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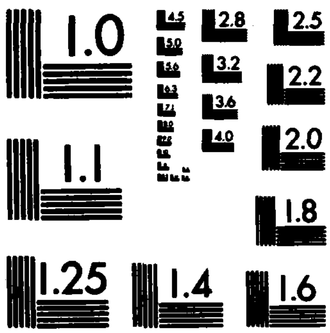
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PROJECT STEAMER: VIII. SYSTEM EVALUATION BY NAVY PROPULSION ENGINEERING TRAINING PERSONNEL

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PROJECT STEAMER: VIII. SYSTEM EVALUATION BY NAVY PROPULSION ENGINEERING TRAINING PERSONNEL

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The STEAMER computer-based propulsion engineering training system was installed at the Surface Warfare Officers School in Newport, R.I. and made available for use by Propulsion Plant Trainer (PPT) instructors. The instructors felt that the STEAMER system could make a valuable contribution to propulsion training and suggested many potential uses for the system in support of training. Also, observations of their use of STEAMER revealed a number of ways in which the user interface could be improved. The results of this evaluation are being incorporated into the STEAMER development

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) process and a subsequent evaluation period involving both students and instructors is being planned.

FOREWORD

This research and development was conducted under contract with Bolt Beranek and Newman, Inc. in support of subproject Z1177-PN.03 (STEAMER: Advanced Computer-based Training for Propulsion and Problem Solving) and was sponsored by the Chief of Naval Operations (OP-01). The main objective of the STEAMER effort is to develop and evaluate advanced knowledge-based techniques for use in low-cost, portable training systems. The project is focused on propulsion engineering as a domain in which to investigate these computer-based training techniques.

This report is the eighth in a series on the STEAMER project. Previous reports described an initial framework for developing techniques for automatically generating explanations of how to operate complex physical devices; a user's manual for the STEAMER interactive graphics package; a method for generating explanations using qualitative simulation; CONLAN, a constraint-based programming language well suited for describing and analyzing complex devices; a mathematical simulation of the STEAMER propulsion plant; the then-current STEAMER prototype and basic support software, and a computer-based training system for monitoring a boiler light-off procedure (NPRDC TNs 81-21, 81-22, 81-25, 81-26, 81-27, and 82-25 and NPRDC TR 82-28). This report describes an on-site evaluation of the STEAMER system at the Navy Surface Warfare Officers School (SWOS) in Newport, Rhode Island. Results are intended for Navy training managers and designers and developers of computer-based training systems.

Appreciation is expressed to the SWOS staff, especially CDR Bissonnette, LCDR Ogurek, and Chief Tradevman Henley for their help in arranging the placement of a STEAMER system on site and scheduling SWOS staff members to observe it.

The contracting officer's technical representative was Dr. James Hollan.

J. W. RENARD
Commanding Officer

JAMES W. TWEEDDALE
Technical Director

SUMMARY

Problem

Naval officers, technicians, and operators have insufficient opportunity to practice complex skills such as those involved in the operation of propulsion engineering plants. For many complex skills, increased practice is so prohibitively expensive that Navy personnel have had only a minimal level of practice. Accordingly, the STEAMER effort was originated to develop advanced knowledge-based techniques for use in low-cost portable computer-based training systems. The ultimate goal is an inexpensive desktop-sized computer training system that will greatly increase the amount of practice and quality of training available to Navy personnel. To ensure that the development efforts meet Navy training requirements, an in situ development plan is being pursued. At all stages of development, STEAMER is made available for use by Navy training personnel.

Objective

The objective of this effort was to conduct a user evaluation of a prototype STEAMER system.

Approach

STEAMER was installed at the Surface Warfare Officers School (SWOS) in Newport, Rhode Island and made available to SWOS officers and instructors.

Results

SWOS instructors and staff members made strong positive comments about STEAMER and suggested many potential uses for the system in support of training. Observations of their use of STEAMER revealed a number of ways in which the interface could be improved.

Follow-on Efforts

1. The results of this evaluation are being incorporated into the STEAMER development process.

2. STEAMER is currently being used by students at the Propulsion Engineering School, Great Lakes, Illinois.

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INTRODUCTION

Problem

Naval officers, technicians, and operators have insufficient opportunity to practice complex skills such as those involved in the operation of propulsion engineering plants. For many complex skills, increased practice is so prohibitively expensive that Navy personnel have had only a minimal level of practice. Accordingly, the STEAMER project was originated to develop and evaluate advanced knowledge-based techniques for use in low-cost, portable, computer-based training systems. The ultimate goal of the project is to provide a detailed, easily inspected simulation and automatic tutor in a desk-top sized training device. The project is developing techniques for displaying and controlling simulation models and for automatically providing tutorial advice and explanations. It is focused on propulsion engineering as a domain in which to investigate these techniques.

Background

Since the STEAMER system was to eventually include an automated tutor, it was necessary to determine the nature of the explanations given by human tutors and authors. Accordingly, the first report on STEAMER (Stevens & Steinberg, 1981) developed a taxonomy for generating explanations of how to operate complex physical devices; and the second (Stead, 1981), the development of the STEAMER graphics editor. This software system supported the creation of plant diagrams on a color graphics display device. The graphics editor is at the heart of the user interface to the mathematical model. Forbus and Stevens (1981) described some exciting new work in the use of qualitative simulation to generate real-time explanations of operating complex physical devices. They built a software system that could not only simulate the behavior of a steam reducing valve, but also give an account of its own behavior in terms a human student could understand. Roberts and Forbus (1981) described the LISP language implementation of the mathematical simulation model that the STEAMER system uses to simulate the behavior of a steam propulsion plant. Other reports described the computer language used in STEAMER (Forbes, 1981), the entire STEAMER system as of 1982 (Stevens, Roberts, Stead, Forbus, Steinberg, & Smith, 1982), and a computer-based system for monitoring the boiler lightoff procedure for a 1078-class frigate (Hutchins, Roe, & Hollan, 1982).

