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NASA TECHNICAL MEMORANDUM

NASA TM X-64979

(NASA-TM-X-64979) SPACELAB MISSION DEPENDENT TRAINING PARAMETRIC RESOURCE REQUIREMENTS STUDY (NASA) 85 p HC $5.00 CSCL 05I

N76-16125

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G3/13 13597

SPACELAB MISSION DEPENDENT TRAINING PARAMETRIC RESOURCE REQUIREMENTS STUDY

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January 1976

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
NASA TM X-64979		

4. TITLE AND SUBTITLE
Spacelab Mission Dependent Training Parametric Resource Requirements Study

5. REPORT DATE
January 1976

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S) Dester H. Ogden*, Harry Watter, Jackie Steadman, and Lora Conrad**

8. PERFORMING ORGANIZATION REPORT #

9. PERFORMING ORGANIZATION NAME AND ADDRESS
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

10. WORK UNIT NO.

11. CONTRACT OR GRANT NO.

13. TYPE OF REPORT & PERIOD COVERED
Technical Memorandum

12. SPONSORING AGENCY NAME AND ADDRESS
National Aeronautics and Space Administration
Washington, D.C. 20546

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Prepared by Systems Analysis and Integration Laboratory, Science and Engineering.
*M&S Computing Inc., Huntsville, Alabama.
**PRC Systems Services Co., Huntsville, Alabama.

16. ABSTRACT

This report addresses the unique training problems of Spacelab mission dependent training. Training flows were developed for typical missions, resource relationships analyzed, and scheduling optimization algorithms defined. Parametric analyses were performed to study the effect of potential changes in mission model, mission complexity and training time required on the resource quantities required to support training of payload or mission specialists. Typical results of these analyses are presented both in graphic and tabular form.

17. KEY WORDS

18. DISTRIBUTION STATEMENT
Unclassified — Unlimited

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	83	NTIS

MSFC - Form 3292 (Rev December 1972)

For sale by National Technical Information Service, Springfield, Virginia 22151

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TECHNICAL MEMORANDUM X-64979

1.0 SUMMARY

1.1 SCOPE

This report contains results from a study of training requirements for Spacelab mission dependent training. A basic training element flow is defined for studying various training scheduling concepts. Training resources and their interrelationships are identified. Training event scheduling options and constraints are assessed to define scheduling algorithms for maximizing training thru-put with fixed resources. A schedule and resource analysis computer program was used to simulate various scheduling options and conduct parametric studies. From these parametric studies preliminary training resource requirements were identified and critical parameters defined.

This study is a continuation of the effort documented in References 1 and 2 and is exclusively associated with mission specific training. Although this study addresses only Payload Specialist training specifically, the techniques apply equally well to Mission Specialist training. Training scheduling concepts, analysis techniques and data which will be useful in the further development of an optimum Spacelab training program are presented.

1.2 SIGNIFICANT RESULTS

Noteworthy results of this study include training concept assessment, resource level simulation and recommendation of minimum resources for Payload Specialist training to support the Yardley "572" Mission Model. Blocks flows of training activity are defined based upon projected Payload Specialists' skill, knowledge and training requirements. Training resources such as classroom, part task area (laboratory), control room and maintenance and storage area are analyzed to determine the training requirements. Spacelab resources [such as racks, panels, command data management (CDMS) consoles and simulation computer access] required for training are assessed. A baseline resource requirement is established for the Yardley "572" Mission Model covering the years 1980 through 1991.

Sequence optimization of activities within individual missions and among missions is investigated and implemented. In addition, parametric studies of the effect of mission model complexity, efficiency improvement, and training cycle length on resource requirements was conducted.

1.3 CONCLUSIONS

Study conclusions are documented in detail in Section 4 of this report. Key points are summarized in the following paragraphs.

Parameters that can have a significant influence upon the training thru-put and effectiveness include the part task area preparation, access to simulation host computer and CDMS computers and the availability of high cost training items such as Payload Specialist Station, CDMS consoles and airlock.

Training activities should be sequenced so that the required time that a part task is set up for a given mission is minimized. Training cycle start date for the individual missions should be sequenced to minimize the number of training cycles overlapped and the quantity of critical resources required.

Analysis of results indicated that resource utilization peaks and spikes adding up to 5% of the total training time are insignificant. That is, plots of resource quantity required 95% of the time are relatively smooth. Training start optimization can be used to significantly reduce these peaks in resource requirements.

Using the Yardley "572" Mission Model, resource requirements are higher in early years (1983 and 1984) than the average launches per year would indicate. These higher requirements result from an above average number of complex missions being flown.

Quantity of resources required to support mission dependent training are highly sensitive to variations in mission frequency and mission complexity. They are, however, relatively insensitive to modest variations in the previous experience of personnel to be trained and, for most resources, to minor mis-estimates in training cycle time.

2.0 INTRODUCTION

The mission dependent training of Payload Specialists presents a training problem new to the space program. Concepts appropriate to this task have been developed and are documented in References 1 and 2. This report presents a study of the resource requirements for potential implementation of the modular or part task training approach, investigated in Reference 1, to Spacelab Payload Specialist training. Schedule optimization techniques were developed both for application to individual mission and for multi-mission training requirements. Operations analysis techniques for data definition were developed to allow parametric analysis of the effect of potential changes in mission model, mission complexity, and training time estimates.

This report documents the key engineering analyses performed in defining the training activity flows, the resource interrelationships, and the optimization techniques. In addition all case studies performed including reference cases using the Yardley "572" Mission Model and parametric studies are discussed and key results documented.

3.0 ANALYSIS DESCRIPTION

3.1 OBJECTIVE

The objective of this study was to develop a Payload Specialist training model for mission dependent training and to apply the model to:

- Optimize training schedules for the mission dependent training of Payload Specialists.
- Determine minimum resource quantities required for the mission dependent training facility, assuming the Yardley "572" Mission Model.
- Perform impact analysis of changes in key parameters such as the mission model, training schedule, or activity time requirements.
- Assess compatibility of training requirements with interfaces to other areas.

3.2 APPROACH

The analysis approach used in accomplishing the study objectives is illustrated in Figure 1. Background documentation was reviewed, crew requirements were assessed and the training functional flow was defined. From this base, training resources were defined and scheduling options identified and analyzed. A schedule and resource analysis computer program was applied to the simulation of baseline data and for the conducting of parametric studies. The results were analyzed and new concepts investigated where applicable.

The analysis conducted and the results achieved at each of the steps in the sequence of activities given in Figure 1 is discussed in detail in the following subsections.

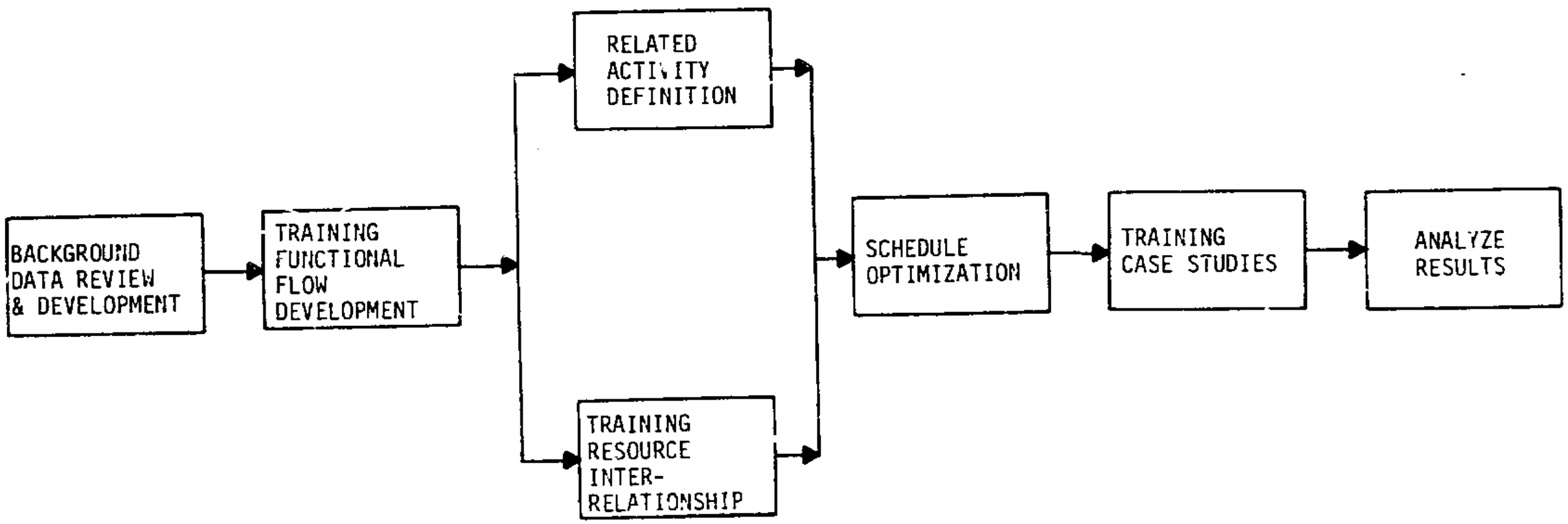

FIGURE 1. SEQUENCE OF STUDY ACTIVITIES

3.3 TRAINING FUNCTIONAL FLOW DEVELOPMENT

To support definition of a set of traceable training requirements for a mission and provide a basis for requirements analysis, a generic functional flow of training activities was needed. Such a baseline flow forms a point of reference against which changes or "deltas" are formulated and assessed.

The basic training flow elements were defined as shown in Figure 2 for Payload Specialist mission dependent training. The pretraining activity is assumed to include mission independent training at JSC, consultant work and briefings at user facility, and participation in mission planning. The pretraining activity represents external scheduling constraints which must continuously be assessed as the program evolves.

Training facility preparation is accomplished to set up the part task area. The first training activity, orientation, includes facility orientation presentation, soft mockup review, and hardware experiment familiarization. Experiment-specific training, consisting of classroom and part task training, is followed by training verification, retraining (as required) and integrated mission simulation. Premission/post training tasks, including participation in Levels III, II and I integration, represent external scheduling constraints.

From these basic building blocks, a general flow chart of the Spacelab Payload Specialist movement through the training network was developed as shown in Figure 3. The nominal location of training is illustrated by the left hand index and vertical placement of blocks. This functional flow diagram structures the training for systematic analysis yet is flexible to allow efficient training of unique missions. Each of the four missions to be simulated was modeled in this form as shown in Appendix A, Figures A-1 through A-4.

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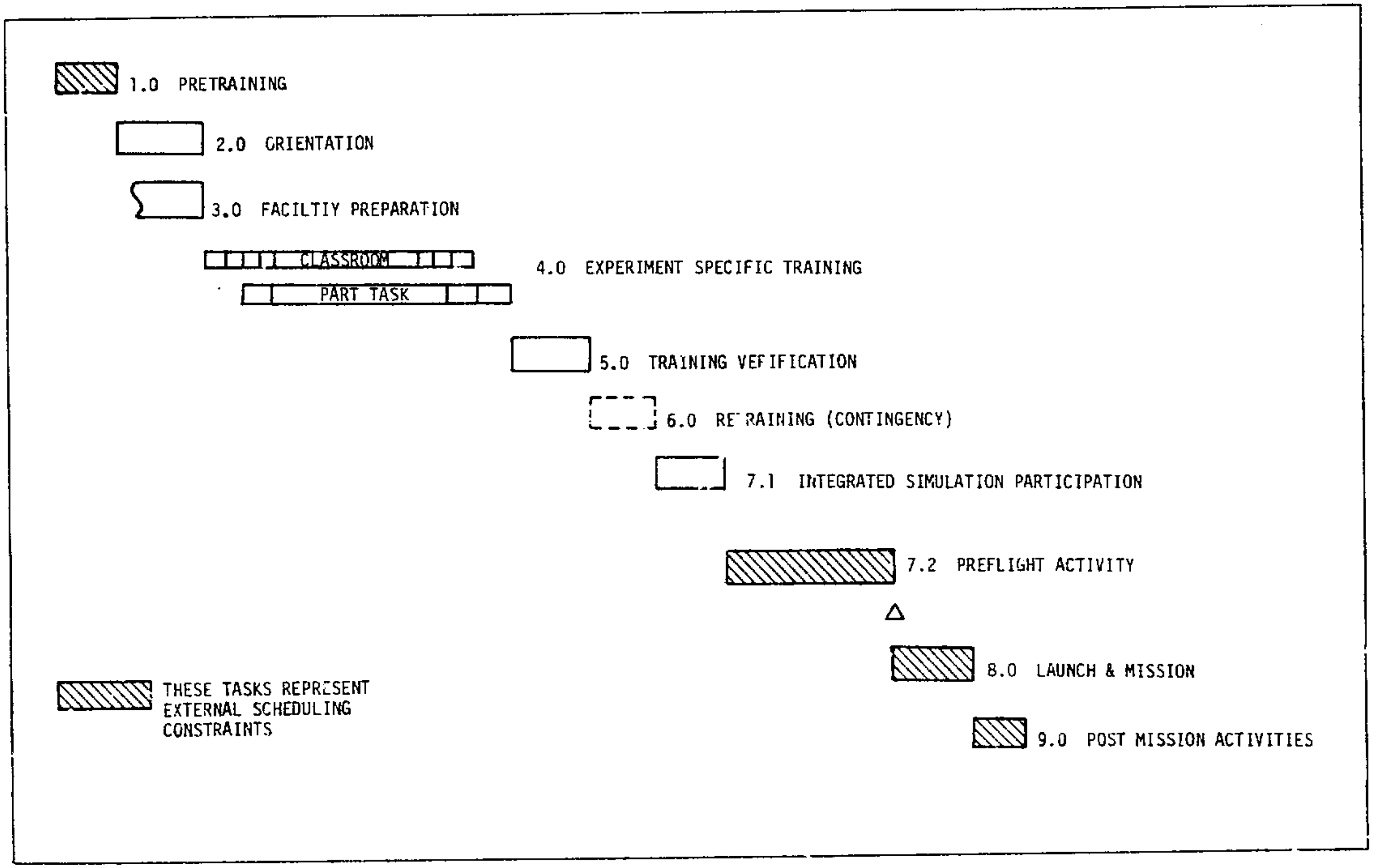

FIGURE 2. BASIC TRAINING FLOW ELEMENTS

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BASIC MSFC TRAINING FLOW FOR SPACELAB PAYLOAD SPECIALIST

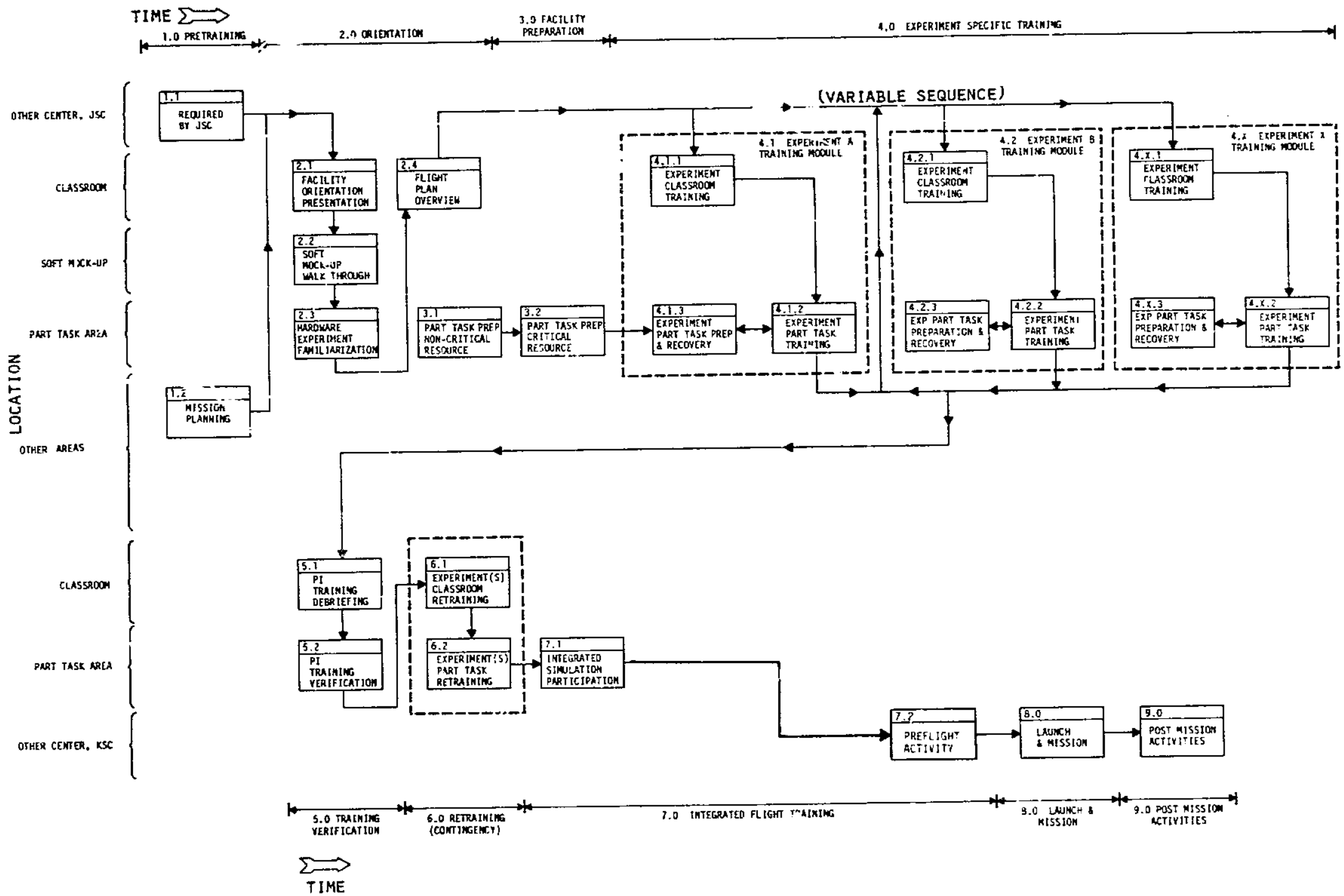

FIGURE 3. BASIC MISSION DEPENDENT TRAINING FLOW

3.4 RELATED ACTIVITY DEFINITION

For each activity defined in the training functional flow of Figure 3, sufficient understanding and information is needed so as to define the time, scheduling constraints, resource requirements and available options for that activity. Previous analysis work, References 1 and 2, had generated data such as time and resources for a number of the training activities. However, those activities related to the actual training had not been previously considered. These activities, facility preparation and prelaunch activity, were analyzed in depth for this study.

3.4.1 Facility Preparation

3.4.1.1 Definition

Facility preparation or part task preparation is the process of obtaining, configuring, installing, checking out and verifying Spacelab trainers and other part task area equipment for Payload Specialist training.

The objective of part task preparation is to have the necessary part task trainers and instructional equipment ready for operation at the proper time. The preparation process must be accomplished with minimum interference with training operations in progress. The setting up of training hardware and software should be designed and accomplished such that critical training resources "tie-up" is minimized.

Facility preparation activity is scheduled so that completion is just prior to the start of the first part task training within a given mission training cycle.

3.4.1.2 Requirements

The operational and resource requirements of facility preparation were analyzed to support activities 3.1, 3.2, and 4.x.3 in the training flow of Figure 3.

It was assumed that facility preparation is accomplished by dedicated training facility personnel. It was also assumed that two shifts a day were used for this activity. Facility disassembly after a training cycle was assumed to take place during one third shift period. Hardware for moving training equipment from storage to the adjacent part task area includes moving equipment and fixtures similar to that used in Spacelab ground processing. Special handling fixtures specifically tailored to the part task preparation processes might be used to make the operation more efficient.

Figures 4 through 6 are block diagrams of training facility preparation work flow for the three types of Spacelab configurations as represented by Mission 10 - pallet only flight; Mission 14 - lab only flight; and Missions 11 and 19 - lab and pallet flights. Assembly and checkout of experiments, simulators with racks and other support equipment will involve processing similar in many respects to flight hardware ground operations processing. The analysis of the part task preparation requirements, as shown in the figures, used the detailed definition sheets for Level III integration, Reference 12, as a starting point.

Analysis results indicate that part task preparation procedure and task sequence have a significant effect upon training cycle thru-put. Special attention should be given to designing the training facility to allow flexibility and efficiency in preparation of the part task area.

3.4.2 Prelaunch Activity

The prelaunch activity period, for this study, is defined as that period from completion of integrated mission simulation to orbiter launch. During this prelaunch activity period the crew participation in Spacelab integration, Levels III, II and I will be relatively fixed with respect to the launch. Also, this period provides time for any additional retraining of Payload Specialists required in the event of a last minute change in the mission plan. The period must be long enough to provide for scheduled crew activities and contingencies yet must not be long enough to reduce training effectiveness.

