COMPUTER-SUPPORTED OPERATOR TRAINING

FOR

SHIPS INERTIAL NAVIGATION SYSTEMS

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ABSTRACT

The U.S. Navy's new Computer Supported Operator Training System simulates in a series of instructional games the operational environment of the Ships Inertial Navigation System, used as a precision source of navigation data aboard aircraft carriers and submarines. Designed for use at ashore schools for initial operator training and aboard ship for refresher training, the training system's digital computer simulates dynamic, realistic at-sea conditions. A unique Self-Instruction computer program module provides for automatic loading, sequencing, monitoring, and evaluating of games; computer control of time-compression permits twelve hours of ship patrol to be presented in one hour of instructional time. Thus the Computer Supported Training System effectively multiplies the availability of equipment for operational training while reducing operating hours of costly simulated equipment. No new hardware is required: the training system is made up of the inertial navigator's own dedicated digital computer and input-output devices along with special training computer tapes and instructional game workbooks.

INTRODUCTION AND PROBLEM STATEMENT

U.S. Navy electronic technicians assigned to shipboard operator duty on the Ships Inertial Navigation System (familiarly called "SINS") often require six months of on-job experience under patrol conditions to qualify for basic operator duty. Even with shipboard experience SINS operators find it difficult consistently to maintain operational accuracy at levels required by new weapon systems which use SINS data. Two factors are involved in those statements:

1) the problems inherent in the operational environment of SINS

2) the problems of providing effective SINS operator training

The Operational Environment of SINS

SINS is a complex system of inertial sensing devices (gyroscopes and accelerometers) digital computers, computer input/output devices, and data transmission elements, all of which are devoted to the task of generating accurate values of ship ground speed, latitude, longitude, roll, pitch, and heading information. These data are used not only for ship navigation but also by various ship weapon systems, and, aboard carriers, to align aircraft inertial navigation platforms. (See figure 1.) The job of the SINS operator is to keep those data as accurate as possible for as long a period of availability as possible. The measure of operational quality is Effectiveness - the product of Accuracy and Availability - and effectiveness is directly translatable into the ability successfully to align aircraft for missions.

Operators monitor SINS operation by means of teletypewriter typeouts and cathode ray tube terminal readouts. Based on analysis of SINS data presented on these devices (and on the processing of tactical information such as ship power and ancillary equipment status, impending ship maneuvers, and the availability of external reference information), critical decisions must be made:

- To modify SINS operation by selecting one of ten modes and submodes of operation, or to leave SINS alone.

