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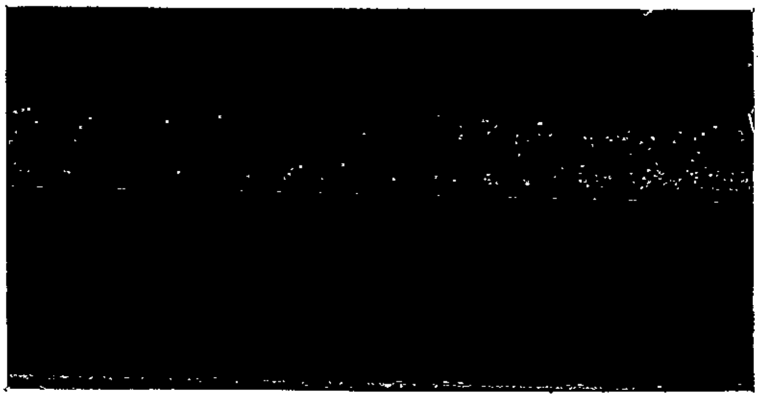

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FLIGHT OPERATIONS PAYLOAD TRAINING
FOR CREW AND SUPPORT PERSONNEL
TASK 3
CONTRACT NAS9-14676
INFLIGHT OPERATIONS AND
TRAINING FOR PAYLOADS

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FOREWORD

This document has been prepared by United Airlines Flight Training Center and the Denver Division of Martin Marietta Aerospace for the National Aeronautics and Space Administration, Johnson Space Center. It is submitted in fulfillment of DRL line item 6 of Contract NAS9-14676 and constitutes the final report for Task 3 - Flight Operations Payload Training for Crew and Support Personnel of the Inflight Operations and Training for Payloads Study. All inquiries and comments should be submitted to:

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I. INTRODUCTION

Participation by the Orbiter Commander and Pilot in payload operation is desirable to accomplish more effective utilization of crew members on STS flights. Normal on-orbit orbiter duties free the Commander and Pilot for considerable periods of time, during which they are available to perform certain payload operations. Using their skills and experience could conceivably reduce the size of the orbiter crew for some STS missions. This reduction in crew size would be extremely beneficial for long missions or when flying heavy payloads. Consumables and waste disposal requirements could be reduced saving both weight and storage space required for additional crewmen and also ease cramped flight deck conditions on multi-discipline pallet only Spacelab flights.

This study examines various degrees of Commander/Pilot involvement in on-orbit operation of payloads. Constraints and limitations resulting from their participation or affecting their ability to participate are identified. Four options, each representing a different set of involvement depths and concepts are analyzed. Options identified are boundaries around extremes in Commander/Pilot payload involvement. Real world choices may fall somewhere in between, but for the purposes of this study the options as represented provide a matrix from which logical and practical decisions can be made about crew participation in payload operations.

Options selected for study are shown in the following Matrix of Study Options. Crews are identified as Generalized or Specialized with high payload involvement and low payload involvement.

	LOW INVOLVEMENT	HIGH INVOLVEMENT
GENERALIZED CREW	OPTION I (BASELINE)	OPTION II
SPECIALIZED CREW	OPTION III	OPTION IV

MATRIX OF STUDY OPTIONS

Option I was selected to be the baseline option from which drivers and constraints could be applied as weighted factors to determine a comparative impact on each of the options.

A Generalized crew would be a Commander and Pilot trained and qualified to participate in on-orbit payload operation on any STS flight (i.e., any crew to any mission/payload). A Specialized crew would be a Commander and Pilot trained and qualified to participate in a certain designated category of missions and payloads.

The degree of payload involvement will be explored for each of these crew concepts, (1) the Generalized crew with low payload involvement, (2) the Generalized crew with high payload involvement, (3) the Specialized crew with low payload involvement, and (4) the Specialized crew with high payload involvement.

The study approach is illustrated in Figure 1, Study Methodology. Detailed development of options, functional categories, drivers, crew functions, and weighted methodology are contained in Appendices I through V. Appendix I, Commander/Pilot Payload Participation Options, defines the Generalized and Specialized crew concepts and specifies generic tasks relative to high and low payload involvement.

Appendix II, Drivers - Constraints and Considerations Affecting Commander/Pilot Training for Participation in On-Orbit Payload Operation, identifies factors which impact upon training the Commander and Pilot to participate in payload operation.

Appendix III, Functional Payload Categorization, identifies and defines specialization of payload categories.

Appendix IV, On-orbit Crew Functions for Payload Operation, identifies and defines the generic payload crew tasks involved with the four options selected for the study.

Appendix V, Weighted Methodology, contains computations for the four study options utilizing weighting factors developed for drivers identified in Appendix II.

Data developed in these Appendices are used in the analysis of the Commander/Pilot involvement in on-orbit payload operations. From this analysis the functional tasks involved with each option are weighed against the drivers and an assessment made using the broad training background and experience of United Airlines. As a result of this assessment a recommendation will be made about each option identifying its applicability and practicability to on-orbit payload operation by the Commander and the Pilot.

