

# Computer Science Research Projects 2006-07

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## The Design and Use of Digital Identities

Ana Anton; Julia Earp  
Purdue University  
\$103,006  
09/15/2004- 08/31/2007

This project will address a wide variety of digital identity needs by developing required Flexible, Multiple and Dependable Digital Identity (FMDDI) technology, based on a sound underlying set of definitions and principles. We will apply, expand, and refine the theory of identities, the mechanisms to embody and enforce them, as well as study the implications of their use, and develop appropriate educational vehicles to teach people how digital identities should be used effectively.

## Collaborative Research: A Comprehensive Policy-Driven Framework for Online Privacy Protection: Integrating IT, Human, Legal and Economic Perspectives

Ana Anton; Ting Yu; David Baumer ; Michael Rappa  
National Science Foundation  
\$534,000  
09/15/2004- 08/31/2007

Privacy is increasingly a major concern that prevents the exploitation of the Internet's full potential. Consumers are concerned about the trustworthiness of the websites to which they entrust their sensitive information. Although significant industry efforts are seeking to better protect sensitive information online, existing solutions are still fragmented and far from satisfactory. Specifically, existing languages for specifying privacy policies lack a formal and unambiguous semantics, are limited in expressive power and lack enforcement as well as auditing support. Moreover, existing privacy management tools aimed at increasing end-users' control over their privacy are limited in capability or difficult to use.

## ITR: Encoding Rights, Permissions, and Obligations: Privacy Policy Specification and Compliance

Annie Anton; Julie Earp; Lynda Aiman-Smith ; David Baumer  
National Science Foundation  
\$932,000  
09/15/2003- 08/31/2007

This research focuses on how society uses, values, and protects citizens' personal information. From the perspective of system design, software engineers need methods and tools to enable them to design systems that reflect those values and protect personal information, accordingly. This research examines how privacy considerations and value systems influence the design, deployment and consequences of IT. The goal is to develop concepts, tools and techniques that help IT professionals and policy makers bring policies and system requirements into better alignment. An action-oriented set of conceptual tools, including guidelines and privacy-relevant policy templates will be constructed and validated.

## CAREER: Adaptive Automated Design of Stored Derived Data

Rada Chirkova  
National Science Foundation  
\$489,810  
08/ 1/2005- 07/31/2010

The goal of this project is to develop an extensible framework for designing and using derived data in answering database queries efficiently. The outcomes of the project are expected to be general and independent of a specific data model (e.g., relational or XML), while giving guarantees with respect to query-performance improvement. The approach consists of developing and evaluating mathematical models and algorithms for common types of queries on relational and XML data. Expected outcomes of the project include automated tuning of data-access characteristics in a variety of applications, thus enhancing the quality of user interactions with data-intensive systems.

## Efficient View-Design Algorithms To Achieve Near-Optimal Performance Of Sets of Relational Queries

Rada Chirkova  
National Science Foundation  
\$253,180  
09/15/2003- 08/31/2007

The goal of this proposal is to develop effective methods to improve performance of frequent important queries on large databases. This problem is important for improving efficiency of user interactions with relational data-management systems; solving the problem will have effect in query optimization, data warehousing, and information integration. The project focuses on evaluating queries using auxiliary relations, or views. Our main objective is to develop theoretically rigorous yet practically applicable techniques needed to design views that would help in computing sets of frequent and important queries with optimal or near-optimal speedup on large databases with given statistics.

## Runtime/Operating System Synergy to Exploit Simultaneous Multithreading

Vincent Freeh; Frank Mueller  
National Science Foundation  
\$380,000  
08/ 1/2004- 07/31/2008

This proposal focuses on a synergistic approach combining runtime and operating system support to fully exploit the capabilities of SMTs. To meet this objective, it studies three different approaches. First, it investigates the benefits of using a helper thread along side the primary thread, by building a reference implementation of an SMT-aware Message Passing Interface library. Second, it investigates the benefits of dynamic mode switching between single-thread and multi-threaded configurations. Third, it modifies the operating system creating an SMT-aware scheduler. The benefits are demonstrated for a variety of applications, including large-scale benchmarks and other nationally relevant parallel codes.

## CAREER: New Directions in Managing Structured Peer-to-Peer Networks

Khaled Harfoush  
National Science Foundation  
\$408,894  
03/15/2004- 02/28/2009

In the research component of my career development program, I focus on strategies for addressing the challenges and opportunities that face the deployment of structured P2P systems. In particular, I introduce new schemes to locate resources and strategies to serve them. I also introduce new schemes for topology interference, integration, and organization in order to optimize content distribution. The proposed educational aspect of my career development program focuses on (1) enhancing our department's networking curriculum, (2) extending opportunities for women, under-represented minorities, and undergraduates in research, (3) encouraging students to participate in the computer science community outside the university.

### **Roaming WLAN Networks: Security and Performance Implications**

*Khaled Harfoush*

CACC

\$40,000

01/ 1/2006- 12/31/2006

Our focus in this proposal will be on providing seamless and secure transitions between wireless islands for real-time connections, which may be sharing the wireless space with other real-time and non-real-time applications.

### **CAREER: Assisted Navigation in Large Visualization Spaces**

*Christopher Healey*

National Science Foundation (ACIR/ACR)

\$370,403

02/ 1/2001- 01/31/2008

This project will investigate methods for navigating complex information spaces. Work will focus on a system designed to help viewers visualize, explore, and analyze large, multidimensional datasets. Detailed local displays will be combined with a high-level global overview of areas of interest within a dataset. Local views will use perceptual cues to harness the low-level human visual system. Global overviews will identify and cluster elements of interest to produce an underlying graph that: (1) support efficient navigation via graph traversal, and (2) provide an effective visualization of the areas of interest and their relationships to one another.

