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**Naval Postgraduate School**
Monterey, California 93943-5138

# *SUMMARY OF RESEARCH 1998*

## Department of Computer Science

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Prepared for: Naval Postgraduate School
Monterey, CA 93943-5000

**NAVAL POSTGRADUATE SCHOOL**
**Monterey, California**

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13. ABSTRACT (Maximum 200 words.)

This report contains summaries of research projects in the Department of Computer Science. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, technical reports, and thesis abstracts.

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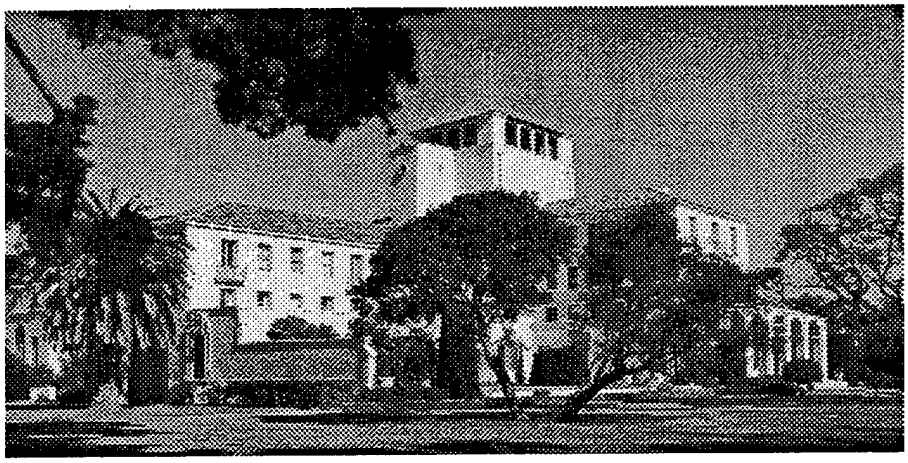
# DEPARTMENT OF COMPUTER SCIENCE

**Dan Boger**
**Acting Chair**

## THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to increase the combat effectiveness of U.S. and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges.



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## PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the School's eleven academic departments, seven interdisciplinary groups, and the School of Aviation Safety. This volume contains research summaries for the projects undertaken by faculty in the Department of Computer Science during 1998 Also included is an overview of the department, faculty listing, a compilation of publications/presentations, and abstracts from theses directed by the department faculty.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the NPS Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, http://web.nps.navy.mil~code09/.

## INTRODUCTION

The research program at the Naval Postgraduate School exits to support the graduate education of our students. It does so by providing militarily relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, permitting them to maintain the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. This capability is especially important at the present time when technology in general, and information operations in particular, are changing rapidly. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focussed graduate education, is one of the most effective methods for both solving Fleet problems and instilling the lifelong capability for applying basic principles to the creative solution of complex problems.

The research program at NPS consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with other government laboratories and universities, provides off-campus courses either on-site at the recipient command or by VTC, and provides short courses for technology updates.

- NPS Institutionally Funded Research Program (NIFR): The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursable sponsored, (4) to contribute to the recapitalization of major scientific equipment, and (5) to cost-share the support of a strong post-doctoral program.

- Institute for Joint Warfare Analysis (IJWA) Program: The IJWA Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of research faculty.

In 1998, the overall level of research effort at NPS was 145 faculty workyears and exceeded $35million. The Department of Computer Science's effort was 10.98 faculty workyears and exceeded $3.6 million. The sponsored research program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY98, over 81% percent of the NPS research program was externally supported. In the Department of Computer Science 91% was externally supported.

The department's research sponsorship in FY98 is provided in Figure 1.

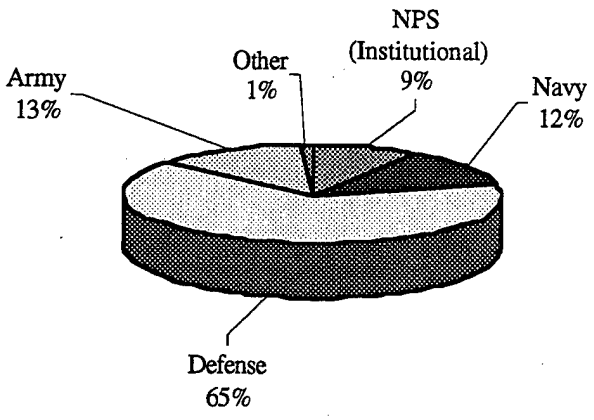


Figure 1. FY98 Sponsor Profile of the Department of Computer Science

These are both challenging and exciting times at NPS and the research program exists to help ensure that we remain unique in our ability to provide graduate education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

October 1999

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## DEPARTMENT SUMMARY

The Department of Computer Science provides graduate education in the major area of Computer Science. Degrees offered include the Master of Science in Computer Science, Master of Science in Modeling, Virtual Environments and Simulation, and Doctor of Philosophy in Computer Science.

The Department has on-going active research programs in several important areas of interest to the DoD/DoN. Primary research focus areas include:

- Software Engineering
- Programming Languages and Foundations
- Computer Graphics and Visualization
- Artificial Intelligence and Robotics
- Parallel, Distributed, and Networked Computing
- Computer Security
- Databases

To support the rigorous coursework and research, the Department hosts several laboratories; two are general purpose while the rest are highly specialized to focus on specific areas of research.

- Computer Science Academic UNIX Laboratory
- Computer Science Academic PC Laboratory
- Computer Graphics and Video Laboratory
- Artificial Intelligence and Robotics Laboratory
- Visual Database and Interface Laboratory
- Computer-Aided Prototyping Laboratory

## INERTIAL MOTION TRACKING TECHNOLOGY FOR INSERTING HUMANS INTO A NETWORKED SYNTHETIC ENVIRONMENT

**Eric R. Bachmann, Instructor**
**Robert B. McGhee, Professor**
**Michael J. Zyda, Professor**
**Department of Computer Science**
**Sponsors: U.S. Army Research Office and Naval Postgraduate School**

**OBJECTIVE:** The goal of this project was to show the feasibility of tracking angular motion of human limb segments using miniaturized inertial and magnetic sensing devices together with an innovative quaternion-based nonlinear attitude estimation filter. This effort was initially undertaken with NPS Institutional Funded Research funds to provide the basis for a proposal to the U.S. Army Research Office (ARO) to develop and test a full instrumented "body suit" capable of tracking the motion of fifteen human limb segments in real-time and displaying the results over a computer network as realistic 3D motion of an articulated body model of a human figure.

**SUMMARY:** All goals of the first year of this project have been accomplished. A miniaturized nine-axis sensor system (three axes each of linear acceleration, angular rate, and ambient magnetic field) was designed and constructed. Prototype software was developed by simulation means. The results of these two efforts were combined and functioned correctly. A proposal to the U.S. Army Research Office, Durham, for a two-year project aimed at the development of a full body suit was submitted and subsequently funded in February 1998. The experimental parts of two master's theses relating to this research have been completed. A paper based on these theses (listed below) has been written and submitted for review. Work in the coming year will be concentrated on investigations relating to full body tracking and display using multiple copies of the sensor package developed during the current year along with an enhanced software system.

**DoD KEY TECHNOLOGY AREAS:** Human Systems Interface, Modeling and Simulation

**KEYWORDS:** Body Tracking, Virtual Reality, Human-Computer Interface

## EVALUATION OF C3 ASPECTS OF THE PROJECT ALBERT

**Wolfgang Baer, Research Assistant Professor**
**Department of Computer Science**
**Sponsor: Marine Corps Combat Development Command**

**OBJECTIVE:** Develop a set of spatio-temporal measures of combat potentials appropriate to the MAGTF Commander in an Operational Maneuver From Sea (OMFTS).

**SUMMARY:** Utilizing LOS and Perspective View capability developed at NPS, this project explored the capability of calculating weapons effectiveness potentials for close air support, direct fire, and indirect fire weapons. The resulting potentials are color coded on a high-resolution photo map display at near real time rates. The system is expected to be integrated into constructive tactical battlefield simulations such as JANUS in order to provide weapons effectiveness feedback to the commanders.

**CONFERENCE PRESENTATIONS:**

Baer, W., "Performance Modeling of Parallel Programs in SMP Environments," 6th INFORMS Computer Science Technical Section Conference, Monterey, CA, 7-9 January 1998.

Baer, W., "EO/IR Data Dictionary and Beyond," SISO Synthetic Environment and Sensor Forum, San Diego, CA, 14-15 January 1998.

Baer, W., "Line of Sight and Perspective View Server for Windows NT," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Baer, W., "After Action Review System on UNIX and Windows NT," 66th Military Operations Research Symposium Poster Session, Monterey, CA, 23-25 June 1998.

Rowe, N., Reed, C., Baer, W., and Jackson, L., "A Planner for Constructing Customized Terrain Databases," 1998 Command and Control Research and Technology Symposium, Monterey, CA, June 1998.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Other (Weapons Effectiveness)

**KEYWORDS:** Weapons Effectiveness, High Resolution Terrain, Modeling Simulation

## HIGH RESOLUTION TERRAIN SYSTEM DEVELOPMENT I AND II

**Wolfgang Baer, Research Assistant Professor**
**Department of Computer Science**
**Sponsor: U.S. Army Test and Experimentation Command**

**OBJECTIVE:** Develop line-of-sight and perspective view server using 1-meter terrain.

**SUMMARY:** This project developed a high speed line-of-sight (LOS) and video realistic perspective view generation (PVG) in low cost PC based hardware running Windows NT. Utilized advances in disk capacity, execution speed, and symmetric multi-processing configurations allow scalable servers to be built which can provide LOS and PVG services in an interactive networked environment at low costs. The server is now available in low cost PC based hardware running Windows NT.

The server was a component of an After Action Review Systems supporting trial control and post trial analysis in operational tests being integrated by TEXCOM at Fort Hood, TX. The system components included a rapidly configurable PV-Wave graphics interface networked with a high-speed line-of-sight (LOS) and the video realistic perspective view generator (PVG) server.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation

**KEYWORDS:** High Resolution Terrain, Databases, Modeling Simulations

## AUTOMATION SUPPORT FOR SOFTWARE EVOLUTION

**Valdis Berzins, Professor**
**Department of Computer Science**
**Sponsor: U.S. Army Research Office**

**OBJECTIVE:** The objective of the proposed effort is to design a system for automating the configuration management needed to keep track of the evolution of a software prototyping during a typical application of the evolutionary software prototyping method supported by the Computer-Aided Prototyping System (CAPS). CAPS is an integrated software development environment aimed at rapidly prototyping hard real-time embedded software systems, such as missile guidance systems, space shuttle avionics systems, robots, automated factories, telecommunications systems, computer-controlled vehicles, and computer-controlled consumer appliances such as microwave ovens and sewing machines.

**SUMMARY:** The design and refinement of an integrated set of models covering both software products and the development environment was completed. These models provide mathematical representations for the important design aspects of the software product. Each of the models addresses decision support and partial automation for the corresponding aspect of software evolution.

The evolution model represents attributes of and dependencies between versions of software components and the analysis and design activities that produce them. This model encompasses plans for future evolution, the current status of ongoing efforts, and the evolution history of the current system, including branching history and parallel lines of development. The software components can include representations of rationale, requirements, architectures, implementations, and other aspects of software systems. The evolution model supports computer-aided planning and cost estimation, automated configuration management, automated team coordination, automated project scheduling, and automated project status monitoring. This model provides a formalism for automatically managing design information (software documents), design rationale (evolution history and dependencies), human resources (design rationale (evolution history and dependencies), human resources (design team, schedules, and work assignments), and plans (proposed software evolution).

**PUBLICATION:**

Berzins, V., "Computer-Aided Software Evolution Based on Relational Hyper-graph Model," International Conference on Software Engineering, submitted 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** CAPS, Design

## AUTOMATED REASONING FOR COMBINING CHANGES

**Valdis Berzins, Professor**
**Department of Computer Science**
**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** The proposed research will investigate effective automated reasoning support for combining changes to software systems. The capability is relevant for reliably combining the results of concurrently developed enhancements to a software system. Improved decision support in this area should reduce the incidence of software system integration problems. The proposed work will focus on methods for assessing the compatibility of concurrent changes, for suggesting ways to resolve conflicting decisions if the changes are not found to be compatible, and for formulating guard constraints that will ensure concurrent efforts by different designers will remain compatible. The ideas will be validated by developing prototype versions of tools for automatically combining compatible changes, and for diagnosing incompatibilities.

**SUMMARY:**

The project completed the implementation and evaluation of a method for combining changes to hierarchical design structures. This method is the first of its kind with the ability to automatically detect and automatically recover from conflicts between the independently developed changes to be combined. This is possible in this context because of the following special characteristics of hierarchical software design structures: (1) the extension of the design structure lattice to a Brouwerian algebra preserves the least upper bounds of the original lattice and (2) the semantics of the design (although not its understandability) is independent of the hierarchical structure. The first property ensures that reasoning in the extended algebraic structure is also valid with respect to the embedded model of proper designs, and the second ensures that weakening approximations with respect to the Lattice structure do not throw away practically vital information. Our initial experimental assessments of the implementation indicate that the method is computationally tractable and produces reasonable results.