STUDY METHODOLOGY

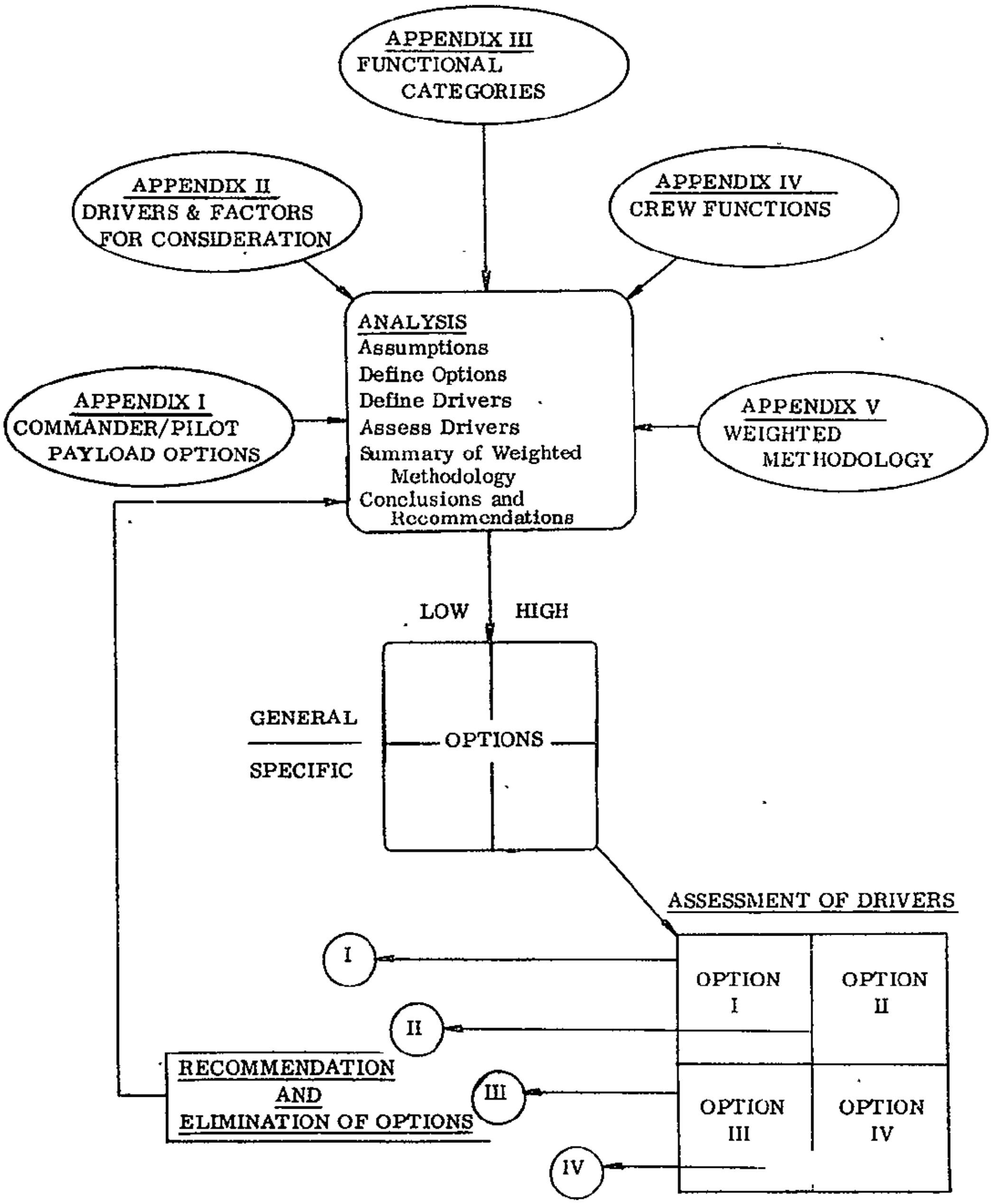

FIGURE 1 - STUDY METHODOLOGY

II. SUMMARY

The objectives of this study were to assess the feasibility of Commander/Pilot participation in on-orbit payload operation, identify the limitations and constraints affecting that participation and determine the impact on crew requirements as a result.

It was determined that from a utilization standpoint Commander/Pilot involvement in payload operation is desirable and for certain crew flight frequencies attainable. Crew involvement options were developed and the impact of crew flight frequencies on these options were assessed. Four options were identified for analysis to test the feasibility of crew participation in payload operation. The four options are:

- Option I - Generalized Crew - low involvement.
- Option II - Generalized Crew - high involvement.
- Option III - Specialized Crew - low involvement.
- Option IV - Specialized Crew - high involvement.

Using various flight frequencies from 1 to 6 flights a year, available training time between flights was identified and a definition of training hour requirements to be accomplished during this available time was developed. Three types of training were identified and a baseline training hour requirement determined for each one.

- Orbiter Recurrent Training
- Flight Specific Training
- Payload Specific Training

Orbiter Recurrent training includes that portion of Commander/Pilot Basic and Advanced training subject to recurring proficiency requirements. Baseline hours for this training were developed by utilizing the recurrent training requirement ratios of airline training and applying them to projected JSC training hour requirements.

The Flight Specific training hour baseline was developed by analyzing generic functional tasks currently identified in JSC projected Flight Specific training hour requirements.

Payload Specific training hour requirements were developed from the training plan for the Life Sciences, Test II, simulation.

