
Unfunded  
01/31/06 - 01/30/10  
IPA Extension for Jim Chang

**IPA Agreement with US Army Research Laboratory**  
Jim C Chang  
US Army Research Laboratory (ARL)  
$194,564  
03/01/10 - 02/29/12  
IPA Agreement: no abstract required.

**Multiscale Issues and Simulation-Based Science and Engineering for "Material-by-Design"**
Jim C Chang  
US Air Force-Office of Scientific Research (AFOSR)  
$64,373  
12/01/09 - 02/28/10  
Through actively participation, engagement and steering community activities and literature survey, this project is to evaluate the progress and the state-of-the-art of the multiscale research issues, and to arrive at a strategy for planning and execution of programs to achieve the vision of "material-by-design".

Center of Excellence in the Area of Human and Robotic Structures Technologies for Lunar and Planetary Exploration  
National Institute of Aerospace  
Unfunded  
10/01/02 - 09/25/12

Collaborative Research: GOALI: Ais Gene Library Based Real-time Resource Allocation On Time-sensitive Large-scale Multi-rate Systems  
Mo-Yuen Chow  
National Science Foundation  
$197,984  
09/01/08 - 08/31/11  
This project uses Gene Library to classify and detect abnormality in vehicle movements in various traffic environments and to provide optimal real-time sampling rate adaptations and emergency interventions. The gene library stores relevant information in the memory for real-time fetching to avoid on demand optimization and computation. Artificial Immune Systems (AIS) optimization is used to tune the gene library so that the gene library can be used in real-time as well as can adapt to its environment for optimal solutions. The primary purpose is to prevent accident caused by abnormal behavior of the impaired drivers during driving.

Distributed Control of FREEDM System (former Distributed Grid Intelligence)  
Mo-Yuen Chow  
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)  
Unfunded  
09/01/08 - 08/31/10  
See attachments of documents - - Project renamed "Distributed Control of FREEDM System". This is a continuation of segment 529670 from the prime FREEDM project 529598

Massive Sensor Based Congestion Management System for Transportation System  
Mo-Yuen Chow  
New Jersey Institute of Technology  
$33,405
This research seeks to identify the quantitative requirements for implementing congestion planning using massive real time, sensor data. Specifically, we seek to investigate data gathering using probe vehicles, data transmission using wireless communications, massive data processing, and model building to analyze congestion relief strategies for near- and long-term planning purposes. The deliverables of this proposed work include a set of software tools for analyzing congestion relief strategies, covering all aspects from data gathering to planning. Hardware demonstration includes a preliminary prototype system consisting of a probe vehicle, iSpace communication, and congestion planning.

Small World Stratification For Power System Fault Diagnosis With Causality
Mo-Yuen Chow, Simon M. Hsiang
National Science Foundation
Unfunded
09/01/07 - 08/31/11
The REU student is expected to: - Involve in group research meetings related to the NSF ECS-0653017 project; - Assist the Graduate Research Assistant of this project to prepare and produce simulation study on the data mining on the GIS data of the power distribution systems; - Assist to develop and update the Web of this NSF project for public information dissemination.

CESR Membership Agreement
Gregory T. Byrd, Thomas M. Conte
Cisco Systems, Inc.
Unfunded
01/01/08 - 12/31/10
The Center for Efficient, Scalable and Reliable Computing researches, designs, and builds computer systems that are Efficient, Scalable and Reliable. Increasingly, these are the key requirements for a wide range of computing systems --- from ASICs to cell phones to corporate servers: efficient in their use of energy, space, and memory; scalable in performance and cost; and reliable in the face of high transaction rates and adverse environments. We address these challenges through research in VLSI design, processor architecture, compilers, operating systems, memory systems, system architecture, and application software. This proposal is for Center membership of one of our industrial partners.

Collaborative Research: Collaborative Quickest Detection in Ad hoc Networks with Application in Cognitive Radio
Huaiyu Dai
National Science Foundation
$93,326
09/01/08 - 08/31/11
This project studies collaborative quickest detection in ad hoc networks, in which nodes exchange observation statistics and make local decisions about distribution change. In contrast to existing theory of decentralized quickest detection, the collaborative quickest detection does not need a data processing center, thus avoiding the round-trip time overhead and possible data congestion. Moreover, collaboration can enhance the agility and robustness of the detection of change. This research involves aspects of statistical signal processing (e.g. detection rule), information theory (e.g. source coding) and networking (e.g. scheduling or broadcast).

WN: Collaboration of Networked Nodes through Belief Propagation: Where Computing Meets Communications
Huaiyu Dai
National Science Foundation
$195,958
09/01/07 - 08/31/11
This project concerns distributed information processing in wireless networks through node collaboration. The aim is to exploit relevant methodologies from mathematical and artificial intelligence research to design robust, scalable, and energy-efficient algorithms and protocols, and provide solid performance analysis, explicitly considering practical communication constraints. Two general research philosophies thread throughout the proposed research: first, exploitation of application-specific and data-centric nature of wireless networks, and second, joint consideration of issues across different layers.

Architectural Evaluator For Three-Dimensional Integrated Circuits
William R. Davis, Paul D. Franzon
Semiconductor Research Corp.
$240,000
07/01/08 - 07/01/11
One of the primary drivers for new systems-on-chip is increasing memory. Studies of memory cost have predicted that as memory density increases, 3D integration becomes necessary to reduce cost-per-bit. This project will create an easy system for evaluating the performance of a new system-on-chip in a 3D process. This three-year research project will develop an open-source CAD framework and process design kit (PDK) and predictive memory generator to greatly simplify the task of evaluating the marginal cost of adopting 3D integration.

CAREER: Design Methodologies for Three-Dimensional Integrated Circuits
William R. Davis
National Science Foundation
$409,643
04/15/07 - 03/31/11
The goal of this 5-year project is to develop the fundamental design methodologies needed to make three-dimensional integrated circuits (3D ICs) a viable alternative to continued scaling of transistor gate lengths. The first objective is to develop the techniques needed to design 3D memories, clock-trees, and floor-plans. The second objective is to research methods for thermal verification. The third objective is to search for new computing applications with latency and
power that cannot be achieved with traditional IC technology. This project will also improve engineering education by developing a free design kit for the latest integrated circuit technology.

FreePDK: An Open-Source, Variation-Aware Design Kit
William R. Davis, Paul D. Franzon
Carnegie Mellon University
$50,250
09/01/07 - 10/31/09
This work will create an open-source, variation-aware 45nm PDK (Process Design Kit) for use in VLSI education and small-businesses. This kit will include the necessary layout design-rules and extraction command-decks to capture layout-dependent systematic variation and perform statistical circuit analysis. The kit will also include a standard-cell library with the necessary support files to enable full-chip place & route and verification for System on Chip designs.

Test Bed For Steep Subthreshold-Slope Transistor Circuits
William R. Davis
Wyle Laboratories
$118,830
08/19/08 - 02/28/10
The DARPA STEEP program seeks to demonstrate transistors with delays of less than 5 ps, off-state/on-state power reduction of 10X/4X in phase I and 100X/25X in phase II. This work proposes to create a baseline-circuit test-bed for measuring delay and power of simple circuits to evaluate whether or not the goals of the STEEP program have been met.

CSR--EHS Rapid Efficient Implementation of Communication Protocols for Embedded Systems
Alexander G. Dean, Mihail L. Sichitiu, Thomas G. Wolcott
National Science Foundation
$337,000
08/15/05 - 07/31/09
In this project we propose to develop methods, a toolbox and an associated communication framework to allow users to quickly implement software-based controllers for customized network communication protocols. More specifically, we will provide a complete networking stack featuring several options at each layer in the stack. Users will select specific protocol characteristics, and the tools of the framework will generate (and compile) the code that implements the specific protocol options for the desired application.

CSR-EHS: Integrated Memory Allocation and Scheduling for Real-Time Embedded Systems
Alexander G. Dean, Eric Rotenberg
National Science Foundation
$180,000
Real-time embedded systems execute multiple tasks within fixed time-constraints, i.e., deadlines. A large body of work has been developed for formally constructing real-time schedules in which all tasks satisfy their deadline constraints. Traditionally, real-time scheduling abstracts the processor in a gross way, without underlying details. This overly abstract framework is no longer sufficient given the complexity of memory hierarchies in contemporary embedded systems. There are at least two problems. First, there is little support to real-time system designers for transparently managing the memory hierarchy given real-time constraints. Second, by ignoring the memory hierarchy, there is lost opportunity for jointly allocating memory to tasks and scheduling the tasks. Conventional scheduling algorithms may not yield the best performance or power, compared to our new scheduling algorithms influenced by memory constraints.

Ultrasonic Communications for Down-Hole Applications: A Feasibility Study Proposal
Alexander G. Dean
Weatherford International Ltd.
$85,161
09/01/09 - 08/30/10
The goal of the proposed supplemental work is to adapt an existing ultrasonic underwater communication system (developed for the RaPTEX project at North Carolina State University) for communication in down-hole applications in the oil and gas well industry.

Network Visualization and Optimization through Accurate Traffic Characterization
Mihail Devetsikiotis, Harry G. Perros
NCSU Center for Advanced Computing & Communication
$38,400
07/01/09 - 06/30/10
We design a passive network monitoring tool able to characterize new applications, provide early warning for security incidents and provide measurements to the community through a web-based NCSU/NCREN network map. We also develop a traffic modeling mechanism to identify the structural dependencies of traffic as it relates to social connectivity graphs and distances. Specifically: (1) we conduct trials to capture data and identify the emerging traffic patterns; (2) we use the trial results to analyze networking and social distances of next generation users; (3) we incorporate these traffic patterns into a queueing model for end-to-end delay and packet loss rate.

Networked 3D Virtual Computing for Collaborative Environments in Science and Education: Towards VCL 3.0
Mihail Devetsikiotis, Mitzi M. Montoya-Weiss
NCSU Center for Advanced Computing & Communication
Unfunded
07/01/08 - 12/31/09
The objectives of this project are to study the communications, computing and social networking
challenges of building effective large-scale, dynamic collaborative environments (CEs) through the VCL. In concert, the VCL and related CEs aim to support virtual work and distributed collaborations especially those that are fundamental to scientific exploration, collaborative visualization, and education.