**PUBLICATION:**

Berzins, V., "Recombining Changes to Software Specifications," *Journal of Systems and Software,* August 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Automated Reasoning Support, Software Systems

## AUTOMATED REASONING FOR COMBINING CHANGES TO SOFTWARE SYSTEMS

**Valdis Berzins, Professor**
**Department of Computer Science**
**Sponsor: U.S. Army Artificial Intelligence Center**

**OBJECTIVE:** The proposed research will investigate effective automated reasoning support for combining changes to software systems. This capability is relevant for reliably combining the results of concurrently developed enhancements to a software system. Improved decision support in this area should reduce the incidence of software system integration problems. The proposed will be validated by developing prototype versions of tools for automatically combining compatible changes and for diagnosing incompatibilities.

**SUMMARY:** The project completed the implementation and evaluation of a method for combining changes to hierarchical design structures. This method is the first of its kind with the ability to automatically detect and automatically recover from conflicts between the independently developed changes to be combined. This is possible in this context because of the following special characteristics of hierarchical software design structures: (1) the extension of the design structure lattice to a Brouwerian algebra preserves the least upper bounds of the original lattice and (2) the semantics of the design (although not its understandability) is independent of the hierarchical structure. The first property ensures that reasoning in the extended algebraic structure is also valid with respect to the embedded model of proper designs, and the second ensures that weakening approximations with respect to the lattice structure do not throw away practically vital information. Our initial experimental assessments of the implementation indicate that the method is computationally tractable and produces reasonable results.

The project has also developed a method for merging changes to black-box specifications for software modules, expressed using logic. This introduces a boolean difference operator into the logic, which has not been extensively studied and has somewhat surprising properties. Experience with applying the method shows that changes that intuitively seem independent may not actually be independent. The conjecture is that this may be relevant to the feature interaction problem in software requirements.

**PUBLICATION:**

Berzins, V., "Recombining Changes to Software Specification," *Journal of Systems and Software,* Vol. 42, No. 2, August 1998.

**DoD KEY TECHNOLGY AREA:** Computing and Software

**KEYWORDS:** Automated Reasoning Support, Software System Integration

## TRAINING SPATIAL KNOWLEDGE ACQUISITION USING VIRTUAL ENVIRONMENTS

**Rudy Darken, Assistant Professor**
**Department of Computer Science**
**Sponsor: Office of Naval Research**

**OBJECTIVE:** The objective of this research program is to determine if virtual environments can be useful for the purpose of acquiring spatial knowledge of specific spaces or for training effective spatial behaviors. This is of particular interest to a wide variety of military communities due to the importance of navigation in many operational tasks. The approach is to conduct a series of experiments using real environmental fidelity, interface fidelity, and training methods in the acquisition of spatial knowledge.

**SUMMARY:** To date, four studies have been completed (one FY97, three FY98) in this program. Three primary areas were pursued: (1) environmental familiarization of a natural terrain using a portion of the former Fort Ord., (2) environmental

familiarization of an urban terrain using Herrmann Hall, and (3) training navigation skill for helicopter pilots in cooperation with HS-10 at NAS North Island. The research has shown that virtual environments are clearly not a panacea for learning about spaces. In fact, subjects who used the virtual environments tended to perform significantly worse on navigation tasks than subjects who used only a map. Future studies will investigate why this occurs and how to remedy this situation. Early work with HS-10 indicated that virtual environments might be a powerful tool for training junior pilots how to navigate from a contour map, thus improving their performance in any environment on any mission.

**PUBLICATION:**

Darken, R., Allard, T., and Achille, L., "Spatial Orientation and Wayfinding in Large-Scale Virtual Spaces: An Introduction," *Presence: Teleoperators and Virtual Environments,* 7(2), pp.101-107, 1998.

**CONFERENCE PRESENTATIONS:**

Sullivan, J., Darken, R., and McLean, T., "Terrain Navigation Training for Helicopter Pilots Using a Virtual Environment," Third Annual Symposium on Situational Awareness in the Tactical Air Environment, Piney Point, MD, 2-3 June 1998.

Goerger, S., Darken, R., Boyd, M., Gagnon, T., Liles, S., Sullivan, J., and Lawson, J., "Spatial Knowledge Acquisition from the Maps and Virtual Environments in Complex Architectural Spaces," 16th Applied Behavioral Sciences Symposium, U.S. Air Force Academy, Colorado Springs, CO, 22-23 April 1998.

Darken, R. and Banker, W., "Navigating in Natural Environments: A Virtual Environment Training Transfer Study," Virtual Reality Annual International Symposium, VRAIS '98, Atlanta, GA 1998.

**THESES DIRECTED:**

Sullivan, J., "Helicopter Terrain Navigation Training Using a Wide Field of View Desktop Virtual Environment," Master's Thesis, Naval Postgraduate School, September 1998.

Goerger, S., "Spatial Knowledge Acquisition and Transfer from Virtual to Natural Environments for Dismounted Land Navigation," Master's Thesis, Naval Postgraduate School, September 1998.

Cevik, H., "Map Usage in Virtual Environments," Master's Thesis, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Human Systems Interface, Modeling and Simulation, Other (Training)

**KEYWORDS:** Virtual Environments, Training, Navigation

## MANAGEMENT SYSTEM FOR HETEROGENEOUS NETWORKS (MSHN)

**Debra Hensgen, Associate Professor**
**Taylor Kidd, Associate Professor**
**Department of Computer Science**
**Sponsor: Defense Advanced Research Projects Agency**

**OBJECTIVE:** Research and design effort directed at solving the fundamental problems associated with and creating a distributed metacomputer.

**SUMMARY:** In 1998 MSHN completed its second year and started its third year of work. During this year, the co-investigators at the University of Southern California and Purdue completed new and fundamental work in the scheduling of complex tasks in heteorogeneous and non-deterministic environments. The co-investigator, Cynthia Irvine, Naval Post-

graduate School Department of Computer Science, continued to explore the ramifications and issues associated with handling security in a SMSHN like environment. At NPS, ground breaking work was performed in several areas, generating several student theses and a number of published papers. Areas of emphasis for 1998 included, among many others of equal importance: (1) development of a mechanism for the monitoring of low-level resource usage via wrappers, (2) determination of the CORBA mechanisms that are mature enough for MSHN use, (3) development of a mechanism for secure communications between MSHN components, (4) the ramifications of non-deterministic resource usage on scheduling decisions, and (5) the determination of the fidelity required in modeling the OS network and CPU allocation policies. In addition, the MSHN team made several presentations and demonstrations to a variety of activities, including Quorum PI meetings, including the Naval Surface Warfare Center (NSWC), University of Texas at Arlington, Teknowledge Corporation, and SPAWAR.

**PUBLICATIONS:**

Kresho, J., Hensgen, D., Kidd, T., and Xie, G., "Determining the Accuracy Required in Resource Load Prediction to Successfully Support Application Agility," *Proceedings of the 2nd Conference on European Parallel and Distributed Systems* (EURO-PD '98), Vienna, Austria, July 1998.

Xie, G., Hensgen, D., Kidd, T., and Yarger, J., "SAAM: An Integrated Network Architecture for Integrated Services," *Proceedings of the 6th International Workshop on Quality of Service*, Napa Valley, CA, May 1998.

Freund, R., Gherrity, M., Ambrosius, S., Campbell, M., Halderman, M., Hensgen, D., Keith, E., Kidd, T., Kussow, M., Lima, J., Mirabile, F., Moore, L., Rust, B., and Siegel, H., "Scheduling Resources in Multi-User, Heterogeneous, Computing Environments with SmartNet," *Proceedings of the IEEE Workshop on Heterogeneous Computing Systems* (HCW '98), Orlando, FL, March 1998.

Armstrong, R., Hensgen, D., and Kidd, T., "The Relative Performance of Various Mapping Algorithms is Independent of Sizable Variances in Runtime Predictions," *Proceedings of the 7th IEEE Workshop on Heterogeneous Computing Systems* (HCW '98), Orlando, FL, March 1998.

**THESES DIRECTED:**

Duman, A., "The Use and Run-Time Overhead of CORBA in MSHN Project," Master's Thesis, Naval Postgraduate School, September 1998.

Schnaidt, M., "MSHN: Design of a Client Library to Monitor Resource Usage," Master's Thesis, Naval Postgraduate School, December 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Heterogeneous Networks, Distributed Computing, Data Staging, Metacomputing

## MANAGEMENT SYSTEM FOR HETEROGENEOUS NETWORKS (MSHN): QUALITY-OF-SERVICE SECURITY STUDY AND MODEL

**Cynthia E. Irvine, Assistant Professor**
**Department of Computer Science**
**Sponsor: Defense Advanced Research Projects Agency**

**OBJECTIVE:** The objective of this research is to study the proposed architecture for the Management System for Heterogeneous Networks and, within the context of the Quality-of-Service task, determine how requirements for security can be addressed.

**SUMMARY:** This effort investigated the security services to be provided in the context of a Management System for Heterogeneous Networks. A security architecture based upon separation of services into four distinct domains was developed. It is designed to take advantage of possible underlying operating system support for integrity domains. Cryptography was used to provide domain separation. A demonstration prototype was developed using the Intel Common Data Security Architecture.

**PUBLICATION:**

Wright, R., Shifflett, D.J., and Irvine, C. E., "Security Architecture for a Virtual Heterogeneous Machine," *Proceedings of the 14th Annual Computer Security Applications Conference*, pp. 167-177, Phoenix, AZ, December 1998.

**CONFERENCE PRESENTATION:**

Wright, R., Shifflett, D.J., and Irvine, C.E., "Security Architecture for a Virtual Heterogeneous Machine," 14th Annual Computer Security Applications Conference, Phoenix, AZ, December 1998.

**OTHER**

Wright, R., Shifflett, D.J., and Irvine, C.E., "Security Architecture Prototype for Virtual Heterogeneous Machines," code delivered to DARPA integrator (Teknowledge) for the DARPA Quorum/Quite research project, September 1998.

**THESIS DIRECTED:**

Wright, R.E., "Management System for Heterogeneous Networks Security Services," Master's Thesis, Naval Postgraduate School, June 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Information Systems Security, INFOSEC, Information Assurance, Network Security, Distributed Systems Security

## INFORMATION ASSURANCE RESEARCH CHALLENGES

**Cynthia E. Irvine, Assistant Professor**
**Department of Computer Science**
**Sponsor: Defense Advanced Research Projects Agency**

**OBJECTIVE:** The objective of this research is to investigate possible information assurance research initiatives for DoD. Areas to be explored may include: the relationship between security and network management functions; cross fertilization through other disciplines; counter measures to denial of service; and metrics for assurance.

**SUMMARY:** This effort resulted in two invitational workshops attended by the sponsor and researchers from NPS and elsewhere. The first workshop addressed the problem of security management in large-scale distributed networks. The notion of a centralized security service desk intended to collect sensory data, integrate and analyze data from distributed nodes, and provide security management services was discussed. A few of the challenges associated with developing systems to provide these services were identified in the area of policy management and implementation, data archiving and analysis, visualization, and integration of network security status into command and control architectures. A second workshop, entitled Information Assurance Summer Camp, provided a venue for in depth exchanges on selected topics in visualization, data mining, use of signal processing and other analysis techniques, such as Baysean networks

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Computer Security, Network Security, Heterogeneous Systems, INFOSEC

**CENTER FOR INFOSEC STUDIES AND RESEARCH**
**Cynthia E. Irvine, Assistant Professor**
**Department of Computer Science**
**Sponsors: National Security Agency, Naval Postgraduate School,**
**Defense Information Systems Agency, and Space and Naval Warfare Systems Command**

**OBJECTIVE:** The objective of this research is to provide sustained support for the development of the NPS Center for Information Systems Security (INFOSEC) Studies and Research (CISR) in the areas of curriculum development, trusted systems laboratory development, faculty development in INFOSEC and information assurance, a visiting professor program, an invited lecture series, academic outreach, and graduate utilization. It provides an integrated approach to INFOSEC research and education that focuses on important problems of DoN, DoD and U.S. Government, thus serving the needs of the warfighter and intelligence community.

**SUMMARY:** The effort to build a high assurance multilevel secure local area network continued. A system architecture was developed. Design and implementation of system components is ongoing. A high level design and prototype implementation for an executive for a TCB extension was completed.

This research supported a security kernel design using split address space technology to provide high assurance support of threads in an environment intended to create partially ordered privilege domains. This base will be used to support a system for the dynamic adaptation and retooling of software in the context of transaction processing.
In ongoing research, conducted with G. Xie (Naval Postgraduate School Department of Computer Science), the development of protocols and protection techniques to provide confidentiality and integrity for IP datagrams when ATM switching services are located at OSI Layer 2 was investigated.

The broad NPS CISR effort in the area of computer security education continued and included development or improvement of intermediate and advanced graduate courses in computer security, dissemination of course materials using both traditional and electronic media, an invited lecture series on computer security topics, and participation in regional and national computer security education activities. The second Workshop on Education in Computer Security was organized and chaired by NPS CISR staff.

**PUBLICATIONS:**

Irvine, C.E., Chin, S-K., and Frinke, D., "Integrating Security into the Curriculum," *IEEE Computer,* Vol. 31, No. 12, pp. 25-30, 1998.