The current STEAMER system (Figure 1) consists of a computer-based simulation of a 1078-class frigate propulsion plant, a color graphics display for inspecting and controlling the simulation, and a black and white display for exercising other features of the system. STEAMER is controlled by a device, called a "mouse," which is used to point at items on the two screens. The student uses the mouse to manipulate the simulated steam plant by pointing at displayed valves, causing them to open or shut, pointing at other components to turn them on or off, and adjusting other simulated components such as throttle valves. This procedure is so simple that it requires almost no instruction or practice to master. Changes in state of the components are indicated by color changes or by changes on depicted indicators such as dials, thermometers, and digital readouts. For example, in Figure 2, which illustrates the major plant parameters, the throttle setting is depicted in the column above the throttle valve. To change the throttle setting, the student simply points at the setting he desires on this column and clicks the mouse, which causes the throttle to assume the indicated setting. As the throttle changes, the turbine RPM, steam flow, main steam pressure, and flow into the hotwell change accordingly. As the hotwell level changes, the flow through the condensate pump, governed by submergence level, also changes and the flow rate is shown dynamically in the pipes.

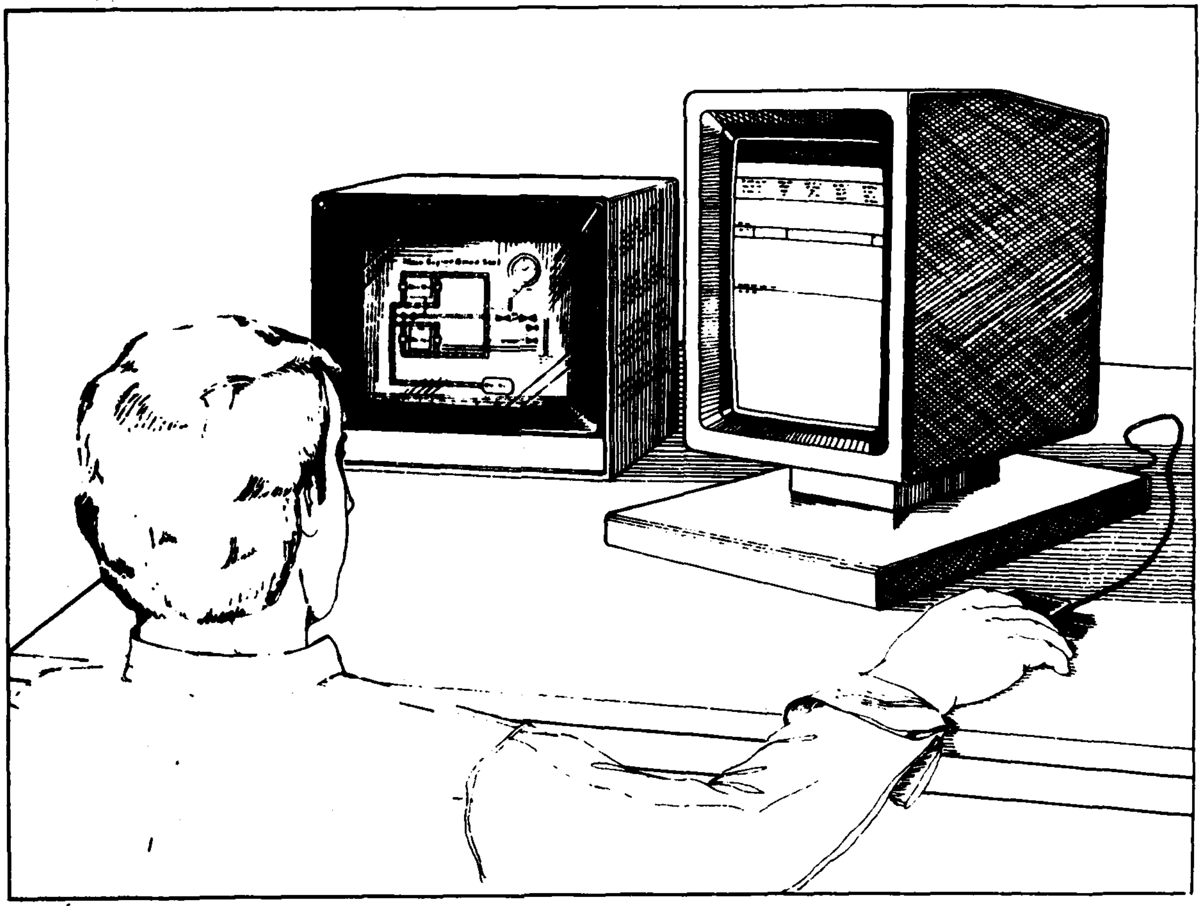

Figure 1. The STEAMER system as it appears to a user.

