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A Heuristic Approach for the Scheduling of Technical Training Courses in the U.S. Navy

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ABSTRACT

The generation and maintenance of feasible schedules for Navy training courses are labor intensive throughout the Naval Education and Training Command. The major constraints affecting this scheduling are planned input requirements and the suitability/availability of instructors, equipment, and facilities. An additional constraint is that schedules must be established for the current year, updated and revised as necessary, and projected for the out-year planning requirements of the 5-Year Defense Plan.

This thesis documents the essential components of scheduling for training at a representative training center, the Fleet Anti-Submarine Warfare Training Center, Pacific. It provides details for the automation of the current scheduling process, with a limited demonstration for a sample of courses. Conclusions and recommendations for the development of an automated optimal scheduling system are presented.

A HEURISTIC APPROACH FOR THE SCHEDULING OF TECHNICAL TRAINING COURSES IN THE U.S. NAVY

BY

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THESIS

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STATEMENT OF THE PROBLEM

The generation and maintenance of a feasible schedule for Navy training courses are labor intensive throughout the Naval Education and Training Command (NAVEDTRACOM). The major constraints affecting this scheduling are planned input requirements and the suitability/availability of instructors, equipment, and facilities. An additional constraint is that schedules must be established for the current year, updated and revised as necessary, and projected for the out-year planning requirements of the 5-Year Defense Plan.

The present scheduling system can be characterized as reactive and highly labor intensive. Guidance is minimal resulting in scheduling processes which are subject to the vagaries of individual style and competency. An improved method for arriving at schedules is needed. Such a scheduling method should optimize the utilization of school resources in meeting training requirements. Other potential benefits which may be derived from the application of this methodology are the reduction of average on board (AOB), the establishment of more defensible training capacity figures, and an increased availability of personnel for other school requirements.

BACKGROUND

Operational readiness is a function of the effectiveness of the Navy's education and training programs. Efficient management is the

key to maintenance of these programs. Therefore, training policies, plans, and programs must be fully capable of meeting current and future training requirements with reasonable levels of effectiveness and efficiency. The latter can be enhanced by exploiting the current concepts and techniques of operations research, educational technology, systems analysis, and management science in the design and management of Navy training.

The complexity of the scheduling of training within the NAVEDTRACOM has resulted in a process which terminates when a feasible plan is achieved, even though that plan may not be optimal in terms of resource utilization. Trade-offs in schedules are made by exception when a crisis situation occurs. The short planning horizon, possibly a week, is designed to result in a responsive scheduling system. Unfortunately, this results in minimum trade off consideration and resource surpluses to maintain responsiveness. Initial indications are that under the present system course planners require approximately 3 months to generate a feasible schedule.

In the search for a viable alternative to the present system, a variety of approaches to operations scheduling employed in industry were examined. In essence, the approaches were found to be inappropriate because they were unable to accommodate the complexity of the variables associated with the scheduling of Navy training courses. Thus, it was determined that the present scheduling system had to be documented in detail, with the necessity for manual scheduling being eliminated through automation, and the feasibility of an optimal resource utilization/scheduling algorithm being established.

The Fleet Anti-Submarine Warfare Training Center, Pacific (FLEASWTRACENPAC) was selected as the site at which to accomplish the above objectives for the following reasons:

. it provides an operational setting.

. ASW School personnel have solicited assistance, are receptive to assistance, and have a comprehensive understanding of the problem.

The major scheduling effort at the ASW School is divided between surface and submarine sonar technician training. These two areas are comprised of 87 courses, approximately 300 instructors, and a myriad of training equipment both simulated and operational.

PURPOSE

The purposes of this thesis are to:

. survey a variety of scheduling techniques and in industry for possible applications.

. document the essential components of scheduling training at the FLEASWTRACENPAC.

. provide results of initial effort to automate the current manual scheduling process.

. demonstrate the automated process on a limited sample of courses.

. provide conclusions and recommendations for an optimal scheduling system.

ORGANIZATION OF THE REPORT

In addition to this introduction, the report is divided into three other sections. The next section contains an overview of indus-

trial scheduling methodology and its application to Naval training. Section III provides an analysis of the current scheduling approach for a typical training activity. It contains explications of the logic and rationale currently used in arriving at feasible schedules. Preliminary results concerning the automation of this process are presented in section III. Section IV contains the conclusions derived during the limited study period as well as recommendations for additional study efforts related to the development of an automated optimal scheduling system. Appendix A contains a listing of the computer program for the automation of the manual scheduling process with representative outputs provided in Appendix B.

INDUSTRIAL SCHEDULING METHODOLOGY AND ITS APPLICATION TO NAVAL TRAINING

To schedule is to make a timetable for activities. Primary interest is in making a timetable for offering Navy training courses using available resources, initially the scheduling problem appears to be not too different from those encountered in setting industrial schedules. Consequently, the scheduling methodology used in industry may be applicable to the scheduling of training courses. This section will present how production scheduling is techniques done in industry and then single out concepts and techniques which may be useful for the scheduling of Navy training courses.

INDUSTRIAL SCHEDULING METHODOLOGY

In an industrial production system, the variables subject to control are, fundamentally, labor, materials, and capital inputs. More labor effort will theoretically generate more volume of output, so the employment level and use of overtime are highly relevant. Materials can also be used to regulate the flow of output by studying and depleting inventories, backordering, and sub-contracting items to other firms. In addition, the capital input represents a variable controlling the overall plant capacity in a longer-range sense.

Figure 1 depicts the major interrelationships of the industrial production planning and scheduling activities. A production plan is a statement of production goals, based on forecasts of demand and resource availability, that consciously attempts to manage employment

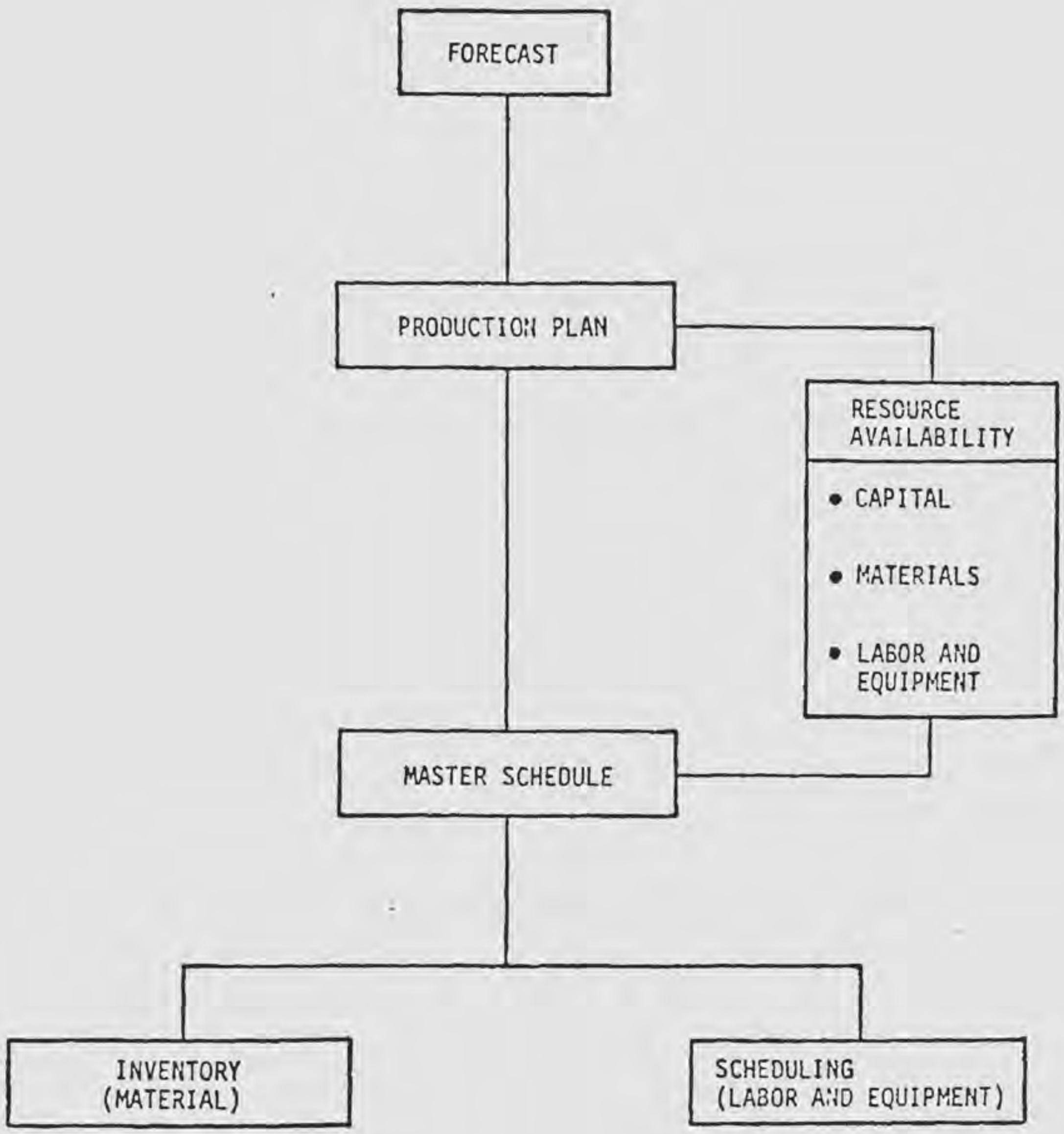

Figure 1. Major Interrelationships of the Industrial Production Planning and Scheduling Activities

and inventory levels to attain organizational objectives. The master schedule flowing from the production plan is a high-level schedule that translates the production plan into specific product terms by specifying what end products are to be produced and the time periods during which they are to be made. From the master schedule are derived the component inventory and scheduling requirements. The detailed schedule is a low-level schedule specifying precisely what must be produced and the starting and/or completion dates.

Not all industrial firms performs the same production control functions. Indeed, there is a striking difference between the production control activities in continuous, intermittent, and project-type operations.

ASSEMBLY LINE BALANCING

Continuous systems are designed to produce large volumes of a single item (or relatively few items) on specialized, fixed-path equipment. They often utilize assembly lines (e.g., the automotive industry, television producers) or continuous-processing equipment (e.g., oil refineries). Raw materials and component parts are common to each unit produced, labor operations are repetitive, and the transformation technology used is the same in each case. Scheduling in this mode of production system consists of establishing the rate of flow of raw materials and subassemblies to the line, balancing the capacities of workers and machines along the line, and smoothing the flow and shipment of items off the line. This type of problem is called the assembly line balancing problem.

The number adjacent to each node is the time required for the work element. This type of problem attempts to determine the best grouping of work elements for workstations such that the processing time for each workstation is an uniform as possible.