A Reconfigurable Outdoor Wireless Channel Measurement System
Hans D. Hallen, Alexandra Duel-Hallen
Army Research Office
$267,384
06/07/09 - 06/03/11
Wireless communications systems are widely modeled and measured. The successful model by is used by many groups and forms the basis for understanding propagation effects in a standard wireless system. It only allows statistical description of a channel, however, so is not adequate for testing algorithms whose performance is strongly affected by the precise local environment. In particular, testing these algorithms requires the creation of scenarios that are typical and others that are challenging. An example of such an algorithm is long-range prediction, which has been shown to enable adaptive modulation to achieve significant gains on the wireless channel, and is becoming widely studied. The variation of the channel parameters with position plays a large role in determining the achievable performance of the algorithm. We have developed a physical model to test long-range prediction. It provides the necessary insights for predicting challenging or typical scenarios, and creates simulated channels for testing long-range prediction that include physically realistic parameter variation in space. The physical model compares well with measurements for narrow band channels in a suburban environment, as judged by the performance of the long-range prediction algorithm. This is in contrast to the prediction of a Jake's model simulated channel, which does not include physically meaningful parameter variations (it is stationary). As we modify the model to other situations, such as prediction at a frequency other than the one sampled, prediction near complex scattering objects, and peer-to-peer systems that utilize sectored antennas, we have moved well beyond comparison of the model to measured channels. The measurements needed to verify the model in these cases are too involved and need too much interaction with model building to be realistically carried out by a remote group. We therefore propose here to purchase equipment and develop the measurement capabilities to insure that the models are reasonable and to develop insights to further enhance the model for these and future projects.

Channel Modeling and Adaptive Transmitter/Receiver Design for Outdoor Ultrawideband Communication Systems
Alexandra Duel-Hallen, Hans D. Hallen
National Science Foundation
$74,861
03/15/08 - 08/31/09
The objective of this research is to alleviate potential outages in outdoor Ultrawideband systems
due to shadowing and other challenging propagation environments by exploiting the frequency-
dependent distortion of individual multipath components. The approach is to create a novel
physical model and to use it in testing robust receiver algorithms and adaptive transmission
methods for outdoor Ultrawideband systems. This research is an interdisciplinary effort in
communication theory, physics, and signal processing.

**Attitude Control System for a Pico-Satellite Plug-and-Play System**
William W. Edmonson
University of Florida
$45,947
09/03/08 - 12/31/09
Development of miniaturized attitude control systems (ACS) that significantly increase the
agility of small satellites is desirable. A redundant CMG (r-CMG) actuation system can be
designed to be cost effective and responsive. This is accomplished through the use of a
standardized self-contained design actuator that is spacecraft independent. The redundancy
allows for more sophisticated control and steering logic capabilities. The proposed project will
be to develop a complete standalone r-CMG that will also include the digital processing unit for
computing the control dynamics, and sensor inputs from GPS and Star Tracker.

**Collaborative Research: Advanced Space Technologies Research and Engineering Center**
William W. Edmonson, Winser E. Alexander
National Science Foundation
$224,000
08/01/08 - 06/30/13
Small satellites complements the services provided by larger satellites by providing cost effective
solutions to communications, remote sensing, and rapid response science and military missions.
This proposal is to establish a collaborative NSF I/UCRC between University of Florida and
North Carolina State University. The Advanced Small Satellite Technologies Research and
Engineering Center objective is to develop technology that produces improvements in time to
orbit, cost, and performance of satellites. The Center will perform multidisciplinary research in
the areas of small satellite technologies in the pico/nano-class. The expected first demonstration
project will address on-orbit services such as debris removal.

**IPA With NASA-LaRC For William Edmonson**
William W. Edmonson
National Aeronautics & Space Administration (NASA)
$87,856
06/01/09 - 12/31/09
This IPA will support the design and definition of a GPS instrument for retrieving radio
occultation data for the Climate Absolute Radiance and Refractivity Observatory (CLARREO)
mission. The CLARREO spacecraft will carry three instruments that will measure the radiated
infrared energy emission, the reflected solar radiation, and atmospheric refractivity with active
limb sounding using GPS receivers for deriving vertical profiles of temperature and pressure. During this IPA term Dr. Edmonson's responsibility will be to serve as the CLARREO GPS RO Instrument Systems Engineer and lead the conceptual design of a GPS RO instrument.

**MPCore Mapping Tool Research**  
William W. Edmonson, Winser E. Alexander  
ETRI (Research Inst.-Electronics & Telecommunications)  
$40,000  
10/01/08 - 12/31/09

Reconfigurable computer architectures are able to bring flexibility and computing power to execute today's applications. However, mapping on these reconfigurable platforms in an efficient way is still a problem that has not effectively been solved. High-level design entry tools are essential for reconfigurable systems, especially coarse-grained reconfigurable architectures. However, the mapping tools for coarse-grained reconfigurable architectures are far from mature. This research proposes a method for mapping applications onto a coarse-grained reconfigurable architecture. We propose a mapping methodology that tackles the complex problem in four phases: translation, clustering, mapping and allocation.

**Precision Attitude Control Methods**  
William W. Edmonson  
University of Florida  
Unfunded  
02/09/09 - 07/31/10

This effort will focus on development and implementation of advanced control methods for CMG actuated satellites. Initial will focus on the development and implementation of adaptive attitude controllers that exploit redundancy of the CMG configuration for precision attitude control.

**Technology Roadmap/Design Center Development**  
William W. Edmonson  
University of Florida  
$32,000  
02/09/09 - 07/31/10

This work involves two projects that will provide direction and a systematic design process. The Center’s 5 year plan will be addressed through the creation of a technology roadmap, which will identify critical satellite subsystem technologies and associated technology gaps. The design center development will provide the Center with design tools and processes for researchers to do architecting and development.

**CAREER: Complex Polarization Gratings? Extreme Fresnel Zone Plates, Agile Vortex Beam Tools, and Enhanced Distributed-Feedback**  
Michael James Escuti
The overall objective is to develop liquid crystal (LC) polarization gratings (PGs) for novel photonic elements (Fresnel optics, vortex beam tools, and polymer lasers) with exceptional control over the intensity, direction, orbital angular momentum, and polarization of light. First, develop PG-based Fresnel zone plate optics, with potential for remarkably small f-numbers, unique polarization behavior, and compelling switchable lens devices. Second, investigate efficient and scalable helical (vortex) beam tools, based on forked PGs, with unprecedented ability to generate and measure orbital angular momentum. Third, employ small-period gratings (sub-micron) to investigate distributed feedback effects.

Enhanced Polymer Polarization Gratings for Reflective Liquid Crystal Microdisplays
Michael James Escuti
ImagineOptix Corp
$215,000
09/14/09 - 09/13/10
The PI and team will investigate polymer Polarization Gratings (PGs) optimized for reflective Liquid Crystal (LC) microdisplay projector systems. The target is to employ optical techniques and materials improvements to develop PG elements that produce enhanced extinction ratio and brightness of a PG-based projector using a reflective LC microdisplay, and to develop PG processing techniques and tools that enable commercially viable fabrication. As part of the effort, the NCSU team will coordinate and interact with the sponsor and with various microdisplay, projector, thin-film manufacturing, and optical companies, who are engaged by the sponsor.

High Energy Testing of Polarization Grating Beam Steerers
Michael James Escuti
Science Applications International Corporation (SAIC)
$48,939
10/13/09 - 01/31/10
For the purposes of this proposal, the PI will provide the US Army Space and Missile Defense Command with multiple liquid crystal polarization gratings (LCPGs), assembled into two wide-angle beam steering prototypes: (I) a one-dimensional, discrete, non-mechanical, electrically-switchable LCPG ternary beam steerer; and (II) a two-dimensional, continuous, mechanical, polymer PG beam steerer (known as a Risley Grating pair). We will optimize the material properties for PG operation at a near-infrared wavelength (1.550 or 1.064 μm to be determined by the sponsor), which will involve both theoretical modeling and experimental fabrication.

Midwave Infrared Polymer Polarization Gratings for Beam Steering
Michael James Escuti
Boulder Nonlinear Systems
$27,416
04/01/09 - 10/31/09
For the purposes of this proposal, the PI will provide Boulder Nonlinear Systems (BNS) with multiple polymer polarization gratings (PGs), on glass substrates provided by BNS. We will optimize the material-properties for PG operation at midwave infrared (MIR) wavelengths (4.5-5 μm), which will involve both theoretical modeling and experimental fabrication. The number of final delivered gratings will be as follows: x28 polymer PGs (circular-type), and up to x10 intermediate development samples. The deliverables will have the following specs: 4.5 cm diameter clear aperture, +/-7.5 deg diffraction angle (at 4.5 um), and approximately 99% diffraction efficiency into steered order.

Modular Laboratory Experiments on Organic Electronics and Liquid Crystal Displays for Undergraduates
Michael James Escuti
National Science Foundation
$154,410
01/01/07 - 07/31/09
The overall goal of this proposal is the development of a series of laboratory experiments for advanced undergraduate electrical engineering students that give hands-on experience with organic electronic materials and liquid crystal display technology. Inherently modular laboratory experiments are proposed for the fabrication and characterization of four devices: a single-pixel liquid crystal display (LCD), a polymer light-emitting-diode (pLED), a polymer field-effect-transistor (pFET), and an organic photo-voltaics (OPV). We will also design a comprehensive lab manual and identify a low-cost "kit" of materials and equipment necessary for its implementation, in such a way as to be inherently transferable to other universities.

Polymer Polarization Gratings For Liquid Crystal Microdisplays
Michael James Escuti
ImagineOptix Corp
$246,219
05/01/08 - 07/31/09
For the purposes of this proposal, my university lab at NCSU will provide ImagineOptix Inc with multiple polymer polarization gratings (PGs) on glass substrates for the purposes of integration into a transmissive-mode liquid crystal microdisplay projection system. We will optimize the material-properties of polymerizable liquid crystals for achromatic PG operation in the context of an LC projector system, which will involve both theoretical modeling and experimental fabrication.

Reduced-Dispersion Beam Deflector for LED Source
Michael James Escuti
Boulder Nonlinear Systems
For the purposes of this proposal, the PI will provide Boulder Nonlinear Systems (BNS) with an assembly of multiple switchable polarization gratings (PGs) on glass substrates (provided by BNS), for the purposes of developing a simple beam deflector (steerer) for a light-emitting-diode (LED) light source. A key aspect of this research is to implement and evaluate techniques that will reduce or eliminate the chromatic dispersion of the steered beams.

Risk Reduction Study of Near-Infrared Liquid Crystal Polarization Gratings
Michael James Escuti
Raytheon
$71,095
06/30/09 - 12/18/09
For the purposes of this proposal, the PI will provide Raytheon Network Centric Systems with multiple switchable liquid crystal polarization gratings (LCPGs), predominantly fabricated at NCSU but employing substrates and materials substantially provided by Raytheon. We will optimize the material-properties for PG operation at near-infrared wavelengths (1.064 um), which will involve both theoretical modeling and experimental fabrication.

