A MULTIAGENT AND SERVICE-BASED COMPUTING SIMULATION TESTBED:

ENABLING REPEATABLE EXPERIMENTATION OF NETWORK-CENTRIC SYSTEMS

ABSTRACT

Submitted to the Office of Naval Research

Funding is requested to acquire key instrumentation to create a Multiagent and Service-Based Computing Simulation Testbed (MSCST) at Drexel University. The primary purpose of the MSCST will be to support existing Department of Defense (ONR, US Army, and DARPA) sponsored projects in engineering design, wireless networks, telecommunications, software engineering, robotics, scientific computation, and cognitive science. The Drexel MSCST will consist of:

- One high performance computing cluster; and
- Four workstations.

The MSCST will provide exciting capabilities to Drexel University—creating a shared center for high-performance computing, and human-computer interaction. Researchers will use these tools to enhance existing DoD sponsored research by adding capabilities to simulate massive networks up to two orders of magnitude larger than current systems.

The MSCST will greatly enhance the research capabilities in several Department of Defense projects at Drexel and will have a large research impact on Drexel University as a whole. Further, this instrumentation will create significant new research capabilities which will allow for the pursuit of research in service to other DoD programs and research problems. It will be housed in a dedicated facility at the Applied Communications and Information Networking (ACIN) Center. The ACIN Center is operated by Drexel University under a contract with the US Army's Electronics Research, Development and Engineering Center (CERDEC) with the goal of enabling rapid deployment of technologies to the benefit of Warfighters and other First Responders.

BUDGET

ITEM	DESCRIPTION	PHOTO	COST
Hyperform iServ Cluster	Rack mounted cluster with 16 computing nodes, each with two quad-core Intel Xeon processors and 24GB of RAM for a total of 128 processors and 384GB of RAM. One additional node to act as a head and another to act as an InfiniBand storage node with 16TB of drive space. Price includes UPS power source, one InfiniBand switch, a KVM switch, and rack.		$117449
	Source: Silicon Mechanics TEL: 1.866.352.1173 WEB: `www.siliconmechanics.com` **Sales Representative**: Michael Bueche **Quotation**: #146564		
Workstations	Four (4) Dell Precision T3400 nSeries 525W Workstations with flat panel LCD monitors for interacting with the cluster. Each workstation has a 4 cores, 8GB of RAM, and 500GB of storage. The workstations will be used to develop, debug, monitor, demonstrate, and visualize simulations performed on the cluster.		$19046
	Source: Dell Inc. TEL: 1.800.388.8239 WEB: `premier.dell.com` **Sales Representative**: N/A **Quotation**: #1006961135858		
Mobile Workstations	Two (2) Dell Precision M6300 mobile workstations, each with 2 cores, 4GB of RAM, and 320GB of storage. Each mobile workstation will also have an LCD, keyboard and mouse such that it can be docked and used as extra workstations for interacting with the cluster. The primary use of the mobile workstations will be for off-site integration visits with our sponsors.		$7777
	Source: Dell Inc. TEL: 1.800.388.8239 WEB: `premier.dell.com` **Sales Representative**: N/A **Quotation**: #1006961135858		
Shipping/Freight	(Estimated)		$700

Total Actual Cost (including academic discounts): $144972

Academic prices represent an approximate 4–10% discount to list prices.

A Multiagent and Service-Based Computing Simulation Testbed:

Enabling Repeatable Experimentation of Network-Centric Systems

Submitted in Reference to Fiscal Year 2009 AFOSR-BAA-2008-5 (ONR)

Instrumentation Support for DoD Sponsored Projects:
Applied Communications and Information Networking (#DAAB07-01-9-L504)
Group Communications to the Tactical Edge (NRL/OSD)
Tactical Service Provider (OSD)
Tactical Information Technologies for Assured NetOperations (CERDEC)

William C. Regli

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The following sections, in turn, directly address the questions posed in "AFOSR BAA 2008-5: Defense University Research Instrumentation Program" for fiscal year 2009.

