

Electrical and Computer Engineering Research Projects 2008–09

Collaborative Research: Advanced Space Technologies Research and Engineering Center

Winsler E. Alexander, William W. Edmonson
National Science Foundation
\$1,120,000
08/01/08 - 06/30/13

The objective of this project is to develop technologies that produce improvements in time to orbit, cost, and performance of U.S satellite systems. Through these efforts, the pre-eminence of the U.S. space industry can be regained. In order to accomplish this objective, the Center will perform multidisciplinary research in the areas of small satellite technologies. The Center will utilize a design-build-fly (DBF) philosophy (similar to that utilized by the UAV community) to accomplish rapid transitions from low technology readiness levels to actual flight test. The emphasis will be on small satellite systems (particularly pico and nano-class) because they (i) provide rapid access to space, (ii) are technology drivers (mass, volume, power constraints) and (iii) are economically feasible. Broader impact: To be good stewards of our space environment, the ASTREC is cognizant of [WE2]the potential impact of its DBF approach to the problems of space debris. In this regards, it is expected that one of the first demonstrators to be developed and evaluated by ASTREC will address on-orbit services such as debris removal though autonomous rendezvous and docking. Furthermore, it is imperative that this recovery capability becomes routine to the space industry, otherwise the community will not migrate towards Risk Tolerance because of the fear failure. However, with a capability for recovery, the fear of failure can be reduced, and in fact, the lessons learned from the failure can be utilized in a positive manner to develop a better product.

ITWF: Collaboration Through Agile Software Development Practices: A Means for Improvement in Quality & Retention of IT Worker

Laurie A. Williams, Mladen A. Vouk, Jason A. Osborne,
Winsler E. Alexander, Sarah B. Berenson
National Science Foundation
\$2,437,761
07/15/03 - 06/30/09

We propose to conduct a meeting of the principal investigators (PIs) and Co-PIs of the Information Technology Workforce program (ITWF). There are about 50 projects funded by the National Science Foundation (NSF) in the fiscal years 2000-2004 that are still current. One person, preferably the PI, from each of the 50 projects will be invited to attend the meeting. It is estimated that 70 PIs will attend the conference and will receive support for airfare, hotel, meals, and conference registration. In addition, two NSF representatives, 2 speakers, and 10-12 additional participants such as students helping with the conference and local PIs would also attend the meeting/meals.

GaN Impact Ionization Characterization for Generation 2 Power Devices

B. Jayant Baliga
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
\$61,035
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)
\$136,379
09/01/08 - 08/31/09

In the ERC program, the primary side of the Solid-State Transformer (SST) requires asymmetric n-channel IGBTs with 15kV blocking voltage capability. In contrast, the Fault-Interruption-Device (FID) requires reverse blocking complementary 15kV IGBTs. Such high voltage IGBTs have not yet been demonstrated. This project will be conducted in close collaboration with CREE. The design of the 15kV IGBT device structures will be performed to be compatible with best practices for manufacturing SiC devices at CREE. The chip layout will explore the design space for obtaining optimum electrical characteristics. The process flow will be defined in collaboration with CREE. Device fabrication will be performed at CREE. Devices will be tested at wafer level at NCSU. Packaging will be performed at CREE. Power Device testing will be performed at NCSU and CREE

ERC College Education Program

Mesut E. Baran
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
\$38,981
09/01/08 - 08/31/09

To implement college education program at NCSU and at other campus schools New master program New concentration for undergraduate students Course crosslisting New course Budget \$5000 is to support the summer salary of the PI. \$20000 is to support other curriculum development efforts.

Load Modeling and State Estimation Methods for Power Distribution Systems

Mesut E. Baran
EnerNex Corporation
\$496,246
08/08/07 - 08/07/09

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.

Notional FREEDM System Model For Simulation and Analysis

Mesut E. Baran
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
\$68,382
09/01/08 - 08/31/09

This project has two objectives. The main objective is to develop a notional Freedm sys-tem 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 simula-tion, 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)
\$47,787
09/01/08 - 08/31/09

To develop high current (up to 100A) and low voltage (300V to 12 00V) 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
\$960,224
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)
\$8,000
03/27/09 - 09/27/09

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.

Normally Off GaN MOSFETs For High Electrical Efficiency Electronics

Douglas W. Barlage
Kyma Technologies, Inc (formerly Carolina Sputter Solutions)
\$12,500
01/01/09 - 06/30/09

Kyma Technologies of Raleigh was awarded \$60,000 to work with researchers at North Carolina State University to develop a very efficient, lower-cost electric switch to be used in a broad range of applications including hybrid and all electric vehicles, legacy and renewable electric grids and power supplies in general.

Dilute Magnetic Semiconductor Devices Based on Fermi Level Engineering

Nadia A. El-Masry, Salah M. Bedair
Army Research Office
\$1,824,440
10/01/07 - 02/28/10

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. Correlation of these properties with the polar orientation of the GaN crystals is expected to lead to a better understanding of the physical mechanisms underlying FM behavior in III-nitride semiconductors.

Improved LED Performances by Sidewal 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 principle technical barrier in improving LED performance is the low quantum efficiency and optical gain found in high percentage InGaN compounds. Recent research efforts have found that the use of the non-polar orientations of GaN is encouraging and that strategies that mitigate the detrimental piezoelectric field effects using m-plane are

promising. 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
 \$3,443,442
 05/01/08 - 04/30/11

The first cascade multiple junction solar cells reported by Bedair (1979) was based on AlGaAs/GaAs for the top and bottom cell with 16% conversion efficiency. Recent progress based on three junctions cell: GaInP(1.85eV)/GaAs(1.42eV)/Ge(0.67eV) with conversion efficiency ~32% and 40% at one sun 240x, respectively was reported. It has been realized that conversion efficiency $\eta > 35\%$ and $\eta > 45\%$ at one sun and high x respectively can be achieved in four junction structure. The four junction cell requires materials system with band gap Eg: 1.9 eV/1.5 eV/1.0 eV/0.67 eV(Ge). Material system with Eg > 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 $\eta = 45\% - 50\%$ 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.

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.

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)
 \$238,467
 09/01/08 - 08/31/09

The Generation 1 of SST is required to be a bidirectional Si- baseline single-phase 10kVA system which can interface with existing 12kV distribution voltage and deliver 120V ac single phase output. One design of SST has three components: (a) rectifier stage for interface with 12kV distribution grid which will be implemented by MST, (b) bidirectional isolated dc-dc converter and two different topologies will be implemented and evaluated by FSU and NCSU, (c) inverter stage with single phase 120V ac output implemented by ASU. These SST components (from the multi-campus projects) with their controls will then be integrated in one prototype system and tested to verify all functionalities of SST at NCSU laboratory. The Generation 1 of SST will be a demonstration of a functional and tested SST prototype by the end of Year 1.

STATCOM Controller Design and System Performance as a FACTS Device

Subhashish Bhattacharya
Hyosung Corporation
 \$133,930
 07/01/07 - 08/31/08

This project addresses all aspects of STATCOM control and evaluates its performance under various power system conditions. Reliable and satisfactory operation of STATCOM under system faults is imperative and when its reactive power support is required the most. The STATCOM controller design and its system level performance evaluation by simulation and hardware model will be verified. Converter aspects will also be investigated.

Carbon Nanostructures and Wide Bandgap Semiconductors for Vacuum Thermionic Energy Conversion

Raymond E. Fornes, Griff L. Bilbro, Robert F. Davis, Zlatko Sitar, Robert J. Nemanich
University of California - San Cruz
 \$1,618,999
 05/21/03 - 06/30/09

Thermionic energy conversion is typically achieved through the combination of a hot electron emitter (cathode) with a somewhat cooler collector (anode). The NCSU program in this option period of the TEC MURI will involve two projects. The first project will work towards the development of thermionic energy conversion based on thermionic emission from low work function n-type diamond semiconductor emitters. The second project will focus on the development and optimization of a high-growth rate process for growth of large area HOD films on Si, thermal, structural, and electrical characterization of these films, and fabrication of free-standing substrates for TEC applications.

Fast and Robust Target Tracking

Griff L. Bilbro
Army Research Office
 \$100,000
 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 - 04/30/10

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. The work will perform detailed tradeoff analyses of architectural alternatives, especially with respect to memory hierarchy and interconnection networks, in order to discover approaches that fully exploit the benefits of 3D integration. This analysis will be performed at both the architectural level and the physical design level, and tools will be developed to allow information and constraints to smoothly flow between levels, enabling new opportunities for collaboration between architects and chip designers. The studies will be driven by highly-parallel applications that require high performance within strict power and thermal constraints, such as video compression and signal processing in embedded environments. The goal is to find the killer apps that will fully exploit highly-connected 3D chip multiprocessors.

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.

IPA Agreement with Asian Office of Aerospace Research & Development

Jim C Chang
US Air Force
 \$751,840
 01/31/06 - 01/30/10
 IPA Extension for Jim Chang

A Joint Exploratory Study on the Applicability of Networked Control Systems For Critical Multi-variable Systems

Mo-Yuen Chow
National Science Foundation
 \$8,591
 08/15/06 - 07/31/08

This project will provide a unique opportunity to test the NCS technology developed in a practical test case on the Networked Control Scheme for a 500 MWE Nuclear Power Plant that has the capability of online tuning. (This kind of opportunities are highly unlikely in US.) The scheme would be tested on a simulation environment in collaboration with the Nuclear Power Corporation, Mumbai in order to assess the ability to cope up with different transients. The actual experimentation can provide valuable experimental feedback information to help the PI to advance the NCS technologies, and to bring the technologies one step closer to actual engineering applications, which will substantially benefit the US society. The broader impacts of this project are far reaching to many different industries such as the power sector, manufacturing sector, transportation sector, and education sector. For example: provide a benchmark demonstration for the next generation high dimension process control using NCS to achieve a more effective, more flexible, more economical, more reliable, and safer operations for industries to follow suit.

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

In this project, we propose to use 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 of IDEA is to prevent accident caused by abnormal behavior of the impaired drivers during driving. At this phase, the attention is directed at assistive technology which warns the driver and drivers in the impact neighborhood of potential safety problem and generates the necessary corrective commands only under emergency situations. In order to achieve this goal, we propose to use the Intelligent Space (iSpace) concept, which is to integrate globally distributed sensor agents, distributed actuator agents, and distributed controller agents over networks to make optimal local decisions which cannot otherwise be achieved.

Distributed Grid Intelligence

Mo-Yuen Chow
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
 \$13,970
 09/01/08 - 08/31/09

The primary objective of this task is to define the system control & management requirements for the DGI within the IEM/IFM. Requirements are determined from and generated with the SMC thrust for control algorithms, the RSC subthrust for communications, and with computer science and engineering knowledge of system management of distributed resources

Intelligent Human-Machine Interface & Control for Highly Automated Chemical Screening Processes

David B. Kaber, Robert A. St. Amant, Mo-Yuen Chow
National Science Foundation
 \$798,132
 10/01/04 - 09/30/08

The main outcome of the work will be a prototype of the intelligent, adaptive interface with content defined based on cognitive model predictions of operator performance (during various phases of chemical screening). The overall process control system will incorporate unique local control (software) agents to monitor robot system states and manage emergency conditions, as well as software to monitor remote operator functional states. Models of this data will be developed and input into the cognitive model to facilitate effective dynamic interface configuration and remote process control as well as operator workload management. The intellectual merits of this work will include: cognitive task analysis of human interaction with life sciences automation; cognitive modeling of screening process operator performance in multiple robot control; network-based, remote control of screening processes and experimental data analysis under varying communication conditions; and neural-network based classification of operator functional states in screening control (in hard real-time) and prediction of information requirements for effective performance. The main broader impact of the research is the enhancement of safety and effectiveness of high-throughput, chemical agent screening. The research will also provide specialized training for graduate students through faculty development of new course modules, related to the project, integrated in existing computer science, electrical engineering, and industrial engineering curriculums.

Massive Sensor Based Congestion Management System for Transportation System

Mo-Yuen Chow
New Jersey Institute of Technology
 \$33,405
 06/13/08 - 06/12/09

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
 \$246,000
 09/01/07 - 08/31/10

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.
 \$99,000
 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.

Confidence in Computer Architecture Modeling and Simulation

Thomas M. Conte
National Science Foundation
 \$150,940
 09/15/05 - 08/31/08

Over the last decade, there has been an explosion in research into fast simulation of computer architectures. Coupled with this is also research into approximate models of architectures. The majority of this work is either implicitly based on basic statistical sampling or on stochastic methods. Unfortunately, the explicit connections to random processes and statistics remains to be made. What has resulted is a collection of simulation and modeling techniques that are fast, but of unknown quality. Most of the studies that introduce the new techniques present some empirical evidence that the reduced models are relatively accurate to some more detailed simulation. Knowing that the instruction level parallelism in a program is 3.0 is meaningless if the error is plus or minus 1.5 instructions per second. In natural sciences and many branches of engineering, statistical sampling theory is used to predict the confidence in the simulation methods. It is time to enhance the science used in computer architecture with sampling theory. When possible, this project will adapt sampling theory to predict confidence in reduced models. Architecture presents a unique situation for sampling theory, and new statistical techniques will be developed as needed in this project to rise to the occasion. The principal investigator will extend his students' and his path breaking work a decade ago to the current computer architecture challenges. When appropriate, new techniques will be developed as needed.

Membership Agreement for the North Carolina State University Center for Efficient, Scalable and Reliable Computing

Gregory T. Byrd, Thomas M. Conte
Qualcomm
 \$33,000
 01/01/08 - 12/31/08

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.

Membership in the Center for Efficient, Secure, and Reliable Computing (CESR), Affiliate Member

Gregory T. Byrd, Thomas M. Conte
Red Hat, Inc.
 \$50,000
 09/01/04 - 12/31/08

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.