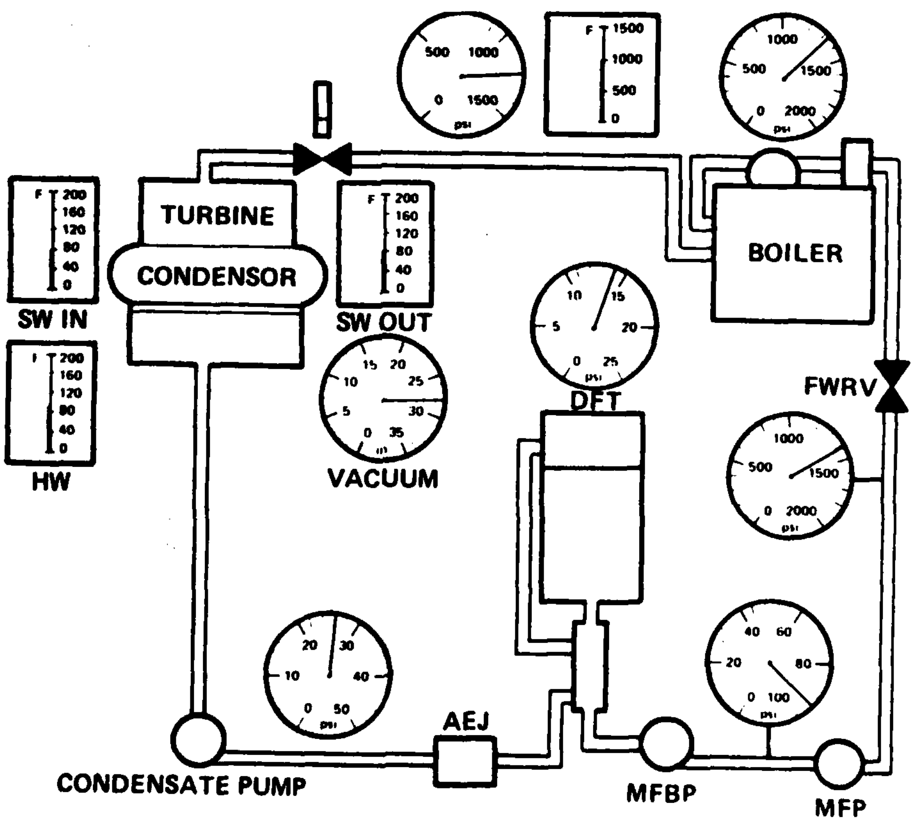

Figure 2. A top-level display showing the major plant parameters.

Figure 2, the engineroom schematic diagram available to the student in this example, shows only 20 or so components and indicators. A steam plant is much more complicated than that. Using STEAMER, the student can access other propulsion plant subsystems by using the mouse to select other views from a menu of choices displayed on the black and white "command" screen. For example, if the student selects "Main Engine Lube Oil" from the menu, the engineroom diagram in Figure 2 is replaced with the diagram of the main engine lube oil system shown in Figure 3. Using this diagram, the student or instructor can experiment with and observe the complex control dynamics in the lube oil system. He can close the throttle to decrease the shaft rpm (141 in the figure) and observe the oil pressure dropping, causing the pressure sensor (number 1) on the most remote bearing to close and the standby pump (LOSP 1A or 1B) to come on line. He can go to a casualty panel, cause the standby lube oil pump to fail, and then go through the exercise again to see how the emergency pump backs up the standby pump. He can observe the unloading valve opening and dumping oil to the sump if the shaft rotation increases and electrical pumps are not shut off. He can even observe the effects on pressure of such casualties as a clogged strainer.

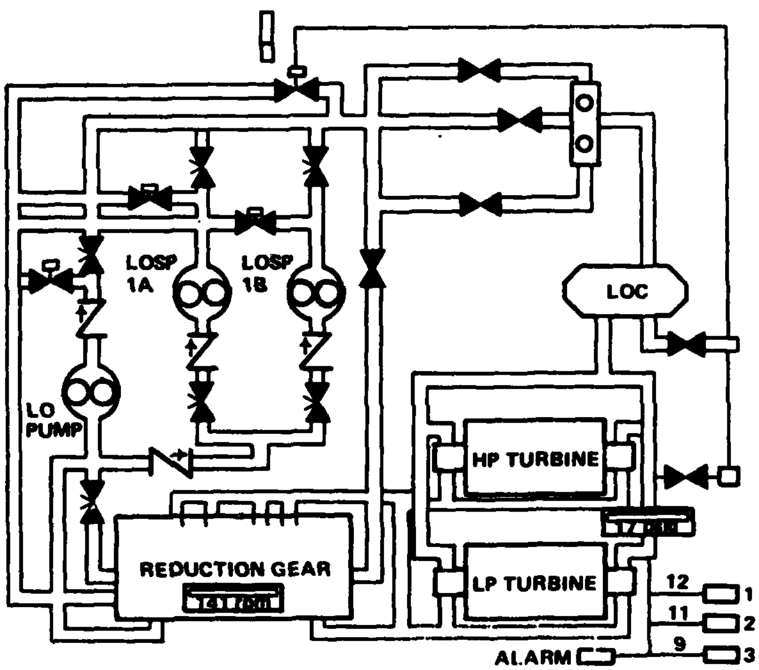

Figure 3. An interactive diagram of the main engine lube oil system.

It is useful to contrast this interactive, inspectable simulation with other training environments. On a ship, the main engine lube oil system is intertwined with several other systems in the engineroom. Since virtually all of the lube oil system is constructed from opaque material, it is extremely difficult to view it and grasp what is happening. This same problem applies to full-scale simulation mockups such as the Navy's 19E22 trainer. With a STEAMER display, the whole lube oil subsystem and its important parameters can be inspected in a single view. The rapid control dynamics can be seen and understood in a glance. Other propulsion plant systems can be examined by simply selecting other diagrams for display. Because STEAMER is based on a simulation, the student or instructor can experiment with and observe the effects of various casualties without fear of damaging real equipment.