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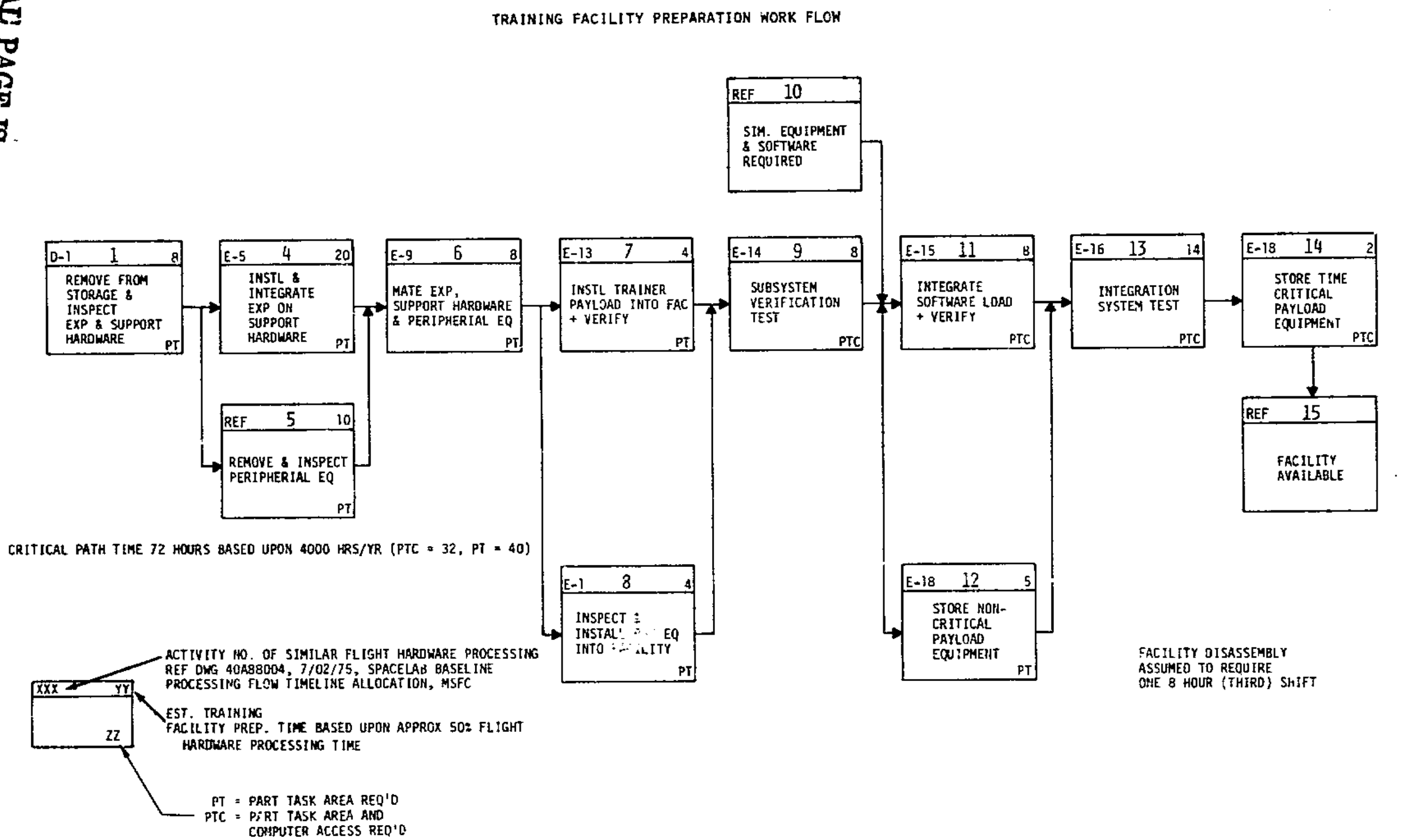

FIGURE 4. TRAINING FACILITY PREPARATION WORK FLOW FOR MISSION 10

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TRAINING FACILITY PREPARATION WORK FLOW

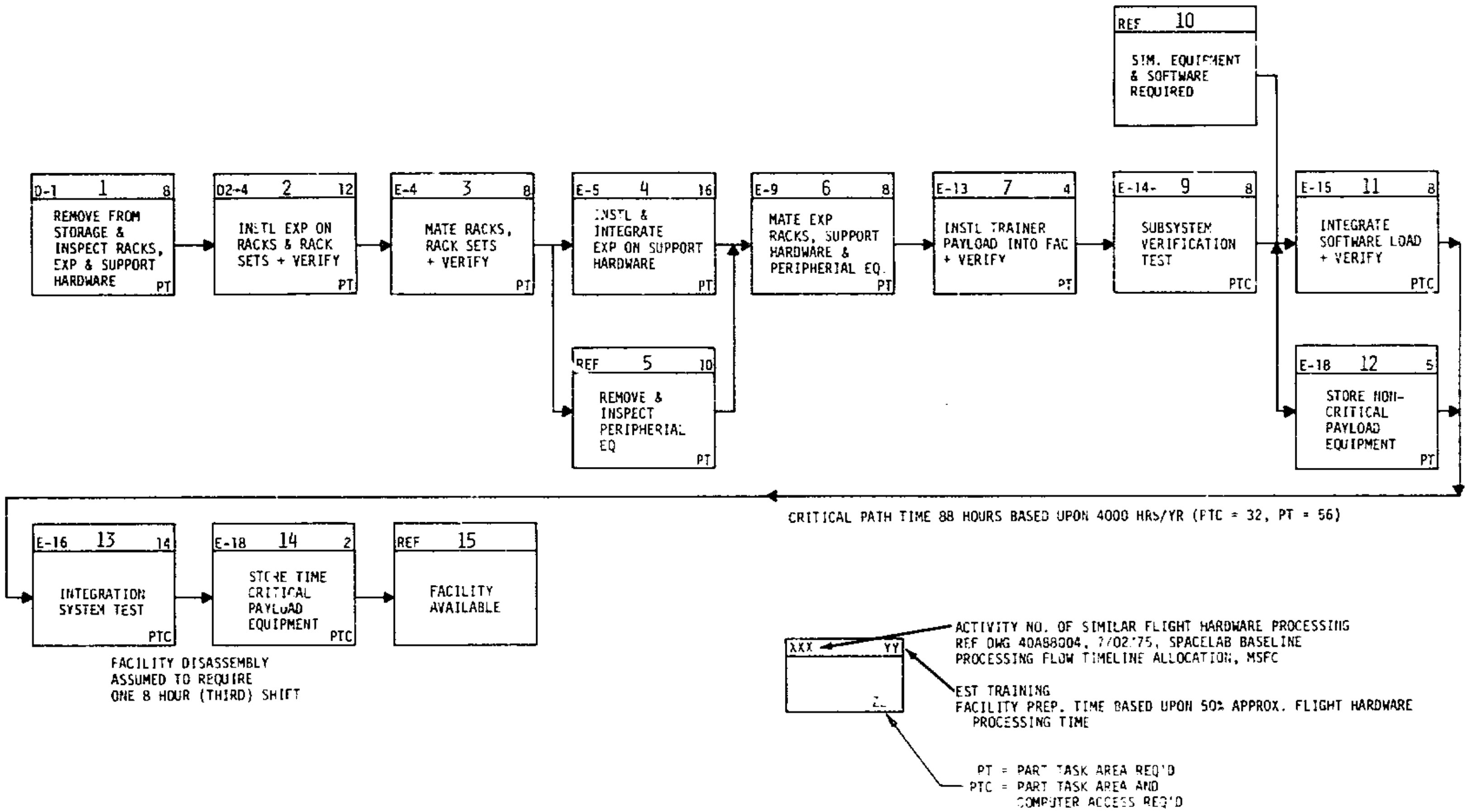

FIGURE 5. TRAINING FACILITY PREPARATION WORK FLOW FOR MISSION 11

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TRAINING FACILITY PREPARATION WORK FLOW

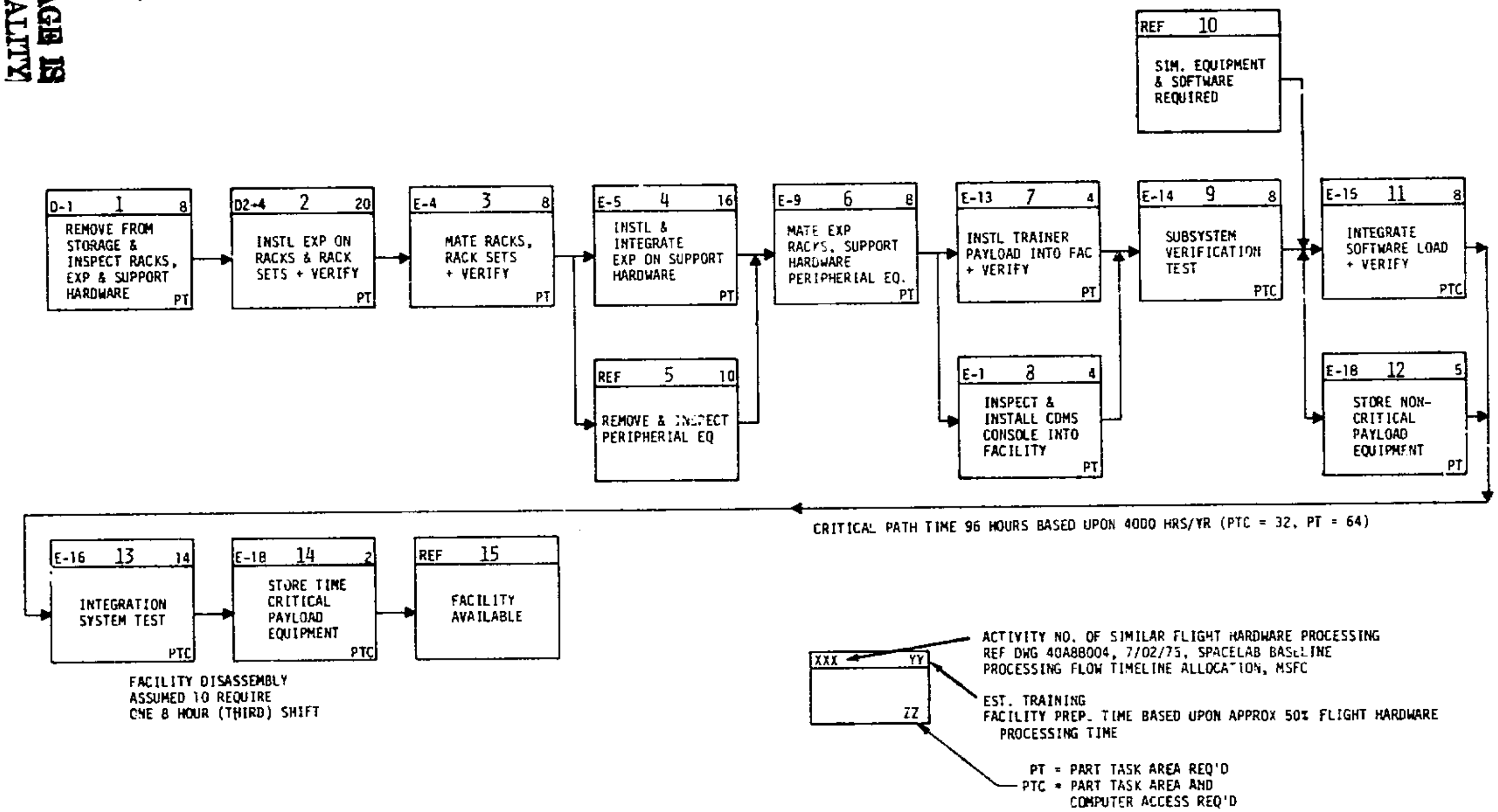

FIGURE 6. TRAINING FACILITY PREPARATION WORK FLOW FOR MISSIONS 14 AND 19

In establishing the "best" duration for the prelaunch activity period, probable interface of Payload Specialists with ground operations must be assessed. Figure 7 is a tabulation of prelaunch activities in which Payload Specialists might be called upon to participate. The participation in Level II integration at KSC is believed to be a firm requirement. Participation by Payload Specialists in Level III integration as active consultants or to resolve problems is considered a contingency requirement.

The earliest Level III integration activity in which the Payload Specialists would be called upon to assist is the Subsystem Verification Test starting 150 hours before launch. Although the requirement for the Payload Specialist to participate in the Level III integration is not a firm requirement at this time, a duration of 150 hours (3.75 weeks) was selected for the nominal preflight activity duration. This period should allow adequate time for any additional retraining to be intersequenced with participation in payload integration activities.

This activity as used in the following analysis is represented by activity 7.2 of the functional flow diagram in Figure 3.

3.5 TRAINING RESOURCE INTERRELATIONSHIP

3.5.1 Major Facility/Resource Areas

Training requirements were analyzed to group training resources into logical categories associated with the different facility areas referenced in the functional flow of Figure 3. These areas are classroom, part task training, control room, soft mock-up area and maintenance and storage area. These areas, with their designated resource identification number, are described in the following paragraphs.

01 Classroom

Classrooms are required for facility orientation briefings and lecture type instruction identified by the user or training supervisor.

ACTIVITY NO.	PRELAUNCH ACTIVITY	TIME (HRS BEFORE LAUNCH)		
		START	END	DURATION
	LEVEL III INTEGRATION			
E14	SUBSYSTEM VERIFICATION TEST	-150	-142	8
E15	INTEG. SOFTWARE, LOAD & VERIFY	-142	-140	2
E16	INTEG SYS TEST	-140	-126	14
E18	STORE NON-TIME CRITICAL ITEMS	-126	-123	3
	LEVEL II			
G12 THRU G20	PREPOWER INTERFACE VERIFICATION THRU SPACELAB CLOSEOUT	-83	-51	32
	LEVEL I			
H6	ORBITER INTEG. TEST	-43	-37	6
H8	POST TEST SECURE & ORBITER CLOSEOUT	-37	-34	3
RH9	SERVICE DISCONNECT (LOAD TIME CRITICAL ITEMS)	-3	-2	1
	TOTAL HOURS OF PROBABLE PS PARTICIPATION			69

DATA FROM MSFC DWG 40A88004, SPACELAB BASELINE PROCESSING FLOW TIMELINE ALLOCATION, JULY 1975.

FIGURE 7. PROBABLE INTERFACE OF PAYLOAD SPECIALIST WITH GROUND OPERATIONS

Associated resources include lesson plans, training manuals, scale models, visual aids, and instructor personnel.

04 Part Task Area

The part task areas will provide sufficient facilities to simulate Spacelab work stations. The part task trainer concept, as defined in Reference 1, requires the use of separate Spacelab support trainers which isolate experiments into separate compartments where Payload Specialists can be trained simultaneously and independently for the particular tasks they are to perform. Spacelab similar racks and panels will be utilized with the capability to interface rack-mounted equipment to the CDMS through remote access units (RAU's). These areas will be linked to a simulation computer. Video cameras will be mounted to allow observation of the area. Audio communication and data links will be provided from the part task area to the control room. At the completion of part task training the partitions can be removed and the compartments joined for an integrated payload simulation.

16 Soft Mockup

A segment of the training area will be used for full scale mockups of the Spacelab interior layout. These mockups will be constructed of wood and inexpensive material to provide the Payload Specialist an orientation of experiment layout in relation to other experiments.

35 Control Room

The control room will contain training supervisor consoles with CCTV viewing of the part task areas. The consoles will contain a command keyboard which will permit experiment control and faulting. Data displays, audio/video communication loops with the part task area will be provided. Facilities will be provided within the control room for principal investigators or their representatives to view and monitor the training process.

36 Maintenance and Storage

This area will be used for packing, unpacking and inspection of experiment and simulation hardware. Minor mechanical and electrical repair and refurbishment will be conducted in this area. A security storage room will be required for special experiment hardware within this area.

3.5.2 End Item Resources

Resources required within the major training areas, designated end item resources, were assessed and their interdependency was analyzed to help establish the supportive resources relationship. For example, control and display (C&D) panel type and quantity are functions of the training experiment and mission type. C&D panels require support racks and in most cases some type of simulation/input-output device, i.e., simulation computer access, peripheral simulation equipment and appropriate software.

End item training resources appeared to fall into three general categories, i.e., constraining resource, auxiliary resource, and supportive resource.

The constraining resources are defined as those which impose major requirements upon other resources. This type of resource acts as a "major driver" on the auxiliary and supportive types of resources. Examples of constraining resources are: Crewmen; Payload Specialist Station (PSS); Command Data Management System (CDMS) Console; and C&D Panels Types A, B, C, D and E.

Auxiliary resources are those which may be required only rarely, depending on the nature of the payload or experiment. These items include common payload support items for the Spacelab such as Scientific Airlock; Workbench; Viewport; Film Vault and Storage Container.

The third category, supportive resources, as the name implies, are used to supply support functions for the constraining resources and/or auxiliary resources. Supportive resources tracked within this study are: Simulation Computer (Sim Com) Access; Sim Com Software; CDMS Com Access; Peripheral Sim Equipment; Racks; and Closed Circuit Television (CCTV).

A description of these end item type resources is presented in Reference 1 and in Appendix A of this report.

3.6 SCHEDULE OPTIMIZATION

3.6.1 Objective and Approach

One of the objectives of this study was to identify and apply techniques for minimizing training resource requirements for a baseline mission model.

The approach taken was to identify a critical resource parameter and attempt to minimize this parameter with given constraints. The critical resource parameter selected was the quantity of part task areas required. Part task area was selected since this area involves significant cost items of facility space and training equipment. Part task utilization is an indicator of the utilization of major training equipment such as CDMS, consoles, PSS consoles and simulation computers. Part task utilization also acts as a "driver" on the control room requirement since training monitoring and supervisory personnel as well as control room equipment are involved with any part task training activity.

A single part task preparation is assumed to be all that is required for each flight. (Reconfiguration by experiment is assumed not required.) Once a training setup is completed the setup will not be taken down until completion of the total training cycle for that flight.

The problem of optimizing a training sequence was twofold: scheduling training activities within individual missions and scheduling training activities among missions. The technique for optimization within individual missions was developed and applied to the basic data set utilized in all cases simulated. The technique for optimization among missions, being dependent on additional factors, was verified by application to a single case as discussed in Section 3.7.3.

3.6.2 Scheduling Within Missions

Within the individual missions the time in which a part task area is dedicated to that mission should be as short as possible, consistent with maximum learning efficiency. By compressing the time of part task area dedication for individual missions the overlap of part task area requirement among missions can be reduced.

Several options exist for sequencing classroom and part task training among the numerous experiments of an individual mission. The option selected can affect the total time for which a part task area is dedicated to a given mission. The following subsections discuss the options for handling the various part task and classroom requirements, the reasons for accepting or rejecting the scheduling option, and the assumptions used in performing the scheduling optimization.

3.6.2.1 All Classroom First

The concept of scheduling all classroom training first, as a block, for all Payload Specialists on a mission, was investigated. This concept has the advantage that the training sequence is simple and the time that the part task is occupied is minimum for a given flight. Training thru-put capability is increased. The concept has the disadvantage of imposing a lengthy time lapse between classroom and part task training and can be expected to significantly decrease learning efficiency in the part task area. The all classroom first concept may be applicable to some special mission training; however, this concept is not recommended for use in a baseline training program.

3.6.2.2 Early Grouping of Classroom

In some cases critical training resources remain idle while classroom training is in progress. One method of eliminating this idle time is to group and schedule these blocks of classroom training early in the training cycle. This early grouping of classroom concept assists in reducing the amount of time in which the part task area is occupied for a given flight and thereby increases training thru-put. This concept also has the disadvantage of time lapse between classroom and associated part task training. This training option is recommended for special cases to prevent overlapping training cycles requirements from exceeding maximum resource capabilities.

3.6.2.3 Intermixed Classroom and Part Task

This training concept is characterized by intermixing classroom and part task training for a given experiment. Minimum increments of one-half day in classroom or part task area is assumed. This training concept has the advantage of developing skills in the part task area incrementally with knowledge gained in the classroom. The close time relationship between classroom and part task training results in minimum loss of proficiency by the Payload Specialists. This concept has the major disadvantage of tying up part task areas for a longer period, i.e., the combined classroom and part task activity time. Wide variation in the required part task and classroom training on individual experiments make intersequencing training for different experiments complex and difficult. Because of these disadvantages this training concept was excluded from use in this study.

3.6.2.4 Experiment Classroom Followed By Part Task

This concept requires completion of the entire classroom training on an individual experiment to be immediately followed by the entire part task training for that experiment. This concept allows developing operational skills on the entire experiment during the part task period. This concept offers a good compromise between the all classroom first concept and the intermixed classroom-part task training concept. Therefore, it was selected for use in this study.

3.6.2.5 Scheduling Assumptions

Scheduling-related assumptions used in establishing a baseline training cycle, Figure 3, were as follows:

1) Activities 1.1, 1.2 - Assume crews are available when needed for mission dependent training. Activities 2.1 through 2.4 - Assume all crew members training simultaneously, whenever practical. Activity 3.1 - Assume materials required for setup are available.

2) Activity 3.2 and 4.1.3 through 4.N.3 - Assume one part task preparation is all that is required for each flight. (Reconfiguration by experiment is not required.) Once a training setup is completed it will not be taken down until completion of the total training for the prime and backup crew.

3) Activities 4.1.1 to 4.x.2 are scheduled according to a scheduling algorithm, the prime criterion being to minimize the total time required of the constraining resource(s), within the known limitations, constraining resource capacity not to be exceeded.

4) Activity 4.0 scheduling limitations will be that: (a) each crew member is available for formal training eight hours per day, (b) classroom training must precede the corresponding part task training, and (c) prime crew trains on first shift; backup crew trains on second shift, and uses the same procedures as the prime crew.

5) Activities 5.1 and 5.2 - Assume that one day is required for PI debriefing and verification of all crew members. For retraining, Activities 6.1 and 6.2, it is assumed that 10% of total training time is required, with a minimum of eight hours, where all part task resources configured for this flight are required.

6) Activity 7.1 requires a total crew and uses all resources configured for the given flight. Activity 7.2 will be included in a post-training time block before launch that will have a duration of approximately 150 hours (3.75 weeks).

7) Launch and mission duration will be defined by the mission mix, and launch dates assumed (the mission model used). Post mission activities will not be scheduled initially as each crewman required on a flight is assumed available when required (see Item 1).

8) An eight-hour day, five-day week, 2080 hours per year is selected as a baseline for each crew member trained.

3.6.2.6 Algorithm for Scheduling Activity Within a Mission

A systematic procedure for sequencing training activity to assist in minimizing part task area dedication time within a given training cycle was developed. This procedure or algorithm was used for sequencing training activities for the four representative missions, as shown in Appendix A, and is applicable to similarly defined training missions. Table 1 summarizes the scheduling procedure for series and parallel type training activities.

3.6.3 Scheduling Among Missions

As th frequency of missions increases, training cycle overlap increases, thus increasing training resource requirements. For a given launch schedule, the requirement for training part task areas is not likely to be constant, as training will not be driving the launch schedule. Rather, at times spike requirement values exist while at other times the number of part task areas utilized is very low as illustrated in Figure 8. Since the quantity, and therefore the cost, of resources obtained can be driven by the maximum requirement values, it is necessary to minimize the peak number of resources utilized. Several options

EXAMPLE OF OPTIMIZING TRAINING START TIME

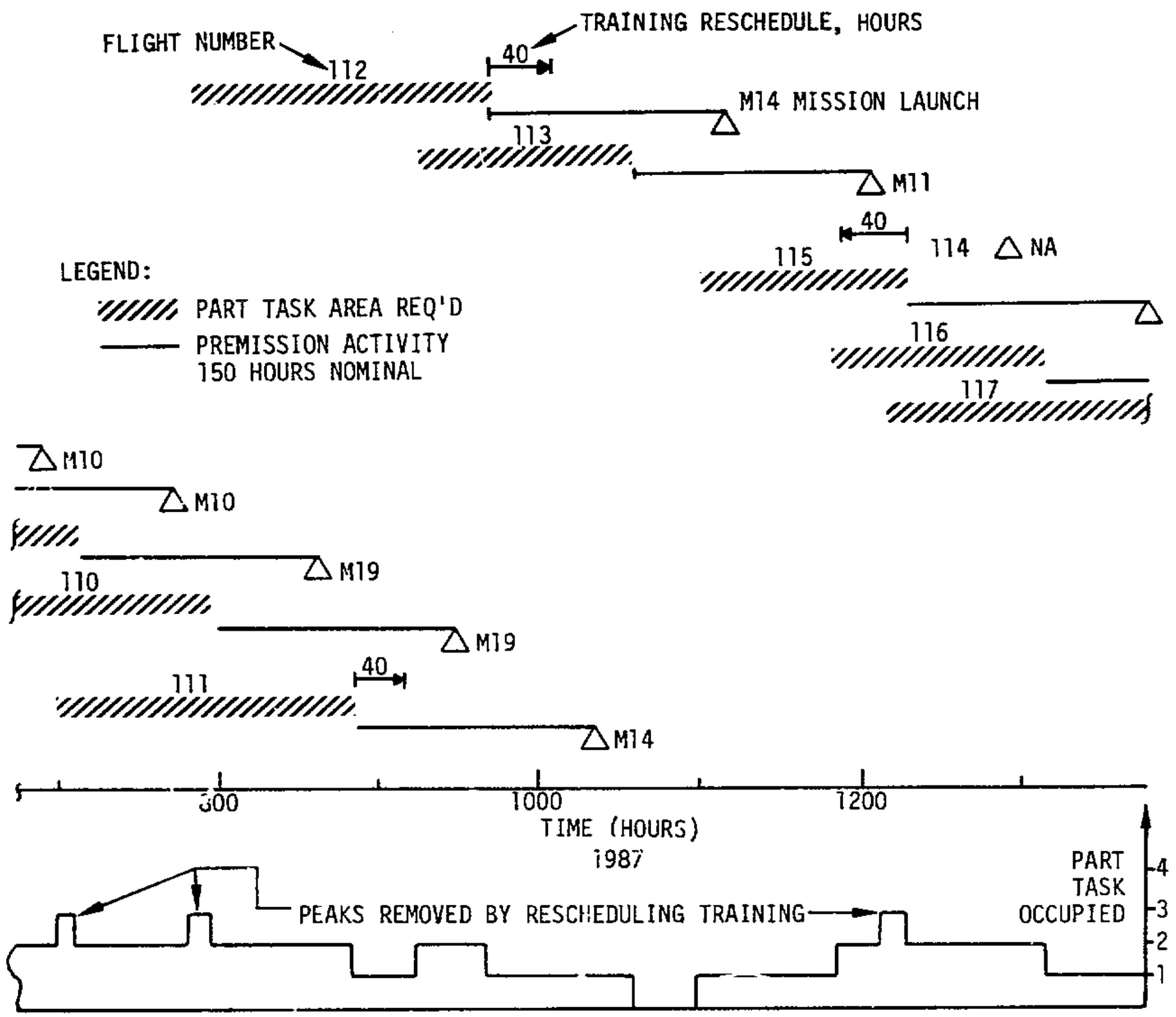

FIGURE 8. EXAMPLE OF OPTIMIZING TRAINING START TIME

TABLE 1. SCHEDULING ALGORITHM FOR ACTIVITIES WITHIN A GIVEN MISSION

FLIGHT SCHEDULE ALGORITHM

Prime criteria is to minimize the total time required for the constraining resource(s), within the known limitations, constraining resource capacity not to be exceeded.