### **Visualizing Network Data and Environments**

*Christopher Healey*

CACC

\$40,000

01/ 1/2006- 05/31/2007

This proposal describes a one-year research project to apply techniques from scientific visualization to the problem of displaying, monitoring, and analyzing network-based data.

### **A Bioinformatics Computing Cluster for NC State University**

*Steffen Heber*

North Carolina Biotechnology Center

\$227,029

02/ 1/2007- 01/31/2008

The Bioinformatics Research Center (BRC) at NC State University is one of the world's premier centers for education and research in bioinformatics. Funding will provide a 54 dual-Xeon compute node Linux cluster to enhance the computational resources of the BRC. BRC will partner with

NC State Information Technology Division (ITD) to leverage the proposed cluster investment in two ways: first, BRC faculty will gain access to the high performance computing (HPC) resources - currently more than 400 blade processors. Second, by having a shared, ITD housed and administered computing resource, personal systems will not need to be purchased or maintained.

### **Symbolic Representation Based Partial Order Methods**

*S. Purushothaman Iyer*

National Science Foundation

\$160,000

09/ 1/2002- 08/31/2006

Symbolic representations are used in analysis of finite and infinite state concurrent system. However, they could be subjected to constraint explosion much like state explosion in analysis of finite state designs of concurrent systems. The reason for both of these explosions is the consideration of all interleavings, of a concurrent system, during their analysis. Partial-order techniques depend upon the notion of independence among actions to avoid considering all possible interleavings. The proposed research will investigate the notion of unfolding, which aids both in discovery of independent actions and in succinctly representing the state space of systems.

### **Request for Support for the International Conference on Information and Communications Security (ICICS 2006)**

*Dennis Kekas*

National Science Foundation

\$5,000

09/15/2006- 08/31/2007

The International Conference on Information and Communications Security will be held in December 2006 in the Research Triangle of North Carolina. This is a well-established security conference being held for the first time in North America. Support from NSF is sought to broaden participation, particularly of students, provide improved access for researchers to the latest research results, and to promote the development and dissemination of solutions to some of the nation's pressing security needs in the computing and communications areas.

### **NSF Partnership in the Center for Advanced Computing and Communication**

*Dennis Kekas; Mladen Vouk*

CACC-NSF

\$492,240

09/15/1999- 08/31/2007

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. North Carolina State University was selected by National Science Foundation in 1981 as a site for an industry/university cooperative research center in communications and signal processing. The center was named the Center for Communications and Signal Processing until 1994 when a second center site at Duke University was added. 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.

### **Bayesian Pedagogical Agents for Dynamic High-Performance Inquiry-Based Science Learning Environments**

*James Lester; Hiller Spires; John Nietfeld*  
*National Science Foundation*  
 \$605,436  
 01/ 1/2007- 12/31/2009

Pedagogical agents are embodied software agents that have emerged as a promising vehicle for promoting effective learning. The proposed work has two complementary technology and learning thrusts. First, it will develop a full suite of Bayesian pedagogical agent technologies that leverage probabilistic models of inference to systematically reason about the multitude of factors that bear on tutorial decision making in dynamic high-performance inquiry-based science learning environments. Second, it will provide a comprehensive account of the cognitive processes and results of interacting with Bayesian pedagogical agents in inquiry-based science learning by conducting extensive empirical studies of learning processes and outcomes.

### **CAREER: Transparent, Interactive Desktop Parallel Computing for Scientific Data Processing**

*Xiaosong Ma*  
*National Science Foundation*  
 \$400,000  
 03/ 1/2006- 02/28/2011

While individual workstations in scientific research environments have become more powerful, they cannot meet the needs of today's interactive data processing tasks. Meanwhile, idle desktop resources are not efficiently utilized. This project aims at harnessing the collective idle resources within institutional boundaries to speed up computation- or data-intensive tasks routinely executed on desktop machines. We will build a novel desktop parallel computing framework, which will integrate distributed computing and storage resources to create an execution platform similar to that provided by a parallel computer, while maintaining the comfort and responsiveness of desktop sequential computing and the autonomy of resource donors.

### **Runtime Data Management for Data-Intensive Scientific Applications**

*Xiaosong Ma*  
*US Department of Energy*  
 \$299,992  
 08/15/2005- 08/14/2008

Many applications currently used on daily basis by scientists fail to take advantage of state-of-the-art computer systems. This problem is more severe for many data-intensive applications, such as bioinformatics and visualization codes, whose parallelization are more recent and less studied in parallel architectures' design, compared to traditional simulations. We propose to address the above problems by investigating efficient runtime data management for data-intensive applications. We plan to build novel technologies for generic, automatic parallel execution plan optimization and enhancing parallel scientific data libraries by hiding I/O costs.

### **Transparent Data Recovery for Parallel File Systems**

*Xiaosong Ma*  
*Oak Ridge National Laboratories - UT-Battelle LLC*  
 \$31,846  
 02/15/2007- 09/30/2007

Dr. Xiaosong Ma and her students will attack the problem of transparent data recovery to improve the reliability of large parallel file systems. With this proposed technique, job input data will be automatically staged into a supercomputer, while a modified system to perform just-in-time patching to make sure the staged data are available when the corresponding job is scheduled.

### **Joint Faculty Appointment**

*Xiaosong Ma*  
*UT-Battelle, LLC*  
 \$253,484  
 09/21/2003- 08/15/2007

Xiaosong Ma's joint work with NCSU and Oak Ridge National Laboratories (ORNL) will bridge the gap between the two organizations in a practical manner to cooperatively research parallel I/O in conjunction with the Genomes to Life (GTL) and Scientific Data management projects within the Computer Science and Mathematics Division at ORNL.