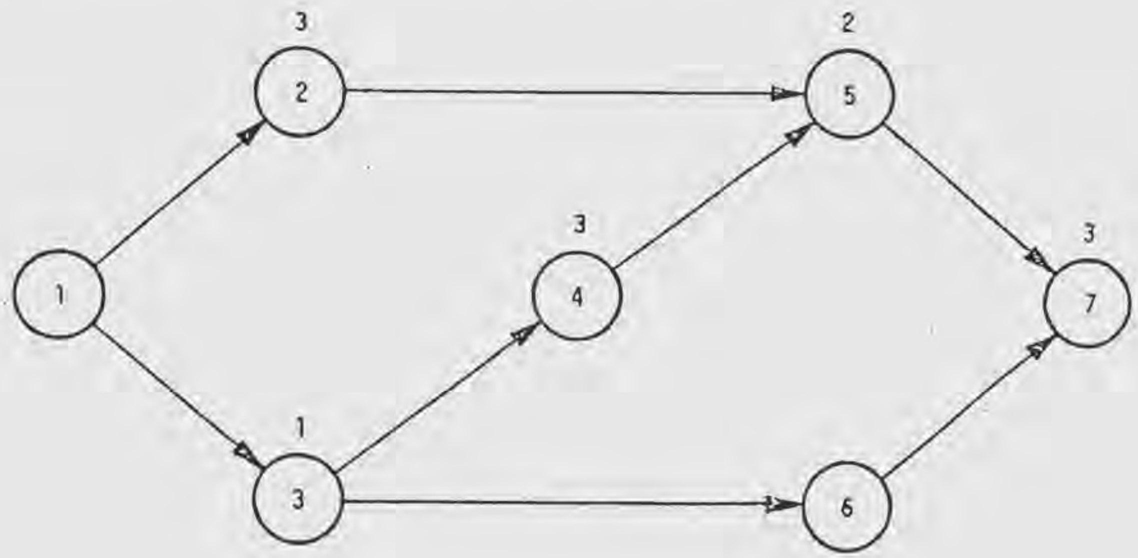

Figure 2. Network Representation of a Line Balancing Problem

The assembly line balancing problem is one of the combinatorial problems which has been proved to be frustrating to deal with, and no optimum algorithm has been developed to solve it. For an assembly line with 70 work elements (nodes in the network) and 105 precedence relations (arcs), an estimate of the number of feasible sequences is $70!/2^{105} = 10^{65}$. It would take years to find the optimal solution even with the fastest computer presently available. Arcus (1965), Kilbridge and Webster (1961), among others, have proposed heuristic procedures to obtain a good schedule for the line balancing problem.

JOB SHOP SCHEDULING

The second mode of production is intermittent systems which are designed to produce small quantities of many items on relatively general purpose equipment. More specifically, a number of jobs, each comprising one or more operations to be performed in specified sequence on specified machines and requiring certain amounts of time, are to be scheduled such that due dates associated with each job will be met or, failing this, some measure, such as the sum of lateness times, is minimized. Such a problem is called the job shop scheduling problem.

Like the assembly line balancing problem, the job shop scheduling problem is a difficult combinatorial problem. Normally, the solution method is to lay out all possible sequences and then pick the best. Despite the power of modern computers, such a method is not feasible for any real-world problem. For J jobs and M machines, in the general case there will be $(J!)^M$ such sequences. A small problem with 5 jobs and 5 machines, for example, would have approximately 2.5×10^{10} sequences to evaluate.

In the past two decades there has been a substantial growth in the field of job shop scheduling research. However, no exact optimum algorithm has been found, and, in fact, research results indicate the optimal solution for the job shop scheduling problem is computationally difficult to obtain. Thus, numerous simulation studies are made to see which heuristic scheduling rules are best. For example, the shortest-job-first rule has been shown to be rather favorable in some cases. In a recent paper by Panwalker and Iskander (1977), a list of

over 100 scheduling rules is given according to different categories. The scheduling rules are presented in a form that can be readily used by both practitioners and researchers. Conway, Maxwell, and Miller (1967) and Baker (1974) also provide a detailed account of job shop scheduling rules.

PROJECT SCHEDULING

The third mode of production is large-scale one-time project systems. Projects usually consist of multiple parts and components and involve huge labor hours, dollars, and equipment requirements. Such complexity makes project scheduling of extreme importance, since operations performed out of schedule can cause delays and extra costs. Problems concerning the control and coordination of projects are called the project scheduling problem.

Since the late 1950s, the critical path method (CPM) of scheduling has been used to sequence project activities so that the project completion is minimized. The method provides a knowledge of permissible slack or schedule slippage of certain activities. This slack in the schedule gives management flexibility in achieving the schedule.

Like the assembly line balancing problem, project scheduling problems can be represented by a network. Figure 3 shows the network representation of a project containing six activities: A, B, C, D, E, and F. The network depicts the logical relationships, and the number adjacent to each arc is the time duration for the activity. For example, activity F cannot be started until D and E are completed. The dashed line 3-4 is a dummy activity of zero duration, used for correct logic in some situations. In this example, activities A, B,

D, and F are critical ones. An excellent coverage of the CPM is found in Moder and Phillips (1970).

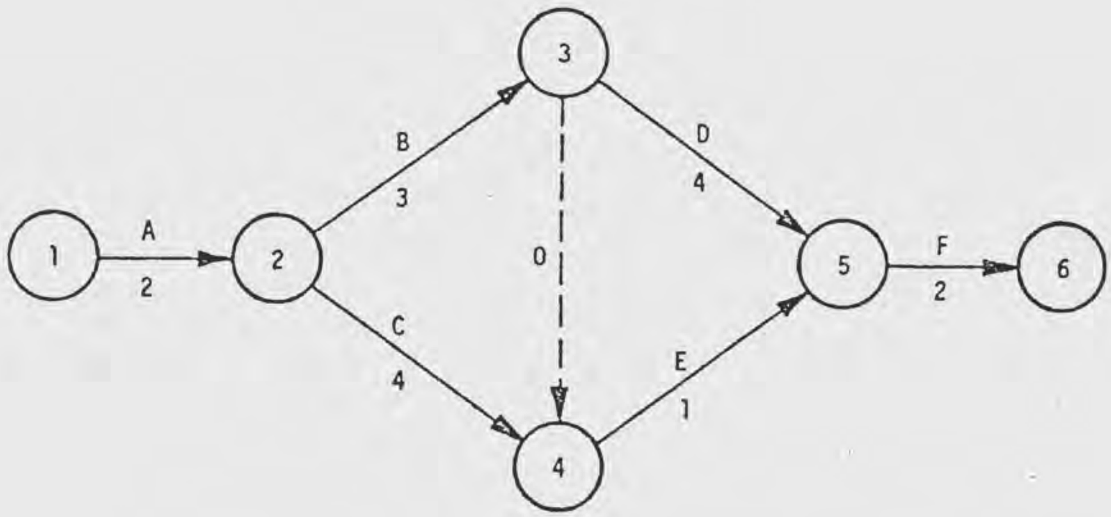

Figure 3. Network Representation of Project Scheduling

The basic CPM assumes unlimited resource availabilities. In some situations, one may desire to complete the project by a specified due date while utilizing resources at a relatively constant rate. Thus, the objective of the leveling process is to smooth as much as possible the demand for each specific resource during the life of the project. This is accomplished by judicious rescheduling of activities within their available slack to give the most acceptable resource constraints. This type of problem is called the unlimited resource leveling problem.

In some situations, however, the unlimited resource assumption is invalid. One may be given fixed amounts of resources during each

period of project duration. When the amount available are not sufficient to satisfy demands of concurrent activities, sequencing decisions are required, often resulting in some increase in total project completion time. Thus, the scheduling problem here is to meet project due dates as much as possible, subject to stated constraints on available resources. This is called the limited resource allocation problem.

While the basic critical path schedule can be optimally determind rather easily, finding an optimal schedule for projects with resource constraints is as difficult as that for line balancing and job shop scheduling problems. Heuristic scheduling rules seem to be the only promising way in large real-world problems. Burgess and Killebrew (1962) described a simple procedure based on minimizing the sum of squares of resource requirements in consecutive time periods to deal with unlimited resource leveling. Levy, Thompson, and Wiest (1963) proposed an approach of setting "trigger levels" of maximum resource usage and attempting to smooth resources to fall within these levels.

A number of heuristic procedures have been proposed for the limited resource allocation problem. Davis (1973) provides an excellent overview and classification of contributions to the project scheduling field up to 1973. Wiest (1967) developed a computer program called Scheduling Program for Allocation Resources (SPAR). His procedure is based on two scheduling rules: the activity with the least slack is scheduled first and the one with the shortest time

duration is scheduled first if two activities with the same slack are eligible for scheduling. The program has been applied to single and multiple project problems of more than 200 jobs and 20 different resource types. Other important papers in the development of this subject are written by Fendley (1968), Cooper (1976), and Thesen (1976).

Table 1 summarizes industrial scheduling problems and solution techniques. All in all, industrial scheduling problems comprise a class of difficult combinatorial problems. This class of problems is characterized by a factorial growth in the amount of computation required to consider all possible solutions as problem size increases. However, there are strong similarities among some of these problems, to the extent that solution procedures developed originally for one type problem have been applied on the other, with considerable success. This cross application of solution procedures is one of the important development in this field.

APPLICATION TO NAVAL TRAINING

The Naval course scheduling problem does not appear to resemble the three basic types of industrial scheduling problems as reviewed earlier. Although training a student may be viewed as assembling a car, the nature of the scheduling problem in an assembly line, mainly, desiring the smoothing of product flow by grouping of work elements, is not nearly the same as that of course scheduling. In a job shop environment, job shop scheduling rules are intended to resolve conflicts of the cross-utilization of expensive machinery

TABLE 1. SUMMARY OF INDUSTRIAL SCHEDULING PROBLEMS AND SOLUTION TECHNIQUES

	Line Balancing	Job Shop Scheduling	Project Scheduling
Nature of Problem	Smooth flow of assembly line	Resolve conflicts of cross-utilization of machinery	Identify and control critical activities in projects
Solution Techniques	Arcus (1966) Helgeson and Birnie (1961) Kilbridge and Webster (1961)	Baker (1974) Conway (1967) Panwalker and Iskander (1977)	Burgess and Killebrew (1962) Cooper (1976) Fendley (1968) Levy, et al. (1963) Moder and Phillips (1970) Thesen (1976) Wiest (1967)

and/or high-skilled labor. Some similarities exist between courses and jobs and between training resources (instructors, trainers, and facilities) and job shop machinery. Cross-utilization of training resources, however, does not seem to exist at the Pacific ASW School; instructors and trainers are seemingly dedicated to the respective courses.

Initially, project scheduling with resource constraints was thought to be an excellent modeling technique for the Naval course scheduling problem. It was thought that an enlisted trainee completing some NEC skill came close to accomplishing a project with interrelated course requirements. Based on this thinking, course schedules with a reduced AOB level and leveled resource utilization could have been developed by employing scheduling techniques reviewed earlier. It turned out that interrelationships among courses were rather simple; namely, one following another. For example, to be rated in 26 BX maintenance, one must take the basic core course (6 weeks), self-paced Basic Electricity and Electronics (6 to 9 weeks), Sonar Electronics Intermediate (17 weeks), and then 26 BX maintenance (20 weeks). This simplicity nullifies the powerfulness of project scheduling techniques.

During visits with the Pacific ASW School, two observations were made. Utilization of resources appeared unleveled. For instance, it was observed that classrooms were likely to be used for 20 hours in a week, 60 hours in the following week, 40 hours following that, and then 80 hours. The second observation made was that the existing scheduling procedure did not seem to consider minimization of

trainees' waiting time for courses. The existing course schedule are laid out uniformly distributed throughout the year. If the number of classes needed is greater than the number of weeks available in the year, double shifts are made and uniformly distributed again.

It is believed that some modifications to the existing course scheduling procedure may result in a more level resource utilization and reduced AOB level. The first suggestion is that the idea of resources leveling, as described earlier, be incorporated. The second suggestion is that course schedules be generated with consideration to the average student load.

ANALYSIS OF THE TRAINING SYSTEM

This section describes the career paths of sonar technicians in order to provide a better understanding of the training requirements for this type of specialized training. In addition, the data inputs and calculations used to derive school resource requirements are analyzed. The documentation of this process formed the conceptual foundation for the attempt to automate the manual scheduling process.

CAREER PATH OF SONAR TECHNICIAN

The training requirements are reflected by career paths because of the various sequences of courses a technician can take during his career. The number and interaction of possible sequences contribute significantly to the complexity of the scheduling problem.