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<u>For Single Series Training</u>

1. Schedule orientation activities

2. Schedule experiment(s) that require classroom training only.

3. Schedule classroom and associated part task experiment training which do not use a critical resource.

4. Schedule experiment training which use critical resource. Longest duration classroom first.

5. Schedule debriefing, retraining, integration mission simulation and prelaunch activity.

6. Schedule end of part task preparation at start of first part task which uses a critical resource.

<u>Series/Parallel Schedule Algorithm</u>

1. Schedule orientation activities followed by experiment specific training in which total crew participates.

2. Schedule experiment(s) that require classroom training only.

3. Schedule classroom and associated part task experiment training which do not use a critical resource in parallel with training which do use critical resource.

4. Interweave parallel training part task and classroom not exceeding quantity of critical resource.

5. Schedule debriefing, retraining, integrated mission simulation and prelaunch activity.

6. Schedule end of part task preparation at start of first part task training which uses a critical resource.

exist for reducing these peak values such as personnel overtime, split shift or resequencing of training cycles for specific missions. The utilization of overtime or shift options was not treated as a resource optimization parameter, but was left as a contingency option. Resequencing of training activity so as to minimize training cycle overlaps appears to be a practical approach to reducing resource requirements.

Figure 8 illustrates the basic resource leveling technique used to reduce the peak values of training resources over time. The top portion of this figure shows training time for individual launches. The cross-hatched bar represents the time a part task area is dedicated to a given mission. This dedication period starts at part task facility preparation and ends after the integrated mission training activity. The line between training and launch is the time allocated to flight crew's prelaunch activity. This prelaunch activity is assumed to be 150 working hours or approximately four weeks as discussed in Section 3.5 of this report.

The bottom portion of Figure 8 is a profile of number of part task areas occupied versus time. The peaks are removed by making the prelaunch activity time a variable and shifting the training start time. For this study training start date was varied from start two weeks early to a one week delayed start. Rescheduling was accomplished in whole day (eight hour) increments.

Results obtained from applying the technique of shifting training cycle start time to level resource requirements is discussed in Section 3.7.3 of this report.

3.7 TRAINING CASE STUDIES

Several different training case studies were conducted in an effort to determine minimum training resource quantities required for the mission dependent training facility and to assess the influence of key parameters such as mission complexity, training schedule and activity time requirements.

Figure 9 summarizes the significant features of the case studies. These significant features are further defined along with input data assumptions, analysis and results in the following six sections. These case studies are:

1) Maximum thru-put cases which assess the maximum number of mission crews that can be trained with given, fixed resources, for various mission complexities.

2) Case A which analyzes the resource requirements for the Yardley "572" mission model. (Refer to Appendix A.)

3) Case AØ which assesses the extent of resource reduction thru training sequence and schedule optimization.

4) Cases B, C and D which analyze resource requirement variations with mission complexity.

5) Case B_2 and B_3 which assess the effects of training efficiency improvements on resource requirements.

6) Cases A $\pm$ 10, 25, 40 and 50% which analyze changes in resource requirements with variations in training activity duration.

All cases utilized the four basic training missions M10, M11, M19 and M14 and the resources discussed in Appendix A. The techniques and approaches discussed in Sections 3.3, 3.4, 3.5 and 3.6 were applied to assure a thorough, consistent analysis of the resource requirements for these various options.

Except for the maximum thru-put study, all cases were simulated utilizing the Resource Utilization Program. This program and typical output are discussed in Appendix B. For each case simulated a complete set of computerized reports was produced to support the engineering analysis discussed in the following subsections.

CASE NUMBER	REPORT SECTION	DESCRIPTION	REFERENCE CASE NUMBER	RESOURCES AVAILABLE	MISSION COMPLEXITY MIX	LAUNCH FREQUENCY	PRELAUNCH ACTIVITY DURATION	TOTAL TRAINING TIME PER MISSION
			SIGNIFICANT FACATORS					
MX	3.7.1	MAX-THRU-PUT ANALYSIS	—	1 PT	EQUAL	U	C	FIXED
MX0	3.7.1	MAX-THRU-PUT ANALYSIS	MX	2 PT	EQUAL	U	C	FIXED
MX1	3.7.1	MAX-THRU-PUT ANALYSIS	MX	1 PT	M10	U	C	FIXED
MX2	3.7.1	MAX-THRU-PUT ANALYSIS	MX	2 PT	M19	U	C	FIXED
MX3	3.7.1	MAX-THRU-PUT ANALYSIS	MX	1 PT	M10	U	C	FIXED
MX4	3.7.1	MAX-THRU-PUT ANALYSIS	MX	2 PT	M19	U	C	FIXED
A	3.7.2	BASELINE "572" YARDLEY MISSION MODEL	—	U	YARDLEY	YARDLEY	C	FIXED
Aϕ	3.7.3	OPTIMIZED TRAINING CYCLE START TIME	A	U	YARDLEY	YARDLEY	U	FIXED
A+10%	3.7.6	VARIATION IN TRAINING TIME	A	U	YARDLEY	YARDLEY	C	+10%
A-10%	3.7.6	VARIATION IN TRAINING TIME	A	U	YARDLEY	YARDLEY	C	-10%
A+25%	3.7.6	VARIATION IN TRAINING TIME	A	U	YARDLEY	YARDLEY	C	+25%
A-25%	3.7.6	VARIATION IN TRAINING TIME	A	U	YARDLEY	YARDLEY	C	-25%
A+40%	3.7.6	VARIATION IN TRAINING TIME	A	U	YARDLEY	YARDLEY	C	+40%
A-40%	3.7.6	VARIATION IN TRAINING TIME	A	U	YARDLEY	YARDLEY	C	-40%
A+50%	3.7.6	VARIATION IN TRAINING TIME	A	U	YARDLEY	YARDLEY	C	+50%
A-50%	3.7.6	VARIATION IN TRAINING TIME	A	U	YARDLEY	YARDLEY	C	-50%
B	3.7.4	AVERAGE MISSION COMPLEXITY	—	U	AVG YARDLEY	4 TO 32	C	FIXED
C	3.7.4	ALL SIMPLE MISSIONS (M10)	B	U	M10	4 TO 32	C	FIXED
D	3.7.4	ALL COMPLEX MISSIONS (M19)	B	U	M19	4 TO 32	C	FIXED
B2	3.7.5	EFFICIENCY IMPROVEMENT (95% LEARNING CURVE - LC)	B	U	AVG YARDLEY	32	C	LC
B3	3.7.5	EFFICIENCY IMPROVEMENT (80% PREVIOUSLY TRAINED - PREV)	B	U	AVG YARDLEY	32	C	PREV

NOTES:

PT = PART TASK AREA
U = UNCONTRAINED
C = CONSTRAINED
FIXED = TIME ESTIMATES AS DOCUMENTED IN FIGURES A-1 THRU A-4

FIGURE 9. INTERRELATIONSHIP OF CASES ANALYZED

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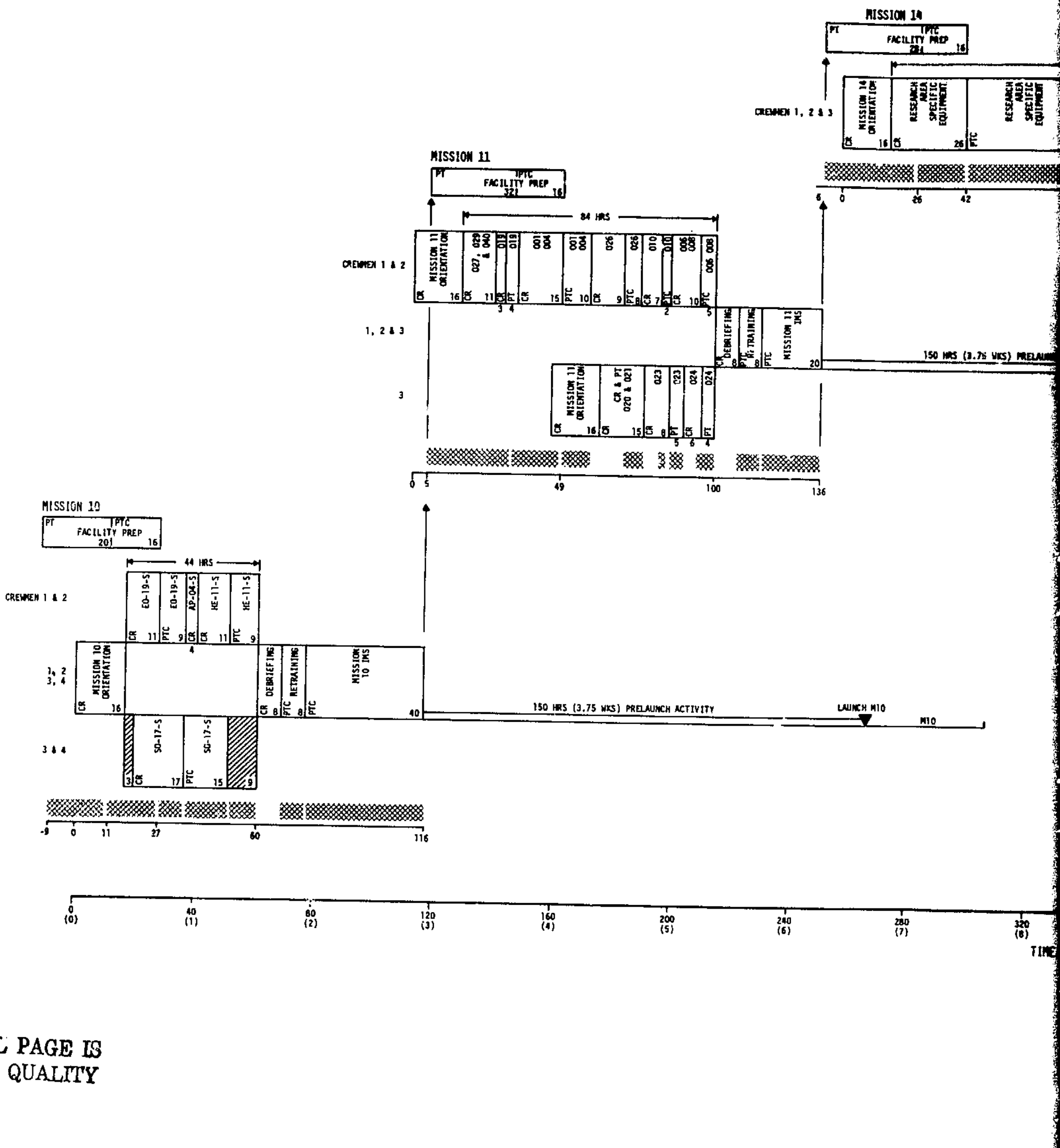
3.7.1 Maximum Thru-Put

3.7.1.1 Definition

As a first step in establishing a baseline training simulation maximum training thru-put under fixed resources and conditions was investigated. The maximum thru-put case is based upon maximum utilization of the part task area, a critical training resource. Maximum training thru-put is a capacity definition case in which the launch dates are allowed to vary according to the demands of training. Even though in all likelihood training demands will not dictate launch schedules the maximum thru-put case serves as an ideal condition and forms a basis of comparison.

3.7.1.2 Significant Features

The following steps and assumptions are made to set up the maximum thru-put study. Training functional flows are sequenced using scheduling algorithms discussed in Section 3.6 of this report to minimize the time in which the part task area is tied up during a training cycle. From these functional flows a multiple-activity chart is constructed which graphically displays crewman training activity versus time for the four reference missions as in Figure 10. Individual blocks of classroom (CR), part task (PT), and part task area with simulation computer access (PTC), are shown starting with mission orientation and extending through Integrated Mission Simulation (IMS). Facility preparation is scheduled to be completed just prior to the first experiment part task training in which the simulation computer, PTC, is required. Following completion of the experiment specific training a contingency retraining session is assumed. This retraining period is assumed to be ten percent of the experiment specific training with a minimum of one day, eight hour, period. A constant value of prelaunch activity of 150 hours or approximately four weeks is assumed as discussed in Subsection 3.4.2.



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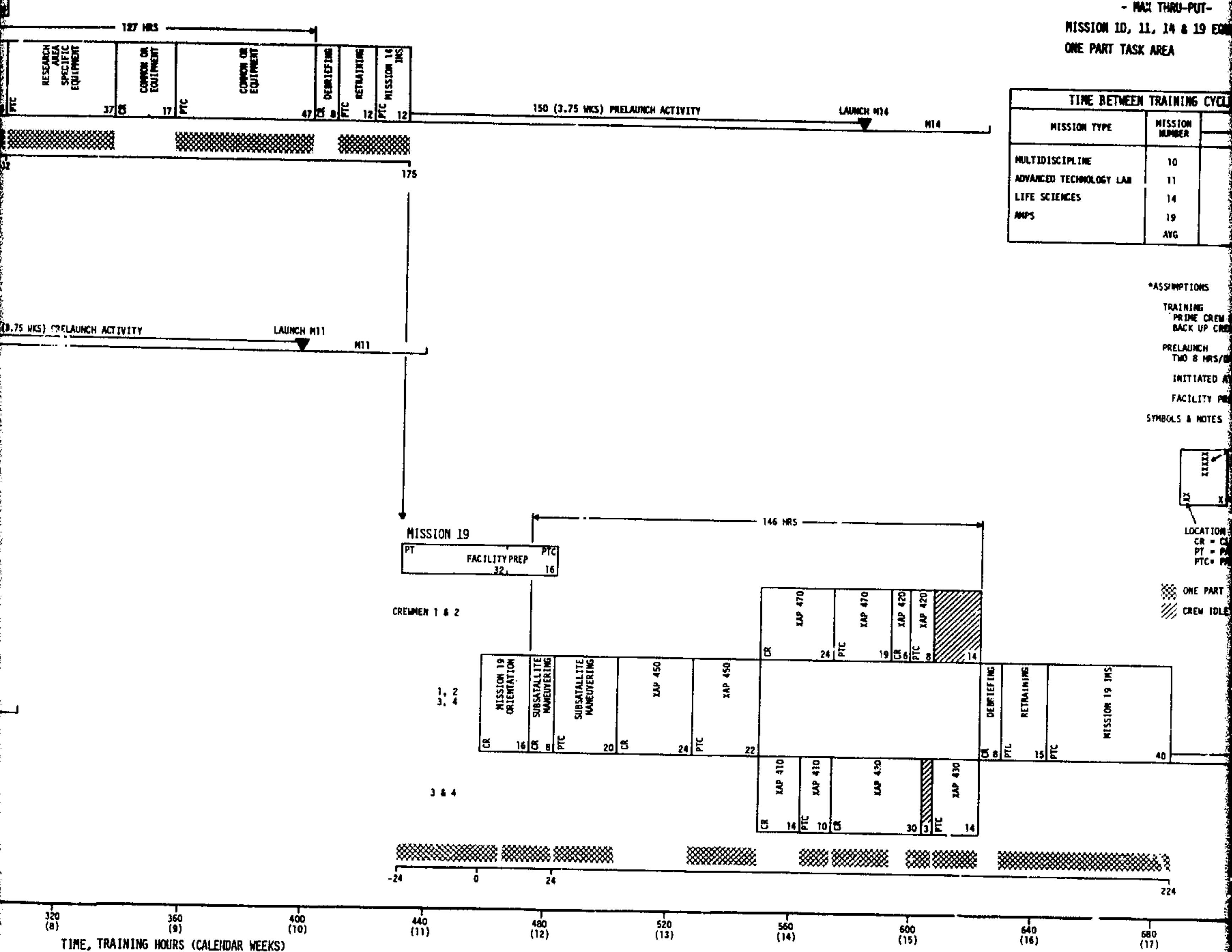
- MAX THRU-PUT-
MISSION 10, 11, 14 & 19 EQ
ONE PART TASK AREA



TIME BETWEEN TRAINING CYCL		
MISSION TYPE	MISSION NUMBER	
MULTIDISCIPLINE	10	
ADVANCED TECHNOLOGY LAB	11	
LIFE SCIENCES	14	
AMPS	19	
	AVG	

*ASSUMPTIONS

TRAINING
PRIME CREW
BACK UP CRE

PRELAUNCH
TWO 8 HRS/

INITIATED A

FACILITY PR

SYMBOLS & NOTES

LOCATION
CR = C
PT = P
PTC= P

ONE PART

CREW IDLE

FIGURE 10. MULTIPLE ACTIVITY THRU-PUT

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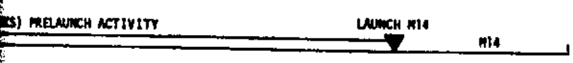
OLDOUT FRAME 2

- MAX THRU-PUT-

MISSION 10, 11, 14 & 19 EQUIMIXED,

ONE PART TASK AREA



TIME BETWEEN TRAINING CYCLE COMPLETION				POTENTIAL THRU-PUT WITH ONE PT AREA MISSION/YR
MISSION TYPE	MISSION NUMBER	PART TASK AREA DEDICATED TIME		
		HOURS	WEEKS	
MULTIDISCIPLINE	10	125	3.13	16,64
ADVANCED TECHNOLOGY LAB	11	131	3.28	15.88
LIFE SCIENCES	14	181	4.53	11.49
AMPS	19	248	6.2	8,39
	AVG	171	4.28	12.16

*ASSUMPTIONS

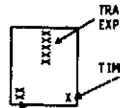
TRAINING
PRIME CREW 8 HRS/DAY 5 DAYS/WEEK SH T #1
BACK UP CREW 8 HRS/DAY 5 DAYS/WEEK IFT #2

PRELAUNCH
TWO 8 HRS/DAY 5 DAY/WEEK SHIFTS

INITIATED AT START OF LEVEL III TEST & C/O.

FACILITY PREP. REQUIRES USE OF SIM COMPUTER ACCESS

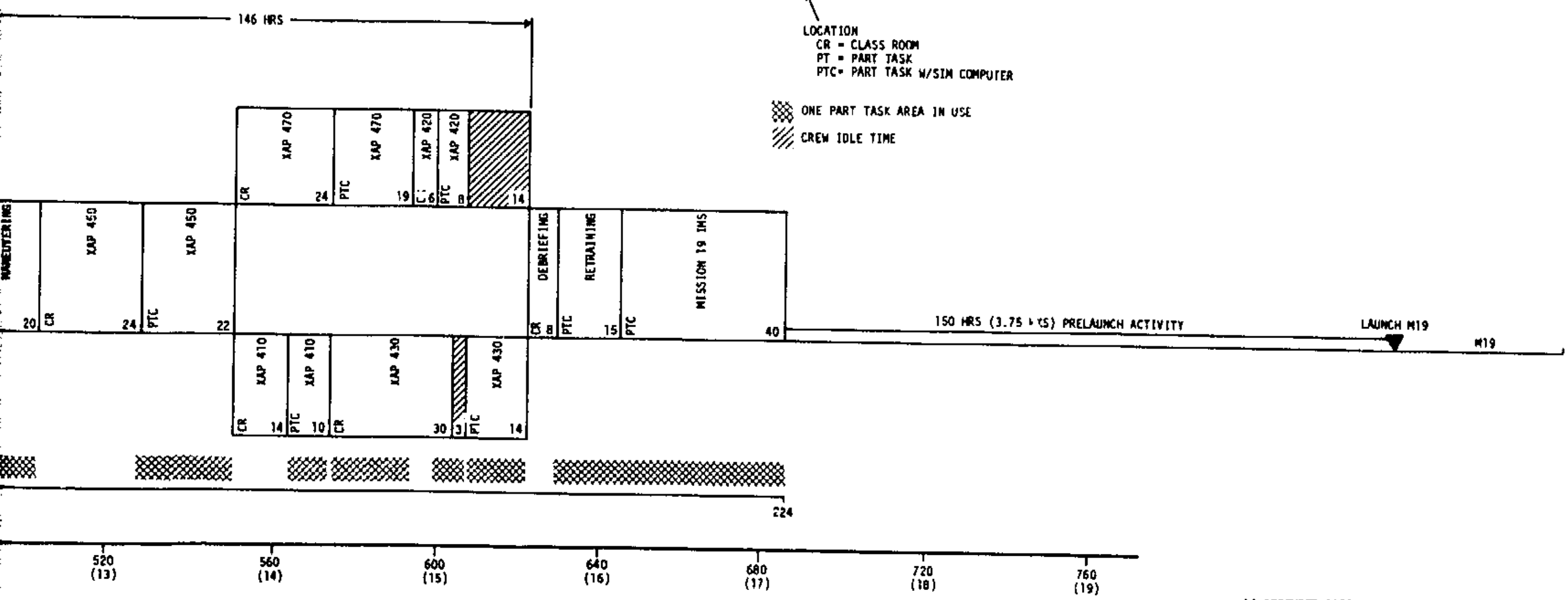
SYMBOLS & NOTES



LOCATION
CR = CLASS ROOM
PT = PART TASK
PTC= PART TASK W/SIM COMPUTER

ONE PART TASK AREA IN USE

CREW IDLE TIME



16 DECEMBER 1975

FIGURE 10. MULTIPLE ACTIVITY CHART ILLUSTRATING MAXIMUM TRAINING THRU-PUT

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FOLDOUT FRAME 3

Maximum thru-put for an equal mix of mission complexity type flights was first analyzed as shown in Figure 10. Mission 11 training start time is based upon completion of Mission 10 integrated mission simulation coincident with the start of Mission 11 part task facility preparation. In like manner Mission 14 and Mission 19 training starts are scheduled. Scheduling training cycles in this manner results in the part task area(s) being continuously utilized, and thus defines the maximum thru-put capacity.

3.7.1.3 Results

The time in which the part task area is dedicated to a specific mission (t_{pt}) is an important parameter which can be used as an index of mission complexity. The potential training cycles per year is a direct function of t_{pt}. That is:

$$M = \frac{t_b}{t_{pt}}$$

where M = Potential training cycles per year

t_b = Time base, 2080 hrs/year

t_{pt} = Mean value of time a part task area is dedicated to each mission, hrs.

For example if all missions flown have a mean complexity equivalent to Mission 10 where t_{pt} equals 125 hours then the potential training thru-put is 16.64 missions per year assuming one part task area. The average part task area dedicated time, t_{pt}, for an equal mix of the four representative missions is 171 hours resulting in approximately 12 missions per year as the maximum thru-put per part task area.