Workload Characterization of Multithreaded, Multiprocessor and Clustered Applications

Thomas M. Conte
Hewlett-Packard Co.
 \$41,692
 08/01/07 - 07/31/08

Workload characterization is an integral part of the process of designing and optimizing computer systems. Being able to accurately predict the performance and power of a given system configuration has also become a fundamental decision support technology for provisioning computing and storage resources in a datacenter setting. Simulation technology has not yet scaled to the new challenges posed by the complexity and variability of modern computing systems and workloads. For this reason, HP Labs has invested on execution-driven simulation as a more accurate tool to predict system performance or power. However, even the most advanced execution-based approaches are at least 1-2 orders of magnitude slower than what is needed to simulate full workloads of interesting applications. Hence, it becomes very important to be able to simplify the problem by only simulating the relevant parts of an application. The technology that is responsible for selecting representative parts of an application is commonly referred to as sampling. This project will investigate and develop multithreaded sampling techniques for accelerating simulation approaches.

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

The purpose of this project is to study 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, our proposed scheme 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. An important application of collaborative quickest detection is spectrum sensing in cognitive radio systems. In such a system, secondary nodes need to monitor the activity of primary users, and should quit the frequency band once primary users emerge. It is essentially a problem of quickest detection since the secondary nodes need to detect the change as quickly as possible. Our proposed research can substantially reduce the response time of secondary nodes and decrease false alarms. The research on collaborative quickest detection comprises the following four thrusts: 1. Aspect of statistical signal processing: we plan to study the rules of change detection when observations from different collaborators have different delays; we also plan to use Skorokhod embedding to study the performance of quickest detection. 2. Aspect of communication and information theory: we plan to study source coding for exchanged information as well as the corresponding communication complexity. 3. Aspect of networking: we plan to study the scheduling of broadcast for collaborative quickest detection in wireless networks, as well as the topology control for information exchange. 4. Aspect of application in cognitive radio: we plan to study monitoring the change of primary radio users in single or multiple frequency bands. **Broader Impact:** The proposed research will contribute fundamental concepts and analytical tools to the new arena of collaborative quickest detection. It also provides new methodologies and techniques for fields like signal processing, communication theory and wireless networking. We also plan to apply the results of our proposed work in collaborative projects with Oak Ridge National Lab (ORNL). The inter-disciplinary essence of our proposed research also lends itself to cross-disciplinary education. We plan to devise a one-semester graduate level lecture introducing quickest detection, cooperative communication and cognitive radios. Besides involving graduate students working toward master and doctoral degrees, this project also expects to attract traditionally underrepresented groups, particularly through the collaboration with the UTK chapter of the National Society of Black Engineers (NSBE).

Exploiting Multiple Antennas in Multiuser Wireless Networks

Huaiyu Dai, Brian L. Hughes
National Science Foundation
 \$1,065,879
 07/01/05 - 06/30/09

This proposal requests supplemental funds to support an undergraduate student, Mr. Alan Graham, to conduct research directly related to the objectives of this NSF-sponsored project. Mr. Graham is an African-American student, who is currently a senior at North Carolina State University pursuing a double major in electrical engineering and computer

engineering. Mr. Graham is one of the top students in the senior class and has a very strong record of performance (GPA 4.0) in some of the most demanding courses in mathematics and engineering at NCSU. Mr. Graham began work in February 2007 on a project to investigate interference cancellation in wireless communication systems using a new kind of multiple-antenna system, called a vector antenna. Thus far, most work on interference cancellation has focused on arrays of scalar sensors, each of which measures only one component of the electric or magnetic field. More recently, some studies have considered the use of dual-polarized sensors that measure two components of the electric or magnetic field. However, since the electromagnetic (EM) signal detected at the receiver consists of 6 field components (3 electric and 3 magnetic), most of the information contained in the signal is currently neglected. In principle, an array of vector antennas that can detect or excite all 6 components of the EM field might boost wireless capacity by a factor of 3 over comparable dual-polarized arrays, and by a factor of 6 over comparable scalar-sensor arrays. The use of vector-sensor receivers to estimate the direction of electromagnetic sources in line-of-sight propagation has been extensively investigated; however, the possibility of using these antennas for wireless communication in multipath propagation environments, particularly at the transmitter, has received little attention and is poorly understood.

WN:Collaboration of Networked Nodes through Belief Propagation: Where Computing Meets Communications

Huaiyu Dai
National Science Foundation
\$587,874
09/01/07 - 08/31/10

This research comprises the following three main thrusts. 1) Convergence and correctness of the BP algorithm on general graphs, a challenging problem of high impact on its own, will be studied in the context of specific applications. The connection between BP fixed points and stationary points of some constrained minimization problems will also be pursued, and protocol designs will be jointly considered with theoretical study. 2) The influence of communication constraints will be explored with respect to message representation, message error and message scheduling, culminating in a comprehensive study on the tradeoffs among energy efficiency, accuracy, computational complexity, and delay. 3) The synergy of generalized belief propagation (GBP) with sensor networks, an almost brand-new area, will be explored. We will particularly study efficient methods of region partitioning for GBP, which is still more an art than a science. We also propose to study hybrid structures which can combine the advantages of in-network processing and data fusion. Broader Impacts: Though this proposal targets wireless sensor networks, the proposed framework and fundamental research apply largely to general ad hoc networks as well. They can even be extended to virtual scenarios where a set of ?sensors? distributed over the Internet cooperate on a joint task through information exchange. If we think of wireless networks as a new kind of computer systems, belief propagation can serve as an effective programming language for them. The proposed work lies in the interface of networking, communications, and computing, heavily relying on the knowledge in information theory, communication theory, Bayesian inference, graph theory and models, and communication/computation/information complexity. It has the potential to advance the theory and practice of these areas, and contribute to the evolution of next generation

wireless networks. The PI will seek to incorporate material inspired by this work (at an appropriate level) into the undergraduate and graduate curricula at North Carolina State University. Various channels will be utilized to disseminate research findings to industry and the broader public.

Architectural Evaluator For Three-Dimensional Integrated Circuits

William R. Davis, Paul D. Franzon
Semiconductor Research Corp.
\$480,000
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. Companies will avoid adopting 3D integration until it becomes the most cost-effective way to meet their system performance goals. Designers are also having difficulty evaluating 3D alternatives to 2D implementations. Therefore, an easy system for evaluating the performance of a new system-on-chip in a 3D process is needed to determine the performance enhancement offered by 3D. This document proposes a three-year research project to develop an open-source CAD framework and process design kit (PDK) 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
\$1,228,929
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 scientifically viable alternative to continued scaling of transistor gate lengths. A fully successful program will provide the models and methods needed to optimize, verify, and experimentally demonstrate high-performance and low-power 3D ICs. The first objective is to research the high-level abstractions needed to optimize energy and delay through memory structure, clock-tree topology, and floorplanning constraints. The second objective is to research methods for thermal verification of 3D ICs with analyses of the prediction error of current methods and new mathematic formulations to overcome the fundamental limitations of simulating heat-flow in 3D IC systems. The third objective is to experiment with these optimization and verification techniques in search of new computing applications with latency and power that cannot be achieved with traditional IC technology. Successful experimental confirmation of these methodologies will consist of fabricated 3D ICs that achieve half of the computational latency and power dissipation of traditional ICs with comparable transistor feature sizes.

FreePDK: An Open-Source, Variation-Aware Design Kit

William R. Davis, Paul D. Franzon
Carnegie Mellon University
\$141,987
09/01/07 - 08/31/09

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 and I/O-pad library with the necessary support files to enable full-chip place & route and verification for System on Chip designs. Test-chips designed with this PDK will be fabricated by an SRC member company, allowing validation of the design-rules so that the rules may be used in future multi-project runs and design contests.

Test Bed For Steep Subthreshold-Slope Transistor Circuits

William R. Davis
Wyle Laboratories
 \$76,980
 08/19/08 - 08/30/09

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. In order to allow the test-bed to operate at the highest speeds possible, it will be implemented as core to be integrated on-chip with the test circuits. To ease the insertion of this core into other processes, it will be implemented using a standard-cell approach as much as possible. To facilitate ease in testing, a simple interface will be developed, so that tests can be initiated using low-frequency pattern generators.

CAREER: Software Thread Integration for Low-Through High-End Embedded Systems

Alexander G. Dean
National Science Foundation
 \$680,000
 02/01/02 - 01/31/09

Software thread integration is a compiler technique enhances fine-grain concurrency of generic processors and increases a thread's instruction-level parallelism. The research simplifies the process of adding extremely fine-grain concurrency real-time tasks (primarily network support) to embedded systems while reducing development and unit costs, component count and overall device size and weight. The research also makes existing and future high-performance processors execute programs faster by using existing instruction-level parallelism resources more efficiently. This enables more sophisticated applications and improves execution performance and power consumption.

CSR - EHS Rapid Efficient Implementation of Communication Protocols for Embedded Systems

Alexander G. Dean, Mihail L. Sichiuiu, Thomas G. Wolcott
National Science Foundation
 \$337,000
 08/15/05 - 07/31/09

Research scope includes development of new methods and a framework to allow users to quickly implement efficient software-based controllers for customized network communication protocols; development of methods, a toolbox and an associated communication framework to allow users to quickly implement software-based controllers for customized network communication protocols. More specifically, the project will provide a complete networking stack featuring several options at each layer in the stack. The work will allow practitioners to implement optimized protocols,

by providing the design and analysis tools that bridge the gap between network and CPU simulation. While the proposed tool will be very general and target a broad range of hardware (microcontrollers and transceiver), we will use two sample applications from two such unrelated fields as a reality check mechanism.

CSR-EHS: Integrated Memory Allocation and Scheduling for Real-Time Embedded Systems

Alexander G. Dean, Eric Rotenberg
National Science Foundation
 \$120,000
 08/01/07 - 07/31/09

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.

Networked 3D Virtual Computing for Collaborative Environments in Science and Education: Towards VCL 3.0

Mihail Devetsikiotis, Mitzi M. Montoya-Weiss
NCSSU Center for Advanced Computing & Communication
 \$40,000
 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 - 06/06/10

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.

Adaptive Transmission and Channel Modeling for Frequency Hopping Communications

Alexandra Duel-Hallen, Hans D. Hallen

US Army

\$270,000

06/20/05 - 06/19/09

The objective of the proposed research is to explore adaptive signaling, reception and channel modeling issues for slow frequency hopping (SFH) communications. The SFH systems suffer from performance degradation due to severe time-varying channel impairments, including long- and short-term fading and interference. To improve the bit rate, it is desirable to jointly adapt the transmitted and the received signal to these variations. In practice, such adaptation requires accurate channel estimation and prediction. Moreover, channel modeling that provides insights into the nature of channel impairments is required in the design and validation of adaptive methods. While the PIs have recently demonstrated that reliable adaptive modulation aided by long-range channel prediction (LRP) is feasible for SFH systems with coherent detection, greater gains are desirable for realistic SFH channels. It is proposed to develop more reliable prediction methods to achieve higher spectral efficiency, and to combine the proposed adaptive techniques with mitigation of partial band interference. The proposed algorithms will be validated using the enhanced physical model designed for practical peer-to-peer SFH communications. The proposed research is an interdisciplinary effort in communication theory, physics, and signal processing that encompasses novel physical models, channel prediction and tracking methods, and adaptive signaling algorithms. The interdisciplinary nature of proposed research benefits graduate students involved in the project. The infrastructure for research and education is enriched by incorporating the methods investigated in this research in senior and class projects and by integrating with wireless communications activities at NC State. Validation using measured data and experimental verification of proposed techniques is envisioned using the resources of the Wireless Communications Laboratory and enhanced by collaborations with industry and government labs. The overall objective is to improve efficiency and robustness of mobile radio systems.

Channel Modeling and Adaptive Transmitter/Receiver Design for Outdoor Ultrawideband Communication Systems

Alexandra Duel-Hallen, Hans D. Hallen

National Science Foundation

\$149,722

03/15/08 - 08/31/09

The objective of the proposed research is to improve performance of the Ultrawideband (UWB) systems by exploiting their physical channel characteristics. UWB communications has the potential to provide low cost and high speed service, and has attracted increasing interest since the release of Federal Communications Commission (FCC) spectral masks. The proposal focuses on alleviation of potential outages in the outdoor UWB systems due to shadowing and other difficult propagation environments by exploiting novel transmitter and receiver design methods. Due to its very large bandwidth, the UWB channel suffers from frequency-dependent distortion of individual multipath components. This per-path distortion is not significant in systems with smaller bandwidth employed in most wireless systems. However, in UWB systems, some challenging propagation environments that can cause in outage, e.g. shadowing, reflection by a small reflector, or penetration through objects are characterized by per-path distortion and the associated frequency-dependent propagation loss. Moreover, these challenging scenarios are more prevalent in outdoor than in indoor UWB systems. For example, they arise when transmitting in a canyon-like street or over a hill. Most of the research on UWB communication has focused on the indoor systems. Thus, characterization of per-path distortion has received little attention, and exploitation of the frequency dependency to alleviate potential outages has not been proposed previously. In the proposed research, a novel physical model of the outdoor UWB channel will be developed. This model will be provide typical and challenging data sets and insights required for designing and testing proposed communications algorithms for outdoor UWB systems.