### **Collaborative Research: Application-Adaptive I/O Stack For Data-Intensive Scientific Computing**

*Xiaosong Ma; Vincent Freeh; John Blondin*  
*National Science Foundation*  
 \$266,002  
 09/15/2006- 08/31/2009

In this proposal, we address the I/O stack performance problem with adaptive optimizations at multiple layers of the HEC I/O stack (from high-level scientific data libraries to secondary storage devices and archiving systems), and propose effective communication schemes to integrate such optimizations across layers. Our proposed PATIO (Parallel Adaptive I/O) framework will coordinate storage resources ranging from processors to tape archiving systems.

### **Collaborative Research: Reusable, Observation-Based Performance Prediction Across Platforms**

*Xiaosong Ma; Frank Mueller*  
*National Science Foundation*  
 \$76,566  
 08/ 1/2004- 07/31/2006

This project investigates observation-based execution time estimation for resource planning and usage estimation in the grid environment. The proposed approaches will collect/manage/utilize application characteristics and performance results, and transfer such information across applications and platforms. Thus, performance data from one application's executions on one platform helps predict the performance of another application on another platform. The expected outcome of this research is a meta-predictor, an efficient and sufficiently accurate cross-platform performance prediction tool that provides performance predictions as a service to grid users. These approaches will be validated on production platforms with applications representative for nationally relevant high-end applications.

### **CAREER: Exploiting Binary Rewriting to Analyze and Alleviate Memory Bottlenecks for Scientific Applications**

*Frank Mueller*  
*National Science Foundation*  
 \$400,000  
 06/ 1/2003- 05/31/2008

Today, high-performance clusters of shared-memory multi-processors (SMPs) are employed to cope with large data sets for scientific applications. On these SMPs, hybrid programming models combining message passing and shared memory are often less efficient than pure message passing although the former fits SMP architectures more closely. For more information on this project check Dr. Mueller's Web Page

### **MOLAR: Modular Linux and Adaptive Runtime Support for HEC OS/R Research**

*Frank Mueller*  
*US Department of Energy*  
 \$93,708  
 02/ 1/2005- 01/31/2008

This project addresses issues of adaptive, reliable, and efficient operating and runtime system solutions for ultra-scale high-end scientific computing with the following goals: (1) Create a modular and configurable Linux system based on the application / runtime requirements. (2) Build runtime systems that leverage the OS modularity and configurability to improve efficiency, reliability, scalability, ease-of-use. (3) Advance computer reliability, availability and serviceability management systems to work cooperatively. (4) Explore the use of advanced monitoring and adaptation to improve application performance and predictability of system interruptions. Our focus is on developing scalable algorithms for high-availability without single points of failure and without single points of control.

### **ITR: Collaborative Research: SPARTA: Static Parametric Timing Analysis to Support Dynamic Decisions in Embedded Systems**

*Frank Mueller*  
*National Science Foundation*  
 \$130,000  
 09/ 1/2003- 08/31/2007

Embedded systems with temporal constraints rely on timely scheduling and a prior knowledge of worst-case execution times. Static timing analysis derives safe bounds of WCETs but its applicability has been limited to hard real-time systems and small code snippets. This proposal addresses these limitations of timing analysis for embedded systems. It contributes a novel approach to program analysis through parametric techniques of static timing analysis and provides innovative methods for exploiting them.

### **Online Data Reconstruction for Supercomputers**

*Frank Mueller*  
*Oak Ridge National Laboratories*  
 \$15,000  
 01/ 1/2007- 06/30/2007

This work seeks to build online recovery mechanisms for transient supercomputer job data. With the proposed on-demand data reconstruction, staged input files that are unavailable due to I/O node failures in a parallel file system are transparently patched from source copies using the recovery metadata.

### **Collaborative Research: Effective Detection and Alleviation of Scalability Problems**

*Frank Mueller; Jerzy Bernholc*  
*National Science Foundation*  
 \$231,652  
 09/ 1/2004- 08/31/2008

The focus of this project is to develop tool support to provide the ability for scientific programmers to inquire about scalability problems and correlate this information back to source code. Furthermore, we believe that tools should be able to suggest and evaluate optimizing transformations to alleviate these problems. This would constitute a significant improvement over current performance analysis practice. The key intellectual merit is in providing an automatic framework for detecting scalability problems and correlating them back to source code. We will experiment with our framework on the ASCI codes, which is intended to stress high-performance clusters.

### **Virtual Simple Architecture (VISA): Exceeding the Complexity Limit in Safe Real-Time Systems**

*Frank Mueller; Eric Rotenberg*  
*National Science Foundation*  
 \$275,000  
 08/15/2003- 07/31/2007

While essential for real-time scheduling, deriving worst-case execution times (WCET) for contemporary processors is intractable. The Virtual Simple Architecture (VISA) framework shifts the burden of bounding the WCETs of tasks, in part, to hardware. A VISA is the pipeline timing specification of a hypothetical simple processor. WCET is derived for a task assuming the VISA. Tasks are executed speculatively on an unsafe complex processor. Yet, before deadlines becomes jeopardized, a simple mode is entered. Overall, VISA provides a general framework for safe operation on unsafe processors.

### **CAREER: Towards Trustworthy and Resilient Sensor Networks**

*Peng Ning*  
*National Science Foundation*  
 \$400,000  
 07/ 1/2005- 06/30/2010

Sensor networks are ideal candidates for a wide range of applications such as critical infrastructure protection. It is necessary to guarantee the trustworthiness and resilience of sensor networks as well as the sensing applications. The objective of this project is to develop practical techniques for building trustworthy and resilient sensor networks as well as instructional materials that facilitate the education of these techniques. The research activities are focused on practical broadcast authentication, trustworthy and resilient clock synchronization, and light-weight and collaborative intrusion detection in sensor networks, seeking effective integration of cryptographic techniques, application semantics, and other knowledge or constraints.