Figure 11 is a typical example of parametric data based upon training thru-put and mission complexity. Points at the bottom of the curve correspond to all missions of the simple Mission 10 type. Points at the top of the curve correspond to all missions during a given period being a complex Mission 19 type. The maximum thru-put approach can

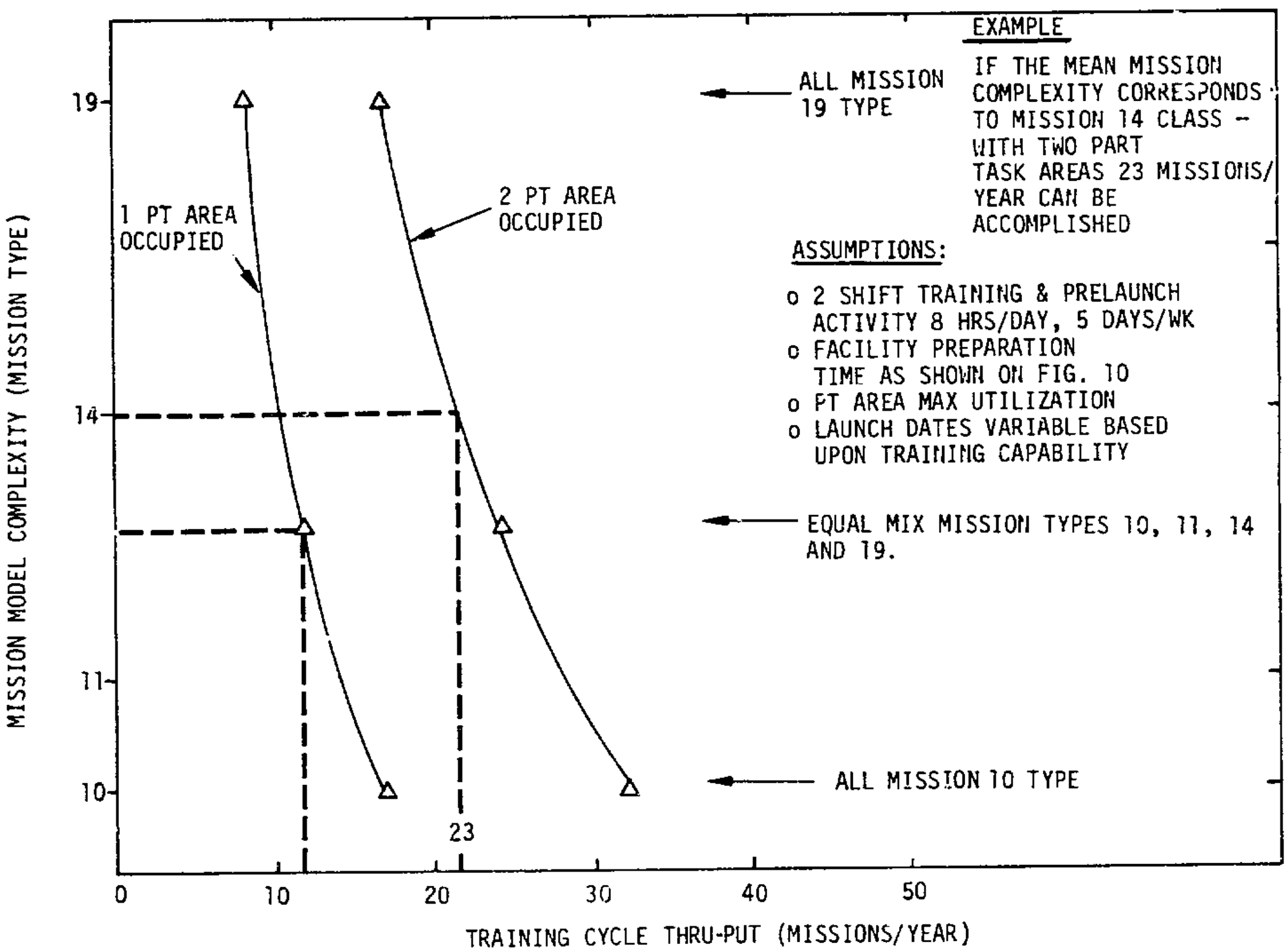

FIGURE 11. TRAINING FACILITY MAXIMUM THRU-PUT PARAMETRIC RESULTS, TYPICAL

also be used to conduct rapid parameter sensitivity assessments. Figure 12 is an example sensitivity curve showing training mission thru-put versus time assuming a critical resource is used in the part task preparation task.

The point to be made is that training mission thru-put is a good index for comparing various training concepts, mission complexity and constraining resource level. Total training time or time a critical resource is required is a corresponding parameter useful in rating training complexity of a given mission. Maximum thru-put assessment was made in this study to evaluate various sequencing concepts and to arrive at training sequence optimization procedures.

3.7.2 Yardley "572" Mission Model, Baseline

3.7.2.1 Definition

Case A assesses the training resource requirements for the current Space Shuttle mission model, the Yardley "572" Mission Model. This can then serve as a baseline against which to compare the requirements established for the parametric cases in the following subsections of this report.

To perform this simulation the basic missions as defined in the maximum thru-put case were utilized. The four missions utilized, referred to as M10, M14, M19, and M11, were defined as discussed in Appendix A (see Figures A-1 through A-4), through the mapping of basic requirements into the functional flow of Figure 3. The optimization within each mission of the activities was utilized as illustrated in Figure 10, employing the scheduling assumptions defined in Section 3.6.2.5.

The flight frequency and mission complexity assumed was based upon the Yardley "572" Mission Model as discussed in Appendix A of this report. Training resources are simulated for the 12-year period of 1980 through 1991. Launch rates of from one through twenty-two missions per year are involved with various mission complexities. As only four representative or reference missions had been thoroughly

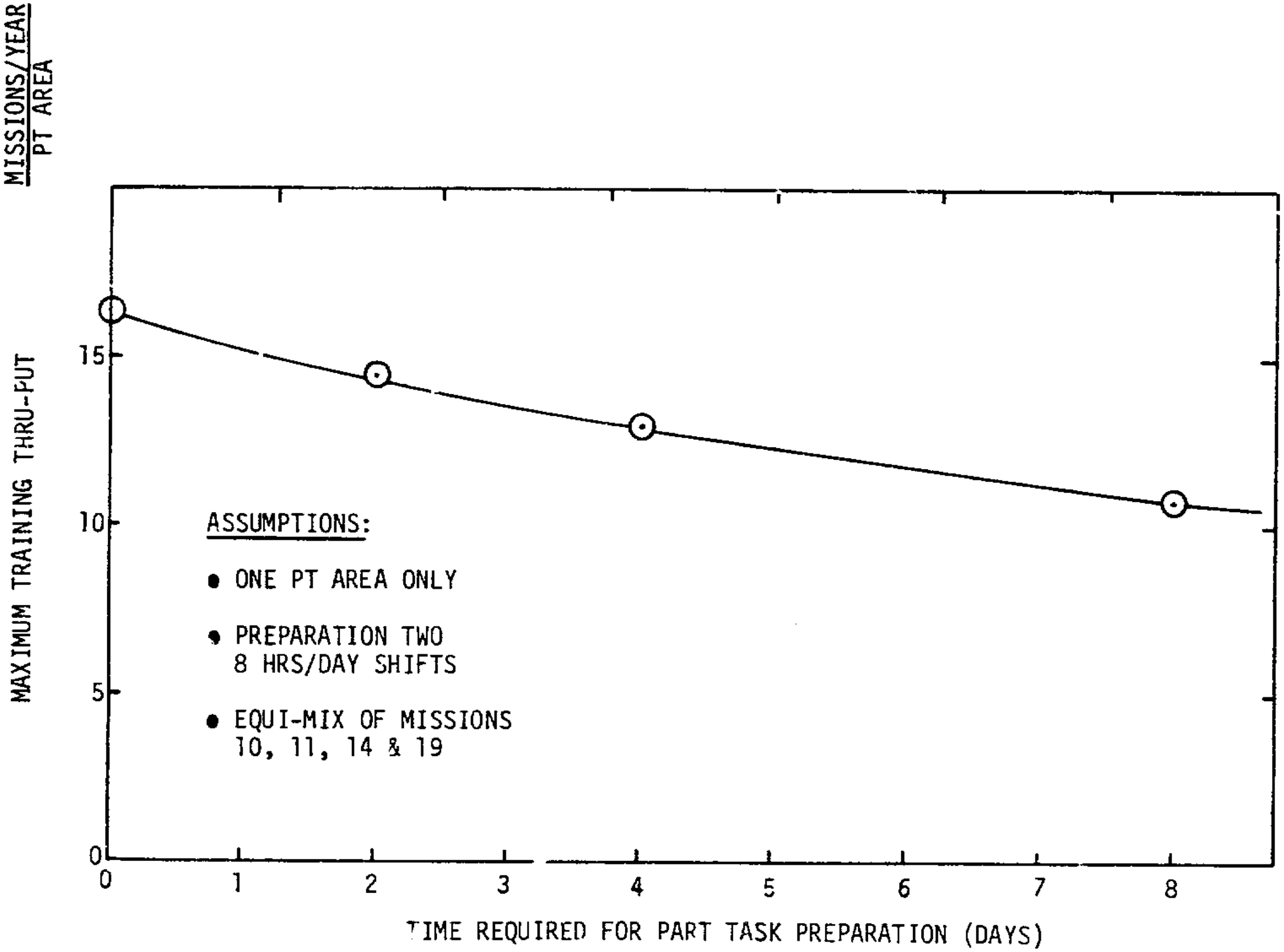

FIGURE 12. TYPICAL EXAMPLE OF PARAMETER SENSITIVITY CURVE GENERATED USING MAX THRU-PUT CONCEPT

analyzed for training resource requirements, these were matched with missions defined in the Yardley "572" Mission Model. The criteria utilized included analogous complexity, payload type, discipline and crew involvement. A summary of the resultant model as it was applied to the MSFC mission dependent training problem is given in Figure 13. Missions judged not applicable to mission dependent training at MSFC are listed so as to show the full mission model relationship.

Launch dates of missions were based upon equispace launches within a given year. Training of the prime crew on a 40 hours per week, 52 weeks per year basis with alternate or backup crew training on the second shift is assumed. The third shift was reserved for equipment maintenance, modification and necessary checkout. No optimization among missions was employed. Rather, a fixed interval between the end of training and the launch date of 150 hours was assumed.

3.7.2.2 Results

Resource requirements for twenty-three resource categories were determined over the twelve year period covered by the Yardley "572" Mission Model. Significant findings from this assessment are outlined below.

Analysis of quantity of resources required versus time indicates that a number of short duration spike requirements exist (see Figure 14). An assessment of the magnitude and duration of these spikes was made on a year by year basis. The cumulative duration of these resource requirement spikes was found to be 100 hours or less per 2080 hour year interval, i.e. 5%. Analysis of the cumulative requirements indicates that the 95% level was firm and seemed to represent a break point. That is, further reduction of a few percentage on the cumulative distribution curve had little effect in reducing resource requirement levels. Figure 15 is a typical graphical comparison of maximum values required and 95% level requirements versus time. Figure 16 is a tabular listing of typical resource requirements level of maximum values and and 95% level requirements for Case A.

TRAINING REF MISSION	MISSION TYPE	TOTAL TRAINING FACILITY TIME (HRS)	FLIGHT FREQUENCY												
			80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
19	SOLAR PHYSICS	248	0	0	1	2	2	1	2	1	2	1	2	1	15
19	AMPS		0	1	1	2	2	2	2	2	2	2	2	2	20
14	LIFE SCIENCE	181	0	2	2	2	2	2	2	2	2	2	2	2	22
14	MULTI-USER		1	1	1	2	1	2	2	3	3	3	3	3	25
11	SPACE TECHNOLOGY	131	0	1	1	2	3	3	3	4	4	4	5	5	35
10	MULTI-APPLIC. & SPACE PROC.	125	1	0	2	2	2	2	2	3	3	4	4	5	30
10	SPACE PROCESSING & SPACE MFG.		0	0	1	1	3	3	3	3	3	3	3	4	27
MSFC RELATED MISSIONS			2	5	9	13	15	15	16	18	19	19	21	22	174
MISSIONS NOT APPLICABLE TO MSFC			0	1	3	4	4	5	5	6	5	5	6	7	52
TOTAL MISSIONS			2	6	12	17	19	21	21	24	24	24	27	29	226

FIGURE 13. YARDLEY "572" MISSION MODEL SUMMARIZED FOR TRAINING

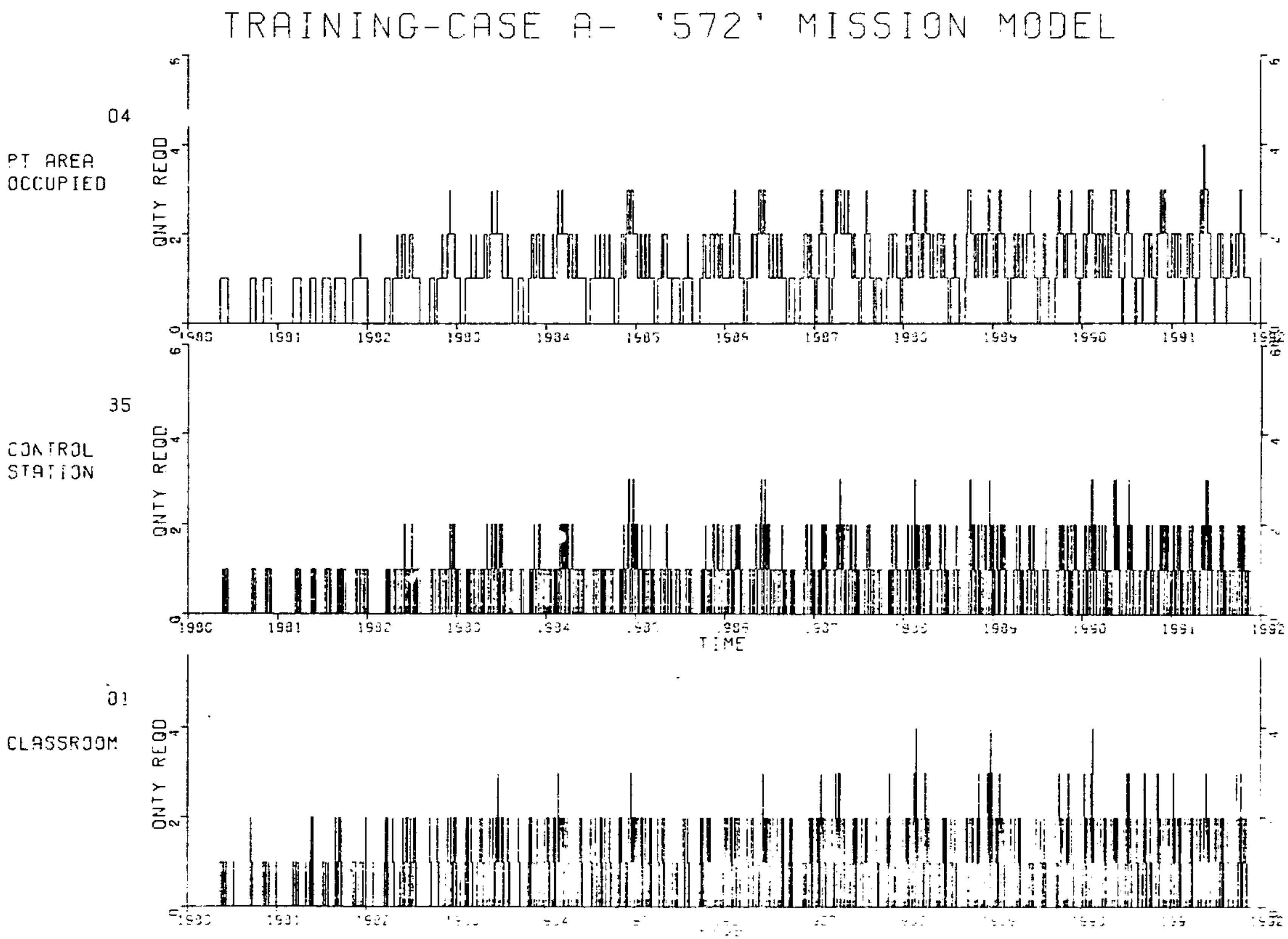

FIGURE 14. TRAINING CASE A RESOURCE UTILIZATION, TYPICAL

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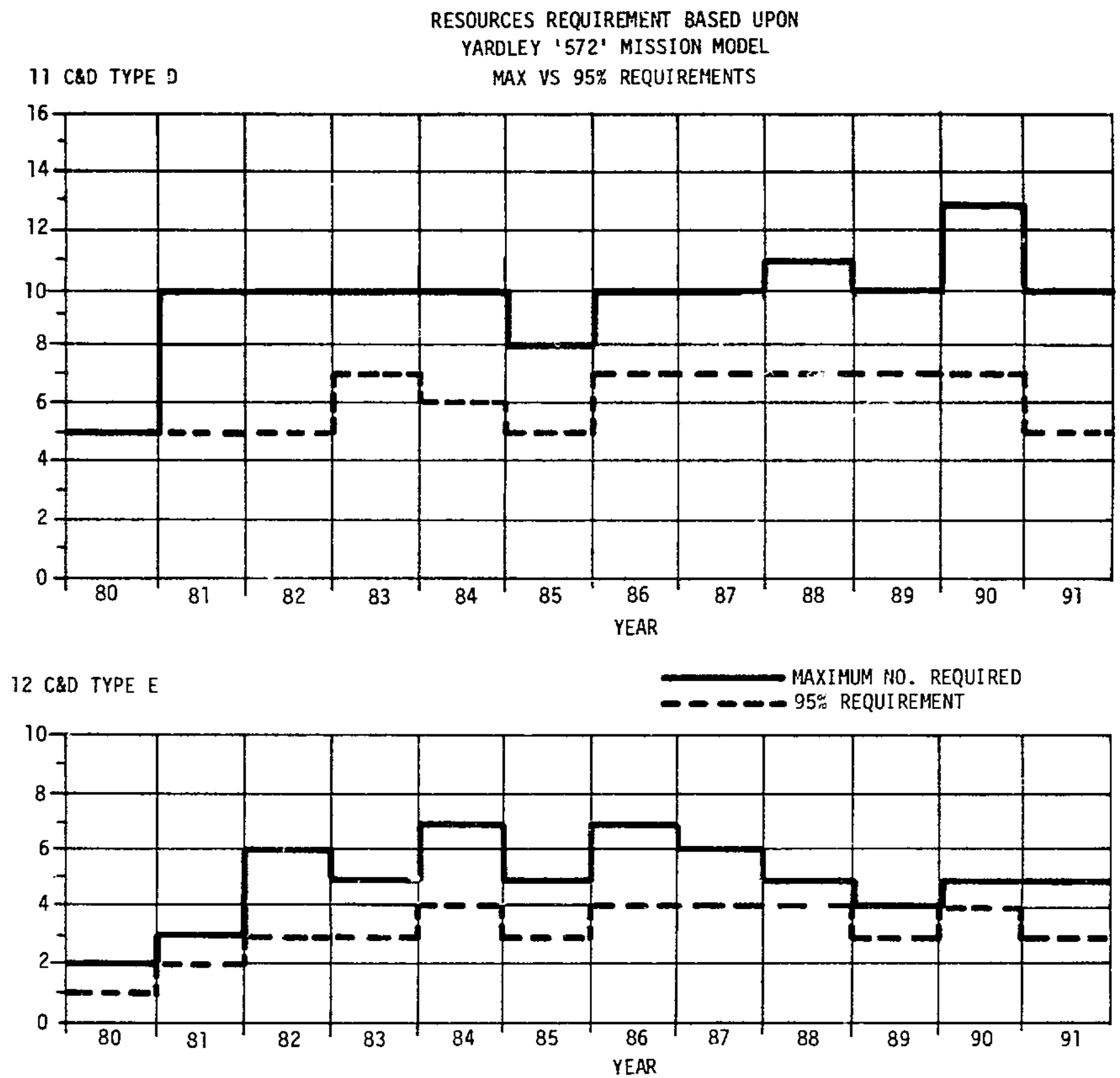

FIGURE 15. GRAPHIC COMPARISON OF MAXIMUM VALUES AND 95% LEVEL REQUIREMENTS FOR CASE A

RESOURCE/LEVEL	YEAR & RESOURCE QUANTITY											
	80	81	82	83	84	85	86	87	88	89	90	91
01 CLASSROOM												
MAX VALUE	2	2	2	3	3	2	3	3	4	3	4	3
95%	1	1	2	2	2	2	2	2	2	2	2	2
04 PT AREA OCCUPIED												
MAX VALUE	1	2	3	3	3	2	3	3	3	3	3	4
95%	1	1	2	2	2	2	2	2	2	2	2	2
31 RACKS												
MAX VALUE	16	32	48	48	48	32	48	48	41	41	48	48
95%	16	16	32	32	32	32	32	32	32	32	32	32
35 CONTROL ROOM												
MAX VALUE	1	1	2	2	3	2	3	3	3	2	3	3
95%	1	1	1	2	2	2	2	2	2	2	2	2

FIGURE 16. TABULAR COMPARISON OF MAXIMUM VALUES AND 95% LEVEL REQUIREMENTS FOR CASE A

Another observation of results of Case A is that training requirements of the 1983 and 1984 time period are more complex than the average missions per year indicates. Many of the resources reach their maximum requirement level during this period.

3.7.3 Training Start Optimization

Possible reduction of maximum resource requirements by optimizing training sequence and schedule was assessed in Case A∅, through application of the resource leveling optimization concept outlined in Section 3.6.3 of this report.[1]

As stated in the previous section a number of resource requirement spikes were noted in analyzing Case A data. Many of these spikes resulted from short term overlap in a number of training missions. Case A reserved a constant 150 hours (approximately four weeks) between end of scheduled training and launch. By allowing this prelaunch activity time to vary, resource leveling can be accomplished by optimizing the training start schedule, without affecting launch dates.

Case A∅ used the same data as Case A including Yardley "572" Mission Model, training activity schedule and duration and corresponding activity resources. The only exception is that the training start time is varied by allowing prelaunch time to increase up to two weeks or to decrease by up to one week. These variations were introduced in order to decrease peak resource requirements.

The resource most indicative of total resource requirements is the part task area. Any time the part task area is in use, the majority of the training resources for that mission are also required. Therefore, part task area is utilized as the optimization parameter. A graphical analysis of the part task utilization profile and the training mission overlap from the Case A results was performed. Training starts were rescheduled in one day increments so as to eliminate training cycle overlaps or spikes in resource requirements where possible. This resource

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[1] As the training facility becomes more firmly defined in terms of materials, machinery, space and cost, a more extensive procedure for resource budgeting or leveling should be utilized. Candidate optimization techniques amenable to rapid computer computation are outlined in References 13 and 14.

leveling of the part task area utilization required resequencing training start time on 58 out of the 174 Spacelab training missions.

Figure 17 is a plot of Case AØ requirements for part task areas, control stations and classrooms. The effectiveness of optimization can be judged from a comparison of Figure 14 and Figure 17. A significant reduction in the resource requirement spikes for both the part task areas and control stations can be noted. For example, the number of times that three part task areas are required is reduced from 31 for Case A to 4 for Case AØ. The number of times that three control stations are required is reduced from 12 for Case A to 1 for Case AØ.

Minimization of the number of part task areas and control stations is a significant factor in reducing both training facility fixed and operational costs, as this is also reflected in reduced requirements for most other resources.

Although minimization of part task areas generally reduces the maximum level of resources associated with the part task area, this change is not uniform across all resources as is illustrated by Figure 19. Non-uniformity results from interactions of training elements of the training cycles in progress. A typical comparison on a statistical basis is shown by Figure 18. Optimization reduces the variance and reduces the tail-off on the right hand side of the curve. From analysis of Case AØ results it can be concluded that optimization of training cycle start time can smooth out transient peaks in most resource requirements and reduce the maximum quantities of resources required. However, a very few resources, such as classroom requirement, are in conflict with part task area utilization, as can be seen from Figures 14 and 17. Due to the training resource relationship as defined in Appendix A, this is an insignificant increase compared to the reduction in requirements for the majority of, and particularly for the most expensive, resources.