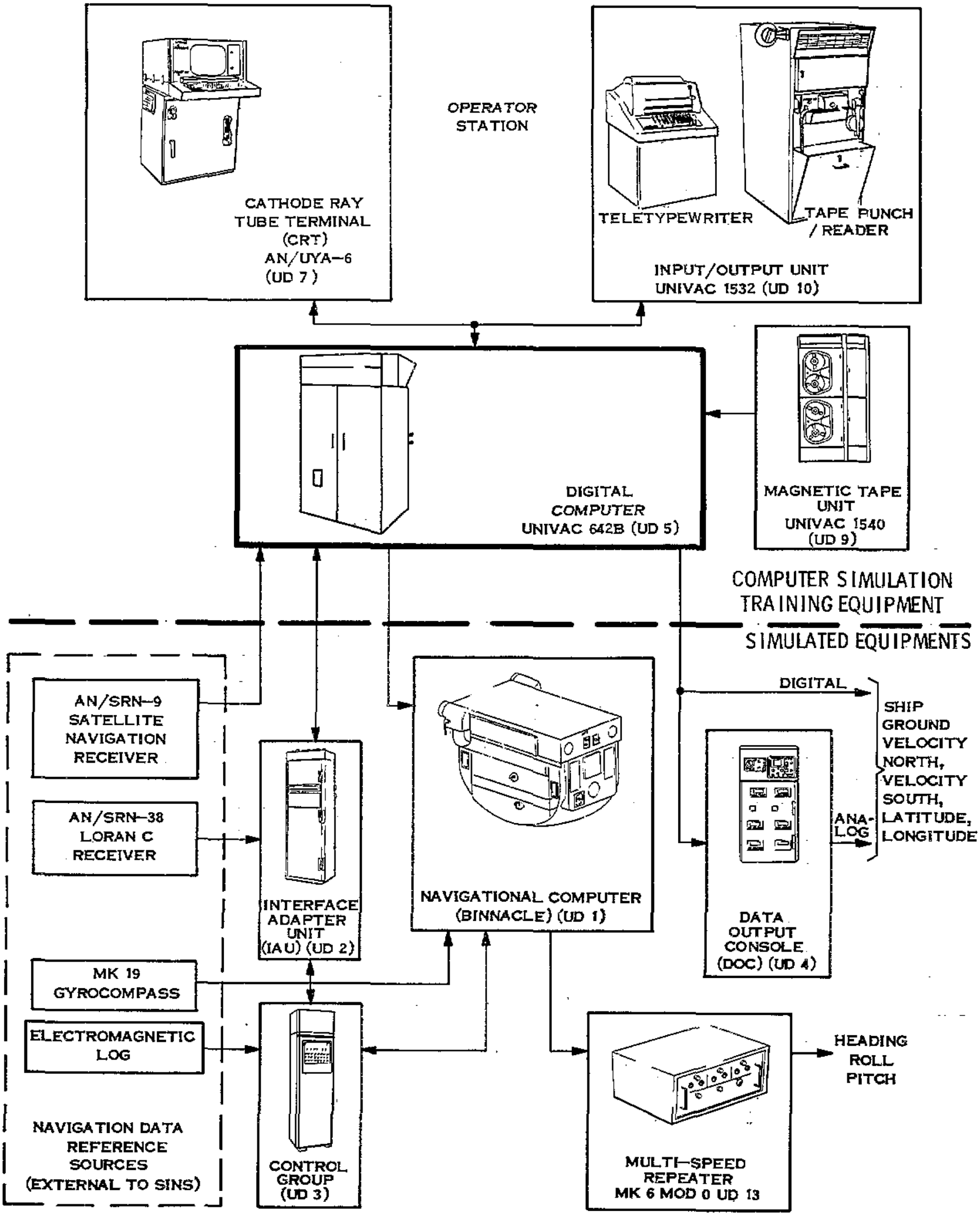


FIGURE 1
SINS MK 3 MOD 7 BLOCK DIAGRAM

- To calibrate or repair SINS if data indicate need for maintenance. (The SINS operator is also the maintenance man.)

Once the decision is made to perform an operational procedure, the actual implementation is relatively simple - control of SINS is carried out either by use of control set pushbuttons or by insertion of computer words at the CRT keyboard.

It should be noted that the operational decisions:

1) require a high order of discriminative and integrative ability

2) are critical in the sense that ship mission effectiveness can be directly affected, and

3) must be made rapidly and decisively under stringent ship tactical conditions.

SINS operators, in brief, are put into a complex situation where critical decisions must be made and implemented. Let's examine the preparation they receive for that assignment.

SINS Operator Training

On-board qualification through on-job experience is often marginally effective and always inefficient: shipboard experience (like most experience) is a poor teacher, because there is little control possible over the type, sequence, or quantity of operational experience. Many critical operational situations do not occur during any one training period; thus the occasion for practical experience may not arise. The tactical shipboard equipment, once started and calibrated, is rarely made available for operational practice, not to mention experimentation.

Initial operator training is the province of the formal ashore Operation and Maintenance Course. But the ashore school situation (where at least the environment is dedicated to training and full-time instructor attention is available) is also ill-suited to effective operator training. Twelve students must share one set of training equipment. The equipment in the school lab does not roll, change heading, nor accelerate, and there is no economical way of making it do so. Students experience none of the dynamic variations in data which so complicate the shipboard environment. The long start-up, settling, and response times characteristic of inertial navigators (preparing for certain operational procedures requires six to twelve hours) result in long periods of valuable training time being wasted or used ineffectively. Instructional control of the "live" SINS — in terms of being able to set up standard, reproducible operational conditions for training — is very difficult. Finally, the expensive inertial components - which must be energized in order to perform operating procedures - accumulate many running hours and start-stop cycles as students attempt to acquire operational experience. Thus, as presently constituted, neither the ashore school nor on-job experience can provide effective or efficient SINS operator training.

Given these elements, how can SINS operator effectiveness be significantly increased at a reasonable cost? The specific aims of the Computer Supported Operator Training System are to:

- provide adequate individual instruction in all operator tasks under a variety of dynamic tactical conditions

- be usable aboard ship or at the ashore school

- use no hardware other than tactical SINS equipment

- increase equipment availability for operator training through the use of computer time-compression

- permit SINS operation with reduced capability and/or maintenance training to be carried out while operator training is going on

- reduce running time and start cycles on costly precision gyros and accelerometers by turning them off during simulation

THE COMPUTER SUPPORTED TRAINING SYSTEM

The term "Computer Supported Training" (CST) was coined to distinguish the system from Computer Assisted Instruction (CAI), in which the training going on is usually unrelated to the skills of computer system operation, and Computer Managed Instruction (CMI), in which the computer acts as a scheduler and housekeeper of instructional requirements. Computer Supported Training is close in concept to "imbedded" computer training; the skills the student uses in operating the simulator as a learning device are identical to those required in the real-word application. The hardware is the same, the computer software appears the same, and the human performance is identical; therefore, there are few problems of transfer of skills from training to real life.

The CST system uses the UNIVAC 642B Computer, the UNIVAC 1532 Input/Output and Teletypewriter Unit, the UNIVAC 1540 Magnetic Tape Unit, and the Philco-Ford UYA-5 Cathode Ray Tube Terminal, all components of the SINS MK 3 MOD 7 inertial navigation system. The other units of SINS are not required during simulation; they can be turned off or used for maintenance training during simulation. A Computer Supported Training System Magnetic Tape, which contains both the simulation program and the instructional games, takes the place of the SINS Navigation Program. Game Workbooks provide instructions to the student for use of the games. The normal SINS library of auxiliary magnetic tapes and technical manuals is used during training. For specifications of the computer used in the CST system, see the appendix.

Simulation and Instruction

The design of a Computer Supported Training System involves two broad (and overlapping) areas of activity:

1) Simulation - programming the digital computer to faithfully reproduce on demand the dynamic realistic SINS output data associated with any tactical operating condition and any operator input.

2) Instruction - programming the digital computer and generating other materials to 1) provide a controlled sequence of instructional experiences to which students can respond; 2) provide for measurement of responses, and 3) provide for feedback contingent on the response.