SBIR Phase I: Low Cost, High Performance, Compact Wavelength Blocker For Reconfigurable Optical Add/Drop Multiplexers
Michael James Escuti
Southeast TechInventures (STI)
$32,937
01/01/09 - 09/30/09
For the purposes of this proposal, the PI will provide Southeast TechInventures (STI) with multiple polarization gratings (PGs) on transparent substrates, in both switchable and polymeric modes. We will optimize the material-properties and fabrication for the purposes of the C and L telecommunication bands (around 1550 nm), which will involve both theoretical modeling and experimental fabrication.

SBIR Phase II Wide-Angle Nonmechanical Steering Development
Michael James Escuti
Boulder Nonlinear Systems
$299,175
10/16/07 - 04/16/10
For the purposes of this proposal, my university lab at NCSU will provide Boulder Nonlinear Systems (BNS) with large-area polarization gratings (5 cm aperture) for beam-steering, including both switchable and polymerized versions. These will be optimized for a near-infrared wavelength (1.5 microns), have diffraction efficiency of 95% or greater into a single order, have low insertion loss (e.g. less than 5%).
Career: A Stochastic Approach to the Design of Communication Networks: An Alternative to Fluid Modeling
Do Young Eun
National Science Foundation
$442,810
03/01/06 - 02/28/12
The aim of this research is to understand the fundamental limitations of the fluid-based approach and of the deterministic optimization for large networks and then to develop a stochastic framework for large networks in which one can compute the performance metrics more accurately, while at the same time exploiting the simplicity caused by the interaction among many users, seeking to obtain new, efficient design guidelines and algorithms for a number of important networking problems including congestion control, network optimization, and peer-to-peer networks.

NEDG: Efficient Design and Control of Heterogeneous Mobile Networks: Beyond Poisson Regime
Do Young Eun
National Science Foundation
$299,872
09/01/08 - 08/31/12
Mobility is central to various applications, from searching for a moving target and rescue mission in military and disaster settings, to deploying mobile ad-hoc/sensor networks for surveillance and data communication over hostile terrain and underwater. While the random mobility pattern of nodes in these networks has been considered as the main source of uncertainty and disruption of communication links, it can also facilitate reliable and predictable performance, if properly controlled and actively exploited. Our goal is to develop a unified methodology for efficient protocol design and control of nodes in heterogeneous mobile ad-hoc networks and delay/disruption-tolerant networks under non-Poisson contacts.

TF-SING: A Theoretical Foundation of Spatio-Temporal Mobility Modeling and Induced Link-Level Dynamics
Do Young Eun, Wenye Wang
National Science Foundation
$270,000
09/01/08 - 08/31/12
The usage of wireless devices unavoidably induces user mobility in diverse settings over multiple space/time scales. The goal of this research is to develop a theoretical foundation for wireless mobile networks, through characterization of link-level dynamics by stochastic analysis approach. Specifically, the research focuses on (i) modeling, analysis, and statistical characterization of mobility-induced link dynamics, (ii) spatio-temporal dynamics in mobility
modeling in multiple space/time scales rather than being dependent on networking environments a priori, and (iii) scaling limits for link-level metrics under various network operating regimes.

**Algorithms and Structures For Self Healing Circuits**

Paul D. Franzon, Michael B. Steer, Mo-Yuen Chow  
Raytheon  
$2,432,796  
07/29/09 - 03/19/11  
NCSU will develop algorithms, sensor and sensor processing circuits for self-healing analog and radio frequency (RF) integrated circuits.

**Computer Aided Design For Digital Trust**

Paul D. Franzon  
Irvine Sensors Corporation  
$120,000  
02/01/07 - 08/31/09  
NCSU will support Irvine Sensors in the development of CAD strategies to ensure that chip sets that can be secured from reverse engineering and tampering attacks

**CPA-DA: Nanocrystal Computing**

Paul D. Franzon  
National Science Foundation  
$400,000  
07/01/08 - 06/30/11  
Research Experience for Undergraduates Supplement.

**Determination of time-temperature history during thermal processing using MEMS and RF telemetry**

K. P. Sandeep, Paul D. Franzon, Josip Simunovic  
Ohio State University Research Foundation  
$48,172  
06/01/09 - 06/30/11  
Researchers have been attempting to address the growing need in the food industry to monitor temperatures at various locations within food products (under batch and continuous flow conditions) to facilitate filing of a process with the FDA, to improve product quality, and enhance food safety measures. In thermal processing of particulate foods, the temperature at the critical point (slowest heating point in the system) is of particular interest. The current study will focus on developing a sensor to measure internal temperatures of particulates in real-time and tailoring it to meet the needs of the food industry.

**Development and Use of Sensors in Validating Aseptic Processing of Multiphase Foods**

K. P. Sandeep, Paul D. Franzon, Josip Simunovic
The overall objective of the current study is to develop a sensor that can be used to determine the location and internal temperature of food particles as they flow through the heating, holding, and cooling sections of an aseptic processing system. The sensor will then be implanted in the cavity of a "conservatively" designed carrier particle (conservative from a heat transfer and flow standpoint) such that the thermal treatment received by this particle will always be less than that received be every other particle in the real food product.

Integrated 3D packaging for Microscopic Systems
Paul D. Franzon
University of California - Berkeley
$308,700
11/01/09 - 10/31/12
NCSU will investigate the following: Energy-efficiency-optimized system integration and packaging Unconventional, optimized package design for microscopic sensor systems and RF Packaging for energy-harvesting microscopic systems

Micromachined Braille Reader
Paul D. Franzon, Tushar K. Ghosh
US Dept. of Education (DED)
$597,612
10/01/07 - 09/30/10
An integrated, low-cost Braille reader will be developed using micromachining techniques and polymer actuator technologies.

Multimode Interconnect
Paul D. Franzon
Semiconductor Research Corp.
$300,000
11/01/06 - 09/30/10
With higher core clock speeds, and the trend to multi-core, the demands on chip I/O are increasing rapidly. The key question is how to increase both the density and speed of chip I/O without increasing packaging costs. In this research, we will investigate coding and circuit techniques that enable a group of signals to travel down a wire bundle, and potentially connectors and cable assemblies, without crosstalk. This will enable wires to be spaced at minimum manufacturable spacings permitting an overall increase in wire density of a factor of two or more.

Reconfigurable RF Electronics
Paul D. Franzon, Mehmet C. Ozturk, Michael B. Steer
NCSU will model a high tuning range varactor and a reconfigurable RF electronic structure using it.

Support for Tezzaron 3D Integrated Circuit (3DIC) Run
Paul D. Franzon
Tezzaron Semiconductor
$50,000
11/17/08 - 09/30/10
NCSU will provide support for the Tezzaron 3DIC run.

System Packaging With AC Coupled Interconnect
Paul D. Franzon
Irvine Sensors Corporation
$346,920
11/01/06 - 02/28/10
NCSU will support ISC in 3D packaging.

System Technologies for AC Coupled Interconnect for Low Power SpaceBorne Electronics
Paul D. Franzon, John Michael Wilson, Angus I. Kingon
US Air Force Research Laboratory (AFRL)
$1,287,807
09/25/06 - 06/30/11
ACCI promises high-density, low-power chip I/O, sockets and connectors. In year 05-06, we demonstrated the robustness of ACCI for capacitive and inductive connections. We also had extensive engagements with several technology transfer partners. The intent this year is to produce a complete transferable technology, including demonstration of issues related to laminate packaging, demonstration of a socket system and a connector system. In addition, we will complete the design and deliver a board for a planned test in near earth orbit.

Electrical Inert Crack Monitoring Gauge
Jerome J. Cuomo, Roger C. Sanwald, Edward Grant
DRS Technologies, Inc.
Unfunded
06/01/07 - 06/30/10
Complete the revision of the software for the second generation motes to use the Freescale silicon and the 15.4 PHY layer Testing to determine range and reception Testing of the second generation motes encased with encapsulant, potting compound, and/or conformal coatings to determine any RF performance effects Perform testing to determine load cycle and assure five
year battery life Complete the revision of the software for the iPAQ Confirm performance via
test on C-130 aircraft On platform testing with additional aircraft selected by the customer

**MRI: Development of a Quantum Engineering Laboratory**
Alexej I. Smirnov, William C. Holton, Ki Wook Kim, Veena Misra
National Science Foundation
$1,116,256
09/01/04 - 08/31/10

Advanced Power Devices and Converters
Alex Q. Huang
Sandia National Laboratories
$445,344
11/15/07 - 09/15/10
Continue the development of ETO based AC breaker.

**Consortium of Advanced Power Electronics and Energy Storage-CAPES (within SPEC) Pool Agreement**
Alex Q. Huang
NCSU Semiconductor Power Electronics Center (SPEC)
$1
07/01/06 - 12/31/10

**Distributed Power Flow Controller (DPFC)**
Alex Q. Huang
Missouri University of Science and Technology
$119,518
07/01/08 - 12/31/09
This is a subcontracted to North Carolina State University (NCSU) from MST. NCSU will focus on design, development and demonstration of a distributed power flow controller for series applications. Software simulations shall be conducted to show the control and operation of the ETO-based DPFC. The developed controller shall be verified at NCSU.

**Membership in Power Management Consortium (PMC), Associate Member**
Alex Q. Huang
International Rectifier
Unfunded
10/01/05 - 12/31/11
Renewal to Principal Membership

**New High-Energy Nanofiber Anode Materials**
Xiangwu Zhang, Alex Q. Huang, Peter S. Fedkiw, Saad A. Khan
US Dept. of Energy (DOE)
The objective of the proposed work is to use electrospinning technology to integrate dissimilar materials (lithium alloy and carbon) into novel composite nanofiber anodes, which simultaneously have high energy density, reduced cost, and improved abuse tolerance. The nanofiber structure also allows the anodes to withstand repeated cycles of expansion and contraction. These composite nanofibers are electrospun into nonwoven fabrics with thickness of 50 um or more, and then directly used as anodes in a lithium-ion battery. This will eliminate the presence of non-active materials (e.g., conducting carbon black and polymer binder) and result in high energy and power densities. The nonwoven anode structure also provides a large electrode-electrolyte interface and, hence, high rate capacity and good low-temperature performance capability.

