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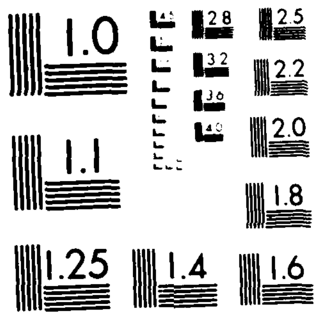
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THE BASIC ORGANIZING/ OPTIMIZING TRAINING SCHEDULER (BOOTS): SYSTEM OVERVIEW

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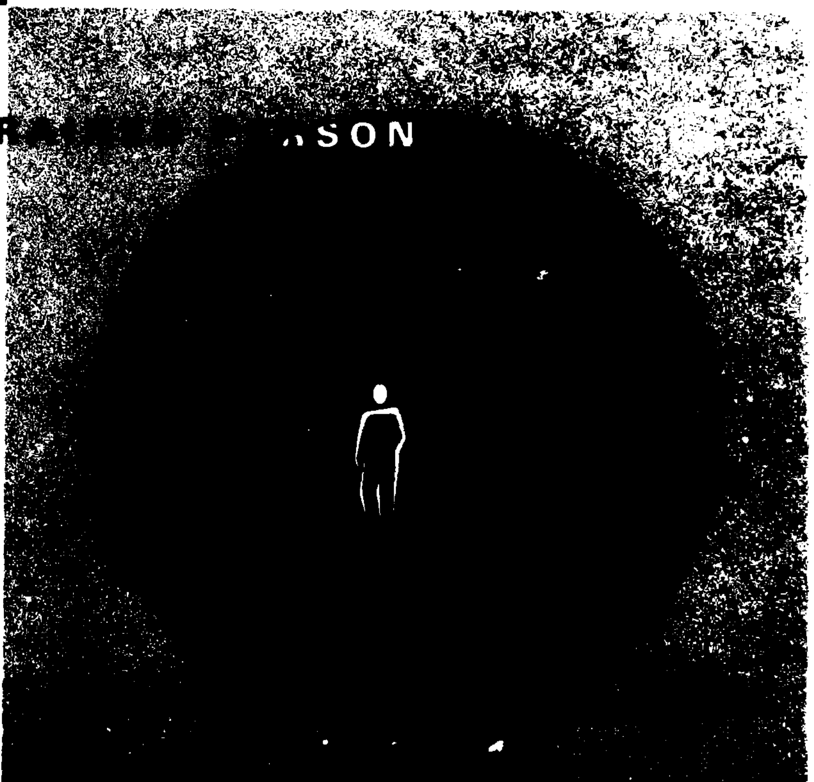

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TRAINING ANALYSIS AND EVALUATION GROUP
ORLANDO, FLORIDA

Technical Report 150

THE BASIC ORGANIZING/OPTIMIZING TRAINING SCHEDULER (BOOTS): SYSTEM OVERVIEW

F. Laurence Keeler
Richard L. Church

Training Analysis and Evaluation Group

September 1983

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This report provides an overview of the Basic Organizing/Optimizing Training Scheduler (BOOTS) system and its operation. The BOOTS is a computerized tool designed to aid in the creation of Master Training Schedules for each Navy Recruit Training Command. The system is defined in terms of three operating functions: (1) data file editing in which the user defines the scheduling parameters and constraints, (2) scheduling, in which the user either manually builds the training schedule while using the

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system to monitor all of the defined constraints or directs the system to optimize the schedule in terms of these constraints, using a Lambda-Opt heuristic, and (3) data output generators for formatting and printing hard copies of the resultant schedules and supporting data.

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Appreciation is tendered to CAPT B. R. Nyce, CAPT P. B. Boyne, and CAPT J. K. Gardella, commanding officers of the three Recruit Training Commands, for their support. Their staff personnel provided much needed expertise concerning the recruit training process. CAPT L. W. Fernald (USN retired), former Commanding Officer RTC Orlando, is also cited for his unfailing encouragement and support during the early stages of the program.

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The following TAEG professionals have contributed substantially to the success of the program. Mr. D. R. Copeland initiated the effort to develop a computerized scheduling system for the RTCs and served as the team leader for the project. Mr. M. G. Middleton provided key professional guidance in the selection of the equipment upon which the system was implemented.

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SECTION I

INTRODUCTION

The Navy currently trains between 90,000 and 100,000 recruits each year. This training is conducted at the three Recruit Training Commands (RTCs) located at Great Lakes, Orlando, and San Diego. The large throughput requires that new companies (training units) be formed and commence training almost daily at each RTC. Consequently, a complex set of company training schedules called the Master Training Schedule (MTS) is required for each RTC. Each company schedule must account for the entire training curriculum and, at the same time, avoid conflicts in resource utilization with any other company schedule within the MTS. Because of the complexity of having multiple companies utilizing one set of resources while operating on different schedules, the preparation of the MTS is a highly labor intensive task. The manual development of the MTS also results in errors or conflicts in the schedule. As a result, each RTC spends considerable effort in checking and rechecking the MTS to minimize such problems and to ensure that adequate resources are available.

The current training curriculum[1] contains 93 individual training functions and topics which must be scheduled within a total of 380 training periods over a length of 7.7 weeks. Each schedule in the MTS must adhere to a set of rules which dictates the separation and grouping of these 93 training elements. Further, special functions (e.g., Pass-In-Review) must be scheduled at prespecified times. Finally, the MTS must maintain a prescribed order for certain training events (e.g., one medical exam must precede TB skin test reading). Multiple companies are started almost daily (each following a different schedule), and the MTS must ensure that facility and staff limitations are not exceeded in any period of any day.

The RTCs experience a seasonal peak in recruit input in the early summer with much lower input during the winter. In addition, there are substantial variations in the daily recruit input. Thus, the MTS must also be able to accommodate the seasonal and daily fluctuations in the number of recruits undergoing training.

The scheduling of recruit training has been a continuing concern of the Chief of Naval Education and Training (CNET).[2] Accordingly, in December 1979, the TAEG was tasked to conduct a series of studies concerned with recruit training.[3] This tasking included the definition of an optimum schedule for recruit training. The start date for this effort was October 1981. However, a working conference held at the Chief of Naval Technical

[1] Curriculum Outline for U.S. Navy Recruit Training, X777-7770, Revised December 1981, Chief of Naval Technical Training, NAS Memphis (75), Millington, TN 38054.

[2] The length of recruit training has been changed 26 times since 1944. These changes have necessitated major revisions to the MTS at each of the RTCs.

[3] CNET ltr Code N-53 of 6 December 1979.

Training (CNTECHTRA) on 3-5 March 1981[4] resulted in major changes to the curriculum, and the CNET priority on the development of an optimum schedule was changed. As a result, the TAEG effort addressing optimum scheduling was initiated in April 1981.

In response to this tasking, the TAEG has developed a computerized system designed to considerably simplify the scheduling task. A flexible user-oriented system, called Basic Organizing/Optimizing Training Scheduler (BOOTS) was developed with the support of the three RTCs and is currently in use to develop a Mobilization Schedule (under conditions of national emergency) for RTC Orlando. An operational system for use by the scheduling officer is being installed at RTC Orlando.

Two documents have been prepared which describe the system and its employment. The present report is devoted to an overview of the BOOTS system and chronicles its development. The second report[5] is the BOOTS User Guide which provides step-by-step instructions on how to use BOOTS in preparing Master Training Schedules.

PURPOSE

This report presents an overview of the concepts and approaches used in the development of the BOOTS system. In developing the BOOTS system, the major objective was to design a flexible, user-oriented system capable of generating an MTS. This tool would simultaneously address all scheduling constraints in order to produce an optimal MTS. In addition, the system was to be designed so that it could be implemented at each of the RTCs and be operated by current RTC scheduling personnel.

METHOD

The BOOTS system was developed with the cooperation and support of the three RTCs. The RTCs' staff played an indispensable role in defining the scheduling problem presented in this report. Representatives of each department and training division were interviewed concerning how they used the training schedule to accomplish their assigned functions. One company at RTC Orlando was monitored for the entire period of training including in-processing and graduation. This provided information on how the schedule is used daily by the company commander and what problems are encountered by companies in utilizing the training schedule. Considerable time was spent with the scheduling officer and his staff at each RTC to gain an in-depth understanding of the total scheduling process. This information was used in defining the size and scope of the scheduling problem. A set of generic constraints comprehensive enough to describe all of the conditions which apply to the scheduling process was then defined.

[4]CNTECHTRA msg 062235Z Mar 81, Subj: Recruit training.

[5]Richard L. Church and F. Laurence Keeler. The Basic Organizing/Optimizing Training Scheduler (BOOTS): User's Guide. Technical Report 151, September 1983. Training Analysis and Evaluation Group, Orlando, FL 32813.

Using well known operations research methodology, a formalized integer-linear programming (ILP) model of the scheduling problem was then developed. Various approaches to solving the ILP model were considered and the two most promising approaches were selected. These were the Interactive Mode Processor (IMP) and the Heuristic Optimizing Processor (HOP). Finally, a computerized system of data files and computer programs was developed for implementing the selected approaches.