Figure 4 provides an overview of the training career paths open to the surface sonar technician. Similar career paths, with appropriate training, are characteristic of all enlisted Navy ratings or skill categories. All surface sonar technicians take basic core requirements; i.e., STG-A, for 6 weeks. If the trainee is a 4-year obligor (4YO), he then proceeds to one of the four class "A" operator courses (3 to 8 weeks) before going to the fleet for a period of 18 to 24 months. Thirty percent of the 6 year obligor (6YO) students proceed directly from STG-A to a pipeline composed of 6 to 9 weeks of Basic Electricity and Electronics (BE&E), 17 weeks of Sonar Electronics Intermediate (ESI), and finally 12 to 31 weeks of specific operator and maintenance

SURFACE SONAR TECHNICIAN CAREER PATH

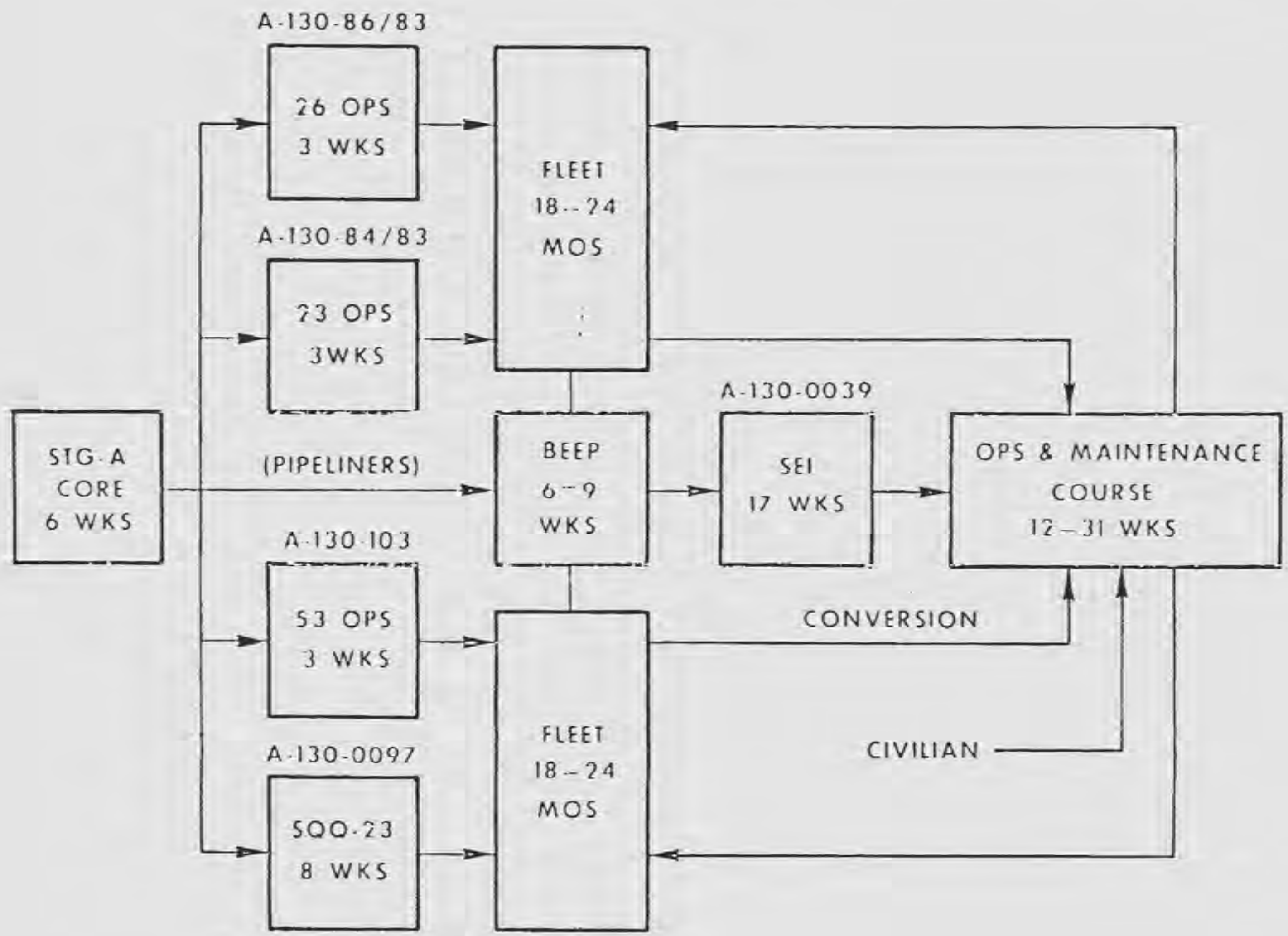

Figure 4. Surface Sonar Technician Career Path

class "C" schools before going to the fleet. The remaining 70 percent of the 6YOs go to the same "A" school operator courses as the 4YOs and then directly to the fleet. After 18 to 24 months with the fleet, this 70 percent resume training on the same pipeline as the other 6YOs previously described. The only additional inputs to the training program are the conversion of sonar technicians from one equipment specialty to another usually necessitated by a change in class of ship assignment and the aperiodic addition of civilians such as contractor or governmental personnel.

The scheduling of training courses in a manner which is responsive to the numerous career paths and pipelines throughout the Navy's rating structure is complex and difficult. The following provides a description and analysis of the manual scheduling system presently used at the FLEASWTRACENPAC. This description is limited to "A" and "C" Schools.

THE FLEET ANTI-SUBMARINE WARFARE TRAINING CENTER, PACIFIC

The scheduling process at this activity is assumed to be representative of other Navy training activities. Figure 5 illustrates the general developmental flow of a schedule and identifies the constraints and requirements impacting on this flow. The training requirements or demand figures generated by the Chief of Naval Operations (CNO) via the Bureau of Naval Personnel (BUPERS), and the Chief of Naval Technical Training (CNTECHTRA) are the basic input to the scheduling process. Based on the availability of suitable equipment and authorized manpower levels for instructor billets as

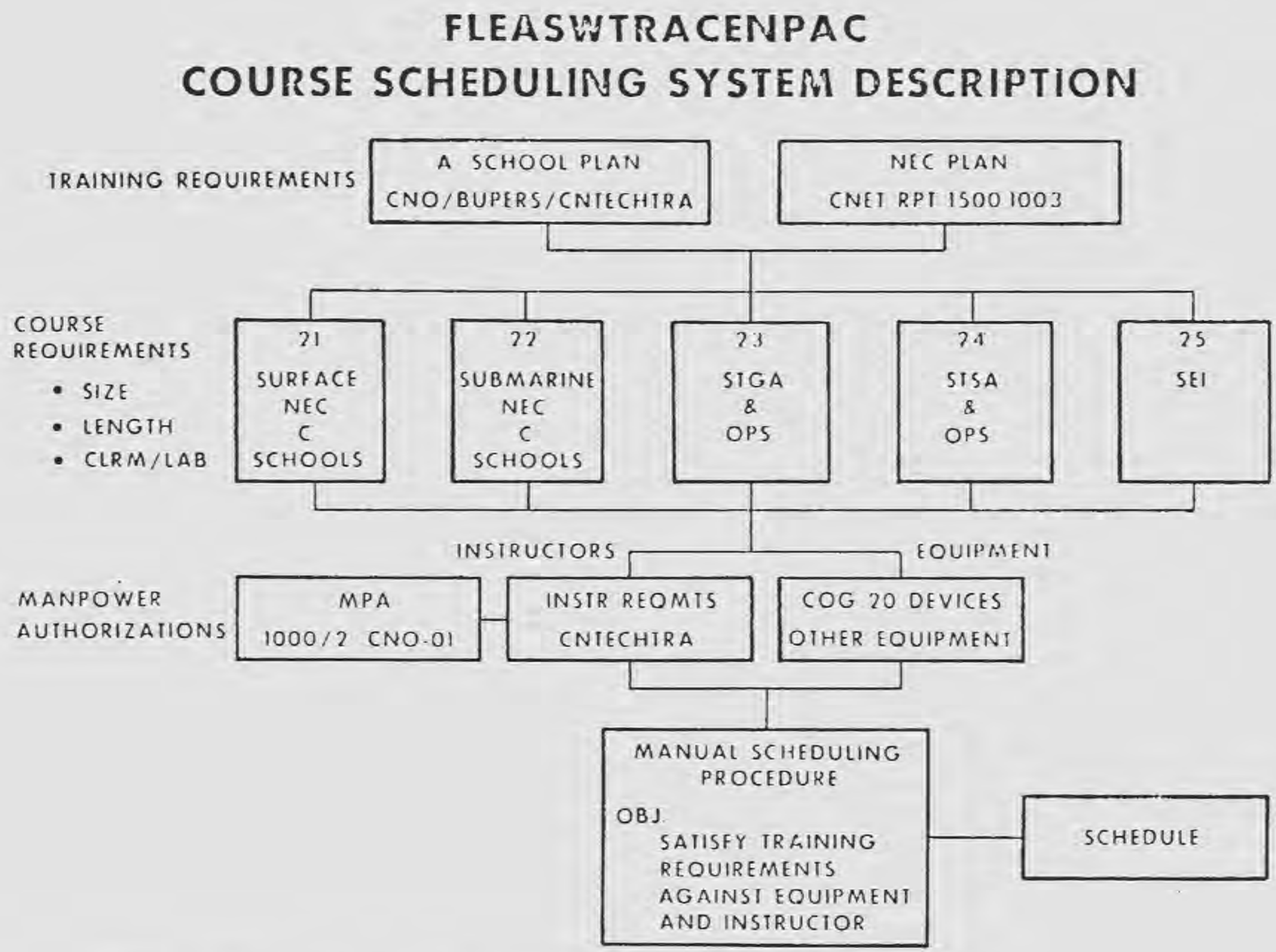

Figure 5. FLEASWTRACENPAC Course Scheduling System Description

established by CNO 1000/2 report, an assessment is made as to whether the input requirement can be feasibly met. If requirements can be accommodated, a schedule is generated. If the training requirements cannot be met, the viable alternatives are limited to either a reduction in the training requirement for this activity, subject to its capacity constraints, or sufficient equipment and/or personnel are added. The latter alternative also has associated with it the additional problem of long lead times.

COURSE REQUIREMENTS

The Chief of Naval Operations, BUPERS, and CNTECHTRA establish the specific training requirements for each training activity and each course. The documentation of the process is beyond the scope of this study.

Subsequent to the identification of requirements or demand levels for each course, specific course descriptive data such as the course identification number (CIN), the title, the length, and class size are input for consideration. The total demand, or planned input, is divided by the class size to determine the number of course offerings needed to satisfy the input. The number of instructional weeks in a year is then divided by the number of classes required to determine the convening frequency. Based on convening frequency, the number of classes required to be in session concurrently is easily obtained by division of the course length by the convening frequency. This establishes a baseline for the minimum resource requirements necessary to satisfy the training requirements. This process is outlined in Figure 6.

