THE GENERALIZED SONAR MAINTENANCE TRAINER

DR. MORTON A. BERTIN
MR. EDWARD L. PARKER
Human Factors Research Inc.

It is my intent this afternoon to describe the results obtained during a two-year research effort sponsored by the U. S. Naval Training Device Center. The basic purpose of the research program was to determine the feasibility and the desirability of developing a new type of training device called a Generalized Sonar Maintenance Trainer, or G. S. M. T., for use in teaching calibration, alignment, and troubleshooting skills to maintenance technicians.

The basic premise underlying the development of this trainer is that functional similarities and design similarities exist among contemporary sonars which can be capitalized upon in the design of training equipment. These equipment similarities generate common skill and knowledge requirements. It is possible, therefore, to design a training device which embodies all common sonar circuitry, illustrates all important equipment functions, and allows all normal maintenance techniques to be exercised. Skills and knowledges acquired through the use of such a trainer will then transfer to any of a variety of actual sonar equipment.

The approach traditionally taken to sonar maintenance training, in fact to Navy maintenance training in general, has been to use operational equipment as training devices. This has been called the "vehicular" training concept and is recognized and employed at the present time in our electronic schools. Despite the apparent validity of training maintenance personnel on actual equipment, there are a number of practical problems and limitations associated with this procedure that have been known to training specialists for some years. First, due to the rising cost of operational equipment, the schools typically have only a few units available for maintenance training. Consequently, the ratio of students to sonars is often very high. Traditionally there has been competition between the Fleet and the schools for delivery of early models at the very time when training needs are most critical. Second, the physical layout of operational electronic equipment has not been designed with training in mind and often is not suited to the training process. Because of packaging density, calibrations and test procedures are difficult to demonstrate and troubleshooting is difficult to observe. Third, the physical layout of an item of electronic equipment may not be related to its functional organization. For example, a single signal processing channel may extend through several equipment cabinets. Consequently, it is difficult to organize lectures and demonstrations around functional equipment units even though it is natural for student technicians to think in functional terms. Fourth, the sonar used for basic maintenance training is often different from that to which the graduate is assigned. Students often do not recognize the common features which sonars share. They often indicate that they are not in any way capable of maintaining an unfamiliar piece of equipment because they have not received training on it. Fifth, it is difficult and time-consuming to introduce malfunctions and miscalibrations into the equipment for student diagnosis. Also, the expense of the equipment tends to preclude the introduction of serious malfunctions because of the physical damage to the equipment which may result. Sixth, it is difficult to isolate the weaknesses of individual students and to ensure that each student engages in the necessary practice. Much of the activity is necessarily cooperative with the result that one strong student will often carry along several weaker ones. Finally, training on the general principles of sonar circuitry is very likely to be deemphasized in favor of the specific characteristics of the equipment being used as the training vehicle. This is due in part to the instructor's familiarity with the particular sonar used during training. Students tend to become bogged down with specific equipment details which may be of little or no use to them in the future and, in fact, may be the basis for negative transfer of training.

Because of these seven inherent limitations of actual equipment used as training vehicles, it was predicted that a generalized training device might enhance training effectiveness given the same amount of exposure. Trainees would receive much more practice in actually working with sonar circuitry and at a small fraction of the cost involved when operational equipment is used. It was also predicted that there would be greater transfer of training from a generalized training device to an unfamiliar sonar than there would be from one sonar to another. These, then, are the assumptions underlying the development of the G. S. M. T.

I would like to turn now to a description of the procedure by which the prototype trainer was developed. This procedure may, for convenience, be divided into three phases. First, identification of all common equipment features and maintenance requirements in a sample of contemporary sonar systems. Second, incorporation of all common equipment features into an experimental training device. Third, validation of the basic notions underlying the trainer through the conduct of an experimental training study at the U. S. Fleet ASW School.

A sample of six operational sonar equipments was first selected for study. Sonars were picked from among those installed aboard submarines, helicopters and destroyers. They included both vacuum tube and transistorized equipments, and included modular as well as traditional construction techniques. It should be noted that no micro-miniaturized sonars were present in this sample of equipments as none have been installed in the Fleet thus far.