The Simulation Program

The simulation program is divided into six functional groups:

1) System Executive and Control
2) Self-Instruction
3) SINS Environment Simulators
4) Equipment Simulators
5) SINS Operational Program Simulators
6) Service Programs

The general composition and relationship of these groups is shown in the Simulator System Block Diagram, Figure 2.

The System Executive and Control Group performs primary system initialization at start, maintains system time in real or compressed time, and calls all other system programs in the proper sequence. All operator inputs and outputs to/from the system as a whole are listed in the requirements for this group.

The System Executive and Control Group consists of one program module called the Executive and Control Module (EXEC).

The Self-Instruction Group provides the student self-instruction capability by initializing and continuously controlling the parameters and progress of all simulator functions; it also evaluates student actions. The Self-Instruction Group consists of one program module, called the Self-Instruction Module (SI).

The SINS Environment Simulators Group simulates the training problem time and day, ship motion over the surface of the earth, disturbances to that motion (such as ocean currents), and the true inertial quantities experienced by the SINS inertial components as a result of the combined ships motion, earth rotation and inertial disturbances (such as gravity anomalies). The outputs of this group feed the Equipment Simulators Group. The SINS Environment Simulators Group consists of three program modules:

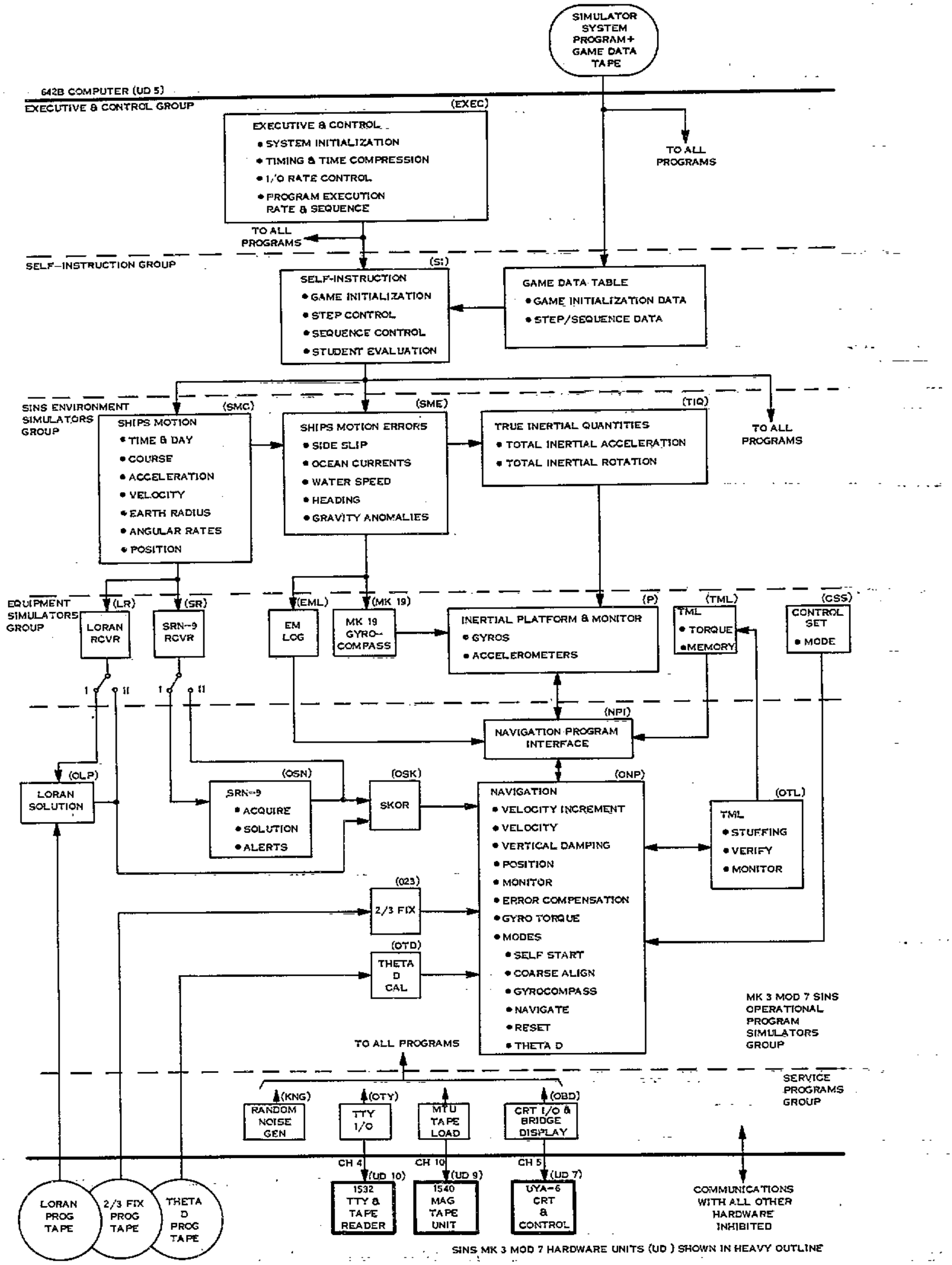


FIGURE 2
SIMULATOR SYSTEM BLOCK DIAGRAM

1) Ships Motion Simulation Module (SMS) - Generates time, day, course, acceleration, velocities, earth radius, angular rates and position.