Power Management Consortium (PMC) Membership Agreement - Principal Member
Alex Q. Huang
Toyota Motor Engineering & Manufacturing North America, Inc.
Unfunded
01/01/09 - 12/31/11
New membership

Power Management Consortium-PMC (within SPEC) Pool Agreement
Alex Q. Huang
NCSU Semiconductor Power Electronics Center (SPEC)
$1
09/01/05 - 12/31/10

Power Management IC and Power Device Research, SPEC Core Project
Alex Q. Huang
NCSU Semiconductor Power Electronics Center (SPEC)
Unfunded
06/01/09 - 12/31/09
This project will focus on several advanced power manage IC control concepts such as variable phase number control in VRM and constant on-time control, as well as advanced power device study via simulation and literature review. Due to the limited funding this year, two half time students will be supported by this project, one on IC design and one on device study.

Ambalux Phase II STTR: Novel Coding Methods and Receiver Designs for Underwater Optical Communications
Brian L. Hughes, John F. Muth
Ambalux Corporation
Unfunded
08/05/08 - 08/04/10
This program will investigate the performance improvements of underwater optical communication systems that can be obtained by the use of modern error-control coding techniques. The project entails fabrication of an FEC subsystem for underwater communications as well as integrating the FEC processor with a coherent receiver developed by Ambalux. This is a $750,000 Phase II STTR program joint with Ambalux with $225,000 applied to NC State: $135,000 in the first 24 months and a $90,000 option for the following 8 months.

**Communications Theory Perspectives on the Design of Compact Multi-Antenna Wireless Transceivers**
Brian L. Hughes, Gianluca Lazzi
National Science Foundation
Unfunded
09/15/07 - 08/31/10
This proposal requests supplemental REU funds to support two undergraduates to conduct research directly related to the objectives of this NSF-sponsored project. Both research projects will be conducted in the first half of 2010 in the Wireless Systems Engineering Laboratory at North Carolina State University.

**Development of FREEDM System Control and Digital Testbed, FREEDM Core Project**
Zhenhua Jiang, Mesut E. Baran
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
07/01/09 - 06/30/10
The is a new FREEDM segment from the FREEDM Industry Project 529737 - see supporting attached documents.

**Carrier Spin Dynamics and Device Applications in Carbon Nanotube**
Ki Wook Kim, Marco Buongiorno-Nard
National Science Foundation
$239,979
09/01/06 - 08/31/10
The objective of this research is to explore spin dependent properties of the carriers in carbon nanotubes and their potential device applications. The approach is based on the theory and numerical (ab initio) modeling of carrier spin relaxation and transport dynamics in carbon nanotubes. Specific concepts/structures leading to a novel class of spintronic nano-devices is also pursued beyond the current scaling limit.

**Center on Functional Engineered Nano Architectonics**
Ki Wook Kim
University of California - Los Angeles
$410,887
As a member of the FCRP Center on Functional Engineered Nano Architectonics led by UCLA, our primary aim is to exploit novel ideas with significant potential device impacts in the newly emerging nanoengineered hybrid (or composite) structures by combining the advantages of multiferroics and semiconductors. The emphasis for semiconductors will be on atomically thin cases in a multilayered environment to facilitate nonlinear (or correlated) phenomena. Specifically, we will theoretically investigate various structures and materials in search of realizable and robust combinations for device applications. Relevant physical models will be developed and the feasibility of the underlying mechanisms in multiferroic hybrid structures examined in close collaboration with experimental groups. The application of proposed hybrid switches to memory and logic functions will be analyzed to establish the performance metrics. Device modeling will follow for the optimal design and operating conditions for experimental verification.

First Principles Calculations of Electronic and Phononic Transport: A Practical Tool-set for Efficient Design of Novel Materials and Devices for Nanoelectronic Applications
Marco Buongiorno-Nard, Ki Wook Kim, Eric D. Sills
Army Research Office
$76,366
06/15/10 - 06/14/11
We propose the development of a theoretical and computational tool-set for the first principles determination of charge and heat transport in novel materials and devices. The tool-set will be based on state-of-the-art first principles electronic/phonon structure calculations and will allow the systematic evaluation of carrier scattering rates and heat dissipation processes in nanoscale systems. The work envisioned in this proposal intrinsically crosses multiple disciplines and is multi-scale in character: from the quantum mechanical limits of carrier transport and dissipation, to the macroscopic parameters needed for the engineering of real devices. As such it requires expansion of high performance computing capabilities.

Graphene Nanostructures for Novel Spin Magnetic Device Applications
Ki Wook Kim
Army Research Office
$132,001
10/01/09 - 01/31/11
This research program proposes to theoretically exploit nanoscale graphene based structures for spintronic applications at room temperature. To overcome the nonmagnetic nature of intrinsic graphene, two promising phenomena will be explored that can introduce desired spin magnetic functionalities with electrical control. The first approach attempts to incorporate the magnetism by forming a hybrid structure with appropriate magnetic materials, while the second envisions utilizing nonzero magnetic moments induced at the edge states, defects, vacancies, etc. With the
development of appropriate models, the main focus of investigation is to analyze the physical
properties and basic functionalization principles.

MARCO Center on Functionally Engineered Nano Architectonics (FENA)
Ki Wook Kim
University of California
Unfunded
09/01/03 - 10/31/09
As a member of the MARCO team led by UCLA, the main aim of this effort is to develop
theoretical models capable of simulating nanostructures based primarily on semiconductors and
to investigate their characteristics comprehensively. Particularly, fundamental limitations and
optimum design guidelines are examined for various novel nanoscale devices and the new
paradigm of information processing/storage is explored. The focus is on the devices that can be
integrated with the CMOS.

Nanoscale Phonon Transport for Thermal Management
Ki Wook Kim
University of Texas
$150,000
04/01/08 - 03/31/11
As a member of the South West Academy of Nanoelectronics (SWAN) sponsored by the Nano
Electronics Research Corporation (NERC) Nanoelectronics Research Initiative (NRI), the focus
of the NC State team is on accurate modeling of phonon transport properties at realistic
interfaces with materials and/or dimensional mismatch including graphene on a dielectric or a
substrate. Following a hierarchical strategy, the specific aim is two-fold: (1) Develop/calculate
first principles phonon structures based on the density functional theory and (2) formulate a
phonon/thermal transport model for a variety of nanoscale interfaces through extracting relevant
parameters from the microscopic calculations.

Novel Non-Volatile Memory Devices Based on Magnetic Semiconductor Nanostructures for
Terabit Integration
Ki Wook Kim
Army Research Office
$258,652
07/01/06 - 10/31/09
This program explores novel spin memory devices that utilize carrier spin-dependent interactions
in magnetic semiconductor nanostructures. It is aimed at demonstrating the viability of non-
volatile memory concepts that can be highly scalable, can have extremely low power dissipation,
and can be readily merged with the CMOS platform. The primary focus of the effort is on the
concepts utilizing electrical control of the magnetism, i.e., the phenomena based on the
electrically induced magnetic phase transition and magnetization reversal. A theoretical
investigation is pursued by developing physical understanding of the related phenomena, followed by the device modeling for optimum structure design.

**QMHP: Exploring the Limits of Energy Scavenging - From Microwave to Nanoscale**
Ki Wook Kim, David Schurig, Robert J. Trew
National Science Foundation
$327,843
04/01/08 - 03/31/11

The objective of the proposed research is to explore the feasibility of engineering quasi-coherent thermal emission for application to thermal energy harvesting. The approach is to utilize the high energy density stored in the evanescent field of the surface excitations present on a thermal source composed of a polar semiconductor, by transforming it into spectrally and/or spatially selective radiation for ready extraction. Both theoretical and experimental methods will be used to demonstrate the concept.

**Theory and Modeling of Graphene-Based Carbon Electronics for RF Applications**
Ki Wook Kim, Marco Buongiorno-Nard
HRL Laboratories
$249,928
11/03/08 - 04/30/10

As a member of the team led by HRL on carbon electronics for RF applications, the NCSU participants will perform state-of-the-art first principles electronic/phonon structure calculations of graphene nanostructures based on Density Functional Theory for band structure engineering, and conduct transport simulations to establish the relevant properties (such as the velocity vs. field characteristics) leading to the optimal device design. Once completed successfully, this research effort will provide a multi-scale modeling hierarchy where the results of the first principles calculations will be used as parameters of macroscopic models for the evaluation of carrier scattering rates, mobility mechanisms, carrier transport and in general develop realistic transport models in graphene based electronic devices.

**Rare Earth Materials**
Robert M. Kolbas, John F. Muth
CAS, Inc.
$39,675
02/20/08 - 09/27/09

Rare earth elements have many photonic applications and unusual properties. In this study, rare earth doped materials will grown and provided to an Army research lab.

**Bio-inspired Invariants: Target Representation and Classification towards Scene Understanding**
Hamid Krim
US Navy-Office Of Naval Research
At the center of cognition, lies understanding brain functionality which remains a hot topic of research to address the slow progress in machine-based image understanding. Biological systems (e.g. one may recognize an object despite some occlusion and/or additive noise) have increasingly attracted more researchers as a rich source of inspiration, which has led to investigations of smaller and potentially simpler biological entities. The goal in this effort is to exploit biologically inspired invariants in objects to develop a methodology to efficiently and accurately represent 2/3D objects as weighted-graphs for classification and recognition problems as is crucially important in scene understanding applications.

Graphs and Homology in 3D Object Classification
Hamid Krim
US Air Force-Office of Scientific Research (AFOSR)
$281,864
01/15/07 - 05/31/10
To complement our current effort on 3D target modeling and classification, we propose to focus on two main tasks: - Explore well suited features in target imagery to be integrated in an existing Tracking Algorithm, - Develop a hierarchical set of features which remain as invariant as possible to the Euclidean Group of transformation. The invariance seeks to preserve "tracking lock" while the hierarchical property is for layered registration to adapt to dynamic environments requiring different levels of precision and hence difficulty in acquiring registration.

Multiscale Image Fusion
Hamid Krim
Rockwell Collins
$80,000
05/01/09 - 09/10/10
This work is to adapt a fusion algorithm developed in this group and make it compatible to imagery and computable on a dedicated Processing Architecture.

Sensing Topologies and Intelligent Processing
Hamid Krim
US Air Force-Office of Scientific Research (AFOSR)
$331,266
06/01/10 - 03/31/13
The realization and acceptance that cooperative processing by a sensor array has been born out by many real successes, have turned this strategy into a source of inspiration to addressing a myriad of practical problems. The availability of cheaper and increasing computational power are further accelerating the search for solutions to complex problems pervading every sector of society, from economy to environmental preservation, from transportation and health-care to surveillance and security. Our central interest in this proposed effort is to investigate sensor-
centric practical solutions to a large class of problems which seemingly appear different. In a proper mathematical framework, and an adapted judicious approach, these problems will turn out to be just different faces of the same object.

