SIMULATION VS STIMULATION IN ELECTRONIC WARFARE TRAINERS

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ABSTRACT

The design of an EW trainer involves a decision to simulate EW functions via computer software or to incorporate actual EW hardware within the trainer and stimulate it with required signals. This paper compares the requirements and relative advantages of software simulation vs. hardware stimulation in EW trainers. Aspects discussed include cost of hardware and software, computer load, trainer fidelity to real-world conditions, documentation and data requirements, interaction among EW units, testing requirements, and trainer modification. Both approaches have particular advantages and problems in each of these areas. In conclusion, the choice of simulation or stimulation, or mixture of both, in a given trainer should be based on careful study of particular circumstances and requirements.

INTRODUCTION

Electronic warfare trainers are designed to provide a student with training on electronic warfare equipment acting in an EW environment. In a typical trainer the environment consists of a number of radar emitters scattered throughout a war gaming area, emitting signals that are received by the student's ownship. The EW equipment in the trainer may include radar receivers and analyzers, chaff and flare dispensers, jammers, and so forth.

Many trainers involve training on specific EW equipment, such as a particular model of radar warning receiver or jammer. When such specific equipment is included in a trainer the design question arises: should the trainer simulate the equipment via computer software or should the trainer include actual equipment that is stimulated to produce the desired effects?

This paper examines the question of simulation vs stimulation, particularly with regard to radar-based trainers, and draws on experience with EW trainers developed by AAI Corporation for A-10 and F-16 aircraft flight simulators. Both trainers include the AN/ALR-69 Radar Warning Receiver and other EW equipment. The A-10 EW trainer includes an actual ALR-69 unit stimulated with video pulse trains, while in the F-16 trainer the ALR-69 is simulated entirely by computer software.

TRAINER CONFIGURATIONS

A modern training simulator for electronic warfare consists of several major functional components, as illustrated in Figure 1. A threat environment is generated and continuously updated by several related functions. A mission generation module defines the environment and places the trainer's ownship within the environment. A threat tactics module defines the signal generation modes of the threats, thus defining the types of signals to be generated. Further processing defines exact characteristics of the threat signals. Ownship countermeasures such as jamming, chaff, flares and maneuvering may be made to affect the threats' signal generation modes.

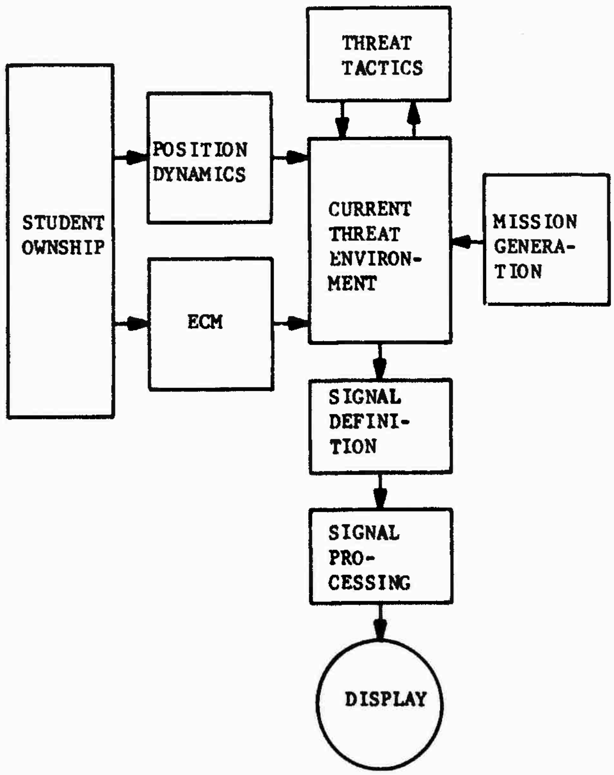

Figure 1. EW Trainer Configuration

The signal processing functions are then performed. Threat signals are analyzed according to the algorithms employed by the equipment associated with the trainer. Processing may be performed by actual EW equipment or may be simulated by computer software. This signal processing may be simple or elaborate according to equipment characteristics and trainer requirements. Outputs from the signal analysis are used to drive display hardware consisting of display screens, indicator lights, and speakers.

Figures 2 and 3 compare implementations of the basic functional design in Figure 1. The definition of the threat environment, and all of its associated activities, must almost necessarily be implemented in computer software. Even if some functions may be performed by digital hardware circuits, this hardware is merely performing logical functions that assist in the threat simulation. The real choice comes in the area of signal processing equipment. If it is to be simulated as in Figure 2, computer software defines the signal characteristics, simulates the signal processing functions and triggers hardware to drive the displays. If a stimulation is used as in Figure 3, the threat environment definition software directs pulse generators to generate pulse trains which are sent to the signal processing hardware. This hardware then performs whatever signal processing is appropriate and generates output to drive the display hardware.