2) Ships Motion Errors Simulator Module (SME) - Generates side-slip, ocean currents, water speed, heading and gravity anomalies.

3) True Inertial Quantities Simulator Module (TIQ) - Generates true acceleration and angular rate.

The Equipment Simulators Group simulates the functions of equipment units which are not being used directly in the training system. The outputs of this group feed the SINS Operational Program Simulators Group. A program module is used for each of the seven equipments simulated. (See also Figure 1.)

1) Control Set (CS) - SINS UD 3

2) Electromagnetic Log (EML)

3) MK 19 Gyrocompass (MK 19)

4) Inertial Platform and Monitor (P) - SINS UD 1 (Binnacle)

5) Torque Maintenance Loop (TML) - Part of SINS UD 2 (IAU)

6) SRN-9 Satellite Navigation Receiver (SR)

7) LORAN Navigation Receiver (LR)

The SINS Operational Program Simulators Group simulates the functions of those MK 3 MOD 7 SINS operational programs required for the training system. In most cases, the simulations are duplicates of the actual programs with minor modifications to achieve time compression and isolation from the actual hardware.

In all cases, the normal operator-addressed variables are located at their normal addresses and the normal SINS data outputs and alarms are presented. The simulated operational programs communicate with the equipment simulators through interface submodules which convert data to the proper format. The SINS Operational Program Simulators Group consists of seven program modules:

1) Navigation (NP) - Performs all normal inertial platform alignment and support functions and operational modes.

2) Torque Maintenance Loop (OTM)

3) SKOR Automatic Inertial Navigator Reset (OSK)

4) SRN-9 Satellite Navigation (OSN)

5) Loran Navigation (OLP)

6) 2/3 Fix Reset (023)

7) Theta-D Calibration (O_{TD})

The Service Programs Group perform functions of a utility nature which are used by all of the other programs in the simulation system. These include the Display and Input/Output Subgroup and the Random Noise Generator. The Display and I/O subgroup receives and decodes operator inputs from the CRT and TTY, properly formats all simulator outputs for display and typing, and handles magnetic tape input and output via the MTU. The Service Programs Group consists of four program modules:

1) CRT Handling Module
   (CRT) - All UYA-6 handling functions
   (OBD) - Operational Bridge Display Program

2) TTY Handling Module
   (TTY) - All 1532 handling functions
   (OTY) - Operational typewriter printout program

3) MTU Handling
   (MTU) - All 1540 handling functions

4) Random Noise Generator
   (RNG) - Generates white or Markovian noise for general simulator use

A simulator by itself is not a trainer; in the following pages we will describe the process of design and development of the CST instructional exercises which use the tool of computer simulation as the key medium of training communication.

THE INSTRUCTIONAL PROGRAM

Game Design

Instructional game design followed a systematic series of steps (figure 3). Most of the steps are commonly used in instructional program development, but a few notes may help to explain the process of development.

A complete SINS operator task list was made, and the decision points in those tasks were identified. Next, the human behavior involved in making the operational decisions was prescribed. That is, the decision-making behavior of an expert operator was graphically displayed in terms of the stimuli which call up specific elements of behavior, and the response to those stimuli. A simple example might be:

S (stimulus) →	R (response)
SINS alarm light ON	Check SINS for malfunction

The result is a "picture" of the behavior involved in operational decisions. These prescriptions (or behavioral pictures) are very helpful in understanding the problems operators experience in performing correctly.

The prescriptions may show, for example, that an operator must discriminate among a multiplicity of very similar stimuli to select the proper course of action. A discrimination might look like this:

S →	R
Velocity error greater than 6 KTS	Turn SINS Off
Velocity error between 2 KTS and 6 KTS	Change mode to Coarse Align
Velocity error between 0 and 2 KTS	Continue monitoring

Discriminations - which are difficult training problems - require that a student receive many practice exercises in which the differences between stimuli are emphasized. Simulation makes such presentation of multiple examples an easy matter.

The behavioral pictures also reveal instances of generalization behavior - where operators must recognize the essential similarity (rather than the differences) among the tactical stimuli which call for the same operational response. Generalizations look like this:

S	R
Longitude error greater than 3 NM →	Reset SINS
Latitude error greater than 3 NM →	Reset SINS

Behavioral chains involve situations where a single stimulus calls for a single operational response, which, in turn, is the single stimulus for the next response. The first example above depicts one element of a chain, which may have many "linking" steps. This kind of step-by-step behavior is the easiest to learn, assuming that the chains are short. It is generally much more economical to document long chains of behavior than to attempt to train people to remember them.

To completely prescribe SINS operator behavior - to get a full picture of task requirements - searching questions must be asked. We want to know not only what decisions must be made and how they are implemented, but also why and under what specific set of conditions decisions are made. Technical manuals are consulted, shipboard operators interviewed, system and field engineers cross-examined. Sometimes these investigations reveal that decisions are made "because we always do it that way, that's why!" Differences of opinion on procedures must be settled: it's not enough to tell a student, "You can select this mode or this mode or this mode," when you are attempting to shape optimum decision-making behavior.

The simulator will quickly put to the test differences in theories on how best to operate SINS. The result is that some long-accepted operational doctrines are no longer valid, and students are learning simpler and more effective operational procedures. The final product of this step is a set of performance objectives for the behavior required on the job.