ORGANIZATION OF THIS REPORT

In addition to this introduction, the report contains four sections and three appendices. Section II describes the recruit scheduling problem. A number of alternative ways to solve the described problem are discussed in section III. Section III also provides detailed descriptions of the two approaches chosen for development. BOOTS, the computerized system that has been designed to optimize the scheduling of training functions, is described in section IV. Section V contains a summary and recommendations for use and extension of the BOOTS system. Definitions of all mathematical variables and terms used in the presentation of the MTS scheduling problem are provided in appendix A. Appendix B presents equipment options required to support the operation of the BOOTS system. Finally, sample pages from listings of the data files created by the BOOTS system are contained in appendix C.

SECTION II

THE SCHEDULING PROBLEM

All elements of the recruit training process must be scheduled to avoid conflicts of space and time. The elements to be scheduled include:

- training topics (instructional elements; e.g., fire fighting)
- training functions (noninstructional elements; e.g., medical examinations)
- meals (breakfast, lunch, and dinner).

The training topics and training functions, along with the number of training periods required for each, are specified in the <u>Curriculum Outline for U.S. Navy Recruit Training</u>, X777-7770, published by CNTECHTRA. A schedule is required to specify the exact sequence and times for all activities including meals. Meal serving times must be set in cooperation with the galley at each of the RTCs since the galleys are operated under the Naval Administrative Command.

Although many tasks are performed in the course of operating an RTC, the development of the complex MTS is the most important and complex. Each RTC develops an MTS to accommodate its specific resources and environmental conditions. Since the individual base resources vary, the schedules are often quite different among RTCs. In addition, special schedules are used at some locations but not at others. For example, RTC Orlando utilizes recruits who are members of regular training companies to form a flag, drill, and chorus group for Pass-In-Review ceremonies. These recruits may miss certain training events when they practice and perform these special functions. The classes and exercises which are missed must be made up outside of normal training, either during Ships Service Work Week or after normal training hours. However, at RTC San Diego and RTC Great Lakes, special companies for flag and drill teams and a band (plus staff and chorus for Great Lakes) are started each week. These companies utilize special training schedules which incorporate the extra duties in lieu of the tasks normally assigned during the Ships Service Work Week.

The major problem in setting up a schedule is the assignment of space. While space assignment may not, at first, seem difficult, the complexities of operating a facility where new companies begin training almost every day present many problems. At RTC Orlando a maximum of two companies start training each day, one using the Alpha schedule and the other the Bravo schedule. Given the current 38 day (7.7 week) curriculum, and two schedules (Alpha and Bravo), there is the potential requirement for 76 different daily schedules.[6]

[6]The special staff and drill company schedules add to the complexity of schedules at the other two RTCs.

In addition, every company starting training in the same week must Pass-In-Review on the same day (the last Friday of training). Thus, if a company starts on a Monday, it will Pass-In-Review on the 35th day of training (called the 7-5 day because it is the 5th day of the 7th week). A company starting on a Tuesday will have its last Friday of training and Pass-In-Review ceremonies on the 34th day of training (7-4 day). Therefore, since all companies starting in the same week (in the same training group) Pass-In-Review on the same day, there must be 10 (2 X 5) variations of the schedule. In scheduling, training area usage must be tallied for each training area for each day of the week and period of the day for up to 76 different companies each starting on one of 38 different days and each using one of 10 variations of the 38 day schedule. Clearly, making up an MTS is a formidable scheduling task.

Current preparation of the MTS is a labor intensive task with few or no special aids being employed. Revisions made to the MTS to accommodate mandated curriculum changes frequently fail to consider one or more scheduling constraints (e.g., capacity, separation, precedence) and must be modified, often more than once, until all scheduling conflicts have been resolved. The scheduling process requires keeping track of a myriad of details on resource usage as well as on curriculum requirements. Computer technology is ideally suited for increasing the efficiency of such record keeping and assignment tasks.

ASSOCIATED SCHEDULING FUNCTIONS AT THE RTCs

In addition to being used by the company commander to move his company through the 7.7 week curriculum, the MTS is used by every department of the RTC. The Standards, Testing and Evaluation (STE) Department uses the MTS to make up tests. Each test is made up according to the testable classes assigned to the MTS before a given examination period. Furthermore, the MTS is used by the Scheduling Officer in preparing the Recruit Plan of the Day (RPOD). The RPOD is published daily and specifies for each company in training, the schedule used and the current day of training in that schedule. Any changes or deviations to the company schedules for that day are also noted in the RPOD. The RPOD is usually made up several days in advance.

The RPOD is used in conjunction with the MTS by all departments of the RTC. From the RPOD, a department can easily determine when and how many companies are scheduled for a given function on a given day. For example, the Basic Military Officer (BMO) utilizes the RPOD to schedule platform instructors. By using the RPOD and the MTS, the BMO can estimate several days in advance the total number of classroom instructors needed in each period. He can then schedule his platform instructors (usually on a rotational basis) to meet the teaching demands. In a similar way, the STE Department schedules proctors for examination periods and the Military Inspection Department (MID) schedules inspectors. Further, the galley utilizes the RPOD to determine the exact demand for meals and when they are to be served. Although all these scheduling tasks are largely controlled by the MTS, they are secondary as compared to the development of the MTS and are not included in the BOOTS system.

SCHEDULING PROBLEM CONSTRAINTS AND OBJECTIVES

The MTS is composed of a set of individual company schedules. The schedules are based on the day of week that training begins as well as on special conditions (e.g., the requirements of special companies which participate in several Pass-In-Review ceremonies). At times of peak recruit input, all schedules in the MTS will be used simultaneously. The simultaneous use under peak input conditions will determine the peak demands on RTC resources and services such as classroom space, instructor pool, galley serving capabilities, and medical evaluation teams. Each schedule needs to be determined with respect to the resources used by the other schedules to prevent the assignment of more companies to an individual RTC training area than the capacity of that area.

In addition to capacity limitations, there are a number of other factors involved in assigning training events to a schedule. With the assistance of RTC personnel, 11 generic factors (including capacity) were defined (see table 1). These factors are comprehensive and can be used to develop and evaluate a Master Training Schedule. The 11 factors listed in table 1 form the backbone of the BOOTS system.

THE BOOTS APPROACH TO GENERATING AN MTS

Each of the factors given in table 1 can be defined in quantitative terms. Together, these quantitative terms can be used to define (in a formal way) a mathematical programming problem representing the problem of creating an MTS. Solving the mathematical programming problem, then, is equivalent to solving the scheduling problem.

The BOOTS system is based on the definition of a formal mathematical programming problem encompassing the 11 factors. The mathematical programming problem is described in terms of a set of constraints (see table 2) and a set of objectives (see table 3). Although a full understanding of these conditions is not necessary, it is important to recognize that the MTS scheduling problem has been structured using common operations research methodology and that this structure encompasses the 11 major factors identified by RTC personnel as the key factors for developing an MTS. With this criteria set, the BOOTS system can easily rate any MTS and look for changes that can improve it. The rating of a schedule is based on a simple weighted combination of the 11 factors to form a composite measure of effectiveness. This rating system is given in table 4. The BOOTS system is designed to either assist in developing an MTS (using the IMP) or independently generate an MTS (using the HOP). In either case, the result is an MTS complying with this set of factors.

The mathematical programming problem structured in tables 2 and 3 is an ILP model of the MTS scheduling problem. With a minimum of 10 different schedules, 38 days of training, 10 periods per day, and 20 different training areas, over 4 million variables would be required (and almost 4 million constraints) for its solution using conventional integer programming techniques. Because of the enormous size of the problem, it is impossible to solve the BOOTS model with a straightforward integer programming software package. Section III of this report presents a set of alternative approaches to this problem and discusses the techniques selected for implementation in the BOOTS system.

TABLE 1. MAJOR FACTORS USED IN EVALUATING A SCHEDULE

Factor	Definition	Requirement
Clustering	Formulation of a restriction element by grouping one or more training periods from one or more training topics/functions, and designating the number of training events complying with the constraints of this restriction element which must be assigned in the schedule	To group and/or divide the training periods allocated to the training topics and functions designated by the curriculum outline into schedulable training events (e.g., the grouping of stencilling with uniform issue or the dividing of the 32 periods of PT into several separate training events).
Assignment	Inclusion of each training event in the schedule	To insure that every training event and thus every training element and every training topic or function in the Curriculum Outline is included in the schedule.
Blocking	Preferred scheduling of two or more different training events together	To logically group compatible training events when constraints do not dictate otherwise (e.g., the grouping of Company Commander time before a scheduled barracks inspection).
Type Smoothing	Dispersion of similar types of training events	To avoid the concentration of any one type of training on any one day (e.g., the banning of more than one session of physical training on any single day).
Separation	Prescribed minimum and/or maximum number of days between pairs of training events	To maintain prescribed periods of time between certain medical functions or to establish sufficient time between training events for necessary auxiliary functions to have occurred (e.g., a 2-week period between the preclassification briefing and classifying to allow time for all necessary paper work to be accomplished).