Attitude Control System for a Pico-Satellite Plug-and-Play System

William W. Edmonson

University of Florida

\$45,947

09/03/08 - 09/02/09

The development of miniaturized attitude control systems (ACS) that significantly increase the agility of small satellites with respect to state-of-the-art components is desirable. Three solutions considered for this type of ACS include: reaction wheel actuators (RWA)-based systems, underactuated control moment gyroscope (CMG)-based systems, and redundant CMG-based systems. In general, RWA-based systems require more power and provide less torque for a given mass/volume when compared to CMG actuators, due to the torque amplification characteristic of CMGs. Therefore, RWA-based systems are not ideal for attitude control of rapid retargeting small satellites. Underactuated CMG systems have been suggested for small satellite systems, but their application is ad hoc, requiring specificity of the spacecraft to which they are being applied. Furthermore, in the event of a failure of one of the CMG actuators in an underactuated system, the ACS will experience total system failure. Both of these traits are counter to the National Space Policy needs of lower-cost, more-responsive space systems, thereby, rendering the underactuated CMG concepts inappropriate for cost effective responsive small satellite attitude

control. A redundant 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 and only requires integration into the spacecraft. Additionally, a failure of a single CMG does not cause ACS failure and the system can accommodate the reduced operational capability via software update. Furthermore, the redundancy allows for more sophisticated control and steering logic capabilities to avoid singularities, a condition suffered by all CMG-based attitude control systems (i.e., there are gimbal configurations in which the actuator cannot produce torque in an arbitrary direction). Therefore, a once-redundant four single-gimbal control moment gyro configuration is perceived as most cost effective and responsive ACS design. By this redundant CMG (r-CMG) being a self-contained system allows it to be structured for plug-and-play satellite bus. 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. A bus protocol and form factor will be established in conjunction with NASA-Ames who is submitting a complementary proposed project.

Collaborative Research: Advanced Small Satellite Technologies Research and Education Center (AS2TREC)

William W. Edmonson
National Science Foundation
 \$10,000
 08/01/07 - 07/31/08

The overall objective of this center is a transformation of the space industry from Risk Aversion to Risk Tolerant through on-orbit demonstrations of satellite technologies using primarily, pico and nano-class satellite platforms, although larger mini and micro satellites will be considered. Spacecraft are inherently multidisciplinary systems, and so the center will (i) perform multidisciplinary research in the areas of spacecraft subsystems and (ii) validate the technological advancements resulting from the research through on-orbit flight tests. This letter of intent describes the foundation for a new I/UCRC, with the University of Florida (UF) and North Carolina State University (NC State) as the center sites, tentatively known as the Advanced Small Satellite Technologies Education and Research Center (AS2TREC). Small satellites are becoming increasing viable solution for mitigating the exorbitant cost and long acquisition times inherent to the current modus operandi of the space industry. The focus of the center is to research, develop, and test on-orbit advanced concepts for transitioning small satellites into a mature technology. In conjunction with the research focus will be an emphasis on educating the next generation of ?rocket scientists,? through the end-to-end hands-on experience that small satellite projects bring about in a K-12 setting. With the creation of the proposed center, numerous and durable partnerships will be forged among industry, government, and academia through common interests from small satellite-based space and earth science to applications of national security. The research focus of the proposed center directly addresses current initiatives in a variety of commercial and governmental institutions: Boeing, Lockheed--Martin, Harris Corporation, Microcosm, United Applied Technologies, Aerospace Corp., Honeywell, Northrop Grumman, DARPA, NASA, NRL, and AFRL. There is a strong interest for participation in the proposed AS2TREC center from several of these organizations based on preliminary discussions.

IPA with NASA-LaRC for William Edmonson

William W. Edmonson
National Aeronautics & Space Administration (NASA)
 \$158,958
 06/01/08 - 05/31/09

There is a large amount of research and development in avionics for NASA use being done at the various NASA centers. This work is being done by both in-house and contract effort, and is primarily focused on the particular Center's programs. Very little coordination is done between the Centers to take advantage of others experience and expertise. There needs to be a coordination of these various activities and expertise with the emphasis on solving NASA's current and future plans that require new and improved avionics devices, circuits and electronic systems. This includes space, science, and aeronautics objectives. A plan will be developed and maintained that will bring collaboration between all the NASA centers to help solve vital avionics needs at each center, and help define common objectives and goals. The plan will result in a common direction to focus NASA's effort and resources. This will result in avionics that have greater functionality, flexibility, lower development and lifecycle costs, and promotes evolutionary design. In addition to a general roadmap for future improved avionics, each center's strategic technical challenges that require improved avionics will be documented, and enveloped into the roadmap. An example of this is the "Nine Revolutionary Technical Challenges" developed by upper management at LaRC. The benefits of this roadmap include bringing NASA avionics technology together, so that future needs can be developed more quickly and at a lower cost. Other benefits include elimination of duplicate efforts, helping NASA avionics development personnel to have knowledge of other NASA center's avionics expertise and capital equipment, and maintaining a focus on future NASA avionics needs. The specific benefits for Langley include reduced cost advanced avionics for at least five of the "9 Revolutionary Technical Challenges," as well as for space, science, and aeronautics in-house development of avionics systems.

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 be to support the design and definition of the GPS instrument for retrieving radio occultation data for the Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission. This mission represents one of the decadal survey missions and its role is to address the following societal objectives: 1) benchmark a climate record that is global, accurate, tested against independent strategies that reveal systematic errors, and tied to international standards; 2) contribute to the development of an operational climate forecast model; and 3) to provide a disciplined decision structure that brings together data and forecasts into products that promote international commerce, social stability and security. The CLARREO spacecraft will carry three instruments that will measure the radiated infrared energy emitted from the Earth, the reflected solar radiation from the Earth, and atmospheric refractivity with active limb sounding using the Global Navigation Satellite System (GNSS) and associated receivers for deriving vertical profiles of temperature and pressure. The latter instrument is the GPS radio occultation, or GPS RO instrument. 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 to be presented at the CLARREO Mission Concept Review (MCR) in December 2009.

MPCore Mapping Tool Research

William W. Edmonson, Winser E. Alexander
ETRI (Research Inst.-Electronics & Telecommunications)
 \$80,000
 10/01/08 - 05/30/09

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. A coarse-grained reconfigurable architecture is used to demonstrate the proposed mapping method. During the translation phase, an input program written in a high-level language is translated into a control data flow graph (CDFG). Transformations and simplifications are performed on the CDFG. In the clustering phase, the CDFG is partitioned into clusters and mapped onto an unbounded number of fully connected array architectures. In the mapping phase, the graph obtained from the clustering phase is scheduled, taking array structure into account. The mapping and scheduling algorithm attempts to minimize the number of clock cycles used for the given application under the constraints of the number of arrays.

Beam Deflector for LED Source

Michael James Escuti
Boulder Nonlinear Systems
 \$8,475
 07/14/08 - 09/15/08

For the purposes of this proposal, the PI will provide Boulder Nonlinear Systems (BNS) with multiple polymer and switchable polarization gratings (PGs) on glass substrates, for the purposes of developing a simple beam deflector (steerer) for an light-emitting-diode (LED) light source. We will optimize the material-properties for PG operation at visible wavelengths, which will involve both theoretical modeling and experimental fabrication. The number of final delivered gratings will be as follows: x2 achromatic PGs (polymer), x2 conventional PGs (polymer), x1 conventional PG (active), and up to x4 intermediate development samples.

Feasibility Study of Polarization Gratings for Midwave Infrared Polarimetry

Michael James Escuti
University of Central Florida
 \$35,282
 05/05/08 - 08/30/08

For the purposes of this proposal, the PI will provide University of Central Florida (UCF) with multiple polymer polarization gratings (PGs) on silicon substrates. We will optimize the material-properties of polymerizable liquid crystals for achromatic PG operation at midwave infrared wavelengths, which will involve both theoretical modeling and experimental fabrication. The number of final delivered gratings will be between four to six, depending on the results of the theoretical analysis. The deliverable polymeric PGs will be (as a set) optimized for operation across the midwave infrared wavelengths (5 μm to 40 μm), have a clear aperture of 2 cm or greater, and diffract the aforementioned wave-

lengths into angles 5μ or greater. We will aim for diffraction efficiency of 90% or greater into the first orders (E-mode and O-mode), low overall absorption (e.g. less than 2%), and low zero order leakage (e.g. less than 2%), but we must note that these parameters are precisely the unknown quantities that this research aims to measure for the first time at midwave infrared wavelengths. A further deliverable will be summary report of the theoretical modeling, including a recommended design of PGs for the SOPHIA telescope project, and evaluation of any limitations. Over the seven-weeks of the proposed project, the PI will design and fabricate the aforementioned PG samples, forward them to UCF, and assist in the midwave infrared data analysis. PG fabrication will require the purchase of various polymer materials and several optical and opto-mechanical parts. Travel funds are required for the PI to travel to a technical conference, and also to visit expert chemistry scientists at specialty-materials vendors to advise on the materials-optimization process. As this work is part of feasibility research testing PGs for use in astronomical polarimetry applications, the PI will also support the characterization of the deliverables at UCF, and look forward to joint publications/proposals based on our findings.

Liquid Crystal Polarization Gratings for Photonics Applications

Michael James Escuti
National Science Foundation
 \$697,370
 09/01/06 - 08/31/09

This request is to support a talented, early-stage, female, PhD student (US citizen) to conduct research that contributes to and compliments the currently funded ECCS NSF grant (nsf proposal 0621906). Note that this is a GRS renewal, but is actually a new supplement. This student, Ms. Elena Nicolescu, will be enabled to invest fully into PhD research, and empowering her to expand her minority outreach activities.

Midwave Infrared Polymer Polarization Gratings for Beam Steering

Michael James Escuti
Boulder Nonlinear Systems
 \$27,416
 04/01/09 - 07/31/09

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 diffraction angle (at 4.5 μm), and ≈ 8805 ; 99% diffraction efficiency into steered order. Further support (analysis and discussion) will be provided to assist BNS to characterize the optical properties at the MIR wavelengths (a capability that NCSU does not have). Over the four-months of the proposed project, the PI will actively oversee the project, complete the theoretical design effort, analyze results, and supervise the student. The student will be responsible to complete the experimental optimization, fabrication, and characterization of PGs. PG fabrication will require the purchase of various liquid crystal and polymer materials and a stylus-type profilometer for characterization.

Modular Laboratory Experiments on Organic Electronics and Liquid Crystal Displays for Undergraduates

Michael James Escuti
National Science Foundation
\$308,820
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 as way as to be inherently transferable to other universities. “Soft” organic materials are at the forefront of much current research and are the core technology of an increasing number of consumer products available now or in the near future (e.g. displays, lighting, flexible electronics, renewable energy devices). We maintain that soft electronic and photonic devices are some of the most compelling and accessible topics for undergraduates and their fabrication is comparably much simpler than the more traditional solid-state devices. We therefore aim to open this window of opportunity by creating coherent instructional materials that offer the hands-on experience of building and characterizing electronic and photonic devices (with minimal investment).

Polymer Polarization Gratings For Liquid Crystal Microdisplays

Michael James Escuti
ImagineOptix Corp
\$738,657
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. The number of final delivered gratings meeting all specifications will be at least 10, but many dozens of intermediate PGs will be fabricated (some of which will be made available to ImagineOptix Inc. for evaluation upon request). Preliminary and final integration of the PGs into the projector system will be done in close collaboration with ImagineOptix Inc. The deliverable polymeric PGs will be optimized for operation across the visible wavelength range (450 nm to 650 nm), have diffraction efficiency of 95% or greater into the first orders, have low insertion loss (e.g. less than 2%), have low zero order leakage (e.g. less than 2%), diffract green (530 nm) light into angles 12° or greater, and have a clear aperture of 2 cm or greater. Uniformity and cleanliness will be a top priority, with an objective to have high diffraction over the entire aperture with a variation of less than 2%. After integration of the PGs into the projection display system, the objective is an overall contrast ratio of greater than 500:1 with a three-color light-emitting-diode (LED) light source. Over the one-year

of the proposed project, Dr. Escuti and graduate students will design, fabricate, and characterize the PGs, and integrate them into a transmissive-mode LC microdisplay projector system (provided via ImagineOptix Inc.).

Reduced-Dispersion Beam Deflector for LED Source

Michael James Escuti
Boulder Nonlinear Systems
\$38,425
05/16/09 - 12/31/09

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 an 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. We will optimize the material-properties for PG operation at visible wavelengths, which will involve both theoretical modeling and experimental fabrication. The number of final delivered gratings will depend on the dispersion-reduction study and final design to be determined within this project, but will likely be in the following range: up to x12 polymer PGs, up to x6 switchable PG, and up to x12 intermediate development samples. The deliverable will be an assembly of stacked PGs, which overall has the following specs: 35 mm diameter clear aperture, 15 maximum steering angle, approximately 2 steering resolution, and will be optimized for blue LED defined by BNS with approximately 6 divergence angle. A further deliverable will be summary report of the theoretical modeling of the dispersion-reduction techniques, and a full spectral characterization of the samples.

SBIR Phase I: Low Cost, High Performance, Compact Wavelength Blocker For Reconfigurable Optical Add/Drop Multiplexers

Michael James Escuti
Southeast TechInventures (STI)
\$65,874
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. The number of final delivered gratings will be 20 to 40, depending on the results of our theoretical analysis and initial experimental studies. The deliverable PGs will be optimized for operation around 1550 nm, have a clear aperture of 2 cm or greater, and diffract the aforementioned wavelengths into angles 5° or greater. We will aim for transmitted attenuation of over 25 dB, insertion loss in transmitting state of less than 0.2 dB, low polarization sensitivity (polarization dependent loss), and low temperature dependent loss, but we must note that these parameters are precisely the unknown quantities that this research aims to optimize. A further deliverable will be summary report of the theoretical modeling and measured electro-optical data on the PG components and evaluation of any limitations. Over the one year proposed project, the PI and a graduate student (currently supported on an unrestricted fellowship) will design and fabricate the aforementioned PG samples, forward them to STI, and assist in the data analysis. PG fabrication will require the purchase

of various liquid crystal and polymer materials and several optical and opto-mechanical parts. Travel funds are required for the PI and/or a graduate student to travel to a technical conference to report on this work, and to publish this work jointly with STI in at least one peer-review journal.