Limitations and constraints affecting accomplishment of this training were identified and an adjustment methodology developed to give a weighted value to each one. The weighted factor identified was applied to each constraint associated with each of the four selected options. Using this methodology, between flight training hour requirements were developed for a payload of average complexity and one dedicated discipline requiring training at only one location, for each option. Varying these weighted factors to suit each identified payload will produce a training hour requirement identification to accommodate any STS payload.

An analysis of the effects of crew flight rates and crew specialization as opposed to generalization, on overall crew acquirements was made. Crew specialization into specified payload categories provides the greatest opportunity for Commander/Pilot payload involvement but has insignificant impact on total crew requirements based upon current mission model. This analysis supports a suggested crew flight rate of four flights a year.

III. ANALYSIS

A. GENERAL

Prior to the Space Transportation System program, each manned mission in space was basically a one-flight operation utilizing a great deal of expendible equipment and vehicles. Each mission was unique and training and planning was designed for only one specific mission at a time. The STS program by contrast, is a recurring program utilizing flight crews and equipment over and over again to carry vast numbers of experiments and cargo back and forth into space. As the name implies it is a transportation system.

As a transportation system, it bears a great resemblence to other airborne transportation systems operated by the United States Air Force and commercial airlines. Flight crews will fly the same or similar vehicles on a fairly frequent schedule performing many identical manuevers as their airplane counterparts. Safety of flight is a paramount concern and takes precedence over all other mission objectives. Crews will fly the orbiter into space and back carrying a wide range of cargo, some of which will be left in space for future recovery or sent into deeper orbits or trajectories and expended upon completion of the mission.

There are several significant differences in the STS program that must be considered when comparing it to other airborne transportation systems. These differences present a unique set of conditions that affect training requirements for almost every on-orbit functional task to some degree. Primary differences of an Orbiter flight which impact on the training requirements are:

1) Length of the missions (duration).

2) Support provided by the orbiter vehicle and crew to the payload.

3) The habitat under which the crew must live and work.

4) The payloads are loaded, off loaded, and/or operated by the airborne crew.

Except for these differences, operation of orbiter tasks and procedures required to fly an STS mission closely parallel the airplane operation of other airborne transportation systems. Reference orbiter and airplane training comparison, Figure 2. Flight crew training and qualification requirements necessary to operate the orbiter can be closely compared to the training and qualification requirements demanded of flight crews of other airborne transportation systems.

ORBITER UNIQUE

1. Rendezvous and docking.
2. Deploy and recover payloads.
3. Manage orbiter power and consumables furnished to payload.
4. Habitability procedures.
5. Data acquisition and management.

AIRPLANE/ORBITER COMMON

1. Operation of airplane systems.
2. Communications and navigation.
3. Flight maneuvers and techniques.
4. Approach and landing profiles & procedures.
5. Irregular operation (contingencies).
6. Emergency operation.

FIGURE 2 - ORBITER AND AIRPLANE TRAINING COMPARISON

It is necessary to look at the training and qualifications procedures developed by the other transportation systems to produce a quality product in the shortest possible time. In the airline industry, it is a matter of economics to have the best qualified pilots in the cockpit, and to utilize them effectively to reduce the total number that must be kept on the payroll. Economically, a pilot produces income only when he is flying passengers and cargo. Training time required in classrooms, simulators, and airplanes keep him away from the job of flying and making a profit. A great deal of study and effort has been accomplished by the airlines to reduce training times and costs without sacrificing pilot qualifications and safety.

Airline training has been shortened and training costs reduced by development of training systems utilizing a systems approach. This is not a magic new concept; it is merely a realistic look at the pilot's job and analyzing and identifying behaviors necessary to operate the airplane he will fly in the way you expect him to fly it. After the tasks involved in operating the airplane and its systems are analyzed, specific behavioral objectives (SBO) are developed which identify the task, the stimulus that initiates the task, conditions under which the task is performed, and the criteria of performance (how you know when the task is properly accomplished). Wasting time and money teaching details concerning equipment and systems that the pilot cannot monitor, control, or operate are eliminated from the training program under this concept. Consideration is given to prior training and demonstrated knowledge so that subjects such as theory of flight, basic electricity, hydraulic systems, and theory of jet engines have been eliminated from the training cirriculum. This systems approach to training with emphasis on operation of the airplane and its systems, along with the applications of a more realistic training environments using part task trainers and high fidelity simulators has reduced overall training time as much as 50%.

The ultimate objective of airline pilot training is zero airplane time in training. The costs involved in flying 350 empty seats in a 30 million dollar airplane, around the traffic pattern and at the same time burning 15,000 pounds of fuel an hour are extremely high from an economic point of view. Add to this the environmental and energy shortage impact and the incentives to achieve zero airplane time becomes enormous. Zero airplane time is essentially what flight crews will face in the STS program. The first approach and landing made in the real world environment on a STS mission may be the first time the crew performs the maneuver outside of the simulator. This fact is probably the most compelling reason for development of high fidelity simulation for orbiter crews. There should be other reasons, however. One that is pertinent to this study is the reduction of training time required to qualify crews for STS missions. If the Commander and Pilot are to participate in payload operation beyond providing orbiter maneuvering and support requirements they must be trained and qualified to perform payload experiments. One of the biggest constraints that will influence the ability of the Commander and Pilot to participate in payload operation is to find the time in a busy high frequency flight schedule to train for payload operation.