LOGIC FOR COURSE REQUIREMENTS

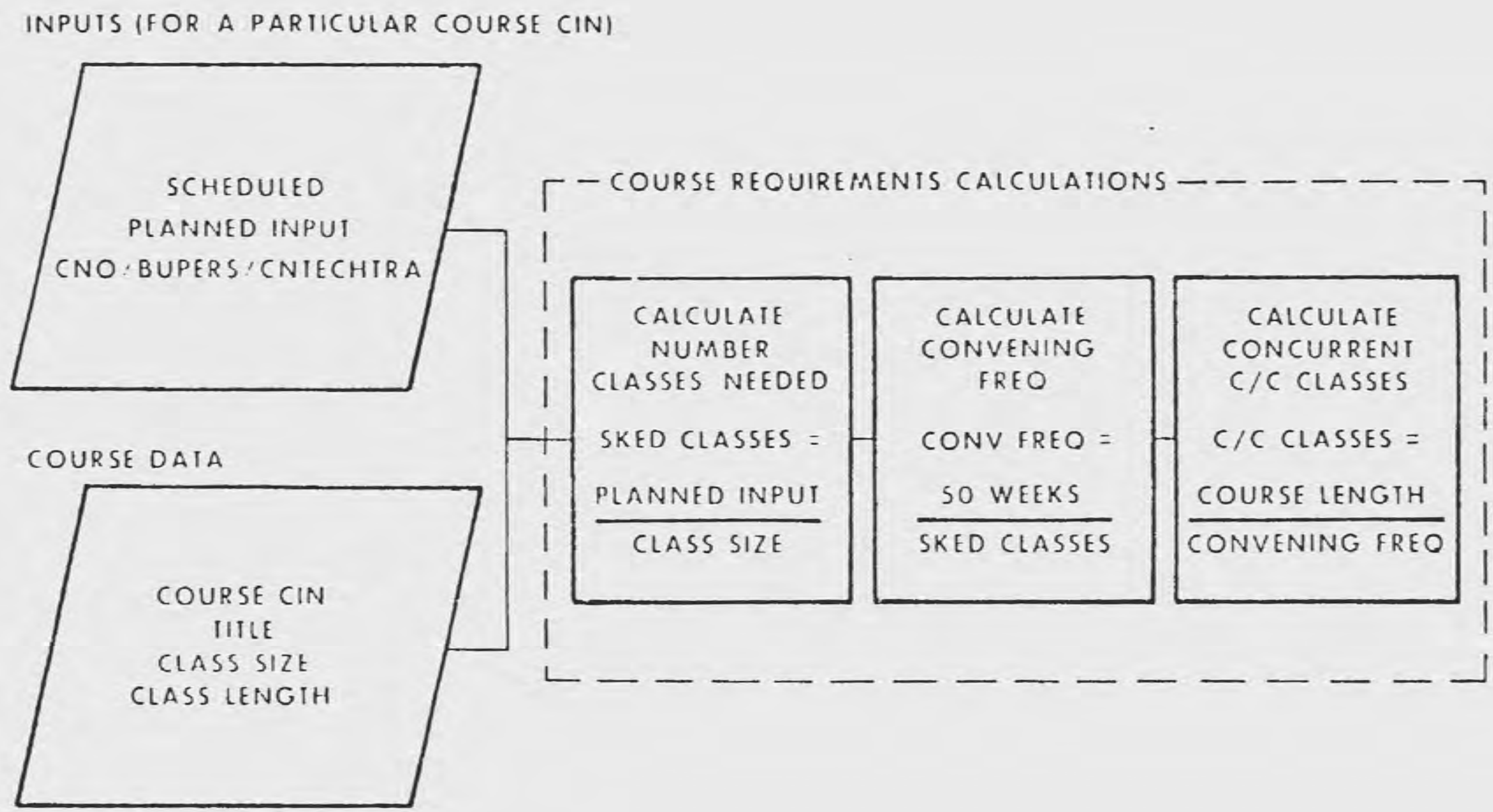

Figure 6. Logic for Course Requirements

INSTRUCTOR REQUIREMENTS

Instructor requirements for a course are established by CNTECHTRA Instruction 5311.1A. The logic used in the generation of instructor requirements is shown in Figure 7. This logic employs the course descriptive data used in the generation of course requirements. In addition, up to seven pairs of student/instructor ratios with appropriate instructional contact hours are used. The total contact hours are calculated by summing the quotients of the individual pairs of contact hours and student/instructor ratios, and multiplying this sum by the class quota or size. Basic instructor requirements are then determined by considering the convening frequency, the number of contact hours an instructor teaches per week; e.g., 25, and adjusting this Figure with a 10 percent increase to cover supervision. The final instructor requirements or fractional instructor requirements are adjusted 12 percent to take into account such considerations as leave and duty. This figure is then rounded upwards to give a whole number value for instructor requirements.

FEASIBILITY ASSESSMENT OF PROPOSED SCHEDULE

Once the basic course requirements; i.e., number of convenings required, are established the course schedule is subjected to a feasibility assessment. As Figure 8 illustrates, the assessment examines the resource constraints for meeting the requirements. The basic instructor requirements, calculated as described previously, are compared with the manpower authorizations as established by CNO

LOGIC FOR INSTRUCTOR REQUIREMENTS

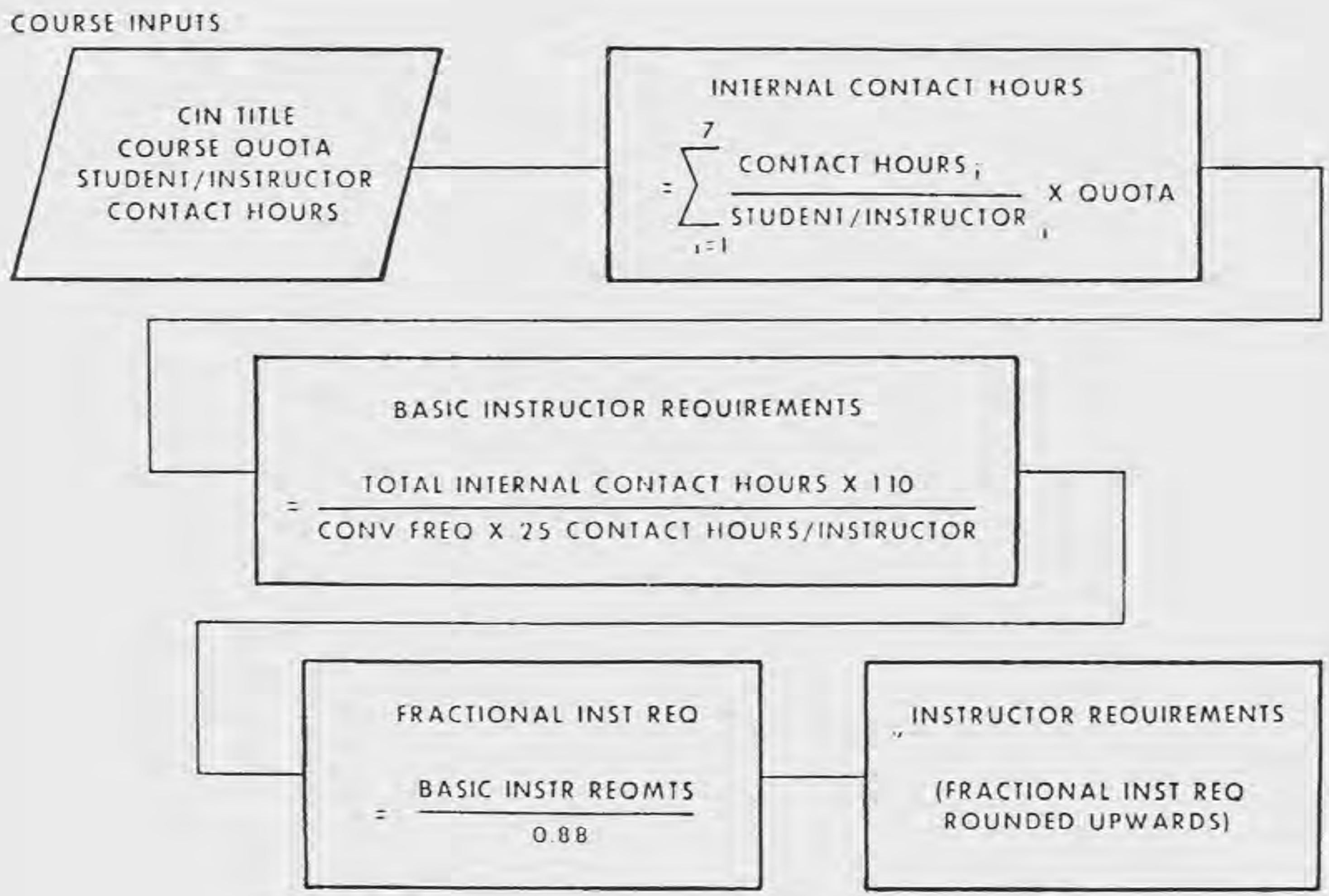

Figure 7. Logic for Instructor Requirements
(Source: CNTECHTRAINST 5311.1A)

FEASIBILITY ASSESSMENT OF PROPOSED SCHEDULE

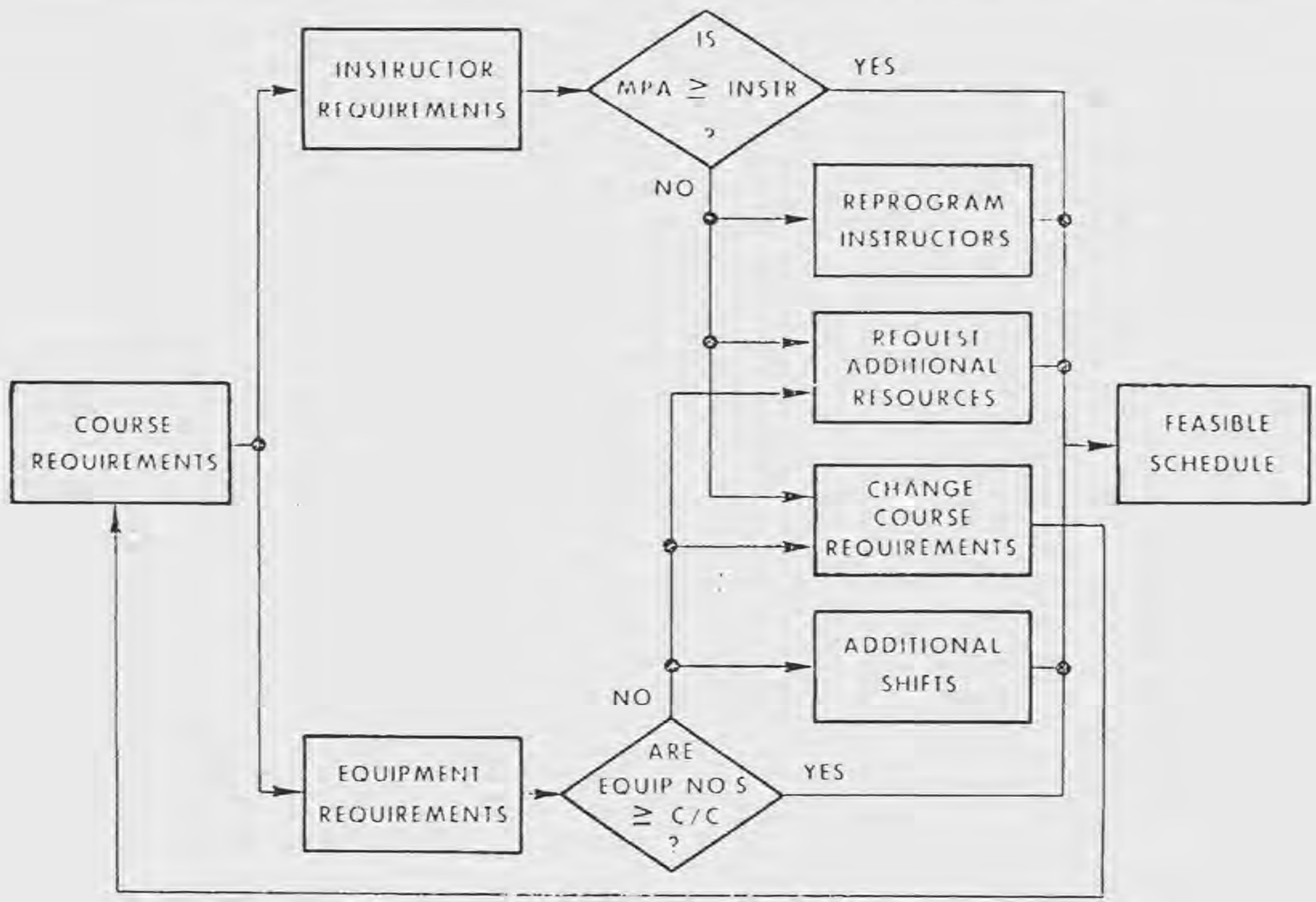

Figure 8. Feasibility Assessment of Proposed Schedule

1000/2 report. If the manpower authorized is equal to, or exceeds, the basic requirements, it is then possible to proceed with scheduling. If, however, the instructor requirements exceed those authorized, there are several options available to the school. The first is to reprogram instructors within the school from areas which have a surplus. The second is to request additional instructors from external sources. Third, the basic requirement can be modified to agree with capacity figures based on instructor availabilities. The latter tactic is the one usually followed because the first two involve significant time lags. Occasionally, however, the requirement remains fixed and the school must utilize existing resources to meet the requirement. This is accomplished by increasing individual class sizes, but the school tries to avoid such a situation because the resultant training is considered to be degraded.