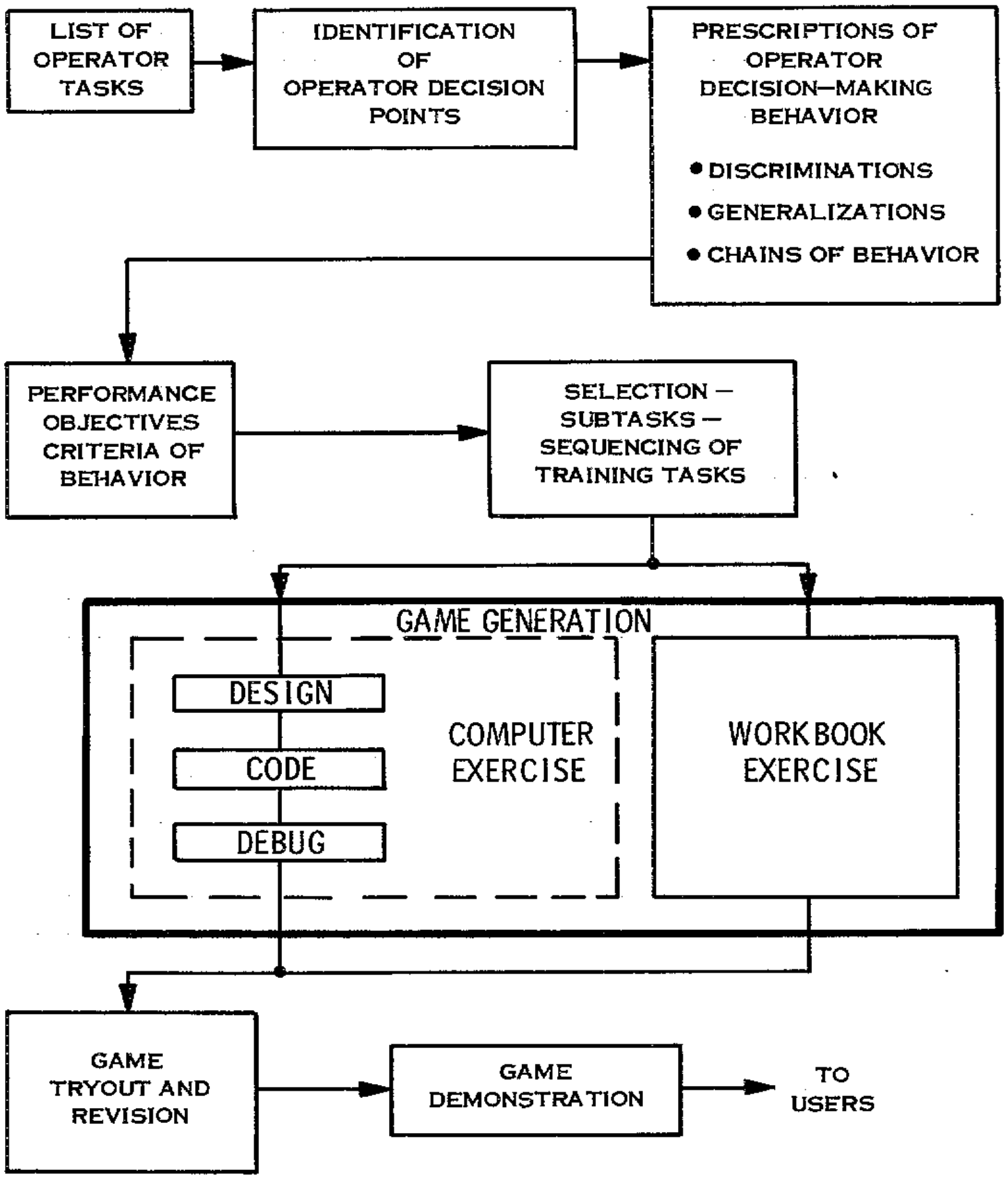


FIGURE 3
INSTRUCTIONAL GAME DESIGN AND DEVELOPMENT

Not all of the behavior required on the job will become the subject of simulation, however. Some tasks can be accomplished only (or more economically) on the complete, live system. A second group can be satisfactorily learned by simpler, less expensive methods than computer simulation. Finally, some tasks can be satisfactorily documented as operational procedures, and need not be learned at all.

Those tasks which are suited to simulation — where repeated practice with varying input conditions is facilitated by the time-compression capability of the simulator — are selected as training tasks. Since most operator tasks involve combinations of discriminations, generalizations and chains, and thereby contain behavior too complex for presentation (and assimilation) in one exercise, the major tasks are divided into sub-tasks. For example: Bringing SINS up from the Off condition to the Navigate mode involves making the decisions to switch SINS from Self-start mode to Coarse Align mode, from Coarse Align mode to Coarse Gyrocompass mode, and so on (through five possible modes) up to the desired Navigate condition. Each of these mode-changing actions involves a critical discrimination, and each qualifies as a sub-task. Since the discrimination is the crux of the operational problem, it is generally desirable to arrange for discriminations to be learned first when sequencing the presentation of sub-tasks. Once those discriminations can be reliably made, the student is ready to integrate the sub-tasks into a complete task.

Game Development

At this point in the design process we know just what we must teach (the content), in what order the content should be taught (the sequence), and what level of mastery is to be achieved (the criteria of performance). Now we are ready to develop learning exercises - in game workbooks and on the computer - which will change the behavior of students.