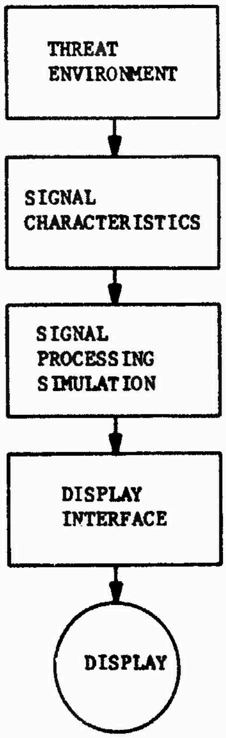

Figure 2. Software Simulation

In reality, nearly every trainer includes both simulation and stimulation techniques to some degree. A stimulation-oriented trainer will include a simulation of the threat environment and computer-controlled generation of threat signals. Furthermore, a simulation trainer must include some signal generation if only to drive display hardware or produce audio tones. The real question centers around the number and type of functions to be implemented by simulation or stimulation.

A discussion of the relative merits of simulation versus stimulation involves a number of considerations such as the cost of hardware and software, trainer fidelity to real world conditions, documentation and data requirements, testing requirements and trainer modifications.

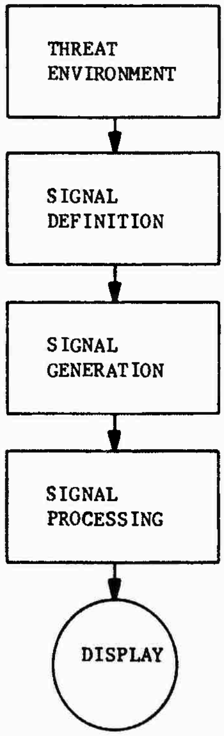

Figure 3. Hardware Stimulation

COST

If a hardware stimulation is being considered, the cost and availability of the EW hardware must be taken into account. Advanced EW equipment may be very expensive and its inclusion into the trainer may increase its cost significantly. Even if the EW hardware is provided as Government Furnished Equipment the overall cost to the customer must include the cost of the equipment. The availability of the equipment must be considered as well. If few of the units are manufactured, if all of the units are committed to other purposes, or if the units are out of production, it may be difficult to obtain units for inclusion in the trainers. The cost of maintenance and updating facilities for the EW equipment must also be taken into account.

The cost of support hardware and software in the trainer can be considerable as well. A complex EW environment requires a bank of signal generators for stimulating the EW equipment. Special effects such as scan patterns and range attenuation are produced by further hardware. All of these signals must be coordinated and interfaced with the EW equipment. The design, testing and manufacture of this hardware can run to sizeable expense, especially if the hardware configuration is large and elaborate.

A hardware stimulation also requires special software to control the signal generation hardware. When a threat enters the environment, a signal generator must be selected, loaded with pulse generation data if necessary and turned off when the threat leaves the environment. Special hardware effects are also controlled by software. The cost of design, development and testing of this software must be included into the special costs of a hardware stimulation.

The cost of a software simulation must be weighed against the cost of a hardware stimulation. As described earlier, a modern training simulator relies heavily on a computer to perform a number of supervisory and simulation functions. The computer generates and controls the threat environment and may interact with ownship and visual systems. The addition of a software simulation of EW equipment may not involve an extremely large further effort. However, as will be discussed later, development and testing of simulation software can pose major difficulties. And if specific EW equipment is being simulated, it is likely that the actual equipment will undergo revisions. The cost of changing the software to simulate these revisions can be quite large.

Software simulations hold a definite production cost advantage in trainers where many units are to be produced. Once the original simulation has been developed, additional units are produced merely by copying the software onto the mass storage devices of the new units. This is a trivial part of copying general simulation software to the new system.

Producing new hardware stimulation units requires more effort and expense. Not only must the EW equipment be procured and installed, but the signal generation hardware for each new unit must be manufactured and tested. Each new unit thus incurs significant new production costs.

Simulation and stimulation therefore both involve their own special costs. The relative costs of each vary from trainer to trainer, depending on the equipment configurations and numbers of units involved.

DOCUMENTATION AND DATA REQUIREMENTS

Software simulation and hardware stimulation both have their special data requirements. A software simulation requires extensive documentation on the EW equipment being simulated. A realistic trainer must be based on detailed specifications of all displays produced by the equipment, including threat indications on display screens, patterns of flashing lamps, audio tones, and so forth. Processing of various emitters must be described in sufficient detail to imitate the same results as produced by the actual EW equipment. In the case of a signal processor analyzing a dense threat environment, the designers of a simulation will require a large amount of threat data and sufficient functional documentation to develop software processes that handle the threats in the same manner as does the EW hardware.