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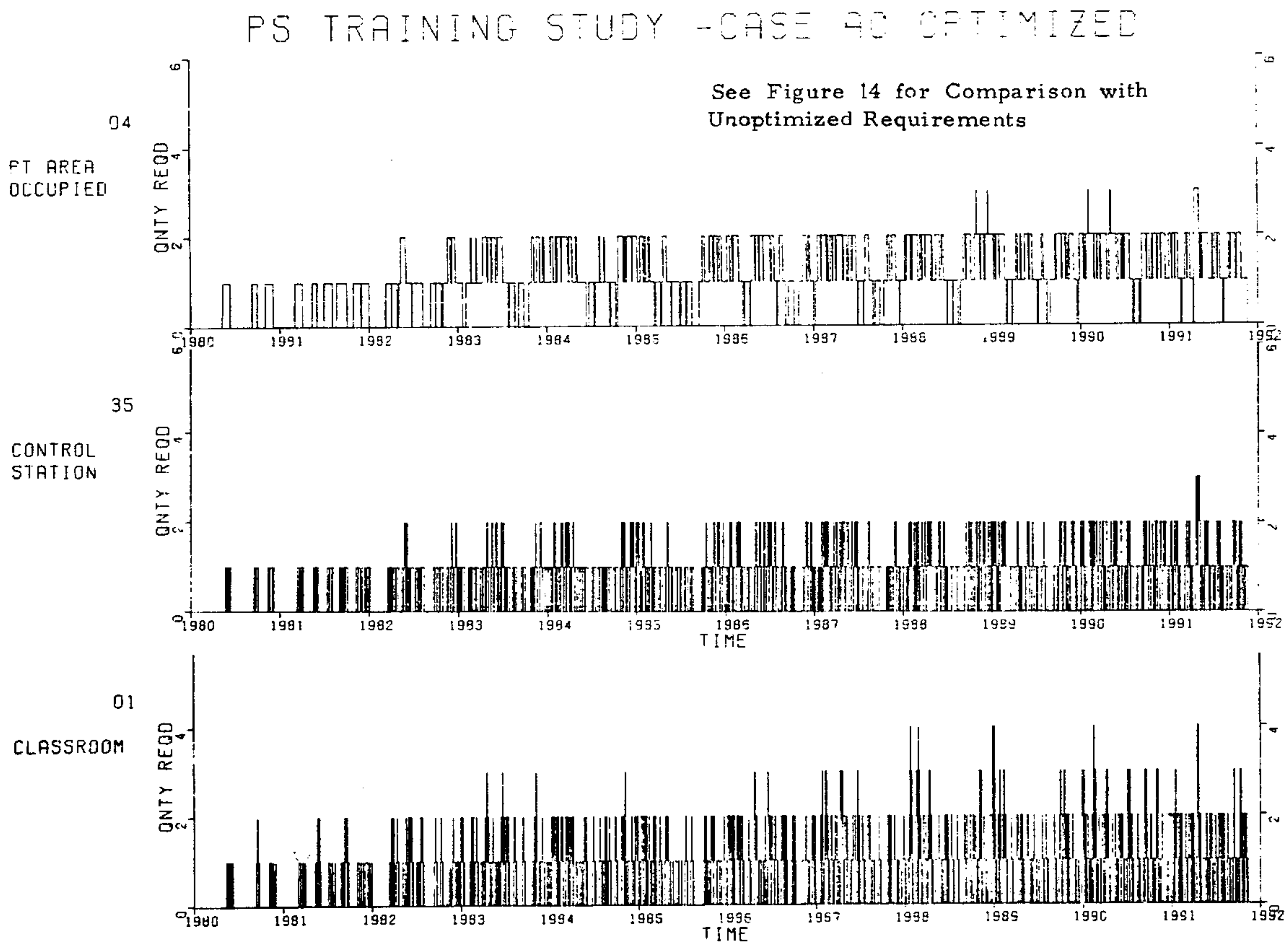

FIGURE 17. TRAINING START OPTIMIZATION EFFECTIVENESS

EFFECT OF OPTIMIZING TRAINING

START TIME, 1991

04 PT AREA OCCUPIED

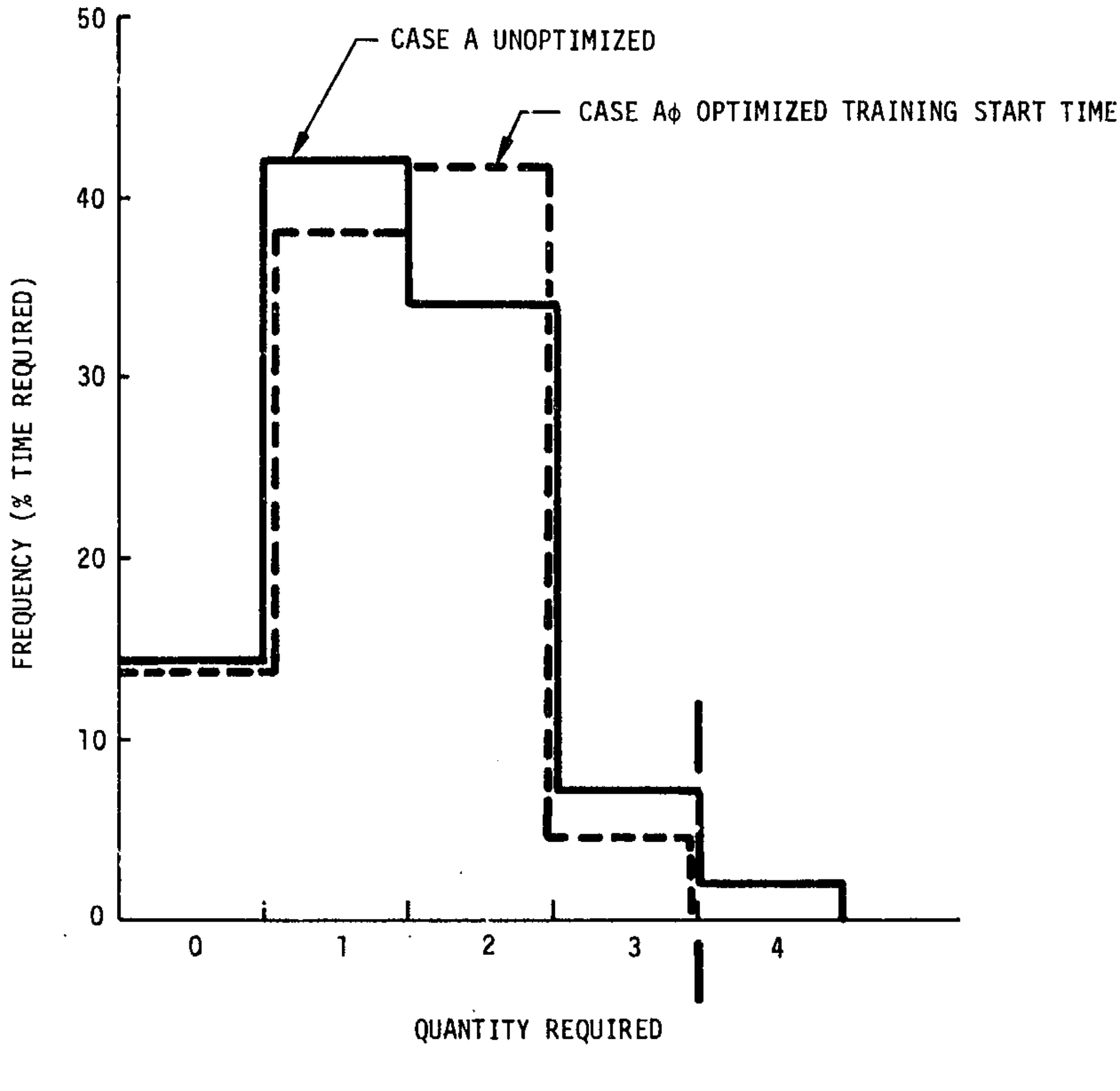

FIGURE 18. FREQUENCY DISTRIBUTION MAXIMUM VALUE COMPARISON CASE A AND CASE AØ, TYPICAL

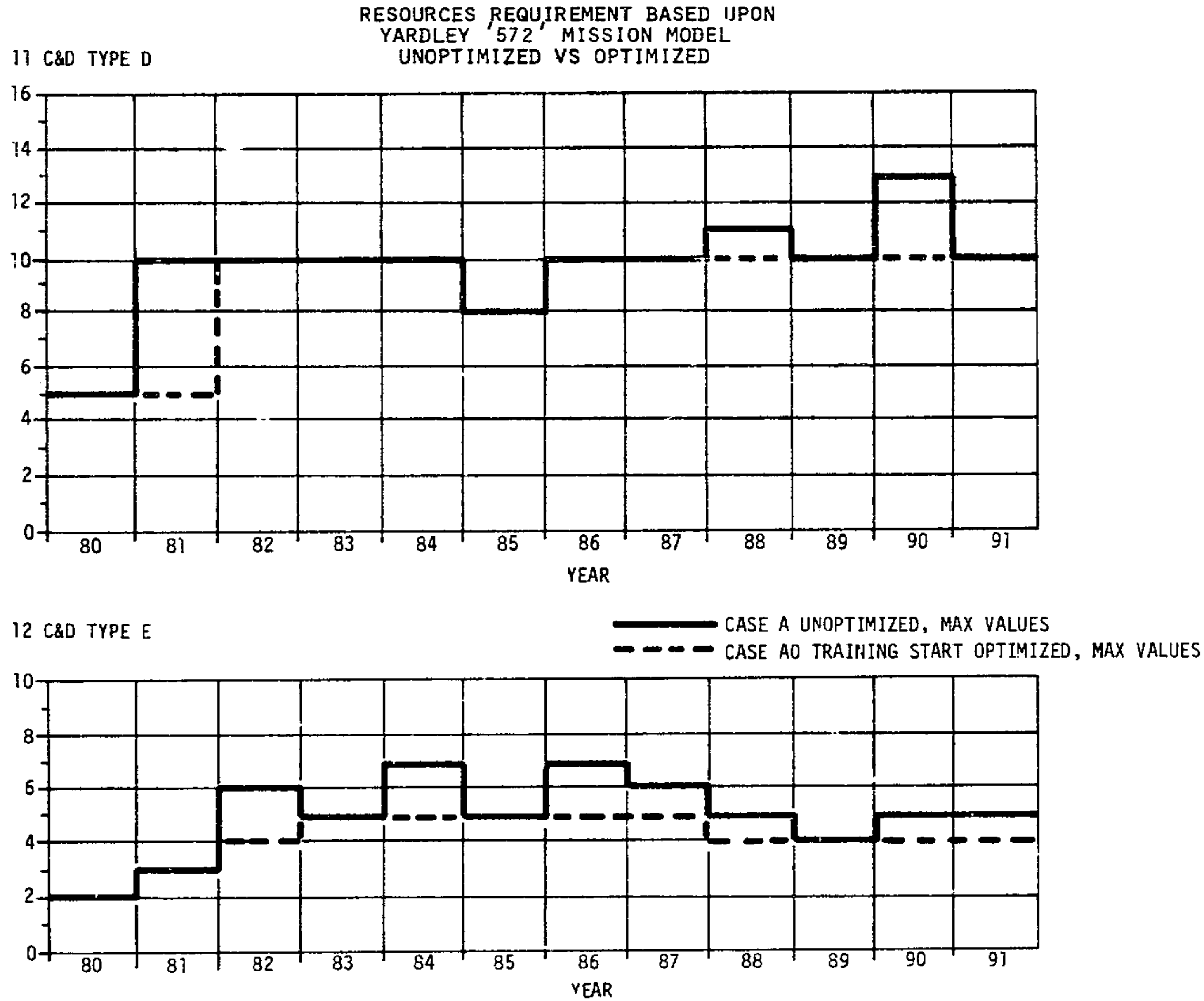

FIGURE 19. MAXIMUM VALUE COMPARISON CASE A AND CASE AØ

3.7.4 Mission Model Complexity Analysis

To assess resource requirement sensitivity to change in mission model complexity, three case studies (B, C, and D) were made, which bound the problem. These cases correspond to an average, minimum and maximum training complexity mission selection respectively.

Each case used the basic training data of Case A, including training time, activity sequence, and resource requirements for the individual mission types. Instead of the Yardley "572" Mission Model, launch rates of four through thirty-two launches per year with equal interval launches were assumed, with mission complexity as the variable.

Case B uses an average Yardley "572" Mission Model complexity. This average complexity was achieved by using the overall ratio of each of the four reference training missions as presented in Figure 13. The ratio of launch types used the totals across the 1980 through 1991 time period. Specific values used were 35/174, 47/174, 35/174, and 57/174 for reference training missions 19, 14, 11 and 10 respectively. The mission type for launch was selected by the resource utilization program based upon these overall launch ratio values. Launch time was based upon equal time between each launch for each of the parametric run years.

Case C assumed that all of the missions launched within the parametric launch rate (4 to 32) were the simple pallet only Mission 10 type. Case D assumed that all the missions within the study were the complex pallet plus laboratory Mission 19 type.

Figure 20 illustrates typical trends in resource requirements for Cases B, C, and D. Requirements for simulation computer access and part task area utilization are shown versus launch rate for the three different mission complexity cases. Values shown are for the 95% value on the cumulative distribution of resource requirements. Some general conclusions which can be made from the results are as follows.

Many of the resource types required are different where mission complexity differs widely. For example, the pallet only Mission 10 does not require use of the CDMS console, racks, airlock, viewport,

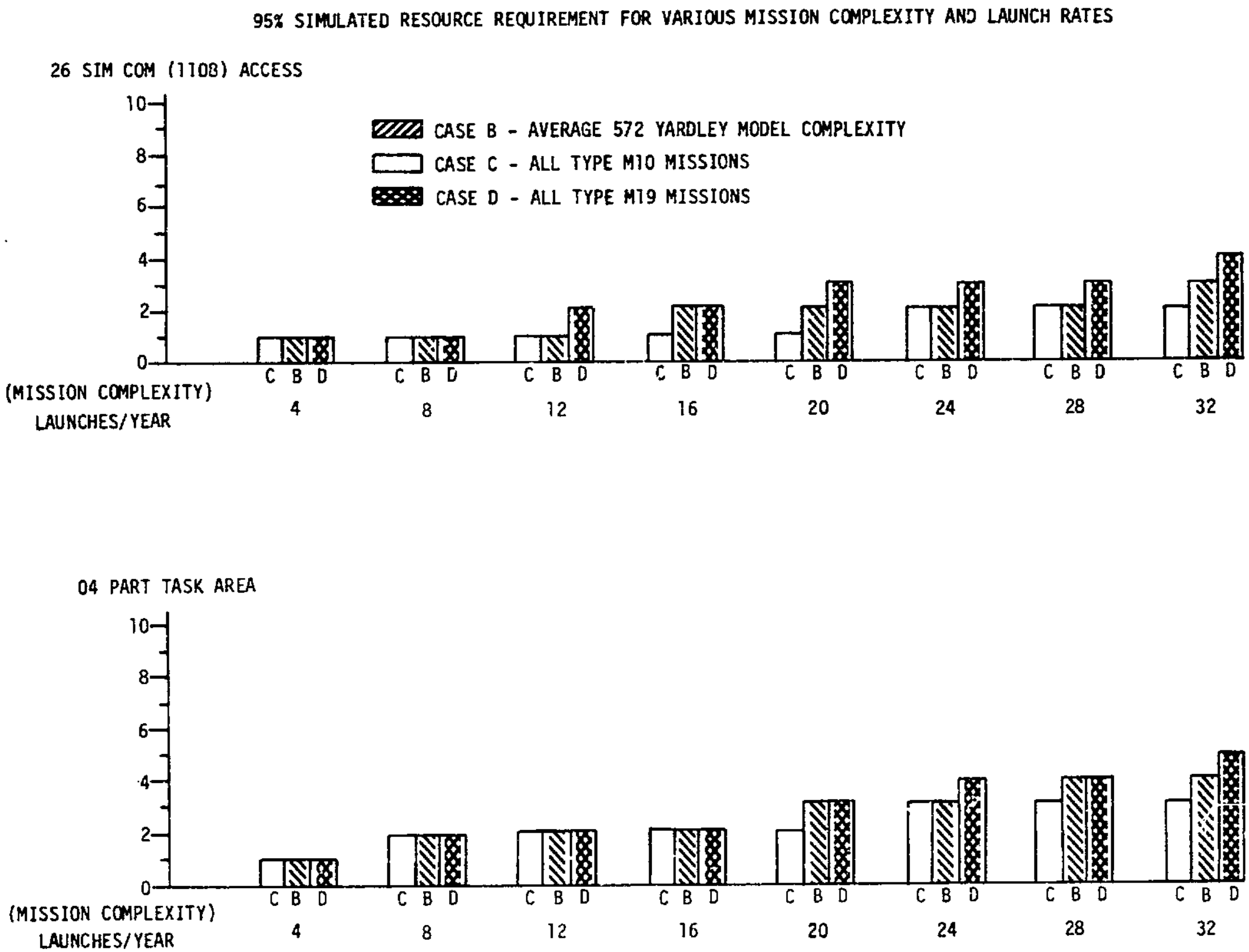

FIGURE 20. 95% CUMULATIVE RESOURCE REQUIREMENT FOR VARIOUS MISSION COMPLEXITY AND LAUNCH RATES

film vault, storage container and racks. The pallet and laboratory Mission 19 type does not utilize the orbiter Payload Specialist Panel. Therefore, a shift in the average complexity of the mission model could significantly impact the number and type of such resources required.

For resources common to Cases B, C, and D at low launch frequencies (of from one to eight launches per year), the resource level appears to be less sensitive to change in mission complexity. For high launch frequencies the resource level becomes very sensitive to the mission complexity. This relationship results from the fact that at low launch rates the "training pipeline" is in the process of being filled up. For the less complex mission model, Case C, using all Mission 10 types, resource quantity is more prone to rise to a given level and remain constant longer.

3.7.5 Efficiency Improvement Analysis

The various factors that influence training efficiency and training cycle time were investigated. The primary factors identified were:

Crewman Learning. The probability that individual crewmen have been previously trained or have flown on a similar mission increases as the flight frequency increases. Application of the classical learning curve may not be applicable even at high launch frequencies because of the following factors.

1) Critical training time tends to be limited by the slowest learner of the team.

2) Flight or mission dependent training by a crewman on a different type mission would not change training time significantly.

3) Loss of proficiency by Payload Specialists between missions takes place.

4) From a classical learning curve standpoint, the number of flights on which a particular crewman will have flown will be small.

Instructional Efficiency and Facility Preparation. Efficiency improvements resulting from evolution in training methods and equipment plus normal learning of support personnel is logical. However, gains in these areas probably will be counterbalanced by increased complexity of experiment equipment and training requirements.

Experiment Complexity. Complexity will probably increase as the payloads become increasingly more involved as technology evolves. As in the case of the former Skylab program the tendency will probably be to perform an increasing number of experiment operations within a given mission. It is felt that the increase in experiment complexity will tend to counterbalance improvement in efficiency of facility preparation and instructions.

Three case studies were used to evaluate possible effects of reduction of training time due to crewman learning. Case B was the same as discussed in the previous section; namely, an average Yardley "572" Mission Model complexity was assumed with launch dates equally spaced during a given year, with no improvement in training efficiency. A launch frequency of 32 flights per year was analyzed.

Case B_2 applied a 95% learning curve to each of the training functions plus facility preparation time, as defined for Case B. The learning curve factor was applied for 32 flights and training times were held constant for a 32 flights per year comparison period. Missions flown during the comparison year were the same for Cases B_2, B, and B_3.

Case B_3 was based upon 80% of the crewmen with previous mission experience or previously trained. Individual times for each training task of the four reference missions were evaluated and assessed. Some tasks were significantly reduced while others were unchanged depending upon the skills and knowledge requirements involved. The training times for all crewmen previously trained and all crewmen untrained are shown on the block diagrams of Figures A-1 through A-4, as defined by Reference 1. To compute an 80% previously trained activity time the following equation was used:

$$0.20\ (NPT) + 0.8(T) = T_A$$

where

NPT	=	Time required for an activity if no crewmen are previously trained
T	=	Time required for an activity if all crewmen are previously trained
T_A	=	Training activity time if 20% of crewmen are untrained, 80% previously trained.

In like manner a comparison period of 32 launches per year was used.

Analysis indicates that the percentage improvement in total average training cycle time over Case B is approximately 22.6% and 20% for Cases B_2 and B_3 respectively. Comparison of maximum values of resource requirements indicates that in both cases maximum values of Case B were reduced with learning; however, the amount of decrease was not uniform for the various resources. In general, resource quantities appear to be more sensitive to change in mission complexity or launch interval than to such reductions in training time. However, sufficient data to accurately evaluate efficiency improvement is not available at this time. Rather the general conclusion reached from the efforts to assess the effect of crewman learning, Cases B_2 and B_3, on resource requirements is that a more general assessment of the effect of changes in training cycle length should be made. By dealing with change in training activity time on a percent of baseline basis, the effect of any combination of factors which influence training system time requirements can be evaluated.

3.7.6 Resource Sensitivity to Training Cycle Length

An analysis was conducted to assess training resource requirement sensitivity to variations in training activity duration.

The training data base used was that defined for Case A, Subsection 3.7.2. The mission model, training sequence, and resource data were the same; only the duration training activity time was varied for each run. All training associated activities including facility preparation were changed by a fixed ratio. Cases were simulated at increased activity training time of +10, +25, +40, and +50 percent of the Case A values. Decreased training activity times of -10, -25, -40, and -50 percent of Case A values were also simulated.

Figure 21 presents representative resource quantity for each year from 1980 through 1991 for the parametric runs Case A, AØ, Case A ± 25% and Case A ± 50%. It should be noted that values are 95% cumulative requirements, not maximum values. Analysis of results indicates that some resource types are more sensitive to change in training cycle length than others. Figures 22 through 24 are representative displays of resource quantity versus training time. A large percentage of resources have a flat segment on the quantity versus training time curve. These flat areas indicate relative areas of insensitivity of resource requirement to changes in training cycle time.

