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**MODELING AND SIMULATION EDUCATION:
IS THERE A NEED FOR GRADUATE DEGREES IN MODELING AND SIMULATION?**

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ABSTRACT

The authors represent educational institution that currently offer simulation programs and non-educational organizations with vested interests in simulation education. The programs represented by the panel members provide a varied perspective on the answer to the questions "What skills do simulation professionals need?"; "Are separate simulation programs needed?"; "Is there a sufficient body knowledge to warrant programs in simulation?"; "Do existing programs in computer science, operations research, and engineering provide sufficient simulation education to meet simulation demand?". Panel discussions will center on these and other issues related to the growth and need of degree programs in simulation.

INTRODUCTION

The increasing success and promise of simulation methodologies and technologies to contribute to the solution of the complex of challenges confronting industry, government, military, and education has created an unprecedented demand for skilled simulation professionals at multiple levels. Simulation professionals are needed to:

- Discover, design and develop basic simulation principles and methodologies.
- Design, develop, and manufacture simulation product.
- Apply and use simulation products to meet specified goals and objectives of an enterprise.
- Manage and integrate simulation into projects and enterprise wide development plans.
- Integrate simulation into the decision processes of managers and leaders..

However, the questions confronting the demand sources are, "Where do simulation professional come from?" and "Exactly what skills do simulation professionals need?"

A number of academic institutions have tried to answers these questions through programs which provide tracks, options, and even degrees in simulation. These academic institution's answers have, in turn, raised more questions, questions such as: "Are separate simulation programs needed?"; "Is there a sufficient body knowledge to warrant programs in simulation?"; "Do existing programs in computer science, operations research, and engineering provide sufficient simulation education to meet simulation demand?"; "What is a simulation professional?"

BACKGROUND

Simulation is ubiquitous in today's leading-edge concepts and applications in entertainment, training, design, planning, and decision making. Current realities include virtual environments where soldiers conduct exercises with teams around the world without leaving their home base. No new auto assembly line or microchip fabrication facility would be built today without extensive simulation of every aspect of the proposed operation. In the development of new aircraft, parts are tested for form, fit, and function in a simulation before they are turned over to manufacturing to build. Simply, simulation reduces risk in endeavors where failure cannot be afforded even once. For better or worse, in today's competitive and dynamic environment, the number of failures an enterprise can or will accept is dropping and, in the process, creating an increasing demand for simulation products and services.

The U.S. Military alone has committed tens of billions of dollars to simulation and simulation based technologies and processes over the last decade. Further, simulation is one of few areas of DoD's budget which has been increasing over the last few years. The May 1996 issue of *Industrial Engineering Solutions* provided a buyer's guide for simulation software targeted to manufacturing and service organizations that identified 30 companies selling simulation software. The combined sales of these companies are in the hundreds of millions of dollars. The Winter Simulation Conference's growth from a few hundred attendees a decade ago to close to a 1000 attendees today reflects the increasing interest and importance of simulation to a variety of segments of the world economy. While these anecdotal stories do not tell the full story, the simulation industry is clearly an integral and critical part of the world's military and industrial base. Further, the simulation industry represents a significant economic force in itself through its direct employment of tens of thousands if not hundreds of thousands of people.

Given the importance of simulation both as a fundamental tool for enterprise operations and as a significant economic segment of the economy, it is surprising that simulation exposure in most formal education programs has been through adjunctive or elective courses and projects. Few formal programs exist which purport to emphasize simulation or integrate it thoroughly in the philosophy of the curriculum. Those that do claim a simulation emphasis have only begun to do so in recent years.

Today's simulation professionals are typically a product of the equivalent of a high-tech apprenticeship and on-the-job training. Simulationists have typically evolved under the mentoring/apprenticeship of others

such as a university researcher or organizational leader or simply by successfully responding to pressures of competition and opportunity. While the simulationist's education has typically been grounded in traditional science and engineering degrees, their breadth and depth of simulation knowledge has come primarily through direct trial and error empiricism or through a corporate oral tradition of lessons learned. Not surprisingly, this hap-hazard approach has led to what Dr. Anita Jones, Director of Defense Research and Engineering at the U.S. Department of Defense, refers to as "...a lack of a gene pool [in simulation]".