SBIR Phase II Wide-Angle Nonmechanical Steering Development

Michael James Escuti
Boulder Nonlinear Systems
 \$598,350
 10/16/07 - 10/15/09

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%), and be arranged to diffract into the following angles: 1.25, 2.5, 5, 10, and 20. Uniformity and cleanliness will be a top priority, with an objective to have high diffraction over the entire aperture with a variation of less than 2%. All work will be done in close collaboration with BNS, and the number of final delivered gratings will be somewhere between 20 to 40 gratings, and will depend on the testing of the multiple approaches in the first year.

Career: A Stochastic Approach to the Design of Communication Networks: An Alternative to Fluid Modeling

Do Young Eun
National Science Foundation
 \$1,030,293
 03/01/06 - 02/28/10

Our goal in this project is to understand the fundamental limitations of the fluid or mean-field approach to many network problems, and as a remedy, to develop a stochastic approach to the analysis and design of large networks. By judiciously applying appropriate limit theory with key randomness inherent in the network dynamics still intact, we will provide new guidelines on large network design and achieve far better resource utilization, all of which are impossible to obtain via the traditional fluid or mean-field approach.

NEDG: Efficient Design and Control of Heterogeneous Mobile Networks: Beyond Poisson Regime

Do Young Eun
National Science Foundation
 \$299,872
 09/01/08 - 08/31/11

Over the last several decades, mobility has been central to various applications, ranging from the classical problems of 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. In particular, recent technological advances in communicating/sensing devices as well as abundant network protocols designed for mobile ad-hoc/sensor networks have opened up a new possibility for viable networks with satisfying performance over such unpredictable, mobile, and disadvantaged environments. While the random mobility pattern of mobile nodes in these networks has posed

serious challenges and been considered as the main source of uncertainty and disruption of communication links among nodes, the mobility can also enable us to achieve reliable and predictable performance, if it is properly controlled and actively exploited. The long-term goal of this proposed research is to develop a unified methodology for efficient protocol design and control of nodes in heterogeneous MANETs under non-Poisson contacts. While the non-Poisson contacts and inherent heterogeneity among mobile nodes pose serious challenge, we take this challenge as a golden opportunity toward 'high-performance' MANETs, by exploiting unknown heterogeneity and non-Poisson dynamics in an adaptive but rigorous manner. Our goal further extends to the use of mobile nodes with controllable mobility that can autonomously exploit the changing diversity in non-Poisson heterogeneous dynamics of nodes' mobility.

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 - 08/31/11

This proposal focuses on the theoretical foundation for wireless mobile networks, particularly on the characterization of link-level dynamics by a stochastic analysis approach. A detailed research plan is proposed which addresses the unique challenges presented by mobility-induced link dynamics. This plan concerns not only fundamental understanding of {\em delay-sensitive} communication networks, it also studies contact/inter-contact dynamics in {\em delay-tolerant} networks which may play an important role in mobile social networks. In particular, the research plan focuses on three issues: (1) Modeling, analysis, and statistical characterization of mobility-induced link dynamics. Our objective is to study a set of metrics at the link-level, such as inter-contact time, residual link lifetime, path-breakage rate, and more because of their immediate effects on network design and performance. More importantly, we will provide a plethora of statistical properties over a wide range of {\em timescales} as well as {\em physical environments} via microscopic link modeling and stochastic ordering. These works, which have not been carefully investigate before, clearly distinguish our proposed work. (2) Spatial-Temporal Dynamics in mobility modeling in multiple space/time scales rather than being dependent on {\em a priori} networking environments. In particular, we take a multiscale mobility modeling approach to capture the interdependency between spatial and temporal dynamics of mobile nodes, such as diffusive behaviors. In a stochastic setting, mean square displacement (MSD) is used to study {\em micro-scale, meso-scale, macro-scale} mobility trajectory and their impact on link-level dynamics by quantifying the degree of spatio-temporal interdependencies among link-level metrics and the network operating points. Therefore, our results will provide an integrated framework of mobility modeling and operation regime. (3) The scaling limits for link-level metrics under various network operating regimes. As a new research thrust, we will develop a systematic approach to explore scaling regime subject to network architecture and configuration, such as the number of mobile nodes, size of the domain, and employed forwarding/routing algorithms. Specifically, we will identify the inherent causes of Poisson limits as a limiting random process that occurs in various mobile ad-hoc networks. Further, we will find the scaling regime that is valid for different time-scale link-level dynamics.

CAD Support For the Third MIT-LL 3D-Integrated Circuit Run

Paul D. Franzon, William R. Davis
Massachusetts Institute of Technology
 \$54,143
 04/01/08 - 12/30/08

North Carolina State University (NCSU) will produce a Cadence process design kit (PDK) for the third MIT Lincoln Laboratory (MIT-LL) 3-dimensional integrated circuit Multiproject Run.

Computer Aided Design For Digital Trust

Paul D. Franzon
Irvine Sensors Corporation
 \$450,000
 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
 \$806,250
 07/01/08 - 06/30/11

Research Experience for Undergraduates Supplement.

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

K. P. Sandeep, Paul D. Franzon, Josip Simunovic
US Dept. of Agriculture
 \$557,872
 09/01/06 - 08/31/10

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 by every other particle in the real food product. Thus, if this carrier particle receives adequate heat treatment (pre-determined F0 value), then the entire food product would be rendered commercially sterile. The need for this study arises from the recommendations of a workshop sponsored by the Center for Advanced Processing and Packaging Studies (CAPPS) and the National Center for Food Safety and Technology (NCFST) which was also attended by FDA and industry personnel. Tetra Pak made use of the results of this workshop to successfully "file" an aseptic process for multiphase foods with the FDA. However, this product-process combination was not commercialized. Several food processors have been trying to develop a similar process for their food products and one of the main problem is the lack of a reliable tool to validate their process and at the same time ensure a high product quality. The sensor system to be developed in this study will serve as that tool.

Micromachined Braille Reader

Paul D. Franzon
US Dept. of Education
 \$1,792,836
 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.
 \$900,000
 11/01/06 - 10/31/09

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. At high speeds, crosstalk issues typically dictate inter-pair spacings of four times the wire width in PCBs, and rich use of power and ground shields in connectors. 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.

System Packaging With AC Coupled Interconnect

Paul D. Franzon
Irvine Sensors Corporation
 \$1,687,783
 11/01/06 - 09/30/09

NCSU will support ISC in 3D packaging.

System Technologies for AC Coupled Interconnect for Low Power SpaceBorne Electronics

Paul D. Franzon, Angus I. Kingon, John Michael Wilson
US Air Force Research Laboratory (AFRL)
 \$7,726,842
 09/25/06 - 12/31/09

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.

Test Devices for Molecular Electronics Applications

Paul D. Franzon
University of Virginia
 \$400,000
 05/11/06 - 11/10/08

Molecular electronics holds the promise of outscaling CMOS technology. However, the organic-inorganic interface is difficult to build. In this research, NCSU will determine approaches to building the inorganic portion of the system to permit fundamental studies in this interface.

Ultra High Density Computer Interconnect

Paul D. Franzon
National Science Foundation
\$700,000
09/01/02 - 08/31/08

We are determining new approaches to interconnect large systems at the system level. These approaches promise high density, low power and low cost.

Expertiza: Reusable Learning Objects Through Active/Collaborative Learning and Peer Review

Edward F. Gehringer
National Science Foundation
\$254,714
01/01/06 - 03/31/09

Peer review is an active-learning technique that gives students the opportunity to interact with, and learn from, each other. Instructors are increasingly employing Web-based systems to manage the process. This opens wide new vistas for creating learning objects to enhance the educational experience. Instead of all students doing the same assignment, our Expertiza software allows each student or team to select from a list of tasks that will help enhance the course. Students submit their work, the work is peer-reviewed, and then the best work is chosen to be shared with the rest of the class. One task might be to devise an example that explains a difficult concept; another might be to improve a visualization of a topic covered in lecture; a third might be to write questions for a “mastery” quiz on a particular lecture. Successive classes can improve and extend the resources created in this way. Not only are these objects produced through active learning, but they offer active-learning experiences to those who use them later, to those who, for example, take the mastery quizzes or interact with the simulations produced through this process. Moreover, the learning objects produced with Expertiza can easily be published to a Web database accessible to other instructors for use in their classes. The Expertiza process has many concomitant benefits. It offers a way to produce high-quality educational materials with less investment of faculty time. It allows distance-education students to participate fully in active-learning exercises. It diminishes the opportunity for plagiarism because students don’t all do the same assignment, and they build on the work of previous classes rather than duplicate it. It overcomes the handicap of teaching large classes, because large classes can produce many more resources. The proposed work is to deploy Expertiza in ten to twenty classes and measure the benefits. These range from ways of applying Expertiza in diverse subject fields, to comparisons of student performance in first-time Expertiza courses with later semesters in which students are using Expertiza-developed material from earlier semesters.

Electrical Inert Crack Monitoring Gauge

Jerome J. Cuomo, Roger C. Sanwald, Edward Grant
DRS Technologies
\$540,000
06/01/07 - 12/31/09

Demonstrate next level of system reliability that will allow “prototypes” to “flow” on a test bed. This will include additional electronic design support for wireless sensors for airframe crack detection.

Innovative Tools and Techniques for Robotic Heart Surgery

Gregory D. Buckner, Denis R. Cormier, Edward Grant,
Bryan W. Laffitte
National Institutes of Health
\$1,336,792
08/16/04 - 05/15/09

Today’s surgical robots employ generalized end effectors that directly extend the motions, capabilities, and limitations of a surgeon’s own hands. These robots give surgeons the ability to work on very small scales, with great precision, and through smaller incisions. They provide direct visualization through the use of magnified 3-D images and greater accuracy through motion scaling and active filtering of hand tremors. In the specific field of cardiac surgery, minimally invasive robot-assisted (MIRA) procedures show improvements in patient satisfaction and key outcome parameters including decreases in overall hospital stays. Unfortunately, these gains have been offset by significantly increased operative times, resulting in increased overall healthcare costs. Based on East Carolinas University’s experience in MIRA mitral valve repairs, patient bypass times are currently increased approximately 60% (2.6 hours with MIRA vs. 1.5 hours using conventional procedures). It is evident that specific technological advancements could significantly decrease MIRA mitral valve repair times. Surgeons and researchers working in this field expect that costs will dramatically decrease as surgeons and medical device manufacturers collaboratively develop robotic tools and technologies specifically suited for MIRA cardiac procedures. Additionally, these procedures could be made less invasive with “totally-endoscopic” technologies. Accordingly, the specific aims of this multidisciplinary research program focus on developing technologies that facilitate and extend the capabilities of MIRA cardiac surgery. These include: (1) Devices for rapid and secure fixation of suture materials and prosthetic devices: specifically instruments and cartridges that provide “push-button” fixation for specific procedures (e.g. atrial closure and leaflet repair) using both existing suture materials and advanced clips and staples. (2) Endoscopic retractors to improve visualization of essential cardiac structures: endoscopically-deployable retractors that utilize the superelastic properties of Nitinol to facilitate totally closed surgical procedures. (3) Systems to aid the surgeon in incision planning, robotic navigation, and operative training: technology that can be used to measure and register critical anatomical landmarks with pre-operative and intra-operative spatial data to identify optimal port placement and robot instrument trajectories.

Nonwoven Based eTextiles and Disposable Sensors

Behnam Pourdeyhimi, Edward Grant, H. T. Nagle
Kimberly Clark Corporation
\$64,414
01/02/08 - 12/31/08

This proposal addresses the investigation and feasibility of producing specialty engineered functional nonwoven fabrics focusing on incorporating them into wearable electronics (such as strain sensors). Functional electronic textiles has found use in many applications including computers, electronics, automotive, instrumentation, military, communications, flexible printed circuits in applications such as RFID (radio frequency identification) tags, wearable electronic devices and “intelligent textiles” including clothing that can dispense medication, provide fragrance or change of color in response to change in body temperature, biomet-

ric bodysuits and many more. These types of fabrics, also referred to as eTextiles and "smart" fabrics are currently under development for a variety of applications. However, the vast majority of the work completed to date has utilized conventional textiles (knits, wovens, etc.) as the substrate to enable incorporation of electronic function into garments. The opportunity exists to expand the use of eTextiles into semi-durable or disposable applications by shifting the focus to nonwoven substrates.

MRI: Development of a Quantum Engineering Laboratory

Alexej I. Smirnov, William C. Holton, Ki Wook Kim, Veena Misra

National Science Foundation

\$2,232,512

09/01/04 - 08/31/09

10 MVA ETO-based STATCOM: Digital Controller Hardware In the Loop (CHIL) Test with the real Time Digital Simulator (RTDS) at Florida State University (FSU)

Alex Q. Huang, Subhashish Bhattacharya

Florida State University

\$48,954

03/31/08 - 12/31/08

The following tasks are proposed to FSU for funding to NCSU so that NCSU can support the CHIL activity at FSU. Overall, the proposed tasks and activities also support the plan to have a 10 MVA ETO STATCOM installed and commissioned at BPA Condon wind farm in the near future. The proposed tasks will be performed by NCSU at both NCSU facility and at FSU facility.

Advanced Power Devices and Converters

Alex Q. Huang

Sandia National Laboratories

\$889,303

11/15/07 - 09/30/09

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

Development of a 69 kV Class Solid State Current Limiter (SSCL)

Alex Q. Huang

Silicon Power Corporation

\$99,993

12/01/06 - 11/30/08

The objective of this project is to develop a Solid State Current Limiter (SSCL) to limit fault current issues and to take advantage of above benefits. The SSCL interrupts or limits fault current from new generation or transmission, reduces switching surges, and offers an environmentally benign alternative to circuit breakers. Silicon Power Corp. (SPCO), together with NCSU, has recently proposed to EPRI and

DOE to develop, build and deliver a 69 kV/3000A transmission level SSCL that is extremely reliable as well as compact enough to be applied in urban transmission. Additionally, it must be maintainable by traditional utility personnel, and priced at a cost-effective level. NCSU's objective in this project is to assist SPCO, in the selection of power devices, design of AC switch assembly, and the design of SSCL, as well as the SSCL control system.