A realistic software simulation should not only generate the major functions of the EW equipment, but should also reproduce subtle and anomalous effects found in the actual EW units. Complex EW hardware may produce unexpected effects in extreme or unusual combinations of circumstances. In normal operation the equipment may exhibit unwanted side effects on its displays, and hidden bugs in the EW equipment software may alter the basic standard specifications. An ideal simulation would reproduce all of these effects. However, some of these effects may have little or no training value and thus may not be required in specifications for the trainer. For other effects, no definite information may be available, rendering these effects impossible to simulate with any realism.

Considering the extent of the data that could be required for a realistic software simulation, it is essential that the specifications for the simulation describe the behavior to be simulated and the data available on this behavior. In the absence of adequate data, the software designers must either ignore the behavior or make their own guesses about specifications.

Hardware stimulation may likewise require a large amount of data and functional description. On the hardware level, timing diagrams, pulse widths, bus protocols, etc., must be specified exactly since input signals are fed into EW equipment itself. These specifications may seem straightforward, but problems may develop in actual interfacing with the EW hardware. The EW hardware may not perform exactly as described in the specifications, or it might have requirements not clearly stated in the interfacing protocols. Solving these kinds of problems will require further research to discover modified or hidden requirements.

The functional requirements of the inputs must likewise be specified carefully. EW equipment that performs elaborate and discriminating signal analysis will probably require highly realistic inputs. The designers of the stimulation equipment will thus require complete data on all of the signals to be input into the EW equipment. In the absence of explicit input parameter data for particular cases, it may be necessary to "reverse-engineer" the input data from the signal analysis processes used by the EW equipment. This may require detailed and precise information on the exact algorithms used within the EW equipment. At times this data requirement may be more exacting than for a software simulation design.

However, given the correct inputs, a hardware stimulation should by its nature produce all of the intended and anomalous effects generated internally or by the inputs. Not only will the major and minor display effects appear realistically, but special peculiarities and overload behavior will perform the same as in field units. Fidelity to real world phenomena is thus more attainable, as the EW equipment is presenting realistic displays to the trainee. Once again though, the realism of the output depends on the realism of th stimulating inputs.

INTERACTIVE EFFECTS

An EW trainer becomes particularly complex when it contains several pieces of EW equipment interacting with each other under power management or some other configuration. The interactions between the units can be particularly difficult to simulate, especially in the areas of subtle and anomalous effects which may be poorly understood. When the actual EW unita are installed in the trainer and connected together, they automatically produce all of the subtle interactive effects that may be extemely difficult to reproduce in a software simulation.

On the other hand, if the additional EW units are quite simple or require extensive additional signal inputs, a software simulation may be simplar and more cost-effective. However, a software simulation interacting with hardware is subject to difficulties both in software development and in hardware interfacing.

TESTING

Simulation and stimulation trainers each have particular testing requirements. Testing of a hardware stimulation is presumably more straightforward, as tha EW equipment is expected to produce a set of well-known results. As was noted aarlier, the major and minor displays, anomalies and pecularities should be documented beforehand and observable during testing. However, if unpredicted results appear during testing, the origin of the problem may be difficult to pinpoint. The chain from input data specification through signal generation to signal analysis end display contains a number of separate links, each quite distinct from the others. The nature of the problem may make it difficult to determine whather the inputs have been generated incorrectly or whether the EW equipment is exhibiting a heretofore unknown enomaly. If the output results are not according to specification, it may be that the inputs are not sufficiently realistic for processing by the EW equipment. More aleborately reelistic inputs may be required to produca the correct results. On the other hand, en unexpected output from the EW equipment may be a correct rasult that has not previously been documentad. Unusual signels or combinations of signals mey produce rasults that have not been observad prior to the testing of the trainer. In this cese, the testing personnel will hava to re-avalueta the test critaria and revise them eccordingly.

A software simulation can be mora difficult to debug and test. All of the output effects originally specified for the treiner must be tested and evaluated. Since the effects ara being ertificially ganaratad, thay do not automatically displsy the realism essociated with a stimulation. Thus disagreements may erisa during testing as to whether the simulated effect is acceptably reelistic. Furthermore, the full range of secondery and subtle effects of the actual EW equipment ere rarely, if ever, programmed into the simulation. Unless the list of required effects has been carefully specified beforehand, testing the simulation mey give rise to disagreements over whether particular effects that have been omitted are actually necessary. Unfortunately, many such effects are not readily specified beforehand and can be defined and judged only upon inspection of the simulation itself. Unforeseen anomalies may arise during testing of a software simulation as well. In a well-structured software program the source of such anomalies can be identified fairly readily, but it is more difficult to determine whether they properly belong in the simulation. The simulation designers can claim that the anomaly is a necessary consequence of a realistic simulation, while the testing personnel deny that the EW field units exhibits such behavior. Only an examination of actual equipment operation can determine whether the behavior really occurs.