High fidelity simulators will provide quality training as quickly as any known training device short of the real vehicle. However, they are also expensive and their utilization rates limited by maintenance and modification requirements. Attempts to reduce simulator training time must also be considered. There are two courses of action that will achieve this purpose. Increase the utilization rate by delaying modifications and maintenance (which may in time result in negative training if the simulator fidelity is degraded) or reduce the number of simulator hours required for crew training.

The second objective may be achieved by application of the SBO concept. This procedure will reduce the length of the simulator program by eliminating those things about the flight that a pilot can already accomplish in a proficient manner. It will also identify those tasks which could be adequately trained in less sophisticated part task or procedures trainers. Training of procedural steps necessary to operate orbiter sub-systems in a procedures trainer would make more time available for training in tasks that interface with other orbiter systems that must be done in a high fidelity simulator.

Reduction of the Commander and Pilot Orbiter and Flight Specific Recurrent Training time will allow more time for payload operational training increasing the possibility for Commander/Pilot participation in payload objectives.

B. GROUND RULES AND ASSUMPTIONS

A set of ground rules and assumptions were developed to provide a baseline for accomplishment of this study. Assumptions were made from documentation obtained from NASA and from discussion with various NASA personnel from the training environment and the astronaut office. Alteration of these assumptions will affect the limitations and constraints identified in this study. The basic Commander/Pilot payload involvement concepts discussed in the study will not be affected by changes in these assumptions but the drivers affecting each concept will change.

The following ground rules and assumptions were used to develop the findings and conclusions of this study:

1. DEFINITION OF HIGH AND LOW PAYLOAD INVOLVEMENT

A basic list of generic tasks which identify the concept of high and low payload involvement is shown in Table 1 - Generic Payload Tasks. Some operational payload involvement is included in the low involvement concept. It consists mostly of support to the primary operator of the payloads. In contrast the high involvement concept includes detailed operation, repair, and servicing of payloads.

COMMANDER/PILOT ON ORBIT PAYLOAD INVOLVEMENT	
LOW INVOLVEMENT	HIGH INVOLVEMENT (PRE-DETERMINED EXPERIMENTS)
1. Deploy and activate payloads. 2. Recover and deactivate payloads. 3. Act as subject for experiments. 4. Support Payload contingencies a. Simple repair/trouble shooting. b. Recycle/restart. c. Confirm cable connections d. Component (black box) replacement. e. Assist in checklist accomplishment.	1. Operate individual experiments/payloads or predetermined sequences. 2. Act as subject and observer of experiments. 3. Operate a predetermined subset of experiments. 4. Perform payload contingencies. a. Perform involved repair/trouble shooting. b. Accomplish contingency checklists.

TABLE 1 - GENERIC PAYLOAD TASKS

2. DEFINITION OF GENERALIZED AND SPECIALIZED CREWS

The basic assumption of the study is to consider two types of crews for training - Generalized and Specialized. The Generalized crew would fly any payload and mission type on any flight while the Specialized Crew would perform only flights that contain specific payload/mission types. This definition is developed in detail in Appendix I.

3. ON-ORBIT CREW AVAILABILITY

Normal orbiter tasks do not require the full time participation of the Commander and Pilot. Each crew member will be available to work with the mission and payload specialist in performing payload tasks. Table 2, Commander/Pilot Utilization, illustrates typical daily programmed Commander/Pilot manhour utilization for on-orbit duties during a STS mission.

	AVAILABLE MAN HOURS	ORBITER TASKS & CREW REST	SYSTEMS OVERHEAD	AVAILABLE FOR PAYLOAD OPERATION
COMMANDER	24 Hrs.	12:30	2:00	9:30
PILOT	24 Hrs.	12:30	2:00	9:30
TOTAL	48 Hrs.	25:00	4:00	19:00 Man-Hrs/Day

TABLE 2 - COMMANDER/PILOT UTILIZATION

About 40% of the Commander and Pilot time on-orbit will be available for payload and experiment operation. The following assumptions are made concerning utilization of the Commander and Pilot manhours for payload operation:

a. Orbiter duties will not require participation of both pilots at the same time.

b. Where a crew conflict exists between payload operations and orbiter duties a satisfactory crew activity planning work around can be accomplished; i.e., all crew payload requirements can be accommodated within the total time available constraints.

c. Orbiter requirements can be alternated between Commander and Pilot so one will be available for payload involvement 19 hours each day.

d. Both Commander and Pilot will be available simultaneously 9½ hours each day if payload tasks require participation of two operators.

4. MISSION SAFETY

a. Any on-orbit function, either payload or orbiter which involves safety of flight or inflight maneuvering of the orbiter or payload, will be performed or monitored by the Commander or the Pilot.

b. Contingency or Emergency EVA's will be performed by the mission specialist with the pilot as a back-up.

The implications of these safety assumptions is that the Commander and/or Pilot will be involved any time a rendezvous and docking maneuver is required, a change in orbiter pointin or attitude is made, a payload is removed or installed in the orbiter bay, the orbiter bay doors are opened or closed, or any contingency payload operation is required that the Commander interprets to involve safety considerations.