Computer simulation and game workbooks are combined as methods of presentation in the CST system. The computer is used to develop and present the realistic, varying data which acts as the stimulus for decision-making behavior. The computer is programmed to monitor and evaluate student responses, because it does these tasks quickly and efficiently. The paper workbook provides textual instruction, charts, teletypewriter records, and graphics which are costly, time-consuming, or impossible to present on the computer. The paper workbook can be kept by the student as a repository of notes and a record of his progress. In short, of those instructional actions which must be performed, the computer does what it only can do, and the workbook does what it can do more economically than the computer.

When a person, given a set of specific stimuli, performs a desired response to a desired level of accuracy in a desired number of instances, the response is said to be learned. One systematic way of achieving learning involves three steps:

- a demonstration is made of the desired behavior in the presence of the normal stimuli
- practice exercises are provided to the student, and, finally
- the student is evaluated to determine his qualification

In the demonstration, complete instructions for the student to perform the desired response are provided, he is guided to make the correct response, and feedback about the suitability of the response is made available to the student for purposes of reinforcement. In succeeding practice exercises, the operational conditions are varied and the instructions for performance are gradually removed. After a series of such practice exercises, the student is ready to perform without assistance and under all required conditions. He is ready for qualification.

The Demonstration Exercise

A sample demonstration exercise, which is typical of the workbook/computer interaction in the CST system, is shown in figure 4. The textual instructions are kept to a minimum - in this instance, SINS is in the process of settling (a process in which SINS errors are gradually reduced over a 50-minute period) and the student is instructed to plot the errors in ground speeds ΔV_X and ΔV_Y as settling goes on. The student is

A "demonstration" exercise.

Theory of operation and criteria for performance are provided

GAME 2 BASIC SINS MODE CHANGES

With the ship underway, EM log disturbances cause the velocity differences to be difficult to monitor. In the next run, YOU plot the velocity differences each time the simulator freezes; then unfreeze and monitor to the next stop.

Refer to pullout 2 for COARSE ALIGN criteria. Note these requirements for sequencing from CA to CGC:

REQUIREMENT	HOW TO VERIFY
Monitor Table Working	Typeout of M Line
Torque Maintenance Loop Working	Types *** STATUS REPORT *** (TIME) TOK (TML IS OK)

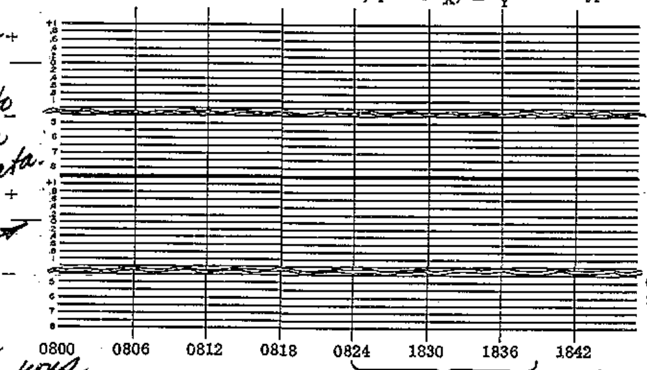
Student starts the simulator

3 CONDITIONS: Ship underway, CA mode has just started, monitor table on, TML is OK.

OBSERVE: Settling of ΔV_X, ΔV_Y in CA

ACTION: Each time the simulator freezes, plot ΔV_X, ΔV_Y for the typed-out times. Then Unfreeze.

Student observes and plots data when simulator "freezes". This is designed to draw attention to required data.



Connect the points and fair in the settling curve: compare with PO 2.

These are fairly "clean" velocity differences: the ship maneuvers are small.

Student follows specific instructions for responding

When the ΔVs stay below 0.5 Kts for these 15 minutes, change to CGC.

▷ Record time and CGC on the teletypewriter when you're ready to change mode.

▷* Don't forget to use the * when you set the DATA INPUT back to OFF.

Instructions for interpreting the game typeouts are provided

Interpretations:

IF SIMULATOR TYPES	YOU SHOULD
PROCEDURE ERROR, ENTER STEP NO.	Repeat ▷3 ; do not enter anything except the mode change to CGC
MODE ERROR, ENTER STEP NO.	Repeat ▷3 ; carefully check your mode word; be sure to turn DATA INPUT to OFF.
RETURN TO WORKBOOK and freezes	Plot data on graph above.
DECISION REQUIRED, with or without freeze	Make mode change
GOOD DECISION STEP COMPLETE ENTER STEP NO.	Continue reading paragraph 5 on the next page; good work so far!

PLOTTING SINS VELOCITY DATA - COARSE ALIGN 2-5

14

FIGURE 4
SAMPLE GAME WORKBOOK PAGE

instructed to change mode from Coarse Align (CA) to Coarse Gyrocompass (CGC) when settling is complete. The symbol 3> signifies to the student that he is to type 3 on the SINS teletypewriter, thereby automatically starting this simulation run. Note that the CONDITIONS of the simulator run are specified, the data the student is to OBSERVE identified, and the ACTION to be taken is clearly listed. In this exercise, all of the computer typeouts (the teletypewriter records as many as eight complete lines of SINS data every six minutes) are suppressed with the exception of the one line containing the desired data. Thus, a large quantity of distracting stimuli which would very likely confuse the beginning student, are removed.