Irvine, C.E., Anderson, J.P., Robb, D., and Hackerson, J., "High Assurance Multi-level Services for Off-the-Shelf Workstation Applications," *Proceedings of the 21st National Information Systems Security Conference*, pp. 421-431, Crystal City, VA, October 1998.

Macchione, W.A. and Warren, D.F., "The Macro Virus and Virus Scanning Software: Analysis of Their Interaction," *Proceedings of the 21st National Information Systems Security Conference*, pp. 84-90, Crystal City, VA, October 1998.

Irvine, C.E. and Shockley, W.R., "Roundhouse: A Security Architecture for Active Networks," Naval Postgraduate School Technical Report, NPS-CS-98-002, May 1998.

Irvine, C.E., "Security Issues for Automated Information Systems," *Handbook of Public Information Systems*, G.D. Garson, (ed.), 1998, accepted.

Irvine, C.E., NPS CISR *Annual Report*, July 1998. Also available at http://cisr.nps.navy.mil/Publications.html.

**CONFERENCE PRESENTATIONS:**

Irvine, C.E., "Exploitation of a Covert Channel," Workshop on Computer Security Education, Pacific Grove, CA, January 1998.

Irvine, C.E., "Meeting Security Requirements for Global Commerce: Can Education Help?" National Colloquium for Information Systems Security Education, Harrisonburg, VA, June 1998.

Michael, J.B., "Computer Security Issues Related to Using COTS Software," IEEE International Workshops on Critical-Functions Considerations for ISO/IEC 15288 — System Life Cycle Processes: Safety, Off-The-Shelf Items, Quality Management and Engineering Principles," Monterey, CA, 10 August 1998.

Michael, J.B., "Network Security I: Network Security Policy," Fifteenth Annual California Law Enforcement Telecommunications System Training and Technology Conference, Anaheim, CA, 23 September 1998.

Michael, J.B., "Network Security II: Boundary Controllers," Fifteenth Annual California Law Enforcement Telecommunications System Training and Technology Conference, Anaheim, CA, 24 September 1998.

Irvine, C.E., Anderson, J.P., Robb, D.A., and Hackerson, J., "High Assurance Multi-level Services for Off-the-Shelf Workstation Applications," 21st National Information Systems Security Conference, Crystal City, VA, October 1998.

Irvine, C.E., "Do Attack/Defend Exercises Belong in the Classroom?" 21st National Information Systems Security Conference, Crystal City, VA, October 1998.

Macchione, W.A. and Warren, D.F., "The Macro Virus and Virus Scanning Software: Analysis of Their Interaction," 21st National Information Systems Security Conference, Crystal City, VA, October 1998.

**OTHER:**

Irvine, C.E., "Secure Systems: A Security Penetration Analysis with Clark Weissman," CD ROM containing instructional materials, December 1998.

**THESES DIRECTED:**

Darroca, G., "Framework for a Link Layer Packet Filtering (LLPF) Security Protocol," Master's Thesis, Naval Postgraduate School, September 1998.

Hackerson, G., "Design of a Trusted Computing Base Extension for Commercial Off-the Shelf Workstations (TCBE)," Master's Thesis, Naval Postgraduate School, September 1998.

Isa, H.R., "Utilizing Hardware Features for Secure Thread Management," Master's Thesis, Naval Postgraduate School, December 1998.

Macchione, W.A., "The Capabilities, Propagation Effects, and Targeting of Computer Systems," Master's Thesis, Naval Postgraduate School, March 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Computer Security, Network Security, High Assurance Systems, INFOSEC, Education, Research

## STUDY INITIATING DIRECTIVE FOR THE TRAINING INFORMATION MANAGEMENT SYSTEM (TIMS)

**Ted G. Lewis, Professor**
**Department of Computer Science**
**Sponsor: U.S. Marine Corps Combat Development Command**

**OBJECTIVE:** The Director, Training and Education Division, Marine Corps Combat Development Command (MCCDC), has tasked his staff to develop a plan to re-engineer current information systems in order to improve the management of Marine Corps training.

**SUMMARY:** The current collection of information systems supporting the Marine Corps Training and Education (T&E) establishment are legacy "stove-pipe" database systems that marginally support the required reservation, scheduling, training resource tracking, and curriculum development functions. Further, they are not Defense Information Infrastructure (DII) Common Operating Environment (COE) compliant and have only fragile linkages to manpower management systems and other service training management systems. Therefore this study recommended a "re-architecting" of the U.S. Marine Corp Training & Education Information System capable of tracking and managing individual Marines. The results of the study will be used to construct a System Decision Memorandum (SDM) for the development of TIMS applications.

**PUBLICATIONS:**

El-Rewini, H. and Lewis, Ted, *Distributed and Parallel Computing,* Prentice-Hall, 350 pp., 1998.

Lewis, Ted, "A Rose by Any Other (Domain) Name," *Internet Computing,* pp. 92-93, March-April 1998.

Lewis, Ted, "Why the Economy is So Good?" *Computer,* pp. 110-112, May 1998.

Lewis, Ted, "What to do About Microsoft?" *Computer,* pp.109-112, September 1998.

Lewis, Ted, "The New Economics of Information," *Internet Computing,* pp.93-94, September-October 1998.

Lewis, Ted, "The Legacy Maturity Model," *Computer,* pp.125-128, November 1998.

## FORMAL MODELS USED FOR AUTOMATION IN SOFTWARE DEVELOPMENT

**Luqi, Professor**
**Department of Computer Science**
**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** The objective of the proposed research is the design of an integrated set of formal models and methods for automating a wide range of design and development tasks for real-time systems. The methods used will focus on automation of design activities that appear in an evolutionary prototyping approach to software development. The significance of the research is to improve productivity and software quality by enabling a higher level of automation in software development. The result of this research will broaden the definition of automatic programming and will make automatic programming a practical approach for increasing productivity in the software lifecycle. Automated decision support functions used will ensure software quality by decreasing the human effort required and minimizing the incidence of human error. The approach controls the complexity and high degrees of freedom of the software process by using computer aid. Earlier user feedback for validating and refining specifications through trial use of operational system prototypes experimentally ensures that the formal specifications correspond to user needs. Maintenance costs will be minimized by reducing the need to repair requirement errors after system deployment and by using specification-based automatic program correction methods sensitive to both syntax and semantics.

**SUMMARY:** The project focused on automation of design activities that appear in an evolutionary prototyping approach to software development. This research used a set of state-of-the-art formal methods in software engineering to construct a cohesive set of formal models. These models were used to create and to unify automated processes for computer-aided prototyping. Mathematical models for implementing a set of automated and integrated software tools were developed. This research combines very-high-level specification abstractions and concepts with formal real-time models, automated management of software design data and human resources, transformations, change emerging, and automated retrieval of reusable software components to provide automated methods for generating real-time programs and for coordinating teams of developers.

**PUBLICATION:**

Luqi, "Formal Models and Prototyping," *Proceedings of the Requirements Targeting Software and Systems Engineering Workshop,* Munich, Germany, April 1998.

**THESIS DIRECTED:**

Kominiak, J., "Software System Requirements for the Fuel Automation Subsystem of the Integrated Combat Service Support System (ICS3) Using the Computer-Aided Prototyping System (CAPS)," Master's Thesis, Naval Postgraduate School, March 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Prototyping, Software Life-cycle

## A NON-INVASIVE ACOUSTIC VITAL SIGNS MONITOR FOR BATTLEFIELD MEDICAL CARE

**Luqi, Professor**
**Department of Computer Science**
**Sponsor: Office of Naval Research**

**OBJECTIVE:** To develop a military version of the non-invasive acoustic vital signs monitor (N-AVSM). The Software Engineering Group at the Naval Postgraduate School completed a preliminary requirements analysis and developed a prototype of a wireless acoustic monitor system that could protect babies at risk of Sudden Infant Death Syndrome (SIDS). The technology can be used to build a smart stretcher where casualties could be monitored on the way to the hospital.

**SUMMARY:** A revised N-AVSM prototype was developed using the Computer-Aided Prototyping Systems (CAPS) and presented to several military officer students for evaluation. Several improvements to the user interface were suggested by the military domain experts to make the N-AVSM more user-friendly to battlefield medical care providers, resulting in the updated user interface. Key additions to the user-interface include facilities for the field technicians to customize the N-AVSM for individual patient. Revised CAPS augmented data flow graphs of the top-level architecture of the new N-AVSM were created, which contain additional functions to process the information input from the updated user-interface. Continued development effort is needed to implement the updated N-AVSM on a PC.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Wireless Acoustic Monitor Non-invasive Acoustic Vital Signs Monitor (N-AVSM), Sudden Infant Death Syndrome (SIDS)

## MODULAR SOFTWARE ARCHITECTURE OF JANUS (A)

**Luqi, Professor**
**Department of Computer Science**
**Sponsor: U.S. Army Training and Doctrine Analysis Command-Monterey**

**OBJECTIVE:** To modernize the software of the Janus (A) systems into a maintainable and evolvable structure. This research develops: (1) a high-level modular architecture for the existing Janus (A) systems using the Computer-Aided Prototyping Systems (CAPS) and (2) an implementation of the design using the Ada95 programming language. The higher level goal of this research is to evaluate the effectiveness of computer-aided prototyping and software evolution tools when applied to legacy software, as opposed to prototype software that is initially developed in the context of the CAPS system and its prototyping language PSDL.

**SUMMARY:** The first step was to gain an understanding of the system. Meetings were held with TRAC-Monterey and Janus manuals were gathered. Next, object models of the Janus System was developed to create the modules and associations amongst them. It required a great deal of analysis and focus to mentally transform the currently scattered sets of data and functions into small, coherent and realizable objects, each with its own attributes and operations. Based on feedback from Janus domain experts at TRAC-Monterey, Rolands and Associates, OneSAF Project, Combat21 Project, and the National Simulation Center, the re-engineering team revised the object models for the Janus core elements and developed a 3-tier object-oriented architecture for the Janus System.

**PUBLICATION:**

Luqi, "Re-Engineering the Janus Combat Simulation System," Naval Postgraduate School Technical Report, NPS-CS-98-007, 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Re-Engineering, Computer-Aided Prototyping, Combat Situation

## ENGINEERING AUTOMATION FOR COMPUTER-BASED SYSTEMS

**Luqi, Professor**
**Department of Computer Science**
**Sponsors: U.S. Army Research Office, Office of Naval Research, National Science Foundation, and Defense Advanced Research Projects Agency**

**OBJECTIVE:** Building quality computer systems that can meet user needs effectively and reliably is currently a major problem. Formal methods that can be partially or completely automated provide a promising approach to this problem. Engineering of systems with computerized components is an important research area for better quality systems as well as speeding up the construction process.

**SUMMARY:** A workshop, sixth in a series of software engineering workshops for formulating and advancing software engineering methodologies and techniques, was held in October 1998. The workshop provided an opportunity to explore efficient methods to overcome the problems that have hindered the advance of software practices, and address the design, development, deployment, and analysis of complex systems whose behavior is determined or controlled by software. The workshop provided a bridge between industry and academia. The program provided a balanced view of academic research and industrial developments.

**PUBLICATION:**

Luqi, "Engineering Automation for Computer-Based Systems," *Proceedings of the U.S. Army Research Office/ National Science Foundation/Office of Naval Research Workshop,* Carmel, CA, 26-29 October 1998.

**CONFERENCE PRESENTATION:**

Luqi, "Engineering Automation for Computer-Based Systems," U.S. Army Research Office, National Science Foundation, Office of Naval Research Workshop, Carmel, CA, 26-29 October 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Software Engineering

## COMPUTER MODELING FOR NETWORK CENTRIC C4I SYSTEMS

**Luqi, Professor**
**Department of Computer Science**
**Sponsor: Naval Postgraduate School-Institute for Joint Warfare Analysis**

**OBJECTIVE:** To model new C4I capabilities, assess network loads implied by new capabilities, and determine the most effective new capabilities that will become possible with the next generation internet technology.

**SUMMARY:** This project provides an embedded software solution to expand the capabilities of current, and future communications assets, without impairing the standards, methods, or other capabilities of such assets. The combined talents of the Naval Postgraduate School and Space and Naval Warfare Systems Center have been researching the area of digital network maximization for the past two years. This project, in association with the Office of Naval Research Real-Time Retargeting, Advanced Capabilities Initiative, has progressed beyond initial prototype. The methods, and embedded applications developed have demonstrated a 300% plus increase in effective information transfer across a constrained bandwidth channel (Link 16), while not affecting the current Link 16 architecture. The approach has been to develop a non-network-specific method to maximize throughput, without modification to existing hardware or software in the host environment. This technology was demonstrated, in live, operational systems, in July 1998. The architecture developed for this effort is well suited for addressing security issues, increasing effective communications capabilities, and improving QoS through the dynamic reallocation of tactical network resources (i.e., broadcast time slots).

**PUBLICATION:**

Luqi, "Autonomous Agents Design for Digital Network Maximization in Joint C4I System," *Proceedings of the Modeling and Simulation of Microsystems, Semiconductors, Sensors and Actuators Conference,* Santa Clara, CA, 6-8 April 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Network Centric, C4I Systems, Real-Time Retargetting Advanced Capabilities

## SYSTEM ENGINEERING AND EVOLUTION DECISION SUPPORT

**Luqi, Professor**
**Department of Computer Science**
**Sponsor: U.S. Army Research Office**

**OBJECTIVE:** The objective of the research is to develop an integrated set of formal models and methods for system engineering automation. These results will enable building decision support tools for concurrent engineering. The research addresses complex modular systems with embedded control software and real-time requirements.