MAINTENANCE AND UPDATES

Hardware stimulation and software simulation both require continual maintenance and updating once the trainer has been installed. EW equipment included in the trainer will require periodic or emergency maintenance, probably by trained personnel. Such maintenance must be provided for either at the trainer site or at the depot level. In addition, the EW equipment will probably undergo revisions in the field. In this case the equipment in the trainer must be modified if it is to be kept current with the field units. Such modifications are typically easy to make on modern military electronics equipment, as they usually involve little more than the replacement of printed circuit boards. This modification can be performed as part of a program of revisions to field units. Even if the revision of the EW aquipment is simple to perform, a revision to the EW equipment may have consequences for the rest of the trainer. Any significant alteration of input requirements may require changes to the signal generation processes of the trainer. The EW revisions may require improved or alterad signal modeling, entirely new inputs or altered timing of existing inputs. Changes may be raquired in signal hardware or even in the simulation software and involve far more effort than the EW equipment modification itself.

Modificetions to a software simulation are typically more difficult to perform as the hardware revisions must be studied, modeled, implamented in software and tested. The softwere changes must go through tha entire design and davalopment process and sra subjected to the same difficulties in testing as ware discussed earlier. This is particularly true if the EW equipment revision results in significantly altered outputs or new enomalous behavior. Data on the new raquirements must be procured end studied, even though documentetion on the revision may be incomplete or difficult to obtein. The affects of the revision must be avalueted end modeled and included into the simulation software. The originel softwere typicelly does not provide for such modifications, so intagrating them into the original software may not be a simple matter. Finelly, testing of the modificeticn is subject to the difficulties discussed earlier, particulerly if the operationel effects of the revision have not been extensively documented.

However, ordinary maintenance of a software simulation is much easier. Once the trainer is in place, the EW software will not require any maintenance unless hidden software bugs are noticed. Any maintenance on the computer CPU or peripherals takes place as part of normal computer operation and is not specifically chargeable to the EW simulation software.

CONCLUSION

Hardware stimulation and software simulation both have their advantages and shortcomings in EW trainers. A hardware stimulation includes actual EW equipment that already comes with a full range of realistic output behaviors, both intended and anomalous, that can be used directly for highly realistic training on the EW equipment involved. If it is part of a larger system, the EW equipment will interface with other components of the system without further development effort, and revisions to the EW equipment can be made relatively easily as part of a general field update program.

Actual EW hardware may present some problems, however. The EW equipment itself may be extremely costly or unavailable for a number of reasons. The software and hardware required in the trainer to produce all of the required inputs may be difficult to design and expensive to produce, and modifications to the EW equipment may have ramifications in the trainer that extend beyond the EW hardware itself.

A software simulation can prove to be less costly to design and produce if exact realism is not required or if many units are to be built. Since a modern trainer performs many functions via a computer, the addition of an EW equipment simulation module may involve only a moderate additional effort. A software simulation also bypasses the elaborate signal generation hardware required by EW equipment stimulation.

A software simulation has difficulties of its own. Trainer realism can be most difficult to achieve, and may be impossible to define and assess. Furthermore, modifications to the simulation require a full design and development process.

Neither approach has an overwhelming advantage over the other, and both have their merits when used in the appropriate situation. A generic trainer involving no specific EW equipment and providing only generalized training should obviously use a software simulation. Any trainer in which EW is secondary or in which moderate realism is necessary is also a candidate for the software approach. On the other hand, a trainer that relies heavily on detailed training on specific EW equipment should probably use hardware stimulation to achieve greatest realism. Furthermore, the greater the complexity of the EW system involved, the greater the advantage of stimulation. Even here, however, recent advances in computer hardware and software techniques have made highly realistic software simulations possible. Thus each trainer design should be considered separately and the approach of simulation versus stimulation chosen according to the particular requirements of the trainer.

ABOUT THE AUTHOR

MR. ROLLIN L. OLSON is a Senior Engineering Analyst in the Electronic Warfare Department, Electronics Division of AAI Corporation. He is currently involved in design and development of simulations of radar warning receivers and radar jammers for Electronic Warfare trainers. He has also developed radar emitter simulations and data entry editors for EW trainers. He was previously involved in quantitative social science research. His educational background includes graduate studies in computer science at Loyola College and in urban planning and history of technology at Johns Hopkins University.