TABLE 1. MAJOR FACTORS USED IN EVALUATING A SCHEDULE (continued)

Factor	Definition	Requirement
Congruence	Keep all variations of a given schedule as similar as possible	Because all companies which start training in the same week must Pass-in-Review on the same day of the final week, their schedules must be different at least during the last week of training. However, because these same companies compete against each other in the competitive inspections and testing system, their training schedules should be as identical as possible.
Day Precedence	Prescribed day-of-training relationship one training event must have to another	To maintain a required order of precedence of training for one or more training events (e.g., the 1st academic test must be preceded by all of the training that is tested by it).
Period Precedence	Proscription from having certain training events precede certain other training events on the same day	To avoid scheduling certain types of training events in incompatible orders (e.g., innoculations must not be followed, on the same day, by physical training).
Window	Days/periods of training in which a particular training event may be scheduled	To establish those days and periods of training upon which a training event may be (and may not be) scheduled (e.g., The Uniform Code of Military Justice must be scheduled during the first five days of training; or, that the issuing of uniforms must be during those periods that supply is open).
Preference	Relative preference for scheduling the training event for each day/period of the window	To distinguish between those days and periods on which it is highly desirable to schedule a training event from those on which it is less desirable (but still feasible) (e.g., it would be most desirable to schedule the final performance evaluation the last day of training with decreasing desirability as the time from that day increases; or, it would be most desirable to schedule physical training early in the morning, as compared to later in the day).

TABLE 1. MAJOR FACTORS USED IN EVALUATING A SCHEDULE (continued)

Factor	Definition	Requirement
Capacity	Keeping the number of companies using a training area less than or equal to its capacity at all times	To avoid exceeding the physical capacity of any training area during any period of any day of the week.
Movement	Restricting the movements from one training area to another to those moves which may be accomplished within a prescribed time, and to minimize total movement	To avoid having the training area of one training event so far from the training area of the preceding training event that it cannot be reached in the allotted time between periods (e.g., the scheduling of physical training on the drill field following a barracks inspection in San Diego).

TABLE 2. MASTER TRAINING SCHEDULE MODEL CONSTRAINTS

FACTOR	MATHEMATICAL EXPRESSION
Assignment	$\sum_{d} \sum_{p} X_{sedp} = 1$ for each s and e.
Capacity	$\sum_{s} \sum_{e} \sum_{d} R_{er} \; D_{sdw} \; X_{sedp} \leq C_r$ for each r, w and p.
Window	$\sum_{d \epsilon D_e} \sum_{p \epsilon P_e} X_{sedp} = 1$ for each s and e.
Day Precedence	$X_{sedp} + \sum_{e' \epsilon E_e} \sum_{d'=1}^{d} \sum_{p'} X_{se'd'p'} \leq 1$ for each s, e, d and p.
Period Precedence	$X_{sedp} + \sum_{e' \epsilon F_e} \sum_{p'=1}^{p-1} X_{se'dp'} \leq 1$ for each s, e, d and p.
Type Smoothing	$X_{sedp} + \sum_{e' \epsilon T_e} \sum_{p' \neq p} X_{se'dp'} \leq 1$ for each s, e, d and p.
Separation	$X_{sedp} + \sum_{e' \epsilon S_e} \sum_{p'} \left(\sum_{d'=1}^{d-v_e} X_{se'd'p'} + \sum_{d'=d-u_e}^{d+u_e} X_{se'd'p'} \right.$
	$\left. + \sum_{d'=d+v_e}^{\bar{d}} X_{se'd'p'} \right) \leq 1$ for each s, e, d and p.

TABLE 2. MASTER TRAINING SCHEDULE MODEL CONSTRAINTS (continued)

VERBAL DESCRIPTION
Each training event, e, must be assigned once in each schedule, s, to a day of training, d, and a training period, p, within that day.
The usage of no training area resource, r, may exceed the capacity, C_r, of that resource.
Each training event, e, must be assigned to a day, d, within its day window, D_e, and a period, p, within its period window, P_e.
No training event, e', from the set of training events, E_e, prohibited from preceding training event e will be assigned to a day which precedes the day, d, to which training event e has been assigned.
No training event, e', from the set of training events, F_e, prohibited from preceding training event e on the same day of training will be assigned to an earlier training period, p', on the same day of training, d, as that assigned to training event e.
No other training event, e', from the same smoothing type set, T_e, as training event e will be assigned to the same day, d, as training event e.
No training event, e', which is of the set, S_e, of training events to be separated from training event e, will be assigned to a day, d', which is not within the minimum, u_e, and maximum, v_e, range of the day, d, to which training event e has been assigned.

TABLE 3. MASTER TRAINING SCHEDULE MODEL OBJECTIVES

FACTOR	MATHEMATICAL EXPRESSION
Day Preference	$\text{Max} \sum_{s} \sum_{e} \sum_{d} \sum_{p} P_{ed} \; X_{sedp}$
Period Preference	$\text{Max} \sum_{s} \sum_{e} \sum_{d} \sum_{p} Q_{ep} \; X_{sedp}$
Blocking	$\text{Max} \sum_{s} \sum_{e} \sum_{d} \sum_{p} \left(X_{sedp} + \sum_{e' \varepsilon B_e} \left(X_{se'dp-1} + X_{se'dp+1} \right) \right)$
Movement*	$\text{Min} \sum_{s} \sum_{d} \sum_{p} \sum_{r} \sum_{r'} D_{rr'} \; M_{sdprr'}$

*The following constraints are necessary to define the movement, $M_{sdprr'}$, variables.

a) $X_{sedp} \leq \sum_{r} \sum_{r'} R_{er} \; M_{sdprr'}$ for each s, e, d and p.

b) $X_{sedp} \leq \sum_{r} \sum_{r'} R_{er} \; M_{sdp-1r'r}$ for each s, e, d and p.

c) $\sum_{r} \sum_{r'} M_{sdprr'} \leq 1$ for each s, d and p.

TABLE 3. MASTER TRAINING SCHEDULE MODEL OBJECTIVES (continued)

VERBAL DESCRIPTION
Maximize the day preference, P_{ed}, of the day, d, to which each training event, e, is assigned.
Maximize the period preference, Q_{ep}, of the period, p, to which each training event, e, is assigned.
Maximize the number of training events, e', within the set, B_e, of training events to be blocked with training event e which are assigned in periods adjacent to the training peric' p, to which training event e is assigned.
Maximize the distance, D_{rr}', between the training area resources, r and r' required by the training events, e and e_{dp+1} assigned to adjacent periods, p and p+1, on the same day, d.

TABLE 4. COMPOSITE MEASURE OF EFFECTIVENESS

$$
\begin{aligned}
\text{CMOE} = {} & + W_{\text{ASSIGN}} \Big(\sum_s \sum_e \sum_d \sum_p X_{sedp} \Big) \\
& + W_{\text{DPREF}} \Big(\sum_s \sum_e \sum_d \sum_p P_{ed} \; X_{sedp} \Big) \\
& + W_{\text{PPREF}} \Big(\sum_s \sum_e \sum_d \sum_p Q_{ep} \; X_{sedp} \Big) \\
& + W_{\text{WINDOW}} \Big(\sum_s \sum_e \sum_{d \in D_e} \sum_{p \in P_e} X_{sedp} \Big) \\
& + W_{\text{BLOCK}} \Big(\sum_s \sum_e \sum_d \sum_p \big(X_{sedp} + \sum_{e' \in B_e} (X_{se'dp-1} + X_{se'dp+1}) \big) \Big) \\
& + W_{\text{CAPAC}} \Big(\sum_s \sum_e \sum_d \sum_p \sum_r \sum_w R_{er} \; O_{rwp} \; D_{sdw} \; X_{sedp} \Big) \\
& - W_{\text{MOVE}} \Big(\sum_s \sum_e \sum_d \sum_p \sum_r \sum_{r'} D_{rr'} \; M_{sdprr'} \Big) \\
& - W_{\text{DPREC}} \Big(\sum_s \sum_e \sum_d \sum_p \big(X_{sedp} + \sum_{e' \in E_e} \sum_{d'=1} \sum_{p'} X_{se'd'p'} \big) \Big) \\
& - W_{\text{PPREC}} \Big(\sum_s \sum_e \sum_d \sum_p \big(X_{sedp} + \sum_{e' \in F_e} \sum_{p'=1} X_{se'dp'} \big) \Big) \\
& - W_{\text{TYPE}} \Big(\sum_s \sum_e \sum_d \sum_p \big(X_{sedp} + \sum_{e' \in T_e} \sum_{p' \neq p} X_{se'dp'} \big) \Big) \\
& - W_{\text{SEPAR}} \Big(\sum_s \sum_e \sum_d \sum_p \big(X_{sedp} + \sum_{e' \in S_e} \sum_{p'} \\
& \qquad \big(\sum_{d'=d-v_e}^{d-u_e} X_{se'd'p'} + \sum_{d'=d+u_e}^{d+v_e} X_{se'd'p'} \big) \big) \Big)
\end{aligned}
$$

SECTION III

SOLUTION APPROACHES

The MTS scheduling model was defined in section II on the basis of 11 different criteria. From these criteria, a mathematical programming problem was developed. The mathematical programming problem given in section II can be classified as an integer-linear programming model with over 4 million variables and constraints. This ILP problem is too large to be solved by the straightforward application of well-known integer programming software. This section describes the conceptual issues involved in solving the MTS scheduling model using alternative approaches. It is not essential for the user of the system to be familiar with these issues; however, the issues presented here, along with the factors presented in section II, form the basis of the BOOTS system design, which is described in section IV.