Equipment requirements and availabilities cause the biggest scheduling constraint at the ASW School in San Diego. The minimum requirements are determined by establishing the concurrent convenings required. If the concurrent convenings exceed the basic number of equipments available, then the options are restricted to requesting additional equipment, changing the basic demand requirements, or scheduling the equipment for more than one shift if instructors are available.

After the feasibility of meeting a training requirement is established, a week-by-week schedule is generated for each course for the fiscal year. Variables or constraints specific to the nature of courses, equipment, pipelines, and people are considered at this time.

Ideally, the courses would be scheduled on a single shift basis, convening at the predetermined convening frequency, and level loaded for the entire year.

As indicated earlier, the scheduling process described in this section is estimated to require 3 man months of labor to arrive at a feasible schedule. The automated scheduling process described in the next section is designed to accomplish the same objective; i.e., a feasible schedule, while reducing the labor intensive aspects of the process.

AUTOMATION OF THE MANUAL PROCESS

The ultimate objective in studying the course scheduling process for Navy specialized training is to develop a methodology which will optimize the schedule and use of resources for a course or group of courses. An initial step in this optimization process is to automate the tedious manual scheduling process and concurrently to determine subsequent efforts to fully optimize the process. An optimal solution will be contingent upon the objectives established by NAVEDTRACOM managers.

Compelling reasons for automating the present manual constructed scheduling system include the following:

- the existing system is most labor intensive.
- the basic logic for calculation used in determining the feasibility of a course schedule is straightforward and adaptable for programming.
- time and resources were adequate to allow initial automation.
- the ASW School would obtain a useful product as a result of involvement in the study.
- the analysis would enable a better understanding of the unique parameter of the technical training system which could be applicable to future modeling efforts in other functional areas.
- the initial effort would:

- provide an assessment of the utility of the automation of the scheduling process.
- identify additional research needs.
- provide an evaluation of the generality of automated scheduling programs.

The computer scheduling program developed during the study does not generate an optimized schedule for a course or group of courses. Rather, it generates a feasible schedule based on stated resource constraints and requirements. This initial iteration could be modified by training planners and individual course coordinators to accommodate the unique characteristics of course content, personnel qualifications, and equipment requirements.

The scheduling program was written in BASIC for use on a WANG 2200 programmable calculator. Figure 9 illustrates the basic inputs and outputs of the program. The program listing is given in Appendix A, with schedules for the surface and submarine sonar technician courses given in Appendix B. It should be pointed out that the data used to illustrate the process is not to be considered an official statement of the FLEASWTRACENPAC schedule. For instance, not all courses are included, some course lengths have changed, and instructor levels may be different.

PROGRAM LOGIC

The program logic is illustrated in the flow chart of Figure 10. The logic follows that of the manual process described in the previous section, which is used by the training planners at the ASW School in

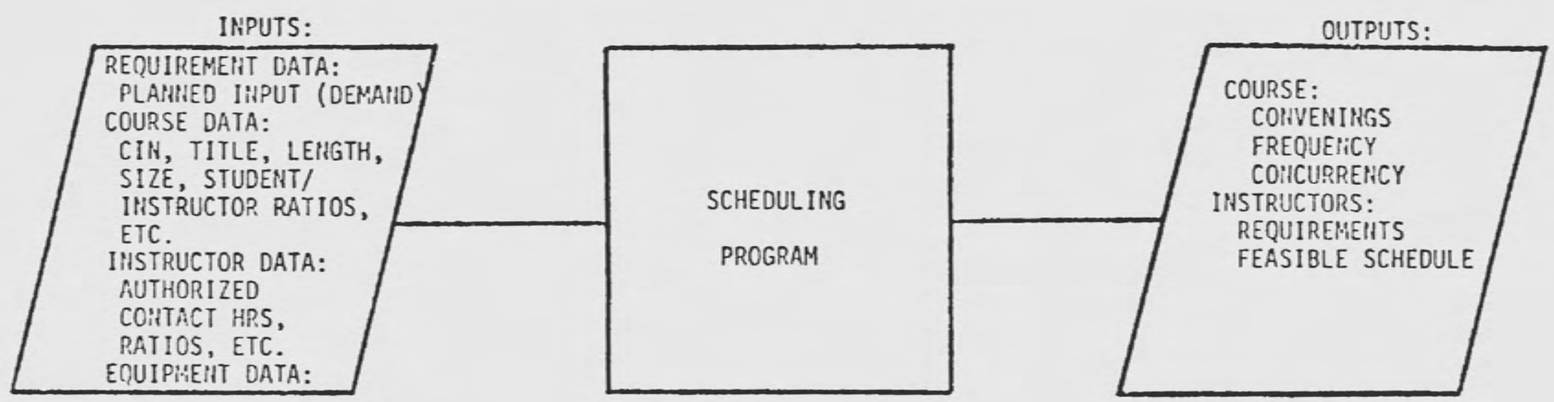

Figure 9. Basic Inputs/Outputs of Scheduling Program

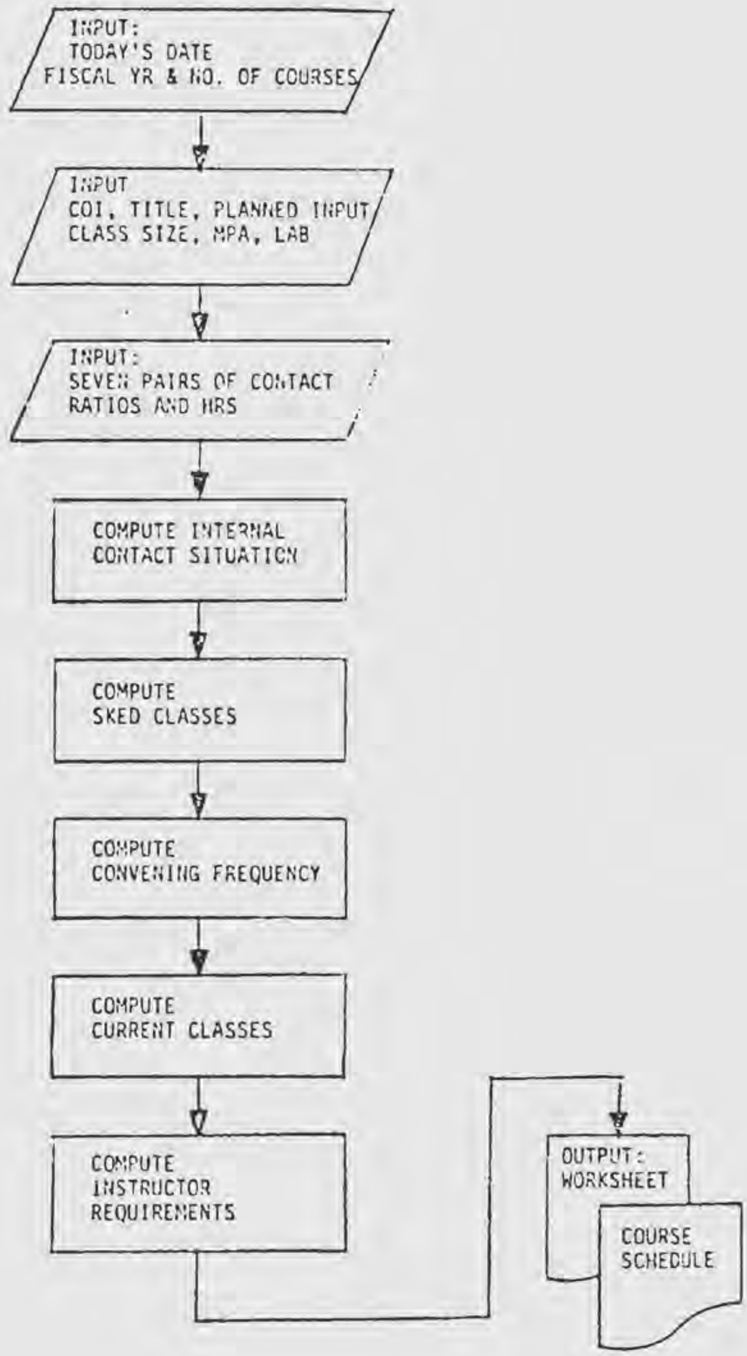

Figure 10. Flow Chart of Program Logic

San Diego to assess the feasibility of a schedule. In addition, the computer program employs the same input data as that used in the manual process.

PROGRAM INPUT

The the purpose of illustration assume that today's date is December 1, 1977, and the schedule to be run is for the SQS-35 course in fiscal year 1979. The data required by the program for a single course is presented in table 2. Data for additional classes would be entered in the same manner.

CIN	TITLE	PLANNED INPUT	CLASS SIZE	COURSE LENGTH	MPA	MPA (Support)	LABS	SEVEN PAIRS CONTACT/RATI CONTACT HOUR
A-130-0069	SQS-35	64	8	13	1	1	1	25/179 5/60 9/148 0/0 0/0 0/0 0/0

*Data in table 2 is available from the NITRAS Master Course Reference File (MCRF).

PROGRAM OPERATION

To run the program and to generate the worksheet and course schedule the following is keyed in:

STEP 1

LOAD DCF 'NEW 2' (Load the program on a floppy diskette into WANG)

RUN

The CRT (screen) responds:

ENTER TODAY's DATE (MONTH, DAY, YEAR) =

STEP 2

Enter 12, 1, 1977 right after the " = " sign, and press the return key.

Then the CRT responds:

ENTER FISCAL YEAR AND NO. OF COURSE

STEP 3

Enter 1979 after the word "course", push return key, and key in the following:

"A-130-0069", "SQS-35", 64, 8, 13, 1, 1, 1

25, 179, 5, 60, 9, 148, 0, 0, 0, 0, 0, 0, 0, 0

STEP 4

CONTINUE OR COMPUTE (reenter step 3 for each additional course)

STEP 5

PRINT (specified input conditions, calculated values, and feasible schedule).

SAMPLE RESULTS

COURSE SHCEDULE WORKSHEET. A sample course schedule worksheet for ASW surface training is presented in Figure 11. This worksheet provides a summary of input data and the results of calculations utilized in generating a schedule. Relevant courses are listed by CIN and short title. The scheduled planned input (SKED PLANNED INPUT)

ASW SURFACE COURSE SCHEDULE WORK SHEET (FY78)

DATE: 12/01/77

CIN	TITLE	SKED PLANNED INPUT	CLASS SIZE	SKED CLASS	CONV FREQ	C/C CLASSES	UNADJ INST	ADJ INST	ON MPA	SUPPORT REQUIRED	SUPPORT ON MPA	LABS	REMARKS
A130-0069	SOS-35	64	8	8	6.25	2.08	2.27	3	1		1	1	
A130-0071	SQS-38	32	8	4	12.50	1.04	1.09	2	8		0	1	
A130-0110	SQR-17	20	8	3	16.66	0.77	1.00	2	5		2	2	
A130-0120	ACOUS ANAL	70	10	7	7.14	0.84	1.83	2	3		0	0	
A130-0109	SQS-548	12	6	2	25.00	0.12	0.21	1	1		0	0	
A130-0033	SEI	980	21	47	1.06	15.98	36.68	37	42		0	0	
A130-0037	STG-A	1170	20	59	0.84	7.08	17.14	18	23		1	1	
A130-0056	MK-111	30	10	3	16.66	1.08	3.35	4	4		2	1	
A130-0057	MK-114	110	10	11	4.54	2.64	5.79	6	6		4	4	
A130-0060	MK-60	16	3	6	8.33	0.24	0.13	1	1		0	1	
A130-0043	230-C	78	12	7	7.14	1.68	4.06	5	7		4	1	
A130-0050	LORA	32	8	4	12.50	0.16	0.19	1	0		0	0	
A130-0036	PAIR	16	8	2	25.00	0.52	0.27	1	2		4	2	
A130-0044	26AXR	20	10	2	25.00	1.04	2.45	3	4		3	1	
A130-0046	26BX	20	10	2	25.00	0.80	2.33	3	3		3	1	
A130-0047	26CX	80	10	8	6.25	4.16	9.75	10	12		6	2	
A130-0102	53	80	10	8	6.25	4.80	10.23	11	15		8	2	
A130-0085	35/38 OPS	120	10	12	4.16	0.95	1.10	2	4		4	1	
A130-0037	PAIR OPS	80	9	9	5.55	1.44	2.46	3	5		4	1	
A130-0103	53 OPS	210	12	18	2.77	1.44	2.80	3	4		5	1	
	GRAND TOTALS	3240						118	150		51		

Figure 11. Sample Course Schedule Worksheet for ASW Surface Training

is provided by BUPERS and CNTECHTRA. The school establishes the most efficient class size for specific courses. The computer program calculates the number of classes (SKED CLASS) required to meet the planned input, how often the class is convened (CONV FREQ), and the number of concurrent convenings (C/C CLASSES). Instructor calculations are derived using CNTECHTRA Instruction 5311.1A as described previously. The worksheet also provides the training planner with support personnel figures for each course and the number of labs available. The number of labs is critical to feasibility consideration since the practical training using training devices, operational equipment, etc., is conducted in the labs. The worksheet provides for a specific fiscal year (FY) consideration but is expandable if desired. Space for specific remarks is also provided for the planner's use.