5. TRAINING CONCEPTS

a. It is assumed that Johnson Space Center will perform all mission independent (Flight Specific) training for all orbiter and payload crews flying STS flights. This training will consist of flight familiarization, Orbiter and/ or Spacelab environmental control and life support systems power distribution, communications, and data management systems, housekeeping, habitability, waste management, food management, safety, and emergency procedures.

b. Mission dependent (Payload Specific) payload training will normally be performed by the payload sponsor, the lead payload center, or the launch site. This training includes mission familiarization, experiment systems and operation, CPSE familiarization and operations, and CDMS experiment computer operation.

c. Multi-discipline mission dependent training will be the responsibility of the lead payload center including Level I, Payload to Orbiter, integration when required.

d. Johnson Space Center will be responsible for STS integrated simulation training for all flights.

e. The Commander and Pilot will receive mission independent (Payload Specific) payload training prior to operating payloads in flight.

f. The Commander and Pilot will perform selected experiments and research required to meet payload objectives for all payloads that they are trained and certified to operate and timelined to accomplish during a particular flight.

g. In a Generalized Crew concept, it is assumed that crews will not fly two consecutive flights with payloads of the same discipline.

APPLICATION OF STUDY

Concepts and task evaluations incorporated in this study pertain to the Commander and Pilot and are not intended to alter the task definitions established for the Mission Specialist and the Payload Specialists.

C. DEFINITION OF OPTIONS

Four options representing varying degrees of Commander and Pilot payload involvement were selected for this study. These options range from a very low on-orbit payload involvement to a relatively high on-orbit payload involvement. All four are considered operationally practical, since on-orbit crew time is available for the

Commander and Pilot to perform in-flight experiments and operate payloads. After assessing the impact of the drivers affecting these options, one or more may be identified as impractical, requiring selection of crew involvement somewhere in between the parameters expressed in these options.

The four options selected involve two concepts of payload participation by the Commander and Pilot. First the crews are identified as either "Generalized" or "Specialized" and second, the degree of payload involvement is termed as either high or low. Table 3, Commander/Pilot Payload Options, is a matrix of these concepts which generates the four options selected for this study. Option I is a Generalized Crew with low payload involvement. Option II is a Generalized Crew with high payload involvement. Option III is a Specialized Crew with low payload involvement, and Option IV is a Specialized Crew with high payload involvement.

CONCEPT	LOW PAYLOAD INVOLVEMENT	HIGH PAYLOAD INVOLVEMENT
GENERALIZED CREW	OPTION I Operates Orbiter on any STS Flight with some minimal payload support.	OPTION II Operates the Orbiter and Payload experiments on any STS Flight.
SPECIALIZED CREW.	OPTION III Operates the Orbiter on Specified Mission categories with some minimal payload support.	OPTION IV Operates the Orbiter and payload experiments in designated mission category.

TABLE 3 - COMMANDER/PILOT PAYLOAD OPTIONS

Definition of generic functions associated with high and/or low payload involvement is contained in the Ground Rules and Assumptions paragraph of this study.

The Generalized Crew Concept implies the Orbiter Commander and Pilot are trained and qualified to fly any STS flight with any STS payload. The crew will face the entire spectrum of payload disciplines and be exposed to all support functions and operational requirements necessary to accomplish the mission objectives of all Orbiter payloads.

The Specialized Crew concept implies that the Orbiter Commander and Pilot are assigned to fly payloads of only certain specifically designated disciplines or categories. This study identifies four specialized categories of STS payloads. Orbiter crews would be assigned and trained to fly STS flights with payloads in their specified category. Payload categories selected for this study are as follows:

CATEGORY I - Spacelab, module or module/pallet combinations.
CATEGORY II - Spacelab, pallet only payloads.
CATEGORY III - Free flyer payloads.
CATEGORY IV - IUS/TUG payloads.

Division of payloads into these four categories was based upon payload flight frequencies, mission objectives, support requirements, orbiter payload interfaces, and identification of homogenous selection of operational tasks. Appendix III, Functional Categories, contains the rationale behind the selection and designation of these four payload categories.

D. DEFINITION OF DRIVERS

Participation by the Commander and Pilot in on-orbit payload operation is influenced generally by two basic drivers. One is making time available during the turnaround interval to train for payload involvement and the other is the number of crews to be trained and the training aids and facilities available for training operational payload tasks. A number of constraints and limitations affect each of these drivers with varying degrees of impact. Each of the limiting factors identified have been considered and the significant items included in the weighted factors applied to the payload involvement options defined in this study Table 4, Limiting Factor Effect on Drivers, identifies which of the limiting factors have an impact on each driver.

LIMITING FACTORS	DRIVERS	
	#1-Available Training Time	#2-Number of Crews to Train
1. SPECIALIZATION VRS. GENERALIZATION	x	x
2. FLIGHT FREQUENCY	x	x
3. PAYLOAD INVOLVEMENT HIGH OR LOW	x	
4. PAYLOAD COMPLEXITY	x	
5. MULTI-DISCIPLINE	x	
6. CONTINGENCY REQUIREMENTS	x	
7. TRAINING LOCATIONS	x	
8. METHODS AND MEDIA	x	x
9. TRAINING LEAD TIME		x

TABLE 4 - LIMITING FACTOR EFFECT ON DRIVERS

Limiting factors listed can be categorized into three groups of considerations. Limiting factors one through three in Table 4 are Option Influences. They are directly related to and created by the Generalized and Specialized Crew concept with high and low payload involvement. Items four through six are Payload Factors, influenced solely by the content and complexity of the payload. Items seven through nine are Training Factors generated by training required for a specific payload involvement option.