COMPARISON OF 95% TRAINING REQUIREMENTS - PARAMETRIC STUDY

CASE A - SIMULATION OF YARDLEY '572' MISSION MODEL - MSFC MISSIONS
A+50 - ALL TRAINING ACTIVITIES INCREASED BY 50% FROM CASE A TIME
A+25% - ALL TRAINING ACTIVITIES INCREASED BY 25% FROM CASE A TIME
Aϕ - SAME AS CASE A WITH TRAINING START TIME OPTIMIZED
A-25% - ALL TRAINING ACTIVITIES DECREASED BY 25% FROM CASE A TIME
A-50% - ALL TRAINING ACTIVITIES DECREASED BY 50% FROM CASE A TIME

RESOURCE		YEAR & RESOURCE QTY											
		80	81	82	83	84	85	86	87	88	89	90	91
01 CLASSROOM	- A+50%	1	1	2	2	3	2	3	3	3	3	3	3
	A+25%	1	1	2	2	2	2	2	2	2	2	3	2
	CASE A	1	1	2	2	2	2	2	2	2	2	2	2
	Aϕ	1	1	1	2	2	2	2	2	2	2	2	2
	A-25%	1	1	1	1	2	1	2	2	2	2	2	2
	A-50%	1	1	1	1	1	1	1	1	1	1	2	2
04 PT AREA OCCUPIED	- A+50%	1	2	3	3	4	3	4	4	4	3	4	4
	A+25%	1	1	2	3	3	2	3	3	3	3	3	4
	CASE A	1	1	2	2	3	2	3	3	3	2	3	3
	Aϕ	1	1	2	2	2	2	2	2	2	2	2	2
	A-25%	1	1	1	2	2	2	2	2	2	2	2	2
	A-50%	1	1	1	1	1	1	2	2	2	2	1	1
11 TYPE D &C&D PANEL	- A+50%	5	5	5	7	7	7	8	8	10	10	10	8
	A+25%	5	5	5	7	6	5	7	7	7	10	10	6
	CASE A	5	5	5	7	6	5	7	7	7	7	7	5
	Aϕ	5	5	5	7	5	5	7	7	7	7	7	5
	A-25%	3	5	5	5	5	5	5	6	7	7	7	5
	A-50%	3	5	5	5	5	5	5	5	5	5	5	5
12 TYPE E C&D PANEL	- A+50%	1	3	5	5	5	4	5	5	5	4	5	5
	A+25%	1	3	4	4	5	3	4	5	4	4	4	4
	CASE A	1	2	3	3	4	3	4	4	4	3	4	3
	Aϕ	1	2	3	3	4	3	4	4	4	3	4	3
	A-25%	1	2	3	3	3	3	3	3	3	3	3	3
	A-50%	1	2	2	3	3	3	3	3	3	3	3	3
26 SIM COMPUTER ACCESS	- A+50%	1	1	2	2	3	2	3	3	3	3	3	3
	A+25%	1	1	2	2	2	2	2	3	3	2	3	3
	CASE A	1	1	2	2	2	2	2	2	2	2	2	2
	Aϕ	1	1	2	2	2	2	2	2	2	2	2	2
	A-25%	1	1	1	1	2	1	2	2	2	2	2	2
	A-50%	1	1	1	1	1	1	1	1	1	1	1	1
31 RACKS	- A+50%	16	16	32	48	48	32	48	48	48	48	48	41
	A+25%	16	16	22	32	34	32	34	32	32	32	34	32
	CASE A	16	16	32	32	32	32	32	32	32	32	32	32
	Aϕ	16	16	32	32	32	32	32	32	32	32	32	32
	A-25%	16	16	16	18	32	16	32	32	32	32	32	25
	A-50%	16	16	16	16	16	16	16	16	16	16	16	16
35 CONTROL ROOM	- A+50%	1	1	2	2	3	2	3	3	3	2	3	3
	A+25%	1	1	2	2	2	2	2	2	2	2	2	2
	CASE A	1	1	1	2	2	2	2	2	2	2	2	2
	Aϕ	1	1	1	2	2	2	2	2	2	2	2	2
	A-25%	1	1	1	1	1	1	1	2	2	2	2	1
	A-50%	1	1	1	1	1	1	1	1	1	1	1	1
MSFC RELATED MISSIONS		2	5	9	11	15	15	16	18	19	19	21	22

NOTE: THE ABOVE RESOURCE QUANTITIES ARE 95% VALUES AND NOT MAXIMUM i.e. 95% OF THE TRAINING TIME, THE ABOVE QUANTITIES OR LESS ARE REQUIRED

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FIGURE 21. RESOURCE REQUIREMENTS FOR TRAINING CYCLE LENGTH VARIATIONS

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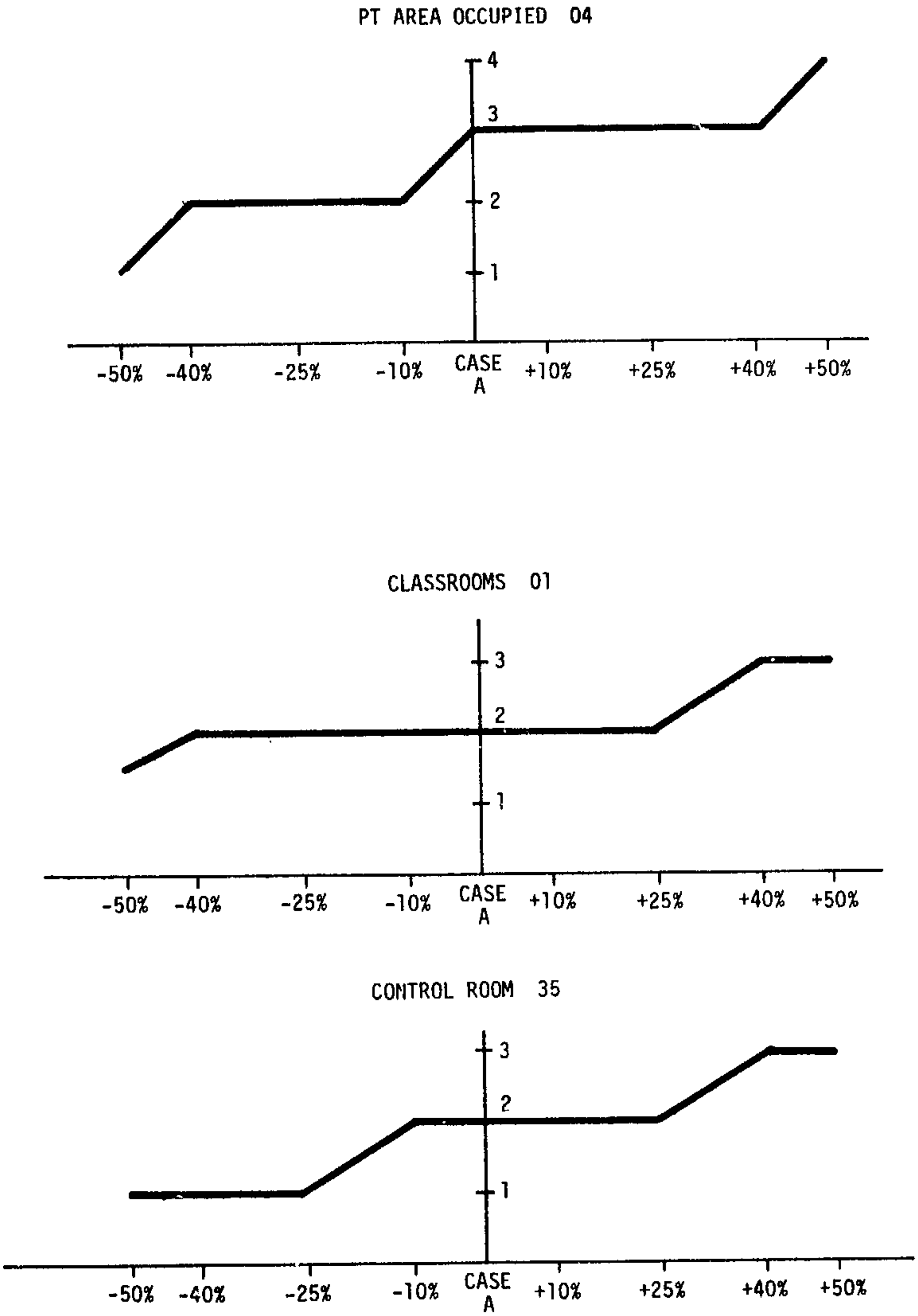

FIGURE 22. MAJOR RESOURCE AREA REQUIREMENT SENSITIVITY TO LENGTH OF TRAINING CYCLE - 1984 TYPICAL

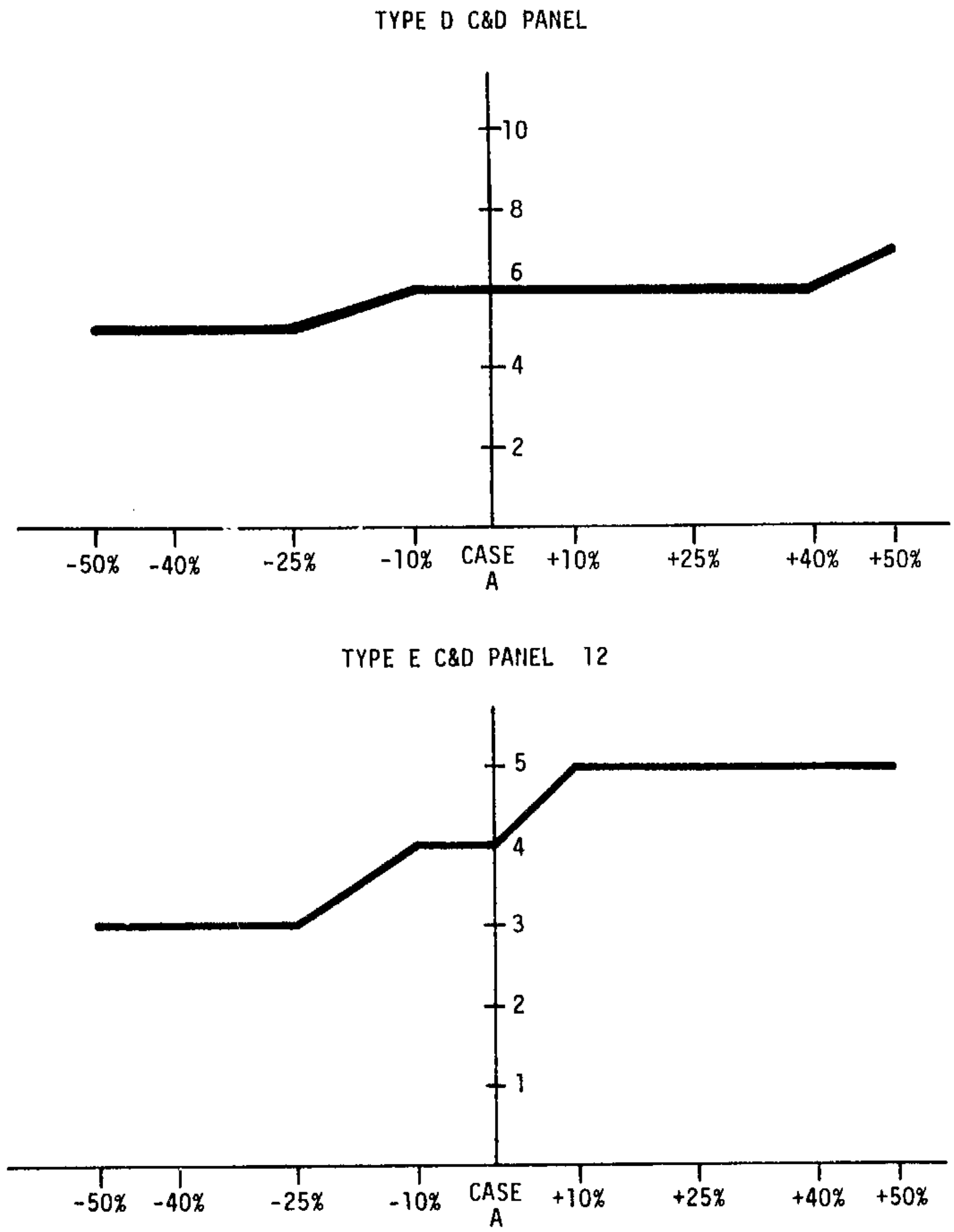

FIGURE 23. RESOURCE REQUIREMENT SENSITIVITY TO LENGTH OF TRAINING CYCLE - 1984 TYPICAL, C&D PANELS

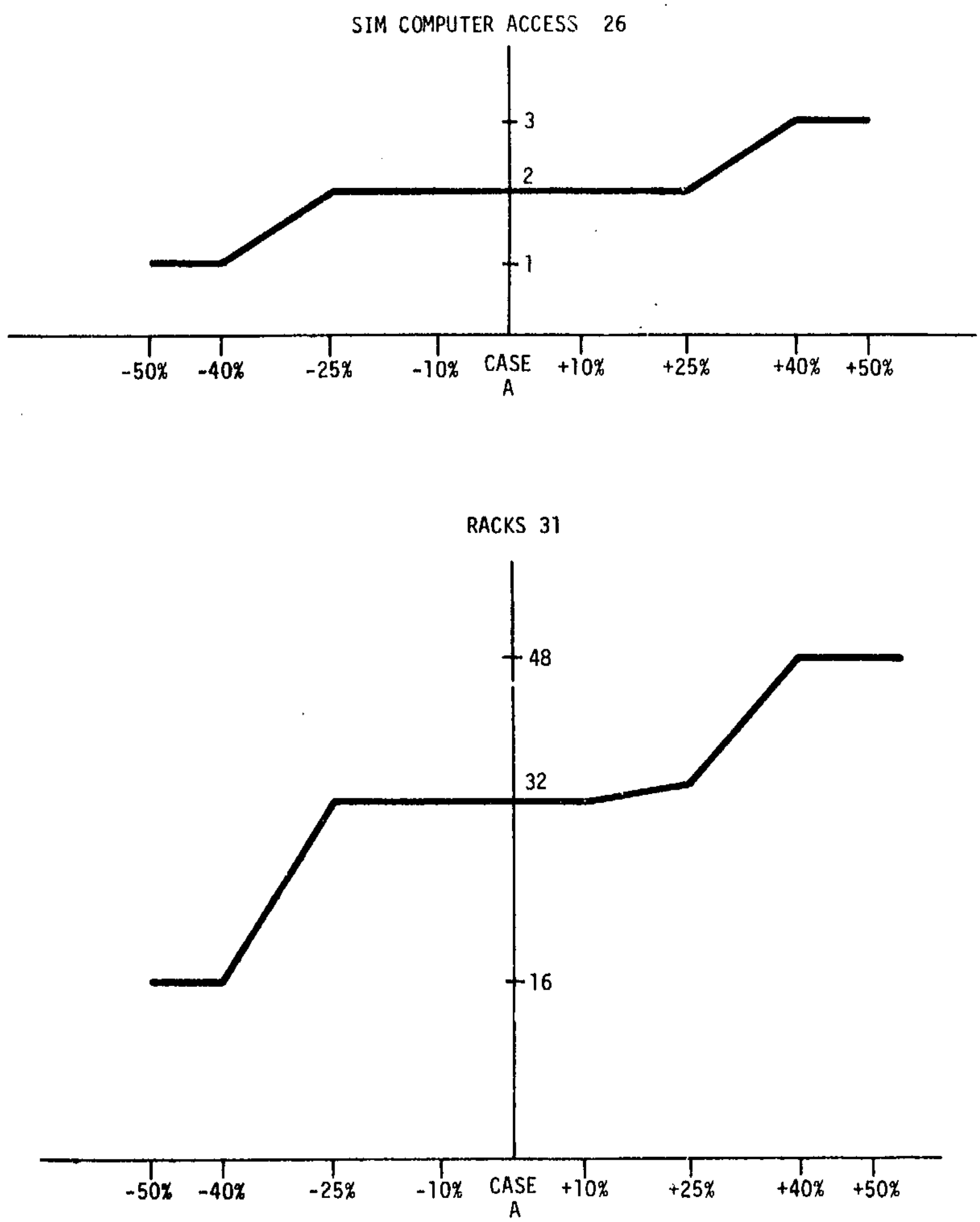

FIGURE 24. RESOURCE REQUIREMENT SENSITIVITY TO LENGTH OF TRAINING CYCLE FOR TWO RESOURCES - 1984 TYPICAL

4.0 CONCLUSIONS

Both within and among missions, schedule sequence is of key importance. The launch schedule and specific mission type selection should:

Be designed to help in smoothing out the peak requirements of resource utilization of ground processing, flight hardware, training, etc.

- Intermixing of mission types should be from an STS resource viewpoint rather than random or controlled by the experimenters.

Parameters that can have a significant influence upon the training thru-put and effectiveness, in addition to actual training time, include the part task area preparation, access to simulation host computer and CDMS computer and the availability of high cost training items such as Payload Specialist Station, CDMS consoles and airlock.

Resource requirement peak values of up to 5% were found to be insignificant, as optimization of training start time alone could remove most such spikes.

Application of anticipated learning efficiency factors to the Payload Specialist training duration has a small impact upon resource requirements.

The 1983 and 1984 early years of the currently used Yardley "572" Mission Model contain a high percentage of complex mission types; therefore, some resource requirements are significantly larger than the number of launches per year would indicate.

The minimum number of key resources required to support mission dependent Payload Specialist training is shown in Figure 25. These values are derived from the optimized case, Case AØ, where the Yardley "572" Mission Model breakout of Figure 13 is assumed.

Further studies dealing with specific rather than typical missions and with more detailed resource definitions will be required to further refine these training resource requirements.

RESOURCE	YEAR & RESOURCE QUANTITY											
	80	81	82	83	84	85	86	87	88	89	90	91
01 CLASSROOMS	1	1	1	2	2	2	2	2	2	2	2	2
04 PART TASK AREAS	1	1	2	2	2	2	2	2	2	2	2	2
06 PAYLOAD SPECIALIST STATIONS	1	1	1	1	1	1	1	1	1	1	1	2
07 CDMS CONSOLES	1	1	2	2	2	2	2	2	2	2	2	2
08 C&D PANEL "A"	1	2	2	2	2	2	2	2	2	2	2	2
09 C&D PANEL "B"	2	2	2	2	2	2	2	2	2	4	4	4
10 C&D PANEL "C"	4	4	6	7	7	7	7	7	7	7	7	7
11 C&D PANEL "D"	5	5	5	7	7	7	7	7	7	7	7	7
12 C&D PANEL "E"	1	2	3	3	4	4	4	4	4	4	4	4
16 SOFT MOCK-UP	1	1	2	2	2	2	2	2	3	3	3	3
18 AIRLOCK	0	1	1	1	1	1	1	1	1	1	1	1
19 WORK BENCH	0	1	1	1	1	1	1	1	1	1	1	1
20 VIEW PORT	0	2	2	2	2	2	2	2	2	2	2	2
21 FILM VAULT	0	1	1	1	1	1	1	1	1	1	1	1
22 STORAGE CONTAINER	0	1	1	1	1	1	1	1	1	1	1	1
26 SIM COM ACCESS	1	1	2	2	2	2	2	2	2	2	2	2
28 CDMS COM ACCESS	1	1	1	2	2	2	2	2	2	2	2	2
30 PERIPHERAL SIM SETS	1	1	1	1	2	2	2	3	3	3	3	3
31 RACKS	16	16	32	32	32	32	32	32	32	32	32	32
32 CCTV	1	1	2	2	2	2	2	2	2	2	2	2
35 CONTROL STATIONS	1	1	1	2	2	2	2	2	2	2	2	2

THE ABOVE RESOURCE QUANTITIES ARE BASED UPON THE 95% REQUIREMENT OF CASE Aϕ
FLIGHT FREQUENCY AND MISSION COMPLEXITY IS BASED UPON THE YARDLEY "572" MISSION MODEL.

FIGURE 25. SIMULATED RESOURCE REQUIREMENT TO SUPPORT MISSION DEPENDENT PAYLOAD SPECIALIST TRAINING

5.0 REFERENCES

1) TMX-64980, "Development and Analysis of a Modular Approach to Payload Specialist Training," January 1976, Jackie Steadman and Harry Watters.

2) MSFC Memorandum EL15 (75-03), "Spacelab Payload Specialist Training Concept Definition," Harry Watters to Distribution, 12 March 1975.

3) MSFC Unnumbered Report, "Summary of Mission 10, Spacelab - Pallet Only High Energy Astrophysics Experiments Deploy Gravity and Relativity Satellite Solar Activity Growth Processes High Speed Interferometer," H. E. Thomason and J. A. McQueen, 16 May, 1975, Preliminary.

4) MSFC Unnumbered Report, "Integrated Mission Planning First Two Years of Shuttle Missions 1970 - 1980," by Program Development, March 1974 (Mission 11).

5) SE012-012-2H, MSFC Report, "Mission 12 Summary - Spacelab Life Sciences Mission Life Sciences Space Laboratory Teleoperator Orbiter Bay Experiment Deploy SEXSAT Satellite," IMAP, July 1975, H. E. Thomason and J. S. McQueen.

6) SE012-013-2H, MSFC Report, "Mission 12 Technical Report - Spacelab - Life Sciences Mission, Life Sciences Space Laboratory, Teleoperator Orbiter Bay Experiment, Deploy SEXSAT Satellite," H. E. Thomason and J. A. McQueen, July 1975.

7) SE012-010-2H, MSFC Report, "Mission 19 Summary - Spacelab - Module and Pallet Atmospheric, Magnetospheric and Plasmas in Space (AMPS), H. E. Thomason and J. A. McQueen, May 1975.

8) MSFC Unnumbered Report, "Mission 19 Technical Report, Spacelab - Module and Pallet, Atmospheric, Magnetospheric and Plasmas in Space (AMPS)," May 1975, H. E. Thomason and J. A. McQueen.

9) "Updated Flight Model for Use in Shuttle, Spacelab and IUS/Tug Procurement and Operations Analysis," 20 September 1974, John M. Yardley.

10) Shuttle Sortie Payload Descriptions, Volumes I and II, July 1975.

11) Training Requirements Data Sheets and Summary Flows, 1975, Unpublished, Provided by H. Watters, MSFC, Systems Analysis and Integration Laboratory.

12) Spacelab Baseline Processing Flow Timeline Allocation, MSFC Drawing Number 40A88004, July 1975.

13) Davis, E. W., Patterson, J. H., "A Comparison of Heuristic and Optimum Solutions in Resource-Constrained Project Scheduling," Management Science Vol. 21, No. 8. April 1975.

14) Burman, P. J. "Resource Budgeting - Chapter 12," Precedence Networks for Project Planning and Control, McGraw Hill.

APPENDICES

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APPENDIX A - BACKGROUND DATA

This appendix contains basic groundrules and assumptions, data for the Spacelab mission types simulated, mission model definition, and training resource descriptions.

In developing the methodology and data with which to analyze the requirements for Payload Specialist training, an in-depth analysis of existing data and supportive documentation was made, from which groundrules and assumptions were formulated and specific data elements defined, as discussed below.

1.0 Groundrules and Assumptions

The basic assumptions utilized in this study are:

1) JSC will perform all mission independent training. This training will include general orbiter and Spacelab system familiarization, housekeeping, habitability, waste management, food management and safety and emergency procedures.

2) Qualification of a Payload Specialist's science expertise and protocol are a user responsibility.

3) Prime and backup crews will be trained in a concentrated block occurring approximately two to three and a half months prior to their scheduled flight date for scheduling consistency.

4) Because of budgetary, spatial and temporal constraints a high fidelity, full-complement trainer for each flight is not feasible. Instead, a part task training concept will be used, as described in Reference 1. This concept uses mobile rack sets and Spacelab trainer segments so that individual and simultaneous training activity can take place. The rack sets and trainer segments may be moved together for use in conducting integrated mission training.

5) Mission dependent training will include:

- Mission familiarization
- Experiment systems familiarization and operation
- CPSE familiarization and operation
- CDMS experiment computer operation through CDMS console or Payload Specialist Station
- Participation in integrated payload operations.

2.0 Spacelab Mission Types Simulated

A major factor in data compilation was the choice of representative Spacelab missions for which sufficient data could be obtained for modeling Payload Specialist training requirements. The mission selection is based upon obtaining missions that have a worst case range of training requirements. Mission complexity variation from simple to very complex is desired to obtain a set of data that would bound the Spacelab training problem.

As a result of analysis of available documentation the missions selected for simulation were:

Mission 10:	Multidiscipline - Pallet Only
Mission 11:	Multidiscipline - Lab and Pallet
Mission 14:	Dedicated - Lab Only
Mission 19:	Dedicated - Lab and Pallet

These missions had been previously defined as discussed in Reference 1, and as given on the Training Requirements Data Sheets, Reference 11. In addition the IMAP documents, References 3 through 8, were used to obtain a thorough understanding of these typical missions.

Figures A-1 through A-4 are flow diagrams of basic training requirements and scheduling constraints for the representative missions. Sequence of training activity was developed using scheduling algorithms discussed in Section 3.6.2 of this report. These representative missions are summarized in the following paragraphs and described in depth in the applicable reference, listed in Section 6.0 of this report.

Mission 10 is a seven-day Space Shuttle flight that has four major Spacelab pallet mounted payloads. The High Energy Astrophysics (HE-11-S) will perform two experiments simultaneously to obtain data on x-ray angular structure and source location. The second payload is the automated Gravity and Relativity Satellite (AP-04-A), which will be deployed on-orbit early in the mission. It will be retrieved on a subsequent flight. The third payload is the High Speed Interferometer (EO-19-S) which will be used to detect and measure atmospheric trace constituents. The fourth payload is the Solar Activity Growth Process (SO-17-S) which will measure phenomena in solar active regions leading to solar flares. Four Payload Specialists are assumed for accomplishing Mission 10. Reference 3 was used as the source of mission definition data. As a pallet-only mission, Mission 10 was selected to provide a representative of a minimum training requirements mission.