COURSE SCHEDULE. As shown in Figure 12, a schedule is plotted for each course on a week-by-week basis. Courses which start 1 week before the end of the current FY and continue into the next year are considered to be current FY courses. The CIN is identified with the short title. The four digit number after each course plot indicates the FY and sequence number of the course; plot indicates the FY and sequence number of the course; e.g., 7827 means 'FY 78' and the '27th' offering of that course.

Complete sample worksheets and shcedules for the ASW surface and submarine sonar technician training are provided in Appendix B.

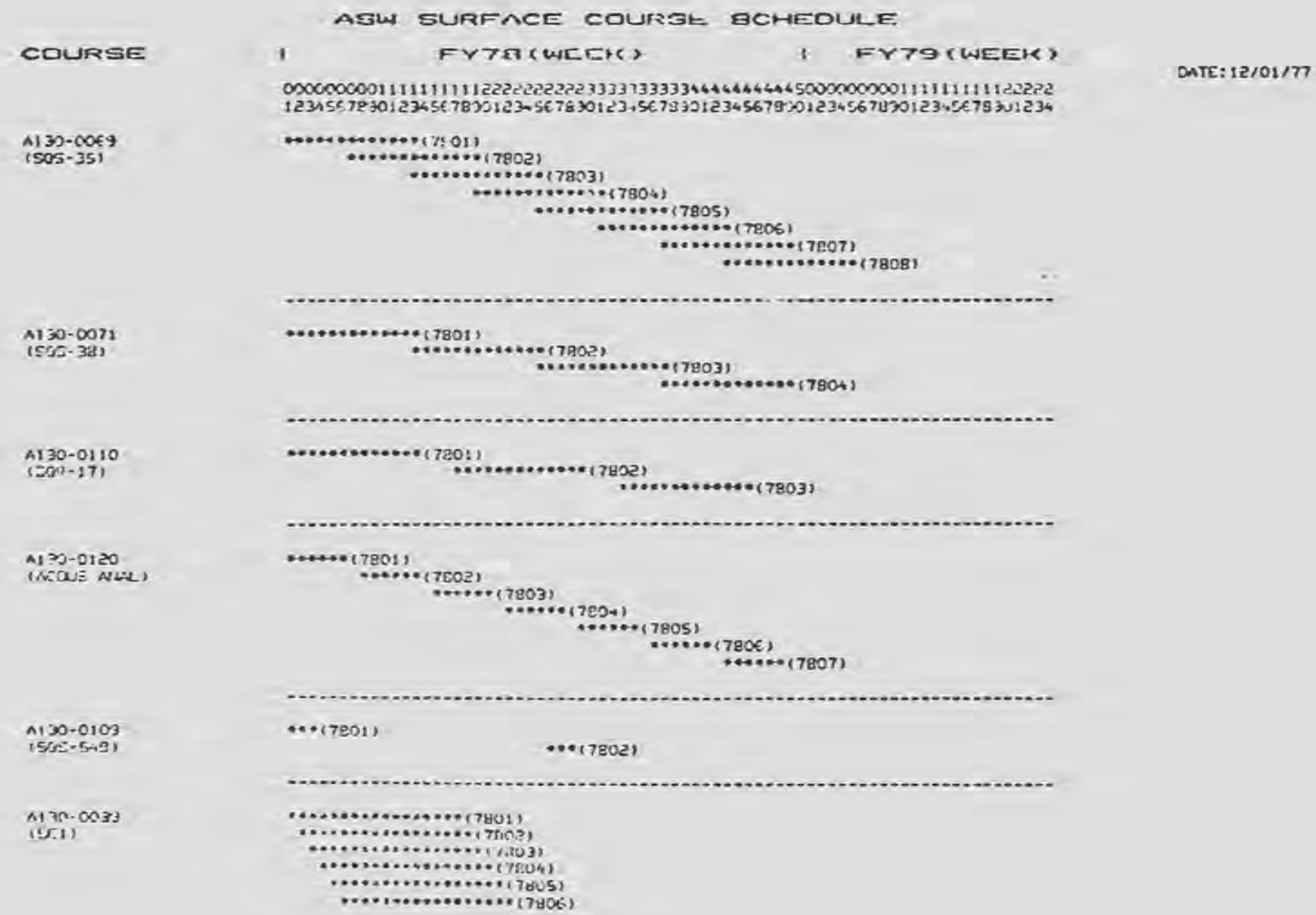

Figure 12. ASW Surface Course Schedule Plotted on a Week-by-Week Basis

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Conclusions based on the analysis of the present system of scheduling ASW courses and the feasibility of automating this system are summarized below:

1. The scheduling problem can be classified as a combinatorial problem involving limited resource allocation.

2. An optimal schedule is difficult to establish due to:

   . varying course lengths and start dates.

   . varying class sizes, student/instructor ratios, and contact hours.

   . course resource interactions and dependencies.

   . the multiple resources required for each course.

   . availability of resources.

   . delays in resource acquisitions.

   . factorial growth in problem complexity.

3. Conflicting scheduling objectives result in suboptimal schedules.

4. There is potential for significant savings resulting from the automation of scheduling in the form of:

   . a reduction in labor to produce a feasible schedule.

   . reduction in AOB levels by reducing the time awaiting instruction.

5. Significant benefits can be accrued in the standardization of the scheduling process. This results in a continuity of the scheduling process with minimal disruptions due to changes in school personnel.

6. Present scheduling necessitates the commitment of classrooms for each course across blocks of time. This results in uneven utilization of classrooms, making the justification for additional classrooms difficult.

RECOMMENDATIONS

An analysis of the documentation of the manual scheduling process and an evaluation of the automation of this process at the FLEASWTRACENPAC lead to several recommendations.

1. Conduct a verification/validation of the automated system. This requires a practical field test and evaluation with improvements/format modifications to be undertaken in cooperation with the FLEASWTRACENPAC.

2. Conduct a cost/benefit analysis of the automated system.

3. Assess the general applicability of the automated scheduling process to other training areas. Conduct a systematic examination of potential program use at the FLEASWTRACENLANT and CNTECHTRA for ASW training. The potential applicability to other specialized training areas should be examined with the other Training Program Coordinators (TPCs) at CNTECHTRA. This analysis should examine the time and effort expended in alternate methods; i.e., manual versus automated. Opportunity costs (i.e., the loss incurred by utilizing a resource in an alternative fashion) need to be considered. This analysis must be

undertaken prior to wholesale investment in automated scheduling of Navy specialized training.

4. Establish the criteria, objectives, and policies which determine the acceptability of schedules at various other activities.