To make STEAMER maximally usable by students, it is designed to incorporate an intelligent tutorial component capable of providing students with guidance in plant operating procedures, instruction in basic operating principles, and explanations of component and subsystem operations. Currently, the tutorial component consists of (1) an initial implementation of a procedures tutor capable of monitoring students as they execute procedures, single-stepping procedures, and displaying those procedures on the black and white screen, (2) an initial implementation of an explanation generation component capable of explaining the operation of a simple feedback system, and (3) a set of "minilabs" for teaching basic principles necessary to understand the plant.

In a powerful computer-based training system like STEAMER, the same hardware that delivers instruction can also support the development and updating of curriculum materials. The major curriculum development tool available in the current STEAMER system is designed to make diagram construction easy. Rather than providing a fixed set of diagrams with which to examine the plant, STEAMER incorporates a graphics editor that makes it possible to build new diagrams or modify old ones by using the mouse to select and lay out the component gauges, pipes, and other indicators on the screen. Thus, an unlimited number of diagrams can be developed.

Even though the STEAMER system is being developed in the domain of propulsion engineering, a large part of the system is generic. Its graphics system and editor, tutorial capabilities, and user interface have all been designed to work with other simulation models. STEAMER is just one instance of a class of training systems based on the idea of an easily inspectable and controllable simulation model.

As a computer-based training system like STEAMER is developed, a large number of design decisions must be made that often take the form of selecting the proper tradeoff among various desirable features. One particularly simple example is the tradeoff between the number of different colors one can display and the amount of animation that can be performed. There can be more animation at the expense of fewer colors, or more colors at the expense of less animation. Too often, such decisions are made based on a system builder's point of view rather than a user's point of view. In determining the optimal balance between users' needs and engineering constraints, consideration must be given to many factors that can only be identified through close collaboration with users of the system. To ensure that such design decisions are influenced by user needs, the STEAMER project has followed an in situ development plan intended to bring users and developers together so that a two-way flow of information is established. Designers learn about the users' needs and the way they interact with the system; and users learn what is and what is not technologically feasible so that they can provide constructive input to the development process.

In February 1981, STEAMER was installed in the Navy Surface Warfare Officer School (SWOS) at Newport, Rhode Island, and evaluated by SWOS personnel. Many subsequent design decisions were based on that evaluaton. During June, July, and August, 1981, development personnel attended the Main Propulsion Assistant 78 course at SWOS to obtain information on which to base decisions as to which critical systems and parameters should be depicted.

Objective

The objective of this effort was to conduct a user evaluation of a prototype STEAMER system.

APPROACH

During March 1982, a prototype STEAMER system, which included the simulation, a set of diagrams, the graphics editor, and a set of minilabs, was installed at SWOS Newport. Even though the current system is not as portable as is ultimately planned, it took less than 2 hours to install. The displays were set up in the Propulsion Plant Trainer classroom, surrounded by tables, chairs, and desks. The processor was placed in the trainer computer room. The most difficult part of the installation was running two cables to connect the displays and the processor.

During a 1-week period in March 1982, SWOS instructors, training managers, and high-level officers spent from 1 to 10 hours, with an average of 3 hours, observing and using the STEAMER system. Also, because the system was located in a high traffic area, many other people informally observed and commented on it. It was anticipated that the evaluation information would be useful in determining the following:

1. General User Acceptance. The "folklore" that new users tend to be intimidated by computer systems was an issue of special concern at SWOS because SWOS personnel have had extensive experience with a large-scale, mock-up propulsion plant simulator, the 19E22, which looks like a steam propulsion plant and is used for "hands-on" training. Since STEAMER, with its two CRT screens, looks more like a computer than a trainer and emphasizes conceptual training, it was felt that it might be negatively perceived.

2. Potential Uses For STEAMER. STEAMER development was begun with a particular set of ideas about its use. During the various development phases, this set has been expanded. It was hoped that the evaluation would provide ideas about STEAMER use to see if (a) the initial ideas seemed to be reasonable and (b) there were new ideas that had not been considered.

3. Interface Design Decisions. As described above, in developing STEAMER, many design decisions were made that influence its usage. It was anticipated that, by letting instructors actually have hands-on experience with STEAMER and carefully observing them and talking with them, developers would be able to see where the design needed revision. This "fine-tuning" of the user interface should contribute greatly to the ease with which computer systems can be used.

The evaluation was informal. SWOS personnel were shown STEAMER, allowed to use it themselves, and asked a number of questions. Notes were taken on all comments made.

RESULTS AND CONCLUSIONS

General User Acceptance

Virtually everyone who saw STEAMER, from SWOS students and their instructors to the commanding officer (CO), were very positive about it. The staff had been instructed not to react to the "pretty colored pictures" but to try to give an honest appraisal of the system. The appraisals were all positive, as evidenced by the following comments:

1. If we had this, we could make everyone a lot smarter.

2. This is a dynamite concept in training.

3. A student could spend 5 minutes playing with this and understand pressure scales (referring to the pressure scales minilab).

4. Letting people see where the flows go is one of our major problems.

5. I saw the little movie at the marine propulsion steering committee, but seeing it for real is much more impressive. Could you take this to the next meeting?