ALTERNATIVE APPROACHES

The BOOTS model is extremely large in both constraints and variables. As indicated earlier, the size of this model precludes the use of a general purpose mathematical programming solution technique. However, there are several alternatives which can be considered in generating a solution. These alternatives include:

- solve the programming problem by decomposition
- segment the problem:
  - assign the training events to days
  - arrange the training events within each day to make a complete schedule
- place in the schedule all training events associated with strong constraints and then optimize the remaining training event assignments
- assign optimally each training event to a week (or other period of time) based upon windows, smoothing, and precedence, then optimize the final placement of those training events within the week
- devise a sampling/generation program to develop a schedule quickly; rerun the system many times and pick the best schedule generated
- structure a simpler problem using preestablished rules to form the training events into groups, then solve the simpler problem package by a network code
- allow the scheduler to place or move training events in the schedule, while providing updates on all constraint violations and assistance in finding appropriate open training periods for

nonscheduled training events (The scheduler would thus interact with the computer in developing a schedule.)

- group all training events on the basis of which week of training they should be scheduled and then optimize the weekly schedules

- develop a heuristic procedure to formally analyze the entire problem simultaneously.

Each of the above approaches is a feasible alternative given appropriate computer resources and personnel. Because of computer limitations, the first five approaches were eliminated from consideration. Approach 6 was eliminated because it was not entirely clear that the problem could be simplified without eliminating some difficult to handle but necessary conditions. This left three approaches. Approach 7 utilizes the capabilities and expertise of the scheduling officer in generating a schedule in an interactive fashion. Since new schedules are often modifications of existing schedules, the interactive approach could also be used to speed up such modifications while making sure that no change violated existing constraints in attempting to meet new objectives. The implementation of this interactive approach in the BOOTS system is called the Interactive Mode Processor (IMP).

An optimizing capability is also required to improve on schedules developed by the IMP or to develop a completely original schedule. The grouping approach (approach 8) and the heuristic approach (approach 9) are both capable of meeting the optimization requirements and both are compatible with the IMP. The grouping approach could accept the training events grouped into the various weeks by the scheduler and optimize the schedule for each week. The heuristic approach (approach 9) could be structured in many ways but in any case it could use the same routines as the IMP to keep track of constraining conditions. In fact, many of the IMP computer routines could become part of the heuristic. It was because of this possibility that a heuristic method was chosen. The implementation of this heuristic approach is called the Heuristic Optimizing Processor (HOP). It should be emphasized that the grouping approach utilizing IMP as the first step is still a viable option, even though it was ruled out for the earlier developmental stages of the scheduling system. At some future time, resources and needs may dictate the further development of this procedure.

DEVELOPING A HEURISTIC APPROACH

The MTS scheduling problem to be solved falls into the wider area of application known as combinatorial optimization. This area encompasses a variety of logistical problems ranging from the optimal design for communications and power distribution networks to the optimization of transportation and warehousing. Scheduling is also included in this class of problem.

Many possible heuristic procedures have been developed to solve combinatorial optimization problems. Of these, one type of heuristic has proved to be very robust. This procedure is called the λ-opt (lambda-opt) method.[7] Since the λ-opt method was first developed, it has been applied to many types of combinatorial optimization problems including location analysis with good to excellent degrees of success.[8]

A λ-opt procedure can be explained using a simple location problem in which five warehouse locations are to be selected from 75 potential locations to serve a set of military bases. Assuming that a reliable cost function is available, the problem is to find the five sites out of a total of 75 sites which provide the least cost supply system. At first, one might suggest enumerating all possible combinations of five sites, evaluating each configuration generated, and selecting the combination having the least cost. Unfortunately, there are 17,259,390 possible combinations and it would be impossible to solve this problem by enumeration in any reasonable amount of computer time. However, as long as the model is reasonably linear, a λ-opt technique, using relatively few computer resources, can be applied to this problem with an extremely high probability of finding the optimum or a close to optimum solution. A description of the λ-opt procedure with λ=1 as applied to the five facility, 75 potential site problem is given below.

Start with a set of any five sites. Call these the facility positions. Pick a potential site (not a facility position) and determine if replacement of any facility position by this site would yield an improved solution. If one or more replacements by this site would yield an improved solution, make the replacement which will yield the greatest improvement. Then pick another potential site and determine if its use as a replacement for any of the five facility positions would yield an improvement in the solution, and again substitute this site for the facility position where the best improvement can be made. Continue to select new sites and compare them with all facility positions until all potential sites have been considered once. This represents one complete cycle. Perform additional cycles until no further improvements occur during a cycle. This marks the end of the 1-opt heuristic. In most cases the 1-opt solution is close to if not optimal for this type of location problem. The 2-opt method is similar to the 1-opt method but two-at-a-time replacements are considered instead of one-at-a-time replacements. In the case where the value is equal to the number of facility positions, the final solution will be globally optimal. For example, if a 5-opt heuristic were employed on this problem, an optimal solution would be obtained. However, this would be the equivalent of complete enumeration since there are 17,259,390 possible ways of picking five replacements. In short, the number of computations rises with increasing values of λ. Practically speaking, the λ-opt procedure is computationally burdensome on most problems when λ is greater than two, and in many cases the 2-opt solution is not any better than the 1-opt solution. Therefore, in practice, λ=1 is most frequently employed.

[7] S. Lin. "Computer Solutions of the Traveling Salesman Problem." <u>The Bell System Technical Journal</u>, December 1965, pp 2245-2269.

[8] R. L. Church and C. S. ReVelle. "Maximal Covering Location Problem." <u>Papers of the Regional Science Association</u>, 1974, Vol. 33, 101-118.

The λ-opt procedure for solving a scheduling problem may be described as follows. Assume a schedule is to be optimized. In order to concentrate on making improvements where problems occur, pick a training event (or meal) in the schedule which creates a "problem" (e.g., violates a constraint for movement, separation, or windows). Check to see if any event (or meal) scheduled elsewhere when switched with the event under consideration will yield an improvement.[9] Many training events may not be eligible for the switch because of constraints and restrictions. If an eligible switch yields an improvement, make that switch, then pick another training event that is associated with a scheduling "problem" and repeat the above process. The implementation of this heuristic procedure for optimizing the schedule will be called the Heuristic Optimizing Processor (HOP).

The IMP and the HOP, described previously, are the two solution approaches selected for implementation in the BOOTS system. The system architecture of the BOOTS system is described in section IV.

[9] In terms of the composite measure of effectiveness presented in table 4.

SECTION IV

THE BASIC ORGANIZING/OPTIMIZING TRAINING SCHEDULER (BOOTS) SYSTEM

This section provides an overview of the Basic Organizing/Optimizing Training Scheduler (BOOTS) system. It contains discussions of hardware requirements, system architecture, data file organization, file editors, processing programs, output programs, and operation of the BOOTS system.

HARDWARE REQUIREMENTS FOR OPERATING BOOTS

Operating the BOOTS system requires the following hardware:

- minicomputer with at least 128k bytes of memory
- disc drive for processing and storing the requisite data files
- video display terminal for interacting with the computer
- printer for creating hardcopies of the created files.

The BOOTS system software has been written for operation on a WANG 2200 MVP or WANG 2200 LVP computer. These computers utilize a high speed multiplexable virtual processor and can service many users, each running a different program, simultaneously. Therefore, it is not necessary for the user of the BOOTS system to possess a computer but merely to have access to one as a user. Because there are a large number of WANG 2200 MVP computers in the Naval training community, gaining access to a computer without purchasing is a viable alternative for potential users of the BOOTS system. If access to a WANG 2200 MVP computer is obtained, the user will require a minimum amount of equipment. This includes:

- modem and telephone line for communications
- video display terminal
- hardcopy printer.

Appendix B lists the specifications and estimated costs of the required items for both options. The total estimated costs are less than $6,000 per site for the less expensive option.

BOOTS SYSTEM ARCHITECTURE

The architecture of the BOOTS system is based on three major functions:

- input and editing of data files
- schedule processing
- output of schedule and data files.

Figure 1 depicts the BOOTS system architecture in terms of these three functions.