APPENDIX A

PROGRAM LISTING

```
100 REM Program > NEW2                         Version 1.0  12-Aug-77
110 REM **  Abstract  ******************************************
120 REM **
130 REM **     THIS PROGRAM PRODUCES COURSE SCHEDULE WORK SHEETS
140 REM **     AND PLOT SCHEDULE CHART
150 REM **
160 REM **  Description of Variables :
170 REM **
180 REM **     C1$() = CDI
190 REM **     I1() = PLANNED INPUT
200 REM **     I2() = UNADJUSTED INSTRUCTOR
210 REM **     I3() = ADJUSTED INSTRUCTOR
220 REM **     L() = LABS
230 REM **     M1() = DN MPA
240 REM **     M2() = DN MPA(SUPPORT)
250 REM **     R() = CONTACT RATIO
260 REM **     S() = INTERNAL CONTACT HOUR
270 REM **     T$() = COURSE TITLE
280 REM **     W() = COURSE LENGTH
290 REM **
300 REM ****************************************************
310 REM
320 REM
330 DIM C1$(50),C2(50),C3(50),C4(50),I1(50),IO$10,Z$E4,A1$2,J1$2,A2$2
340 DIM I2(50),I3(50),C5(50),C6(50),R(7),H(7),S(50),T$(50),W(50),L(50),M1(50),M2(50)
350 REM
360 REM
370 INIT("*")Z$
380 Z5 = 0        :REM SCHEDULE FLAG
390 IO$=HEX(0400FFFF)
400 REM
410 REM
420 INPUT "ENTER TODAY'S DATE (MONTH,DAY,YR)=",Z1$,Z2$,Z3$
430 INPUT "ENTER FISCAL YR AND NO OF COURSE",A1$,N
440 CONVERT A1$TO A2
450 CONVERT A2+1TO A2$,(##)
460 SELECT PRINT 215(132)
470 REM ********************************************
480 REM ******    INPUT DATA                ***********
490 REM ********************************************
500 FOR J=1 TO N
510 READ C1$(J),T$(J),I1(J),C2(J),W(J),M1(J),M2(J),L(J)
520 READ R(1),H(1),R(2),H(2),R(3),H(3),R(4),H(4),R(5),H(5),R(6),H(6),R(7),H(7)
530 S(J)=0
540 FOR K=1 TO 7
550 IF H(K)=0 THEN 570
560 S(J)=S(J)+(C2(J)/R(K))*H(K)
570 NEXT K
580 X=I1(J)/C2(J)
590 C4(J)=INT(X)
600 IF X=C4(J) THEN 620
610 C4(J)=C4(J)+1
620 C5(J)=50/C4(J)
630 C6(J)=W(J)/C5(J)
640 I2(J)=(S(J)*1.10)/(C5(J)*25*.88)
650 I3(J)=INT(I2(J))
660 IF I3(J)=I2(J) THEN 680
670 I3(J)=I3(J)+1
680 NEXT J
690 REM ********************************************
```

```
700 REM ******   PRINT SCHEDULE WORK SHEETS   ************
710 REM ************************************************
720 REM  INPUT "DO YOU WANT SCHEDULE WORK SHEETS(Y/N)?",A3$
730 REM IF A3$="N" THEN 710
740 Z = 55
750 I8=0:I9=0:M2=0:M3=0
760 FOR J=1 TO N
770 IF Z<  55 THEN 850
780 PRINT HEX(0C0E);TAB(10);"ASW SUBSURFACE COURSE SCHEDULE WORK SHEET(FY";A1$;")"
790 PRINT "                                                                                                                   DATE:";
Z1$;"/";Z2$;"/";Z3$
800 PRINT "                                  SKED"
810 PRINT "                                  PLANNED   CLASS   SKED    CONV    C/C      UNADJ    ADJ    ON          SUPPORT         *
820 PRINT " CIN        TITLE                 INPUT     SIZE    CLASS   FREQ    CLASSES  INST     INST   MPA    REQUIRED   ON MPA   LABS   REMAR
KS"
830 PRINT " ---        -----                 -----     ----    -----   ----    -------  -----    ----   ---    --------   -- ---   ----  ------
-------"
840 PRINT
850 Z = 6
860 PRINTUSING 870,  C1$(J);T$(J);I1(J);C2(J);C4(J);C5(J);C6(J);I2(J);I3(J);M1(J);M2(J);L(J)
870        Z#########  ##########     #####     ####    ####   ##.##    ##.##   ##.##    ###    ##                    ###     ###
880 PRINT "-----------------------------------------------------------------------------------------------------------------------------------
-----"
890 Z = Z+2
900 I8=I8+I1(J):I9=I9+I3(J):M2=M2+M1(J):M3=M3+M2(J)
910 NEXT J
920 PRINT :PRINTUSING 930,I8,I9,M2,M3
930 Z        GRAND TOTALS      #####                                                      ###     ###                  ###
940 REM
950 REM ************************************************
960 REM ******   PLOT SCHEDULE                ************
970 REM ************************************************
980 REM INPUT "DO YOU WANT SCHEDULE CHART(Y/N)?",A3$
990 REM IF A3$="N" THEN 1420
1000 Z = 50
1010 FOR J=1 TO N
1020 S2=INT(C5(J))
1030 IF C5(J)=S2 THEN 1070
1040 C5(J)=S2+1 :S3=C4(J)*C5(J) :IF S3<=50 THEN 1070
1050 IF S2<>0 THEN 1060:C5(J)=1:GOTO 1070
1060 C5(J)=S2
1070 S=0
1080 FOR J1=1 TO C4(J)
1090 IF  Z <  50 THEN 1130
1100 PRINT HEX(0C0E);TAB(15);"ASW SUBSURFACE COURSE SCHEDULE"
1110 PRINT
1120 PRINT HEX(0E);"COURSE";TAB(12);HEX(7C);TAB(20);"FY";A1$;"(WEEK)";TAB(37);HEX(7C);TAB(40);"FY";A2$;"(WEEK)"
1130 PRINT "                                                                                                                  DATE:";Z1
$;"/";Z2$;"/";Z3$
1140 PRINT TAB(25);"000000000111111111122222222223333333333444444444450000000001111111111222222"
1150 PRINT TAB(25);"123456789012345678901234567890123456789012345678901234567890123456789012345678901234"
1160 PRINT
1170 Z = 10
1180 IF J1>2 THEN 1190:Z5=1:PRINT C1$(J);:GOTO 1220
1190 IF Z5<>1 THEN 1200:Z5=0:PRINT "(";T$(J);")";:GOTO 1220
1200 IF J1<>1 THEN 1210:PRINT C1$(J);:GOTO 1220
1210 IF J1<>2 THEN 1220:PRINT "(";T$(J);")";
1220 CONVERT J1 TO J1$,(##):   PRINT TAB(S+25);STR(Z$,1,W(J1));"(";A1$;J1$;")"
1230 S=S+C5(J)
1240 Z=Z+1
```

```
1250 NEXT J1
1260 IF J1<>1 THEN 1270:PRINT "(";T$(J);")"
1270 IF Z5<>1 THEN 1290:Z5=0:PRINT "(";T$(J);")"
1280 PRINT
1290 PRINT TAB(25);"--------------------------------------------------------------------------------"
1300 PRINT
1310 Z=Z+2
1320 NEXT J
1330 REM
1340 REM ***************************************
1350 REM *****  SUBSURFACE COURSE DATA  *********
1360 REM ***************************************
1370 DATA "A130-0023","STSA COMET",660,20,6,31,0,0
1380 DATA 25,184,8,26,5,87,0,0,0,0,0,0,0,0
1390 DATA "A130-0188","UA-1283",334,10,4,0,0,1
1400 DATA 25,13,6,17,4,87,0,0,0,0,0,0,0,0
1410 DATA "A130-0183","EMO-2 OP",128,8,4,0,0,0
1420 DATA 8,16,4,101,0,0,0,0,0,0,0,0,0,0
1430 DATA "A130-0190","BMO-5 OP",171,9,5,3,0,1
1440 DATA 25,30,4,120,0,0,0,0,0,0,0,0,0,0
1450 DATA "A130-0027","GSSM(EOR-2)",130,10,26,9,0,4
1460 DATA 25,71,6,104,0,0,0,0,0,0,0,0,0,0
1470 DATA "A130-0172","AUX EQUIP",156,10,12,4,0,2
1480 DATA 25,160,6,180,0,0,0,0,0,0,0,0,0,0
1490 DATA "A130-0169","BOM-17",40,8,4,2,0,1
1500 DATA 25,51,4,65,0,0,0,0,0,0,0,0,0,0
1510 DATA "A130-0111","BQS-15",40,8,3,2,0,1
1520 DATA 25,45,4,45,0,0,0,0,0,0,0,0,0,0
1530 DATA "A130-0036","BQS-8",48,8,3,0,0,1
1540 DATA 25,46,4,36,0,0,0,0,0,0,0,0,0,0
1550 DATA "A130-0168","BLR-14",50,10,2,2,0,1
1560 DATA 25,33,6,24,0,0,0,0,0,0,0,0,0,0
1570 DATA "A130-0026","BQS-4/4A",16,8,18,2,0,1
1580 DATA 25,319,4,219,0,0,0,0,0,0,0,0,0,0
1590 DATA "A130-0065","BQQ-2 CMB",53,10,17,10,0,1
1600 DATA 12,139,6,311,0,0,0,0,0,0,0,0,0,0
1610 REM
1620 REM SURFACE COURSE DATA
1630 REM
1640 DATA "A130-0069","SQS-35",64,8,13,1,1,1
1650 DATA 25,179,5,60,9,148,0,0,0,0,0,0,0,0
1660 DATA "A130-0071","SQS-38",32,8,13,8,0,1
1670 DATA 25,207,5,72,9,107,0,0,0,0,0,0,0,0
1680 DATA "A130-0110","SQR-17",20,8,13,5,2,2
1690 DATA 25,154,5,153,5,46,0,0,0,0,0,0,0,0
1700 DATA "A130-0120","ACOUS ANAL",70,10,6,3,0,0
1710 DATA 25,62,6,123,6,19,0,0,0,0,0,0,0,0
1720 DATA "A130-0103","[illegible]",12,6,3,1,0,0
1730 DATA 25,40,3,7,3,42,0,0,0,0,0,0,0,0
1740 DATA "A130-0035","SEI",920,21,17,42,0,0
1750 DATA 25,356,10,17,7,80,5,49,0,0,0,0,0,0
1760 DATA "A130-0037","SIG-A",1170,20,6,23,1,1
1770 DATA 25,105,12,6,8,28,6,38,0,0,0,0,0,0
1780 DATA "A130-0056","MK-111",30,10,18,4,2,1
1790 DATA 25,143,4,204,3,105,0,0,0,0,0,0,0,0
1800 DATA "A130-0057","MK 114",110,10,12,6,4,4
1810 DATA 25,166,4,184,0,0,0,0,0,0,0,0,0,0
1820 DATA "A130-0060","MK-60",16,3,2,1,0,1
1830 DATA 25,27,4,25,0,0,0,0,0,0,0,0,0,0
1840 DATA "A130-0049","SQD-G",78,12,10,7,4,1
```

```
1850 DATA 25,142,8,102,4,102,0,0,0,0,0,0,0.0
1860 DATA "A130-0053","LORA",32,8,2,0,0,0
1870 DATA 25,32,6,10,4,6,4,8,0,0,0,0,0,0
1880 DATA "A130-0045","PAIR",16,8,13,2,4,2
1890 DATA 25,241,4,11,3,15,0,0,0,0,0,0,0,0
1900 DATA "A130-0044","26AAR",20,10,25,4,3,1
1910 DATA 25,335,10,3,5,275,5,12,3,30,3,29,3,27
1920 DATA "A130-0046","260X",20,10,20,3,3,1
1930 DATA 25,167,5,245,5,12,2,33,3,54,3,89,0,0
1940 DATA "A130-0047","26CX",80,10,26,12,6,2
1950 DATA 25,374,5,3,3,79,5,255,3,87,0,0,0,0
1960 DATA "A130-0102","53",80,10,30,15,5,2
1970 DATA 25,441,5,320,3,139,0,0,0,0,0,0,0,0
1980 DATA "A130-0025","35/38 OPS",120,10,4,4,4,1
1990 DATA 25,23,4,32,0,0,0,0,0,0,0,0,0,0
2000 DATA "A130-0097","PAIR OPS",80,9,8,5,4,1
2010 DATA 25,111,4,104,0,0,0,0,0,0,0,0,0,0
2020 DATA "A130-0103","53 OPS",210,12,4,4,5,1
2030 DATA 25,50,6,56,0,0,0,0,0,0,0,0,0,0
2040 END
```

APPENDIX B

PROGRAM OUTPUTS

ASW SURFACE COURSE SCHEDULE WORK SHEET (FY78)

DATE: 12/01/77

CIN	TITLE	SKED PLANNED INPUT	CLASS SIZE	SKED CLASS	CONV FREQ	C/C CLASSES	UNADJ INST	ADJ INST	ON MPA	SUPPORT REQUIRED	SUPPORT ON MPA	LABS	REMARKS
A130-0069	SOS-35	64	8	8	6.25	2.08	2.27	3	1		1	1	
A130-5071	SOS-38	32	8	4	12.50	1.04	1.03	2	8		0	1	
A130-0110	SGR-17	20	8	3	16.66	0.77	1.00	2	5		2	2	
A130-0120	ACOUS ANAL	70	10	7	7.14	0.84	1.83	2	3		0	0	
A130-0103	SOS-54B	12	6	2	25.00	0.12	0.21	1	1		0	0	
A130-0033	SCI	980	21	47	1.06	15.98	36.68	37	42		0	0	
A130-0037	STG-A	1170	20	53	0.84	7.08	17.14	18	23		1	1	
A130-0056	MK-111	30	10	3	16.66	1.08	3.35	4	4		2	1	
A130-0057	MK-114	110	10	11	4.54	2.64	5.73	6	6		4	4	
A130-0060	MK-60	16	3	6	8.33	0.24	0.13	1	1		0	1	
A130-0049	230-G	78	12	7	7.14	1.68	4.06	5	7		4	1	
A130-0050	LORA	32	8	4	12.50	0.16	0.19	1	0		0	0	
A130-0036	PAIR	16	8	2	25.00	0.52	0.27	1	2		4	2	
A130-0044	26AXR	20	10	2	25.00	1.04	2.45	3	4		3	1	
A130-0046	26UX	20	10	2	25.00	0.80	2.33	3	3		3	1	
A130-0047	26CX	80	10	8	6.25	4.16	9.75	10	12		6	2	
A130-0102	53	80	10	8	6.25	4.80	10.23	11	15		8	2	
A130-0025	35/38 OPS	120	10	12	4.16	0.95	1.10	2	4		4	1	
A130-0037	PAIR OPS	80	9	9	5.55	1.44	2.46	3	5		4	1	
A130-0103	53 OPS	210	12	18	2.77	1.44	2.80	3	4		5	1	
	GRAND TOTALS	3240						118	150		51		