1 Supporting Information

Funding is requested to acquire key instrumentation to create a Multiagent and Network Simulation Testbed (MSCST) at Drexel University. The primary purpose of the MSCST will be to support existing Department of Defense (ONR, US Army, and DARPA) sponsored projects in engineering design, wireless networks, telecommunications, software engineering, robotics, scientific computation, and cognitive science. The Drexel MSCST will consist of:

In particular, the Drexel MSCST will consist of:

- One high performance computing cluster;
- four desktop workstations; and
- two mobile workstations.

The MSCST will provide exciting capabilities to Drexel University—creating a shared center for high-performance computing, and human-computer interaction. Researchers will use these tools to enhance existing DoD sponsored research by adding capabilities to simulate massive networks up to two orders of magnitude larger than current systems.

The MSCST will greatly enhance the research capabilities in several Department of Defense projects at Drexel and will have a large research impact on Drexel University as a whole. Further, this instrumentation will create significant new research capabilities which will allow for the pursuit of research in service to other DoD programs and research problems. It will be housed in a dedicated facility at the Applied Communications and Information

Networking (ACIN) Center. The ACIN Center is operated by Drexel University under a contract with the US Army's Electronics Research, Development and Engineering Center (CERDEC) with the goal of enabling rapid deployment of technologies to the benefit of Warfighters and other First Responders. ACIN current customers include the US Army CERDEC, ARL, NRL, AFRL, DARPA, NSA DTO, DISA, NIJ/DoJ, and the DoE/NNSA. ACIN currently has projects supporting two Joint Capability Technology Demonstrations, one Army Technology Objective, and two DARPA offices.

1.1 How Will the Proposed Instrumentation Enhance the Quality of Research and Research-Related Education Currently Funded by DoD?

This DURIP will support several major DoD-sponsored projects at Drexel University, each of which involves the modeling and simulation of—and creation of algorithms for—distributed mulatiagent systems running on wireless networks. These projects all fall under the umbrella of the Applied Communications and Information Networking (ACIN) Project[1], on which the PI is a co-PI. ACIN is a collaboration between the Department of Defense, Drexel University and industrial partners under DoD contact #DAAB07-01-9-L504. The goal of ACIN is to develop, build and evaluate technologies for the generation-after-next networked battlespace. Project ACIN supports an annual budget on the order of $4M in Drexel University research[2]. The two key activities of this effort related to DURIP are in the areas of:

- **Ad-hoc wireless networks for mobile telecommunications and battlespace applications:**
- **Secure, distributed and survivable multi-agent systems for battlespace applications:**

Specific results of this research project can be found in the following publications [14, 12, 8, 9, 6, 7, 13, 5, 2, 15, 4, 10, 16, 11, 3, 1].

Three ACIN projects would particularly benefit from the proposed DURIP instrumentation; they are introduced in the next paragraphs, followed by a discussion of how they would benefit.

Drexel is in an ongoing collaboration with Joseph Macker of the Naval Research Laboratory in support of group communication to the tactical edge (funded by Cynthia Dion-Schwartz of the OSD). This project is intended to forward intelligent systems running atop tactical networks such that information can be efficiently exchanged between, for example, battleships and air vehicles.

