DEVELOPMENT OF AN INTERACTIVE WARFARE SIMULATOR

INTRODUCTION

In principle, in order to evaluate the usefulness of a new weapon or sensor system, a conflict is first simulated without it. The simulation is then repeated with the proposed system present. A comparison of the results determines its presumed value.

In the 1960's, models were developed for the Navy to aid in the analysis of a particular weapon or sensor system or tactic for specific configurations and types of engagements,[1] but the narrow scope of the models limited the questions that could be answered. One could determine how well an attack submarine can trail an enemy nuclear-missile-launching submarine, the best force disposition for protecting a carrier battle group from an enemy air raid, or the quality of surveillance of a particular ocean area. However, there were no models for evaluating performance at the command level of an entire theater of operations (such as the North Atlantic), where combinations of manual analytical techniques, automated calculation aids, and *a priori* results from specific engagement models have to be used. A weapon system, for example, could not be evaluated with confidence at the theater level on the basis of its performance in a more limited engagement model.

At a Fleet Command Center, information management is, for the most part, a manual process. A Fleet Commander has at his disposal only the information his staff can collect, refine, and present. Also, tactical decisions concerning the dynamic disposition of forces and their allocation in reaction to events as perceived at the Command Center (in contrast to the way they are seen by the individual task force commanders) are at the heart of an analysis at the theater level. These factors can be modeled in part, but actual human interactions with the simulation by persons familiar with the fleet command process are also needed. Previous hardware and software technology could not accommodate this human interaction simultaneously with the requisite detailed engagement analysis.

A properly aggregated interactive computer simulation can provide a far more powerful analytic tool than previous simulations could. The APL-implemented Naval Warfare Simulator permits highly sophisticated and versatile simulations of naval conflicts at the theater-of-operations level. Its purpose is to allow the evaluation of weapon and sensor systems, tactics, and doctrines on the basis of how they influence naval conflicts. It can model naval campaigns of several months duration in simulated time, taking into account hundreds of participating ships and airplanes and allowing for interactions with theater commanders as they direct their forces and initiate actions.

SIMULATOR DESIGN

The design of this unique simulation was a joint effort of Navy and APL personnel. Navy analysts imposed requirements encompassing all aspects of naval warfare. The simulation specialists were concerned with feasibility, consistency, and the availability of data.

The simulator has three interactive operator stations: one each for the opposing theater commanders and a third for an umpire who provides overall monitoring and control. The main simulation is carried out on an IBM 3033 computer. The interfacing between the host computer and the operator as well as the graphics processing functions are provided by a PDP-11 minicomputer (Fig. 1).

A unique feature of the system involves the interaction of the theater commanders with the simulator in an order/report protocol by which orders are given and activity reports are received in a manner that resembles the actual communication process. Each theater commander has a terminal to receive reports and transmit orders in addition to a graphical display unit that has a map of the theater showing the location and identities of his own forces and of enemy units detected by sensors (Fig. 2). The graphical display allows the theater commander to determine positions and distances and to plot courses for his units. The plotted course is then displayed alphanumerically in a format that can be transmitted as an order.

As orders are carried out and interactions occur, resultant reports are generated and stored. When a report previously designated "critical" is generated, the simulation program is suspended and theater

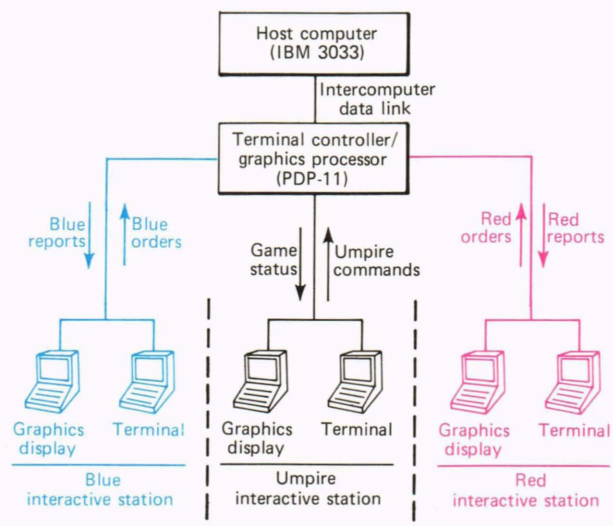

Fig. 1—Schematic diagram of information flow between the three interactive stations (Blue, Red, Umpire) and the simulation program.