To accomplish the first function, the BOOTS system contains several file editors. The file editors are used to develop the specific data sets associated with a particular scheduling problem. The data sets associated

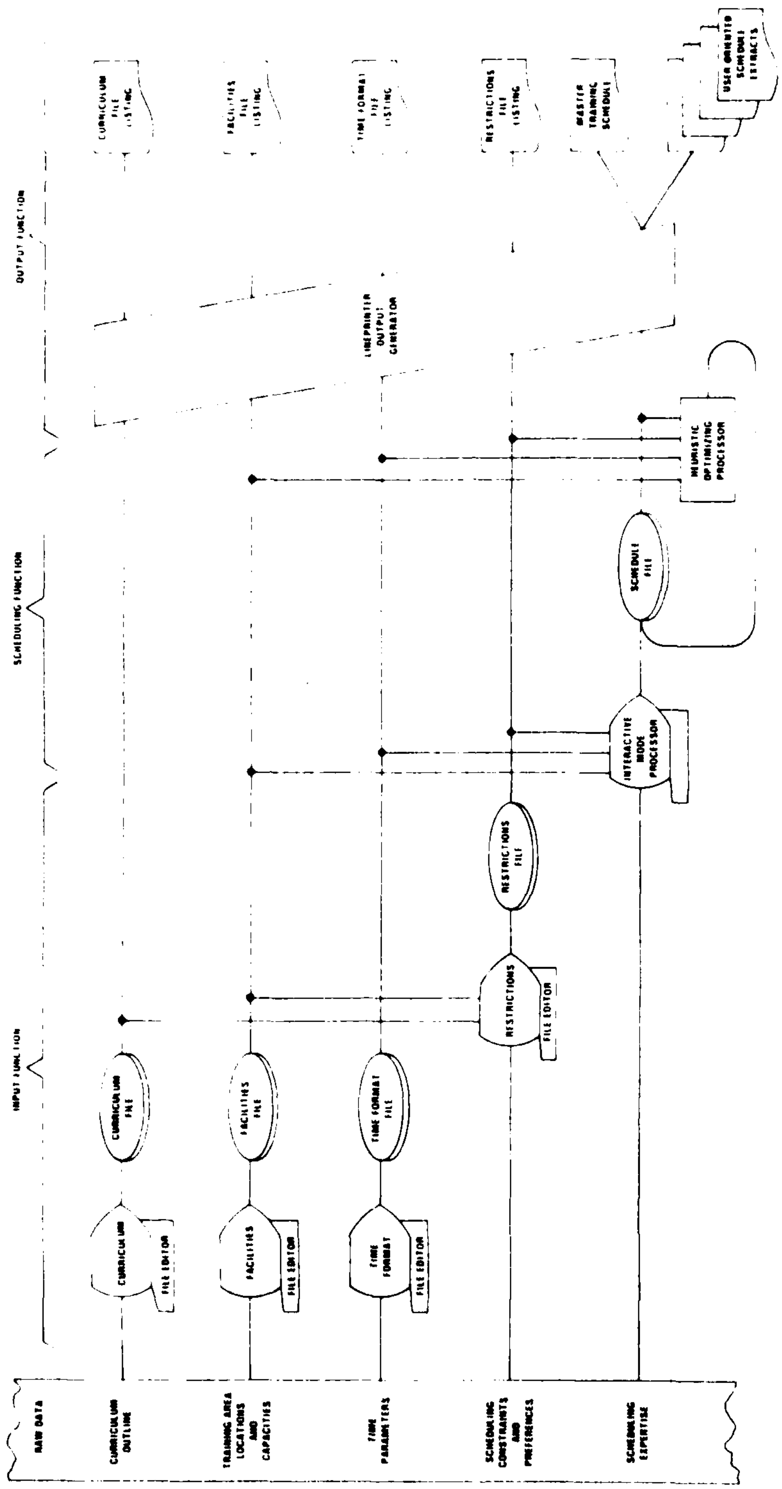

FIGURE 1. BOOTS SYSTEM ARCHITECTURE

with a given RTC will differ markedly from the data sets of the other RTCs since each will contain resource and layout data that is specific to that RTC.

The second function, schedule processing, implements the interactive approach and the heuristic optimizing approach discussed in section III of this report. These two approaches are accomplished by the IMP program and the HOP program, respectively. These processor programs use the data files developed by the first function to help generate a coded version of the schedule which is then stored in the Schedule File.

The third function uses the Lineprinter Output Generator (LOG) to print copies of the different data sets and to print the intermediate and final versions of the schedule. With these three functions, the BOOTS can assist in generating MTSs encompassing a wide range of scheduling objectives and constraints.

DATA FILE ORGANIZATION

The following paragraphs describe the files which are a part of the BOOTS system. These files are also listed in table 5, along with the file interdependencies. In addition, table 5 outlines the data elements contained in each file and the constraints and/or preference factors for which that data is required. As a further aid to understanding the type of data contained in those files, sample pages from file listings are presented in appendix C.

1. **Curriculum File**. The Curriculum File contains the topic/function numbers, names, and the number of periods required for each training element in the Curriculum Outline. In addition, it indicates whether all periods of the training element must be part of the same training event (i.e., cluster) or may be separated for placement in different training events. As a further aid to the scheduler, a one character code may be used to indicate which test in the curriculum the training element must precede.

2. **Facilities File**. Specific information regarding the training areas is required to evaluate capacity and movement factors. The Facilities File contains, for each training area, the name, capacity, and measure of difficulty in getting to and from each of the other training areas. Since each RTC has a unique physical plant, each RTC will require its own distinct Facilities File.

3. **Time Format File**. As previously stated, the number of days of training as well as the number of training elements in the curriculum outline frequently changes. In addition, the number of major schedules in operation varies. Currently there are two at RTC Orlando, three at RTC San Diego, and four at RTC Great Lakes. This information along with other time related information is contained in the Time Format File. It contains information regarding the number of major schedules, the number of training days, the number of training days in a week, the number of periods in a day, the name and starting and ending times for each period.

TABLE 5. BOOTS DATA FILES

File Name	Files Referenced By This File	Files Referencing This File	Constraints/ Objectives Requiring This File	File Description
Curriculum File (rtcC_ _ _ _)		Restrictions File		Specifies for each training topic and function in the CNTECHTRA Curriculum Outline, the: Topic/Function Number Topic/Function Name Number of Periods If periods must be contiguous If time is critical
Facilities File (rtcF_ _ _ _)		Restrictions File Schedule File	Capacity/ Movement	Specifies for each training area, the: Training Area Name Number of companies it can accommodate Difficulty of movement to/from every other training area
Time Format File (rtcT_ _ _ _)		Schedule File		Specifies the: Number of schedules and the name, type, and days of week each may be started Number of days of Training Number of Training Days in a week Number of days in Ships Service Work Week Number of periods in a day and the name and starting time for each Periods and serving times for each meal
			Congruence	Number of days which same named schedule with different starting days will be identical (Bulkhead)
Restrictions File (rtcR_ _ _ _)	Curriculum File Facilities File Time Format File	Schedule File	Clustering	Defines each Restrictions Element in terms of one or more periods of one or more unit topic/ functions from the Curriculum File, and for each, the:
			Capacity/ Movement	Training area required
			Day Preference/ Window	Preference for each day
			Period Preference/Window	Preference for each period of the day
			Blocking	Restrictions Elements to be scheduled in adjacent periods if possible
			Day Precedence	Restrictions Elements that must come before/after this Restrictions Element
			Period Precedence	Restrictions Elements that must not come before/after this Restrictions Element on the same day of training
			Separation	Minimum and Maximum days of separation from a second specified Restrictions Element
			Type Smoothing	Type of Restrictions Element (Medical, Inspection, PT, etc.) Number of Training Events which must adhere to this set of restrictions
Schedule File (rtcS_ _ _ _)	Facilities File Restrictions File Time Format File			Specifies the day and period for each Training Event of each Restrictions Element for each schedule

4. **Restrictions File**. The Restrictions File contains the training events defined in terms of the training elements designated in the Curriculum File. These training events are the smallest, inseparable, schedulable entities which may be manipulated by the IMP and the HOP. In addition to a short name and the number of periods required, the Restrictions File contains the other constraints applicable to each training event; e.g., the training area required, the preference for each day and each period of the day, and the training events it is to be blocked with, separated from, and preceded by. Since each training event consists of one or more periods from one or more training elements from a coded Curriculum File, and must be assigned a training area, a specific Curriculum File and specific Facilities File must be referenced by the Restrictions File.

5. **Schedule File**. This file designates the training event assigned for each period of each day for each schedule. This information is contained in the Schedule Layout Assignment Matrix (SLAM). The SLAM is the largest array in the BOOTS system and is the coded version of the MTS. The Schedule File also contains three auxiliary arrays for the additional information that is required for schedule processing. Two cross referencing arrays, one for training events comprised of training elements and one for meals, serve as directories as to when each training event and meal is scheduled. The third array is a facilities usage array which contains the training area usage for each period of each day of the week.