Mission 11 is a seven-day Advanced Space Technology mission utilizing the Spacelab laboratory and pallets. This payload will contain unique experiments in the following six disciplines: communication/navigation, earth observations, physics and chemistry, microbiology, components and system testing, and environmental effects. About one-half of the instruments are located in the Spacelab and the rest are located on the pallets. Reference 4, Mission 11 Sortie Mission - Space Technology Laboratory Section, was used for the source of mission definition. Three Payload Specialists were assumed necessary to perform the in-orbit experiments. This mission was chosen for the variety of training requirements encompassed.

Mission 14 used in this study is a Life Sciences mission using Spacelab to conduct a wide range of biomedical research activities. This

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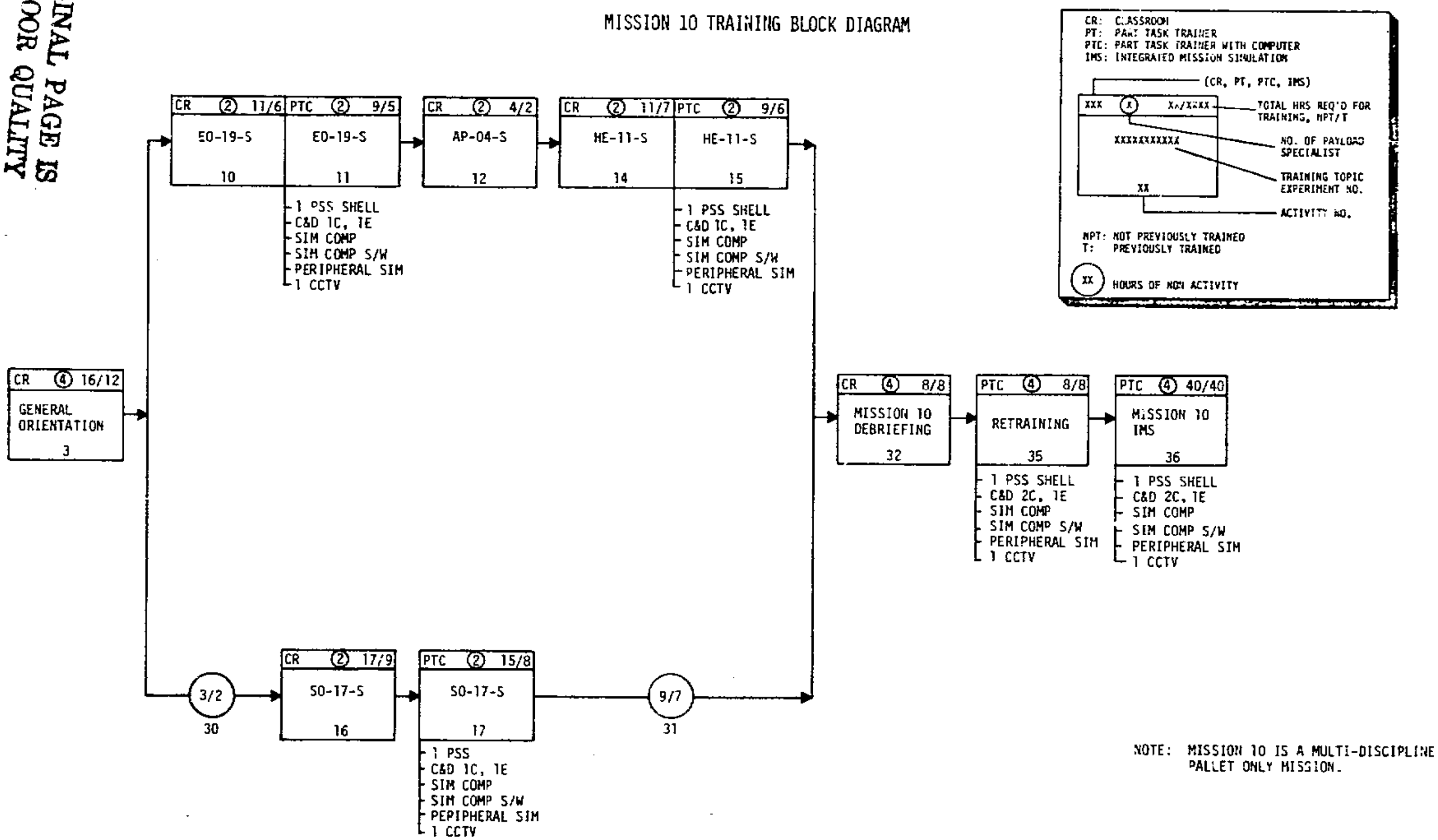

FIGURE A-1. MISSION 10 TRAINING BLOCK DIAGRAM

MISSION 11 TRAINING BLOCK DIAGRAM

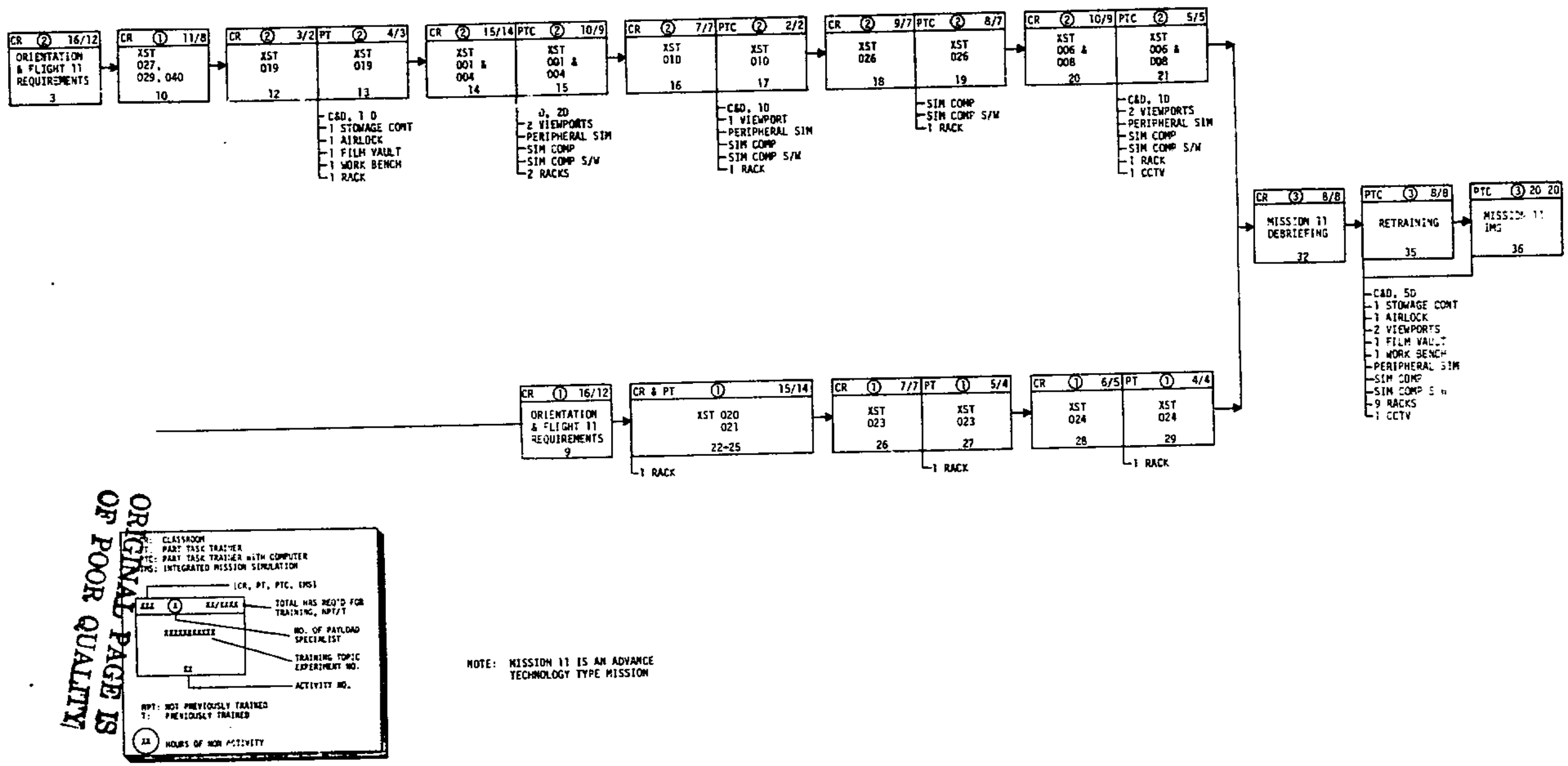

FIGURE A-2. MISSION 11 TRAINING BLOCK DIAGRAM

MISSION 14 TRAINING BLOCK DIAGRAM

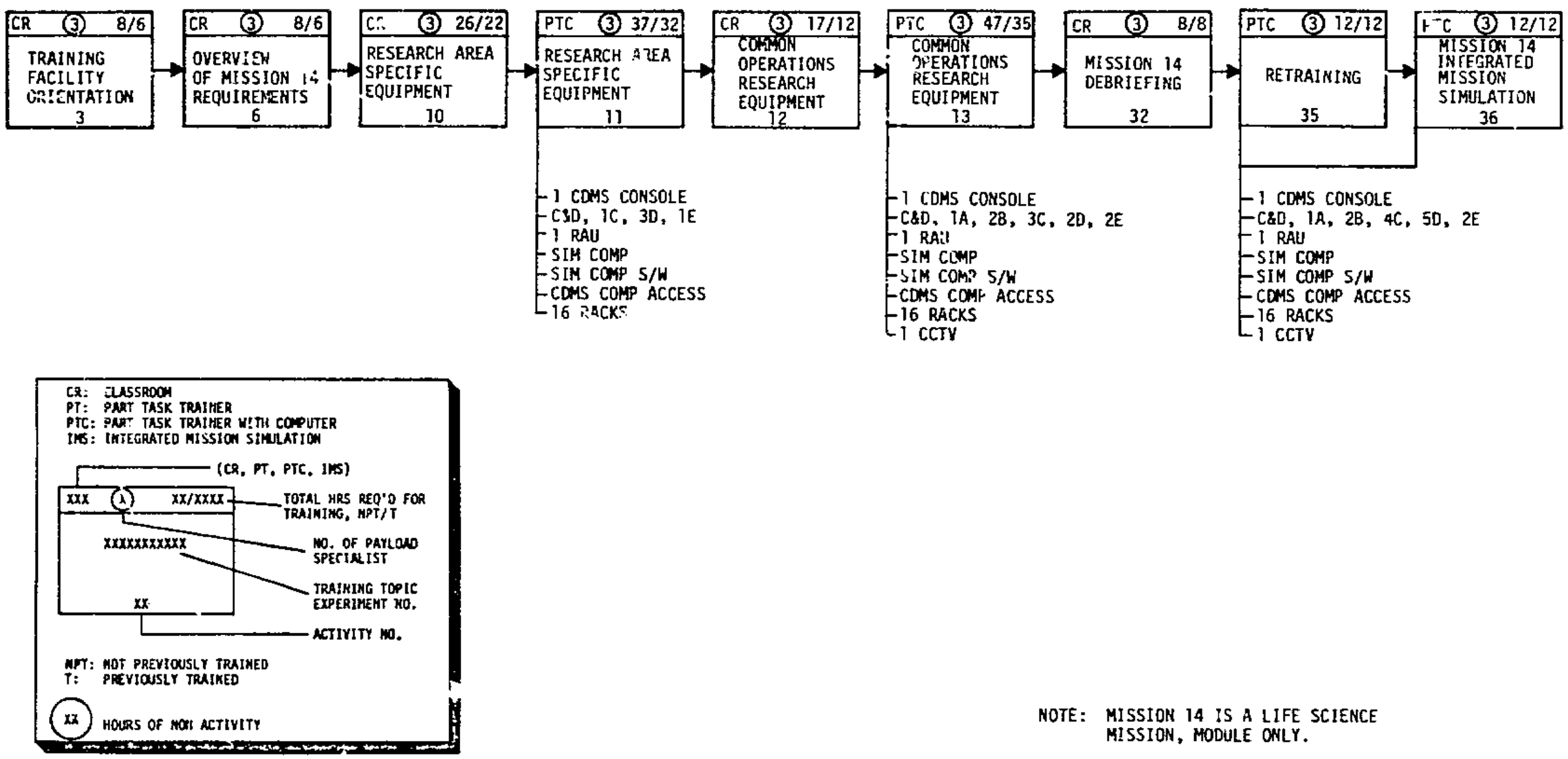

FIGURE A-3. MISSION 14 TRAINING BLOCK DIAGRAM

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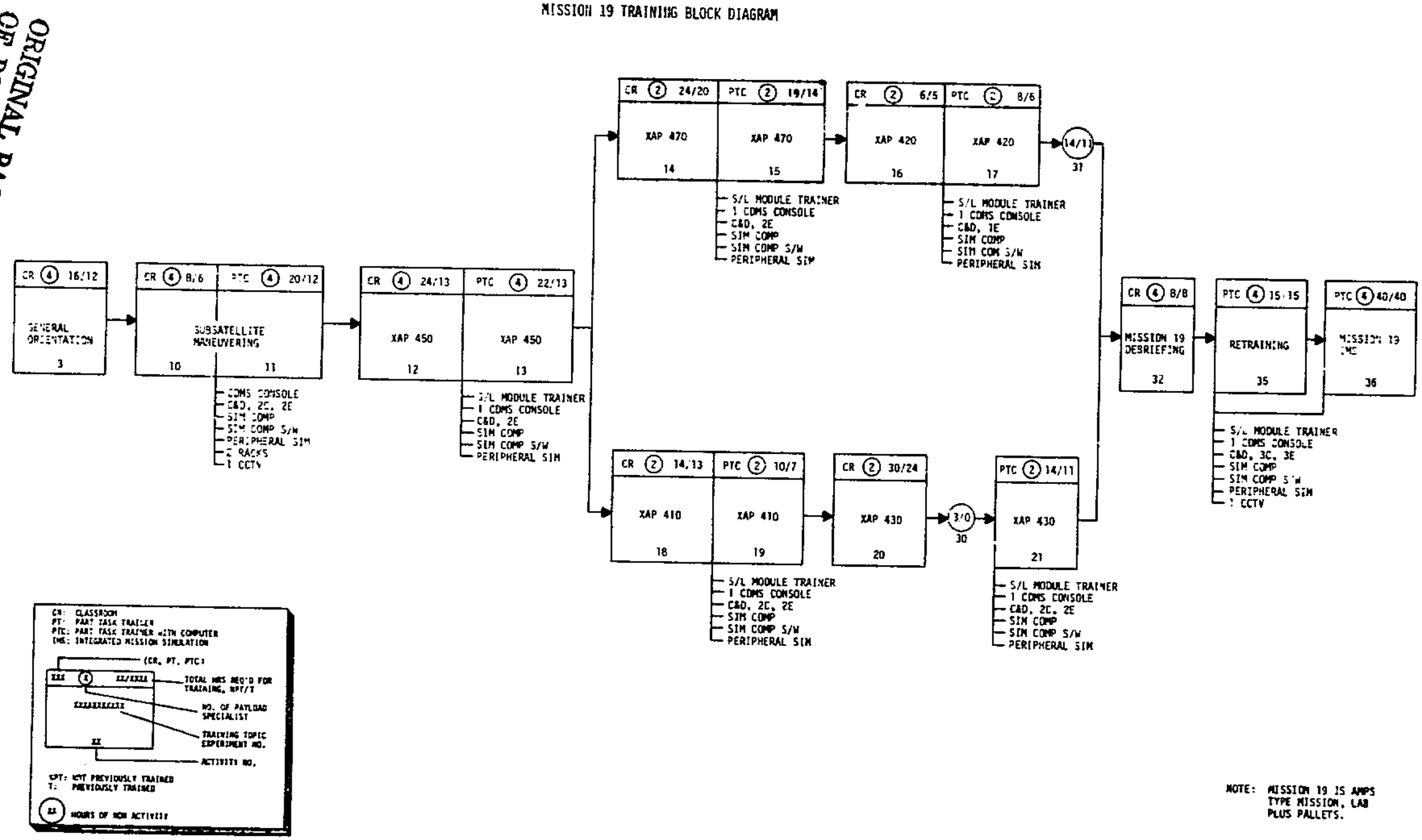

FIGURE A-4. MISSION 19 TRAINING BLOCK DIAGRAM

mission will use live specimens, specifically monkeys, rats, cells and tissue for studying biological response to space flight. Special emphasis will be placed on organic systems previously found to be influenced by gravity. Experiments include the LS-09-S medical emphasis mission, deployable SEXSAT satellite, the free-flying teleoperator to provide repair, refurbishment, checkout, retrieval, etc. Three Payload Specialists are required during this seven-day Shuttle payload mission. The mission defined in References 5 and 6 is designated training mission 14 and used in this study. This mission was chosen due to the unique requirements represented by this Life Sciences mission.

Mission 19 was selected to represent a mission of high complexity from a crew training viewpoint (References 7 and 8). This mission, IMAP Mission 19, is an Atmospheric Magnetospheric and Plasmas in Space (AMPS) type. Investigation will be performed to better understand mechanisms which control the near space environment of earth and the planetary and cometary phenomena. Five primary experiments which require intensive Payload Specialist training are: subsatellite maneuvering, wave characteristics - XAP 410, Wave/Particle Interactions - XAP 420, Wake and Sheath Experiments - XAP 430, Global Emission Survey - XAP 450, and the Magnetospheric Topology Experiment - XAP 470. Four Payload Specialists were assumed for this mission.

3.0 Yardley "572" Mission Model

The Yardley "572" Mission Model, Reference 9 and the Space Shuttle Payload Description (SSPD) Data Sheets, Reference 10, were used as a basis for the description of a typical mix of missions and to support data validation. The Yardley "572" Mission Model was also utilized to define the baseline simulation against which most cases were simulated.

The Yardley "572" Mission Model was designated by John Yardley on 20 September 1974 as the flight model for use in Shuttle and Spacelab program analysis. This designation is in terms of a flight frequency per year for specified payload designation and configuration. From this basis various agencies have interpreted this data to the individual flight requirements definition as presented in Figure A-5. The data as shown in Figure A-5 was used in developing the training interpretation of Figure 13. This data is used by both the MSFC Program Development Office and the MSFC Systems Analysis and Integration Laboratory, Ground Operations Branch.

4.0 Training Resource Description

Major facility/resource areas are classroom, part task area, soft mockup, control room and maintenance and storage area. These resource areas are discussed in Section 3.5.1 of this report.

The following is a brief description with identification numbers, as used in the Resource Utilization Program, of the resources tracked during this study.

06 Payload Specialist Station

The Payload Specialist Station is equivalent to the Payload Specialist work area within the orbiter cabin. CRT and keyboard operations are equivalent to the flight configuration. This station in ludes C&D functions and accommodations for experiment peculiar hardware. One type E C&D panel which interacts with experiments through the CDMS or experiment simulator is included in the PSS.

07 CDMS Console

Command Data Management System (CDMS) Console is made up of a Spacelab rack and two type E C&D panels. The console interacts with the experiments through the CDMS.

08 - 12 C&D Panels

The control and display (C&D) panels were categorized into five types depending upon their design and functional complexity. These C&D panel categories and associated complexity are as follows:

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YARDLEY '572' SORTIE MISSION MODEL