Development of a Scalable, Transportable Energy Storage System for Effective Integration of Renewable Energy Sources

Alex Q. Huang, Mesut E. Baran, Subhashish Bhattacharya

Bonneville Power Administration

\$2,499,987

04/17/07 - 08/01/08

The objective of this project is to develop a scalable, transportable energy storage devices based on the emerging ETO Light Converter technology. Not only we will be able to demonstrate the performance advancement offered by the ETO Light Converter, but also demonstrate the reduced cost and improved reliability. The delivered energy storage device will solve practical problem at the identified wind farm location. The delivered unit can also be relocated to other BPA renewable energy locations to address the intermittent power issue such as those found in an ocean wave park. The rating of the unit can be scaled to higher level for future applications.

Development of a Scalable, Transportable Energy Storage System for Effective Integration of Renewable Energy Sources

Alex Q. Huang

Bonneville Power Administration

\$16,216

06/23/08 - 08/30/08

The objective of this supplemental contract is to provide for the design and manufacture of four specialized circuit boards that are needed to form the interface between a computer controller and a large power system simulator (RTDS) located at Florida State University, Center for Advanced Power Systems.

Distributed Power Flow Controller (DPFC)

Alex Q. Huang

Missouri University of Science and Technology

\$119,518

07/01/08 - 09/15/09

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.

High Power Building Block for Affordable Power System

Alex Q. Huang, Srdjan Miodrag Lukic

Raytheon

\$80,650

07/07/08 - 06/30/09

Advanced electronic systems require power converters that have to meet conflicting requirements of equipment susceptibility, distribution complexity and voltage quality with high power density, reliability and reduced total cost of ownership. At the same time, multiple power architectures employed by various systems make it increasingly difficult to standardize power conversion, control and distribution equipment. As a result, custom power components and subassemblies have to be fabricated and stocked as spares for specific needs in low volumes driving up their cost. A high power, standardized line of power converters serving multiple platforms and applications are among the items enabling more affordable systems. Such converters have to be capable of operation from a wide range of input voltages and provide bidirectional power flow capability. Another major item is the ability to support pulse loads without adversely affecting the prime power source and creating potential instability of the distribution network.

Membership in Consortium for Advanced Power Electronics and Energy Storage (CAPES), Principal Member

Alex Q. Huang
ABB, Inc
 \$75,000
 07/01/06 - 12/31/08

The Consortium for Advanced Power Electronics and Energy Storage (CAPES) is a government, utility company, equipment maker, university and national lab based consortium to leverage resources and expertise to develop and demonstrate key power electronics and energy storage technologies for transmission and distribution grids.

Membership in Consortium For Advanced Power Electronics and Energy Storage (CAPES), Principal Member In-kind

Alex Q. Huang
Progress Energy Carolinas
 \$1
 01/01/07 - 12/31/08

The Consortium for Advanced Power Electronics and Energy Storage (CAPES) is a government, utility company, equipment maker, university and national lab based consortium to leverage resources and expertise to develop and demonstrate key power electronics and energy storage technologies for transmission and distribution grids.

Membership in Power Management Consortium (PMC), Associate Member

Alex Q. Huang
Intel Corp.
 \$30,000
 01/01/06 - 12/31/08

Renewal to Principal Membership level

Membership in Power Management Consortium (PMC), Associate Member

Alex Q. Huang
Fairchild Semiconductor
 \$30,000
 09/01/05 - 12/31/08

Renewal to Principal Membership level

Membership in Power Management Consortium (PMC), Associate Member

Alex Q. Huang
International Rectifier
 \$60,000
 10/01/05 - 12/31/11

Renewal to Principal Membership

Power Management Consortium (PMC) Membership Agreement - Principal Member

Alex Q. Huang
Toyota Motor Engineering & Manufacturing North America, Inc.
 \$90,000
 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)
 \$35,771
 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
 \$135,000
 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
\$250,000
09/15/07 - 08/31/10

Recent research on multiple-input multiple-output (MIMO) communications has shown that deploying arrays at the transmitter and receiver can dramatically improve the capacity of wireless multipath channels. This project seeks to develop a systems-level perspective on the design of compact array transceivers for wireless communications. The aim is to understand how antennas, matching networks, amplifiers and communications algorithms interact to determine overall performance, and to jointly optimize the design of these interacting subsystems. Three issues are addressed: (1) channel models which incorporate diverse noise sources, transceiver design and interference from other users for both narrowband and broadband channels; (2) the impact of different noise sources and propagation environments on the fundamental performance limits of coupled MIMO systems, as well as on performance of specific diversity and multiplexing techniques; (3) information-theoretic design criteria to jointly optimize the array, matching, amplifiers and communications algorithms. Broader Impacts: This multi-disciplinary project combines theoretical studies with experiments using an antenna testbed. The mix of theory and hardware demonstrations will provide opportunities for student participation at all levels. This work has the potential to significantly advance science and engineering by providing a more unified view of the RF front end and by developing new models, communications algorithms and matching techniques which may significantly improve wireless performance.

NIRT: Reduced Degree of Freedom Predictive Methods for Control and Design of Interfaces in Nanofeatured Systems

Donald W. Brenner, Marco Buongiorno-Nard, Ron O. Scattergood, Mohammed A. Zikry, Gerald Iafrate
National Science Foundation
\$3,960,550
07/01/03 - 06/30/09

This research studies the quantum-mechanical behavior of nanocomponents embedded in a dissipative environment. An interacting harmonic oscillator and angular momentum oscillator are utilized to simulate the interaction of an electromagnetic field mode with an atom in an embedded micro or nano cavity to provide atomic transitions in absorption and emission; as the cavity boundaries are influenced by a surrounding environment, the cavity modes are perturbed thus influencing the transition characteristics. The objectives are to study the nanocomponent-environment interaction, and to provide adequate modeling capability for elucidating the robustness of the nanocomponent quantum characteristics due to the interaction with the environment.

CACC Administrative Expenses

Dennis H. Kekas
NCSU Center for Advanced Computing & Communication
\$78,494
07/01/03 - 06/30/10

CACC Membership Pool Agreement

Dennis H. Kekas
NCSU Center for Advanced Computing & Communication
\$1
07/01/06 - 06/30/10

Increasing the Pipeline: Research and Education on Stimulating Interest in High Confidence Software and Systems

Dennis H. Kekas, Glenn Kleiman
National Science Foundation
\$210,000
07/01/08 - 06/30/10

Center for Advanced Computing and Communication in association with the Friday Institute, National Science Foundation, and NSA High Confidence Software and Systems (HCSS) seek to advance outcomes from the recent National Workshop on Stimulating and Sustaining Excitement and Discovery in K-12 STEM (Science, Technology, Engineering, Mathematics) Education by supporting a new online computer science curriculum pilot, aiding the NC State Kenan Fellows program to expand to national audience, and supporting existing residential middle grade math and related science summer camp sponsored by UMES.

Membership in CACC

Dennis H. Kekas, Mladen A. Vouk
Cisco Systems, Inc.
\$450,000
07/01/00 - 06/30/09

Cisco Systems is extending membership in CACC through June 30, 2009.

Membership in CACC

Dennis H. Kekas, Mladen A. Vouk
Ericsson, Inc.
\$360,000
07/01/00 - 06/30/09

The Center for Advanced Computing and Communication (CACC) is a membership-based industry/university cooperative research center co-located at North Carolina State University and Duke University. Expertise in the center is focused in the areas of information security, business intelligence, software engineering, extreme programming, networking, wireless technologies, autonomic computing, power visualization, business analytics, sensor-based systems, and display technologies. The CACC research goal is to create concepts, methods and tools for use in the analysis, design and implementation of advanced computer and communication systems.

Membership in CACC

Dennis H. Kekas, Mladen A. Vouk
Tekelec
\$300,000
07/01/04 - 06/30/10

The Center for Advanced Computing and Communication (CACC) is a membership-based industry/university cooperative research center at North Carolina State University. Expertise in the center is focused in the areas of information security, business intelligence, software engineering, extreme programming, networking, wireless technologies, autonomic computing, power visualization, business

analytics, sensor-based systems, and display technologies. The CACC research goal is to create concepts, methods and tools for use in the analysis, design and implementation of advanced computer and communication systems. Our mission is to carry out basic and applied research on fundamental problems with both industrial and academic relevance, to transfer these results to our members, and to provide our students with a unique and challenging educational opportunity.

Membership in CACC, Associate Member

Dennis H. Kekas, Mladen A. Vouk
 MCNC-RDI
 \$160,000
 07/01/03 - 06/30/11

The Center for Advanced Computing and Communication (CACC) is a membership-based industry/university cooperative research center co-located at North Carolina State University and Duke University. Expertise in the center is focused in the areas of information security, business intelligence, software engineering, extreme programming, networking, wireless technologies, autonomic computing, power visualization, business analytics, sensor-based systems, and display technologies. The CACC research goal is to create concepts, methods and tools for use in the analysis, design and implementation of advanced computer and communication systems. Our mission is to carry out basic and applied research on fundamental problems with both industrial and academic relevance, to transfer these results to our members, and to provide our students with a unique and challenging educational opportunity.

NSF Partnership in the Center for Advanced Computing and Communication

Dennis H. Kekas, Mladen A. Vouk, Laurie A. Williams
 National Science Foundation
 \$1,566,496
 09/15/99 - 12/31/08

The purpose of this budget is to MIPR funds through NSF to CACC. Funds requested are those to be paid by National Security Agency (NSA) for membership 07/08 and continuing support of NSA CACC enhancement project 522836.

On the Use of Software Metrics as a Predictor of Software Security Problems, CACC core project

Dennis H. Kekas, Laurie A. Williams
 Army Research Office
 \$116,266
 06/01/09 - 06/01/12

Extensive research has shown that software metrics can be used to identify fault- and failure-prone components and to predict the overall quality of a system early and throughout the software development lifecycle, before products are released for use. We seek to extend this work to identify security metrics to effectively identify vulnerability-prone and attack-prone components of software run in a virtualized computing environment and to predict the overall security of the virtualized system prior to release. Specifically, we will examine the capability of security metrics obtained from code artifacts, inspections, and testing to highlight security for the risk-based prioritization of re-design, inspection, and testing efforts to fortify software as necessary.

Secure Open Systems Institute

Dennis H. Kekas, Peng Ning, Mladen A. Vouk, Rudra Dutta, John C. Bass
 Army Research Office
 \$48,300,000
 04/03/08 - 11/30/12

This program will establish a national Secure Open Systems Institute (SOSI), located on North Carolina State's premier Centennial Campus that will be a global center for Open Systems security research and development.

Workshop on STEM Education K-12

Dennis H. Kekas, Glenn Kleiman
 National Science Foundation
 \$198,520
 07/15/07 - 06/30/10

Center for Advanced Computing and Communication in association with the Friday Institute, National Science Foundation, and NSA High Confidence Software and Systems (HCSS) seek to advance outcomes from the recent National Workshop on Stimulating and Sustaining Excitement and Discovery in K-12 STEM (Science, Technology, Engineering, Mathematics) Education by supporting a new online computer science curriculum pilot, aiding the NC State Kenan Fellows program to expand to national audience, and supporting existing residential middle grade math and related science summer camp sponsored by UMES.

Carrier Spin Dynamics and Device Applications in Carbon Nanotube

Ki Wook Kim, Marco Buongiorno-Nard
 National Science Foundation
 \$479,958
 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 will also be pursued beyond the current scaling limit. Intellectual merit: This research effort will provide (1) theoretical understanding of the mechanisms of carrier spin dynamics in carbon nanotubes; (2) design of novel device architectures that exploit the unique spin transport properties; (3) a coherent hierarchy of spin device simulation methods that can be scaled to large-scale processes. Overall, the key outcome will be a fundamental description of the feasibility of advanced spintronic devices based on carrier spin dynamics in carbon nanotubes.

MARCO Center on Functional Engineered Nano Architectonics (FENA)

Ki Wook Kim
 University of California
 \$620,895
 09/01/03 - 10/31/09

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 fa-

cilitate 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.

Nanoscale Phonon Transport for Thermal Management

Ki Wook Kim
University of Texas
 \$300,000
 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 will be on accurate modeling of phonon transport properties at realistic interfaces with materials and/or dimensional mismatch including silicon-on-insulator, graphene on a dielectric or a substrate (e.g., SiC), nanowire/tube on a dielectric as well as nanowire/dot grown on 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 the density functional perturbation 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
 \$1,293,260
 07/01/06 - 10/31/09

This is a supplementary proposal to an existing ARO award. The proposed add-on research effort will explore the use of graphene nanostructures for spin-based memory and logic devices. It is aimed at demonstrating that the novel electronic properties of atomically thin graphene can be used as the basis of non-volatile memory and logic devices. It is possible that graphene nanostructures can lead to device concepts enabling electrical control of the magnetic state. Specifically, the add-on research will examine in detail the phenomena based on changes in the band structure of graphene through electrically modulated magnetic interactions. A theoretical study will be pursued to develop the physical understanding of these phenomena, coupled with device design to optimize memory and logic operations. This effort is leveraged against significant advances in measuring properties of graphene nanostructures along with recent results concerning spin-based magnetic devices achieved by the PI.

QMHP: Exploring the Limits of Energy Scavenging - From Microwave to Nanoscale

Ki Wook Kim, David Schurig, Robert J. Trew
National Science Foundation
 \$655,686
 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 - 12/30/09

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.