6. Make up and excess feed is hard for students to understand. This makes it easy.

7. I can even do a flex test on this boiler [followed by doing it].

8. Instead of having to run all over to look at different parameters changing, you can do it all right here.

9. It's clear that systems like this are going to play a major role in Navy training in the future.

As indicated above, it was anticipated that STEAMER might be contrasted unfavorably with the 19E22 trainer. However, as the week went on, it became clear that SWOS staff members genuinely accepted STEAMER and felt that it would be very beneficial to their training program. More than anything else, this acceptance was evidenced by the following oft-repeated scenario. Two SWOS staff members would sit down, leaning back in their chairs some distance from the screen. A researcher would give one the pointing device (the "mouse"), assure him that nothing would break, and tell him what to do, step by step. The staff member would dutifully go through those steps, bringing up a diagram and starting the system running. At this point, his attitude could be characterized as "interested but skeptical." He might bring up the LOSP 1A diagram, and the researcher would show him how to point to its components and manipulate them. Often he would spontaneously begin the light-off procedure or a PMS check on the relief valve, going through it step by step. As he did and as things began to happen, both staff members would start to lean in and crowd toward the screen, their interest level picking up. The researcher would then direct them to another diagram, main engine gland seal, and show them how to cause a casualty. The unloader would fail and the GS pressure would drop. At this point, the instructors often made comments concerning the events represented by the diagram, suggesting that they were no longer in the world of computers but, rather, in the world of steam plants. One instructor said, "We're probably losing condenser vacuum. How do we check that?" He then brought up the throttleman's panel, saw that it did indeed register a loss of vacuum, and then returned to gland seal to fix the casualty.

The instructors found STEAMER easy to use. Most were quite happy to sit down and experiment with it; few seemed to be intimidated. It was clear that the ease of pointing, the assurance that nothing would break, and the minimal use of a keyboard all contributed to this. It was particularly impressive to find SWOS instructional personnel spontaneously exploring the system when researchers were not present.

Serveral staff members suggested that STEAMER's ability to easily "move around" the plant and examine different subsystems during an evolution or a casualty gives it a major advantage over actual hot plants or simulation mock-ups. STEAMER takes 10-20 seconds to switch from one diagram to another, which is much quicker (and easier) than physically moving from one watch station to another. Since the simulation is also under user control, it can be stopped at critical points and many different subsystems examined, effectively making it possible to be in many places at once.

Potential Uses of STEAMER

All personnel who examined and used STEAMER were asked to provide suggestions about its use. The potential uses suggested tended to mirror the instructors' experience. In many ways, STEAMER is not simply a training system but also an instructional medium that can be adapted for a large number of different uses. Thus, asking instructors how they might use STEAMER is similar to asking them how they might use viewgraphs, film, or slides. There are many potential uses, depending on the curriculum, what the instructor is trying to teach, the instructor's imagination and creativity, where the system is being used, and what type of students he is dealing with. STEAMER's good user interface; general-purpose, easily modified, animated graphics; inspectable simulation; and minilab capabilities allow large sets of instructional materials to be easily developed and stored. By serving as an easy-to-use development tool and storage medium, it is likely that the usefulness of STEAMER systems will be greatly increased as the number of curriculum materials developed by Navy training staffs is increased. Experience with previous computer-based educational systems suggests that this is likely. A good example is the PLATO system, which provided a number of basic curriculum development tools and indexing facilities and consequently grew into a large library of teaching materials (Lyman, 1975).

Suggestions provided were divided into two groups--those that require only the current STEAMER capabilities and those that require modifications to STEAMER. These suggestions are described below.

Suggestions Requiring Only Current STEAMER Capabilities

The following suggestions are organized according to roles in training. None requires significant additional development or major extensions of STEAMER functionality.

Classroom Use. Almost all users suggested that instructors could use a large-screen version of STEAMER in a classroom to illustrate operating principles, flow paths, operating and casualty procedures, and basic physics. The major concern expressed was that a large-screen version should have resolution and color quality equal to that of the current STEAMER monitor.

STEAMER produces a standard, high quality video signal that can be used to drive many different types of commercial monitors. This signal can also be encoded into the standard signal used by the American television industry. The encoding process degrades the signal somewhat. However, once encoded, any monitor that can be used for television, including projection systems, could be used to show STEAMER diagrams. To preserve quality, a configuration that uses multiple monitors in a classroom could be used. The STEAMER project is currently examining different monitor configurations.

Shipboard Use. Instructors could use STEAMER on board ship to illustrate operating principles, flow paths, operating and casualty procedures, and basic physics. Since smaller groups of students would be taught, a standard-screen version of STEAMER would be adequate. Currently, STEAMER runs on a computer very similar to the Three Rivers Perq computers that have been installed on USS CARL VINSON, so there is already a precedent for such machines aboard ship.

Augmentation to a Full-scale Trainer (either a simulation mock-up or a hot plant). STEAMER could be used at individual watch stations to show what is going to happen, what is happening at other places in the plant, and what is happening inside different systems during the course of various evolutions. During complex evolutions, such as a plant lightoff, STEAMER would allow students to see their role in the evolution, which is currently very hard to do.

The current STEAMER system could support such training. For situations where one needed to show only what was happening inside a single system, independently of other systems, a smaller microprocessor-based system might be sufficient. An interesting extension of this idea that could be applied to team training is to connect together a set of systems communicating over a network, each with a subsystem simulation. These "watchstation simulators," when run together, would simulate an entire system. Each watchstander would be responsible for his own station, but team and communications training for major evolutions could also be conducted.

Remedial Training. Students having trouble on examinations could use STEAMER to experiment with systems they were having trouble understanding instead of having to study manuals. This is a straightforward application of STEAMER, which was subsequently attempted at SWOS during July 1982.

