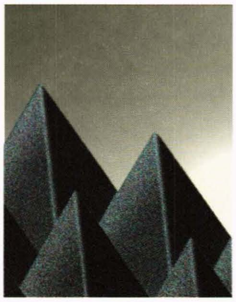

Modeling and Simulation: Guest Editor's Introduction

Suzette Sommerer

Modeling and simulation provide powerful tools with which to examine existing and proposed systems and to predict their performance under various conditions. A model is an abstract representation of some physical system or process. It can be a physical model, a set of mathematical equations, a description in the form of computer instructions, or any other abstraction of the system's essential elements that captures or in some way reproduces its behavior. A simulation is a computer program that implements a model or mimics the operation of a real or imagined system.

This issue of the *Technical Digest* and the one to follow focus on a few of the simulations developed and used at APL. The simulations vary greatly in complexity, level of detail, types of systems modeled, and application of results. Although only a few simulations are presented, they demonstrate both the utility and the versatility of the simulation approach. APL analysts build simulations to characterize the performance of proposed systems, to determine the effectiveness of new algorithms for existing systems, and to observe the interactions of diverse systems in realistic environments. Simulation permits the investigation of many options without the expense or time needed to build and test equipment or to stage complicated or impractical scenarios. Simulated opponents to a combat system can exercise all its features and expose possible deficiencies before actual combat conditions arise. Simulation of a space-based sensor allows hardware design trade-offs and testing of various signal processing algorithms before ever launching or building the component. The articles in this issue illustrate the process of developing models and simulations and show how their results can be used.

Menner's "Introduction to Modeling and Simulation" opens this issue with an excellent discussion of how to use modeling and simulation to solve real problems. It provides a helpful introduction to the topic for those who have never constructed a model or written a simulation, and details the steps needed to obtain credible results by simulating a system of interest. Menner presents a number of relevant topics, including definitions of modeling and simulation, discussion of how to formulate a problem into a simulation, computer implementation issues, conducting different studies with simulations, statistical interpretations of the output, confirmation of model correctness, and documentation of the results. This article serves as background and context for all the other articles in this issue and the one to follow.

Brintzenhofe's "Deriving Effective Sweep Width for Intermittent Signals" guides the reader through the derivation of a parameter needed to calculate an intermittent signal's detection probability. The author develops a mathematical model of effective sweep width, emphasizing the theoretical underpinnings rather than the implementation or results. By focusing on the derivation, Brintzenhofe demonstrates how a relatively simple expression in a simulation can sometimes require a great deal of theoretical work and attention to detail. Without such meticulous and well-documented arguments for the expressions used, a simulation's results are vulnerable to challenge. Although simulation designers need not always derive everything from first principles, their results are only as reliable as their assumptions and equations.

In "Measuring and Modeling Scan Modulation of an Infrared Seeker," Howser describes an in-depth simulation of the performance of an existing seeker. The model incorporates the seeker responses to targets and backgrounds, seeker scanning and detection signals, gyroscope dynamics, signal processing, and acquisition and tracking. It also includes several sources of error, such as noise, optical blur, gyroscope errors, and scan modulation. Howser describes the seeker simulation and gives particular attention to scan modulation, an artifact of the seeker spin caused by magnetic coupling of the gyroscope and nonuniform radiation from seeker components. She presents the theoretical basis for the simulation and explains the validation tests in which an actual seeker produced results similar to those of the model. This simulation reliably predicts seeker performance under various conditions and provides a good test environment to try out new signal processing algorithms.

Yionoulis describes a simulation of the Midcourse Space Experiment's ultraviolet and visible imagers. The experiment will track a variety of objects from space, including stars, atmospheric phenomena, other spacecraft, and ground-launched rockets. The simulation allows instrument performance predictions, provides test images for development of target identification algorithms, and serves as a tool for mission planning and analysis. Yionoulis discusses the physical aspects of the imagers that he modeled, provides the supporting equations, and shows some of the resulting images.