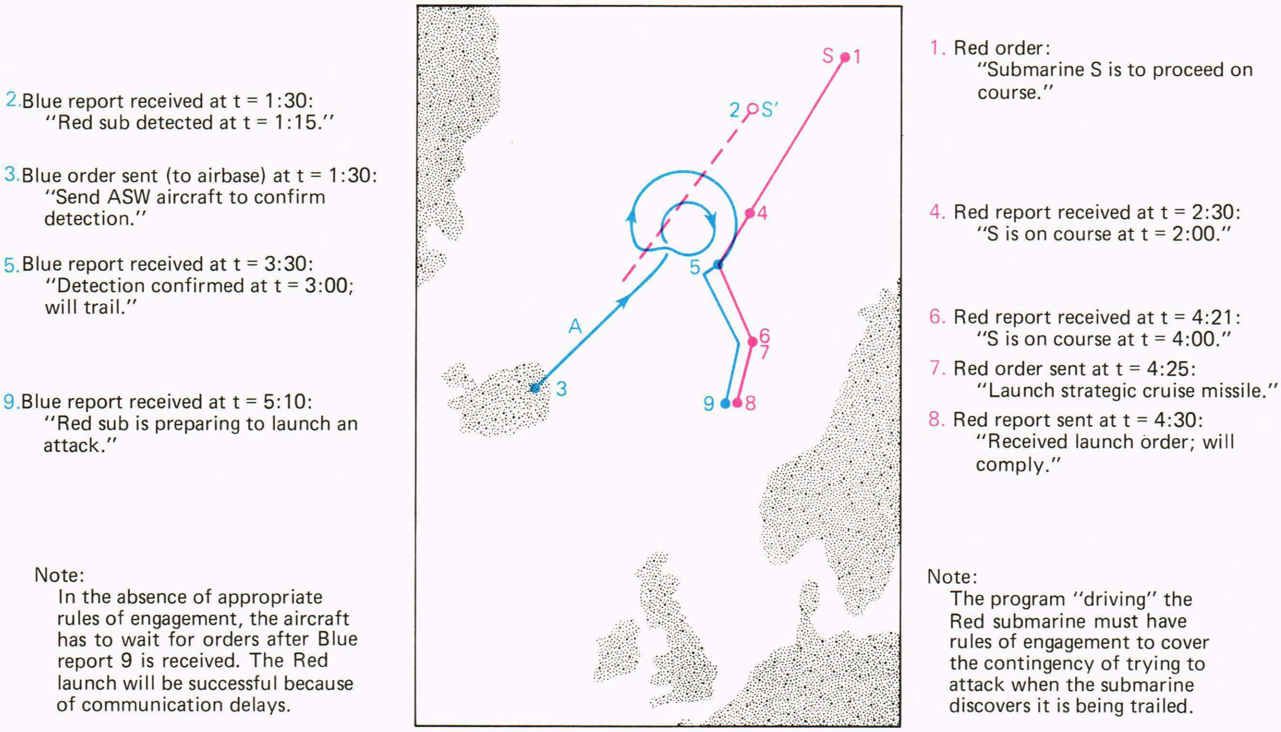

Fig. 2—Example of an order/report protocol for a hypothetical submarine-aircraft interaction in the North Atlantic theater. The Red interactive station prepares Red orders and receives only Red reports during the course of the simulation. The correct position of the Red submarine (S), which is proceeding in the Atlantic based on Red order 1, is indicated on the Red display screen every time a Red report is received. The Blue interactive station becomes aware of the approximate position of a Red submarine (S′) via Blue report 2. Appropriate Blue orders and reports follow. A Blue airplane (A) is assigned to the task of localizing and trailing the Red submarine. When, after search near an expected intercept, contact is made in Blue report 5, the updated position of the Red submarine becomes available to the Blue interactive station. The positions of the Blue airplane and the best available position of the Red submarine are indicated on the Blue display screen each time a Blue report is received. The true position of the Red submarine displayed on the Red interactive station and the position shown on the Blue display screen are not necessarily the same. (The area shown in this figure is the northeastern portion of the North Atlantic theater, which is normally displayed.)

commanders receive their accumulated reports. The simulation proceeds when both theater commanders have transmitted new orders.

SIMULATOR PROGRAMS

A communications degradation routine provides for realistic modeling of the communications process by adding scenario-dependent delays to the order/report protocol. Therefore, the simulation does not give a theater commander total or immediate control over his units. The interfacing of these degradation algorithms into the command and communication process within a simulation architecture was a complex and unique portion of the overall project.

For warfare simulation to be effective, it must include algorithms of surveillance, detection, trailing, approaching, patrolling, attacking, and evading. Each algorithm is complicated by the need for partially autonomous execution—each simulated unit must have a predetermined logic that remains in force until an appropriate order is received from the theater commander. This may involve several hours of simulated time and may include previously accepted rules of engagement for various contingencies. However, the rules can be altered by the theater commander by means of an order issued during the simulation.

Interrelationship graphs and decision tables were developed to provide a structure for and a record of the complicating interactions in the simulation of behavior at the unit level. They specify requirements in operational terms to give Navy analysts a direct hand in the construction of simulation logic. A decision table is a record of logic that demonstrates the completeness of the set of variables used to simulate a particular operation for a unit. An interrelationship graph is a network diagram that describes the logic of a simulation the way a map describes a city (Fig. 3). It maps all the modeled states of a unit, all possible routes from one state to another (as well as the points at which a particular rule of engagement is invoked), and the points at which actions may occur that call for