SPACELAB FLIGHTS

RES[1] UTIL PROG CONFIG	MISSION TYPE		CONF.	LAUNCH SITE	FLIGHT DURATION	TYPICAL[2] PAYLOADS	RESOURCES[3]												FLIGHT FREQUENCY[6]														
							PALLET SEG.	RACKS	BASIC MOD	EXT MOD	AFT UTIL BRIDGE	AFT BLKHD	IGLOO	IPS	TUNNEL	PSS PANELS	P.S.[4]	[5] TRN REF M	80	81	82	83	84	85	86	87	88	89	90	91	SUB TOTAL	TOTAL	COMMENTS
P6A7	HIGH	PHY 6A	P	ETR	7	HE-13-S	3				1		1			1	1	NA			H	H	H	H								2	H = HALF A MISSION
P6B7	ENERGY	PHY 6B	P	ETR	7	HE-12-S	2				1		1			1	1	NA			H	H	H	H								2	
P6C7		PHY 6C	P	ETR	7	HE-11-S	2				1		1			1	1	NA				H		H		H	H		H	:		3	RESOURCES ARE ALSO FOR HALF
P6D7		PHY 6D	P	ETR	7	HE-16-S	2				1		1	1		1	1	NA				H		H		H	H		H	H		3	
P6X7		SL-2[8]	P	ETR	7	HE-18-S (IMAP-10)	4				2		1	1		1	2or3	10	1													1	
P6E3		PHY 6E 30	P	ETR	30	HE-18-S	2				1		1			1	1	NA							1	1	1	1	1	1		6	
																			1	0	1	2	1	2	1	2	2	1	2	2	17		
P7A7	AMPS	PHY 7A	C	ETR	7	AP-06-S	3	6	1		1	1			1	1	4	19		1	1	1		1			1	1		1		7	
P7B7		PHY 7B	C	ETR	7	AP-06-S	3	6	1		1	1			1	1	4	19					1		1	1			1			4	
P7C7		PHY 7C	C	WTR	7	AP-06-S	3	6	1		1	1			1	1	4	19				1	1	1	1	1	1	1	1	1		9	
																			0	1	1	2	2	2	2	2	2	2	2	2	20		
L2[illegible]7	LIFE	LS 2 A7	M	ETR	7	LS-09-S		16	1	1		1			1	1	3	14		2	2											4	
L2A3	SCIENCES	LS 2 A30	M	ETR	28	LS-09-S		16	1	1		1			1	1	3	14				2	2	2	2	2	2	2	2	2		18	
																			0	2	2	2	2	2	2	2	2	2	2	2	22		
S2A7	SPACE	ST 2A	C	ETR	7	ST-21-S	2	16	1	1	1	1			1	1	3	11		1	1	1	1	1	1	1	1	1	1	1		11	
S2B7	TECHNOLOGY	ST 2B	C	ETR	7	ST-21-S	2	16	1	1	1	1			1	1	3	11				1	1	1	1	1	1	1	1	1		9	
S2C7		ST 2C	C	ETR	7	ST-22-S	3	6	1		1	1			1	1	3	11					1	1	1	1	1	1	1	1		8	
S2D7		ST 2D	C	ETR	7	ST-22-S	3	6	1		1	1			1	1	3	11								1	1	1	2	2		7	
																				1	1	2	3	3	3	4	4	4	5	5	35		
MU17	MULTI-USER	MU-1	C	ETR	7	IMAP-14	3	6	1		1	1			1	1	3	14		1				1		1		1	1	1		6	
SL-1		SL-1[8]	C	ETR	7	EO-704/CN-701/CN-704/ OP-03-S	1	16	1	1	1	1			1	1	2	14	1													1	
MU27		MU-2	P	ETR	7	IMAP-21	4				2		1	2		1	3	14			1	2	1	1	2	2	3	2	2	2		18	
																			1	1	1	2	1	2	2	3	3	3	3	3	25		
O1AK	MULTI-	OA 1A	C	ETR	7	EO-01-S/CN-05-S/OP-03-S	2	16	1	1	1	1		1	1	1	2	10			1					1		1	1	1		5	
O1AW	APPLICA-	OA 1A	C	WTR	7	EO-01-S/CN-05-S/OP-03-S	2	16	1	1	1	1		1	1	1	2	10					1		1		1	1		1		5	
O1BK	TION	OA 1B	C	ETR	7	EO-01-S/CN-05-S/OP-03-S	2	16	1	1	1	1		1	1	1	2	10				1					1		1	1		4	
O1BW		OA 1B	C	WTR	7	EO-01-S/CN-05-S/OP-03-S	2	16	1	1	1	1		1	1	1	2	10						1		1		1	1	1		5	
S1A7	SPACE PROC	SP 1A	C	ETR	7	SP-14-S	1	16	1	1	1	1			1	1	2	10			1	1	1	1	1	1	1	1	1	1		10	
																			0	0	2	2	2	2	2	3	3	4	4	5	29		
N1AK	EARTH	NND 16A	C	ETR	7	IMAP-14	3	6	1		1	1			1	1	3	NA			1		1		1		1		1	1		6	
N1AW	OBS	NND 16A	C	WTR	7	IMAP-14	3	6	1		1	1			1	1		NA				1	1	1	1	1	1	1	1	1		9	
																					1	1	2	1	2	1	2	1	2	2	15		
N1B7	AST	NND 16B	P	ETR	7	IMAP-21	4				2		1	2		1	3	NA						1		1		1		1	4	4	
[illegible]	SPACE PROC	SP 1B	P	ETR	7	SP-15-S (1/3 FLT)	1									1	2	10			3T	3T	6T	6T	6T	6T	6T	6T	9T	9T		20	T = 1/3 FLIGHTS
N1S7	SPACE MFG	NND 13	P	ETR	7	SP-15-S (1/3 FLT)-	1									1	2	10					3T	3T	3T	3T	3T	3T		3T		7	
																					[illegible]	1	3	3	3	3	3	3	3	4	27		
A001	STELLAR	AST 10A	P	ETR	7	AS-01-S/AS-19-S/AS-14-S	3				3		1	3		1	2	NA		1	1											2	
A002	AST	AST 10B	P	ETR	7	AS-05-S/AS-03-S/AS-19-S	4				2		1	3		1	2	NA				1										1	
A003		AST 10C	P	ETR	7	AS-01-S/AS-19-S/AS-03-S	3				3		1	2		1	2	NA						1								1	
A004		AST 10D7	P	ETR	7	AS-15-S/AS-08-S	2				1		1	2		1	1	NA					1									1	
A005		AST 10D7	P	WTR	7	AS-15-S/AS-08-S	2				1		1	2		1	1	NA						1								1	
A006		AST 10D30	P	ETR	30	AS-15-S/AS-08-S	2				2		1	2		1	1	NA									1					1	
A007		AST 10D30	P	WTR	30	AS-15-S/AS-08-S	2				2		1	2		1	1	NA										1	1			2	
A008		AST 10F	P	ETR	7	AS-07-S	3				3		1	1		1	2	NA							1							1	
A009		AST 10I	P	ETR	7	AS-09-S	2				2		1	1		1	2	NA							1							1	
A010		AST 10J	P	ETR	7	AS-10-S/AS-08-S/AS-04-S	3				2		1	3		1	2	NA								1						1	
A011		AST 10K7	P	ETR	7	AS-20-S/AS-04-S	2				2		1	2		1	TBD	NA								1						1	
A012		AST 10K30	P	ETR	26	AS-20-S/AS-04-S	2				2		1	2		1	TBD	NA											1	1		2	
P013		AST 10L	P	ETR	7	AS-03-S/AS-19-S/AS-10-S	3				3		1	2		1	2	NA												1		1	
A014		AST 10M	P	ETR	7	AS-04-S/AS-08-S/AS-18-S	4				3		1	2		1	2	NA										1				1	
																			0	1	1	1	1	2	2	2	1	2	2	2	17		
SP01	SOLAR	AST 11E	P	ETR	7	SO-01-S	4				2		1	3		1	4	19			1	2	2		1							6	
SP02	PHYSICS	AST 11C7	P	ETR	7	SO-01-S	4				2		1	3		1	4	19						1								1	
SP03		AST 11C30	P	ETR	18	SO-01-S	4				2		1	3		1	4	19							1							1	
SP04		AST 11D30	P	ETR	18	SO-01-S	4				2		1	3		1	4	19								1						1	
SP05		AST 11E 7	P	ETR	7	SO-01-S	4				2		1	3		1	4	19									1		1			2	
SP06		AST 11E30	P	ETR	18	SO-01-S	4				2		1	3		1	4	19									1	1	1	1		4	
																			0	0	1	2	2	1	2	1	2	1	2	1	15		
																	TOTALS IN "WHOLE" FLIGHTS[7]		2	6	12	17	19	21	21	24	24	24	27	29		226	

6-25-75; Revision 7-23-75

1. CONFIGURATION CODE USED TO IDENTIFY THE MISSION TO THE RESOURCE UTILIZATION MODEL; FOR STUDIES IN SUPPORT OF EL-13.
2. PAYLOADS TYPICAL OF THIS MISSION TYPE WERE PROVIDED BY M. ALLEN, PM01, IN WORKING PAPERS, MAY, 1975.
3. RESOURCES AS DEFINED IN MEMC PD31-75-66, "SPACELAB FLIGHT CONFIGURATIONS: FROM PHIL SUMRALL, PD34, JUNE 17, 1975.
4. PAYLOAD SPECIALISTS ASSIGNED FOR THIS FLIGHT TYPE FROM "SUMMARIZED NASA PAYLOAD DESCRIPTIONS, SORTIE PAYLOADS, LEVEL A DATA, [illegible] JULY, 1974.
5. TRAINING REFERENCE MISSION USED FOR TRAINING FACILITY RESOURCE UTILIZATION STUDIES, AS DEFINED BY EL-15, H. WATTERS
6. FLIGHT FREQUENCY DISTRIBUTION AS DEFINED BY M. ALLEN, PM01, IN WORKING PAPERS, MAY, 1975. (TO BE OFFICIALLY RELEASED IN THE NEAR FUTURE).
7. TOTAL SPACELAB FLIGHTS PER YEAR AS DEFINED IN MEMO, "UPDATED FLIGHT MODEL FOR USE IN SHUTTLE, SPACELAB AND IUS-TUG PROCUREMENT AND OPERATIONS ANALYSIS.", FROM M/ ASSOCIATE ADMINISTRATOR FOR MANNED SPACE FLIGHT, JOHN M. YARDLEY, 20 SEPTEMBER 1974.
8. "VERIFICATION FLIGHT TEST REQUIREMENTS; 6-2-75.

FIGURE A-5. YARDLEY "572" MISSION MODEL INTERPRETATION

Type A - Discrete one to ten channels

Type B - Discrete ten or more channels

Type C - Variable meters, gauges, etc.

Type D - Requires computer simulation for feedback

Type E - Requires CDMS; has one keyboard and one CRT.

19 Work Bench

The work bench is intended for use in the core segment, a lab, and is standardized in size in order to support a wide range of experiment work. The work bench has associated drawers and file cabinets. Lighting provisions are provided in a recessed area above the primary working surface.

20 Viewport

The training viewports consist of two panes of 30 cm dia tor safety glass with associated mounting structure. The viewports are interchangeable between the top of the module location and the aft end cone location. In some cases viewport holding fixtures will be used in visual simulations of pallet experiment operations.

21 Film Vault

The film vaults are containers that fit in standard Spacelab racks. The film vaults are modular in design to accommodate different storage requirements for various missions. Each vault has drawers for film cassette location with straight or hinged pullout capability, depending on the vertical location of containers in the Spacelab.

22 Storage Container

The storage containers provide storage space for experiment hardware, spare parts, consumables and other loose equipment. The subcompartment arrangement of these containers will depend upon the specific mission, experiment and stowage plan.

26 Simulation Computer Access

The simulation computer, a Univac 1108 or equivalent, drives the simulation by providing a data stream generated from experiment models or providing the stimulus input to experiment hardware.

27 Simulation Computer Software

Simulation computer software consists of real time stimulus simulation routine, data processing programs and interactive response from trainer consoles. For training resource analysis a requirement for simulation computer software was assumed when the simulation computer was accessed.

28 CDMS Computer Access

The CDMS computer access will be required to process data from experiments and provide information to the Payload Specialist, instructors and control room personnel. The CDMS computer is accessed by the CDMS console, Payload Specialist Station, experiments and training control room.

30 Peripheral Simulation Equipment

Peripheral simulation includes simulation of views out of viewports, pallet operations and orbital operations outside of the orbiter bay.

31 Racks

Racks used for Payload Specialist training will be equivalent in fit, form and function to the flight Spacelab racks. These racks and rack sets are designed for maximum flexibility for accommodating various experiments, support equipment and C&D panels.

32 CCTV

Closed circuit TV capability is desired in experiment training which requires close observation of operations within a confined area.

In addition to these resources the total number of crewmen within the training network was determined and tracked.

APPENDIX B - COMPUTER PROGRAM APPLICATION

To perform the detailed and extensive calculations required to define resource requirements against the various mission mixes, flight frequencies, etc., modeled in this study, a computer simulation was essential. The computer program applied was the Resource Utilization Program developed in support of the Operations Development Division of the Systems Analysis and Integration Laboratory, MSFC.

This program was designed to model the type of resource requirements problems associated with a long-range project using numerous resources. It was still in development when this study was initiated, and thus was adapted as needed to provide the capability required in this study. In addition the Resource Utilization Program has been applied extensively to ground operations requirements studies. Documentation of the model itself is not available, but will be forthcoming.

The Resource Utilization Program is a scheduling and resource analysis program which can process a set of user defined activities or missions as a function of time, as illustrated by Figure B-1. For each mission type, a set of resource requirements must be provided. In addition a mission model scheduling routine or a set of specific launch dates must be supplied to the program. From this set of data, the program calculates, summarizes, and plots the detailed requirement, to the hour, of each resource over the specified time period or mission model. The program has additional options to allow processing of learning curves as defined by the user, to vary calculation time bases, to adjust total time estimates up or down, and to produce reports to the level of detail required by the user.

Figures B-2 through B-5 illustrate some of the types of output produced by the model for each different case processed. The report illustrated by Figure B-2 gives a detailed schedule of start and finish times for each activity in every mission simulated. The report in Figure B-3 contains an hour by hour profile of the level of requirement for

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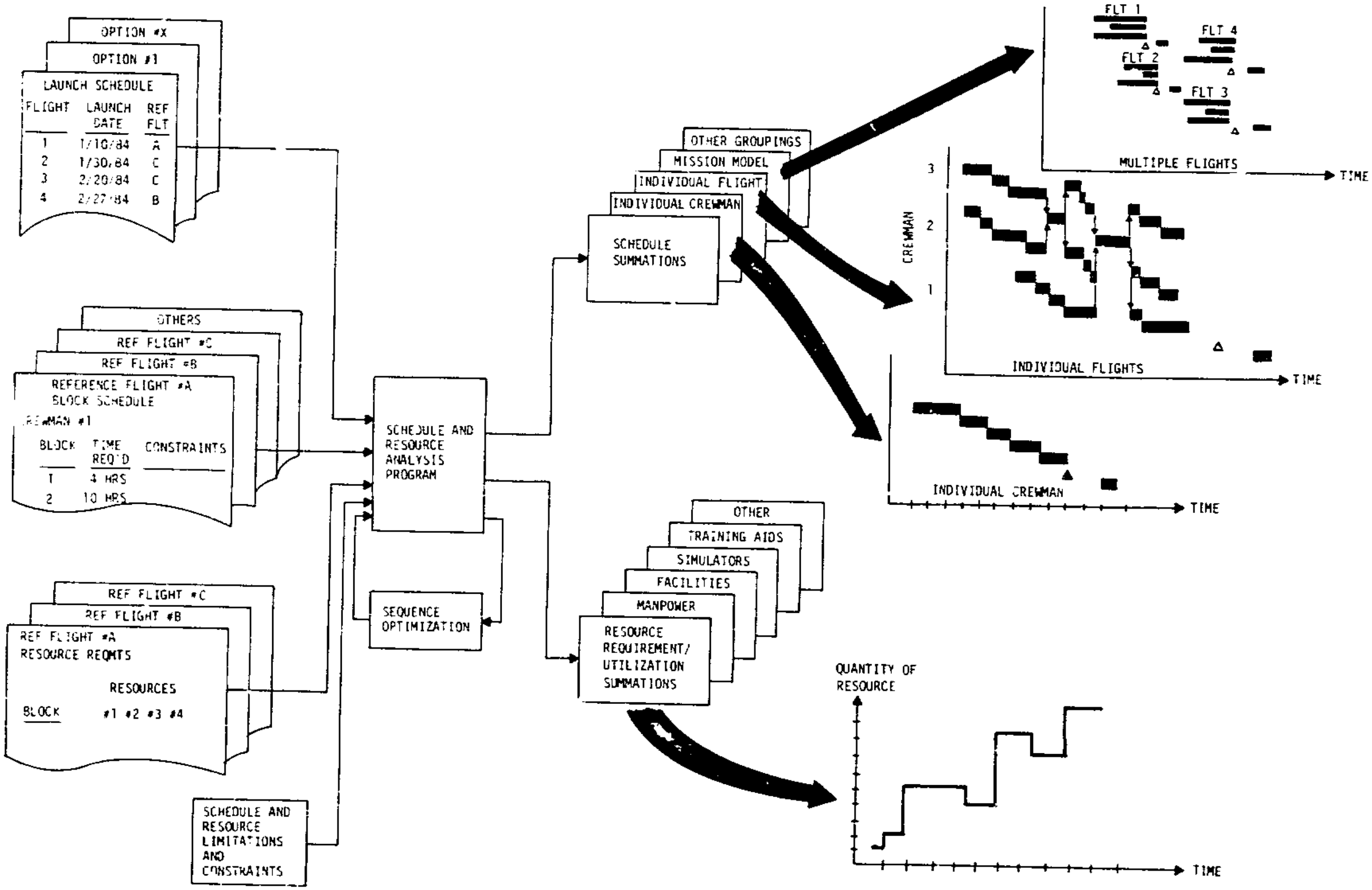

FIGURE B-1. COMPUTERIZED ANALYSIS APPROACH

RESOURCE UTILIZATION PROGRAM (VERSION DATE 082175, REEL 09759)

REPORT 6 PS TRAINING STUDY -CASE AO OPTIMIZED RUN DATE 090375 OGDEN PAGE 87

CALCULATED START/FINISH TIMES FOR EACH FLIGHT SEQUENCED BY START TIME

FLIGHT 109 — BASE EVENT YEAR 1987 TIME — 861 UNITS 2080 HOUR CONFIG M19

TIME BLK NUMBER	LABEL OR ID	TIME BLOCK OR ACTIVITY DESCRIPTION	START YEAR	START TIME	FINISH YEAR	FINISH TIME
7	3.1	FACILITY PREPARATION NON CRITICAL	1987	463	1987	495
3	2.1.1	GEN. ORIENTATION C1	1987	487	1987	503
8	3.2	FACILITY PREPARATION CRITICAL	1987	495	1987	511
10	4.1.1	CR-1	1987	503	1987	511
11	4.1.2	PT-1	1987	511	1987	531
12	4.2.1	CR-2	1987	531	1987	555
13	4.2.2	PT-2	1987	555	1987	577
14	4.3.1	CR-3	1987	577	1987	601
18	4.5.1	CR-5	1987	577	1987	591
19	4.5.2	PT-5	1987	591	1987	601
15	4.3.2	PT-3	1987	601	1987	620
20	4.6.1	CR-6	1987	601	1987	631
16	4.4.1	CR-4	1987	620	1987	626
17	4.4.2	PT-4	1987	626	1987	634
30	4.11	HOLD	1987	631	1987	634
21	4.6.2	PT-6	1987	634	1987	648
31	4.12	HOLD	1987	634	1987	648
32	5.1	TRAINING DEBRIEFING CR	1987	648	1987	656
35	6.2	RETRAINING PT	1987	656	1987	671
36	7.1	INTEGRATED SIM. PARTIC.	1987	671	1987	711

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FIGURE B-2. SAMPLE OUTPUT REPORT - CALCULATED START/FINISH TIMES

```
        R E S O U R C E   U T I L I Z A T I O N   P R O G R A M   (VERSION DATE 082175, REEL 097591

REPORT 7                    PS TRAINING STUDY -CASE AD OPTIMIZED                    RUN DATE 090375      OGDEN  PAGE 322

      CALCULATED RESOURCE REQUIREMENTS

RES          31  RACKS
FOR ALL ACTIVITIES

YEAR   TIME    QNTY
    2080HOUR   REQD

1987    154    17 -----------------
1987    155    18 ------------------
1987    159    16 ----------------
1987    167    11 -----------
1987    187     9 ---------
1987    195     0
1987    211    16 ----------------
1987    233     0
1987    247    16 ----------------
1987    276     0
1987    282    16 ----------------
1987    304     0
1987    312    16 ----------------
1987    367     0
1987    463    16 ----------------
1987    511     2 --
1987    531     0
1987    549    16 ----------------
1987    555    32 --------------------------------
1987    577    16 ----------------
1987    591    32 --------------------------------
1987    597    18 ------------------
1987    617    16 ----------------
1987    620     0
1987    626    16 ----------------
1987    641    32 --------------------------------
1987    648    16 ----------------
1987    656    32 --------------------------------
1987    663    16 ----------------
1987    677    32 --------------------------------
1987    706    16 ----------------
1987    711     0
1987    712    16 ----------------
1987    718    32 --------------------------------
1987    734    16 ----------------
1987    742    32 --------------------------------
1987    797    16 ----------------
1987    803     0
1987    820    16 ----------------
1987    828    32 --------------------------------
1987    867    16 ----------------
1987    875    32 --------------------------------
1987    899    16 ----------------
```

FIGURE B-3. SAMPLE OUTPUT REPORT - CALCULATED RESOURCE REQUIREMENTS

R E S O U R C E   U T I L I Z A T I O N   P R O G R A M   (VERSION DATE 082175, REEL 09759)

REPORT 8   P5 TRAINING STUDY -CASE A0 OPTIMIZED   RUN DATE 090375   OGDEN PAGE 9

RESOURCE UTILIZATION SUMMARY PROFILES

RES   04 PT AREA OCCUPIED
FOR ALL ACTIVITIES

TIME PERIOD FROM (19860000) TO (19862080)

QUANT	TOTAL TIME	PERCENT	CUMULATIVE	MAX TIME	NO OF TIMES
0	245	12	11.8	117	5
1	928	45	56.4	131	17
2	907	44	100.0	149	11

TIME PERIOD FROM (19870000) TO (19872080)

QUANT	TOTAL TIME	PERCENT	CUMULATIVE	MAX TIME	NO OF TIMES
0	190	9	9.1	87	6
1	909	44	52.8	125	19
2	981	47	100.0	162	12

TIME PERIOD FROM (19880000) TO (19882080)

QUANT	TOTAL TIME	PERCENT	CUMULATIVE	MAX TIME	NO OF TIMES
0	61	3	2.9	53	3
1	845	41	43.6	125	18
2	1168	56	99.7	131	17
3	6	0	100.0	5	2

TIME PERIOD FROM (19890000) TO (19892080)

QUANT	TOTAL TIME	PERCENT	CUMULATIVE	MAX TIME	NO OF TIMES
0	127	6	6.1	73	5
1	1010	49	55.7	125	19
2	943	45	100.0	125	15

TIME PERIOD FROM (19900000) TO (19902080)

QUANT	TOTAL TIME	PERCENT	CUMULATIVE	MAX TIME	NO OF TIMES
0	52	3	2.5	29	2
1	633	30	32.9	125	18
2	1385	67	99.5	131	18
3	10	0	100.0	6	2

TIME PERIOD FROM (19910000) TO (19912080)

QUANT	TOTAL TIME	PERCENT	CUMULATIVE	MAX TIME	NO OF TIMES
0	51	2	2.5	17	4
1	797	38	40.9	147	18
2	887	43	83.4	137	15
3	104	5	88.4	104	1

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FIGURE B-4. SAMPLE OUTPUT REPORT - SUMMARY REPORT

R E S O U R C E   U T I L I Z A T I O N   P R O G R A M   (VERSION DATE 101675, REEL 28957)

REPORT 8 TRAINING-CASE A= "572" MISSION MODEL RUN DATE 102175 OGDEN PAGE 80

RESOURCE REQUIREMENTS SUMMARY, REPORT OPTIONS

RES/WORK STA	OPTION	YEARHOUR 19800000 19802080	YEARHOUR 19810000 19812080	YEARHOUR 19820000 19822080	YEARHOUR 19830000 19832080	YEARHOUR 19840000 19842080	YEARHOUR 19850000 19852080	YEARHOUR 19860000 19862080	YEARHOUR 19870000 19872080	YEARHOUR 19880000 19882080	YEARHOUR 19890000 19892080	YEARHOUR 19900000 19902080	YEARHOUR 19910300 19912080
01	90 %	1	1	1	1	2	1	2	2	2	2	2	2
	95 %	1	1	2	2	2	2	2	2	2	2	2	2
02	90 %	3	4	4	7	8	6	8	8	8	8	8	7
	95 %	3	4	7	7	8	7	8	8	9	8	10	8
04	90 %	1	1	2	2	2	2	2	2	2	2	3	2
	95 %	1	1	2	2	3	2	3	3	3	2	3	3
05	90 %	1	1	1	2	2	2	2	2	2	1	2	1
	95 %	1	1	2	2	2	2	2	2	2	2	2	2
06	90 %	1	0	1	1	1	1	1	1	1	1	1	1
	95 %	1	0	1	1	1	1	1	1	1	1	1	1
07	90 %	1	1	1	1	2	1	1	1	1	1	1	1
	95 %	1	1	2	2	2	2	2	2	2	2	2	1
08	90 %	1	1	1	1	1	1	1	1	1	1	1	1
	95 %	1	1	1	1	1	1	1	1	1	1	1	1
09	90 %	2	2	2	2	2	2	2	2	2	2	2	2
	95 %	2	2	2	2	2	2	2	2	2	2	2	2
10	90 %	3	4	4	5	5	4	5	5	6	4	5	5
	95 %	4	4	6	7	7	6	7	7	7	7	6	6
11	90 %	3	5	5	5	5	5	5	5	6	5	5	5
	95 %	5	5	5	7	6	5	7	7	7	7	8	5
12	90 %	1	2	3	3	3	3	3	3	3	3	3	3
	95 %	1	2	3	4	4	4	3	4	4	3	4	3
16	90 %	1	1	2	2	2	2	2	2	2	2	2	2
	95 %	1	1	2	2	2	2	2	2	3	2	2	2
18	90 %	0	1	1	1	1	1	1	1	1	1	1	1
	95 %	0	1	1	1	1	1	1	1	1	1	1	1
19	90 %	0	1	1	1	1	1	1	1	1	1	1	1
	95 %	0	1	1	1	1	1	1	1	1	1	1	1

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FIGURE B-5. SAMPLE OUTPUT REPORT - SUMMARY EXTRACTION each resource, resulting from the composite of all missions occurring in the time span simulated. These profiles are used as the base for the remaining reports and for the plot profiles produced such as Figure 14.

The most utilized report for analysis and comparison of requirements among cases is the summary report illustrated in Figures B-4 and B-5. This summarization report compiles on a year by year basis statistical data on each level of resource requirement. This includes total hours each quantity was required, per cent of total time, cumulative per cent, the single longest time the quantity is required, and the number of seize/release points for the quantity. In addition, program reporting options allow the user to extract key information by a user specified algorithm for further analysis. Figure B-5 illustrates this, where the user requested a report of the level of resources required to satisfy all requirements 90% and 95% of the total time in the year.

The volume of computerized output produced in conducting this analysis was far too extensive for inclusion of all results and supportive output in this report. However, detailed computer output documenting the results cited in this document is available.