Next, techniques were developed to identify common equipment features in this sample of sonars. A detailed analysis of the six sonars was made in which the functional purpose of every circuit in every sonar was determined. This step was first attempted using the technical manual data rather than circuit analysis but failed because of the appalling number of errors in nomenclature and equipment descriptions contained in the manuals; on the order of 20 percent. Next, groups of circuits comprising equipment subsections were identified and the functional purpose of each subsection determined. This process was continued through larger and larger equipment groupings until each of the sonars had been entirely described functionally. Common equipment features were then determined at each level of equipment complexity.

From this analysis, a number of interesting results were obtained. First, it was found that a small number of circuit types account for virtually all circuitry within sonar equipment. Figure 135 shows the results of an anlysis at what has been called the "functional block" level. The abscissa shows the various functional blocks arranged from left to right in decreasing order of occurrence. On the ordinate is shown the number of times that each circuit was found in the six sonar sets combined. It may be noted first that 16 functional blocks account for all of the circuitry in all six sonar equipments. Second, it may be noted that 90 percent of all circuitry in all sonars may be accounted for by the four most common functional blocks. The three lines on the slide show the breakdown of circuits for all sonars in a sample, for the entire group less the BQS-6, and for the entire group less only the pre-amplifiers in the BQS-6. It may be recalled that the BQS-6 contains an extremely large number of pre-amplifiers. To avoid a misleading picture of the circuits contained in the group, it was decided to portray the BQS-6 separately.

It is important to note the "J" shaped function shown in this slide. It is a shape which occurred frequently throughout all of the analyses of this type conducted during the project and is indicative of the high degree of commonality found among the various equipments.

Figure 136 presents the results of an analysis of the calibration, adjustment, and alignment requirements of the sample of sonars. Various types of calibrative activities are shown along the abscissa again organized from left to right by frequency of occurrence. The number of instances in which these activities are required to calibrate all six sonars is shown on the ordinate. Again, please note the shape of the function. Very few types of maintenance activities appear to account for the vast majority of activities in this sample of equipments.

Figure 137 shows the results of an analysis of the checks of proper system operation required by the sample of sonars. The abscissa shows the various checks arranged from