A High-Density Microelectronic Tissue for Imaging: Electromagnetic and Thermal Effects
Gianluca Lazzi
US Dept. of Energy (DOE)
$909,531
12/15/03 - 12/14/10
This grant focuses on the electromagnetic and thermal experimental and numerical activities needed toward the development of a retinal prosthesis to restore partial vision to the blind. Computational and experimental models and methods are needed so that a) smaller telemetry coils can be designed, b) the electromagnetic and thermal safety of the telemetry device and implanted microchips can be determined, c) electromagnetic safety in the presence of external sources such as the MRI fields can be established; d) the characteristics of the fields and currents induced in the retina by the stimulating array can be predicted.

Protocol Driven Studies to Measure Absorbed Radiofrequency, Microwave and Millimeter Wave Energy: Computational Electromagnetic
Gianluca Lazzi
Henry M. Jackson Foundation
$109,537
05/28/08 - 09/30/09
The overall goal of this proposal is to develop novel quasi-static and time-domain bioelectromagnetic modeling methods that will ultimately lead to the modeling of human electromuscular incapacitation (HEMI) exposures. Specifically, we will continue the process of adapting our unconditionally stable time-domain electromagnetic method (ADI) to reduce the computational time required for low-frequency bioelectromagnetic simulations necessary for this task as well as consider the use of other codes that we have developed recently, such as the multiresolution impedance method.

Stretchable, Tunable, Self-Healing Micro-Fluidic Antennas
Michael D. Dickey, Gianluca Lazzi
National Science Foundation
$340,706
09/01/09 - 08/31/12
The overall goal of this proposal is to develop novel quasi-static and time-domain bioelectromagnetic modeling methods that will ultimately lead to the modeling of human electromuscular incapacitation (HEMI) exposures. Specifically, we will continue the process of adapting our unconditionally stable time-domain electromagnetic method (ADI) to reduce the computational time required for low-frequency bioelectromagnetic simulations necessary for this
task as well as consider the use of other codes that we have developed recently, such as the multiresolution impedance method.

Collaborative Research: IHCS-Cybersystems: Integration of Protocol and Hardware Designs for Securing Internet Communications
Xun Liu
National Science Foundation
$150,118
08/01/09 - 07/31/12
This proposal describes a collaborative cybersystem research for the next three years. Its main objective is to defend Internet services against malicious attacks through innovative secure mechanisms applied jointly at network and physical layers. The research agenda includes robust on-line network anomaly detection, agile packet filtering, and hardware design innovation for cyber-security. It will deliver effective, low-cost, and easy-to-upgrade solutions to secure the next-generation Internet.

High Power Building Block for Affordable Power Systems
Srdjan Miodrag Lukic, Alex Q. Huang
Raytheon
$20,000
11/17/09 - 08/01/10
Intelligent power systems feature flexibility and scalability and enable new capabilities by reducing fuel consumption for extended missions and improving adaptability and endurance. Such systems accept any number of diverse energy sources and loads. Bidirectional power converters serving multiple platforms and applications are among the components enabling such systems. Such converters have to be capable of operation from a wide range of input voltages and bidirectional power transfer with high efficiency.

Hybrid Intelligent Power (Hi-Power) Management: Study of AC vs. DC Systems
Srdjan Miodrag Lukic, Alex Q. Huang
Raytheon
$41,510
03/09/10 - 07/21/10
In this analytical study we propose to assess the advantages and disadvantages of AC and DC based distribution networks. In particular our investigation will focus on (1) determining and addressing the stability issues in each system (2) determining the protection requirements and (3) determining the requirements for energy storage and load plug-and-play capability.

Carolina Center For Cancer Nanotechnology Excellence
Leda Lunardi, John F. Muth
UNC - UNC Chapel Hill
$105,075
The objective of this project is to fabricate nano-lights arrays where the efficiency of output is mediated by surface plasmon interactions with peptide/protein binding events. This permits the observation of individual elements of the nano-light array to be turned on/off as the cell moves across it while retaining compatibility with standard microscope instrumentation. The transparency of wide band gap semiconductor materials potentially allows the slide to be used with both inverted and non-inverted microscopes.

**ERC Education and Diversity Program**

Leda Lunardi  
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)  
Unfunded  
09/01/08 - 08/31/10  
See attached documents

**Gallium Nitride Materials Processes for High-performance Schottky Barrier Diode Power Devices**

Mark A. Johnson, Leda Lunardi  
Sinmat, Inc.  
$100,000  
05/01/09 - 01/31/12  
An research supplemental through SBIR-II research companies for collaboration with NSF Engineering Research Centers. Supplements available through 'Dear Colleague Letter” of Oct 30, 2008. Sinmat, an existing small business performing a SBIR Phase-II research project will collaborate with researchers in the NSF FREEDM Systems Center ERC on the preparation, characterization and measurement of bulk semiconductor wafers for power devices in the FREEDM Systems Center roadmap. Research will include the fabrication Schottky Barrier Diodes on epitaxially deposited semiconductor layers following Chem-mechanical polishing using Sinmat developed materials and processes.

**Photocatalytic Sensors for VOC Sensing**

Leda Lunardi, John F. Muth  
Valencell Inc.  
$102,196  
09/30/07 - 08/31/09  
Conventional environmental exposure monitoring requires bulky instrumentation without providing a personalized history of environmental exposure. The long-term goal of this feasibility study is to provide a low-cost, noninvasive, low-profile, real-time, personal environmental exposure monitor platform that is virtually unnoticed by the user for maximum performance and convenience. This platform will provide a quantitative, reliable, in-field measurement of personal-level, point-of-contact exposure to a variety of airborne chemical
toxins of particular interest to health conscious end-users, sports enthusiasts, the immunocompromised, and medical professionals.

STTR Phase II: Monolithic Multiwavelength Blue-to-IR LED for Biomedical Diagnostics
Leda Lunardi, John F. Muth, Robert M. Kolbas
Valencell Inc.
Unfunded
01/15/09 - 12/31/10
This project continues development of a multiwavelength light emitter to be incorporated into health monitoring applications designed by Valencell Inc.

Collaborative Research: High Density Metal and Semiconductor Nanoparticles for Memory and Photonic Applications
Veena Misra, John F. Muth
National Science Foundation
Unfunded
06/01/08 - 05/31/11
We seek support for four undergraduate students to support our existing collaborative research activities on high density metal and semiconductor nanoparticles for memory and photonic applications at North Carolina State University and University of Missouri at Columbia. These four undergraduate students, two housed at each university, will be involved in research on i) Stability of nanoparticles formed by ALD and PVD, ii) characterization of MOSFETS made with nanoparticles from both institutions and iii) modeling of nanoparticle formation and devices. These different aspects of the research will provide these undergraduate students with a comprehensive exposure to nanoparticle device research and will be used as a tool to attract them to the graduate program.

GaN Power Device Design and Fabrication
Veena Misra, Alex Q. Huang, Mark A. Johnson
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
09/01/09 - 08/31/10
See attached documents - Dr. Misra please attach your budget justification for this new proposal

Integration of Magnetic Tunnel Junctions with Magnetic Domain Wall Nanowires for Novel Logic Applications
Veena Misra, Mehmet C. Ozturk, Michael James Escuti
University at Albany (SUNY)
Unfunded
04/01/08 - 03/31/11
The use of state variables other than electronic charge offer great new opportunities for novel
logic and memory approaches and can help create a new computation roadmap. Recently, domain wall logic has been demonstrated using ferromagnetic nanowires wherein all the basic logic functions needed to create any arbitrary logic circuit have been realized. This novel logic technology brings with it the possibility of low power electronics, low cost of fabrication and high density. However, a robust interface between the domain wall logic and input/output circuitry has not been established. The goal of this proposal is to integrate domain wall ferromagnetic nanowires with magnetic tunnel junctions via coupled magnetic nanostructures that can provide magnetic gain needed to drive I/O circuitry. The structure would employ stray fields and coupling between magnetic domains to flip the free layer of a magnetic tunnel junction and modulate a current. The proposed device would fill a missing link between devices in the newly emerging field of magnetic domain logic and conventional electronics.

Investigation of Engineered High-K Dielectrics and Metal Electrodes for Applications in Non-Volatile Memories
Veena Misra
Intel Corp.
$120,000
10/01/09 - 09/30/10
This goal of this proposal is to initiate a study to investigate high-K dielectrics and metal electrodes as blocking oxides and control gates, respectively. The overall goal is to understand fundamental charge transfer mechanisms through high-K IPD under program/erase (P/E) and retention conditions. These objectives will be met by conducting the following research Tasks: 1) Explore the role of interfaces, i.e. between IPD and charge storage layer and also between IPD and metal control gate and evaluate the impact on P/E and Retention 2) Investigate IPD composition, microstructure, anneals and charges on the P/E and retention characteristics. This will include single layer IPD vs. multilayer IPD for barrier engineering. 3) Explore the role of work function of the control gate work function on erase and retention characteristics. Evaluate electron back tunneling from gate into the floating gate and hole tunneling in the opposite direction.

Investigation of High-K Gate Dielectric Stacks for SiC MOSFETs
Veena Misra
Cree, Inc.
$60,000
05/12/08 - 08/31/09
The interface region of the dielectric and the SiC is critical in determining mobility characteristics. It is suspected that the high thermal budgets, such as those associated with thermal oxide growth, lead to defect formation in the transition region (SiCxOy) between SiO2 and SiC and also in the SiC layer itself. This suggests that low temperature gatestack formation, such as use of deposited oxides, may be a very useful route in minimizing defects. However, the
interface characteristics of deposited oxides with SiC need to be thoroughly investigated. Although, recently work has shown that MOCVD Al2O3 films deposited on SiC at 190°C have given high mobility values, an ultra thin SiO2 layer under these have given even higher record mobility numbers suggesting that having some SiO2 may be important. This in fact is very similar to what has been observed in silicon CMOS devices and underscores the importance of both the interface region and the thermal budget. Based on the above discussion, the focus of this work is to: i) understand the role of the gate dielectric process on threshold voltage and mobility and ii) engineer the dielectric to optimize the threshold voltage. These two objectives will be met by investigating alternative gate dielectrics via atomic layer deposition.

**Nanostructured Materials for Renewable Alternative Energy**  
Gregory N. Parsons, Orlin D. Velev, Veena Misra, Christopher B. Gorman, Michael D. Dickey  
US Dept. of Energy (DOE)  
$984,000  
07/25/08 - 09/30/10  
The goal of this project is to advance fundamental understanding of novel inorganic nanostructures integrated with photoelectronic organic materials, to expand the field of nanomaterials for renewable energy devices and systems.

