AEGIS MISSION PERFORMANCE SIMULATION (AMPS)

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This paper describes a simulation of the AEGIS Weapon System called AMPS (AEGIS Mission Performance Simulation). The full text discusses the problems encountered and the solutions chosen in the development of this simulation. It is expected that similar types of problems would appear in simulation development for any large scale system which is simultaneously being developed and the approaches to solutions given here may be equally applicable. Other contents of the complete paper are the genesis and purpose of AMPS, its general features and structure, simulation timing, the AEGIS environment and its simulation, the quantitative description of AEGIS as simulated, the operational description of the simulation, and the simulation outputs.

The AEGIS Weapon System itself is being developed as the primary and most modern shipboard defense of U.S. ships and fleets against air attack. The AEGIS system proper consists of a central search, detection and tracking radar; several target illumination radars to aid in defensive missile guidance; several missile launchers; computers; software; and personnel. The functions of AEGIS include search, detection, tracking, threat evaluation, weapon assignment, equipment and engagement scheduling, missile launch, target illumination, missile guidance and flight, interception and kill evaluation. AEGIS must perform in an environment of many friendly ships and aircraft, high seas, adverse weather, proximity to land, chaff and other countermeasures, large and dense attacks of ships, aircraft, missiles and bombs.

Many types of simulations are required in the development of a system as complex as AEGIS. In all of these, compromises must be made between depth (or detail) of representation and breadth (or extent) to which the total system is represented. Depth and breadth also may be definable in terms of the time characteristics of the simulation.

At one extreme of what may properly be called simulations are those representations necessary to aid in subsystem design which require the following of phenomena at very small intervals of time, ranging from nanoseconds to milliseconds, or which require the consideration of so many details as to prohibit the simultaeneous consideration of other subsystems.

The next higher order of simulations are referred to as dynamic system simulations. These encompass all subsystems of the overall system at a somewhat lesser level of detail and operate with time intervals characteristic of subsystem operation. It is possible to accomplish this type of simulation within computer capacity only by restriction of the environment and system decision processes to a single target.

At the other extreme in the context of weapon systems are war gaming simulations. These simulations must have the capability of representing many types of alternative systems at the sacrifice of detail in the representation of any one system.

As AEGIS development progressed, it became apparent that a means of gaining insight into the performance of the complete weapon system in a multi-target, complex hostile environment was essential for testing and evaluating alternative designs of tactical control logic. Typical of this logic are the scheduling of equipments and engagements and the assignment of threat rank to targets. The war gaming or other broad simulations previously developed were found to be inadequate for design evaluation because many of the design decisions involved detail of the system not represented in those simulations. On the other hand, subsystem or detailed system simulations either did not have sufficient breadth of system representation, did not adequately consider the environment in which AEGIS must operate, were limited to a single target, or used excessive computer time because of their microscopic representation of time.

Ultimately, the kind of insight and evaluation we sought requires experience in the operation of the system in its anticipated context. However, one cannot wait for the natural accumulation of experience with the system or economically conduct truly representative large scale tests in all battle conditions before the operational employment of the system becomes necessary. Therefore, the development of an AEGIS simulation designed specifically for this purpose and intermediate to those currently in existance was undertaken.

The required simulation is one of breadth rather than depth in that the simulation is to yield results of tactical or operational significance rather than the details of subsystem performance.

An early decision in the development of AMPS was that it should be a "simulation" not a "simulator" in at least four senses. First, the essence of the system's various operations were to be duplicated rather than the exact procedures. Second, no hardware components of the simulated system were to be employed. Third, the simulation was to be strictly digital. Fourth, no attempt was made to make it interact on-line with an operator.