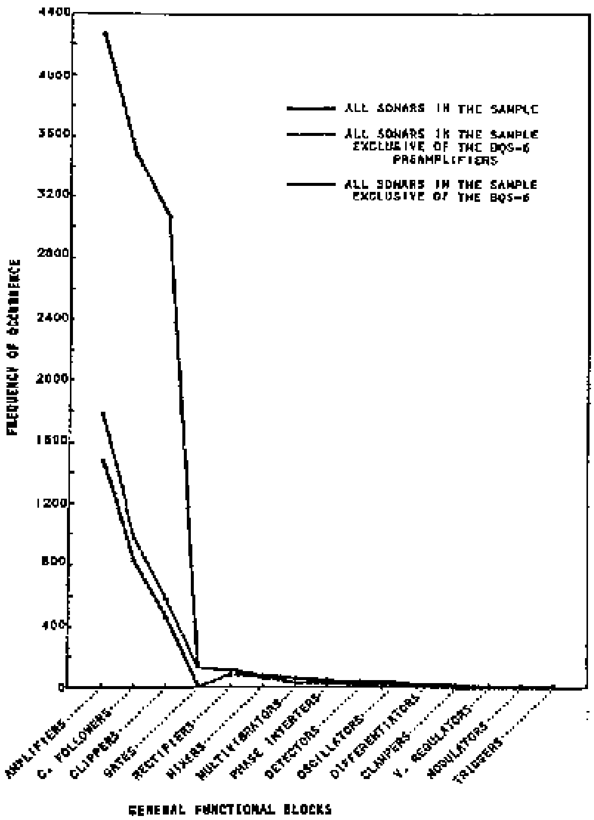

Figure 135. General Functional Blocks

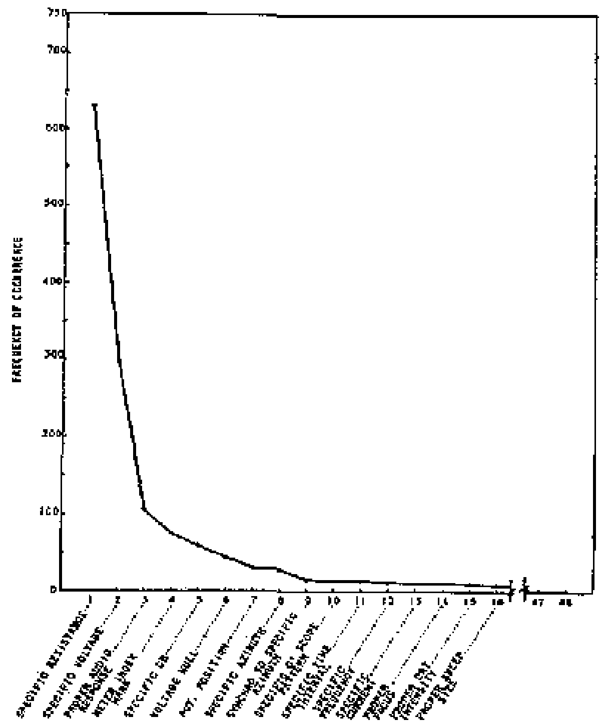

Figure 136. Calibrations and Adjustments Required by Sample

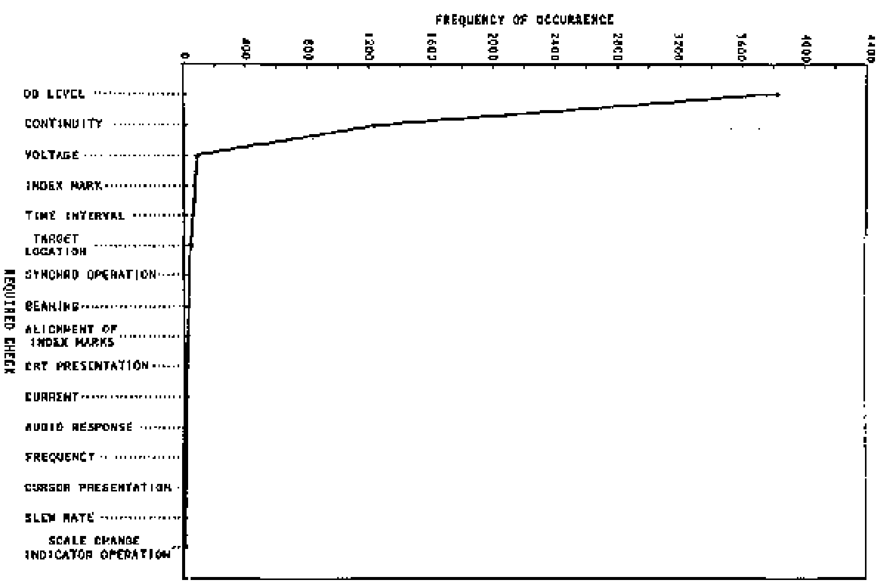