Whether there is a true lack of professionals in simulation or merely a lack of correct classification of professionals can surely be debated. However, simulation is an important and growing industry and industry and government perceive a shortage of qualified and educated simulation personnel. What is not clear is what the market expects from academia in simulation education.

The educational institutions represented in this panel are pursuing educational strategies to meet the perceived needs and markets for advanced education in modeling and simulation. The following provides an indication of the academic discipline base, the philosophy and directions of their efforts. The panel hopes this session is the beginning of a sustained dialogue on need, merits, and directions of simulation education.

AIR FORCE INSTITUTE OF TECHNOLOGY

The Department of Operational Sciences at the Air Force Institute of Technology (AFIT) offers M.S. degrees in both Operations Research and Operational Analysis and the Ph.D. degree in Operations Research. The program offers a specific concentration in modeling and simulation (M&S). The purpose of these programs is to educate Air Force officers and both Department of Defense (DoD) and non-DoD civilians in the theory and practice of operations research, with special emphasis on their application to defense-related problem solving and decision making.

The M.S. program in Operational Analysis is designed to prepare military officers with operational backgrounds to conduct analyses of military forces. It provides its students with a broad exposure to operations research techniques along with coursework that relates specifically to operational Air Force (AF) issues. Graduates of this program among the premier analysts in the AF and are capable of mathematically modeling and simulating various operational situations, including war or peace-time scenarios. Research conducted by these students has examined force-structure tradeoffs,

force employment, campaign planning, and engagement modeling.

The graduate programs in Operations Research are designed to provide mission-ready, advanced-degree officers and civilians with more specific exposure to operations research techniques that support both AF Force and DoD M&S initiatives. Graduates of this program are typically assigned to analysis groups at the Pentagon, major command headquarters, AF product centers, and other DoD agencies. Research conducted by these students has supported resource allocation, cost and operational effectiveness analyses, test and evaluation, and logistics. Many students in this program also tailor their programs to provide a concentration in modeling and simulation.

The department also houses AFIT's Center for Modeling, Simulation, and Analysis which provides the resources necessary for research and consulting activities in all areas of M&S. The Center is AFIT's focal point for modeling, simulation, and analysis and, like the department, actively supports the Air Force's new vector in modeling and simulation. It provides a broad range of faculty expertise that crosses traditional department boundaries and fosters research and consulting efforts in M&S that enable the Air Force to more fully develop and exploit its joint warfighting capability.

NAVAL POSTGRADUATE SCHOOL

The proposed Modeling, Virtual Environments and Simulation (MOVES) Curriculum of the Naval Postgraduate School provides the MS and Ph.D. students both fundamental and specialized courses in applied computer simulation technology and the application of quantitative analyses to human-computer interaction in simulation technology. The MS program is a two year, eight quarter program whose core covers the fundamentals of computer science and human-computer interaction. These topics include object-oriented programming, artificial intelligence, software methodology, computer communications and networks, computer graphics, virtual worlds and simulation systems, probability, statistics, stochastic modeling, data analysis, and human performance evaluation.

Specialization by the MS student is accomplished by choosing a track and completing a sequence of courses providing depth in the selected area. There are two tracks that support the curriculum's research efforts, the Visual Simulation Track and the Human-Computer Interaction Track.

Once the MOVES Curriculum core courses have been taken and while the specialization courses are underway, the final step in the MS degree is the

completion of a written thesis. This thesis is usually conducted on a research problem specified by a thesis advisor attached to a MOVES associated laboratory. Current laboratories working with the MOVES Curriculum are the NPSNET Research Group, a leading developer of networked, large-scale virtual environments, and the Information Infrastructure Research Group (IIRG), whose focus is on advanced network issues such as asynchronous transfer mode (ATM), multicast backbone (MBONE) and internetworking regional research institutions.