To increase the probability that the student will perform successfully - after all, we want to reinforce correct behavior - we do several things to insure (or aid) correct performance during demonstration exercises. We automatically freeze the simulation each time the data should be recorded; we design a plotting board which facilitates making the record we indicate the exact time during which settling will take place: finally, if all else fails, we freeze the simulator and wait for the student to make the correct input. A table of possible simulator responses completes the exercise. When the correct input is received, a confirming GOOD DECISION is printed out, and instructions for going to the next exercise are provided.

The Practice Exercise

It is unsatisfactory to provide such aids to performance continuously: eventually the operator must perform without any such assistance. In order to achieve such mastery behavior, practice is required. Practice involves the gradual removal of all aids to performance. In later steps of the same game, students will be required to identify the critical settling period without the assistance of notes on a graph, and the simulator will not freeze and wait for the student response. In addition to removing the aids, the training task is gradually made more complete and, therefore, more complex. Eventually, all of the sub-task decisions must be made in the proper sequence, and in a reasonable time. Distracting data, which were excluded from the first steps, are gradually introduced in the practice steps.

Finally, all of the typewriter lines and all of the functions found in the fully operating SINS are presented in the practice exercise, and the student, trained now to identify just those stimuli critical to the problem at hand, can accommodate the distractions and respond correctly.

Practice exercises present an opportunity for free-play. Students can experiment with operational decisions in an attempt to improve their performance. When mistakes are made, the game can simply be repeated, with no penalty.

The Qualification Exercise

Has the response been adequately learned? To answer that question, we must evaluate the behavior. Evaluation in the Computer Supported Training System takes the form of a Qualification Game which each student attempts after completing the series of instructional games. No assistance in the solution of Qualification problems is given, and grading is on a pass-fail basis. Provisions are made for varying the conditions of Qualification games, so that Qualification requirements will not be compromised. The Qualification game does not attempt to provide all or even a majority of the combinations of conditions that will be experienced aboard ship. Rather, representative sample patrol conditions, typical of day-to-day routine as well as emergency situations, form the basis for the Qualification Game. Perfect accuracy and very fast response are not required in the Qualification Game; we are, after all, qualifying a beginning operator.

Self-Instruction

It became obvious early in the design phase that while a human instructor could initiate simulator operation and could probably introduce some variations, the task of operating, monitoring, and evaluating student performance in compressed time would be too great. In addition, it was desired to use the training system in locations (e.g., aboard ship) where full-time instructional assistance is unavailable. Consequently, a self-instruction mode of operation was adopted. The Self-Instruction module of the simulation program makes it possible for a Game computer tape to:

1) Supply input variables in a series of time-related sequences

2) Control the stimuli presented to the student

3) Monitor the quality of system operation

4) Evaluate and provide feedback in respect to student responses

Thus, in the game step discussed previously, the speed and direction of ship motion, the ocean currents affecting the ship, and the operational characteristics of internal system components (such as gyro drifts) are varied at specific times. Loss of certain data (as for example, the malfunction of an external or internal sensor) can be simulated. System functions and their readouts which are not required for specific instructional exercises can be turned off, thereby reducing the number of distracting stimuli to which the new trainee is exposed. The quality of simulator operation is continuously monitored in order to detect catastrophic loss of data induced either by gross operator error or by system malfunction.

The Self-Instruction module makes provisions for two types of evaluation. In the Operator evaluation mode, student responses (for example, data words or keys inserted from the CRT keyboard) are evaluated. In the System evaluation mode, the student is not required to respond; the computer automatically evaluates any desired piece of data stored in the computer.

English messages (GOOD DATA, DATA ERROR, GOOD DECISION, PROCEDURE ERROR) are typed out depending on whether the evaluation was a pass or fail. Alternatively, the Self-Instruction module can be made to type out the positive digits 1 through 7 (for pass conditions) and negative digits (for failures) for use when quantitative scores are desired.

The game designers can also use the results of evaluation to control the sequencing of the game. The Self-Instruction module permits the evaluation to cause the simulator to continue to the next exercise, to freeze while the student performs some action, or to abort the step (return to the first exercise).

Student Control

In addition to the automated program game tape control, a considerable degree of manual control over system operation is exercised by the student. Unless a specific operation is inhibited by the game tape, any normal SINS operational procedure can be performed. The student starts games when he is ready, and he can abort a game when he wishes. He can change time compression to speed to a future time or to slow down a complex data variation. He can freeze time while he makes a decision, and unfreeze when he wishes to proceed. All of these student operations are initiated at the teletypewriter where a record of all operations is kept.

Tryout and Demonstration

Although we have concentrated on the perhaps lesser-known elements of computer game design and development, the importance of the tryout and demonstration stages should not be neglected. The final stages of game development insure that the materials and techniques are effective in terms of achieving the desired behavior change and usable by the target population in the environment for which the system was designed. Revisions to materials to satisfy both of these criteria are usually necessary.

The complete system must be introduced and explained to the using personnel. No training system - even a system of self-instruction - can work effectively without the aid and support of the people who will use it.

THE COST-EFFECTIVENESS OF COMPUTER SUPPORTED TRAINING

The cost of developing computer supported training is not difficult to assess; unfortunately, the cost of not having CST is almost impossible to count accurately. If the navigation system is effective for one more day out of an eighty-day patrol, what is the cost benefit of that additional day? If four aircraft launchings in one patrol are successfully made which would otherwise be aborted, what is the dollar value of four successful rather than four aborted launchings? And just how much effectiveness improvement can be expected as a result of a single (though significant) improvement in personnel training?