An interesting consideration in the construction of AMPS was the choice between event and time orientation. The most nearly comparable and existing simulations for other systems were event oriented. In those simulations possible events were identified, event trees were constructed, and successor events were determined on probabalistic or deterministic bases. These events were time ordered. Then, after completion of the operations relative to an event, the simulation would step in time to the next event. Alternatively, the simulation could be constructed such that time would be stepped uniformly and at each time step all operations and decisions would be examined. However, for the AEGIS case, the events which would ultimately be of interest could not be identified with any degree of assurance as to completeness and the occurrence of a next event was thought to be too highly dependent upon the situation at the current and preceeding simulation times. For example, the detection of any target depends upon the jamming interference contributed by all other targets. But, whether any one of these interfering targets exists at the time detection is attempted cannot be determined without proceeding through all the operations of the simulation. On the other hand, at many instants of time, upon reaching that time, it may be easily determined that nothing of significance will happen and those times may be bypassed. Therefore, AMPS became a mixture of time and event orientation with, perhaps, emphasis on the former.

Modularity of simulation construction was motivated by the possibility of more complex changes in the system than can be represented by relatively simple numerical changes (available as user inputs), the requirement of dividing work among several analysts in the development of the simulation and by the natural division of the operation of weapon systems along functional lines. Also, the extent of development of the various parts of the system varied considerably. This necessitated making tentative assumptions relative to the modeling of some functions while maintaining flexibility for quick change of these as more definitive information became available. Moreover, it was essential that this flexibility be accomplished without requiring extensive changes in other parts of the simulation. Indeed, many of the features of the system had not been designed and some had not even been considered at the beginning of AMPS development. On the other hand, the ultimate utility of AMPS depends on completeness of system representation and it was therefore important to provide for this completeness in the simulation architecture. Accordingly, some aspects of AMPS represent possible approaches to system design rather than being representative of firm system characteristics and, therefore, may have to be replaced when their design is addressed for the system. Alternatively, these features as simulated may prove to be useful guidelines for operational development of the corresponding features of the system.

The problem of simulation timing is quite complicated. In the AEGIS system, some functions may be performed as often as 64 times a second. Consideration of the facts that simulated battles would be upwards of 30 seconds in length and consist of many target engagements led to the conclusion that system determinations at such fast rates would produce detail of inconsequence from a system operational point of view. On the other hand, the effect of the simulation time interval upon the overall accuracy of system simulation was unknown. Thus, by input, the user was given the capability of guiding the basic time interval of simulation. However, the simulation adjusts this time interval separately to each of several types of segment events and system processing.

The complete representation of AEGIS requires the input of quantitative parameters relative to all the equipments, processes, and operators. All of the major timing and capacity characteristics of each equipment and operator and the spatial coverage of each equipment are input. The performance characteristics of the multi-function radar and the illuminators are input for each of the several modes of operation. Parameters defining the entry of the radars into their various modes, the development of high quality tracks, and the determination of target priority are given. Launchers are described in terms of their positional and movement characteristics. Missile inventory, guidance requirements, and kill criteria are also specified.

Targets are described in terms of their timing, three dimensional trajectory, launch platform, mutual dependence, radar cross-section, jamming characteristics, and damage producing capability.

The input environment description includes the location and reflectivity of chaff, weather, and land, all of which are caused to affect system performance.

The type of output format was given considerable attention. Essentially, the problem was a tradeoff between computer time and user time with the decision being made in favor of reducing the required time for the user. Outputs of the simulation determinations, for the most part, are in complete English sentences. Further, the simulation outputs, as represented by the current program listing, have been structured according to the following guidelines: 1) output only the most significant information, 2) reduce the periodicity of outputting to some multiple of the simulation interval, and 3) output information pertaining to situation changes only.

Currently AMPS is a program of approximately 4000 FORTRAN IV statements, several hundred inputs, and requires a memory of 210,000 bytes. Running time is scenario dependent but, for typical scenarios, is about one-half real time. No peripheral devices are required other than a card reader, a tape station for the object deck, and a printer. The program runs as a single segment. However, since the program is pushing the 220,000 byte storage limit of the machine, anticipated changes will require segmentation of the program with each segment being run separately and outputting tapes for driving other segments.