### **Cyber-TA: NCSU: Large-Scale Privacy-Preserving Collaborative Intrusion Analysis**

*Peng Ning*  
*SRI International*  
 \$80,107  
 07/ 1/2006- 07/14/2008

We will focus on one thrust of research in the Cyber-TA initiative. We will explore practical schemes for Internet-scale collaborative sharing of sensitive information security log content, while providing extensive guarantees for contributor anonymity. Cyber-TA will enable much greater content sharing of even the most sensitive system and security log content, allowing contributors to release “rich-content” (anonymized) alert information that can enable new directions in ultra-large-scale repository correlation.

### **Efficient and Resilient Key Management for Wireless Sensor Networks**

*Peng Ning*  
Syracuse University  
\$173,165  
05/1/2005- 04/30/2008

Security of sensor networks is a critical issue, especially when the sensor networks are deployed in hostile environments for mission critical applications. This project aims at developing efficient and resilient key management techniques for wireless sensor networks, including novel key pre-distribution techniques, effective use of knowledge extracted from practical sensor deployment models as well as application semantics, effective integration of public key and secret key, and specific techniques for key management in hybrid sensor networks consisting of a small number of resourceful nodes and a potentially large number of resource constrained, regular sensor nodes.

### **Collaborative Research: Trustworthy and Resilient Location Discovery in Wireless Sensor Networks**

*Peng Ning*  
National Science Foundation  
\$150,000  
10/1/2004- 09/30/2007

The objective of this project is to develop a comprehensive suite of techniques to prevent, detect, or survive malicious attacks against location discovery in sensor networks. The PIs will investigate key management schemes suitable for authenticating beacon messages, explore techniques to make existing location discovery schemes more resilient, seek beaconless location discovery that uses deployment knowledge instead of beacon nodes, and finally investigate methods to integrate the proposed techniques so that they can be combined cost-effectively for sensor network applications. This project will provide specific technical solutions that can be integrated with the sensor network techniques currently being developed.

### **ITR: Integrating Intrusion Detection with Intelligent Visualization and Interaction Strategies**

*Peng Ning; Christopher Healey; Robert St. Amant*  
National Science Foundation  
\$415,099  
08/15/2002- 08/31/2006

This project is motivated by current limitations of intrusion detection systems, which are generally unable to fully detect unknown attacks, or even unknown variations of known attacks, without generating a large number of false alarms. The focus of this project is to integrate intrusion detection with visualization techniques and human computer interaction strategies to address these limitations. Our system will include interactive intrusion detection algorithms that capitalize on human knowledge and judgment, novel visu-

alization and interaction techniques to monitor for potential attacks, and semi-automated tools for constructing and evaluating attack profiles to extend the capabilities of an intrusion detection system.

### **ARO Workshop on Security of Embedded Systems and Networks**

*Peng Ning; Frank Mueller*  
Army Research Office  
\$21,000  
09/15/2006- 09/14/2007

Embedded systems and networks are used heavily in critical defense applications. The integrity of embedded infrastructures, such as configuration and code, is of utmost importance. New techniques are needed that allow updates to the infrastructure of an embedded system without violating its integrity. This workshop intends to bring researchers that have expertise in a variety of techniques for ensuring the security and integrity of mission-critical embedded systems and networks.

### **WiSeNet: Wireless Sensor Network Testbed for Research and Education**

*Peng Ning; Injong Rhee*  
Army Research Office  
\$108,105  
05/1/2006- 04/30/2008

This proposal proposes to build a wireless heterogeneous sensor network test-bed consisting of over 200 sensor nodes with varying capabilities in terms of processing, energy efficiency and radio transmission capacities. The proposed test-bed provides realistic large-scale wireless sensor network environments for evaluating and validating the ideas, protocols and systems conceived from various other activities. The data and experience gained from operating and managing a real network environment will also provide practical insights for students and researchers on the operation of large-scale heterogeneous sensor networks which help identify new security and performance problems and develop their practical solutions.

### **Positioning and Reliable Data Transmission of Sensor Networks**

*Peng Ning; Wesley Snyder*  
US Army  
\$199,823  
08/1/2004- 07/31/2007

Reliable and sufficient sensor coverage is an important requirement for a successful sensor network deployment. The goal of the project is to study and develop optimal positioning algorithms for sensor network deployment that provide surveillance and monitoring of assets or facilities. This project considers two scenarios: 1) Assuming we would deploy sensors for asset protection, an optimal sensor positioning and deployment algorithm is needed. 2) If sensors are deployed randomly over a geographical region to protect certain asset, what will be the best scheduling plan to turn on some of the deploying sensors such that sufficient surveillance can be provided.

## IP Triple and Quadruple Play Services: Modeling and Design

Harry Perros; Yannis Viniotis  
CACC  
\$40,000  
07/ 1/2006- 06/30/2007

The award will fund research activities aiming to make significant contributions to the capacity planning and automation for monitoring tools by use of modeling, simulation, testbed emulation and on line optimization. Specific goals include the study of models, response surfaces and advanced simulation methods, and, the creation of an automated paradigm for on-line optimization for capacity tuning.

## CT-ER: Metamorphic Worm Detection

Douglas Reeves  
National Science Foundation  
\$137,057  
08/15/2006- 07/31/2008

Internet Worms are software that propagate from computer to computer across the network, without intervention by or knowledge of users, for the purpose of compromising the defenses of those machines against unauthorized access or use. Worms have the property that they can spread very quickly to the vulnerable population of hosts, sometimes in only seconds, to achieve worldwide penetration. This speed allows them to bypass conventional methods of positive identification and human response.