Inflight on-orbit time is available to allow Commander/Pilot participation in payload experiments and operation. The most significant constraint affecting this participation is accomplishment of training to qualify the crew to operate the payloads and perform required experiments. This training will be in addition to training required to prepare the crew for the next orbiter flight.

E. ASSESSMENT OF DRIVERS

Availability of training time to qualify the Commander and Pilot to participate in on-orbit payload operation is the driver with the most significant impact when crew involvement with payloads is considered. The degree of involvement is directly proportional to training requirements. The deeper a crew becomes involved with payload operation, greater becomes the training requirements necessary for payload qualification. Factors such as payload discipline and complexity further compound the problem of providing adequate training to qualify the crew for payload operation.

1. FLIGHT FREQUENCY - Flight Frequency has the most significant impact upon training time. Assuming eight available hours in a working day. Table 5, Available Training Hours Computation

Flight Frequency Per Year	Annual Weeks	Less Vacation Holidays In-Flight Operation	Available Weeks	Divided by Frequency	Turn Around Weeks	Times 40 Hours	Avail Turn-around Trng. Hrs. at 8 hrs/day, 5/ days/week
1	52	-(6 + 1) =	45	÷ 1 =	45	x 40=	1800
2	52	-(6 + 2) =	44	÷ 2 =	22	x 40=	880
3	52	-(6 + 3) =	43	÷ 3 =	14	x 40=	560
4	52	-(6 + 4) =	42	÷ 4 =	10.5	x 40=	420
5	52	-(6 + 5) =	41	÷ 5 =	8.2	x 40=	328
6	52	-(6 + 6) =	40	÷ 6 =	6.6	x 40=	264

TABLE 5 - AVAILABLE TRAINING HOURS COMPUTATION

identifies how flight frequency reduces time available between flights to accomplish required turnaround training. Training utilization will determine how much of this available time can be effectively used for training purposes. Table 6, Utilization Versus Flight Frequency, identifies available training hours at 4 hours and 6 hours a day utilization.

	FLIGHT FREQUENCY PER YEAR					
UTILIZATION	1	2	3	4	5	6
4 Hrs/Day	900	440	280	210	164	132
6 Hrs/Day	1350	660	420	315	246	198

TABLE 6 - UTILIZATION VS. FLIGHT FREQUENCY

Higher flight rates leave little time for turnaround training but by the same token higher flight rates require less Orbiter Recurrent training between flights. Training hour requirements used in this study were obtained from the Basic, Advanced, and Flight Specific requirements established in JSC training document, dated 19 March, 1976, and recurrent training hours identified in this study are based upon projections contained in this document.

2. PAYLOAD INVOLVEMENT - Based upon the high/low payload involvement concept of this study the second most significant factor affecting utilization of training time is the degree of Commander/Pilot involvement with on-orbit payload operations. The low involvement concept envisions minimal flight crew participation in payload operation. They will possess enough payload knowledge and experience to assist the Payload Specialist or the Mission Specialist in payload operation and to participate in contingency operations affecting safety of flight or accomplishment of mission objectives. High payload involvement envisions actual on-orbit payload or experiment operation on the same basis as the Mission or Payload Specialists, for specified subsets of the experiments. This concept would parallel experiment operations accomplished on previous space missions where the astronaut performed experiment tasks for the scientific community. The flight crew would be limited to only on-orbit payload functions and to pre-planned payload operations for which they are trained and certified. Greater involvement with more payloads will increase training requirements necessary to train the Commander and Pilot in payload operation utilizing a greater share of available turnaround training time.

3. PAYLOAD DISCIPLINES AND COMPLEXITY - The scientific discipline of the payload and the scientific disciplines of the Commander and Pilot will have an impact on training for operation of the payload. This study concerns itself primarily with on-orbit operational tasks involved with payload operation. Those payloads containing experiments or tests which require profound knowledge in a scientific discipline foreign to the Commander and/or Pilot should be disregarded from consideration for flight crew involvement. Training time required to qualify the flight crew to perform tasks involved with these payloads is not available during turnaround training for the next flight.

Multi-discipline payloads introduce a possible requirement for training in more than one scientific discipline if the Commander and Pilot become involved with a high degree of payload operation. These payloads must be evaluated and flight crew participation limited to those experiments that are compatible with the crew background, or for which they can be trained and qualified in the available turnaround training period between flights. High payload involvement on multidiscipline flights may require that the high involvement be directed at only the one discipline most compatible with flight crews' prerequisite skills and experience.

Payload complexity will also increase training time required to qualify the flight crew for participation in payload operation. Training for complex payload operation will not only be more intense but media and methods required to develop complicated behavioral patterns will be more sophisticated. Some complex payloads may require manipulative skills on the part of the operator to accomplish required operational tasks. In addition, the operational objectives may involve some recall, discrimination and problem solving. Each of these considerations or requirements involves a different type of behavioral performance.

a. Training Considerations - Whenever there is essential information about a system or discipline that the crew really "needs to know" to operate it, and the information is not obtained from any outside stimulus, the crew must depend upon recall. If the recall involves following a set of precise steps in a procedure or task, recall may be based upon a sequencing or chaining order of events. If knowing what to do is more important than knowing how to do it, then recall is the principal type of performance.