Individual Student Study. Several instructors suggested that students could use STEAMER to experiment with various system operations and practice standard procedures to see how their actions affected different systems. Some instructors qualified the suggestion by noting that a traditional computer-aided instruction system would not be a good idea. One instructor stated, "We don't want our students staring at CRT screens and answering multiple-choice questions with a light pen."

The STEAMER development plan currently calls for adding various tutorial capabilities to the system, all designed to make it easier for students to use STEAMER without instructor intervention. For example, as described above, the tutorial capabilities will make it possible to step through standard procedures, practice procedures, and ask questions about the reasons for the ordering of procedure steps. An initial implementation of the procedures tutor exists but was not part of the system evaluated at SWOS.

The concern expressed by the instructors reflects the view that a computer-assisted instruction system that simply automates programmed instruction texts is an unsatisfactory alternative. However, by making computer-based training systems interactive, challenging, and clearly job-related, as has been done with STEAMER, it appears that a high degree of user acceptance of individualized instruction is possible.

Competitive Games. STEAMER could be used by two students (or groups of students) in competitive games. One student (or group) could introduce an irregularity into the plant either directly, by reconfiguring a system, or indirectly, through the casualty facility, and the other could try to diagnose and correct it. This mode of learning has been suggested by others (Brown, Burton, DeKeer, & Benhaim, 1976) and observations indicate that both groups learn a great deal. The competition increases motivation and both groups are forced to develop a detailed understanding of the system--one to diagnose the problem and the other to introduce problems that will be difficult to diagnose.

Group Problem Solving. Group problem solving was a common mode of interaction observed with the instructors using STEAMER. This mode took the form of their trying something, observing its effects, and then discussing it among themselves. For example, one instructor opened the gland seal unloader all the way and the gland seal pressure dropped. The group then went to the condenser vacuum gage and had a lively discussion about how fast the vacuum was dropping--one arguing that it was dropping way too slow and another, that it was dropping about right. The argument was resolved when they considered the throttle position, which was about one third, and decided that, at that throttle opening, the condenser vacuum would indeed fall rather slowly. This mode of problem solving serves to stimulate discussion and provides a situation in which a person with the relevant expertise can easily communicate it to others.

Instructor Training. Several SWOS staff members suggested that individual instructors could use STEAMER to increase their level of expertise in propulsion plant principles and operating procedures. Instructor training would likely benefit most from group problem solving or individual study features of STEAMER.

Suggestions Requiring STEAMER Modifications

The following suggestions are for additional capabilities that the SWOS staff felt would add to STEAMER's usefulness. The version of STEAMER used at SWOS had no significant tutorial capabilities, so some of the capabilities suggested are already under development.

Standard Flow Paths. If STEAMER were augmented so that flow paths in diagrams could be turned on in standard flow configurations, students and instructors could have available a library of diagrams illustrating any system in any predrawn state. Since the diagrams would not be connected to a simulation, any diagram desired could be easily constructed and animated. They would not, however, be interactive, and would show only one state. This requires only a minor change to STEAMER. It can be thought of as a "degenerate simulation" with only a single state. It exercises only the graphics capabilities of the system.

System Diagrams. Learning the connectivity of propulsion plant systems is currently time-consuming and difficult for students. This may be due to the fact that learning those systems depends, to a large extent, on knowing general engineering principles (e.g., a positive displacement pump always has a relief valve on its discharge side), as well as specific connections. A STEAMER capability that allowed students to draw selected propulsion plant subsystems and provided real-time correction of their errors could do much to facilitate this learning.

A number of different types of correction could be provided. The simplest would be a check that all components were present and connected correctly. The student could be told what he had omitted, what he had included incorrectly, and which connections were incorrect. The mechanisms for implementing such a capability exist within STEAMER. The graphics editor could provide the student the means for drawing the diagram, and simple algorithms to check components and connectivity could be implemented. Different starting diagrams could be provided. For example, a student could be given all the components and asked only to connect them, as is done with some of the system drawing procedures now. A curriculum development tool that enabled instructors to remove the connections among a set of components and check the students' ability to regenerate the connections could be easily developed using the graphics editor.

The correction capabilities just described are minimal. More sophisticated tutorial capabilities that attempt to diagnose missing general knowledge could be developed. For example, if a student draws a positive displacement pump and omits the relief valve from its line, it indicates a lack of general knowledge about the way positive displacement pumps work. When instructors correct students' drawings, they provide this information. An automated tutor capable of providing this level of advice would be more difficult to develop. It would require analysis of drawings for typical errors and what they indicate. The actual implementation would require a more sophisticated analysis algorithm to recognize these errors in students' drawings.

The ultimate capability would be a tutor that built a simulation from the student's drawing, ran it, and showed him what would happen in critical situations. Instructors provide this type of information when they correct students' drawings. This capability would be difficult to develop. It is similar to that discussed under Instructor Modifiable Simulation below.

<u>EOSS Training</u>. If engineering operation sequencing system (EOSS) procedures were available in STEAMER and could be displayed on one of its screens, students could step through EOSS procedures and see what each step did. This capability is currently being developed as part of the STEAMER procedures tutor. When completed, it will enable students to display an EOSS procedure on a separate screen and step through it so that the effects of each step can be observed. The student will be able to ask questions about step ordering and see explanations in terms of engineering principles. The procedures tutor will also include the capability to monitor the student performing a procedure and provide feedback about its correctness, with respect to both EOSS and engineering principles.