The Laboratory for Human Interaction in the Virtual Environment (HIVE Lab), a part of the Naval Postgraduate School's Computer Science Department, is the premier site for the study of insertion of humans into virtual environments. The HIVE lab is an off-shoot of the NPSNET Research Group - a leading developer of real-time, interactive 3D networked virtual worlds for the combat simulation arena. In recent years, this experience has been utilized to create human-centered training systems in the NPSNET virtual environment (VE); systems to provide shipboard Officer-of-the-Deck (OOD) training, shipboard walkthrough and damage control training, submarine operations training, and naval Anti-Submarine Warfare (ASW) helicopter flight training.

This work is now being expanded for placing humans in the VE in order to deliver more advanced interactive training and analysis systems. The design of human based simulation systems is an interactive process. Work initially focuses on the detailed analysis of the user requirements for these systems. It is then decided what can be accomplished within the present limits of simulation technology. Prototyping of the desired features is done using a variety of tools in order to facilitate analysis of the system components and to allow for user testing. This process is repeated in order to allow for modification of the deployed systems based on previous learning.

Areas of Human Study: development and promotion of standards, user-centered design issues, development and evaluation of tools, CBone and vrtp integration, development of training systems, definition of hardware requirements, development of software architectures, development of network architecture, advancement of DIS and HLA standards, and analysis of existing software.

CRANFIELD UNIVERSITY AT THE ROYAL MILITARY COLLEGE OF SCIENCE

The Cranfield University at Royal Military College of Science's (RMCS) MSc program in Defence Modeling and Simulation aims to explain the main principles of

hardware and software, including the underlying models, used in creating a synthetic battlefield and to consider the issues associated with procuring, using and managing such facilities for the training, testing, and assessment of military forces and equipment. The program provides opportunities for the modeling and simulation of specific systems and practical experience with relevant computer software; lectures, seminars, worked examples and visiting speakers are used as necessary. Modules in the program include: Foundations of Modeling and Simulation, War Gaming and Combat Modeling, Reusable Software, Computer Graphics, Expert Systems, Neural Networks, Parallel Processing, Systems Dynamics, and Modeling and Simulation in Engineering Systems. The RMCS has seen a major investment in simulation by the Royal Ministry of Defence in the setting up of the Simulation and Synthetic Environment Laboratory and the sponsorship of the one week Introduction to Defence Simulation course.

The MSc program in Defence Modeling and Simulation is run by the Department of Applied Mathematics and Operational Research (AMOR) within the School of Defence Management, with substantial contributions coming from other departments within the College. AMOR already runs a set of modular MSc programs in Mathematical Modeling, Military Operational Research, Numerical Methods and Software Systems, and Scientific Applications Software.

UNIVERSITY OF CENTRAL FLORIDA

The simulation focus at the University of Central Florida (UCF) is on the Department of Industrial Engineering and Management Systems' internationally recognized M.S. program in Simulation Systems. Developed in 1984 to support the Center of Excellence in Simulation and Training concept for Central Florida, this program is designed to prepare individuals with undergraduate degrees in engineering, mathematics, or science for careers in the modeling and simulation field.

The Department of Industrial Engineering and Management Systems (IEMS) is a world leader in preparing engineers, scientists and managers to design integrated simulation systems. Its M.S. in Simulation Systems provides the most comprehensive graduate degree program available in simulation. The Masters of Science in Simulation Systems provides a choice of two program tracks: Simulators and Training Systems Track and Simulation and Analysis Track.

The Simulators and Training Systems Track responds to the needs of those who wish to pursue or are currently pursuing careers in the training simulation/simulator industries. The underlying theme

and philosophy of this track is Systems Engineering and Project Management. Graduates of the Simulators and Training System Track possess the basic tools to create system designs for simulators and simulator based training systems and provide project management for the development of such systems. Typical required courses include: Simulator Engineering, Simulation of Real-Time Processes, and Project Engineering. The IEMS Department's close relationship with UCF's Institute for Simulation and Training (IST) and the simulation industry presence in Central Florida provides the opportunity to experience the training simulation/simulator first-hand.