## Tracing Attacks Through Non-Cooperative Networks and Stepping Stones with Timing-Based Watermarking

Douglas Reeves; Peng Ning  
US Department of Interior  
\$1,179,321  
09/29/2003- 02/28/2007

Increasingly the nation's infrastructure is connected by the Internet for computing, communication, monitoring, and control. Adversaries(hackers, criminals, terrorists, etc.)can and do exploit this connectivity to attack networked computers and devices. In order to defend against such attacks, and prosecute the adversaries, it is necessary to be able to identify the source of the attack. Tracing an attack back through the Internet to its source is the goal of this research project. As part of this project, tools for watermarking flows and performing timing correlation in real-time will be developed.

## NeTS-NOSS: Exploring the Design Space of Sensor Networks Using Route-Aware MAC Protocols

Injong Rhee; Robert Fornaro  
National Science Foundation  
\$584,999  
01/ 1/2005- 12/31/2007

As applications for wireless sensor networks are extremely diverse, sensor network designers will benefit immensely from (sensor) network protocols that can provide a wide spectrum of design choices, especially for very low energy budget applications. In this proposal, the PIs plan to develop a suite of new MAC protocols for sensor network applications based on a new approach, called Route-aware Media Access Control (RASMACH), that can greatly diversify design choices for application designers. A comprehensive

evaluation of the developed protocols and their performance models is planned that involves design and implementation of a wildlife tracking system.

## NeTS-NR: Traffic Quantization: A Formal Framework for Quality of Service (QoS) and Scalability in Packet-Switched Networks

George Rouskas  
National Science Foundation  
\$357,314  
09/ 1/2004- 08/31/2008

Traffic quantization is a new approach to supporting per-flow functionality in packet-switched networks in an efficient and scalable manner. We propose the concept of tiered service to alleviate the complexity associated with supporting per-flow QoS: a quantized network offers a small set of service tiers, and each flow is mapped to the tier that guarantees its QoS. Research will consist of four components: develop novel quantized implementations of weighted fair queueing (WFQ); develop Linux implementations of quantized WFQ to validate the theoretical results; extend the quantization approach to multiple traffic parameters; and investigate efficient constraint-based routing algorithms for quantized traffic.

## Collaborative Research: NeTS-FIND: The SILO Architecture For Services Integration, Control, and Optimization For the Future Internet

George Rouskas; Rudra Dutta  
National Science Foundation  
\$220,000  
09/15/2006- 08/31/2008

The objective of this project is to formulate a formal framework for a non-layered internetworking architecture in which complex protocols are composed from elemental functional blocks in a configurable manner, and to demonstrate its potential by developing proof-of-concept prototypes. We propose a new internetworking architecture that represents a significant departure from current philosophy. The proposed architecture is flexible and extensible so as to foster innovation and accommodate change, it supports network convergence, it allows for the integration of security features at any point in the networking stack, and it is positioned to take advantage of hardware-based performance-enhancing techniques.

## A Formal Approach to Traffic Grooming in Optical Networks with General Topologies

George Rouskas; Carla Savage; Rudra Dutta  
National Science Foundation  
\$404,968  
09/ 1/2003- 08/31/2007

We address the problem of grooming traffic into lightpaths for transport over general topology optical networks so as to minimize the network cost. We will first study the traffic grooming problem in a number of elemental topologies such as rings, stars, and trees. We will consequently develop hierarchical approaches to tackle the problem in general topologies by decomposing it into smaller subproblems involving elemental topologies. The end-result of this project will be a suite of traffic grooming algorithms with formally verified properties that can be flexibly and efficiently applied within a variety of optical network and cost models.

## Enumeration and Structure in Families of Partitions, Compositions, and Combinations

*Carla Savage*  
National Science Foundation  
\$183,287  
07/15/2003- 06/30/2007

The proposed research is an investigation of fundamental questions involving the structure of combinatorial families and relationships between families with intrinsically different characterizations. The focus is on families of integer partitions, compositions, and combinations. The topics under investigation include new work on partitions and compositions defined by linear inequalities; new tools for investigating classical questions about generalizations of the Rogers-Ramanujan identities; and symmetric chain decompositions with geometric applications.

## NeTS-NBD: Measurement-Based Mobility Modeling for MANETs

*Mihail Sichitiu (ECE); Injong Rhee*  
National Science Foundation  
\$484,827  
08/15/2006- 07/31/2009

Mobile ad-hoc networks (MANETs) have been the focus of significant research activity in the past decade. Thousands of algorithms and protocols for MANETs have been proposed, evaluated and compared. One of the defining characteristics of MANETs is their mobility. We propose to develop and evaluate a hybrid mobility model that is relatively easy to generate and, at the same time, produces realistic mobility traces, that in turn, result in meaningful simulation results for MANET simulations. The proposed model has the desirable characteristics that it is customizable to match any scenario, while allowing the users to vary key parameters.

## Agent-Based Conceptual Model and Policy Architecture for Virtual Organizations

*Munindar Singh*  
CACC  
\$40,000  
07/ 1/2006- 08/15/2007

Virtual organizations (VOs) are organizations of entities such as people, institutions, businesses, and their computational resources that collaborate to address collective and individual goals. VOs are grounded in the business processes of their members; their behaviors can have financial and legal import. The objective of this project is to address two major, related challenges: (1) how to ensure that the agents interact correctly within and across VOs under different circumstances, and (2) how to specify agents and VOs in a perspicuous policy-based manner that engenders confidence in the functioning of the VOs involved.

## ITR:Computational Principles of Trust

*Munindar Singh*  
National Science Foundation  
\$573,473  
09/ 1/2000- 06/30/2007

Successful interaction relies heavily upon trust. This applies equally to electronic commerce and virtual social communities. However, figuring out who to trust and to what extent is extremely difficult in open networked information environments. Trust is a complex concept and involves aspects of

competence and good nature (of the trusted party) and the risk tolerance and urgency (of the trusting party). This project studies distributed, scalable computational approaches for trust management, especially with regard to aggregate phenomena such as the emergence of subcommunities, pivots (which link different subcommunities), and the sensitivity of a community to invasion by nontrustworthy players.