Materials for Terahertz Generation

Robert M. Kolbas, John F. Muth
Digital Fusion Inc.
 \$108,359
 01/18/08 - 10/18/08

New materials have potential for terahertz devices. Wide-band gap semiconductors, specifically SiC and GaN, have large breakdown voltages and high thermal conductivities, and they are good candidates for next generation high power density switches. A major technological challenge in developing high power widebandgap semiconductor switches is the development of new switching technology that allows 500 fs risetime at 100kW peak power or 50 fs risetime at 1kW peak power.

Rare Earth Materials

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

Rare earth elements have many photonic applications and unusual properties. In this study, rare earth doped materials will be 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
\$95,580
05/15/06 - 09/30/09

Fully automatic understanding and interpretation of a scene have long eluded researchers. Scene understanding often invokes tasks which are hierarchical in nature. The problem of scene understanding is broad in scope and open, and the cognition step, as one of its key components remains one of its major limitations. At the center of cognition, lies understanding brain functionality which by its high complexity remains a hot topic of research to address the slow progress in machine-based image understanding. The robustness and resilience of biological systems (e.g. one may recognize an object despite some occlusion and/or additive noise) have, however, 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 proposed 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. This builds on measured data from a recently funded laboratory which in effect allows easy validation but controlled experiments for quick verification.

Graphs and Homology in 3D Object Classification

Hamid Krim
US Air Force-Office of Scientific Research (AFOSR)
\$470,627
01/15/07 - 11/30/09

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.

Information Systems and Interdisciplinary Research Seminar Series

Hamid Krim
Army Research Office
\$93,996
01/01/06 - 04/30/09

Fundamental problems in the increasingly interdisciplinary areas of research have never been as challenging and exciting. On the other hand, the potential for breakthroughs has never been as promising. The joint research activity in biotechnology, nano-technology and information systems is but one illustration of fruitful interaction and potential avenue for a successful collaborative effort. To address the fast pace of research and seek adapted and more efficient means of communication among researchers, a forum of discussion where free flow and exchange of ideas are encouraged is one such possibility. To that end, a combination of frequent Web and personal meetings/interaction is a way of ensuring a timely flow and exchange of new information among them, For a technologically driven area like the RTP area,

and an environment that thrives on leading edge research, the PI proposes a new injection of learning and research update by holding an interdisciplinary Systems Research Seminar Series with Distinguished Speakers at a three week average frequency. The PI proposes to utilize the NCSU venue for web-casting, possible broadcasting over MBONE over the triangle area and possible other parts of the state as well and maximally reach out the community for a greatest benefit.

Multiscale Image Fusion

Hamid Krim
Rockwell Collins
\$75,000
05/01/09 - 09/11/09

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.

Proposal in Support of the 14th Workshop on Statistical Signal Processing (SSP'07)

Hamid Krim
Army Research Office
\$7,000
08/01/07 - 07/31/08

The 2007 IEEE Workshop on Statistical Signal Processing is tentatively planned for August 26-29, 2007, at the beautiful Monona Terrace Convention Center in Madison, Wisconsin. The purpose of this workshop is to bring together researchers and scientists from the IEEE Signal Processing Society and related fields, for a two-and-one-half-day workshop focused on statistical methods in signal and image processing. The workshop will feature regular contributed paper sessions, special invited paper sessions, and a small number of plenary lectures covering basic theory, methods and algorithms, and applications in statistical signal processing. Areas of interest include array processing, telecommunications, distributed signal processing and networks, biosignal processing and bioinformatics, Monte Carlo methods, statistical image analysis, and machine learning.

A High-Density Microelectronic Tissue for Imaging: Electromagnetic and Thermal Effects

Gianluca Lazzi
US Dept. of Energy
\$2,863,824
12/15/03 - 12/14/10

This proposal is a supplement to the existing grant in support of the electromagnetic and thermal experimental and numerical activities for the development of a retinal prosthesis to restore partial vision to the blind. As outline in the original proposal, the retinal prosthesis system under development by the "Retina Team" requires an efficient and compact wireless telemetry system for power and data, an effective retinal stimulator, and implantable electronics characterized by limited power dissipation. This is critical for progress toward next generation higher resolution retinal prosthetic devices: computational and experimental models and methods, capable of accurately determining electrical and thermal interactions, 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.

Biomimetic Electronic Systems (BIMS): Electrical and Electromagnetic Interactions

Gianluca Lazzi
University of Southern California
 \$666,034
 09/01/04 - 08/31/09

In this project we will investigate thermal effects (models and methods) of bioimplantable devices developed in the ERC at the University of Southern California.

Protocol Driven Studies to Measure Absorbed Radiofrequency, Microwave and Millimeter Wave Energy: Computational Electromagnetic

Gianluca Lazzi
Henry M. Jackson Foundation
 \$347,611
 05/28/08 - 09/30/09

We request an extension to our project “Electromagnetic Simulations in Support of Protocol Driven Studies to Measure Absorbed Radiofrequency, Microwave and Millimeter Wave Energy” to 30 September 2009 to complete the most recent simulations and their analysis as requested by the sponsor. The statement of work is unaltered other than the research task outline in the original statement of work will now be completed no later than 30 September 2009, and we estimate that an additional \$19,000 is necessary to complete the work. The original statement of work still stands other than all work efforts are extended to 30 September 2009. The overall goal of this proposal is to continue our effort toward the development of 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) for reducing the computational time required for low-frequency biotelemetry 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. This work will be conducted in close collaboration with the Naval Health Research Center Detachment, Directed Energy Bioeffects Laboratory, which will provide the models and data to be used in the simulations. Computer codes utilized for the simulations will be shared with Brooks City-Base.

Exploration of Network-on-chip Techniques for Low-power On-chip Data Communication

Xun Liu
Qualcomm
 \$33,000
 09/01/08 - 05/31/09

In this project, the PI will explore NoC techniques to construct on-chip networks for efficient data communication of SoCs. The research emphasis is on the reduction of wiring congestion and power dissipation while satisfying predetermined throughput and latency requirements. In particular, it will be assumed that the SoC-under-design contains a mixed set of slow speed external interfaces, and high and low speed cores. Traditional high-speed and high-throughput bus designs are not efficient solutions. For NoC based solutions, optimization of protocols, switches, routing topologies and algorithms will be performed. A wide range of previous communication architectures including dedicated interconnects, shared buses, segmented buses with bridges, and bus

meshes will also be evaluated for a given SoC design so that a suite of on-chip communication solutions can be created and applied to the target SoC design.

Carolina Center For Cancer Nanotechnology Excellence

Leda Lunardi, John F. Muth
UNC - UNC Chapel Hill
 \$60,215
 09/01/08 - 08/31/09

At present, single cell and single molecule fluorescence studies have been a powerful toolset for understanding cellular processes. However, one can argue that traditional optical microscopy most of the photons are wasted with only a very small number of photons are exciting fluorophores of interest. The remaining photons are producing autofluorescence from the medium, heat within the cell and are undesirable. The goal of this portion of the project is to fabricate an array of nano-lights to create an intelligent microscope slide. By breaking the paradigm of requiring an external light source to propagate through the microscope, the nano-light emitters will be a powerful new tool for investigating cell/surface interactions and performing selective area fluorescence studies of individual cells. In addition to acting as nano-light sources for fluorescence excitation, we can also build intelligence into the nano-lights by constructing using peptides/protein binding interactions to mediate a surface plasmon resonance effect that in turn will alter the amount of light that is emitted from the nano-light.

ERC Education and Diversity program

Leda Lunardi
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
 \$101,047
 09/01/08 - 08/31/09

The College Education Director at NC State, along with her counterparts directors at each partner campuses, will coordinate a network of programs strategically planned to recruit and retain a diverse group of undergraduate and graduate student participants in Center-sponsored degree programs, research experiences, fellowships, and international research collaborations at ETH-Zurich and University of Aachen in Germany.

North Carolina Photonics Initiative Phase II

Leda Lunardi
UNC - General Administration
 \$58,000
 04/21/04 - 10/31/08

In Phase IV we intend to complete the tasks necessary to continue to grow, promote and institutionalize the Carolinas Photonics Cluster. As we organize ourselves through an inter-institutional agreement into effectively one distributed collaborative campus, the rewards for our faculty and students and even more so, our industry partners, will be considerable. We are at a point in time where there is willingness on the part of the campuses involved to invest in the resources, time and energy needed to accomplish this important multi-institutional activity. Coordinated educational programs and complementary research facilities simplifies the Consortium’s engagement with the broader industry driven Cluster.

Photocatalytic Sensors for VOC Sensing

Leda Lunardi, John F. Muth
Valencell Inc.
 \$334,609
 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.
 \$150,000
 01/15/09 - 12/31/10

In this proposed effort with Valencell, Inc., NC State University (NCSU) will be responsible for thin film deposition, device fabrication and optoelectronic characterization of both. NCSU will investigate and optimize thin film deposition parameters such as film composition, temperature and deposition environment to obtain bright phosphors with spectrally narrow luminescence at specific wavelengths. This includes both crystalline materials such as gallium oxide and aluminum oxide, as well as spin-coated materials such as doped spin-on-glass. Multi-wavelength light emitting devices will be fabricated at NCSU using readily available photolithographic techniques to produce both coplanar and vertically stacked phosphor arrays on sapphire, ruby and other substrates. Fabrication process steps will be refined to optimize the efficiency and reliability of the resultant devices including phosphor geometry. Compatibility with unpackaged UV LEDs for monolithic devices will also be investigated. Devices and thin films will be characterized at NCSU, using available visible and near-infrared spectrometers and detectors for wavelength and power optimization.

Valencell: Pulse Oximetry

Leda Lunardi, John F. Muth, Robert M. Kolbas
Valencell Inc.
 \$335,000
 05/01/07 - 12/31/08

Multiwavelength emitters are an important component in devices that measure the amount of oxygen in the blood. This proposal examines how to better make better light sources for pulse oximetry devices.

Collaborative Research: High Density Metal and Semiconductor Nanoparticles for Memory and Photonic Applications

Veena Misra, John F. Muth
National Science Foundation
 \$612,000
 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.

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)
 \$166,666
 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 High-K Gate Dielectric Stacks for SiC MOSFETs

Veena Misra
CREE Research, Inc.
 \$180,000
 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 (SiC_xO_y) 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
 \$1,968,000
 07/25/08 - 01/24/10

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)
 \$70,782
 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. 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.

SGER: Novel Ultra Fast Heating Platform for In-Situ Study of Nanoparticle Based Devices

Veena Misra
National Science Foundation
 \$67,409
 03/01/08 - 02/28/09

We propose to investigate an innovative route in the real-time formation and characterization of nanostructures utilizing a revolutionary platform that provides ultra-fast temperature ramp rates (1000°C/msec). This platform consists of a freestanding membrane that acts as an integrated heater and sample support system and enables ramp rates which are faster than any commercial system. The heater is built directly onto a Si wafer which can enable a highly dense array of microheaters. The goal of this SGER is to exploit this platform to focus on nanoparticle formation and lead to generating fundamental novel insight into kinetics of nanostructures under unconventional temperature treatments.

Solid-State Hybrid Molecular Memory Devices

Jonathan S. Lindsey, Veena Misra
University of California - Riverside
 \$200,000
 09/14/07 - 09/30/08

New porphyrin-based charge-storage materials will be synthesized (Lindsey lab, NCSU) for attachment to electroactive surfaces in nanodevices as required for molecular-based information storage. Novel approaches for development of charge-transfer layers also will be investigated. Molecular-based charge-storage materials will be incorporated into a variety of novel solid-state nanodevices including S/MMM and MIMM junctions (Misra lab, NCSU). Of particular interest are strategies that prevent shorting of via metal penetration of the molecular layer. The Misra lab will explore MIMM junctions as an alternate testbed for molecular electronics. Studies of these structures include time-resolved methods such as pulse measurements to obtain speed response, particularly to elucidate the role of varying dielectric thickness. Frequency dispersion of capacitance will be correlated to charging and discharging of the molecular layer in the MIMM devices. The Misra lab also will place the two terminal MIMM junctions on MOSFET channels to interrogate the impact of redox states on channel current. Such studies will complement physical analysis at UC Riverside such as angle resolved XPS and IR with ultrathin top metals to gauge bonding to the molecules at various buried interfaces. The synthesis of new compounds is an integral part of this effort. In this regard, the Lindsey lab will design and synthesize novel molecules that have more complex features for use in MIMM devices, including multiple states and tethers on both sides of the molecule.

Carolina Center of Cancer Nanotechnology Excellence

John F. Muth
UNC - UNC Chapel Hill
 \$74,740
 09/01/07 - 08/31/08

At present, single cell and single molecule fluorescence studies have been a powerful toolset for understanding cellular processes. However, one can argue that traditional optical microscopy most of the photons are wasted with only a very small number of photons are exciting fluorophores of interest. The remaining photons are producing autofluorescence from the medium, heat within the cell and are undesirable. The goal of this portion of the project is to fabricate an array of nano-lights to create an intelligent microscope slide. By breaking the paradigm of requiring an external light source to propagate through the microscope, the nano-light emitters will be a powerful new tool for investigating cell/surface interactions and performing selective area fluorescence studies of individual cells. In addition to acting as nano-light sources for fluorescence excitation, we can also build intelligence into the nano-lights by constructing using peptides/protein binding interactions to mediate a surface plasmon resonance effect that in turn will alter the amount of light that is emitted from the nano-light.

Defining the Boundaries of Free Space Underwater Communications

John F. Muth
National Science Foundation
 \$594,452
 01/01/07 - 12/31/09

This is a \$10,000 undergraduate Fellowship from the NCMR that is being routed through NSF as a supplement.