<u>Instructor Modifiable Simulation</u>. Currently, STEAMER makes it easy to construct diagrams that show any set of parameters in the 1078-class plant simulation that is part of STEAMER. Many SWOS personnel expressed the desire to have STEAMER construct a simulation that corresponded to the diagrams they drew. This would enable students to experiment with systems in a "design laboratory" where they construct and experiment with various alternate systems.

Several unsolved problems are associated with this general capability, most stemming from the fact that additional information not in the diagram must be inferred or assumed by the simulation building process. If the problem is simplified in various ways and more information is collected from the person drawing the system, some of the capabilities are possible. For example, when drawing a pump, the user could be asked for its standard parameters--horsepower, capacity and head--so that the proper pump model could be used. When drawing a tank, he could be asked for its capacity and depth. With this information, the simulation building system could combine a set of generic component models into a subsystem model that could be run.

An easily modifiable simulation capability would have other major implications for developing training systems like STEAMER. Currently, one of the major costs for such systems will be the development of the simulation model. However, it is by no means a straightforward problem to solve, and several difficult problems would need to be solved before this capability could be provided. It is not currently planned as part of the STEAMER effort.

Particle Animation. A capability based on ideas drawn from currently popular video games was suggested. If it were possible to create animations of molecules, novel training materials for boiler water chemistry could be developed. Although the basic system capabilities required to implement the animation are easy to provide, an underlying simulation of the process, which would require development for each application, is needed.

Curricula For Specific Trouble Areas. Even before EOSS procedures are fully implemented, it might be possible to develop curricula for trouble areas. The student could be guided through a set of steps and alerted to things he should be paying attention to--either by self-guided study after-hours or in a remedial tutorial mode. In either case, it would be useful to provide the instructors with a set of tools for creating those scenarios that they think would be most helpful in getting the message across. This suggestion was made by instructors in regard to some of the main propulsion assistant (MPA) trainees who are having trouble.

Implementation of such a capability is not difficult. The major tool needed is one that would enable an instructor to develop a "script" that intermixes STEAMER commands, plant operation commands, and text for presentation to the student. The student could then run the scenario, see each step, and be given text to read at key points.

The most convenient form of such a capability would be to provide a mode of STEAMER in which all actions are saved as part of a script. An instructor could then simply go through the sequence he wanted to demonstrate, insert textual comments for presentation at appropriate points, and save the whole sequence. Some way of editing the script would also be required and could be done in a similar way, allowing a replay with insertion/deletion of steps allowed.

Diagrams For Local Procedures. A senior chief boiler technician (BTCS) exercised the fuel oil pump diagram and exclaimed, "I just did the relief valve PMS on the fuel oil pump!" Obviously, a number of small diagrams could be created to support many such local procedures. This is an easy addition and requires only constructing the diagrams and pairing them with procedures. It will be possible as soon as the procedures tutor is completed.

STEAMER Curriculum Package

In discussions with officers and instructors about particular problem areas in STEAMER curricula, the following three were identified: automatic boiler control, boiler circulation, and electrical systems. Previous work on STEAMER has been directed at boiler control systems and is continuing; therefore, boiler control problems will not be discussed here.

The set of diagrams necessary to support electrical and boiler circulation curricula was outlined during this evaluation period. Problems with these curricula are discussed below.

Boiler Circulation

It is difficult to visualize what is happening and why it is happening when boiler water circulates. The central problem in understanding natural circulation comes from the fact that there are two opposing forces at work, one promoting circulation and the other impeding it. Circulation is promoted by the thermal driving head so that, as the heat input rate increases, the thermal driving head increases and the circulation rate increases. It is impeded by the effects of head losses so that, as the circulation rate increases, head losses increase and thus opposition to circulation increases. The thermal driving head goes up linearly with heat rate but the head losses go up as the square of circulation rate. The net effect is that, for a range of heat inputs, an increase in heat input will cause an increase in circulation. However, at some point, the increase in circulation ceases and additional heat is not accompanied by additional circulation.

The whole process is further complicated by the fact that this crossover point changes with boiler pressure. Navy boilers are designed so that the fuel oil system cannot provide a heat rate above the crossover point at normal operating pressure. However, at the lower boiler pressures that might occur in emergency situations, the crossover can be reached and the generating tubes damaged.

The natural circulation process also provides the underlying explanation for the counterintuitive phenomenon of boiler shrink and swell. Currently, these concepts are extremely difficult to teach. The following is a minimal list of the diagrams necessary to teach boiler circulation, which was developed with one of the SWOS instructors:

1. A boiler diagram showing steam drum, water drum, a riser, a downcomer, a circulation indicator level in the steam drum, feed flow, main steam flow, and heat rate. Manipulation of heat rate would be allowed.

2. The same diagram but with the addition of a manipulable steam drum pressure.

3. STEAMER dynamic graphs added to the same diagrams so that plots of thermal driving head, heat rate, and head loss can be made dynamically as the system runs.

The simulation for this is not difficult to construct. It would be based on a small set of equations describing the relation between the thermal driving head, circulation rate, head loss, and boiler pressure. The student would use the first diagram to observe the effects of heat rate on circulation rate. A large heat-rate range would allow him to see the point beyond which circulation rate does not increase with heat rate. He would use the second diagram to observe the effects of pressure on this crossover point. The pressure could be decreased and the heat rate manipulated. Finally, with the third diagram, he could construct dynamically a set of graphs similar to those used in current SWOS training materials as the system ran. The remaining parameters shown in the first diagram could be used to show shrink and swell as heat rate changes.