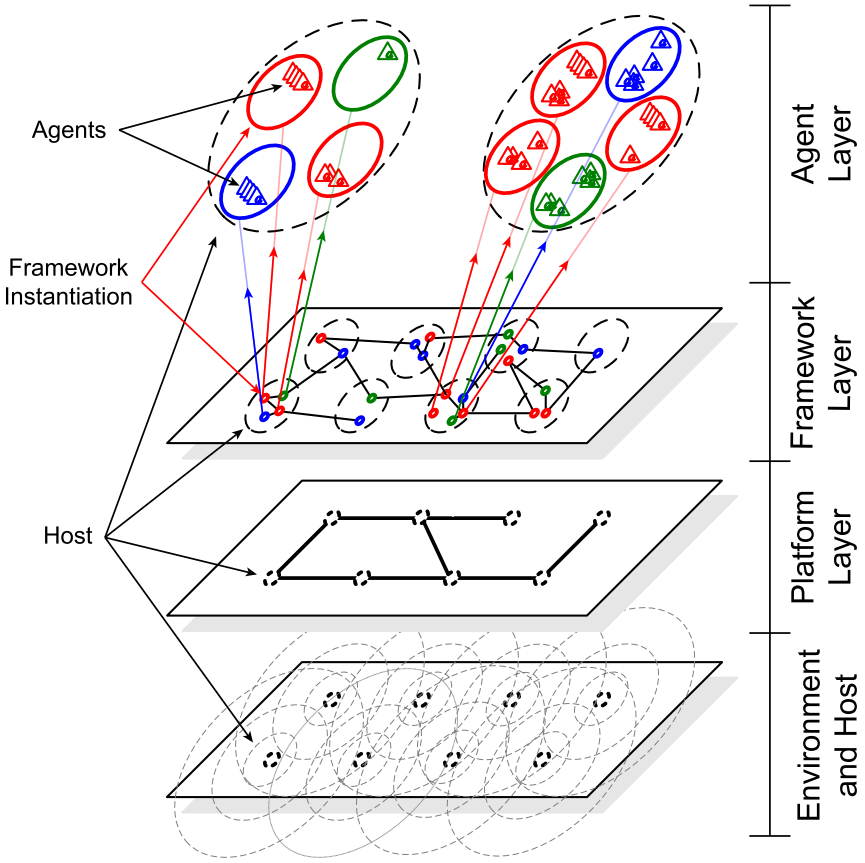
In a similar vain, Drexel is also working in support of the Tactical Service Provider (TSP) Joint Capability Technology Demonstration (JCTD), a project which addresses the issues of "first tactical mile" support to mobile troops. Drexel's specific role is in studying the effects of different hardware types and configurations on network connectivity in varied communications environments. Both the groupwise communication and TSP projects are to be finalized and deployed by the end of 2009.

Drexel is also working on the Tactical Information Technologies for Assured NetOperations (TITAN) program; an Army Technology Objective (ATO) executed out of the US Army CERDEC. The overall goal of this ATO is to demonstrate how emerging information technologies can significantly improve key areas of tactical operations, ultimately resulting in the transition of software developed under the ATO to existing battlefield systems. There are two areas for which Drexel is involved: (1) integration of all the battle command services, and (2) development of the Distributed Battle Command Tracking service (DBCT)/Agent Framework Benchmark. The TITAN project will be demonstrated at Fort Dix in the summer of 2009.

All three of the projects listed above are similar in that they require analysis and testing of complex systems in tactical environments. While testing such systems in the real world is often possible, it is almost always prohibitively expensive in terms of hardware and manpower. A single eight node mobile ad-hoc network experiment usually requires a dozen people for the better part of a day, resulting in a single data point. Drexel is one of the few institutions—academic or otherwise—that has access to a functioning mobile ad-hoc network testbed, so any data real-world produced will be hard, if not impossible, to be reproduced by a third party. Further complicating experimentation is that data must be collected from—and metrics applied to—each of the layers of a multiagent system, as depicted in Figure 1. Instrumenting live systems to collect the requisite data is far more complex (and error-prone) than performing the equivalent in simulation. What is needed is a testbed in which our models of the real world can be employed to simulate these same experiments in parallel.

[1] `http://www.projectacin.com/`

[2] These funds are principally for personnel, students and staff, at Drexel. Funds from ACIN cannot be used to purchase the requested DURIP equipment, but will be used in future years to support equipment administration, installation and maintenance costs.



LAYER	DATA	METRICS
Agent/Framework	Power Levels, Application Flows, Host Connectivity, *etc.*	Message Overhead, Longevity, Throughput, Coordination Messages, Completion %, System Logs, Application Performance
Platform	Coordination Messages, TCP/IP Messages, Packets, Frames, Re-Transmissions, MANET Behavior, Network Logs, Ethernet Sniffing, *etc.*	Convergence Time, Message Overhead, Coverage %, Latency, Scenario-Based, Completion %, Topology, Frame Counts, Message Sizes, Resilience
Environment	Changes in RF Over Time, Based on Scenarios, Within Physical Structures, *etc.*	Signal Strength at Relays and Coverage Test Points

Figure 1: Data that can be collected from the different layers of a multiagent system.