**SUMMARY:** The focus was on automation of design activities that appear in an evolutionary approach to system development. Decision support for design synthesis, reuse and evolution is emphasized. This research extended recently developed

formal methods in system engineering to construct a cohesive set of formal models. These models are used to create and to connect automated processes for computer-aided prototyping, requirements validation, and design synthesis. Mathematical models for implementing a set of automated and integrated engineering automation tools were also developed. Our work combined very-high-level specification abstractions and concepts with: (1) formal real-time models, (2) automated management of system design data and human resources, (3) design transformation, (4) change merging, (5) automated retrieval of reusable system design components, and (6) automated schedule construction. Automated methods were created for: (1) generating real-time control programs, (2) generating simulation of subsystems, and (3) coordinating concurrent work by engineering teams. The work will ensure design consistency and to alleviate communication difficulties.

**PUBLICATION:**

Luqi, Chang, C., and Zhu, H., "Specifications in Software Prototyping," *Journal of Systems and Software,* Vol. 42, No. 2, pp. 150-177, August 1998.

**THESIS DIRECTED:**

Meckstroth, G., "A GUI Interface for Reusable Components Storage and Retrieval in the CAPS Software Base," Master's Thesis, Naval Postgraduate School, March 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Engineering Automation Tools, Decision Support Tools

## IMPROVED COMMUNICATION/DECISION SUPPORT

**Luqi, Professor**
**Department of Computer Science**
**Sponsor: Naval Sea Systems Command**

**OBJECTIVE:** Current aircraft carrier damage control communication systems through the repair lockers require an elaborate hierarchy of verbal communications and redundancy to pass even the simplest forms of direction through the fire party. Often this system breaks down under the weight of its own redundancy or the simple narrow channel through which the communications of the repair locker travel. This project seeks to assess the potential for improved Naval damage control operations using fewer personal by improving communications and decision support technology.

**SUMMARY:** An evaluation of current video teleconferencing (VTC) technology is complete. Evaluation of barcode technology has reached the product identification stage and for lack of materials, may not be adequately considered in this study. A review of the Smart Ship program has been partially completed. Literature review and interviews with crew and design personnel has provided a wealth of information. Wireless LAN technology has been studied and evaluated at the present state of the art. Evaluation of an expert system using a simple inference engine has been completed and indicates this outstanding technology should be organic to the damage control communication system. A small wireless LAN has been constructed to evaluate the viability of signals between computers utilizing COTS hardware and software to gain a working knowledge of the limitations and capabilities of current technology. A live set up and testing was performed on three forms of video teleconferencing to support tele-training for CVX damage control requirements. A small model of an expert system was constructed to demonstrate the ability to program a logical sequence of routines into a simple program on a PC. A small web has been put up of technology sources that have contributed to the knowledge collected thus far in our research.

**PUBLICATIONS:**

Luqi, "Software Process Improvement – Lessons Learned," *Proceedings of the Asia Pacific Forum on Software Engineering, International Conference on Software Engineering,* Kyoto, Japan, 21 April 1998.

Luqi, "The Pacific Rim Process Engineering Research," *Proceedings of the Asia Pacific Forum on Software Engineering, International Conference on Software Engineering,* Kyoto, Japan, 21 April 1998.

**THESIS DIRECTED:**

Rambidis, T., "Security Issues for the Software Evolution Model," Master's Thesis, Naval Postgraduate School, March 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Smart Ship Program, Wireless LAN Technology

## RECOGNIZING CAPTIONS OF PICTURES ON INTERNET PAGES

**Neil C. Rowe, Associate Professor**
**Department of Computer Science**
**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** To develop a prototype system that finds the photographs on Internet-World Wide Web pages, finds their captions and indexes them.

**SUMMARY:** In FY98 the important final phase of processing was added that relates the caption concepts to the image concepts. Domain-independent methods were developed for finding the set of regions most likely to represent the subject of a depictive picture. This required a neural network to rank region candidates, and a combinatorial search to find the region set most likely as a whole to correspond to the subject. This new work is reported in the conference paper. This required considerable work on developing robust image processing software to handle a wide range of captioned images. As before, test examples were used from the Naval Air Warfare Center-Weapons Division (NAWC-WD). The concentration was on the training and analyzing of every region (an average of 100) in every one of the 100 pictures and decide whether it was part of the subject. Work was continued on the natural-language processing component of the MARIE project which is necessary preliminary to the above mentioned work. Another 125 captions were parsed, augmenting the lexicon and occasionally the grammar to handle them. Two good overview papers on the system were prepared and submitted to a journal and a conference.

**PUBLICATIONS:**

Rowe, N.C. and Frew, B., "Automatic Caption Localization for Photographs on World Wide Web Pages," *Informauon Processing and Management,* Vol. 34, No. 1, pp. 95-107, 1998.

Rowe, N.C., "Mapping Between Image Regions and Caption Concepts of Captioned Depictive Photographs," *AAAI-98 Workshop on Representations for Multi-Modal Human-Computer Interaction,* Madison, WI, July 1998.

**CONFERENCE PRESENTATION:**

Rowe, N.C., "Mapping Between Image Regions and Caption Concepts of Captioned Depictive Photographs," AAAI-98 Workshop on Representations for Multi-Modal Human-Computer Interaction, Madison, WI, July 1998.

**DoD KEY TECHNOLOGY AREAS:** Human System Interfaces, Other (Software)

**KEYWORDS:** Images, Captions, Digital Libraries, Information Filtering, Content Analysis

## ARTIFICIAL INTELLIGENCE FOR TERRAIN-DATABASE INTEGRATION

**Neil C. Rowe, Associate Professor**
**Department of Computer Science**
**Sponsor: U.S. Army Training and Doctrine Analysis Command**

**OBJECTIVE:** To develop an intelligent interface to help construct integrated terrain databases by putting together existing simpler databases. The interface will assist the user by analyzing the many options and suggesting the best ones.

**SUMMARY:** Funding for this project expired several years ago. In CY98 one paper based on the earlier work was reported.

**PUBLICATION:**

Rowe, N.C., Reed, C., Baer, W., and Jackson, L., "A Planner for Constructing Customized Terrain Databases," *Proceedings of the 1998 Command and Control Research and Technology Symposium*, pp. 481-486, Monterey, CA, June 1998.

**CONFERENCE PRESENTATION:**

Rowe, N.C., Reed, C., Baer, W., and Jackson, L., "A Planner for Constructing Customized Terrain Databases," 1998 Command and Control Research and Technology Symposium, Monterey, CA, June 1998.

**DoD KEY TECHNOLOGY AREAS:** Human System Interfaces, Other (Software)

**KEYWORDS:** Terrain Databases, Data Structures, Software Integration

## DISTANCE LEARNING DEGREE PROGRAM: MASTER OF SCIENCE IN COMPUTER SCIENCE/SOFTWARE ENGINEERING

**Neil C. Rowe, Associate Professor**
**Department of Computer Science**
**Sponsor: Space and Naval Warfare Systems Center-San Diego**

**OBJECTIVE:** To support the distance learning program on software engineering.

**SUMMARY:** Funding supported work with a student at SPAWAR in San Diego and preparation of a paper with a former student from SPAWAR-SD.

**PUBLICATIONS:**

Rowe, N.C. and Schiavo, S., "An Intelligent Tutor for Intrusion Detection on Computer Systems," *Computers and Education,* Vol. 31, pp. 395-404, 1998.

Rowe, N.C. and Galvin, T., "An Authoring System for Intelligent Tutors for Procedural Skills," *IEEE Intelligent Systems,* Vol. 13, No. 3, pp. 61-69, May/June 1998.

Barrus, J. and Rowe, N.C., "A Distributed Autonomous-Agent Network-Intrusion Detection and Response System," *Proceedings of the 1998 Command and Control Research and Technology Symposium,* pp.577-586, Monterey, CA, June 1998.

## AN ENVIRONMENT FOR DEVELOPING SECURE SOFTWARE

**Dennis M. Volpano, Associate Professor**
**Cynthia E. Irvine, Assistant Professor**
**Department of Computer Science**
**Sponsors: Defense Advanced Research Projects Agency and Information Technology Office**

**OBJECTIVE:** The project aims to develop new techniques to statistically analyze code targeted for remote execution for secure flow violations.

**SUMMARY:** A technique was developed that attempts to construct a proof, for a given program, in a sound flow logic. If such a proof can be constructed then the program is secure. The technique permits remote code, written in Web-based languages like Java and JavaScript, to be analyzed prior to execution in order to determine whether it can be executed safely.

**PUBLICATIONS:**

Volpano, D. and Smith, G., "Confinement Properties for Programming Languages," *SIGACT News*, Vol. 29, No. 3, pp.33-42, September 1998.

Volpano, D. and Smith, G., "Language Issues in Mobile Program Security, in Mobile Agents and Security," G. Vigna, (ed.), *Lecture Notes in Computer Science*, Vol. 1419, pp. 25-43, 1998.

**CONFERENCE PRESENTATIONS:**

Volpano, D., "Probabilistic Noninterference in a Concurrent Language," 11th IEEE Computer Security Foundations Workshop, Rockport, MA, 1998.

Volpano, D., "Confinement Properties for Programming Languages," Office of Naval Research Workshop on Security Directions, Alexandria, VA, September 1998,

Volpano, D., "Confinement Properties for Programming Languages," Stanford Computer Security Seminar Series, Palo Alto, CA, 17 November 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Secure Information Flow, Remote Evaluation

## TYPE SYSTEMS FOR SECURE REMOTE EVALUATION

**Dennis M. Volpano, Associate Professor**
**Department of Computer Science**
**Sponsor: National Science Foundation**

**OBJECTIVE:** This is a joint project with Geoffrey Smith at the Florida International University (FIU). The work is part of a continuing project aimed at investigating the role of programming language design and type systems in ensuring the security of servers in remote evaluation systems. The long-term objective is to identify how languages should be designed in order to guarantee provable confinement properties for all programs expressed in these languages.

**SUMMARY:** Two forms of information flow were treated in systems: flows arising from synchronization in a concurrent language and probabilistic timing channels due to probabilistic thread scheduling. Techniques were developed in each case to eliminate them in systems. Two secure flow properties were identified as a result. One is Possibilistic Noninterference and the other is Probabilistic Noninterference.

**PUBLICATIONS:**

Volpano, D. and Smith, G., "Probablilistic Noninterference in a Concurrent Language," *Proceedings of the 11th IEEE Computer Security Foundations Workshop (CSFW)*, pp. 34-43, June 1998.

Smith, G. and Volpano, D., "Secure Information Flow in a Multi-Threaded Imperative Language," *Proceedings of the 25th ACM Symposium on Principles of Programming Languages (POPL)*, pp. 355-364, January 1998.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORD:** Security

## WORKSHOP ON PROVABLY-SECURE PROGRAMMING

**Dennis M. Volpano, Associate Professor**
**Department of Computer Science**
**Sponsor: Defense Advanced Research Projects Agency**

**OBJECTIVE:** The aim of the workshop was to explore the relationship between the design of programming language and security models.

**SUMMARY:** The workshop was held in Monterey CA, 26-28 March 1997. Its official title is the 1997 Foundations for Secure Mobile Code Workshop. The workshop had around 25 attendees from industry and academia. They were asked to prepare position statements which were provided in advance to all attendees on the web. Statements addressed basically two types of security problems: protecting servers from mobile code and protecting mobile code from malicious servers. The latter problem was viewed as more intractable, given the need for mobile code to rely on an execution platform of some sort. Participants presented their positions and discussion followed. All presentations and discussions were recorded for future reference, however, a final report was not written.

**DOD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORD:** Security

## SAAM: NETWORK MANAGEMENT SYSTEM FOR INTEGRATED SERVICES

**Geoffrey G. Xie, Assistant Professor**
**Department of Computer Science**
**Sponsors: Defense Advanced Research Projects Agency, National Science Foundation and National Aeronautics and Space Administration**

**OBJECTIVE:** A novel server and agent based active management system will be developed for the next generation Internet.

**SUMMARY:** The project team was built up by recruiting one full-time research assistant and six graduate students. The overall architecture of SAAM was developed and identified the important issues that the project should focus on. Work was started on developing a SAAM server. (The present prototype uses the Microsoft NT Server as the development platform.) Designed, implemented and evaluated a preliminary version of the Path Information Base (PIB) was designed, implemented, and evaluated. Work was started on prototyping a SAAM lightweight router. An experimental gigabits ATM switch was obtained through a NSF funded program. The switch provides an open platform for implementing and testing SAAM ideas.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** SAAM, Path Information Base

## PROVIDING APPLICATION LEVEL QUALITY OF SERVICE

**Geoffrey G. Xie, Assistant Professor**
**Department of Computer Science**
**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** The goal of the research is to design networks that guarantee application-level quality of services (QoS) to multimedia applications.