The Simulation Modeling and Analysis Track caters to those who desire to gain expertise in simulation as an analysis and design tool for effective planning and decision making. The emphasis of this track is on problem definition, model formulation, and model based analysis. A graduate will be prepared to work with developers, planning offices and decision makers as they model and evaluate the impacts of proposed policies and systems designs. Typical courses include: Discrete System Simulation, Experimental Design, Object-Oriented Simulation, and Intelligent Simulation. Opportunities are available to work with researchers and faculty on simulation projects.

The University of Central Florida is at the center of the world's largest modeling and simulation community, with a current work force of over 8,000 people. This work force includes over 100 private companies, as well as, the Department of Defense's major commands associated with simulation and training including the Army's Simulation, Training and Instrumentation Command (STRICOM), the Navy's Naval Airwarfar Center-Training Systems Division (NAWC-TSD), and the Air Force's Agency for Modeling and Simulation (AFAMS). A vital component is the Central Florida Research Park. Adjacent to our main campus, the park was established by the Florida Legislature in 1978 and is the home the STRICOM, NAWC-TSD, and AFAMS as well as many of the nation's principle training and simulation/simulator companies.

DEFENSE MODELING AND SIMULATION OFFICE

On June 21, 1991 the Undersecretary of Defense for Acquisition, Mr. Don Yockey, established the Defense Modeling and Simulation Office (DMSO) to serve as the executive secretariat for the Executive Council on Modeling and Simulation (EXCIMS) and to provide a full-time focal point for information concerning DoD modeling and simulation (M&S) activities. Currently

the DMSO promulgates M&S policy, initiatives, and guidance to promote cooperation among DoD components to maximize efficiency and effectiveness. DMSO is a staff activity reporting to the Director, Defense Research and Engineering, office of the Undersecretary of Defense for Acquisition and Technology (USD(A&T)).

The DMSO's functions include, but are not limited to:

- Promulgating policies, at the direction of the USD(A&T), that facilitate the application of M&S among joint education and training, research and development, test and evaluation, and operations and cost analysis disciplines.
- Distributing USD(A&T) approved guidelines to assist in military Service Component development of consistent M&S plans in the areas of: configuration management, verification, validation, accreditation, and releasability.
- Developing USD(A&T) approved liaison processes to coordinate and assist in the development, acquisition, and sharing of M&S technology, standards, verification, validation, and accreditation processes among DoD Components and the Defense industry.
- Developing USD(A&T) approved mechanism to foster cooperation among DoD components to maximize M&S interoperability while eliminating redundant development of advanced M&S technologies.
- Advising USD(A&T) on matters relating to improving the use of models and simulations that support input to the Joint Requirements Oversight Council, Defense Planning and Resource Board, and the Defense Acquisition Board.
- Initiating and sustaining a research and development program aimed at improving M&S tools, data bases, associated network concepts, standards, interoperability, interfaces, and accreditation technologies that are applicable to the operations analysis, RDT&E, and training elements of Defense business.
- Documenting requirements for, and developing programs to establish, a clearinghouse network to facilitate M&S information exchange among appropriate users.
- Determining requirements, delineating procedures, and identifying research and development efforts to improve effectiveness and efficiency among existing systems and facilities where appropriate.
- Identifying high priority M&S technology objectives for future investment.
- Documenting resources required and available to execute candidate M&S improvement projects and providing the EXCIMS a basis to approve joint investment plans for M&S projects.

- Conducting evaluations of funded M&S projects to verify progress and validate candidacy for continued resourcing or termination as appropriate.