The PI and the entire Drexel team at ACIN have extensive experience both instrumenting and simulating live tactical networks. In 2003, Drexel was one of the first academic institutions to produce a functioning network testbed, called the Secure Wireless Agent Testbed [11]. The testbed has been key in several follow-on programs (including the DARPA ATO/SAPIENT and IXO/SPEYES programs) and was/is part of several major demonstration programs for the United States Army, NATO and the United States Department of Justice. A company, Drakontas LLP, is successfully commercializing the SWAT technologies in areas of homeland defense, port security and situation awareness for public protectors. Drexel was called upon to employ the SWAT to study mobile tactical networks in an experiment called "SINCE" conducted by US Army CERDEC. The SINCE experiment received the "Best Network-Centric Warfare Program from a Coalition Partner Award" from the Network-Centric Warfare Conference, and also the "International Collaboration Award" from the 25th Army Science Conference in 2006. Despite its success, however, such experiments take months of preparation and hundreds of man-hours of time to produce.

The PI and several others of the ACIN program have been involved in modeling and simulation of such networks. The ACIN team were the recipient of a $1.5M grant to produce the modeling and simulation environment for the COMPOSER ATO of the Warfighter's Information Network-Tactical (WIN-T). This included extensive network simulation on industry-standard systems like OPNET and NS; while these simulators were excellent at modeling the underlying network dynamics, it was very difficult (and computationally expensive) to additionally model the complex agent- and service-based systems that run atop the networks. This led to the creation of our own specialized simulators [15, 13]. Even so, current workstations on which simulations are performed are hard pressed to simulate just networks of more than two hundred nodes, let alone simulation of the complex systems that run atop the networks. It is anticipated that the proposed hardware testbed will be able to simulate systems at least two orders of magnitude larger. **The direct impact on the quality of the research in these projects will be to enable a vast increase in Drexel's distributed system modeling and simulation capabilities, thus increasing the statistical significance of our data and reducing the need to perform expensive—and often irreproducible—live experiments**.

2 Integration of Proposed Instrumentation with Existing Facilities

The proposed instrumentation requested consists of a high performance computing cluster for modeling and simulation of complex, networked, multiagent and service-based tactical systems. The integration plan is very straightforward.

1. Acquire hardware and furniture, prepare lab space;
2. Install and configure hardware, connect to the network, test.

The facility can be fully up-and-running within 3 weeks of delivery of the equipment. Once available, it is expected many users will flock to use these devices. The computers equipment will be installed by Drexel personnel. The proposed instrumentation will create a unique simulation facility at Drexel University. Presently, the university does not have this capability.

In 2008, ACIN has employed over 50 students and 14 faculty across three Colleges, with over an additional 10 research faculty and staff, all of whom are expected to help maintain and employ the proposed instrumentation.

Other Resources: The PIs of the ACIN program have access to expertise and input from numerous industrial and governmental collaborators. This includes: (1) access to individuals that have constructed and use similar systems outside of academia (*e.g.* NRL, US Army CERDEC, and BBN Technologies); (2) access to datasets and datamodels, both from the institutions/companies and their partners/customers; (3) access to informal and formal project input and guidance from industry/military experts; and (4) access to collaborative university-industry research opportunities for the graduate and undergraduate students on the project.

3 Special Information Regarding Installation and Support of the Instrumentation

ACIN and the Camden Waterfront Technology Center will provide new laboratory space to house the proposed instrumentation. In addition, the University will commit financial resources to ensure that the space will meet the system's power and cooling requirements. The ACIN project shall also furnish all requisite furniture for use by the students and scientists employing the facility.