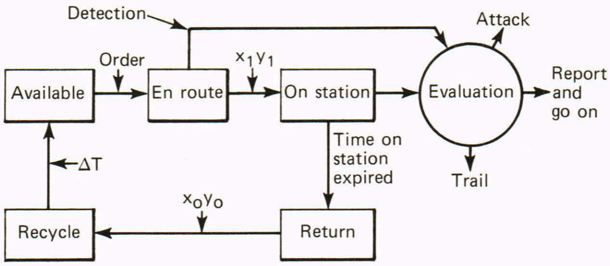

Fig. 3—Sample interrelationship graph for an antisubmarine warfare aircraft. The aircraft (a) is in AVAILABLE state (at point X_0Y_0) until receipt of order, (b) is in ENROUTE state until it reaches point (X_1Y_1) or gains a detection, (c) is in ON STATION state until the time on station has expired or a detection is made, (d) is in RETURN state until reaching point (X_0Y_0), and (e) is in RECYCLE state until time ΔT has elapsed. EVALUATION determines appropriate additional actions of the aircraft.

autonomous reaction. The decision tables and the interrelationship graphs are directly translatable into PL/I code.

The main simulation program is a discrete event-store model written in PL/I. Force assets are modeled as individual units or as aggregates. Land and carrier-based aircraft, early warning aircraft, picket ships, etc., which normally operate as separate entities, are treated individually. Task forces, such as carrier task groups, underwater replenishment groups, convoys, and raiders, are treated as aggregates.

A kinematic program allows for the three-dimensional movement of units in earth coordinates. It predicts future positions and intercepts as well as the mechanics of multiple units in transit or on patrol. Several probability detection packages make use of the movement and sensor-detectability parameters of opposing units. Definite range-law detection is associated with the movement package. However, once a unit has implemented its patrol assignment, probabilistic algorithms based on Koopman's work[2] determine the detection. The successful interfacing of these two almost incompatible methods for making detection calculations was a major design accomplishment.

The implementation of a multiple-terminal interactive display system within the order/report protocol required a minicomputer interface to the IBM 3033. The final software architecture for this "intelligent" display/interaction system involves a sophisticated mix of minicomputer programs, microcomputer-driven graphics programs, and minicomputer-to-mainframe communication programs.[3]

At the end of the simulation, a complete history file of all significant events and engagements on a unit-by-unit and strike-by-strike basis is available for postgame analysis. Cumulative target damage provides data for an analysis of strike effectiveness. The cumulative damage assessment of all naval assets allows residual force capabilities to be analyzed at any point in the campaign. Figure 4 shows the major elements of the simulation.

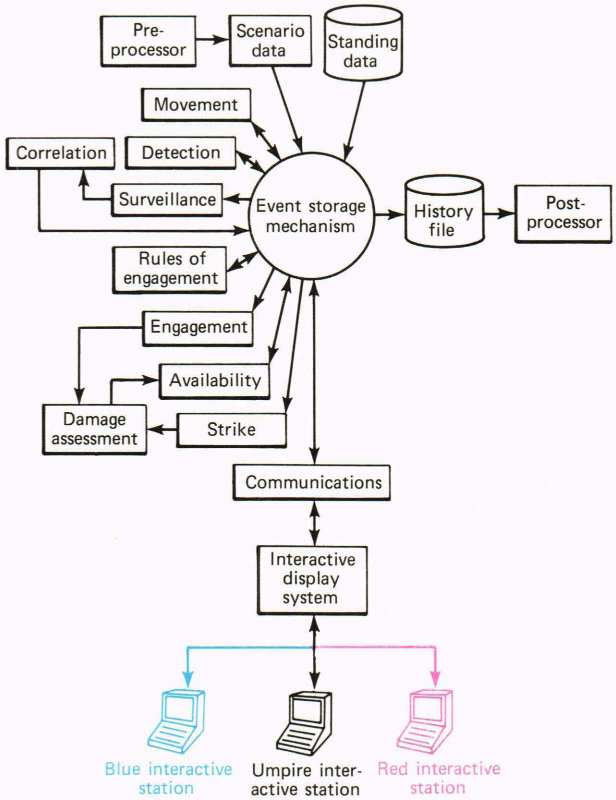

Fig. 4—Schematic diagram showing functional elements of the Naval Warfare Simulator.

The simulator presently is limited to antisubmarine warfare for the testing and evaluation phase of development. As envisioned, the complete simulator will cover all aspects of naval warfare, with force allocation and weapon mixes to be determined by the users. Surveillance systems, damage assessment, unit and weapon availability, countermeasures, communications, and the command structure will interact dynamically to permit a realistic appraisal of each major variable in almost any imaginable situation.

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REFERENCES AND NOTES

[1] L. R. Gieszl, The Art of Simulation: Some Tools and Techniques Developed at the Applied Physics Laboratory, APL/JHU TG 1316, Mar 1978.

[2] Bernard Koopman is a founding member of the Operations Research Society of America and an originator of the field of optimal search. During World War II he was a member of the Operations Group, U.S. Navy, and made major contributions to the design of screening formations to protect our convoys. His work was so successful that engagement analyses that arise from the formulation of closed-form mathematical solutions have become known as Koopman-type algorithms.

[3] L. R. Gieszl and R. A. Freeman, "A Mini-Micro Architecture Enables Main Frame Multi-sided Interactions," to be published in *Proc. 11th ISMM Mini and Microcomputer Conf.*, Jan 1980.