## Principles of Commitment Protocols

*Munindar Singh*  
National Science Foundation  
\$345,000  
05/15/2002- 04/30/2007

Business protocols structure and streamline interactions among autonomous business partners. Traditional representations of protocols specify legal sequences of actions but not their meaning. Thus they cannot adequately support flexible interactions, e.g., to handle exceptions and exploit opportunities. This project is developing a declarative model of protocols that gives meaning to, and reasons about, states and actions based on the participants' commitments. This approach improves flexibility while maintaining rigor. This project is studying practical protocols from real-life domains such as transactions among financial institutions and other varieties of electronic business.

## Toward Cognitive Habile Agents

*Robert St. Amant*  
National Science Foundation  
\$375,266  
01/ 1/2006- 12/31/2008

Tool use is an agent's manipulation of objects in the environment to transform the interaction between the environment and the agent's sensors or actuators such that its goals are more efficiently achieved. We propose four core capabilities for a habile agent: the ability to generalize existing effectiveness to those provided by a tool under the agent's control; the ability to perform detailed internal simulations based on hypothetical application of tool-using abilities; the use of symmetry in recognizing opportunities for tool use; and the use of a general image-schematic representation to control tool-using behavior.

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

*Robert St. Amant; David Kaber; Mo-Yuen Chow*  
National Science Foundation  
\$786,000  
10/ 1/2004- 09/30/2007

The breakthrough information technology that we will develop through this ITR project is an intelligent/adaptive, human-machine interface to support the new role of screening process supervisors in safe and effective, distributed control of high time stress and high risk, automated chemical and toxicity testing. The development of this technology will be based on cognitive modeling of supervisory controller behaviors during actual chemical screening processes and model predictions of operator performance with different interactive information display design alternatives during the (model) design phase and during chemical process run-time.

## Structured Methods to Evaluate the Performance of Distributed Software

William Stewart  
University of California - Riverside  
\$120,738  
02/ 5/2004- 08/31/2006

Collaborative research effort aimed at removing the computational barriers to widespread adoption of Markov chain modeling technology, with its application to performance modeling of concurrent software. We adopt a compositional modeling formalism, in which the underlying Markov chain is kept as a sum of Kronecker products of matrices of small dimension. Goals include (1) Explore relationship between high-level formalisms suitable for modeling concurrent software and their underlying Kronecker structure, (2) Develop efficient solution methods for asynchronous interactions and block-based Kronecker descriptions, and study their complexity, (3) Explore how to combine savings due to lumping with that due to implicit representations.

## Scientific Data Management Center for Enabling Technologies

Mladen Vouk  
U.S. Department of Energy  
\$885,000  
11/15/2006- 11/14/2011

With the increasing volume and complexity of data produced by ultra-scale simulations and high-throughput experiments, understanding the science is largely hampered by the lack of comprehensive, end-to-end data management solutions ranging from initial data acquisition to final analysis and visualization. The SciDAC-1 Scientific Data Management (SDM) Center succeeded in bringing an initial set of advanced data management technologies to DOE application scientists in astrophysics, climate, fusion, and biology. Building on our early successes, we will improve the SDM framework to address the needs of ultra-scale science.

## Center for Scientific Data Management-Agent Technology Enabling Communication Among Tools and Data

Mladen Vouk  
U.S. Department of Energy  
\$906,987  
08/15/2001- 08/14/2007

Scientific Data Management Center is a SciDAC funded center with a goal to establish an Enabling Technology Center that will provide a coordinated framework for the unification, development, deployment, and reuse of scientific data management software, including scientific workflow technologies, specifically through SDM's Scientific Process Automation (SPA) focus area. The goal of this technology is to allow for easy and accurate interactions and flows among distributed computational, storage and application resources used in scientific discovery.

## Women and Information Technology: A Comparative Study of Young Women from Middle Grades through High School and into College

Mladen Vouk; Sarah Berenson; Joan Michael  
National Science Foundation  
\$500,027  
08/15/2002- 07/31/2006

This project is a seven-year longitudinal research study of young women who were identified as talented in mathematics in middle school. The purpose of this research is to address the current low participation of young women in IT careers. The project will develop and test a model of the factors associated with young women's decisions to persist in advanced mathematics and computer science courses so as to prepare themselves for, and decide to make information technology [IT] their career. IT careers are defined in this proposal as those requiring an electrical engineering, computer science, or computer engineering degree.

## Markers of STEM Success (MOSS): An Eleven-Year Longitudinal Study of High Achieving Young Women's Interests, Experiences, and Preparation for STEM Careers

Mladen Vouk (Co-PI); Sarah Berenson (PI); Joan Michael; Roger Woodard; Susan Bracken  
National Science Foundation  
\$511,512  
10/ 1/2006- 09/30/2009

Over the past seven years, we have collected data on 250 high achieving young women, ages 11-20 for an intervention project and an ITWF project. High achieving is defined as those girls selected/electing to take Algebra I in middle grades, putting them on track to take calculus in high school. The proposed research provides an opportunity to extend and redirect the current database for a new study. By 2009 we expect to have 100 longitudinal records to inform post-undergraduate analysis, 200 longitudinal records to inform the undergraduate analysis, and 300 longitudinal records to inform the high school analysis.