Figure 137. Required Check

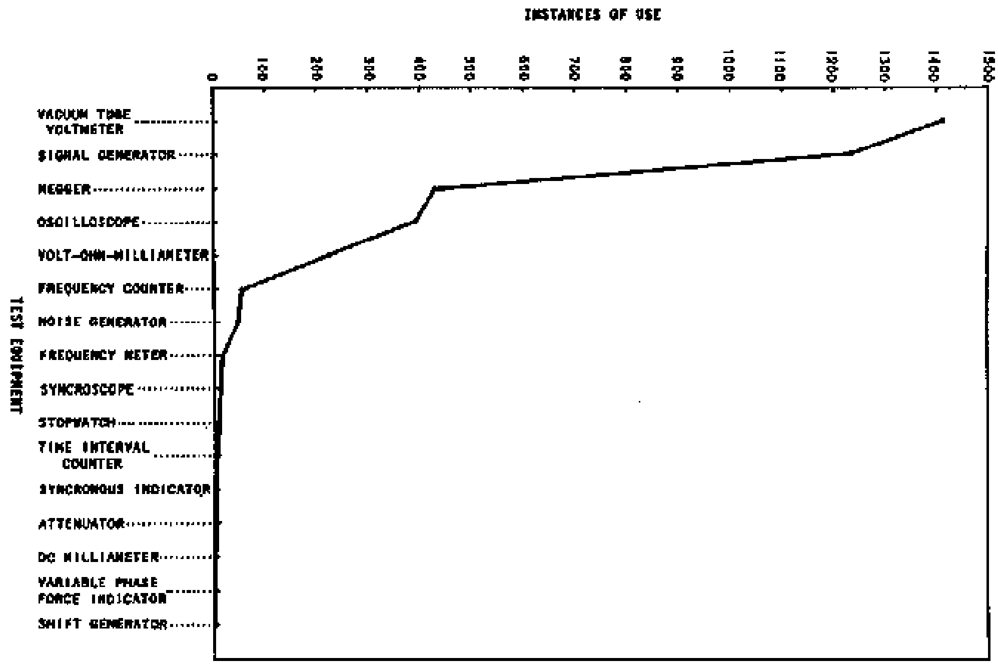

Figure 138. Test Equipment Requirements

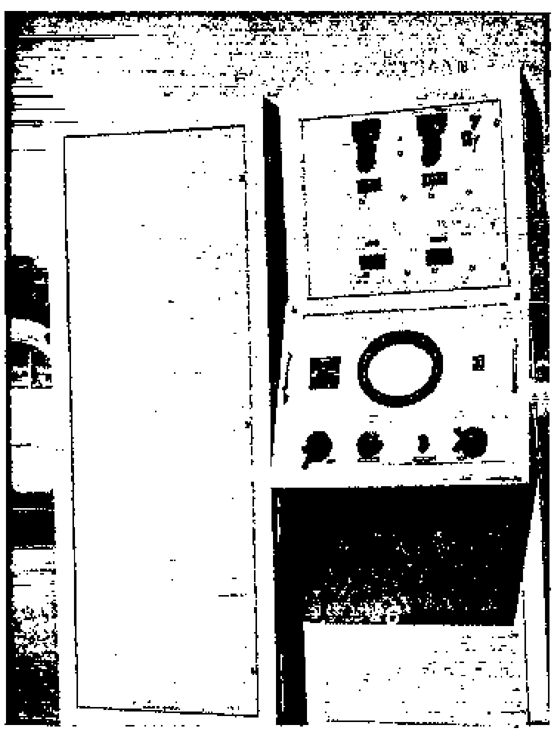

Figure 139. Training Device (Overall View)