ASW SURFACE COURSE SCHEDULE

```
COURSE          :        FY78(WEEK)          :    FY79(WEEK)                  DATE:12/01/77
                000000000111111111122222222223333333333444444444455000000000111111111122222
                123456789012345678901234567890123456789012345678901201234567890123456789012345

A130-0069       **************(7801)
(SOS-35)              **************(7802)
                            **************(7803)
                                  **************(7804)
                                        **************(7805)
                                              **************(7806)
                                                    **************(7807)
                                                          **************(7808)

                ---------------------------------------------------------------------------

A130-0071       **************(7801)
(SOS-38)                    **************(7802)
                                        **************(7803)
                                                    **************(7804)

                ---------------------------------------------------------------------------

A130-0110       **************(7801)
(SQR-17)                **************(7802)
                                **************(7803)

                ---------------------------------------------------------------------------

A130-0120       ******(7801)
(ACOUS ANAL)           ******(7802)
                              ******(7803)
                                     ******(7804)
                                            ******(7805)
                                                   ******(7806)
                                                          ******(7807)

                ---------------------------------------------------------------------------

A130-0103       ***(7801)
(SQS-54B)                         ***(7802)

                ---------------------------------------------------------------------------

A130-0039       *****************(7801)
(SET)            *****************(7802)
                  *****************(7803)
                   *****************(7804)
                    *****************(7805)
                     *****************(7806)
```

ASW SURFACE COURSE SCHEDULE

```
COURSE          :        FY78(WEEK)          :   FY79(WEEK)                DATE:12/01/77

                000000000111111111122222222223333333333444444444445000000000011111111112222
                123456789012345678901234567890123456789012345678901234567890123456789012345

A130-0039             *****************(7807)
(SE1)                  *****************(7808)
                        *****************(7809)
                         *****************(7810)
                          *****************(7811)
                           *****************(7812)
                            *****************(7813)
                             *****************(7814)
                              *****************(7815)
                               *****************(7816)
                                *****************(7817)
                                 *****************(7818)
                                  *****************(7819)
                                   *****************(7820)
                                    *****************(7821)
                                     *****************(7822)
                                      *****************(7823)
                                       *****************(7824)
                                        *****************(7825)
                                         *****************(7826)
                                          *****************(7827)
                                           *****************(7828)
                                            *****************(7829)
                                             *****************(7830)
                                              *****************(7831)
                                               *****************(7832)
                                                *****************(7833)
                                                 *****************(7834)
                                                  *****************(7835)
                                                   *****************(7836)
                                                    *****************(7837)
                                                     *****************(7838)
                                                      *****************(7839)
                                                       *****************(7840)
                                                        *****************(7841)
                                                         *****************(7842)
                                                          *****************(7843)
                                                           *****************(7844)
                                                            *****************(7845)
                                                             *****************(7846)
```

```
                     ASW SURFACE COURSE SCHEDULE
COURSE       !         FY78(WEEK)          !    FY79(WEEK)                DATE:12/01/77
             00000000011111111112222222222333333333344444444445000000000111111111122222
             12345678901234567890123456789012345678901234567890123456789012345678901234
A130-0033                                              *****************(7847)
(SEI)

             --------------------------------------------------------------------------

A130-0037    ******(7801)
(STG-A)       ******(7802)
               ******(7803)
                ******(7804)
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                              ASW SURFACE COURSE SCHEDULE
COURSE                   :           FY78(WEEK)                   :    FY79(WEEK)              DATE:12/01/77

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                         12345678901234567890123456789012345678901234567890123456789012345678901234

A130-0037                                                     ******(7838)
(STG-A)                                                        ******(7839)
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A130-0056                ******************(7801)
(MK-111)                                 ******************(7802)
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A130-0057                ************(7801)
(MK-114)                     ************(7802)
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                   ASW SURFACE COURSE SCHEDULE
COURSE        :         FY78(WEEK)                 :    FY79(WEEK)                 DATE:12/01/77
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A130-0050       **(7801)
([illegible])        **(7802)
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A130-0049       ************(7801)
([illegible])       ************(7802)
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A130-0052       **(7801)
([illegible])            **(7802)
                               **(7803)
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A130-0038       *************(7801)
(PAIR)                         *************(7802)

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A130-0044       **************************(7801)
([illegible])                  **************************(7802)

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[illegible]     *********************(7801)
([illegible])                  *********************(7802)

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A130-0047       **************************(7801)
([illegible])       **************************(7802)
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                                ASW SURFACE COURSE SCHEDULE

COURSE                    I          FY78(WEEK)              I      FY79(WEEK)                  DATE:12/01/77

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A130-0037                                               **************************(7806)
(2601)                                                        **************************(7807)
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A130-0102                 ******************************(7801)
(53)                            ******************************(7802)
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A130-0025                 ****(7801)
(35/38 OPS)                   ****(7802)
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A130-0037                 ********(7801)
(PAIR UPS)                     ********(7802)
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ASW SURFACE COURSE SCHEDULE

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COURSE        :        FY78 (WEEKS)          :     FY79 (WEEKS)                DATE:12/01/77

                000000000111111111122 [illegible]
                123456789012345678901 [illegible]

A130-0103       ****(7801)
(53 UPS)          ****(7802)
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ASW SUBSURFACE COURSE SCHEDULE WORK SHEET (FY78)

DATE: 12/01/77

CIN	TITLE	SKED PLANNED INPUT	CLASS SIZE	SKED CLASS	CONV FREQ	C/C CLASSES	UNADJ INST	ADJ INST	ON MPA	SUPPORT REQUIRED	ON MPA	LABS	REMARKS
A130-0029	STSA CORE	660	20	33	1.51	3.95	18.48	19	31		0	0	
A130-0128	OA-1283	334	10	34	1.47	2.72	8.53	9	0		0	1	
A130-0183	BQQ-2 OP	128	8	16	3.12	1.28	3.48	4	0		0	0	
A130-0190	BQQ-5 OP	171	9	19	2.63	1.30	5.33	6	9		0	1	
A130-0027	CSSM(BQR-2	130	10	13	3.84	6.76	2.62	3	9		0	4	
A130-0172	AUX EQUIP	156	10	16	3.12	3.84	5.95	6	4		0	2	
A130-0169	BQN-17	40	8	5	10.00	0.40	0.68	1	2		0	1	
A130-0111	BQS-15	40	8	5	10.00	0.30	0.52	1	2		0	1	
A130-0036	BQS-8	48	8	6	8.33	0.36	0.52	1	0		0	1	
A130-0168	BLR-14	50	10	5	10.00	0.20	0.26	1	2		0	1	
A130-0026	BQC-4/4A	16	8	2	25.00	0.72	1.08	2	2		0	1	
A130-0065	BQQ-2 CMB	53	10	6	8.33	2.04	4.10	5	10		0	1	
A130-0069	SQS-35	64	8	8	6.25	2.08	2.27	3	1		1	1	
A130-0071	SQS-32	32	8	4	12.50	1.04	1.09	2	8		0	1	
A130-0110	SQR-17	20	8	3	16.66	0.77	1.09	2	5		2	2	
A130-0120	ACOUS ANAL	70	10	7	7.14	0.84	1.83	2	3		0	0	
A130-0103	SQS-54B	12	6	2	25.00	0.12	0.21	1	1		0	0	
A130-0033	SEI	980	21	47	1.06	15.38	36.68	37	42		0	0	
A130-0037	STC-A	1170	20	59	0.84	7.08	17.14	18	23		1	1	
A130-0056	MK-111	30	10	3	16.66	1.09	3.35	4	4		2	1	
	GRAND TOTALS	4204						127	158		6		

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                          ASW SUBSURFACE COURSE SCHEDULE
COURSE              :           FY78(WEEK)            :   FY79(WEEK)         DATE:12/01/77
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A130-0029           ******(7801)
(STSA CORE)          ******(7802)
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A130-01[illegible]         ****(7801)
([illegible])               ****([illegible])
                      ****([illegible])
                       ****(7804)
                        ****([illegible])
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ASW SUBSURFACE COURSE SCHEDULE

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COURSE          !        FY78(WEEK)          !    FY79(WEEK)                DATE: 12/01/77

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A120-0188            ****(7806)
(OA-1223)             ****(7807)
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A130-0187       ****(7801)
(B03-2 OP)         ****(7802)
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ASW SUBSURFACE COURSE SCHEDULE

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COURSE        :          FY78(WEEK)                  :       FY79(WEEK)               DATE:12/01/77
                000000000111111111122222222223333333333444444444455000000000111111111122222
                123456789012345678901234567890123456789012345678901234567890123456789012345
A130-0183                          ****(7810)
(BQQ-2 OP)                            ****(7811)
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                                                     ****(7816)
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A130-0190      *****(7801)
(BQQ-5 OP)       *****(7802)
                   *****(7803)
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A130-0027      ***************************(7801)
(GSSM(BQR-2))     ***************************(7802)
                     ***************************(7803)
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                                          ***************************(7810)
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                         ASW  SUBSURFACE  COURSE  SCHEDULE
COURSE            !           FY78 (WEEK)              !    FY79 (WEEK)              DATE:12/01/77
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A130-0027                                       ***************************(7811)
(GSSM(BQR-21))                                     ***************************(7812)
                                                      ***************************(7813)
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A130-0172         ************(7801)
(AUX EQUIP)          ************(7802)
                        ************(7803)
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                                                            ************(7815)
                                                               ************(7816)
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A130-0169         ****(7801)
(BQN-17)                    ****(7802)
                                      ****(7803)
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                                                          ****(7805)
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A130-0111         ***(7801)
(BQS-15)                    ***(7802)
                                      ***(7803)
                                                ***(7804)
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A130-0035         ***(7801)
(BQS-8)                   ***(7802)
                                  ***(7803)
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ASW SUBSURFACE COURSE SCHEDULE

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COURSE          :          FY78(WEEK)              :     FY79(WEEK)            DATE:12/01/77
                000000000111111111122222222223333333333444444444450000000000111111111122222
                123456789012345678901234567890123456789012345678901234567890123456789012345

A130-[illegible]                         ***(7801)
([illegible])                                    ***(7805)
                                                         ***(7806)
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A170-01[illegible]  **(7801)
(PLP-1[illegible])            **(7802)
                                    **(7803)
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                                                        **(7805)
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A1[illegible]-[illegible]  ******************(7801)
([illegible])                              ******************(7802)
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A1[illegible]   ******************(7801)
([illegible] CMB)         ******************(7802)
                                 ******************(7803)
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[illegible]     ***************(7801)
([illegible])         ***************(7802)
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                                   ***************(7804)
                                         ***************(7805)
                                               ***************(7806)
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[illegible]     ***************(7801)
([illegible])               ***************(7802)
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ASW SUBSURFACE COURSE SCHEDULE

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COURSE          1          FY78(WEEK)              :    FY79(WEEK)            DATE:12/01/77

                000000000111111111122222222223333333333444444444450000000001111111111222222
                123456789012345678901234567890123456789012345678901234567890123456789012345

A130-0110       *************(7801)
(SQR-17)                        *************(7802)
                                                *************(7803)

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A130-0120       ******(7801)
(ACOUS ANAL)           ******(7802)
                              ******(7803)
                                     ******(7804)
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                                                   ******(7806)
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A130-0103       ***(7801)
(SOS-548)                         ***(7802)

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A130-0033       *****************(7801)
(SEI)            *****************(7802)
                  *****************(7803)
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                              ASW  SUBSURFACE  COURSE  SCHEDULE
COURSE          :          FY78(WEEK)                :    FY79(WEEK)            DATE:12/01/77

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A130-0039                             ******************(7823)
(SEI)                                  ******************(7824)
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A130-0037       ******(7801)
(STG-A)          ******(7802)
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NEW [illegible] COURSE SCHEDULE

COURSE# | | DATE: 12/01/77

ASW SUBSURFACE COURSE SCHEDULE

DATE: 12/01/77

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COURSE      !              FY78 (WEEK)                     !   FY79 (WEEK)
            00000000011111111112222222222333333333344444444445000000000111111111122222
            12345678901234567890123456789012345678901234567890123456789012345678901234

A130-0037                                                   ******(7854)
(STG-A)                                                      ******(7855)
                                                              ******(7856)
                                                               ******(7857)
                                                                ******(7858)
                                                                 ******(7859)
            --------------------------------------------------------------------------
A130-0056   ******************(7801)
(MK-111)                    ******************(7802)
                                            ******************(7803)
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