**SUMMARY:** Application-level guaranteed statistical services for real-time traffic were designed and evaluated. Specifically, admission control and loss management algorithms were developed for such services based on a novel traffic model for real-time traffic. Two papers have been published on this topic. A security framework was also designed suitable for fast IP touting based on OSI Layer 2 switching. Two theses have been produced on this topic.

**PUBLICATIONS:**

Xie, G.G. and Lam, S.S., "An Efficient Network Architecture Motivated by Application-Level QoS," *Journal of High Speed Networking*, IOS Press, Netherlands, Vol. 6, No. 3, pp. 165-179, January 1998.

Xie, G.G. and Lam, S.S., "Real-Time Block Transfer Under a Link Sharing Hierarchy," *IEEE/ACM Transactions on Networking*, Vol. 6, No. 1, pp. 205-218, February 1998.

Xie, G.G., Hensgen, D., Kidd, T., and Yarger, J., "SAAM: an Integrated Network Architecture for Integrated Services," *Proceedings of the 6th IEEE/IFIP International Workshop on Quality of Service*, Napa, CA, May 1998.

Kresho, J., Hensgen, D., Kidd, T., and Xie, G., "Determining the Accuracy Required in Resource Load Prediction to Successfully Support Application Agility," *European Conference Proceedings of the 2nd IASTED on Parallel and Distributed Systems*, July 1998.

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**KEYWORDS:** Network Management, Integrated Services, Multimedia, Quality of Service (QoS), Real-Time Data, Agent Technology, Network Security

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## ANALYSIS OF JAVA DISTRIBUTED ARCHITECTURES IN DESIGNING AND IMPLEMENTING A CLIENT/SERVER DATABASE SYSTEM

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Having timely and accurate information is essential for effective management practices and optimization of limited resources. Information is scattered throughout organizations and must be easily accessible. A new solution is needed for effective and efficient management of data in today's distributed client/server environment.

Java is destined to become a language for distributed computing. Java Development Kit (JDK) comes with a broad range of classes for network and database programming. Java Database Connectivity (JDBC) is one such class for providing client/server database access. There are many different approaches in using JDBC, ranging from low level socket programming, to a more abstract middleware approach. This thesis will analyze three different approaches: Sockets, Remote Method Invocation (RMI) and Commercial Middleware servers.

Among the three approaches this thesis examined, database access through RMI is the most viable approach because it uses an effective distributed object model. RMI abstracts the communication interface to the level of a procedure call. Instead of working directly with sockets, programmers can invoke a remote procedure as if it resided locally.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Database, JDBC, Java, RMI, Socket

## AN IMPLEMENTATION OF SECURE FLOW TYPE INFERENCE FOR A SUBSET OF JAVA

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Smart cards play an important role in a digital society. A smart card contains memory or an embedded microprocessor with the capability of enabling a wide variety of services, such as electronic cash in the case of memory cards and digital signature computation in the case of processor cards. A processor card can require a cardholder to authenticate herself in order to prevent others from using the card's services, from forging the cardholder's signature, for example. Authentication can be done by storing a personal identification number (PIN) or digitized fingerprint of the cardholder on the card itself. The PIN or fingerprint must always remain confidential no matter how the card is (ab)used.

This thesis addresses the problem of preserving the privacy of information stored on smart cards. Volpano and Smith have developed a static analysis for analyzing source code for information flow violations. This technique is developed further here for a language called Java Card, in which smart card applications are written. A prototype analyzer is presented for a subset of Java Card and applied to a sample card application to demonstrate its utility in protecting private information stored on smart cards.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Other (Smart Cards, Software Security, Type System)

**KEYWORDS:** Java Card, Smart Cards, Secure Flow Analysis, Type System

## SOFTWARE ARCHITECTURE FOR DISTRIBUTED REAL-TIME EMBEDDED SYSTEMS

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**Michael Holden, Department of Computer Science**

Real-time embedded systems have particularly strict requirements for accuracy, safety and reliability. A central question in the design of such systems is how to support concurrent processing without adversely affecting the timing requirements of the system. Concurrent processing is essential because the only way to successfully meet some tight real-time constraints is to use multiple processors.

This thesis focuses on the distributed scheduling problem. It proposes a distributed scheduling algorithm to allocate and schedule a set of tasks onto a collection of processors linked by a network. It further proposes a distributed software architecture for CAPS (Computer Aided Prototyping System) generated prototypes based on GLADE (GNAT Library for Ada Distributed Execution).

The new distributed CAPS architecture is applied to several prototype examples. The results show that it is possible to build distributed real-time embedded systems under the distributed scheduling model, where sets of tasks run independently on each processor, using GLADE.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Real-Time Embedded Systems, Distributed Systems, Real-Time Scheduling, Software

## REAL-TIME MODELING OF CROSS-BODY FLOW FOR TORPEDO TUBE RECOVERY OF THE *PHOENIX* AUTONOMOUS UNDERWATER VEHICLE (AUV)

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A virtual world provides an exceptional resource for the testing and development of an Autonomous Underwater Vehicle (AUV). The difficulties associated with the underwater environment are numerous and complex. In order to properly verify vehicle results in the laboratory such a world must accurately model the physics associated with the vehicle, its submerged hydrodynamics characteristics, and interactions with the environment. Environmental effects such as wave motion, currents, and flow forces created by bodies moving through the water can cause unpredicted performance variations and failures in the ocean environment. The current *Phoenix* AUV virtual world includes steady-state ocean currents, but does not take into account the environmental effects of waves and flow forces induced by adjacent vehicles (such as a moving submarine docking target).

This work provides a thorough real-time simulation of these complex factors using physically-based models. The problem is broken down into wave motion effects, submarine-induced flow fields, and virtual sensors to improve AUV motion control. Each set of forces is thoroughly analyzed and realistically simulated in real-time through the algorithms developed. In order to maintain real-time response, perturbations in the flow field caused by the AUV itself are assumed to be negligible. Simulated testing is performed across a range of easy to worst-case scenarios in order to justify assumptions. Extensive testing using virtual sensors is used to develop adequate control algorithms in the presence of turbulent cross-body flow.

The result of this research is an enhanced virtual world which more accurately depicts the ocean environment, along with the models and control algorithms required to design and operate an AUV during submarine launch and recovery. A platform independent approach to virtual environment simulation is presented through the use of the Virtual Reality Modeling Language (VRML) and Java. Finally, simulation test results provide strong evidence that AUV control with actual cross-body flow sensors can enable stable navigation, first through a turbulent flow field and then for subsequent docking with a moving submarine.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

**KEYWORDS:** Virtual Environment, Simulation-Based Design, Cross-Body Flow, Autonomous Underwater Vehicle (AUV), Platform-Independent Simulation

## MAP USAGE IN VIRTUAL ENVIRONMENTS

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It is neither practical nor efficient to represent virtual maps as we do for paper maps in the real world due to major differences in hardware and software capabilities and requirements. Instead, the parameters can be determined that affect virtual map representation and that help to construct a mental map, and then manipulate these parameters in order to increase the effectiveness of map representation as an aid in performing navigation tasks.

The approach taken was first to determine and then investigate the parameters that affect virtual map representation through an experiment designed specifically for this thesis. The experiment examined users of an urban and open ocean virtual environment executing a set of navigation tasks with a virtual map with different orientation schemas.

The results of this study showed that, a forward-up map orientation is preferable to a north-up map orientation for egocentric tasks and a north-up map orientation is preferable to a forward-up map orientation for geocentric tasks. Under almost every possible condition, individuals with high spatial abilities will be able to use either a north-up map or a forward-up map better than individuals with low spatial abilities. Furthermore, it was found that these principles apply across types of environment with vastly different spatial characteristics, but sparse environments seem to exhibit less of a performance difference than dense environments.

**DoD KEY TECHNOLOGY AREAS:** Human Systems Interface, Modeling and Simulation

**KEYWORDS:** Virtual Environments, Wayfinding, Navigation, Virtual Maps, Spatial Visualization, Spatial Orientation, Cognitive Maps, Mental Rotation Architecture, Computer Aided Prototyping

## TWO-HANDED, WHOLE-HAND INTERACTION

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This thesis investigates the application of Human Ability Requirements (HARs) to problem of two-handed, whole-handed interaction. The methodology is derived from the use of HARs in the world of human performance evaluation. This re-

search is based on the need to understand how humans perform tasks in order to guide the understanding of the requirements of advanced interface technology development.

The thesis presents the background for these two areas of research, taxonomies and whole-hand interaction. It goes on to develop a taxonomy and classification of two-handed, whole-hand interaction for the real world and virtual environments. This taxonomy is used to analyze a large number of real world tasks, to further the development of a series of tests to externally validate the classification, and to analyze the tasks of the 91B Field Medic. This thesis further presents recommendation for how this methodology can be used to develop taxonomies for other areas of human interaction, for how this taxonomy can be used by researchers and practitioners, and areas of further research related to both areas.

**DoD KEY TECHNOLOGY AREA:** Human Systems Interface

**KEYWORDS:** Virtual Environment

## IMPROVING THE ENGINEER RECONNAISSANCE REPORTING PROCESS THROUGH THE USE OF DIGITAL IMAGERY AND HANDHELD COMPUTERS

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This thesis explores an automated solution to improve the Engineer Reconnaissance Reporting Process. It proposes a proof-of-concept to enhance and improve the digital portion of the reporting process. This thesis defines the current process identifying its capabilities, limitations, and deficiencies. It identifies a prototype suite of equipment to perform the automation. The prototype capitalizes on the inherent capabilities on the reporting process and minimizes the deficiencies.

This thesis investigates emergent Commercial Off-the-Shelf components to locate those devices that satisfy the requirements and take full advantage of current technological advances. It evaluates each component against a criteria of minimum requirements and selects the most compatable device. This thesis performs an actual implementation of the prototype testing its performance against a fictional scenario. It provides a step-by-step description and graphic representation of the implementation. This thesis analyzes and summarizes the data generated during the implementation and provides recommendations. Results of this analysis suggest implementation of the prototype is feasible and that it satisfies the imagery portion of the Engineer Reconnaissance Reporting Process.

**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communication

**KEYWORDS:** Engineer Reconnaissance, Proof-of-Concept, Hand-Held Personal Computer, Digital Imagery, Wireless Communication

## FRAMEWORK FOR A LINK LAYER PACKET FILTERING SECURITY PROTOCOL

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Transport Layer (OSI Layer 3) switching and routing provides routing flexibility but not high throughput. Link layer (OSI Layer 2) switching provides high throughput but not the routing flexibility needed to manage topology change and load fluctuations in the network. Neither Layer 3 routing nor Layer 2 switching protocols were originally designed to support confidentiality and integrity of data, and authentication of participants. Proposals to integrate security may have positive results for data confidentiality, integrity and authentication, but often result in additional overhead, increased transmission

latency, and decreased throughput. An added difficulty is reconciling standards and protocols when integrating heterogeneous routing networks with homogenous switching networks while minimizing impact on throughput.

This thesis examined current Internet extensions and architectures as well as IP security services and Layer 2 switching in IP-based networks. Requirements for a framework for a proposed security protocol include: Link Layer switching and routing; independence of particular communication protocols and standards; IP packet filtering and routing according to predetermined security policies and with no significant impact on throughput; and continued routing flexibility of IP. This security protocol, called Link Layer (Link Layer Packet Filtering (LLPF)), filters packets at the Link Layer, and boasts two innovations: use of an authentication trailer and multiple cryptographic keys with short cryptoperiods.

**DoD KEY TECHNOLOGY AREA:** Other (Computer Network Security)

**KEYWORDS:** Network Security, Asynchronous Transmission Mode (ATM), Internetworking, Protocol

## THE USE OF AND RUN-TIME OVERHEAD OF COMMON OBJECT REQUEST BROKER ARCHITECTURE (CORBA) IN THE MANAGEMENT SYSTEM FOR HETEROGENEOUS NETWORKS (MSHN) PROJECT

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The goal of the Management System for Heterogeneous Networks (MSHN) is to support the execution of multiple, disparate, adaptive applications in a dynamic, distributed heterogeneous environment. MSHN consists of multiple, eventually replicated, distinct distributed components that themselves execute in a heterogeneous environment. This thesis answers the question: Is the performance of the Common Object Request Broker Architecture (CORBA) sufficient to support MSHN's inter-component communication?

This research focuses on the applicability of communication mechanisms from the CORBA 2.2 specification to MSHN. After a careful literature search, four mechanisms were identified for further examination: the Static Invocation Interface (SII), the Dynamic Invocation Interface (DII), the Typed Event Service and the Untyped Event Service. The rationale for selecting these mechanisms includes scalability, flexibility, extensibility, portability, maintainability, and manageability for the MSHN system.

A prototype of MSHN's communication infrastructure was implemented using these four mechanisms, and measured their run-time performance. The overhead added by CORBA for distributed component communication of MSHN system varied from a low of 10.6 milliseconds per service request to a high of 279.1 milliseconds per service request on UltraSparc10 boxes with Solaris 2.6 Operating System and connected via 100 Mbits/sec Ethernet. It is concluded that using CORBA mechanisms will not only substantially decrease the amount of time required to implement MSHN, but if used appropriately they will not substantially degrade performance.