Because the Schedule File requires information regarding the number of schedules, days, and periods, it must reference a specific Time Format File. It must also reference a specific Restrictions File for data concerning the training events to be scheduled.

FUNCTIONAL PROGRAMS

The computer programs required for accomplishing the three major BOOTS functions are divided into groups: file editors, schedule processing programs, and output programs. All programs for the BOOTS system have been written in WANG BASIC-2 for operation in conjunction with a WANG 2200 MVP or WANG 2200 LVP computer because of the availability of WANG computers in the Naval Education and Training Command. However, the software could be readily adapted for use on other hardware.

FILE EDITORS. Each of the first four data files listed in table 5 has a file editor associated with it. The names of these file editors correspond to the associated file names and each file editor is used to input or edit the data concerning the factors controlled by that file.

SCHEDULE PROCESSING PROGRAMS. Schedule processing programs are required for the interactive mode approach and the heuristic optimizing approach described in section III. The IMP program, which is the implementation of the interactive approach, permits the scheduling officer to insert training events into the schedule and to move training events within the schedule. It will automatically monitor each of the 11 criteria factors associated with each such assignment (see table 1). Thus, if queried, the IMP program can instantly inform the user of how many more companies may be assigned a particular training area at a particular time. The HOP program is the implementation of the heuristic approach using a λ-opt technique. Unlike the IMP, the HOP will not provide a means for user intervention (other than to prescribe a specific number of cycles), but it will independently implement the λ-opt technique, swapping training events a pair at-a-time until either the prescribed cycles have been completed or no further improvement, as reflected by the composite measure of effectiveness (see table 4), can be made via pairwise swapping.

OUTPUT PROGRAMS. A set of programs exists for generating hardcopies of each of the files. In addition to producing a hardcopy of the MTS, the programs have the capability of producing hardcopy extracts of the MTS, each designed to meet the needs of a particular user group; e.g., Medical/Dental Department, Military Inspection Department, Basic Military Officer.

OPERATION OF THE BOOTS SYSTEM

The BOOTS system is designed to be a tool to aid in the preparation of MTSs for the RTCs. The following paragraphs describe the operations to be performed and the order of their performance in the normal use of BOOTS. Reference to the procedural flow chart in figure 2 and the BOOTS system architecture depicted in figure 1 (p. 22) will aid in understanding this discussion.

It is assumed that there are no existing files, and that the user will have to create new files using the appropriate file editor in each case. As indicated in figure 2, the first step is to create a Curriculum File using the Curriculum File Editor. Then, the user will be directed to create a Facilities File and a Time Format File, each using the corresponding file editor. Each of these first three files is independent, so the order in which they are created or edited is unimportant. The flow chart will next direct the user to create a Restrictions File using the Restrictions File Editor. This file will reference the first two files since it is dependent upon data contained in them.

Finally, when the Restrictions File, along with the Curriculum, Facilities, and Time Format Files, is ready, the Schedule File may be created. This is done using IMP, the interactive mode processor, to insert the training events defined in the Restrictions File into the SLAM array of the Schedule File. The user may then use the HOP, which will apply the λ-opt heuristic to optimize the schedule. Following application of the HOP, the user may make some final adjustments to the schedule by using the IMP once more. When an acceptable schedule is achieved, the Lineprinter Output Generator (LOG) is used for creating hardcopies of the schedule and schedule extracts.

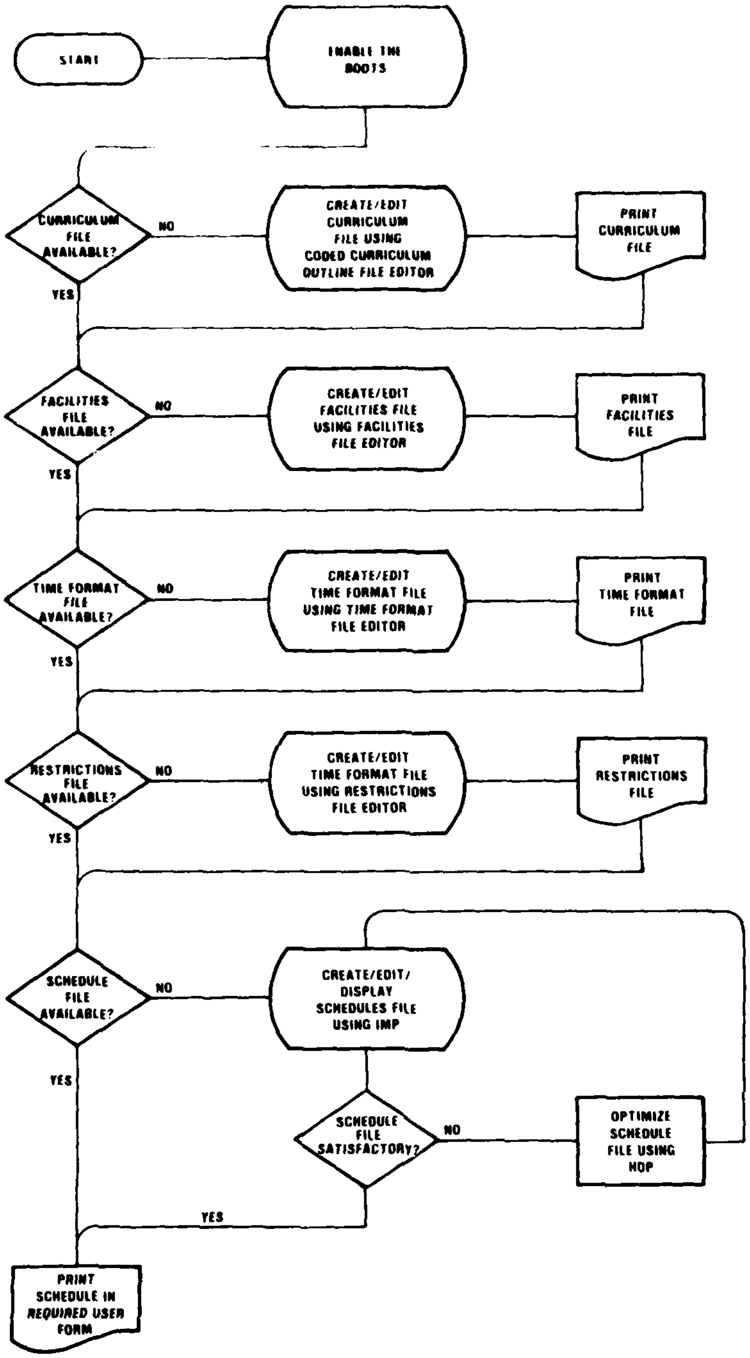

Figure 2. Flow Chart for Creating a Schedule

SECTION V

SUMMARY AND RECOMMENDATIONS

SUMMARY

This report has documented the development of a computerized aid for creating and/or modifying Master Training Schedules at the Recruit Training Commands. The computer system, called BOOTS, is designed to be used by scheduling personnel at each of the RTCs. A companion report[10] is being published concurrently with this report and contains the necessary user information required to operate the BOOTS system. A third report will be published to document the system software and will include variable and array definitions, flow charts, and program listings.

The BOOTS system was developed with the cooperation and support of the three RTCs. Scheduling personnel at each of the RTCs were instrumental in the original stages of this development. The BOOTS system is now in the initial stages of installation at RTC Orlando. At this point, the BOOTS system is being used to generate a mobilization schedule at RTC Orlando. The marginal cost of installation at the other RTC sites has been estimated to be less than $6,000 per site if timesharing access to a WANG 2200 MVP system is made available.

In addition to being used as a scheduling tool at the RTCs, the BOOTS system could be used as a planning tool by CNTECHTRA. Given copies of the Facilities Files created by the RTCs, CNTECHTRA could use the BOOTS system to help evaluate the impact of proposed curriculum changes on each RTC. Because CNTECHTRA already owns WANG 2200MVP hardware, the marginal cost of installing the BOOTS system at CNTECHTRA would be minimal.

The structured data files, which are an integral part of the BOOTS system, provide a repository for the substantial scheduling information that, to date, was not available from a single source. This file information can be used in associated scheduling tasks outlined in section II. These include: developing the Recruit Plan of the Day (RPOD); scheduling instructors, examination proctors, and inspectors; compiling tests and examinations for course groups in flexible schedules; and scheduling galley functions for smoother galley operations over all levels of fluctuating input.

RECOMMENDATIONS

As a result of this study and system development, the following recommendations are made:

- demonstrate the BOOTS system at RTC Great Lakes and RTC San Diego

[10] Richard L. Church and F. Laurence Keeler. The Basic Organizing/Optimizing Training Scheduler (BOOTS): User's Guide. Technical Report 151, September 1983. Training Analysis and Evaluation Group, Orlando, FL 32813.

- make the BOOTS system available for use on a continuing basis at each of the three RTCs
- provide, as a planning tool, the BOOTS system software to CNTECHTRA for use by recruit training management planners on already existing WANG 2200MVP hardware
- expand the BOOTS system to handle the other more frequent scheduling functions related to the MTS. These include:
    - scheduling galley functions for smoother galley operations
    - developing the Recruit Plan of the Day (RPOD)
    - scheduling personnel in the Basic Military Office (BMO); Military Inspection Department (MID); Standards, Testing and Evaluation (STE) Department; and the Medical and Dental Departments.