Quaranta's "Fuzzy Systems for Simulating Human-Like Reasoning and Control" moves from the realm of detailed modeling of physical instruments into the not so well understood area of human decision making. The author describes a general approach to modeling decisions with fuzzy logic. As a specific example, she analyzes an obstacle avoidance problem, showing how both sensory input and decisions based on that input can be formulated as degrees of membership in fuzzy sets. The model manipulates the information according to rule-based inferences, and the results are "defuzzified" into specific steering commands. The model represents a preliminary framework for the study of more complex decision-making processes.

Biemer's "Force-Level Effectiveness Modeling for the Tomahawk Land Attack Cruise Missile" returns to the regime of simulating existing hardware, but takes the much different approach of using several detailed models together to get a higher level perspective of missile performance. The analyst uses a force-on-force level simulation to combine individual radar and surface-to-air missile models with simulations of Tomahawk mission planning and missile performance in operational scenarios. The theater-wide simulation enables study of the effectiveness of multiple Tomahawk missiles in a particular threat scenario. The simulation provides a very flexible tool for evaluating the effects of varying Tomahawk and opponent capabilities, and for determining the sensitivity of the results to specific parameters. Biemer describes the process of selecting and incorporating the low-level models into the force-level simulation and interpreting the results.

The use of models and simulations to provide tactical guidance for employing combat system sensors and weapons under specific readiness and threat conditions is also explored in this issue. Hyer, Johnston, and Roe examine the process of finding or developing the right simulation for the task, validating the model by comparing simulation results to reality whenever possible, formulating an appropriate set of scenarios and parameterizations, interpreting the results to give meaningful insights into the operation of tactical systems, and communicating those insights to the fleet in the form of tactical directives and doctrine. The authors describe the wide variety of models available at APL that are applicable to this problem. These models range from very simple simulations of one combat system element to very complex representations of an entire battle group and the threats it faces. Some are purely mathematical formulations, some are computer implementations, and still others, such as the hardware-in-the-loop facility shown on the inside back cover of this issue, combine actual combat system hardware with simulated hardware, environment, and threats. Hyer, Johnston, and Roe emphasize the variety of tools available and detail the process of using models to produce data on which to base dependable tactical guidance.

Dykton and Sanders's description of the Submarine Combat Information Laboratory (SCIL) and the Object-oriented Rule-Based Interactive System (ORBIS) gives an overview of a distributed simulation capability and the role played by APL's SCIL facility and ORBIS development environment. The SCIL is a physical mockup of a submarine control room equipped with a network of modern computer workstations. It is supported by ORBIS, a rule-based expert system that manipulates objects such as submarines and their component systems according to the tactical and physical rules provided. This combination provides a realistic simulation of submarine operations as perceived by operators in the SCIL. The high-fidelity model of the submarine and its environment allows detailed evaluation of proposed technological and tactical improvements. The SCIL also provides widely distributed theater-level simulations as a node on the Defense Simulation Internet. Man-in-the-loop controlled submarines provided by the SCIL interact with other simulated platforms hosted at facilities across the United States to play out realistic scenarios involving many platforms. The authors show how a single simulation facility can serve many purposes by combining a high degree of fidelity and realism with the flexibility of easy modification.

The models and simulations described here represent just a few of APL's projects in this area. Each of them models some essential aspects of a problem and uses simulation to explore system behavior under conditions that may not be readily available in the real world. Model complexity reflects the fidelity needed to adequately depict a system, and the breadth of study, once the model is built, depends on the information needed by the analyst. The articles in this issue explain both the process of defining and implementing the models and the insight into the performance of real and proposed systems to be gained by using these artificial constructs.

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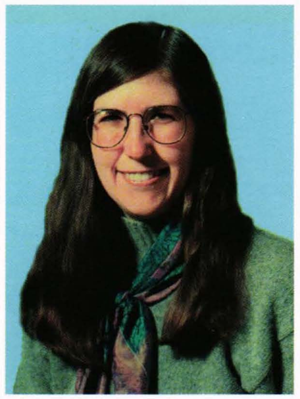

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