**DoD KEY TECHOLOGY AREA:** Computing and Software

**KEYWORDS:** CORBA, Distributed Computing, Performance Overhead

## OBJECT RECOGNITION USING 2D SENSORS AND AUTONOMOUS VEHICLE NAVIGATION ISSUES

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**Master of Science in Electrical Engineering-December 1997**
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This research deals with the problem of extracting features from an image using wavelets and then using these features to recognize objects present in the image. This technique is applied to recognition of Unexploded Ordnance (UXO) objects. However, the concepts described here can be extended to recognition of other objects such as ships, missiles and aircrafts. This work is performed as part of an ongoing effort to develop an autonomous vehicle capable of detecting UXOs.

**KEYWORDS:** Image Recognition, Unexploded Ordnance, Wavelets, Neural Networks, Motion Control

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Electronic Warfare, Modeling and Simulation, Ground Vehicles

## THE NPS LOCATOR SYSTEM

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The purpose of this thesis is to design, develop and implement a personnel locator system at the Naval Postgraduate School (NPS). A prototype locator system was developed and implemented on the NPS TCP/IP network. The locator provides information such as e-mail addresses, phone and fax numbers, and building and office locations, as well as facilities such as hotlinks for e-mail applications and homepages. In addition, the NPS Locator automatically updates its personnel information on a configurable time schedule. This thesis includes a discussion of the prototype development to include requirements tools, and design. Some program code is included as appendices. This paper also discusses the benefits and considerations of intranet technology, and explores a popular Web application architecture on which the NPS Locator is based. Finally, this thesis makes recommendations for improvements to the NPS computing environment to allow for future intranet development.

**KEYWORDS**: Intranet, Directory, TCP/IP Networking, Web Application, HTTP, CCI

**DoD KEY TECHNOLOGY AREA**: Computing and Software

## SPATIAL KNOWLEDGE ACQUISITION AND TRANSFER FROM VIRTUAL TO NATURAL ENVIRONMENTS FOR DISMOUNTED LAND NAVIGATION

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Navigation and terrain familiarity are critical for mission success in the military. Virtual environments (VEs) have often been suggested as a useful tool in addressing these issues. This thesis research addresses the utility of VEs to improve spatial knowledge of and navigation performance through natural terrain compared to traditional methods. In this experiment, fifteen subjects were assigned to one of three training conditions. The map group studied the environment using only an orienteering map. The real world group studied the environment using the map and explored the actual terrain. The VE group studied the terrain using both the map and a real-time VE. Measures were taken of both route and configuration knowledge. The results suggest four conclusions. First, training conditions have no statistically significant effect on an individual's ability to obtain and demonstrate spatial knowledge of a natural environment. Second, spatial ability plays a significant role in navigation performance. Third, exposure to the actual terrain or to a virtual representation of the terrain seems to eliminate ambiguities in an individual's mental map by providing dynamic imagery to clarify propositional knowledge gained from maps. However, this factor has not been shown to improve performance by the measures used here. Fourth, a high resolution 1:5,000 orienteering map provides extensive detail and consequently, navigation performance in this experiment is not likely to be indicative of performance using a conventional 1:24,000 map.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Spatial Knowledge, Virtual Environments, Navigation, Orienteering, Geographic Information Systems, Terrain Visualization, Modeling and Simulation

## DESIGN OF A TRUSTED COMPUTING BASE EXTENSION (TCBE) FOR COMMERCIAL-OFF-THE-SHELF WORKSTATIONS

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United States Policy requires that access to and dissemination of classified information is controlled. Separate networks and workstations for each classification do not meet user requirements. Users also need commercially available office productivity tools. Traditional multilevel systems are costly and are unable to support an evolving suite of Commercial Off-The-Shelf (COTS) applications.

This thesis presents a design for a Trusted Computing Base Extension (TCBE) that allows COTS workstations to function securely as part of a multi-level network that uses high assurance multi-level servers as the backbone. The TCBE will allow COTS workstations to use commercially available software applications, while providing a Trusted Path to a high assurance multilevel server.

The research resulted in a design of a TCBE system that can be employed with COTS workstations, allowing them to function as untrusted clients in the context of a secure multilevel network.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Information Assurance, Multilevel Security, Secure LAN, Trusted Computing Base, Trusted Path

## DESIGN CONSIDERATIONS TO BE ADDRESSED WHEN DEVELOPING WEB BASED APPLICATIONS FOR SENIOR MANAGERS

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This thesis develops guidelines for building Web sites that are useful to senior managers in two ways. First, these managers can obtain information from or pass information to a site in order to accomplish tasks more effectively and efficiently. Secondly, the senior manager must be able to go to a site and use that site without being required to undergo instruction or read manuals before using the site. Web technology is in place to assist these managers in performing at a higher level. Methodologies used in this thesis combine a study using sample web sites, based on the Center for Executive Education Web Site, two surveys, database connectivity, and usability design practices to aid in Internet or intranet based applications. This document contains results from surveys of senior managers which are evaluated to select a suitable methodology for designing Web sites specifically for this subset of users.

**DoD KEY TECHNOLOGY AREA:** Other (Interface Design)

**KEYWORDS:** Usability, ODBC, Interface Design, Senior Management, Senior Managers, Internet, Intranet, Web Based Application Interface

## A STATIC SECURE FLOW ANALYZER FOR A SUBSET OF JAVA

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As the number of computers and computer systems in existence has grown over the past few decades, we have come to depend on them to maintain the security of private or sensitive information. The execution of a program may cause leaks of private or sensitive information from the computer. Static secure flow analysis is an attempt to detect these leaks prior to program execution.

It is possible to analyze programs by hand, but this is often impractical for large programs. A better approach is to automate the analysis; which is what this thesis explores.

Previous research is described and gives background information about secure flow analysis. A secure flow analyzer is presented. It implements a secure flow type inference algorithm, for a subset of Java 1.0.2, using a parser generator called Java Compiler Compiler (JavaCC). Semantic actions are inserted into a grammar specification to perform the secure flow analysis on a given program.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Secure Flow Analysis, Type Inference, Program Certification, Information Flow, Protection

## AN INTEGRATED INS/GPS NAVIGATION SYSTEM FOR SMALL AUVS USING AN ASYNCHRONOUS KALMAN FILTER

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A Small AUV Navigation System (SANS) is being developed at the Naval Postgraduate School. The SANS is an integrated INS/GPS navigation system composed of low-cost, small-size components. It is designed to demonstrate the feasibility of using a low-cost Inertial Measurement Unit (IMU) to navigate between intermittent GPS fixes.

This thesis presents recent improvements to the SANS hardware and software. The 486-based ESP computer used in the previous version of SANS is now replaced by an AMID 586DX133 based PC/104 computer to provide more computing power, reliability and compatibility with PC/104 industrial standards. The previous SANS navigation filter consisting of a complementary constant gain filter is now aided by an asynchronous Kalman filter. This navigation filter has six states for orientation estimation (constant gain) and eight states for position estimation (Kalman filtered). Low-frequency DGPS noise is explicitly modeled based on an experimentally obtained autocorrelation function. Ocean currents are also modeled as a low-frequency random process. The asynchronous nature of DGPS measurements resulting from AUV submergence or wave splash on the DGPS antennas is also taken into account by adopting an asynchronous Kalman filter as the basis for the SANS software. Matlab simulation studies of the asynchronous filter have been conducted and results documented in this thesis.

**DoD KEY TECHNOLOGY AREA:** Electronics, Sensor

**KEYWORDS:** INS, GPS, AUV, Navigation, Kalman Filter

## RE-ENGINEERING OF A MISSION CRITICAL SATELLITE COMMUNICATIONS COMPONENT TD1271B/U

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**and**
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Legacy software in general, and in the DoD environment in particular, presents an ever-growing maintenance challenge to program managers. The software is cumbersome, written in arcane languages and hosted on aging technology hardware. One of the options that is available to the program manager to alleviate this problem is to re-engineer the existing software product and update it to a newer language software hosted on modern equipment.

Existing research was revised, a re-engineering methodology was selected, an implementation strategy was developed and then a "case study" examination of this methodology and strategy was performed. For the case study, a legacy system, the Navy satellite communications multiplexer, the TD1271B/U Multiplexer, its existing documentation was developed, a code analysis tool was developed, the re-engineering on one of its sub-systems was performed, and the results analysed. Observations, recommendations and conclusions on changes, enhancements, and pitfalls to the methodology are provided that will be of assistance in future re-engineering efforts of legacy systems.

**DoD KEY TECHNOLOGY AREA**: Computing and Software

**KEYWORDS**: Reverse Engineering, Re-Engineering, Legacy Systems, TD1271

### FACILITATING RICH ACOUSTICAL ENVIRONMENTS IN VIRTUAL WORLDS

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The visual aspect of virtual environments has advanced at a rapid pace. The audio aspect, however, has not kept pace. Current methods of building virtual models do not address the graphical and audio aspects in an integrated fashion. Furthermore, graphical programming tools have not addressed sound in a satisfactory manner.

As proof-of-concept, a modeling tool was developed to allow a user to build both the visual and the auditory environment simultaneously. A rendering application was developed that would display and browse a graphical environment, an audio environment, or a complete graphical/audio environment.

This thesis demonstrates that building both the auditory and the visual geometry simultaneously allows for rapid, easy development of both the visual and the auditory environment. Enhancements and recommendations to current software technologies and modeling languages are introduced. New models to represent audio are introduced.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation

**KEYWORDS:** Virtual Audio, Virtual Environment, 3-D Audio, Spatialized Sound, Audio Environment

### DEVELOPMENT OF AN INTERNET INTRUSION PREVENTION TOOL

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This thesis explores the current shortcomings in computer and Internet security, and how the lack of user education in basic security concepts is detrimental to computer and network security. The use of cryptography and potentially expensive technical means to secure systems will fail when one neglects security education of users. This thesis addresses a portion of the security education problem by designing and developing a tool to educate users on the two major successful methods for penetrating a computer system—weak passwords and social engineering. The tool can teach users how to pick good passwords and the steps to take to prevent social engineering attacks. The tool consists of a tutorial and ends with an exam to test user comprehension concerning picking good passwords and preventing social engineering attacks.

**KEYWORDS:** Computer Security, Social Engineering, Intrusion Prevention

**DoD KEY TECHNOLOGY AREA:** Computing and Software

## THE DESIGN AND IMPLEMENTATION OF THE PETITE AMATEUR NAVY SATELLITE (PANSAT) USER SERVICES SOFTWARE

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**Second Reader: James A. Horning, Space Systems Academic Group**

PANSAT is an experimental spread spectrum, store-and-forward communications micro satellite. The Chief of Naval Operations C$^4$I staff (N6) sponsors the project in order to determine the feasibility and effectiveness of using such a low-cost satellite to augment or eventually replace the existing military satellite communications architecture. While more than eight years of work has gone into the project, most of the fifty theses thus far have dealt with hardware development. Prior to this thesis, the operations of the satellite were not formally defined, nor the desired software experiments specified.

This thesis develops a detailed definition of the communications software and operating parameters for PANSAT. The formally specified communications software provides electronic mail, binary file transfer, and direct real-time information exchange. This research also designs and develops experimental features which are non-existent on current micro satellites. The new features included provide the spacecraft with a pseudo positional awareness for a system with no sensor support for such, implement a new application layer protocol to optimize data communications, and perform self analysis to find and correct the effects of space anomalies in conjunction with a ground station.

This thesis also implements a subset of the formally specified software for initial operations to begin with spacecraft's launch in October of 1998. Further implementation and refinement will be based on actual operational results from PANSAT.

**DoD KEY TECHNOLOGY AREAS:** Space Vehicles, Command, Control, and Communications, Computing and Software

**KEYWORDS:** PANSAT, User Services, Spacecraft Engineering, Amateur Satellite Communications, Amateur Radio Service, Ground Station, Software Engineering, Fault Tolerance

## CALIBRATION AND EVALUATION OF WATER SPEED INDICATOR AND COMPASS FOR THE SMALL AUTONOMOUS UNDERWATER VEHICLE NAVIGATION FILTER

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There are three major thrusts to this thesis. The first was to design and build a device to measure ground speed for testing the position estimating capabilities of the Small Autonomous Navigation System (SANS) filter. The ground tests consisted by placing the SANS unit on a golf cart and maneuvering it along a known track. The speed sensing device uses a bicycle wheel attached to the golf cart along with an appropriate time to speed software conversion.

The next problem was to determine if the existing paddle wheel in use would be accurate enough for the SANS to conduct underway tests. To perform this, a mechanism had to be built to channel water and measure its speed while allowing the paddle wheel to be in the flow.

Finally, the electronic compass was found to have heading dependent errors, thus a test was designed to determine its deviation. This was performed by swinging the compass using a transit aligned with its axis. This established a deviation table that was inserted into the SANS code, further refining its directional capabilities.

As a final test for determining the effectiveness of the calibrated inputs, tests were conducted that showed that the SANS filter is capable of obtaining 3 meter accuracy with no Global Positioning Update for an excess of two minutes. This is well beyond the initial goals set for the system.