APPENDIX A

VARIABLES, TERMS, AND SYMBOLS USED IN MATHEMATICAL EXPRESSIONS

Variables Terms Symbols	Functional Purpose	Definition
B_e	Blocking	The set of training events to be blocked with training event e.
C_r	Capacity	The capacity of training resource r.
D_e	Window	The set of training days on which training event e may be assigned.
$D_{rr'}$	Movement	The measure of difficulty of movement from training resource r to training resource r'.
D_{sdw}	Capacity	A variable indicating whether training day d occurs on day of the week w in schedule s or not. $D_{sdw} = \begin{cases} 1, & \text{if in schedule s, training day d occurs on day of the week w;} \\ 0, & \text{otherwise.} \end{cases}$
E_e	Day Precedence	The set of training events which must not precede training event e.
F_e	Period Precedence	The set of training events which must not precede training event e on the same day of training.
$M_{sdprr'}$	Movement	A variable indicting whether movement between training areas r and r' occurs on schedule s, day d, after period p. $M_{sdprr'} = \begin{cases} 1, & \text{if movement between areas r and r' occurs on schedule s, day d, after period p;} \\ 0, & \text{otherwise.} \end{cases}$
O_{rwp}	Capacity	A variable indicating whether the capacity C_r of training resource r has been exceeded on day of the week w in period p or not. $O_{rwp} = \begin{cases} 1, & \text{if } \sum_s \sum_e \sum_d \sum_r R_{er} D_{sdw} X_{sedp} > C_r; \\ 0, & \text{otherwise.} \end{cases}$
P_e	Window	The set of training periods in which training event e may be assigned.
P_{ed}	Day Preference	The relative preference for assigning training event e on training day d.

Variables Terms Symbols	Functional Purpose	Definition
Q_{ep}	Period Preference	The relative preference for assigning training event e in training period p.
R_{er}	Capacity/ Movement	A variable indicating whether training event e uses training resource r or not. $R_{er} = \begin{cases} 1, \text{ if training event e uses training resource r;} \\ 0, \text{ otherwise.} \end{cases}$
S_e	Separation	The set of training events which must be separated from training event e by a specified minimum and maximum number of days.
T_e	Type Smoothing	The set of training events which are of the same smoothing type as training event e and from which only a limited number may be assigned on any one day.
W_{Assign}	Weighting	The relative importance of assigning all training events in each schedule.
W_{Block}	Weighting	The relative importance of assigning training events which are to be blocked to adjacent periods in the schedule.
W_{Capac}	Weighting	The relative importance of assigning no more training events which use a particular training resource on any day of the week and period of the day than that training resource can accommodate.
W_{Dprec}	Weighting	The relative importance of assigning training events which must not precede certain other training events so that they do not precede them.
W_{Dpref}	Weighting	The relative importance of assigning training events to days for which there are high preferences for such assignment.
W_{Move}	Weighting	The relative importance of assigning training events so that the difficulty in moving from one training resource to another is minimized.
W_{Pprec}	Weighting	The relative importance of assigning training events which must not precede certain other training events on the same day of training so that they do not precede them on the same day.

Variables Terms Symbols	Functional Purpose	Definition
W_{Ppref}	Weighting	The relative importance of assigning training events to periods for which there are high preferences for such assignment.
W_{Separ}	Weighting	The relative importance of assigning training events which are to be separated from another training event so that they are assigned to a day which is within the allowable range of days from it.
W_{Type}	Weighting	The relative importance of assigning no more than a limited number of training events of any one smoothing type on any one day.
X_{sedp}	Assignment	A variable indicating whether in schedule s, training event e has been assigned to training day d and training period p.
$\in$	Domain	Is an element of. ("$a \in A$" means that a is an element of the set A.)
=	Comparative	Is equal to.
>	Comparative	Is greater than.
$\leq$	Comparative	Is less than or equal to.
-	Subtraction	Subtract the following from the total.
+	Summation	Add the following to the total.
Σ	Summation	Sum the specified elements. ($\Sigma_y z_y = z_1 + z_2 + \ldots + z_{\bar{y}}$)
d	Training day	The index of a training day. $d = 1,2,3,\ldots,\bar{d}$.
$\bar{d}$	Length of training	The last day of training.
e	Training event	The index of a training event. $e = 1,2,3,\ldots,\bar{e}$;
$\bar{e}$	Training event	The last training event.
e_{dp+1}	Next training event	The training event assigned to the period following training event e.

Variables Terms Symbols	Functional Purpose	Definition
p	Training period	The index of a training period. $p = 1,2,3,\ldots,\bar{p}$.
$\bar{p}$	Length of training day	The last training period.
r	Training resource	The index for the training resource. $r = 1,2,3,\ldots,\bar{r}$.
$\bar{r}$	Training resource	The last training resource.
s	Training schedule	The index of a training schedule. $s = 1,2,3,\ldots,\bar{s}$.
$\bar{s}$	Training schedule	The last training schedule.
u_e	Separation	The minimum separation which may exist between training event e and the separated training event, s_e.
v_e	Separation	The maximum separation which may exist between training event e and the separated training event, s_e.

APPENDIX B

BOOTS SYSTEM HARDWARE REQUIREMENTS

Equipment	Vendor Name and Part No.	Function	Cost[1]	Cost[2]
Central Processing Unit (CPU)	Wang 2200/LVP-32X with a minimum of 128K bytes user memory 5M bytes disk storage	Operate BOOTS functional programs	$ 9,984	-
Telecommunication	Wang 2227B Controller	Provide inter-connect to remotely located CPU	-	$ 720
	Rayco-Vadic 3451 Modem		-	(700)
Terminal	Wang 2226DE Interactive DP Workstation	Provide user/ computer system interface	$ 2,112	$2,112
	Wang 2236MXD 4-Port Terminal Multiplexer		$ 1,152	-
Printer	Wang 2233 Matrix Printer	Provide hard-copy listings of data files and schedules	$ 2,400	$2,400
			$15,648	$5,232 (5,212)

[1]If access to a Wang 2200/MVP or Wang 2200/LVP with a minimum of 128K bytes user memory and 5M bytes disk storage is not available.

[2]If access to a Wang 2200/MVP or Wang 2200/LVP with a minimum of 128K bytes of user memory and 5M bytes of disk storage is available.

APPENDIX C

SAMPLE PAGES FROM BOOTS DATA FILES

C-1 Sample page from a Facilities File

C-2 Sample page from a Curriculum File

C-3 Sample page from a Time Format File

C-4 Sample page from a Restriction File

C-5 Sample page from a Schedule File

Facilities File Movement Constrained Capacity --- rtcFOP83

Training Area	Area cap.
GALLEY	99
TRAINING BUILDING	36
ADMIN BLDG--232	2
BLUE JACKET	2
FITNESS TRAIL	2
FIELD HOUSE	2
POOL	2
SOUTH GRINDER	10
GRINDER	10
RIF	4
RIF PSD	2
FIRE F/DAMAGE C B200	4
MEDICAL BLDG--246--	2
ARMORY	2
BARBER SHOP-C.CTR	2
PARADE FIELD	10
RIF DENTAL	2
BARRACKS	99
DENTAL BLDG--246	2
RIF MEDICAL	2

[illegible] Coded Curriculum Outline -- rtcCOP83

Unit Topic Number	Lesson Topic Name	Total PDs	Split/ Combined	Tested on	Special Cndt ns
1.1	Uniform Code of Military Justice	2	C		1
1.2	Code of Conduct & the Geneva Convention	1		1	1
1.3	Chain of Command & Leadership Concepts	1		2	5
1.4	Security Information	1		2	7
1.5	Discharges	1		1	11
1.6	Driver Training	03	C		13
1.7	Law of Armed Conflict	1			15
2.1	Naval Customs and Courtesies(T)	2	C	4	1
2.2	Ship and Aircraft Familiarization	2	C	04	3
2.3	Mission of the Navy	3	C	2	5
2.4	Navy History and Traditions	4	C	1	9
2.5	The Soviet Navy Challenge	1			9
2.6	Ship Organizational Structure	1		1	11
2.7	Chaplain, Red Cross & Navy Relief Orient	1			13
2.8	Leave, Liberty and Conduct Ashore	1		4	15
2.9	Introduction to Fleet Duties & Routines	2	C		17
2.10	Navy's Accident Prevention Program	1		2	19
2.11	Basic Deck Seamanship	2	C	4	21
2.12	Small Boats, Lifevests, Painting & Prsvt	2	C		23
2.13	Basic Damage Control	4	C	3	25
2.14	Career Incentives & Medical Benefits	1			27
2.15	Continuing Education	1			29
2.16	Advancement Procedures	2	C	4	31
2.17	Rating Orientation	2	C		33
2.18	Enlisted Service Record	1		1	35
2.19	Detachment, Transfer and Reporting	5	M		37
2.20	Gp/Indvdl Progress Evaluation & Counslng	22	M		39