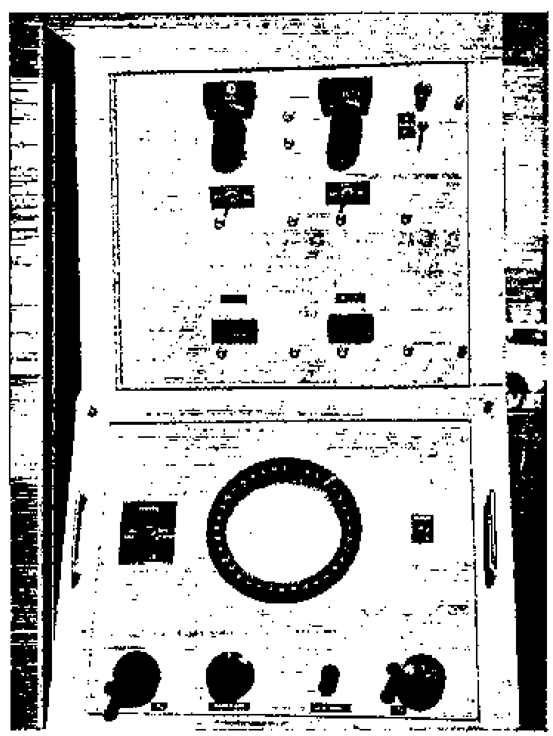

Figure 140. Closeup of Upper Control-Indicator Cabinet

Figure 141. Rear View of Control-Indicator Cabinet

Figure 142. Processing—Equipment Cabinet

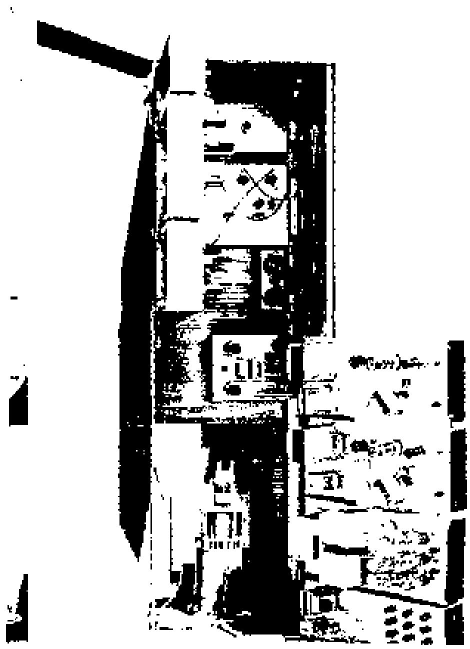

Figure 143. Closeup of Processing Equipment Cabinet

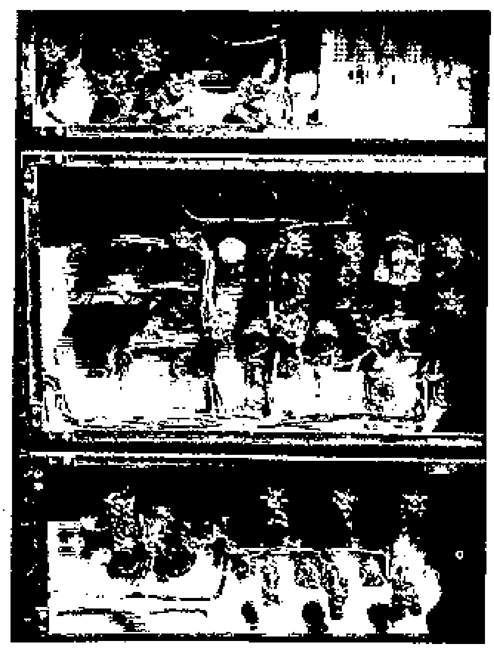

Figure 144. Closeup of One Chassis

left to right in decreasing order of occurrence. The ordinate shows the instances of use of each of these checks which occurred within the sample. It may be noted that three types of checks account for the vast proportion of these activities. The "J" shaped function may again be noted.

Finally, Figure 138 shows the results of an analysis of test equipment requirements for the six sonars. The various items of test equipment are organized along the abscissa in decreasing order of occurrence. The number of instances of use of each item of test equipment is shown on the ordinate. It may be noted that seven items of test equipment account for the vast majority of test equipment requirements. Again, the "J" shaped curve is seen.

The results of these few analyses demonstrate the surprisingly high degree of commonality among the group of sonars examined. It is also interesting to note that many types of circuits now being taught in the schools do not appear in any sonar equipment. For example, six types of oscillators are taught at the schools although only two of these are found in contemporary sonars. It was concluded, as a result of these analyses, that a trainer was entirely feasible and a decision was made to construct an experimental model. All displays, functional units, and equipment features found to be common to the sonar sample were included in the trainer design.

Figure 139 is a picture of the training device. On the right is a control-indicator cabinet (or console) and on the left a processing-equipment cabinet. The console contains a seven-inch P. P. I. scope display on which is presented a circular expanding sweep, an echo-ranging cursor, and a stern cursor. The equipment contains a range-train mechanism, a bearing-train mechanism and associated handwheels, a master gain control, a range-scale selector, range and bearing indicators, a second velocity control, an own-ship-speed control, a target centered/ship centered display control, and a sum/difference brightness control. The location of the various controls may be seen more clearly in Figure 140 which shows a close-up of the upper control-indicator cabinet. Those familiar with contemporary sonars will note that the trainer superficially resembles an AN/SQS-4 equipment. Figure 141 is a rear view of the control-indicator cabinet showing the scope tube, high voltage cage and display circuitry. Figure 142 shows the various chassis in the processing-equipment cabinet. Figure 143 shows these same chassis but swung out to show their accessibility. Finally, Figure 144 shows a close-up of one chassis to illustrate construction techniques and low packaging density. Each chassis contains one sonar functional unit, video processing display, timing, transmission control, and the like.