**KEYWORDS:** Small Autonomous Navigation System, SANS, Global Positioning

**DoD KEY TECHNOLOGY AREAS:** Electronics, Sensors, Modeling and Simulation

## SOFTWARE SYSTEM REQUIREMENTS FOR THE FUEL AUTOMATED SUBSYSTEM OF THE INTEGRATED COMBAT SERVICE SUPPORT SYSTEM (1C53) USING THE COMPUTER-AIDED PROTOTYPING SYSTEM (CAPS)

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**Second Reader: Valdis Berzins, Department of Computer Science**

The United States Army is currently developing and testing Force XXI, an attempt to redesign itself by the early years of the 21st century to incorporate digital technology and advanced weaponry. In 1996, the United States Training and Doctrine Command mandated that all combat service support disciplines be automated to the greatest extent possible. Concurrently, the Deputy Chief of Staff for Logistics, United States Materiel Command, and the Combined Arms Support Command (CASCOM) developed a future strategic vision of seamless logistics support. To support this vision, CASCOM has proposed the implementation of the Integrated Combat Service Support System (1C53) as the Army's single seamless combat service support management system. 1C53 will be a "system of systems" that automates the combat service support disciplines of man, arm, fuel, fix, move, and sustain. Specifically, the combat service support discipline of fuel will be incorporated in 1C53 as the Fuel Automated Subsystem.

This thesis analyzes current Army petroleum operations, identifies petroleum accountability/management procedures as the target domain for automation, and develops the respective software system requirements. From the software system requirements, a prototype for the Fuel Automated Subsystem is successfully developed using the Computer-Aided Prototyping System (CAPS) to illustrate the system's viability.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** CAPS, Systems Analysis, Software Requirements, Prototyping, 1C53, Fuel Automated Subsystem

## A PROTOCOL FOR BUILDING A NETWORK ACCESS CONTROLLER (NAC) FOR "IP OVER ATM"

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The implementation of *label swapping* packet-forwarding technology increases the vulnerability to insider attacks. These attacks refer to unauthorized access from within an enclave to the outside network. In this thesis a protocol is proposed to counter this category of attacks. The proposed protocol provides a means for fast packet authentication. High speed is achieved by the use of a *trailer*, which allows packet filtering at Layer 2, and the use of cheap and fast message digest algorithms. To overcome the weaknesses of a 128-bit message digest algorithm, each key is designed to have a very short cryptoperiod. Such fast rekeying is implemented by key caching (the host has a table of keys). Initial performance measurements indicated that it is possible to use the protocol while maintaining very high data throughput. Specifically, the protocol implements an authentication module, called Network Access Controller (NAC). The NAC's modular nature allows it to be easily integrated with a variety of routing technologies and other security mechanisms while remaining totally independent of them.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Protocol, Network Access Controller (NAC), Internet Protocol (IP), Asynchronous Transfer Mode (ATM)

## SOFTWARE ARCHITECTURE FOR A MULTI-LEVEL REAL-TIME SYSTEM

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When a real-time system has a mixed set of time critical tasks, including tasks with hard deadlines and tasks with soft deadlines, managing a mixed set of tasks in a timely manner becomes harder and requires a multi-level architecture. This thesis concentrates on building such an architecture.

The proposed architecture is based on the current Computer-Aided Prototype System (CAPS) architecture, which only deals with hard real-time and non-time-critical tasks. Priority-based scheduling techniques are used along with Ada tasking to schedule different levels of tasks. Periodic hard real-time polling tasks are used to insert sporadic soft real-time tasks into the system. A method is developed to assign deadlines to soft real-time tasks dynamically. Two tasking packages are added to the system for scheduling and execution of soft real-time tasks. The Earliest Deadline First (EDF) algorithm is used dynamically to schedule soft real-time tasks.

A pilot prototype is developed to test the proposed architecture via a run-time monitoring package. The results show that the proposed system guarantees that all hard real-time tasks meet their deadlines and an acceptably small percentage of soft real-time tasks miss their deadlines.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Real-Time Systems, Real-Time Scheduling, Hard Real-Time Systems, Soft Real-Time Systems, Dynamic Scheduling, Preemptive Scheduling, Priority-Based Scheduling, Ada 95, Prototyping, Uni-processor Scheduling

## FNMOC MODEL VERIFICATION SYSTEM

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Fleet Numerical Meteorology and Oceanography Center (FNMOC) forecasts the atmospheric environment and weather using several meteorological and oceanographic models. These models' forecasting abilities are verified by comparing the model forecast against the observational data and model's analysis. Currently, some models are verified by several inconsistent, maintenance-intense, non-standardized, and hard-to-use model verification systems designed for a particular model. Some models are not verified because there is no model verification system.

This thesis demonstrates the concept of a single model verification system for all FNMOC models to eliminate the inconsistencies and redundancies. The single model verification system standardizes the model verifications and provides the ability to verify those models which are currently unverified. The prototype used a GUI and web browsers to display the model verification statistics. The prototype demonstrates that convenient access to the model verification statistics could aid FNMOC users in evaluating the forecast models' performance.

This thesis identifies and documents the user specified verification requirements for several models and implements the most immediate requirements. A complete quantitative model verification system for all FNMOC models will be implemented incrementally, as all the requirements are identified.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Software Engineering, Prototype, Model Verification

### WIRELESS LOCAL AREA NETWORKS: SIMULATION AND ANALYSIS

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Wireless communication is currently in a state of rapid evolution. This evolution is driven by the numerous advantages of the wireless networks. One major constraint to this evolution is the lack of standardization. Also a major concern are the interference problems of the signal at the reception point caused by the multiple paths that the electromagnetic waves travel (multi-path interference).

This thesis presents two separate simulations. In the first, a realistic physical model of a wireless local area network is developed. In this simulation, the multi-path interference at the reception point is investigated. The results of this physics-based simulation are used to assess an important assumption in the second simulation.

In the second part, we examine the reliability of the wireless standard for the medium access control (MAC) layer, using CACI COMNET III network simulation software. This standard was published in 1997, by the IEEE's working group 802.11 and in this thesis is tested and analyzed under different network loads. One major result is that the optimum load for a five working stations wireless LAN, is from 80 to 200 packets per second. Below that load range the channel utilization is small and above that the network is overloaded.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation

**KEYWORDS:** Multipath Interference, Irradiance, Wireless Local Area Networks, CSMA\CA Wireless I-AN Protocol, Channel Utilization, Packet Delay

### LEVEL OF PRESENCE OR ENGAGEMENT IN ONE EXPERIENCE AS A FUNCTION OF DISENGAGEMENT FROM A CONCURRENT EXPERIENCE

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It is uncertain what effect presence has on virtual environments (VEs) but it is believed to enhance both learning and enjoyment. To date, there exist only subjective methods of measuring the level of presence in VEs. In order to effectively utilize VE technology, it is necessary to gain a greater understanding of presence and the factors that affect it. Therefore, a quantifiable method of measuring presence is needed. This metric would provide a framework for design requirements for predictable, repeatable performance in VEs.

To investigate a proposed new metric, 70 individuals participated in an experiment based on the dual task paradigm of attention theory. The purpose of the experiment was to determine the level of presence or engagement in one experience as a function of disengagement from a concurrent experience. Participants received two simultaneous experiences, one virtual, the other real, and were given quizzes on each to determine their focus of attention at various stages.

Results indicate: 1) HMDs occlude all but one of concurring experiences preventing the dividing of attentional resources; 2) Including sound increases the level of engagement in an experience and allows for dividing of attentional resources between concurrent experiences; 3) Responses to previously established presence questionnaires correlate strongly

with this new measurement of engagement indicating that this method does have validity; and 4) Primed participants exhibit a decrease in levels of engagement in both experiences due to the focus of attention being divided.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Other (Measuring Presence in VE and VR)

**KEYWORDS:** Modeling and Simulation, Measuring Presence, Virtual Environments, Virtual Reality, Computer Graphics. Measuring Presence in VE, Measuring Presence in VR, Telepresence

### DYNAMICALLY EXTENDING A NETWORKED VIRTUAL ENVIRONMENT USING BAMBOO AND THE HIGH LEVEL ARCHITECTURE

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The design and execution of a networked virtual environment (NVE) are challenging tasks made even more difficult by the fact that NVEs are becoming more complex and difficult to manage. In a distributed environment, each simulation not only computes its own behaviors and publishes them to the network, but it must accurately represent all other entities participating in the NVE. To simplify this task, this thesis implements methods to make distributed simulations dynamically extensible, flexible, specific, and consistent. Bamboo provides the ability to dynamically extend the virtual environment by defining a convention by which plug in modules can be added during simulation runtime. The HLA provides the network communication layer that transports entity state updates to all members of the distributed simulation. These two tools combine to create a unique solution to problems inherent in designing modern networked virtual environments. The implementation is dynamically extensible which increases the flexibility implementers have in designing virtual environments. The HLA transports the entity updates and the module name that must be used to represent the entity. This method allows programmers to design only their module because modules representing other entities will load as needed during the execution. This method of implementing virtual environments promises to streamline the design and implementation process.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation

**KEYWORDS:** Network Virtual Environment, Bamboo, High Level Architecture, HLA

### THE CAPABILITIES, PROPAGATION EFFECTS, AND TARGETING OF COMPUTER SYSTEMS

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In this thesis a new Microsoft Word Macro computer virus is constructed and evaluated to determine its capabilities and effects. The Microsoft Word macro virus was selected because in the past two years, it has been the number one reported virus among systems and offers the potential of platform independence. The characteristics of computer systems and an understanding of what constitutes a computer virus are used to identify the particular functions that enable viral activity to occur. The construction of a new virus provides a test program for performing a vulnerability assessment of a computer system. The targeting capabilities of the computer virus are analyzed and an organizational model is presented to evaluate its potential impact. The end result is a systems approach to an Information Warfare problem with a method of attack and an assessment for understanding the impact of such an attack. The assessment of the organizational model can best be analyzed using simulation tools which can produce confidence levels on the impact of the computer virus through the networked organization.

**DoD KEY TECHNOLOGY AREA:** Other (Information Operations/Information Warfare)

**KEYWORDS:** Computer Viruses, Computer Security, Information Warfare, IW Attack Tools, Vulnerability Assessment

## A GUI INTERFACE FOR REUSABLE COMPONENTS STORAGE AND RETRIEVAL IN THE CAPS SOFTWARE BASE

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With the increase in size and complexity of software component repositories, the need for an easy to use search and retrieval process becomes a necessity. Multilevel filtering shows great promise as a quick accurate search algorithm. This approach applies a series of filters starting with high recall, low precision syntactic techniques, moving through a range of more computationally expensive high precision syntactic filters.

The goal of this thesis is to develop a graphical user interface, using multilevel filtering, to make searching the CAPS component repository a less tedious task. The interface will make the retrieval process less error prone. The user would not need to be an expert in how the software base works thus increasing the ease of use and productivity. The current prototype system has a limited user interface capability. This research will add a graphical user interface for both retrieval and maintenance.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Software Reuse, User Interface, Multilevel Filtering, Profile Filtering, Signature Matching

## A TASK ANALYSIS OF UNDERWAY REPLENISHMENT FOR VIRTUAL ENVIRONMENT SHIP-HANDLING SIMULATOR SCENARIO DEVELOPMENT

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While developing a Virtual Reality (VR) Ship-handling simulator for the Surface Warfare Officer School (SWOS) in Newport, RI, researchers at the Naval Air Warfare Center Training Systems Division (NAWCTSD) in Orlando, FL discovered a need for a task analysis of a Conning Officer during an Underway Replenishment (UNREP). The purpose of this task analysis was to document the tasks the Conning Officer performs and cues used to accomplish these tasks. The task analysis would ensure that the correct tasks and cues would be modeled in the VR UNREP scenario.

The approach taken was to survey cognitive task analysis models to find a notation that would document the tasks performed by a bridge team during an UNREP. The Goals, Operators, Methods, Selection Rules (GOMS) model was selected. A GOMS-like model was used to represent the sequential aspects of the UNREP task, while a table was developed to capture the parallelism of the tasks. The UNREP task analysis was then reviewed by qualified Surface Warfare Officers to validate its accuracy.

The result of this effort was a validated task analysis model of a Conning Officer during an UNREP. This model was provided to NAWCTSD in support of their future efforts in the development of a VR UNREP Ship-handling simulator scenario.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Human Systems Interface, Manpower, Personnel and Training, Modeling and Simulation

## USING DISCRETE-EVENT SIMULATION TO ADDRESS THE PROBE EFFECT IN SOFTWARE TESTING OF REAL-TIME DISTRIBUTED SYSTEMS

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The term *probe effect* denotes behavioural changes caused by introducing delays into a concurrent program with synchronization errors. This thesis investigates the feasibility of developing discrete-event simulation (DES) models of software architectures to perform software testing free of the probe effect.

A message-passing subsystem (MPS) and simulated MPS (SMPS) were developed in Java that runs with the same application code. An MPS platform-performance model (MPPM) was developed using dual-loop benchmarking and was integrated into the SMPS. Two demonstration programs were developed to study SMPS timing and its model of a pre-emptive multi-threaded run-time system. The SMPS-based program behavior was compared to hypothetical execution on a platform with a perfect system clock and no execution overhead.