Micromachined Chemical Sensor

John F. Muth
Naval Research Laboratory
 \$1,174,986
 08/15/05 - 08/15/08

The need to be able to detect chemical or explosive agents has grown greatly in importance in recent years. Present sensor systems require the sensor and readout to be at the location of the agent. The ability to remotely interrogate sensors from a distance would be advantageous. This proposal involves the fabrication of micromachined sensors that will be sensitive to chemicals and can be read out by a laser from a distance.

SBIR II Integrated Wide-Bandgap Semiconductor Photoconductive Switch With a Terahertz Antenna

John F. Muth, Gianluca Lazzi, Leda Lunardi
Digital Fusion Inc.
 \$575,412
 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
 \$1,350,000
 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.

National Nanotechnology Infrastructure Network - Triangle National Lithography Center

Carlton M. Osburn
Cornell University
 Unfunded
 03/01/04 - 02/28/09

The ASML 5500/9xx, in the Triangle National Lithography Center (TNLC), is a state-of-the-art, 193 nm optical lithography system for rapid turnaround time, high volume patterning. The stepper, which is slated for 4Q03 installation, will be housed in Class 100 facilities within NC State's Nanofabrication Facility which provides auxiliary capabilities: resist coating, developing, descum, and trim. The tool specifications include 130 nm resolution (half-pitch) and <

40 nm nm alignment, with a 26 mm x 33 mm field size. The system will accommodate wafers up to 200 mm in diameter. Previous experience with other steppers suggest that, once the tool is installed and lithography processes are developed, isolated features as small as 65 nm will be able to be printed. Using the resist trimming processes already developed at NC State, features as small as 20 nm are expected. To complete the patterning process, RIE tools are available for film etching. In conjunction with the Strasbaugh 6EC chemical mechanical polishing tool, damascene patterning can be performed. This stepper has a market value of over \$10M and represents an investment by UNC-CH and NCSU in excess of \$4M.

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.
 \$1,566,642
 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
 \$270,000
 03/01/07 - 02/28/10

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.

Control-Flow Processors

Eric Rotenberg
National Science Foundation
 \$175,000
 09/01/04 - 08/31/08

An architecture is presented that unifies fine-grain control-flow and data-flow dependences in the context of contemporary superscalar processors, preserving highly streamlined mechanisms of superscalar processors while endowing them with dataflow properties. Future independent instructions are fetched, executed, and locally finalized, their results propagated and corresponding resources freed, and their cumulative effects sustained regardless of prior unresolved branch mispredictions. Branch mispredictions no longer serialize execution, leaving exceptions and finite resources as the only remaining serializing constraints in the system. The proposed approach promises to overcome one of the remaining grand-challenge problems in scaling processor performance.

CPA-CSA: FabScalar: A Standard Superscalar Library for Fabricating Heterogeneous Chip Multiprocessors

Eric Rotenberg
National Science Foundation
 \$300,000
 07/01/08 - 06/30/11

This proposal explores a new approach to designing and fabricating superscalar cores, called FabScalar. It borrows the notion of a standard cell library for ASIC design. A standard cell library provides many “flavors” of simple gates, complex logic components, and even whole cores. Not only are there many different component types, but a given component type may come in many variations, with different choices of speed, power consumption, and area. The synthesis tool uses partially or fully specified objectives (frequency, total area, etc.) and selects from the standard cell library to meet specified objectives while optimizing any unspecified objectives. In FabScalar, a “standard cell” is a whole superscalar pipeline stage. A Standard Superscalar Library (SSL) provides many “flavors” of instruction-fetch stages, instruction-decode stages, rename stages, issue stages, and so forth. Thus, it differs from a conventional standard cell library in that its components -- pipeline stages -- are what characterize a canonical superscalar processor, which has been well codified by industry and academia over several decades of study. Its central components are neither logic-level components at one extreme nor whole cores at the other, enabling the high level synthesis of a superscalar processor from the natural pipestage level. Thus, FabScalar is a first step for enabling quick and simple design of effective HCMPs. These HCMPs will provide a better microarchitectural bridge between diverse workloads and underlying technology.

Retention-Aware Placement in DRAM (RAPID): Software Methods for Quasi-Non-Volatile DRAM

Eric Rotenberg
NCSU Center for Advanced Computing & Communication
 \$40,000
 07/01/07 - 06/30/10

We recently proposed Retention-Aware Placement in DRAM (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. We explore three versions of RAPID and observe refresh energy savings of 83%, 93%, and 95%, relative to conventional temperature-compensated refresh. RAPID with off-the-shelf DRAM also approaches the energy levels of idealized techniques that require custom DRAM support. This ultimately yields a software implementation of quasi-non-volatile DRAM. The next step in this research is to integrate RAPID into one or more real system prototypes of interest to CACC members, including a cell phone and/or a sensor node.

Static-Power-Efficient Caches

Eric Rotenberg
Texas Instruments
 \$76,000
 05/16/06 - 08/15/08

There are three research thrusts: (1) Continue our research on static-power-efficient caches. (2) Begin exploratory research on logic-process embedded dynamic random access memory (DRAM) trends. (3) Apply our research on Retention-Aware Placement in DRAM (RAPID) to a real system, such as an ultra-low-power wireless sensor network node.

The Phase Based Behavior of Objects: Enabling a New Generation of Microarchitecture

Eric Rotenberg
Semiconductor Research Corp.
 \$1,200,000
 04/01/07 - 03/31/10

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.

Development of Highly-Sensitive HgCdTe Detectors and Large-Format Focal Plane Arrays for Space-Based Imaging Applications in the 2-14 um Infrared Region and Beyond

Jan F. Schetzina, Mark A. Johnson
US Missile Defense Agency
 \$400,000
 09/30/05 - 09/29/08

This project will employ new epitaxial growth methods for CdTe, along with CdZnTe, and CdSeTe lattice-matched to HgCdTe, in order to achieve the required reduction in HgCdTe device dislocations. In particular, epitaxial layer overgrowth (ELO) techniques will be investigated in detail using vapor phase epitaxial growth techniques in order to dramatically reduce dislocations and, hence, greatly improve the performance of large HgCdTe FPAs over the entire 2-14 mm wavelength range and beyond. Our goal is to reduce dislocations to a level of 103 per cm² or less, such that long wavelength (8-14 mm) HgCdTe detectors and arrays will be limited only by the background radiation (BLIP-limited) when used in satellites to view the earth. This work also represents enabling technology for using sensitive HgCdTe FPAs for certain proposed space-based missile defense systems where the space background is even lower. As the proposed work progresses, we will work closely with scientists at the Army Research Laboratory and the Army Night Vision Laboratory at Ft. Belvoir to transfer the NCSU technology into working IR devices. In addition, these new and improved IR detector materials will be provided to leading DoD industrial suppliers of HgCdTe IR imagers for fabrication and testing of large-format HgCdTe FPAs.

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

Rudra Dutta, Mihail L. Sichitiu
Army Research Office
\$149,960
06/16/09 - 06/15/10

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 be built in two stages: in the first stage, nodes placed on pushcarts will be temporarily placed outdoors for trials and tests; in the second phase, permanent antenna placements will be installed on equipment poles over a large area of the Centennial Campus of North Carolina State University. 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. Current and envisaged research activities of SOSI researchers address secure and redundant routing, energy-efficient routing, topology control, localization, cross-layer optimization, security and performance of SIP and VoIP, secure virtualization of network and compute resources, social networking. 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
\$1,285,237
08/15/06 - 07/31/10

Either for convenience, or for its simplicity the random waypoint (RWP) mobility model is by far the most popular mobility model used in simulation experiments. A much smaller percentage of papers use detailed simulations (e.g., in vehicular networks, using realistic car following models that follow the roads) to generate the mobility traces. Although it was repeatedly pointed out that the results from simulations using RWP differ both quantitatively, as well as qualitatively from those using detailed mobility simulations, most papers avoid the trouble of generating realistic mobility traces. Intellectual merit: 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 (e.g., busses in a city, students in a campus, or zebras in a herd), while allowing the users to vary key parameters (number of nodes, density, etc.). Broader impacts: Since for the foreseeable future MANET performance evaluation will be based on network simulations, we expect that the results of this project will be widely used in the MANET community. We envision that the proposed model will effectively replace the RWP as the standard mobility model used in any MANET performance evaluation.

Research Site of the I/UCRC Entitled: Repair of Building and Bridges with Composites

Sami H. Rizkalla, Rudra Dutta, Mihail L. Sichitiu
National Science Foundation
\$824,000
07/15/02 - 06/30/09

Structural health monitoring (SHM) has matured as an engineering application over the last few decades. The use of advanced composite materials and new construction techniques has increased the need for SHM as a diagnostic tool. However, health diagnostics is a reactive basis to investigate the cause of damage for maintenance decisions. To reduce the risk of failure, maintenance must be carried out in a more proactive way. In support of this goal, predictive techniques are required to identify leading indicators of failure prior to appearance of any macro-indicators of damage. This proposed project is focused on Collaborative Research on Developing a Telematics Platform for Bridge Monitoring and Health Prognostics, as aged and deteriorating bridges are becoming more severe choke points in the economic strength and growth of the United States.

On-the-fly Scene-dependent ATR

Wesley E. Snyder, Siamak Khorram
US Air Force-Office of Scientific Research (AFOSR)
\$1,083,564
02/15/07 - 11/30/09

A hyperspectral imager produces an image with a hundred or more spectral measurements at each pixel. A multispectral imager on the other hand may sample the spectrum in only three to ten bands. Given hyperspectral data, one can synthesize multispectral data by simply integrating over the appropriate portion of the spectrum at each point. One would think that a pattern classifier based on multispectral data would perform poorly as compared to the same type of classifier based on hyperspectral data, since surely information is being lost in going from many measurements to few. However, we know that the hyperspectral data is highly correlated and that much research has shown that the data has many fewer degrees of freedom than the number of individual bands. This work will show how to use the hyperspectral data to its fullest advantage to detect and classify a target, then design a lower dimensional multispectral system that can perform the same task using fewer resources that can be implemented on a smaller platform.

CAREER: Intelligently Managing the Memory Hierarchy of Future High Performance Servers

Yan Solihin
National Science Foundation
\$719,855
03/01/04 - 02/28/09

Continuing trends in chip integration will soon lead to on-Chip Massive Multi Processors (CMMP) for high performance servers in the multi-billion transistor chip era. A unique feature of CMMP is that there will be a large number of threads, up to hundreds of them, simultaneously competing for shared resources such as caches and off-chip bandwidth. This presents unprecedented new challenges in designing the memory hierarchy of CMMP, such as inter-thread cache conflicts, off-chip bandwidth bottleneck, and costly context switches. To tackle the challenges, fine-grain thread-aware resource management of caches, off-chip bandwidth, and the main memory is proposed.

Collaborative Research: Software and Hardware Support for Efficient Monitoring of Program Behavior

Yan Solihin

National Science Foundation

\$150,000

09/01/06 - 08/31/09

It is becoming difficult to assess the performance of a software systems without considering the context in which it will run. However, evaluating the software in all possible configurations and environments is typically infeasible, whereas considering only a subset thereof may not be representative of the way the software is going to be used. Therefore, the analysis of software behavior is shifting from a purely in-house activity to a task that is increasingly performed on live runs in the production environment. This shift has spurred much interest in runtime monitoring approaches that can collect information about software's behavior when it runs on users' platforms. In the last years, monitoring approaches have been defined for a range of domains (e.g., performance optimization, testing, runtime verification, security). Unfortunately, most existing approaches to runtime monitoring are limited in three main ways. First, they are defined ad-hoc, which makes it difficult to extend and adapt them to new contexts. Second, they use monitoring code that is hand-crafted and unmodifiable at runtime, which limits their suitability for highly adaptive, self-monitoring systems. Third, they are typically defined within only one computational layer (e.g., software, operating system, or hardware)--they do not take advantage of the capabilities offered by the other layers and do not leverage the interplay across layers. The long term goal of this proposed research is to define a general approach to efficient runtime monitoring of software that leverages software and hardware capabilities in a synergistic way. The approach will allow for specifying monitoring tasks using a language that provides suitable abstractions.

Electrical Network Design and Characterization For Three Dimensional Integrated Circuits

Michael B. Steer, Kevin Gard

Boise State University

\$80,000

10/01/07 - 12/31/08

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.

Electrical Network Design and Characterization For Three Dimensional Integrated Circuits

Michael B. Steer

Boise State University

\$200,000

04/09/08 - 04/08/10

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 real-

ized. 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)

\$4,705,000

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.

Multi-Physics Field and Circuit Computational Modeling in the Time Domain

Michael B. Steer

Remcom, Inc.

\$50,000

07/14/08 - 12/31/08

This proposal integrates electrical modeling using the circuit simulator fREEDA with a finite difference time domain electromagnetic simulator developed by REMCOM. The combination will enable fully physical modeling of device interactions with time-varying electromagnetic fields. The proposed tool will be able to model the high fidelity time domain of radio transceivers circuits with both nonlinear and dynamic characteristics. Further, the transceiver modeling will be coupled with the ability to model time varying antenna radiation patterns. Thus the goal of this proposed project is to integrate proven circuit modeling tools with electromagnetic modeling and simulation tools. The proposed tool will support not only radiated energy but also the effects of external fields such as co-site interference on the circuitry. This will enable researchers to more completely understand the nature of co-site interference and facilitate the development of co-site mitigation strategies.

Optimum Waveform Design for Electromagnetic Disruption and Probing of Remote Devices

Michael B. Steer

Army Research Office

\$3,200,000

11/01/06 - 10/31/09

It has been shown that a communication device returns an apparently unique signal when scanned by a simple pulsed microwave signal. This project will use a radar-like signal to determine how large a class of devices can be characterized this way. The work is largely experimentally based. The challenging aspects of the work are managing dynamic range, and minimizing the time required to perform a sweep. It is expected that that the data and analysis undertaken will determine the practicality of the reflection technique in characterizing devices using novel waveforms.