## CAREER: Managing Complexity: Fidelity Control For Optimal Usability in 3D Graphics Systems

Benjamin Watson  
National Science Foundation  
\$59,153  
08/ 1/2006- 01/31/2008

Drastic improvements in the speed of 3D graphics rendering hardware have been accompanied by even more drastic increases in the size of displayed models. Researchers trying to display these models have been forced to reduce display speed and interactivity or reduce the fidelity of the displayed views of their models. What are the best methods for preserving visual fidelity as model complexity is automatically reduced? What is the most effective way of striking the display speed vs. visual fidelity compromise? Our research will take examine these questions, resulting in prototype systems and investigations of their effectiveness with user studies.

## Hyper-Resolution Rendering and Display

Benjamin Watson  
National Science Foundation  
\$60,000  
09/ 1/2006- 08/31/2007

Bringing the rendering technology that created the game industry to personal and business imaging will require achieving interactive display at printer resolution. With such displays, documents might be read directly off desktops, and analysts might spread all of a massive dataset across walls, and then lean forward to see the finest data detail. For such display, verbose pixel-by-pixel representations will not scale.

This research will achieve a higher-level representation built on two fundamental technologies: adaptive frameless rendering, which exploits both spatial and temporal coherence in imagery; and change-based rendering, builds imagery using higher-level primitives such as gradients and edges.

### **REU Site:Design Tech: Sparking Research in Interactive Visual Design**

*Benjamin Watson; Christopher Healey; R. Michael Young; Patrick Fitzgerald*  
National Science Foundation  
\$268,763  
03/1/2006- 02/28/2009

Participants of this interactive designed technology hothouse for undergraduate researchers and designers will work with computer science and design faculty and industry on projects spanning artificial intelligence, graphics, visualization as well as visual and interactive design. Sample projects include: advanced AI for interactive narratives and games; including camera control, and story planning and level design; automated tours through virtual and visualized environments; visualizing streaming news feeds using swarming sprites, and interactive, ambient display walls; PDA-based art installations, and real-world navigation tools. Students will gain the cross-disciplinary and cross-cultural teamwork and communications skills so important in designed technology research and industry.

### **ITR: Collaborative Research: Procedural Modeling of Urban Activity and Form**

*Ben Watson*  
Northwestern University  
\$50,000  
5/16/2007-05/15/2008

This subcontract supports work on an award authored by this investigator at another institution. That institution has made a significant change in the research direction of the award, and significantly reduced this investigator's role. The original goal of this award was automating the production of urban settings for digital entertainment and simulation. Since this research direction is no longer the award's priority, this subcontract will only support the development of techniques for high-level, more intuitive control of land use simulation and generation of highly differentiated (not self-similar) buildings.

### **CAREER: The Test-Driven Development of Secure and Reliable Software Applications**

*Laurie Williams*  
National Science Foundation  
\$405,889  
04/1/2004- 03/31/2009

Our nation's critical infrastructure demands that our current and future IT professionals have the knowledge, tools, and techniques to produce reliable and trustworthy software. The objective of this research is to extend, validate, and disseminate a software development practice to aid in the prevention of computer-related disasters. The practice is based upon test-driven development (TDD), a software development technique with tight verification and validation feedback loops. The proposed work extends the TDD practice and provides a supportive open-source tool for explicitly situating security and reliability as primary attributes considered in these tight feedback loops.

### **Hot Spot Identification and Test-Driven Development**

*Laurie Williams*  
Nortel Networks  
\$45,982  
08/16/2006- 12/31/2007

The grant involves the collaboration on two projects for improving software quality at Nortel. In one project, a means for identifying "hot spots" in code will be developed and validated based upon historical data (static complexity, code churn, defect history for the module and potentially code coverage data). In the second project, we will examine the efficacy the test test-driven development practice for improving software quality.

### **In Regression Testing Without Code**

*Laurie Williams*  
ABB, Inc.  
\$115,067  
01/10/2005- 08/15/2007

The goals of this research project are to come up with a validated method of regression test selection for software components for which source code is not available to software development organizations incorporating the components into their products. This includes all third party components that are used "off the shelf", as well as internal components where the source code is not readily available at the time of the regression test selection. This project will involve an understanding of component changes, regression testing, and release documentation.

### **Supporting Evidence-Based Software Engineering**

*Laurie Williams*  
CACC  
\$40,000  
07/1/2005- 12/31/2006

This project will apply research framework to provide industry-based research results of agile software development, software process transition, process customization, reliability and quality prediction, requirements prioritization, pair programming vs. inspection, and distributed software development. Research will also adapt an Eclipse plug-in to enable detailed causal analysis of field failures and to empirically examine the defect-removal efficacy of V&V techniques, such as inspections and unit testing, to build up evidence about these practices.

### **Academy for Software Engineering Educators & Trainers**

*Laurie Williams*  
National Science Foundation  
\$10,000  
09/1/2005- 08/31/2006

A special one-day Academy for Software Engineering Educators & Trainers will be offered on the day prior to the start of The Conference on Software Engineering Education and Training (CSEE&T). The purpose of the Academy is to provide an opportunity for software engineering educators and trainers to learn from master instructors in a highly dynamic, hands-on, interactive environment. The Academy will provide a learning opportunity to PhD students who will

be entering academic careers in the near term, new faculty members, and mid-career faculty members who are beginning to teach software engineering course(s).

### Extending Extreme Programming

*Laurie Williams; Mladen Vouk*  
CACC-NSA  
\$52,800  
09/15/2003- 08/31/2007

The Extreme Programming methodology was designed for relatively small teams of collocated programmers working on non-critical, small-medium, object-oriented projects. Little empirical assessment has been done on the methodology, though a sizable amount of anecdotal evidence supports the use of the methodology under these conditions. We are proposing collaborative research with the NSA and Galois in which we will empirically assess the efficacy of Extreme Programming practices in a high-confidence, secure, functional programming project. Additionally, we will work on integrating formal methods, reliability, and security testing into the set of Extreme Programming practices.