The differences between hypothetical and observed SMPS-based execution were found to correctly reflect the MPPM. The results indicated that it is feasible to develop DES implementations of some software architectures to perform software testing.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation

**KEYWORDS:** Software Testing, Object-Oriented Analysis, Java, Discrete-Event Simulation, Dual-Loop Benchmark, Software Architecture, Real-Time, Distributed Systems

## SECURITY ISSUES FOR THE SOFTWARE EVOLUTION MODEL

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This thesis examines the security requirements of the software evolution model and identifies possible security mechanisms called "control classes" that are applicable to the model. Then, based on combinations of "control classes," proposes a suitable security level for each of the model's databases. Furthermore, this thesis deals with the possibility of using Pretty Good Privacy as a method for protection of software data stored in databases.

The software evolution model captures all the necessary changes in requirements early during the development process in order to help in minimization of project cancellation, delivery delays, and extra costs for fixing errors. The protection of software data against unauthorized accesses and modifications is a primary consideration for the software evolution process. In this way, we can develop a secure environment on which the software evolution can rely for accomplishing its goal.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Database Security, Software Evolution, Software Data Security, Pretty Good Privacy, Data Encryption/ Decryption

## IMPLEMENTATION OF REQUIREMENTS TRACING IN THE PROTOTYPING ENVIRONMENT UTILIZING PROTOTYPING DESCRIPTION LANGUAGE (PSDL)

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The prototyping description language (PSDL), a key component of Computer-Aided Prototyping (CAPS), is a language designed for clarifying the requirements of complex real-time systems. Through the use of prototyping, the functional requirements for an embedded system can be rapidly validated to preclude inefficient usage of resources. This research has concentrated on the software engineering area of extending the PSDL data type and Ayacc source to support requirements tracing. Currently, CAPS doesn't use requirements tracing so the extensions just described are a significant step in that direction. This thesis includes an investigation into the potential use of an OODBMS which will interface with ADA95 and be utilized to store the list of requirement ids for each PSDL component.

Through the ADA95 program implementation and extension to the capabilities of the PSDL data type and Ayacc source, the programmer/designer has automated documentation support which will link the requirement ids to their respective component names. This research demonstrates there is no ADA95 OODBMS at the current time and therefore the requirement ids are stored in a file. There is an ADA95 OODBMS being developed at Lockheed Martin under the project name of FIRM. Also demonstrated is the connection of the unique list of requirement ids in the design phase with their respective PSDL components, so that the link between the design stages and analysis phase support for the modules is more completely established.

**KEYWORDS:** PSDL, ADA95, AYACC, OODBMS

**DoD KEY TECHNOLOGY AREA:** Other (Software Engineering)

## A BENCHMARK USABILITY STUDY OF THE TACTICAL DECISION-MAKING UNDER STRESS DECISION SUPPORT SYSTEM

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This study evaluates the usability of a U.S. Navy Decision Support System (DSS). The DSS was developed to enhance the performance of tactical decision-makers within a Navy Combat Information Center. The goals of this study were to test the DSS against usability criteria and objectives to track future redesign efforts and system improvements. The purpose of this analysis was to: (1) assess the system's usability, (2) identify problems areas in the graphical user interface, (3) report trends in user feedback, and (4) provide recommendations addressing major usability issues encountered by participants. The study tested whether the DSS met the usability objectives of: (a) 90% successful task completion, (b) ease-of-use ratings of somewhat easy or better, and (c) satisfaction ratings of somewhat satisfied or better. The DSS did not meet these usability objectives for task completion or ease-or-use; however, the DSS did meet the usability objective for user satisfaction. All participants reported that they enjoyed working with the DSS and believed that it would be a significant step forward in information management. Based on the usability data gathered in the study, recommendations are provided to address the usability issues.

**DoD KEY TECHNOLOGY AREA:** Human Systems Interface

**KEYWORDS:** Usability, Human Factors, Human Computer Interaction, Synthetic Environments, Decision Support

## IT-21 COMPLIANT CONTROLLED ACCESS TO INTERNET WEB PAGES

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Although numerous resources are available to achieve Internet presence by creating and publishing a web site, security and access control within the site are very limited. The Navy's support of the IT-21 initiative embracing the Microsoft® Windows NT® operating system (OS) provides solutions to not only restrict entry to the site, but also to control access to content on the web page.

Work detailed in this thesis addresses the issue of security by exploring the Windows NT OS and activating its inherent security features to protect the overall system from intrusion and attacks from the Internet. The web pages are published using Microsoft® Internet Information Server 4.0 (IIS) and FrontPage™ 98. Access is controlled by issuing certificates from the resident Microsoft® certificate Server software package or remotely by VeriSign™ OnSite service. Windows NT and IIS permit a certificate to be mapped to a system account to further define the level of access assigned to each user down to the file level.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Electronic Warfare

**KEYWORDS:** IT-21, Microsoft Windows NT, Microsoft Internet Information Server, Certificates

## AUDITORY-VISUAL CROSS-MODAL PERCEPTION PHENOMENA

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The quality of realism in virtual environments is typically considered to be a function of visual and audio fidelity mutually exclusive of each other. However, the virtual environment participant, being human, is multi-modal by nature. Therefore, in order to more accurately validate the levels of auditory and visual fidelity required in a virtual environment, a better understanding is needed of the intersensory or cross-modal effects between the auditory and visual sense modalities.

To identify whether any pertinent auditory-visual cross-modal perception phenomena exist, 108 subjects participated in three main experiments which were completely automated using HTML, Java, and JavaScript computer programming languages. Visual and auditory display quality perception were measured intramodally and intermodally by manipulating visual display pixel resolution and Gaussian white noise level and by manipulating auditory display sampling frequency and Gaussian white noise level.

Statistically significant results indicate that 1) medium or high-quality auditory displays coupled with high-quality visual displays increase the quality perception of the visual displays relative to the evaluation of the visual display alone,

and 2) low-quality auditory displays coupled with high-quality visual displays decrease the quality perception of the auditory displays relative to the evaluation of the auditory display alone. These findings strongly suggest that the quality of realism in virtual environments must be a function of both auditory and visual display fidelities inclusive of each other.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Human Systems Interface, Modeling and Simulation

**KEYWORDS:** Virtual Environment, Auditory Display, Visual Display, Perception, Cross Modal, Fidelity, Experimental Design

## HELICOPTER TERRAIN NAVIGATION TRAINING USING A WIDE FIELD OF VIEW DESKTOP VIRTUAL ENVIRONMENT

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Helicopter terrain navigation is a unique task; training for this task presents unique challenges. Current training methods rely on dated technology and inadequately prepare pilots for real-world missions. Improved training specifically tailored to address the unique needs of the helicopter community that capitalizes on recent improvements in desktop virtual environment (VE) technology could substantially improve the training process and reduce training costs.

Based on the input of subject matter experts in current helicopter terrain navigation training techniques and VE technology, such a system was developed and tested on student pilots performing real-world tasks. A desktop VE that presented a simple to control and learn, interactive fly-though of a terrain model was used to augment conventional training at Helicopter Antisubmarine Squadron TEN (HS-10).

Results indicate that flight time for students that received VE training was more productive than for students that received conventional training. This work justifies the next logical step: fielding a system on a long-term basis as a squadron asset. This system would provide improved training for the helicopter community and an invaluable source of research data for the Naval Postgraduate School.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Other (Training)

**KEYWORDS:** Virtual Environments, Terrain Association, Navigation, Training, Mission Rehearsal, Helicopters

## HANDHELD COMPUTER APPLICATIONS IN THE NAVY COMMAND ENVIRONMENT

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As society becomes increasingly information-oriented, the drive for more capable machines to retrieve, store, process, and present such information anywhere, at anytime becomes paramount to success. This is true of United States Navy and Marine Corps officers who must manage large amounts of information while operating in remote areas. Today's very small, portable computers known as "palmtops" are capable of running powerful scaled-down versions of contemporary operating systems. When coupled with a transmission medium, palmtops represent a portable computer that can be used to communicate and process information in ad hoc environments. The Naval Postgraduate School Staff Officer Palmtop Computer Project is designed to analyze the effectiveness of Windows CE-based palmtop computers as an aide to professional Naval officers. The study project provides Naval officers with a popular palmtop computer and allows them to use the device for

a four-week period. During this time participants are encouraged to use the palmtop for work and personal information tasks. The primary complaints with these devices are ergonomically oriented. There is no convenient and reliable method of data entry and they cannot be easily carried while in uniform. Results from the study indicate that current Windows CE "handheld PCs" are not appropriate for use in this capacity. Recommendations for more useful portable personal computers complete this research.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Human Systems Interface

**KEYWORDS:** Mobile Computing, Handheld Computers, Palmtop Computers, Windows CE

## MIGRATING FROM WIN NT 4.0 TO WIN NT 5.0 IN THE MARINE CORPS ENTERPRISE NETWORK (MCEN)

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The purpose of this study is to provide the United States Marine Corps (USMC) with an analysis of Windows NT 5.0 Network Operating System (NOS). This analysis will assist the Network Operations Center (NOC) in preparation for the eventual migration of Windows NT 5.0 into the Marine Corps Enterprise Network (MCEN).

NT 5.0 offers some significant enhancements over earlier versions. Active Directory provides a unified platform to manage NOS resources by storing user information, network shares and policies. NT File System (NTFS) version 5 permits dynamic allocation of primary storage space to each user. NT 5.0 also improves network security by incorporating use of the Kerberos Version 5 protocol, providing integrated security for authentication and file encryption.

A top-down migration strategy should be incorporated by the NOC. Particularly important is how the NOC builds the Domain Naming Service (DNS) conventions for the MCEN. This will require every subordinate unit to adhere to the naming convention of its chain of command.

Migrating from Banyan Vines to Windows NT presents a significant change to the organization. An effective Change Management strategy can assist members of the organization in understanding the sense of loss and uncertainty that occur in times of transition, and to deal with these changes effectively.

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Computing and Software, Manpower, Personnel, and Training

**KEYWORDS:** USMC, Marine Corps Enterprise Network, MCEN, Network Operations Center, NOC, Network Operating System, NOS, WIN NT 5.0, NT, Change Management

## CHANNEL ALLOCATION IN WIRELESS INTEGRATED SERVICES NETWORKS FOR LOW-BIT-RATE APPLICATIONS

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This work addresses issues related to the design and performance of a wireless integrated services network with emphasis on a tactical framework. We propose an asynchronous transfer mode (ATM)-like protocol architecture for the mobile network, which is an extension of schemes proposed in the literature. A medium-access-control (MAC) scheme, based on slot reservation by the remotes, is proposed for the network. Traffic models for low-bit-rate applications, suitable for low-capacity channels, such as a multiple-access (macrocell) wireless network, are presented. New bi-directional speech-conversation and bursty data models are proposed.

The issue of scheduling in wireline integrated services networks is thoroughly addressed and new algorithms are proposed. An analytical scheme to obtain the required (static) capacity for homogeneous sources based on their Markov-chain characterization is provided. A necessary condition for optimality of a scheduling algorithm is the balance of cell-loss-probability (CLP) ratios to values approaching 1 from below, on the boundary of the admissible region. The balanced-CLP-ratio (BCLPR) algorithm satisfies this condition but ignores the deadlines of the cells. The shortest time to extinction (STE) with BCLPR (STEBR) algorithm, proposed here for the first time, utilizes the earliest-deadline-first concept while satisfying the necessary condition. A proof is provided to show that the STEBR decisions are optimal at each service slot given that no information about future traffic arrivals is available. Simulation results indicate that STEBR admits more sources and yields larger normalized channel throughput (by up to 4%) than STE.

The wireless network presents a case of distributed queues at the command post (CP) and in the remotes, making channel allocation more involved compared to scheduling in wireline systems. Based on the schedulers discussed for the wireline queue, corresponding algorithms for operation in the wireless network are developed. The cases of partial and complete status reports of the remotes are investigated as a function of the network load in five representative scenarios. The following (descending) order of performance under both partial and complete status reports is maintained in all scenarios:STEBR, STE, BCLPR, and static allocation. Performance of the schedulers using partial or complete status reports depends on the value of the normalized throughput. The complete-status mechanism is preferred whenever the normalized throughput is smallerthan 0.70-0.75; partial status reports are sufficient for normalized throughput larger than 0.70-0.75. A hybrid approach that makes use of this outcome is proposed to best utilize the available channel capacity under all possible levels of network load.

**DoD KEY TECHNOLOGY AREA:** Command, Control, and Communications, Modeling and Simulation, Other (Networking)

**KEYWORDS:** B-ISDN, ATM, MAC, Scheduling, Channel Allocation, Mobile Networks, Low-Bit-Rate Source Models

## MANAGEMENT SYSTEM FOR HETEROGENEOUS NETWORKS SECURITY SERVICES

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Military C41 facilities form an enormous network of distributed, heterogeneous computers. Operating these computers such that commanders can exploit their computing power effectively requires a resource management system. Management System for Heterogeneous Networks (MSHN) is a program under development specifically designed to address this need.

Security for distributed computing systems is of particular importance to the Department of Defense. Previously developed resource management systems have largely neglected the issue of security. This thesis proposes a security architecture through which MSHN can achieve its goal of providing optimal usage of compute resources while simultaneously providing security commensurate with the software and data processed. A demonstration of the security framework was created using Intel Corporation's Common Data Security Architecture (CDSA). CDSA provided the cryptographic mechanisms required to build the security framework.

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Computing and Software

**KEYWORDS:** MSHN, Distributed Computing, Security Mechanisms, Common Data Security Architecture, Virtual Heterogeneous Machine

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