Over the life of the system, about 400 students will have access to the present Computer Supported Training System. Since there are about fifty hours of instruction in the present system, there will be a total of around 20,000 student hours, yielding a training system cost of $20 per student hour. Of this cost, 70% (about $14 per student hour) is attributable to development of the simulation program and 30% ($6) to game development. Thus the development of more games (or the use of the basic simulation program in other training systems) would have a large impact on cost. The costs of distribution, administration, and supervision of the new program are not included, since it is likely that the same structure (school and ship organization) presently responsible for SINS training will take over responsibility for the new system.

One hour of computer-simulated operator training time is the rough equivalent of eight hours of actual equipment time. If the CST system were designed to replace an existing equivalent conventional operator training curriculum, the savings in direct labor costs of students and instructors would be substantial. Unfortunately for purposes of cost comparisons (not to speak of on-board effectiveness), there <u>is</u> no present equivalent conventional operator training.

Assuming that the CST system were properly integrated into the school curriculum, maintenance training can be carried out on the assemblies of the SINS not used during operator training (the Binnacle, the Data Output Console, the Interface Adapter Unit, and the Control Set). This feature can minimize the impact on the curriculum of the introduction of the new training system.

A final economy involves the reduction in equipment running time when using the Computer Supported Training System. Operator training involves frequent changing of modes and starting and stopping of the system. Operating mistakes made by inexperienced students, coupled with the excessive start-stop cycles accumulated by the system during operator training, result in very large spares requirements and maintenance expense.

THE FUTURE OF COMPUTER SUPPORTED TRAINING

Computer Supported Training is now a tool available to the Navy. The extent of performance improvement and time and cost savings which can be achieved depend largely on how extensively it is applied. The CST system must be integrated into the present personnel training cycle if its full effectiveness is to be realized. Ashore formal school curriculums and on-board training routines must be modified. The establishment of multiple CST System training stations in the ashore school may be necessary to insure that each student receives ample operator experience. New games required to complete the job of operator training, and variations to existing games to provide additional practice, should be developed.

The present CST program is designed specifically for the SINS application aboard carriers. Extension of applicable games and computer techniques to other SINS environments is certainly feasible. Obviously the more applications that are made of the basic simulation programs, games, and materials, the greater the cost-effectiveness.

CONCLUSION

Computer Supported Training Systems based on simulation of Ships Inertial Navigation System operator tasks is a feasible approach to the solution of difficult shipboard performance problems, the solution of which will lead to improved mission effectiveness. The CST system properly integrated into the personnel training cycle can multiply the effective availability of training equipment in the school and provide, at no additional cost, on-board refresher training where presently none exists.

Cost comparisons are difficult to make, because the costs of systems which offer solutions to problems are being compared to the cost of systems which are ineffective. The CST system is not a panacea; it is only one tool in a group of elements which must be implemented. The amount of improvement in shipboard effectiveness resulting from any one element in a complex performance system is very difficult to measure - much less predict - accurately. The value to the Navy of an improvement of effectiveness is also unknown, although it can be substantial if the improvement permits a critical mission to be completed which would otherwise have been aborted.

We in the training profession tend to concentrate on the value of the human element. And we know - even if we can't assign an exact dollar value - that an operator who goes to his first ship assignment confident that he can perform the basic operating procedures under dynamic conditions, ready to pull his share of the operating duty because he qualified on the Computer Supported Training System, is a valuable resource indeed to the Navy.

REFERENCE

Program Specification for CVA SINS Simulation Program for use with 642B Computer, Naval Strategic Systems Navigation Facility (now NADC, Warminster, Pa.), NSSNF 920673, June 1973.

APPENDIX - COMPUTER CP-642B SPECIFICATIONS

The CP-642B Computer is a general-purpose, stored-program machine capable of processing a large quantity of complex data where heavy input/output communication is required. It is designed for compatibility with the AN/USQ-20 data set of the Naval Tactical Data System (NTDS). Principal features of the computer include the following:

- Internal high-speed storage with a cycle time of 4 microseconds and a capacity of 32,672 words
- Control storage employing magnetic, thin-film memory with a cycle time of 2/3 microsecond and a capacity of 64 words
- Repertoire of 62 instructions, most of which provide for conditional program branches
- 30-bit word length
- Optional operation with 15-bit half-words
- Internally stored program
- Programmed checking of data parity
- Parallel, ones complement, subtractive arithmetic
- Single address instructions with provisions for address modifications via seven index registers
- Internal 7-day, real-time clock for initiating operations at desired times. Location 00160, LSB = 1/1024 second
- Provision for connecting external real-time clock
- Handy immediate addressing
- Optional number of input and output channels of 4, 8, 12 or 16 for rapid data exchanges with external equipment or for communicating with other computers without program attention
- Option of two interfaces; one of the NTDS interface and the other a higher speed interface for faster peripheral equipment. This option may be exercised in 4-channel increments
- Two 32-word nondestructive readout (NDRO) memories, each with a cycle time of 2/3 microsecond, for storage of critical instructions and constants. These memories provide the facility for automatic recovery in the event of temporary program or system failure and for automatic initial loading of programs.

ABOUT THE AUTHOR

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