Electrical Systems

Electrical system training could clearly benefit from STEAMER. The following list of diagrams has been developed by a SWOS instructor for electrical systems:

1. Ship's service diesel generator (SSDG) lube oil system.
2. Generator lube oil system.
3. SSDG fuel oil system.
4. Salt water booster system for the SSDG.
5. Generator air box system.
6. Combustion cycle showing intake, compression, power, and exhaust.
7. Boiler configuration while running ship's service turbine generators (SSTGs).
8. Diagram of two SSTGs in parallel with SSDG set for automatic ops.
9. Synchronizing monitor system with switch alignments.

10. Stator temperature system.
11. Ground detector system.
12. Selective tripping with radial alignment.
13. SSDG governor system.
14. Component procedure to go along with equipment.
15. Fuel oil filter and strainer to show suction side and discharge (pressure side) of how they work in conjunction with the pump.
16. Both sides of the mechanical and electrical governor with the lube oil in the governor.
17. Overspeed trip devices of the SSDG.
18. Injector.

Fourteen of these diagrams are possible with the current STEAMER system. Representing the component procedures will be possible with the first implementation of the procedures tutor. The remaining four diagrams (6, 12, 14, and 16) are illustrations of component parts (e.g., the fuel oil filter) or general processes (the combustion cycle, selective tripping with radial alignment) that require additional simulation capabilities.

Interface Modifications

It is important to emphasize that, in general, SWOS staff members found STEAMER easy to use; many sat down on their own to experiment with it. This section describes suggested aspects to the interface that did cause trouble and that, if modified, would make STEAMER more convenient to use. The modifications are all relatively minor, and several have already been made since the evaluation. The biggest change suggested is to the STEAMER command pane (10 below). A new command pane has been implemented to make the most frequent commands larger and to provide additional status information.

1. Simplified Start-up. It should be possible to completely reinitialize STEAMER with a single key or simple combination of keys.

2. Push Buttons on STEAMER Views. Push buttons in diagrams would be more natural if holding down the mouse button accomplished the holding down of the push button. There are a few instances where that would be inconvienent (e.g., when one wanted to look at another diagram while the button was depressed) but, in those cases, some other mechanism could be used.

3. Conventions For Parts of Diagrams That Can Be Affected. There should be a standard convention for indicating which parts of diagrams can be acted upon and which are insensitive to mouse clicks.

4. Consistent Stopping of The Model. The fact that the model stops when the screen is reconfigured makes the instructions for the introduction of casualties inconsistent. It should not be necessary to say, "You have to click on run again if you are choosing from a newly presented list of casualties; otherwise, the model keeps running." The model should always keep running unless it is explicitly stopped, the STEAMER menu is deselected, or a minilab is run.

5. Small Columns. It is hard to position small column-type valve controllers to extreme positions. Wiring up the valve for discrete on/off would solve the problem but makes for a unnatural sort of interaction. This problem could be solved by changing the column icon so that, if the column position was indicated at, say, less than 5 percent, the

column would be set to its minimum; and, if indicated at greater than 95 percent, to its maximum.

6. Casualty Menu Highlighting. On a reset of the model, casualty conditions are cleared, but the highlighting in the casualty window remains.

7. Alarms. Where alarms are indicated in the diagram, they should flash when triggered. The keyboard audio could be used for primitive acoustic signals.

8. Status Line. The status line should include a list of the casualties that are now in effect.

9. Cursor Color. The white cursor is difficult to see when it is over a yellow background on the color display screen. A cursor, shaded the complement of the color it is over, would be more visible.

10. Command Pane. The command pane should be reconfigured for the user. The commands that are frequently used (space, view, reset, status, run, start, casualties) should be larger than they are now and should perhaps be spatially rearranged to conform to frequent sequences of invocation. Commands that are infrequently used or that are there only for system development should be smaller or should be removed.

11. Command Names and Documentation. More thought should be given to the choice of command names and the wording of the documentation line. "Move the cursor to the AED" wasn't very meaningful to a chief machinist's mate (MMC). In doing this, a consistent model of the system should be imparted to the user.

12. Graphics Editor Commands. On the graphics editor, errors can easily result from having a draw command in both the diagram window and the grid window. The shape command is most frequently used to change size rather than shape.

13. Diagram Changes. On the mcp-submergence diagram, the pump head should be labeled "Pump discharge head." In MEGS, excess gland seal steam should be a different color to emphasize the difference between it and other steam.

14. Icon Changes. There should be a convenient way to indicate level within a circular icon (e.g., an end-on view of the steam drum).

15. Throttle Ticks. Several instructors wanted to do ramp load changes on the system. Ticks on the throttle position indicator on the main interface frame would allow this.

FOLLOW-ON EFFORTS

To evaluate STEAMER's instructional potential for enlisted personnel, the system was recently installed at the Engineering Systems School, Naval Training Center, Great Lakes, Illinois. A controlled experimental evaluation of the use of STEAMER as an instructor aid in the classroom is currently being conducted there. The system is being used to instruct enlisted personnel who are experienced in steam propulsion (E-7s and above who have been reassigned to the fleet) and those who have no prior exposure to steam propulsion systems (students in the 6-year obligatory propulsion engineering program).

In the course of the long-term relationship with SWOS Newport, proposals for subsequent evaluations there have been discussed. A typical MPA class includes a few students who fail exams and are put on a remedial study program. They are required to spend 3 hours a day in the Trainer classroom under supervised study. Currently, the supervision is minimal and consists of having them read technical manuals. SWOS staff felt they would make a ready population of people to use STEAMER, benefiting both SWOS and the STEAMER project.

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