AUTHOR BIOGRAPHIES

RALPH V. ROGERS is Program Coordinator for the Modeling and Simulation Academic Initiative at the University of Central Florida and is an Associate Professor in the Industrial Engineering and Management Systems Department. He is also a member of the Intelligent Simulation Training Systems Laboratory at Central Florida and has performed research for NASA and the FAA on modeling autonomous objects in air traffic control simulation. Prior to joining the faculty of Central Florida in 1986, Dr. Rogers was on faculty of the Industrial and Systems Engineering Department of Ohio University (1984-1989). He has also worked as a senior project engineer for U. S. Navy's Naval Electronics Engineering Center and for Booz-Allen Applied Research in Bethesda, Maryland. Dr. Rogers received his B.S. degree in Electrical Engineering and his M.S. in Industrial and Systems Engineering from Ohio University, Athens, Ohio in 1971 and 1983, respectively, and received his Ph.D. in Systems Engineering from the University of Virginia, Charlottesville, Virginia in 1987.

MICHAEL ZYDA is a Professor in the Department of Computer Science at the Naval Postgraduate School, Monterey, California. Professor Zyda is also the Academic Associate and Associate Chair for Academic Affairs in that department. He has been at NPS since February of 1984. Professor Zyda's main focus in research is in the area of computer graphics, specifically the development of large-scale, networked 3D virtual environments and visual simulation systems. Professor Zyda is a member of the National Research Council's Committee on Virtual Reality Research and Development. Professor Zyda is also the Senior Editor for Virtual Environments for the MIT Press quarterly PRESENCE, the journal of teleoperation and virtual environments. For that journal, Professor Zyda has co-edited special issues on "Pacific Rim Virtual Reality and Telepresence", on "The Application of Virtual Environments to Architecture, Building and Large Structure Design", and on "Networked Virtual Environments and Teleoperation". Professor Zyda has been active with the Symposium on Interactive 3D Graphics and was the chair of the 1990 conference, held at Snowbird, Utah and the chair of the 1995 Symposium, held in Monterey, California. Professor Zyda began his career in Computer Graphics in 1973 as

part of an undergraduate research group, the Senses Bureau, at the University of California, San Diego. Professor Zyda received a BA in Bioengineering from the University of California, San Diego in La Jolla in 1976, an MS in Computer Science/Neurocybernetics from the University of Massachusetts, Amherst in 1978 and a DSc in Computer Science from Washington University, St. Louis, Missouri in 1984.

EDWARD F. MYKYTKA is an Associate Professor of Operations Research and serves as the Acting Head of the Department of Operational Sciences in the Graduate School of Engineering at the Air Force Institute of Technology. He received a B.S. in Mathematics from the University of Dayton in 1976; an M.S. in Industrial Engineering from the University of Iowa in 1978; and a Ph.D. in Systems Engineering from the University of Arizona in 1983. His research interests include discrete-event system simulation (particularly random variate modeling and generation), quality improvement and statistical process control, stochastic modeling, and applied statistics.

LtCol BARTLETT is the Chief of Operations for the Defense Modeling and Simulation Office. A graduate of Texas A. & M. University, LtCol Bartlett entered the Marine Corps in March of 1972 through the officer Commissioning program and was commissioned in July of 1974. He was designated a naval aviator in May of 1976. During 1986 he was assigned as Kilo Company Commander, OCS, MCDEC prior to reporting for Command and Staff College at Quantico, Va. Upon completion of Command and Staff College he continued his professional education with the completion of the Defense Systems Management College, Fort Belvoir, VA. LtCol Bartlett was then assigned to Naval Air Systems Command as the Marine Liaison and as Program Manager for Training Systems and Simulation. During this period he was responsible for acquisition of all training systems and simulators for the Marine Corps. In 1991 he was assigned as the Logistic Officer for MAG-36, 1st MAF Futenma, Okinawa and upon completion of the overseas tour was assigned to the Marine Corps Presentation Team. In January 1993, he was assigned to his current position with the Defense Modeling & Simulation Office

MICHAEL BATHE is Head of Management and Systems Group in the School of Defence Management in Cranfield University at the Royal Military College of Science in Shrivenham, England, UK. His research interest include logistics modeling, decision analysis and combat modeling.