Silicon Circuit Board Electrical Properties

Michael B. Steer
Sixis Inc.
\$15,738
03/01/09 - 06/30/09

The objective of this project is the development of electrical design rules in support of the design of a silicon circuit board demonstration being undertaken by the sponsor. The work will aid in formulating final design and layout rules, implementing test structures on the silicon circuit board, propose changes to the structural process, and verify simulations and assumptions by measurement.

Standoff Inverse Analysis and Manipulation of Electronic System

Michael B. Steer, Kevin Gard
Army Research Office
\$21,587,428
07/01/05 - 04/30/10

This supplemental proposal accelerates the transition of signal modeling and measurement technologies to Army facilities. Technologies proposed herein are targeted for transition to the Army Research Laboratory (ARL) and the Intelligence and Information Warfare Directorate (I2WD). The impact will be broader and address the need for that part of battlefield monitoring concerned with the interaction of fields and electronics. We will research, develop and deploy a simulation environment for modeling the interaction of electromagnetic signals and circuits. Signal processing technologies will be adapted to extract information from scattered returns and in-circuit signals. Parameterized models of systems will be developed. Novel strategies for parallelizing the circuit simulation effort will be explored. Coupled with these activities will be the realization of small ruggedized instrumentation for detecting small signals in the presence of large signals.

Ultra-Wideband Impulse Radio for Ad-Hoc Tactical Military Communications

J. K. Townsend
Army Research Office
\$452,184
05/15/07 - 01/14/10

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). The body of literature on UWB impulse radio is growing. However, most of the work in the area of UWB impulse radio does not address issues that apply to the ad-hoc radio network environment. We propose to investigate ultra-wideband technology with emphasis on the tactical military mission. The requirements of tactical communications have some important differences when compared to commercial radio, and include covertness, survivability, rapid deployment, and low power in an ad-hoc, peer-to-peer environment. Our approach will be to leverage our recent results in the area of chip discrimination with the transmitted reference UWB schemes. This research will provide new theoretical and practical architectures and techniques that do not require the restrictive assumptions of the current state of the art.

IMPATT-mode AlGaIn/GaN mm-Wave HFETs

Robert J. Trew
SVT Associates
\$130,000
10/03/06 - 10/03/08

This research is directed towards investigation of a novel IMPATT mode of operation of AlGaIn/GaN high voltage HFET's. Novel device structures are investigated using a physics-based large signal RF simulator and simulated results are compared to experimental data obtained from industrial collaborators. The simulator is used to provide design guidance, as well as investigate physical operational details.

IPA Agreement With NSF For Robert Trew

Robert J. Trew
National Science Foundation
\$239,411
05/26/09 - 05/25/10

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.

Label-Free THz-Optoelectronic Sensing of Ultra-Low Concentration of Genetic Sequences: Theoretical Treatment

Robert J. Trew, Carl T. Kelley, Peiji Zhao
US Army
\$2,416,683
08/01/04 - 04/30/09

To fully understand the operational principle of the suggested device concept for label-free THz optoelectronic sensing of single or a few DNA molecules, a series of scientific issues associated with the operational principle of the device have to be investigated.

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 proposes to explore the feasibility of engineering thermal radiation for application to thermal energy harvesting. The approach is to utilize the high energy density stored in the evanescent field of 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. 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 convert the power available in evanescent modes to propagating modes with high efficiency. The proposed effort is directed towards advancements in a theoretical model that can be used to both (1) investigate and develop an understanding of the fundamental physical mechanisms associated with the phenomenon, and (2) serve as an aid in designing experiments that can be used to verify the phenomenon, as well as serve as a guide to optimizing device structures.

Reliability Modeling of High Voltage AlGaIn/GaN HFETs

Robert J. Trew
University of California - Santa Barbara
\$360,000
03/14/08 - 04/30/11

This project is directed towards the development of mathematical models for AlGaIn/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 Nitride Electronics

Robert J. Trew
University of California - Santa Barbara
\$679,167
04/01/05 - 03/31/11

This investigation will make use of a series of advanced physics-based device models that have been previously developed. These models will be modified and enhanced with appropriate physical phenomena that will permit accurate simulation of realistic HFET device performance. The models will be used to determine optimized device designs for mm-wave operation.

Estimation And Simulation Of Hyperspectral Images

Henry J. Trussell
Army Research Office
\$49,545
08/16/08 - 05/15/09

We propose to develop theory and practical methods to estimate and simulate hyperspectral images by using recorded data of low spectral resolution images. If range data is also available, we can create a collection of hyperspectral images that simulate the scene as if recorded from varying view points. These data can be used to test algorithms designed for many hyperspectral image analysis tasks, such as target detection, classification and tracking. An advantage is that these images are unclassified and can be used in a university environment where international students are often used. The images are also readily defined to allow ground truth to be known so that accuracy of the image analysis tasks can be measured.

CSR-PSCE, SM: Exploring Helper Computing Parallelism in Multicore Architectures

James Tuck, Yan Solihin
National Science Foundation
\$370,000
09/01/08 - 08/31/10

The project seeks to develop helper computing technology for enhancing reliability and security of computer systems. 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. In the past, the use of helper threads was constrained to prefetching and branch prediction. In this project, we propose exploring a new and novel use of helper computing for improving software reliability and security. With helper computing, reliability

and security functionalities that are normally performed as parts of the application code are off-loaded to the helper thread/process. This enables sophisticated functionalities to be computed in parallel with the application without slowing down the application much.

Energy Efficient Compiler Design for Thread-Level Speculation on a Chip-Multiprocessor

James Tuck
NCSU Faculty Research & Professional Development Fund
\$5,472
07/01/08 - 06/30/09

Relentless transistor integration is driving processor manufacturers to build Chip Multiprocessor (CMP) architectures. However, while CMPs can effectively speed-up parallel programs, much of the application base today is still composed of sequential applications --- for example, non-numerical applications that compilers fail to parallelize. A proposed solution to speed-up these hard-to-parallelize codes is Thread-Level Speculation (TLS). While evaluations of TLS on a CMP have generally shown good, if modest, speedups, an important concern has been the power inefficiency of aggressive speculation. As more tasks are executed speculatively to deliver higher speedups, there is a higher chance of spending power on work that ultimately gets squashed. This trend is especially troubling because the energy efficiency of TLS will decline as CMP designs scale up to more cores. Evidence of this trend is present in a recent study which showed a decline in the energy efficiency of TLS when moving from 2 cores to 4 cores. Given the key importance of power issues, this proposal will advance the design of TLS systems by focusing on compiler techniques that improve the energy efficiency of TLS execution. The compiler plays the primary role in selecting tasks for parallel execution, and, therefore, can have a singularly large impact on the overall efficiency of TLS.

Entrepreneurship Education & Its Impact on Engineering Student Outcomes: The Role of Program Characteristics and Faculty Beliefs

Thomas K. Miller, Stephen J. Walsh, Dianne Raubenhaimer
National Collegiate Inventors & Innovators Alliance
\$165,597
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
\$640,000
03/01/06 - 02/28/10

Multihop wireless networks are expected to provide dependable communications against a wide range of failures, such as failures caused by node mobility and more importantly, misbehaviors and malicious attacks because they promise to have a significant impact on communications, information process, and next generation networking paradigm in complimenting cellular networks, local area Wi-Fi networks, and the Internet. Nevertheless, because of node mobility and distributed architecture, multihop wireless networks render a set of unique dynamics and vulnerability in providing dependable communications. The design goal of resilient networks has an significant impact on design paradigms and methodologies of multihop wireless networks in all aspects, such as routing, scheduling, topology control, quality of service, and access control. The field of resilience-to-failure is still in its adolescence as there is a critical gap in the fundamental understanding we need for future research in protocol design and algorithm implementation for mobile wireless networks. Therefore, we propose to design an analytical framework of network resilience and new algorithms in building a prototype in this work.

FirstComb: A Case Study of the First Generation Communication Backbone for FREEDM

Wenye Wang, Alexander G. Dean
NCSU Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
\$126,322
09/01/08 - 08/31/09

Develop first generation communication system for FREEDM system.

Reliable Medium Access in Wireless Networks: Vulnerabilities, Protection, and Recovery

Wenye Wang, Peng Ning
Army Research Office
\$1,115,355
03/01/05 - 02/28/10

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. The approach will be to start with detailed middle-ware based traffic injecting, monitoring, measurement, and analysis in the Networking of Wireless Information Systems (NeTWIS) lab of North Carolina State University. The collected data will be later used for evaluation and verification of our proposed solutions. We will derive simpler drivers for wireless devices with different power, processing capability, and operation systems to capture all traffic that initiate an effort of communications at the MAC-layer. Then we will develop resilient MAC-layer mechanism, which target to main categories: DoS attacks aimed at reducing network availability, and selfish/greedy behaviors that favor some selected nodes but affect the overall network availability. This effort includes authentication of MAC-layer frames, surviving and recovering from MAC-layer DoS 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.

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

Wenye Wang, Hamid Krim
Defense Threat Reduction Agency
\$1,383,154
04/01/08 - 03/31/11

This project addresses two thrusts, namely network vulnerabilities and recovery strategies in the aftermath of WMD attacks. The proposed research is unique in that (i) it focuses on analysis of new models and on metrics which capture a multitude of failures along with their interdependence in order to understand fundamentals of network response to WMD stresses, and (ii) it focuses on the development and analysis of recovery strategies when there is incomplete knowledge of potential threats, faulty network protocol behavior, and resource outage due to unknown causes. Both issues have not been addressed in previous studies and literature of networking science. In this project, we will be concentrating on military networking infrastructures such as combat strategic systems, and tactical ad hoc networks, which carry time-sensitive information and demand for reliable and non-disruptive communications. The results of this research will advance the state of knowledge on network response to WMD attacks and leverage military communication capabilities by designing robust, self-healing, complex network architecture which interact with other networks.

Time and Data Sensitive Wireless Networked Control Systems

Wenye Wang, Mo-Yuen Chow
National Science Foundation
\$821,151
09/01/05 - 12/31/09

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

Magneto-Transports in Interband Resonant Tunneling Diodes (I-RTDs) and Dilute Magnetic Semiconductor (DMS) 1-RTDs

Weidong Zhang, Peiji Zhao
Army Research Office
\$1,273,335
05/01/07 - 04/30/10

The double-barrier resonant tunneling diodes with staggered band alignments can admit significant interband tunneling current in addition to conduction band electron transport. This research seeks to develop multi-band models for understanding of basic transport physics of I-RTDs when subjected to magnetic fields and when composed of diluted magnetically-ordered type II superlattices. The objectives of this research are: (1) to calculate the resonant conduction-band current and interband Zener tunneling current; and (2) to study the nanoscale feedback dynamic processes arising from interband tunneling and its accompanied space charge accumulation. Therefore, these investigations will develop new models and execute simulations to analyze and engineer specific DMS device configurations suitable for a two-phase charging-discharging THz oscillator and explore other possible applications such as spintronics.

Resonant Tunneling Diode for High-Power Room-Temperature Terahertz Emission

Weidong Zhang
University of Virginia
\$120,000
11/15/08 - 09/10/10

The objective of this STTR program is to model, design, build and demonstrate a novel, hybrid solid-state, inter-band resonant tunneling diode (I-RTD) oscillator capable of operating across broad portions of terahertz frequency band (300-600 GHz) at room temperature, with estimated terahertz output power levels in the 3-10 mW range. Such record terahertz oscillator performance will be of great use in military relevant applications such as chemical and biological agent detection, standoff imaging of concealed weapons and explosives, high-speed data processing and communications, and characterization of bio-molecular based devices and systems. Phase I of this program succeeded in modeling the I-RTD device, and generating candidate device structures based on the InGaAs/GaSbAs/InP compound semiconductor system, which can be synthesized in conventional epitaxial layer deposition systems, and then processed into devices. Phase II will grow epitaxial wafers of these material structures, process them into devices in Spire's semiconductor foundry, and test the devices for terahertz emission spectra, output power vs. drive conditions, and device operating temperature limitations. Phase II will also continue and extend device structure modeling and carry out electrical modeling of the I-RTD devices and their associated circuits.

Development of a Novel Technique For Label-Free DNA Sequencing

Peiji Zhao
Army Research Office
\$999,486
07/01/08 - 06/30/12

Currently, bio-molecular detection techniques based on optical principles can not provide the DNA base sequence information in DNA molecules. This incapability of the detection techniques is caused by the loss of some important information related to the characteristics of the bio-molecule and inspire fundamental research on the characteristics of DNA. In the proposed research, we will investigate the theoretical basis for the development of a novel technique of DNA sequencing. The technique is based on the understandings to the vibrational characteristics of DNA. The goal of the proposed research is the development of the relationship between the DNA base sequences and the current flowing through the molecules.

Nanoscale Imaging Technology for THz-Frequency Transmission Microscopy I.F.T.h (CBT)

Peiji Zhao, Robert J. Trew
Army Research Office
\$333,366
06/01/07 - 05/31/09

A novel nanoscale-engineering research project is proposed for the first-time development of a microscope-system capable of collecting terahertz (THz) frequency spectroscopic signatures from microscopic biological (bio) structures. This unique THz transmission microscopy is capable of detection of the biological materials and agents that produced spectral features within the THz frequency regime (i.e., ~ 300 GHz to 1000 GHz) that appear to be representative of the internal structure and characteristics of the biological samples ? e.g.,

DNA, RNA and bacterial spores. In the proposed research, we will theoretical investigate the crucial issues related to the design of the subwavelength aperture, which is an important component of the proposed THz microscope. Experimental research on the fabrication of the THz microscope will also be performed.

CONTACT INFORMATION

For more information about the Department of Electrical and Computer Engineering at NC State University, visit the department's website:

www.ece.ncsu.edu/