**Process Modules for SiC Devices**  
Veena Misra  
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)  
Unfunded  
09/01/08 - 08/31/09  
The objective of this task is to develop critical process modules to enhance the performance of SiC power devices required for Generation 2 of the FREEDM ERC. Specifically, these devices will consist of 2A, 15kV 4H-SiC IGBTs and diodes that will be used for the primary side of the solid state transformers (SST) and for the Fault Interrupt Devices (FID). Processes developed under this sub-thrust will also improve the performance of the low voltage SiC MOSFETs (100A/300V) that may be used on the secondary side of the SST. There are several critical process challenges that need to be overcome to meet the objectives for the IGBTs and MOSFETs, especially for the primary side of the SST. The objective of this project is to address two critical process modules (in order of percent effort): A) Threshold voltage control via gate dielectric and gate electrode engineering (~80-90%) B) Intermetallic dielectrics to prevent gate to source shorts and leakages (~10%) The focus of the first year will primarily be placed on the first two modules. The third module will be addressed only if time and resources permit, and if necessary, this module will be moved to the second year. This will be a multidisciplinary and a multi-campus effort to effectively meet the goal of Generation 2 SiC power devices.
Defining the Boundaries of Free Space Underwater Communications
John F. Muth
National Science Foundation
$347,226
01/01/07 - 12/31/10
This is a $10,000 undergraduate Fellowship from the NCMR that is being routed through NSF as a supplement.

GaN Materials Research and Process Development for Power Devices
Mark A. Johnson, John F. Muth
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
09/01/08 - 08/31/10
This is a continuation of Project 529716 from the Prime FREEDM project - 529598 - please see attached documents. **Dr. Johnson will need to attach a Budget Justification Word Document during his approval.

GaN Materials Research and Process Development for Power Devices
John F. Muth
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
09/01/09 - 08/31/10
Research into the growth of III-nitride materials and structures in support of PSD device effort in the FREEDM Systems Center. Goal is to epitaxially deposit GaN HFET structures on GaN on Silicon templates suitable for subsequent fabrication of lateral GaN on Si MOS-HFET devices for SST sub-thrust application. Activities include epitaxial growth by metal-organic chemical vapor deposition (MOCVD) and basic materials characterization of the deposited epitaxial layers.

SBIR II Integrated Wide-Bandgap Semiconductor Photoconductive Switch With a Terahertz Antenna
John F. Muth, Gianluca Lazzi, Leda Lunardi
Digital Fusion Inc.
$191,804
12/22/08 - 12/21/10
Professors Leda Lunardi and John Muth will grow materials and fabricated antenna structure as outlined in the Proposal AF073-0004 written by Digital Fusion and NCSU. Professor Lazzi will simulate and design antenna structures in accordance with Proposal AF073-0004 0004 written by Digital Fusion and NCSU.
Underwater Optical System
John F. Muth, Leda Lunardi
Naval Research Laboratory
$450,000
09/12/07 - 09/01/10
The future tactical ocean environment will be increasingly complicated. In addition to traditional communication links there will be increased reliance on underwater networks and a proliferation of unmanned vehicles in space, in the air, on the surface, and underwater. Above the air/water interface wireless radio frequency communications will continue to provide the majority of communication channels. Underwater, where radio waves do not propagate, acoustic methods will continue to be used. However, while there have been substantial advances in acoustic underwater communications, acoustics will be hard pressed provide sufficient bandwidth to multiple platforms at the same time. Acoustic methods will also continue to have difficulty penetrating the water/air interface. This suggests that high bandwidth, short range underwater optical communications have high potential to augment acoustic communication methods.

Recessed SiGe and SiC Source/Drain Engineering For Future CMOS Technologies
Employing Uniaxial Channel Stress For Channel Mobility Enhancement
Mehmet C. Ozturk, Veena Misra
Semiconductor Research Corp.
$440,221
07/01/06 - 12/31/09
Supplement funds are to fund another student to work on the awarded project research.

REU Site: Research Experiences For Undergraduates in the Department of Electrical and Computer Engineering at North Carolina State University
Mehmet C. Ozturk, Mihail Devetsikiotis
National Science Foundation
Unfunded
03/01/07 - 02/28/11
Funds are requested to create a site for research experiences for rising seniors in Electrical and Computer Engineering. Ten students from different institutions will be sponsored every summer for a period of 10 weeks. The students will work on independent research projects with the mentoring ECE faculty and learn about research performed in different ECE specialization areas. The students will be exposed to various elements of academic life including ethics, diversity and forming collegial relationships.

CPA-CSA: FabScalar: A Standard Superscalar Library for Fabricating Heterogeneous Chip Multiprocessors
Eric Rotenberg
National Science Foundation
$300,000
Customizing processing cores to applications is an exciting new direction for continuing to scale performance, as conventional technology and microarchitecture scaling slows. But it raises many intriguing questions. Fundamentally, core customization captures the interplay among application characteristics, microarchitecture, and physical implementation. Therefore, a central question is how to provide real superscalar designs, and arbitrarily many of them. We are currently developing FabScalar, a tool-set that will enable researchers and designers to automatically compose the physical designs of arbitrary superscalar processors. Within our own group, FabScalar provides an infrastructure for exploring a rich research agenda, highlighted at the following website: http://www.tinker.ncsu.edu/ericro/research/fabscalar.htm

Far-Ahead Address Prediction and its Microarchitecture Applications
Eric Rotenberg
Intel Corp.
$30,614
09/03/09 - 12/31/11
Sequential programs spend most of their time iterating over elements of objects. Iteration is launched by a base instruction that produces an initial address, which in turn depends on elaborate computation. A novel technique is proposed whereby distant correlated ancestors predict the initial address. This is exploited for a number of microarchitecture applications that parallelize or accelerate the computation derived from iterating over objects.

Retention-Aware Placement in DRAM (RAPID): Software Methods for Quasi-Non-Volatile DRAM
Eric Rotenberg
NCSU Center for Advanced Computing & Communication
Unfunded
07/01/07 - 06/30/10
We recently proposed RAPID, novel software approaches that can exploit off-the-shelf DRAMs to reduce refresh power to vanishingly small levels approaching non-volatile memory. The key idea is to favor longer-retention pages over shorter-retention pages when allocating DRAM pages. This allows selecting a single refresh period that depends on the shortest-retention page among populated pages, instead of the shortest-retention page overall. RAPID with off-the-shelf DRAM approaches the energy levels of idealized techniques that require custom DRAM support. RAPID promises real value and is inexpensively deployable because it is based solely on software and commodity off-the-shelf DRAM. A prototype is being developed.

SHF: Small: EXACT: Explicit Dynamic-Branch Prediction with Active Updates
Eric Rotenberg
National Science Foundation
Unfunded
09/15/09 - 08/31/12
Continued microprocessor performance scaling is hindered by many factors. One factor above all, the branch prediction bottleneck, constrains the ability to tackle other factors. This project proposes a new direction in branch prediction research.

The Phase Based Behavior of Objects
Eric Rotenberg
National Science Foundation
Unfunded
07/01/07 - 06/30/11
A new execution model is proposed. Changes to a running program’s objects induce specialization of code fragments that may operate next on the objects, simplifying the code based on the new data stored within the objects. Thus, when the data within objects change, the program changes with them in real time, continuously reducing the future dynamic instruction stream in reaction to object modifications. Although the program itself is not parallelized (it is reduced), the many independent specialization tasks corresponding to objects provide abundant meta-parallelism. The responsibility for different objects is distributed among different processors in a multi-core or many-core substrate.

The Phase Based Behavior of Objects: Enabling a New Generation of Microarchitecture
Eric Rotenberg
Semiconductor Research Corp.
$300,000
04/01/07 - 05/31/10
In the 90s, the theme of speculation drove innovation in all aspects of processor design and led to significant cumulative performance gains. Today, single core performance is not scaling as impressively due to technology issues and the lack of a compelling theme to drive a new generation of microarchitecture innovation. While the now popular multi-core theme is important, it poses more of a challenge than a solution because much software remains non-parallel. Thus, the multi-core theme must be combined with a new sequential-program-centric thrust. This project puts forward a new microarchitecture theme. We propose a paradigm in which the processor has an unprecedented view of the structure of a running program. Like speculation in the past, this paradigm will enable a new generation of powerful performance optimizations.

Meta-materials Gradient Index Lenses for GHz Imaging
David Schurig
Central Intelligence Agency (CIA)
$250,000
09/22/09 - 09/21/10
The main objective of the proposed research is the exploration and demonstration of novel metamaterial imagers consisting of focal plane arrays and lenses, all operating at GHz frequencies. Recent discoveries of metamaterials and their unconventional physical properties
suggest that these new systems hold great promise for future technological applications. The assembled team will demonstrate the potential of metamaterials to yield high performance imaging devices needed to address the goals of the intelligence community.

**Quasi-conformal Transformation Optics for Novel Electromagnetic Control Using Applied Metamaterials**

David Schurig  
SensorMetrix  
$123,800  
06/01/09 - 12/16/10  
The goal of this work is to develop and demonstrate a new class of gradient index lenses based on transformation optical designs. Prototype lenses will be fabricated and their operation demonstrated for the X-band frequency range.

**Transformation Optical Metamaterials**

David Schurig  
Duke University  
$402,633  
09/28/09 - 07/14/14  
As part of the fulfillment of the proposed research by the Duke lead team in response to BAA 08-019, NCSU personnel will perform analytical, simulation, design and fabrication tasks. The NCSU effort will focus on the design and fabrication of optical elements, particularly those with near field imaging capability, including near field magnifiers (also known as hyper lenses). Coordinate transformations that correspond near field optical elements will be examined subject to constraints that lead to less extreme material properties, thus facilitating implementation. Unit cells and layouts will be examined with consideration of sample fabrication and measurement issues, for implementations at frequencies up to and including the infrared range.