I would next like to describe the experimental study which was conducted using the training device at the ASW School. Students were selected to participate who had completed Navy training in basic electricity and electronics. All students selected had received instruction on the proper use of test equipment but had not previously been exposed to any operational sonar equipment.

The trainees were divided into two groups matched on the basis of their scores on the Electronics Technician Selection Test, administered routinely to all recruits. One group of students was trained using the experimental device and the other using SQS-29 sonar. Training included calibration, adjustment, and simple fault-finding. Each student then took a maintenance test on SQS-23 sonar; an equipment to which neither group had ever been exposed. Each student was given an accuracy score, an elapsed-time score, and a procedural error score for his performance. Results of the study indicated that both groups performed the maintenance tasks accurately but that the group exposed to the training device performed the tasks significantly faster and with significantly fewer procedural errors. In addition, the variance in the scores of the trainer group was substantially smaller than that of the group trained on operational sonar. That is, students trained using the G. S. M. T. performed more like one another, again indicating a training superiority. These results were interpreted as marked superiority of the experimental group in overall test performance.

I would like now to summarize what I consider to be important implications which follow from the results obtained during this study. First, it was shown that maintenance skills acquired using either an actual sonar as a training vehicle or the G. S. M. T. which, of course, has certain fundamental sonar characteristics, transfer positively to a new and unfamiliar sonar. It is believed that similarity of function, once identified as such to the student, becomes the basic mechanism for transfer of learning.

Second, differential transfer of skills was demonstrated between the group trained using the experimental device and that using actual sonar. The students trained on the experimental device performed significantly faster, with the same or greater accuracy, and with significantly fewer procedural errors.

It should be noted that training during this study was accomplished using project personnel as instructors. Although the potential contribution of individual instructors was counterbalanced between the experimental and control groups, it is possible that the same results would not be obtained in the operational setting; that is, at the sonar schools using Navy instructors.

At the present time, a second study in the planning stage will be conducted at the Fleet Sonar School at Key West early in 1968. In this study, enlisted Navy instructors will be used. These instructors will be trained by project personnel. Various subject areas in the present training program will be identified where use of the trainer can make the greatest possible contribution. One such critical area is in smoothing the transition from classroom lecture on electronic theory to actual maintenance of sonar equipment. This transition is viewed by both sonar schools as the single most serious problem faced in producing qualified sonar maintenance personnel.

As in the previous validation study, the performance of a group of students trained using the experimental device will be contrasted to a group of students trained in the present manner. The performance of both groups of students will be evaluated with tests now used by the schools and an additional test of sonar maintenance currently in preparation.

In closing, I would like to focus attention on what I feel are critical issues. The first is that the G. S. M. T. embodies the concept of generalized training. Although this concept is not new to training specialists, it does represent a departure from standard training procedures now used in Navy training schools which, in general, operate on a one-course-per-equipment basis. It is believed that the use of a trainer such as the G. S. M. T. would reduce substantially the training time required and also would increase the effectiveness of later shipboard training. Circuitry details of specific equipments cannot be retained in memory for very long. In addition, the detailed study of specific circuits does not ensure knowledge of the overall operation of an equipment and the function of major component parts. It is believed that what is lacking today is the "overview" of the organization and function of electronic systems. It is contended that it is easier to learn the function of specific circuits after being exposed to the equipment in its entirety and after a proper framework has been developed within which to organize circuit details.

Finally, it should be obvious that the findings of this study have implications for areas of electronic development other than sonar. To the degree that equipment commonality can be demonstrated among equipments within a class, radars, fire-control equipment, or communications sets, a generalized training approach and generalized training devices appear to make a great deal of sense.