   Discriminative learning requires the crew to differentiate between two or more things. It may be the correct indication on a gauge or scope compared to several wrong indications. It may be a proper indicator light response to the positioning of one or more switches.

   Problem solving requires the crew to compute the best way to accomplish a task when presented with symptoms or cues. It may also involve development of inflight data using prepared checklists or formulas.

   Recall, discrimination, and problem solving training may be accomplished with low fidelity trainers and mock-ups or in a classroom environment. More effective training results are normally obtained, however, if the training device simulates the actual work environment. Use of cockpit procedures trainers or work station procedures trainers will be more productive and help reduce time required to train to end level proficiency.

   Manipulative skills are most effectively developed in high fidelity simulators designed to represent the real environment and programmed to respond to manipulation with the same feel, rates, indications, and reactions as the real vehicle. Complex payload operations requiring a high degree of manipulative skills will not only require more time to train but also a higher degree of simulation to achieve end level performance objectives. Flight crew participation in payloads requiring complex manipulative skills may be limited by availability of turnaround training time and simulators.

b. Impact on Drivers - Multi-discipline payloads and complex payloads support the Specialized Crew concept. Crews flying payloads in a designated category can be trained to become more deeply involved in the discipline and more qualified to perform complex payload functional tasks in the time frame provided by the crew flight rate. Flight Specific and Payload Specific training can be directed towards the Specialization category during each turnaround. If the assumption that Generalized crews will not fly the same payload discipline consecutively, then entirely new training requirements exist before each successive flight unless the Specialized Crew concept is utilized. Multi-discipline payloads will be flown within specialization categories, such as Spacelab. High involvement by the Commander and Pilot in these payloads must be limited to designated subsets of experiments for which traininа time compatible to the crew flight rates.

4. CONTINGENCY TRAINING - Training for contingency operation of payloads is directly proportional to the degree of flight crew involvement. All crews regardless of their degree of involvement will be trained in contingency operation of experiments and payloads that affect safety of flight. Checklists and procedures outlining correct contingency actions need to be developed for all safety of flight considerations, and crew proficiency determined during Flight Specific training before each flight. In a high payload involvement concept the Commander and Pilot will be trained to perform contingency procedures and tasks necessary to assure successful accomplishment of the payload objectives. Payloads composed of many experiments with multiple objectives will require additional contingency training for each individual payload component with the high involvement concept. This additional contingency training should be identified and separated from normal payload operations training if contingency operation is considered a driver affecting overall payload training requirements.

5. TRAINING LOCATION - Location of training sights will impact total training requirements from the standpoint of time lost to travel and sequential timing of training events required to meet training schedules at more than one location. It is not necessarily considered a constraint for the low payload

involvement concept because required payload operational training to satisfy this concept can be accomplished during Flight Specific and Payload Specific training primarily at JSC.

Looking at the high payload involvement concept, the Commander and Pilot will need to be trained at the lead or host payload center to become proficient in operation of the payload. Unless the lead payload center has established training programs to accomplish all training for multi-discipline payloads, flight crews may require training at several payload centers or contractor facilities. This will cause serious degration of training schedules and limit time available for payload training for options which require the most training.

F. SUMMARY OF WEIGHTED METHODOLOGY

Appendix V of this study develops a method to assign weights to several factors that influence training hour requirements for the four options studied. This methodology is employed to estimate the training hours required in the absence of firm training plans for each option.

Several factors were found to influence the hours required to train the Commander and Pilot. These factors are:

- Generalized vs. Specialized Crew
- High or Low Payload Involvement
- Payload Complexity
- Multiple Payload Disciplines
- Contingency Operation Involvement
- Training Locations

These factors are applied only to Flight Specific and Payload Specific requirements as it is believed that the Orbiter Recurrency training is a firm requirement not subject to the impact of specialization or payload involvement.

1. Weighted Factors - Appendix V provides background and development data of weighted factors used in this study to determine turnaround training hour requirements. Table 7 summarizes this data for Generalized crews and Table 8 for Specialized crews.

2. Training Hour Requirements by Option - Weighted factor adjustments were made to the baseline training hour requirements described in Appendix V, and a summary of training hour requirements by flight frequency for each of the four study options was developed in Figures 3 through 6.

CONSIDERATIONS	OPTION I - LOW PAYLOAD INVOLVEMENT: Flight Spec	OPTION I - LOW PAYLOAD INVOLVEMENT: Payload Spec	OPTION II - HIGH PAYLOAD INVOLVEMENT: Flight Spec	OPTION II - HIGH PAYLOAD INVOLVEMENT: Payload Spec
I OPTION INFLUENCES CREW: GENERALIZED	1	1	1	1
PAYLOAD INVOLVEMENT				
LOW	1	1		
HIGH			1	2.0
II PAYLOAD FACTORS				
PAYLOAD COMPLEXITY				
LOW	.8	.8	.8	.8
NORMAL	1	1	1	1
HIGH	1.5	1.5	1.5	1.5
MULTIPLE PAYLOAD FACTORS				
DEDICATED	1	1	1	1
MULTIPLE	1+(.1)(# of additional disciplines)	1+(.1)(# of additional disciplines)	1+(.1)(# of additional disciplines)	1+(.1)(# of additional disciplines)
III TRAINING FACTORS				
CONTINGENCY OPERATION	1	1	1	1.2
TRAINING LOCATION				
JSC	1	1	1	1
MULTI-CENTER	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)