4 Useful Lifespan of the Proposed Instrumentation

The expected lifespan of the acquired instrumentation is between five and ten years. While computing equipment is subject to incredible depreciation due to Moore's Law and economic forces, the cluster is expected to be able to simulate networks on the order of thousands nodes in real time which—given the rate at which interest in network size has increased over the past five years—is foreseen to be sufficient for at least five years of research. It should be noted that the requested funds are to purchase absolutely leading-edge hardware, and, in the probable event that the hardware prices of the specific models described should decline, it is likely that the new state-of-the-art at that point in time will be approximately the same cost.

5 Summary

The MSCST will provide exciting new capabilities to researchers and students throughout Drexel University. The MSCST will create a shared center with current generation tools for high-performance computing for modeling and simulation. Researchers will use these tools to enhance existing DoD sponsored research (#DAAB07-01-9-L504) by adding capabilities to simulate orders of magnitude larger networks and interrogate large software systems.

References

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[16] Evan A. Sultanik and William C. Regli. *Agents and Peer-to-Peer Computing*, chapter "Service Discovery on Dynamic Peer-to-Peer Networks Using Mobile Agents", pages 132–143. Number 3601 in Lecture Notes in Computer Science. Springer-Verlag, Berlin, July 2004.

A Biographical Sketch of William C. Regli

William Regli is a Professor of Computer Science at Drexel University with joint appointments in Mechanical Engineering and Electrical and Computer Engineering. He is also Executive Director of Drexel University's Applied Communications and Information Networking Program; Senior Scientific Adviser to the Department of Justice's Communications Technologies Center of Excellence; and co-founder of Drakontas, a technology company specializing in the development and validation of communications systems for first responders. Dr. Regli has interdisciplinary research interests and his contributions span several computer science and engineering fields (artificial intelligence, solid modeling and graphics, CAD/CAM integration, mechanical design, and wireless networks). His research has been sponsored by a wide variety of organizations (including US Army, DISA, NSF, ONR, NRL, AFOSR, ARO, DARPA, NIST, NIJ/DoJ, DoE, NNSA, SAIC, Boeing, Lockheed, AT&T, GE), supporting over 100 graduate and undergraduate students and producing four patent filings and over 150 technical publications. Regli's research awards include major grants under each of NSF's interdisciplinary research initiatives of the past decade: KDI, ITR and Cyber-Infrastructure programs. Nine of his undergraduates have been acknowledged by CRA. Regli is the recipient of many awards, including the NSF CAREER Award, an NRC Postdoc, NIST Special Service Award, the Drexel College of Engineering Research Award, CERDEC Director's Award; and co-recipient of the Army's 2006 International Collaboration and IDGA's Best NCW Program Award. He is a life member of AAAI and Sigma Xi and a Senior Member of IEEE and ACM. Contact him at `regli@drexel.edu`.

A.1 Research Highlights

Digital Engineering Archives.

Regli was the only academic member of the DoE/NNSA Nuclear Weapons Complex (NWC)-wide Model Archive Standards Team (MAST) during the 2001-2003 period. Contributed to offical documents of the National Nuclear Security Administration (NNSA) used to define preservation strategies for CAD-based engineering artifacts. The Library of Congress' Office of Strategic Initiatives supported subsequent research on CAD archiving under the National Digital Information Infrastructure Preservation Program (NDIIPP). Current results under IIS-0456001, "Digital Engineering Archives" include prototype systems for engineering preservation based on OAIS as well as a format registry for engineering datatypes.

Project ACIN (2001-).

Since August of 2001, Regli has been involved in the US Army Communications Electronics Research Development and Engineering Center (CERDEC) Applied Communications and Information Networking (ACIN) Program (DAAB07-01-9-L504 to Drexel University as Prime Contractor). Since August of 2003, he has served in the role of Associate Technical Director. In this capacity, Regli was responsible, along with Technical Director Moshe Kam, for the coordination the research activities of over 50 graduate and undergraduate students as well as 15 faculty across 5 academic departments. ACIN research programs consisted of over $3M of direct research funding to Drexel University during the 2003-2007 period, funding over 12 separate projects. Additionally, as part of these duties, Regli was involved in matters of document classification, public release, International Traffic in Arms Regulations (ITAR), as well as routine (monthly) briefings to CERDEC and other DoD Program Managers (PMs). Work executed under project ACIN has been transitioned to several PM and PEOs, as well as through transition efforts as part two major DARPA efforts (SAPIENT and SPEYES).