**Centennial Outdoor Wireless Mesh Network Testbed For Research and Education (CentMesh)**

Rudra Dutta, Mihail L. Sichitiu  
Army Research Office  
$149,960  
06/16/09 - 06/14/11  
This proposal proposes to build an outdoor wireless mesh testbed comprised of a large number of low-cost experimental fabricated nodes and a small number of commercially available nodes. The testbed will leverage experience of, as well as enable the research of NCSU researchers participating in the Secure Open Systems Institute (SOSI), currently engaged in DoD, NSF, and other projects. The proposed testbed will provide realistic large-scale outdoor wireless network environments for evaluating and validating the ideas, protocols and systems conceived from these activities.
NeTS-NBD: Measurement-Based Mobility Modeling for MANETs
Mihail L. Sichitiu, Injong Rhee
National Science Foundation
$484,827
08/15/06 - 07/31/10
Although a few MANET testbeds have been implemented, due to the tremendous logistical difficulties and expenses associated with large mobile testbeds, the vast majority of the proposed protocols have been evaluated through simulation. We propose to develop and evaluate a hybrid mobility model that is relatively easy to generate and, at the same time, produces realistic mobility traces, that in turn, result in meaningful simulation results for MANET simulations. The proposed model has the desirable characteristics that it is customizable to match any scenario while allowing the users to vary key parameters (number of nodes, density, etc.).

On-the-fly Scene-dependent ATR
Wesley E. Snyder, Siamak Khorram
US Air Force-Office of Scientific Research (AFOSR)
$361,188
02/15/07 - 05/31/10
An overflight using a hyperspectral sensor characterizes a scene, including a target. Later, a weapon system equipped with a different sensor, having much less capability, must identify that target in that environment, even though the target may have moved. A new shape recognition system was developed which is independent of movement, and a new strategy for combining multispectral information with limited shape (from very small targets) has been developed. Both methods have been tested on realistic data.

Teleoperation of a Team of Robots with Vision
Wesley E. Snyder, Griff L. Bilbro
Army Research Office
$50,000
09/01/09 - 09/30/10
The authors will develop mathematics and algorithms which will allow a single operator to teleoperate a team of robots, using information obtained by cameras on the robots.

Collaborative Research: Software and Hardware Support for Efficient Monitoring of Program Behavior
Yan Solihin
National Science Foundation
Unfunded
09/01/06 - 08/31/10
A new execution model is proposed. Changes to a running program’s objects induce specialization of code fragments that may operate next on the objects, simplifying the code based on the new data stored within the objects. Thus, when the data within objects change, the program changes with them in real time, continuously reducing the future dynamic instruction stream in reaction to object modifications. Although the program itself is not parallelized (it is reduced), the many independent specialization tasks corresponding to objects provide abundant meta-parallelism. The responsibility for different objects is distributed among different processors in a multi-core or many-core substrate.

CSR:Small: Efficient and Predictable Memory Hierarchy For High-Performance Embedded Systems
Yan Solihin, Alexander G. Dean, Mihail L. Sichitiu, Thomas G. Wolcott
National Science Foundation
Unfunded
09/01/09 - 08/31/12
This project will develop a system to monitor estuarine environmental conditions and disseminate the information on the internet. We will develop sensors and a communication system which relays the measured information to a web server; these will be installed at the Chesapeake Bay Environmental Center in Maryland. We will develop methods for improving the design of real-time embedded systems. We will enhance the RaPTEX toolchain (1) to help the system designer select the best real-time scheduler, and (2) to use real-time scheduling methods to enable the use of noisy, simple switching power supplies with sensitive circuits. We will evaluate these enhancements by applying them to the sensor nodes of the estuarine monitoring system.

SHF:Small: Collaborative Research: Beyond Secure Processors - Securing Systems Against Hardware Attacks
Yan Solihin
National Science Foundation
$230,229
09/15/09 - 08/31/12
Increasing amounts of potentially valuable data are stored and processed in computer systems, which motivates increasingly sophisticated attacks to obtain and/or tamper with this information. Protection against such attacks is needed for many important features of secure computing, such as enforcement of copyright protection for content and software, prevention of reverse engineering, trusted distributed computing, and fairness (prevention of cheating) in virtual environments. One important emerging threat are hardware attacks, which exploit the fact that data can be read or modified directly in the system’s memory using devices that dump or scan memory chips. Data transferred along system buses is similarly vulnerable to hardware attacks. These attacks may be more difficult to perform than software-based attacks, but they are also very powerful. A physical attack can bypass all software security protection in the system,
allowing attackers to read memory locations that store cryptographic keys and other sensitive information that may be used in software protection schemes. Widely available and inexpensive mod-chips that bypass Digital Rights Management in game systems demonstrate that physical attacks are very realistic threats. We propose: (1) To conduct detailed investigation into secure booting and configuration mechanisms for secure processors, (2) To explore how secure processors can support system features such as virtualization, virtual memory, inter-process communication, secure I/O communication, and achieve all those with low performance and storage overheads, and (3) To investigate how secure processor technology can be supported in a variety of computer platforms such as single processor systems, mobile systems, and multiprocessor systems with various interconnect topologies.

**Biomimetic Electronic Systems (BIMS): Electrical and Electromagnetic Interactions**
Daniel D Stancil, Gianluca Lazzi
University of Southern California
$404,145
09/01/04 - 08/31/10
In this project we will investigate thermal effects (models and methods) of bioimplantable devices developed in the ERC at the University of Southern California.

**Advanced Audio Workshop**
Michael B. Steer
Army Research Office
$26,083
06/01/10 - 05/31/11
The annual Workshop on Audio Technologies is sponsored by the Office of the Chief Scientist and by the Army Research Office in March or April of each year. This project is for the support of the fifth workshop in the Washington, DC area. The aim of the workshop is providing the intelligence community an exposure to the state-of-the-art audio-related technologies, and also exposure the academic community to areas of concern to the community.

**Electrical Network Design and Characterization For Three Dimensional Integrated Circuits**
Michael B. Steer
Boise State University
$135,000
04/09/08 - 05/17/11
Three dimensional silicon interposer technology will combine active silicon integrated circuits with silicon layers comprising passive components to enable complex electronic systems to be designed and cost-effectively realized. Enhanced performance will be achieved by enabling close integration of high performance passives with active integrated circuits. This project will design, model and experimentally characterize the passive circuits to be used in the interposer concept.
Novel radio frequency circuits including matching networks, filters, chokes, transformers and baluns will be developed.

**Electromagnetic Modeling Tools for Three Dimensional Integrated Circuits**  
Michael B. Steer, William R. Davis, Paul D. Franzon  
Parametric Technology Corporation (PTC)  
$1,720,000  
07/05/04 - 01/13/10
The central aim of this proposal is development of a workflow that supports three dimensional integrated circuit (3DIC) design and, with minimal change, will support module design. Work will address partitioning of high performance functions among individual integrated circuits in the 3DIC stack, reuse of the existing integrated circuit design infrastructure, and the critical thermal environment in 3DICs. The project requires good thermal modeling and thermally-oriented design.

**High Performance Tunable Materials Program**  
Jon-Paul Maria, Michael B. Steer  
Defense Microelectronics Activity  
$1,112,900  
10/19/09 - 04/30/11
The team will develop tunable materials in accordance with the Defense Microelectronics Activity (DMEA) High Performance Tunable Materials Program. The materials development effort will be founded on combinatorial synthesis methods ideally suited to solving issues of defect chemistry which regulate the relationships between the non-linear dielectric response and dielectric loss. Furthermore, a combination of microwave theory and electromagnetic simulations will be used to identify the best methods for incorporating ferroelectric capacitors into microwave circuits. Finally, this collective learning will be translated into a set of prototype microwave circuits of military and commercial interest.

**Optimum Waveform Design for Electromagnetic Disruption and Probing of Remote Devices**  
Michael B. Steer  
Army Research Office  
$900,000  
11/01/06 - 10/31/10
Waveforms will be designed to examine the characteristics of wireless devices. A wireless device consists of an antenna, frequency-dependent circuitry, and a nonlinear device. Identification is dependent on the ability to generate a large signal at the nonlinear device. Waveforms will be explored and validated that exploit radio frequency characteristics of antennas and circuitry.
Simulation and Measurement of Silicon Circuit Board Electrical Properties
Michael B. Steer
Sixis Inc.
$35,000
01/01/10 - 06/30/10
Abstract: High speed digital interconnect test structures will be measured and these measurements will be experimentally correlated with models and simulated transmission lines. Electrical models for use in circuit simulators will be developed for through silicon vias and selected other structures.

Standoff Inverse Analysis and Manipulation of Electronic System
Michael B. Steer, Kevin Gard
Army Research Office
$5,050,600
07/01/05 - 08/31/11
This is a program to probe, locate and identify wireless electronic circuits using electromagnetic probing. The program develops the required fundamental understanding of the phenomena involved through theoretical developments; and engages in experimental and modeling-based phenomenological investigations. In particular we are developing high power, wideband passive circuits with low passive intermodulation performance.

Ultra-Wideband Impulse Radio for Ad-Hoc Tactical Military Communications
J. K. Townsend
Army Research Office
$150,728
05/15/07 - 05/14/10
Ultra-wideband (UWB) impulse radio has been shown to offer advantages that make it well-suited for many tactical, military applications. In particular, the UWB waveform has the potential for good Low Probability of Intercept/Low Probability of Detection (LPI/LPD). We propose to investigate ultra-wideband technology with emphasis on the tactical military mission. Our approach will be to leverage our recent results in the area of chip discrimination with the transmitted reference UWB schemes, with the aim to provide new theoretical and practical architectures and techniques.

IPA Agreement With NSF For Robert Trew
Robert J. Trew
National Science Foundation
$478,822
05/26/09 - 05/25/11
This is an IPA agreement between NCSU and NSF for Dr. Robert J. Trew to serve as Director of the ECCS Division at NSF for one year.
Novel Nanoscale Technology for Thermal Energy Harvesting
Robert J. Trew, Ki Wook Kim
Army Research Laboratory
$320,000
05/19/09 - 11/19/12
This research program explores the feasibility of engineering thermal radiation for application to thermal energy harvesting. The high energy density stored in the evanescent field of surface excitations present on a thermal source composed of a polar semiconductor is transformed into spectrally and/or spatially selective radiation for ready extraction. At nanoscale distances, near-field thermal excitations of polar semiconductors occupy narrow bands at THz frequencies. These excitations, in the form of surface waves, establish a quasi-coherent, evanescent field with high energy density. Properly designed surface microstructures can potentially convert power available in evanescent modes to propagating modes with high efficiency.

Reliability Modeling of High Voltage AlGaN/GaN HFETs
Robert J. Trew, Griff L. Bilbro
University of California - Santa Barbara
$180,000
03/14/08 - 04/30/11
This project is directed towards the development of mathematical models for AlGaN/GaN HFETs that can be used to investigate physical phenomena that affect both short term and long term reliability. Physical processes are modeled and used as a basis to explain reliability issues.