Time Format File --> rtcTOP83 page 1

Schedule Parameters

Description	Value
Number of training days including service work week	56
Number of days in service work week	5
Number of days in each week	5
Number of periods in each day	15
Day of bulkhead	31
Number of companies per regular company schedule	1
Existence of drill/flag companies (1=YES 0=NO)	0
Number of days of service work week that drill/flag company can use	0
Number of drill/flag companies per schedule	0
Total number of schedules	2

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Restriction File --> rtcROR83

No.	Unit/Topic	Unit/Topic Name	Training Area	dup	Total pds	Day Window 1st	Day Window Last	Pd Window 1st	Pd Window Last	Separated from TE(min-max)	Smoothing Type	[illegible]
001	1.1	[illegible]	TRAINING BUILDING	01	02	1-1	1-3	04	14			
002	1.2	Code of Conduct	TRAINING BUILDING	01	01	1-1	2-4	04	14			
003	1.3	Chain of Command	TRAINING BUILDING	01	01	2-5	4-4	04	14			
004	1.4	Security Information	TRAINING BUILDING	01	01	2-5	4-4	04	14			
005	1.5	Discharges	TRAINING BUILDING	01	01	1-1	2-4	04	14			
006	1.6	Driver Training	TRAINING BUILDING	01	03	1-1	8-5	04	14			
007	1.7	Law of Armed Conflic	TRAINING BUILDING	01	01	1-1	8-5	04	14			
008	2.1	Naval Customs & Cour	TRAINING BUILDING	01	02	7-1	7-5	04	14			
009	2.2	Ship & AC Familiar.	TRAINING BUILDING	01	02	7-1	7-5	04	14			
010	2.3	Mission of the Navy	TRAINING BUILDING	01	03	2-5	4-4	04	14			
011	2.4	Navy Hist.&Tradition	TRAINING BUILDING	01	04	1-1	2-4	04	14			
012	2.5	The Soviet Navy Chal	TRAINING BUILDING	01	01	1-1	8-5	04	14			
013	2.6	Ship Organ'l Struct.	TRAINING BUILDING	01	01	1-1	2-4	04	14			
014	2.7	Chaplain, Red Cross	TRAINING BUILDING	01	01	1-1	8-5	04	14			
015	2.8	Leave & Liberty Cond	TRAINING BUILDING	01	01	7-1	7-5	04	14			
016	2.9	Intro. to FDAP	TRAINING BUILDING	01	02	4-1	4-5	04	14			
017	2.10	Navy Accid. Prevent.	TRAINING BUILDING	01	01	2-5	4-4	04	14			
018	2.11 2.10	Deck Seamanship Boats & Lifevests	TRAINING BUILDING	01	02 02	7-1	7-5	04	14			
[illegible]	[illegible]	Basic Damage Control	TRAINING BUILDING	01	03	6-1	6-5	04	14			
[illegible]	2.14	Career Incentives	TRAINING BUILDING	01	01	1-1	8-5	04	14			
[illegible]	2.15	Continuing Education	[illegible]	01	01	1-1	8-5	04	14			
[illegible]	2.16	Advancement Proced.	TRAINING BUILDING	01	02	7-1	7-5	04	14			
[illegible]	2.17	Rating Orientation	TRAINING BUILDING	01	02	1-1	4-5	04	14			
[illegible]	2.18	Enlisted Service Rec	TRAINING BUILDING	01	01	1-1	2-4	04	14			
[illegible]	[illegible]	Detachment &Transfer	[illegible]	04	01	7-3	8-5	02	08			

Schedule File (Numeric) Outline --> rtcGORG3
ALPHA
Schedule Main

Day window	H1	H2	H3	1	2	3	4	5	6	7	8	9	10	11	12
				Periods											
1-1	B-0540	6.2	6.6	6.4	6.4	6.4	6.4	L-1210	6.4	6.4	6.1	4.19	4.19	6.3	D-1740
1-2	B-0600	B-0600	7.1	7.1	7.1	7.1	7.5	L-1200		8.4		3.1	3.1	6.5	D-1740
1-3	B-0520	3.7	3.7	5.5	5.5	5.5	3.7	L-1200		2.17	2.17	6.7	6.9	D-1650	
1-4		B-0610	7.2	7.2	7.2	7.2	7.2	L-1220	L-1220	7.4	7.4		D-1740	D-1740	6.9
1-5	B-0540	B-0540	2.15	7.4	7.4	7.4	4.20	3.5	L-1300	L-1300	6.8	6.8	6.8	D-1750	7.7
2-1	B-0500		3.7	3.3	3.3	3.4	3.4	L-1210	L-1210	3.1	3.1	2.21	6.9	D-1700	3.1
2-2	B-0520		3.7	8.3	8.3	8.3	8.3	L-1150		3.1	3.1	6.9	3.1	3.1	D-1710
2-3	B-0500		3.7	2.4	2.4	2.4	2.4	L-1210	L-1210	7.5	7.1	9.3	2.20	3.6	D-1750
2-4	B-0540	B-0540	3.7	1.1	1.1	1.2	1.5	L-1210	L-1210	2.6	2.18	7.3	3.1	3.1	D-1710
2-5	B-0530		3.7	5.2	5.4	2.20	5.1	L-1220	L-1220	3.1	8.1	8.1	3.1	3.1	D-1750
3-1	B-0570		8.2	8.2	8.2	8.2	2.20	L-1230	L-1230	8.2	3.1	3.1	3.1	3.7	D-1750
3-2	B-0520		3.7	3.6	2.20	9.2	9.1	9.3	L-1050	L-1050	3.1	2.26	2.26	3.1	D-1700
3-3	B-0540	B-0540	3.7	2.3	2.3	2.3	L-1100		3.6	5.2	2.20	2.23	2.24	2.11	D-1800
3-4	B-0500		5.0	2.20	3.7	3.1	5.4	L-1220	L-1220	7.3	7.3	3.1	3.1	2.20	D-1610
3-5	B-0510		3.7	2.25	2.25	3.1	L-1120	L-1120	9.3	3.1	3.1	2.20	3.1	3.1	D-1720
4-1	B-0510		3.7	4.12	4.13	4.14	4.16	L-1220	L-1220	3.1	4.1	4.15	4.15	3.1	D-1720
4-2		B-0610	3.1	5.4	2.20	3.7	3.1	L-1230	L-1230	1.4	1.3	2.9	2.9	3.1	D-1710
4-3	B-0550	B-0550	9.4	9.4	9.4	9.4	9.4	9.4	L-1300	L-1300	4.19	4.19	4.19	4.19	D-1750
4-4		B-0500			3.7	3.7	3.7	L-1230	L-1230	4.1	4.1	3.9	3.9	3.6	D-1610
4-5	B-0550	B-0550	3.7	2.20	5.1	3.6	5.3	L-1240	L-1240	2.20	9.3	9.3	3.1	3.1	D-1720
5-1				3.8	3.8	3.8	3.8	3.8		3.8	3.8	3.8	3.8	3.8	
5-2				3.8	3.8	3.8	3.8	3.8		3.8	3.8	3.8	3.8	3.8	
5-3				3.8	3.8	3.8	3.8	3.8		3.8	3.8	3.8	3.8	3.8	
5-4				3.8	3.8	3.8	3.8	3.8		3.8	3.8	3.8	3.8	3.8	
5-5				3.8	3.8	3.8	3.8	3.8		3.8	3.8	3.8	3.8	3.8	

GLOSSARY OF TERMS AND ABBREVIATIONS

Term/Abbreviation	Definition	Page First Appearing
BMO	Basic Military Officer.....................	7
BOOTS	Basic Organizing/Optimizing Training Scheduler.................................	4
CNET	Chief of Naval Education and Training.......	3
CNTECHTRA	Chief of Naval Technical Training..........	4
HOP	Heuristic Optimizing Processor.............	3
ILP	Integer Linear Program.....................	5
IMP	Interactive Mode Program...................	5
LOG	Lineprinter Output Generator...............	23
MID	Military Inspection Department.............	7
MOE	Measure of Effectiveness...................	16
MTS	Master Training Schedule...................	3
RPOD	Recruit Plan of the Day....................	7
RTC	Recruit Training Command...................	3
SLAM	Schedule Layout Assignment Matrix..........	25
STE	Standards, Testing and Evaluation Department............................... .	7
TAEG	Training Analysis and Evaluation Group......	3
λ-opt	Lambda-opt (heuristic method for optimization using a pair-swapping procedure where λ indicates the number of pairs to be swapped at a time)....	18

Training Element	a Training Function or Training Topic as listed in the Curriculum Outline
Training Event	a group or cluster of Training Elements which must be scheduled together at one time
Training Function	a noninstructional element of the curriculum; e.g. medical exams
Training Topic	an instructional element of the curriculum; e.g. first aid

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