Secure Wireless Agent Testbed (a.k.a. SWAT) (2001-).

In 2001, Regli, along with colleague Moshe Kam, initiated a project under the ACIN Program to study information assurance techniques for handheld devices on wireless networks. The project produced multi-year research effort effort resulting in the design, development and deployment of the Secure Wireless Agent Testbed. The testbed has been key in several follow-on program (including the DARPA ATO/SAPIENT and IXO/SPEYES programs); and was/is part of several major demonstration programs for the United States Army, NATO and the United States Department of Justice. A company, Drakontas LLP, is successfully commercializing the SWAT technologies in areas of homeland defense, port security and situation awareness for public protectors.

Engineering Informatics (1997-).

Regli established several interdisciplinary initiatives at Drexel in the area of Engineering Informatics. The objective of these programs is to fuse computer science with the needs of engineerings, specifically data management,

CAD search, manufacturing planning and collaborative design. Regli was PI on over $4M of activities in this area, including the 1998 "KDI: Networked Engineering" project (part of the NSF's Knowledge and Distributed Intelligence Initiative, and one of 42 awards of 755 submissions); as well as the 2006 "CI-TEAM Implementation Project: Cyber-Infrastructure for Engineering Informatics Education", awarded by the NSF Office of Cyber-Infrastructure.

A.2 Appointments

09/2007-present Professor, Drexel University, Department of Computer Science; also Departments of Mechanical Engineering and Electrical and Computer Engineering (by courtesy)

09/2003-present Associate Technical Director, Applied Communications and Information Networking Program (Project ACIN), Drexel University & U.S. Army CERDEC

09/2001-08/2007 Associate Professor, Drexel University, Department of Computer Science, Department of Mechanical Engineering and Mechanics (by courtesy)

09/2003-present Associate Technical Director, Applied Communications and Information Networking Program (Project ACIN), Drexel University & U.S. Army CERDEC

10/2003-05/2005 Visiting Researcher, Lockheed Martin Advanced Technology Labs, Artificial Intelligence Lab, Cherry Hill, NJ

06/1999-09/1999 Visiting Research Fellow, AT&T Labs, Internet Platforms Division, San Jose, CA

07/1997-08/2001 Assistant Professor, Drexel University, Department of Math & Computer Science

01/1997-08/1997 Visiting Research Engineer, Carnegie Mellon University, Institute for Complex Engineered Systems (ICES), Carnegie Institute of Technology

05/1992-01/1997 National Research Council, Post-Doctoral Research Associate and Computer Scientist, National Institute of Standards and Technology

05/1989-12/1995 Research Assistant, University of Maryland at College Park, Department of Computer Science and Institute for Systems Research (ISR)

05/1987-05/1989 Research Assistant, Saint Joseph's University, Center for Machine Learning

A.3 Publications

Please consult the attached bibliography for a list of recent relevant publications.

A.4 Professional Preparation

Institution	Major	Degree, Year
University of Maryland, College Park	Computer Science	Ph.D., 1995
University of Maryland, College Park	Computer Science	M.S., 1994
Saint Joseph's University	Mathematics/Computer Science	B.S., 1989

A.5 Awards and Honors

2006	Int'l Collaboration Award (co-recipient)	US Army
2003	Research Achievement Award	Drexel University College of Engineering
1998	CAREER Award	National Science Foundation
1995	Post-Doctoral Fellowship	National Research Council
1995	Special Service Award	National Institute of Standards and Technology
1995	The George Harhalakis Outstanding Systems Engineering Graduate	The University of Maryland at College Park Institute for Systems Research