The Millimeter-Wave Initiative for Nitide Electronics
Robert J. Trew, Griff L. Bilbro
University of California - Santa Barbara
$150,000
04/01/05 - 03/31/11
Advanced physics-based device models for AlGaNGaN HFETs are developed and enhanced with appropriate physical phenomena that permit accurate simulation of realistic HFET device performance. The models are used to determine optimized device designs for mm-wave operation. Physical effects to be investigated include, channel charge transport, space-charge and high current density effects in the source-gate region, channel current non-confinement under large-signal RF voltage, electron transit-time and channel depletion region phenomena, and thermal effects. The models are calibrated with experimental data and are used to investigate physical phenomena limiting device performance, as well as for determining improved device designs.

CSR-PSCE, SM: Exploring Helper Computing Parallelism in Multicore Architectures
James Tuck, Yan Solihin
National Science Foundation
$370,000
As software complexity increases and threats from security attacks grow, a new low-overhead approach for improving software reliability and security is urgently needed. In helper computing, relatively autonomous "helper" threads or processes execute extra code on behalf of the application on separate processors or thread contexts. The project seeks to develop helper computing technology for enhancing reliability and security of computer systems.

Software Exposed Hardware Signatures for Code Analysis, Optimization, and Debugging
James Tuck
National Science Foundation
$99,839
09/15/09 - 02/28/11
Effective dynamic memory disambiguation limits many practical approaches for code analysis, optimization, and debugging. A potential avenue for overcoming the traditional limits of hardware memory disambiguation is through the use of signature registers. Such registers can operate on hundreds of addresses simultaneously and can be exposed to software through a flexible and general interface for a wide variety of uses. However, because signatures represent sets of addresses imprecisely, they are prone to false positives that limit their accuracy and effectiveness. This research will investigate the potential of exposing signature registers to software in the context of code analysis and optimization.

Entrepreneurship Education & Its Impact on Engineering Student Outcomes: The Role of Program Characteristics and Faculty Beliefs
Thomas K. Miller, Stephen J. Walsh, Dianne Raubenheimer
National Collegiate Inventors & Innovators Alliance
$55,199
01/01/09 - 12/31/11
Driven by changes in the global economy, entrepreneurship has become one of the fastest growing academic areas within the nation's 335 engineering schools. As a result, hundreds of courses and programs in entrepreneurship are now offered to engineering students. Despite the widespread adoption of these curriculum changes, we have done little to examine different program models, faculty beliefs and teaching practices, and infrastructure and how these differences relate to students' entrepreneurial knowledge, skills, and attitudes. Clarifying the relationship between faculty beliefs and practices, program characteristics, and student learning is necessary if we are to provide guidance to faculty in how to create and improve these educational experiences and evaluate their success. In response to the above needs, we propose to conduct in-depth examinations of entrepreneurship initiatives at three schools that produce large numbers of engineering graduates. We will examine faculty beliefs and teaching practices, program and course characteristics, and assessment practices, and will analyze how they relate to student learning outcomes.

CAREER: A Unified Study of Resilience-to-Failure in Multihop Wireless Networks
Wenye Wang
National Science Foundation
Multihop wireless networks can offer a wide variety of important applications that could have a substantial impact throughout society as mobile devices become more and more critical to our day-to-day lives. However, the infrastructure of such networks is vulnerable to many types of network dynamics such as node mobility, potential attacks, and misbehavior. This research aims to develop models and algorithms for a deeper understanding of multihop networks when multiple failures are present.

FirstComb: A Case Study of the First Generation Communication Backbone for FREEDM
Wenyang Wang, Alexander G. Dean
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Unfunded
09/01/08 - 08/31/10
Develop first generation communication system for FREEDM system.

NSF Engineering Research Center for Future Renewable Electric Energy Delivery and Management (FREEDM) Systems
Alex Q. Huang, Mark A. Johnson, Edward A. Baker, Srdjan Miodrag Lukic, Wenyang Wang, Mesut E. Baran
National Science Foundation
$18,499,962
09/01/08 - 08/31/13
The Future Renewable Electric Energy Delivery and Management (FREEDM) Systems Center, headquartered on NC State University's Centennial Campus, is one of the latest Gen-III Engineering Research Centers (ERC) established by the National Science Foundation in 2008. The FREEDM Systems Center will partner with universities, industry, and national laboratories in 28 states and nine countries to develop technology to revolutionize the nation's power grid and speed renewable electric-energy technologies into every home and business. The center is supported by an initial five-year, $18.5 million grant from NSF (award #0812121, Division of Engineering Education and Centers) with an additional $10 million in institutional support and industry membership fees. A large number of utility companies, electrical equipment manufacturers, alternative energy start-ups, and other established and emerging firms are part of this global partnership. The core universities of the center are NC State University, Arizona State University, Florida A&M University, Florida State University, and Missouri University of Science and Technology. The core international universities of the center are RWTH Aachen University in Germany and the Swiss Federal Institute of Technology in Switzerland.

Reliable Medium Access in Wireless Networks: Vulnerabilities, Protection, and Recovery
Wenyang Wang, Peng Ning
Army Research Office
The goal is to study vulnerabilities of medium access in wireless networks and develop preventive algorithms for protection and reactive algorithms for recovery in the aftermath of cyber-attacks. By considering multi-radio networks as a promising technique for military applications, we propose to design a MAC-oriented resource management framework for enhancing network availability. This mechanism is capable of precisely discovering accessible wireless networks and fairly allocating transmission slots to solve the unreliable medium access problems by combining cryptographic approaches and networking design.

**Robust Network Architecture Against Random Threats in WMD Environments: Theoretical Limits and Recovery Strategies**

Weny Wang, Hamid Krim
Defense Threat Reduction Agency
$691,577
04/01/08 - 03/31/11

This project addresses two thrusts, namely network vulnerabilities and recovery strategies in the aftermath of WMD attacks. More specifically, this research targets a set of fundamental issues to understand network response following an attack by WMD/WME: how to model a network topology in the presence of attacks/failures from random threats; how to estimate or predict network survivability to sustain critical applications; how to design/form network architecture to approach the theoretic limits of network robustness. The results of this research will advance the state of knowledge on network response by designing robust, self-healing, complex network architecture which interacts with other networks.

**Satellite Connectivity**

Weny Wang
University of Florida
Unfunded
02/09/09 - 07/31/10

The objectives of the project will be achieved by evaluating the technology for single-hop communication links, including an investigation of both radio and laser options. The study will also create mobility models based on link path dynamics. At the end of project, we will deliver 1) report on down selection of inter-satellite communication link technology, with proof-of-concept demonstrations. 2) Small satellite communications-based mobility model ; 3) Network routing protocol with accompanying performance analysis

**Time and Data Sensitive Wireless Networked Control Systems**

Weny Wang, Mo-Yuen Chow
National Science Foundation
$273,717
This is a request for supplemental funding to support extensive stay at an international institute by the PI and her graduate student to gain international research experience and perspective, and to enable closer research interaction between North Carolina State University and Wireless Research Institute at Shanghai Jiaotong University, China

Improving Predictive Models of Biochemical Pathways in the Presence of Uncertainty
Cranos Williams
NCSU Faculty Research & Professional Development Fund
$4,947
07/01/09 - 06/30/10
The predictive ability of any biochemical pathway model is solely based on our ability to estimate the appropriate values, or range of values, of the component concentrations and kinetic parameters. These values should effectively capture the range of activity of the pathway given the observed activity seen in the measurements. In considering erroneous measurements where any concentration within some upper and lower bound of the measurement is equally valid, it is imperative to estimate the full range of component concentrations and kinetic parameters that are consistent with the potential range of valid measurement concentrations. We propose to develop a bounded estimation approach for biochemical pathway models that will estimate the range of parameters and concentrations that are consistent with the uncertain measurements. An accurate range on these estimates better reflects the uncertainty associated with the model and allows us to better predict the range of possible activity given this uncertainty. Our proposed method is an extension of the classical predictor-corrector approach, which has been shown to be useful in other estimation approaches.

Magneto-Transports in Interband Resonant Tunneling Diodes (I-RTDs) and Dilute Magnetic Semiconductor (DMS) 1-RTDs
Weidong Zhang, Peiji Zhao
Army Research Office
$254,667
05/01/07 - 12/31/11
This research seeks to develop multi-band models for understanding of basic transport and photonic physics of heterostructures with staggered band/broken-gap alignments when subjected to electric field/magnetic fields and when composed of diluted magnetically-ordered superlattices. Here magnetically ordered superlattices refers to the situation where a small percentage of sublattice cation sites from one or two heterostructure layers are substituted by Mn magnetic ions, which carry localized magnetic moments. The investigations will develop new models and execute simulations to analyze and engineer specific device configurations suitable for THz oscillations.

Resonant Tunneling Diode for High-Power Room-Temperature Terahertz Emission
Weidong Zhang
University of Virginia
$120,000
11/15/08 - 09/10/10
This STTR project is to model, design, build and demonstrate a novel, hybrid interband resonant tunneling diode (I-RTD) terahertz oscillator capable of operating across 300-600 GHz at room temperature with output power levels in mW range. The performance will be of great use in applications such as biochemical agent detection and standoff imaging of concealed weapons and explosives. Phase I succeeded in modeling I-RTD device, and identified InGaAs/GaSbAs/InP structures. Phase II will grow epitaxial wafers, fabricate into devices in Spire and test devices for terahertz emission spectra. I-RTD modeling and antenna designs will be carried out by UVa and NCSU.

CAREER: Architectural Support for Automated Software Debugging
Huiyang Zhou
National Science Foundation
$388,229
08/17/09 - 04/30/13
Given their ever increasing complexity, modern software systems are plagued with software defects, commonly known as bugs. Due to the limited on-chip resource at the time, traditional architectural support for debugging was limited to a basic set of primitive functions like breakpoints and watchpoints. With the advances in semiconductor technology, the resource constraint is less of a concern and much more powerful architectural support becomes possible to be implemented. In this research, novel software-hardware integrated approaches are developed to automatically pinpoint software defects.

TC: Medium: Collaborative Research: Side-Channel-Proof Embedded Processors with Integrated Multi-Layer Protection
Huiyang Zhou
National Science Foundation
$100,000
09/15/09 - 08/31/11
Cryptographic algorithms are widely used in digital systems to protect sensitive information. Recently, it has been noted that malicious attackers against computer systems, especially embedded systems, have switched their targets from the cryptographic algorithms themselves to the hardware/software implementations of these algorithms, through “side-channel” chip measurements. The goal of this research is to develop a universal solution that synergistically combines both architecture-level and circuit-level countermeasures for mitigating all major categories of side-channel attacks, to yield an extremely secure, highly flexible, low overhead digital system design methodology.