### BPC-A: The STARS Alliance: A Southeastern Partnership for Diverse Participation in Computing

*Laurie Williams; Mladen Vouk; Sarah Berenson*  
UNC-Charlotte (NSF)  
\$285,698  
03/ 1/2006- 02/28/2009

Our goal is to broaden participation in computing by developing a Southeastern partnership to implement, institutionalize and disseminate effective practices for recruiting, bridging, retaining and graduating women, under-represented minorities and persons with disabilities into computing disciplines. The Alliance will implement a comprehensive set of activities to provide high-quality opportunities to a large audience of post secondary students, including a Student Leadership Corps, pair programming, a Web portal, and Marketing and Careers Campaign, summer REUS, and a STARS Celebration Conference and Exchange.

### Collaboration through Agile Software Development Practices: A Means for Improvement in Quality and Retention of IT Workers

*Laurie Williams; Mladen Vouk; Jason Osborne ; Winsler Alexander; and Sarah Berenson*  
National Science Foundation  
\$812,587  
06/15/2003- 06/30/2008

This ITWF award to NCSU, NCA&T, and Meredith College will support a three-year study of the collaborative aspects of agile software development methodologies. We believe the collaboration and the social component inherent in these methodologies is appealing to people whose learning and training models are socially oriented, such as some minority groups, women, and men. The project's objective is to perform extensive, longitudinal experimentation in advanced undergraduate software engineering college classes at the three institutions to examine student success and retention in the educational and training pipeline when the classes utilize an agile software development model.

### On Expediting Software Engineer AWAREness of Anomalous Code

*Laurie Williams; Tao Xie*  
CACC  
\$40,000  
07/ 1/2006- 12/31/2007

The objective of our research project is to continue CACC-supported development of the Automated Warning Application for Reliability Engineering (AWARE) tool. AWARE will continuously provide the programmer with prioritized and trained information on faults revealed via compilation, static analysis, and dynamic testing. AWARE will provide the programmer with better diagnosis information, and ultimately, we believe will improve programmer productivity and product quality. We will assess the efficacy of providing the programmer with this stream of information by working with CACC members.

### Continuous Checking of Static Analysis and Automated Unit Tests for Java Programs

*Laurie Williams; Jun Xu*  
CACC  
\$40,000  
07/ 1/2005- 12/31/2006

Researchers propose to develop "Continuous Checking" tool that would use the computer's available CPU cycles and continuously provide feedback to software developers on compilation, static analysis, and testing defects. The user can train the tool to reduce false positives reported from static analysis. Researchers will implement Continuous Checking as a plug-in for the open source Eclipse development environment and will validate the effectiveness of the tool via empirical studies of open source programs and by working closely with CACC members.

### CAREER: Automated Synthesis of Bidding Strategies for Trading Agents

*Peter Wurman*  
National Science Foundation  
\$300,010  
08/ 1/2001- 07/31/2007

This project will investigate approaches to building a strategy generation engine as a component of a flexible trading agent that converts user preferences, auction rules, and a model of the other agents into a decisionable format. The first strategy generation engine will produce game-theoretic representations of the decision problem. For small problems, the game can be solved and an equilibrium bidding strategy selected. However, for intractable larger problems, alternate strategy generation engines will be constructed which use other decision technologies. Ideally, the agent will be able to make this decision by assessing the structure of the problem instance.

### Integrating Static and Dynamic Analysis to Improve Automatic Unit-Test Generation

*Tao Xie; Jun Xu*  
CACC  
\$40,000  
07/ 1/2006- 06/30/2007

Unit testing is an important activity in assuring high quality of software programs. Although there exist object-oriented test-generation tools for Java programs, two important issues pose barriers for their wide adoption. We propose to

integrate static and dynamic analysis to improve automatic test generation by considering usage contexts of the unit in the system. We use static and dynamic analysis to collect usage context information for the unit under test, and then use context information to guide test generation. Developers can use the resulting improved Java test-generation tools to augment their manually written tests to better assure high software quality.

### Creating Effective Task Descriptions from Action Plans

*R. Michael Young*  
National Science Foundation  
\$315,000  
08/15/2004- 07/31/2008

Artificial intelligence planning systems are being put to use to determine the activities of a wide range of intelligent interactive systems. The ability for these kinds of systems to explain their plans to human users is essential for the systems' successful adoption and use. We are investigating the generation of natural language descriptions of plan data structures. This work will develop a cognitive and computational model of task context and its role in the generation of action descriptions.

### CAREER: Plan-Based Integration of Control and Coherence in Intelligent Exploratory Environments

*R. Michael Young*  
National Science Foundation  
\$480,695  
03/15/2001- 08/31/2007

The use of virtual environments has shown success in applications ranging from education to entertainment. One limitation of these systems is that users' activities within them are over- or under-constrained. In this project, I will develop new models for the structure of user interactions within virtual worlds. Because a user's understanding of the activity in a world provides scaffolding for her own exploration, presenting the user with an environment in which action can be readily understood encourages the user to acquire and employ knowledge of the environment. This activity leads to an increased understanding of the world the environment models.

### HI-FIVES: Using Web-Based Gaming to Improve Student Comprehension of Information Technology in Science

*R. Michael Young (Co-PI); Leonard Annetta; Deborah Mangum ; Thomas Miller*  
National Science Foundation  
\$1,197,270  
09/ 1/2005- 08/31/2008

Researchers in science education, computer science, distance education, and the NC Department of Public Instruction are partnering with the Kenan Fellows Program to harness the untapped potential of inexpensive, online multi-user competitive simulation software in improving the science achievement and IT skills of NC's grade 6-12 students. Over three years, teacher participants will learn how to use this technology to increase student science achievement and motivation to enter IT-related science careers. Intellectual merits of the project entail rigorous assessment and evaluation of how these environments most effectively improve the IT skills and science content mastery of students.

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