TABLE 7 - WEIGHTED FACTORS FOR GENERALIZED CREWS

SPECIALIZED CREW CONCEPT

CONSIDERATIONS	OPTION III - LOW PAYLOAD INVOLVEMENT Flight Spec	OPTION III - LOW PAYLOAD INVOLVEMENT Payload Spec	OPTION IV - HIGH PAYLOAD INVOLVEMENT Flight Spec	OPTION IV - HIGH PAYLOAD INVOLVEMENT Payload Spec
I OPTION INFLUENCES				
CREW (3 Flts or Less)	.7	.7	.7	.7
(Over 3 Flts/Year)	.6	.6	.6	.6
PAYLOAD INVOLVEMENT:				
LOW	1.0	1.0		
HIGH			1.0	2.0
II PAYLOAD FACTORS				
PAYLOAD COMPLEXITY				
PAYLOAD CATEGORY				

	I	II	III	IV
Low			.8	.8
Normal		1		
High	1.5			

CONSIDERATIONS	OPTION III Flight Spec	OPTION III Payload Spec	OPTION IV Flight Spec	OPTION IV Payload Spec
MULTIPLE PAYLOAD FACTORS				
DEDICATED	1	1	1	1
MULTIPLE	1+(.1)(# of additional disciplines)	1+(.1)(# of additional disciplines)	1+(.1)(# or additional disciplines)	1+(.1)(# of additional disciplines)
III TRAINING FACTORS				
CONTINGENCY OPERATION	1.0	1.0	1.0	1.2
TRAINING LOCATION				
JSC	1.0	1.0	1.0	1.0
MULTI-CENTER	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)

TABLE 8 - WEIGHTED FACTOR FOR SPECIALIZED CREWS

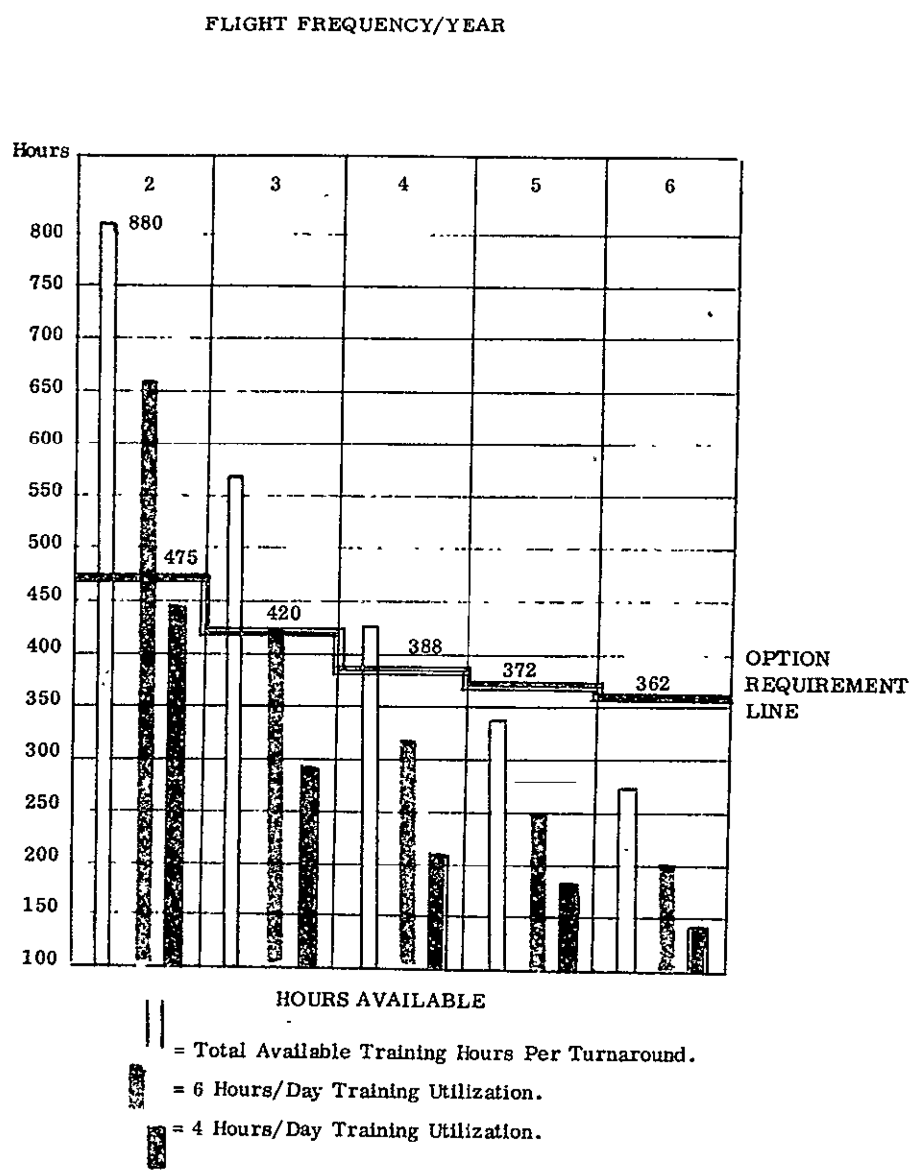

FIGURE 3 - TRAINING HOUR REQUIREMENT VRS. AVAILABILITY - OPTION I

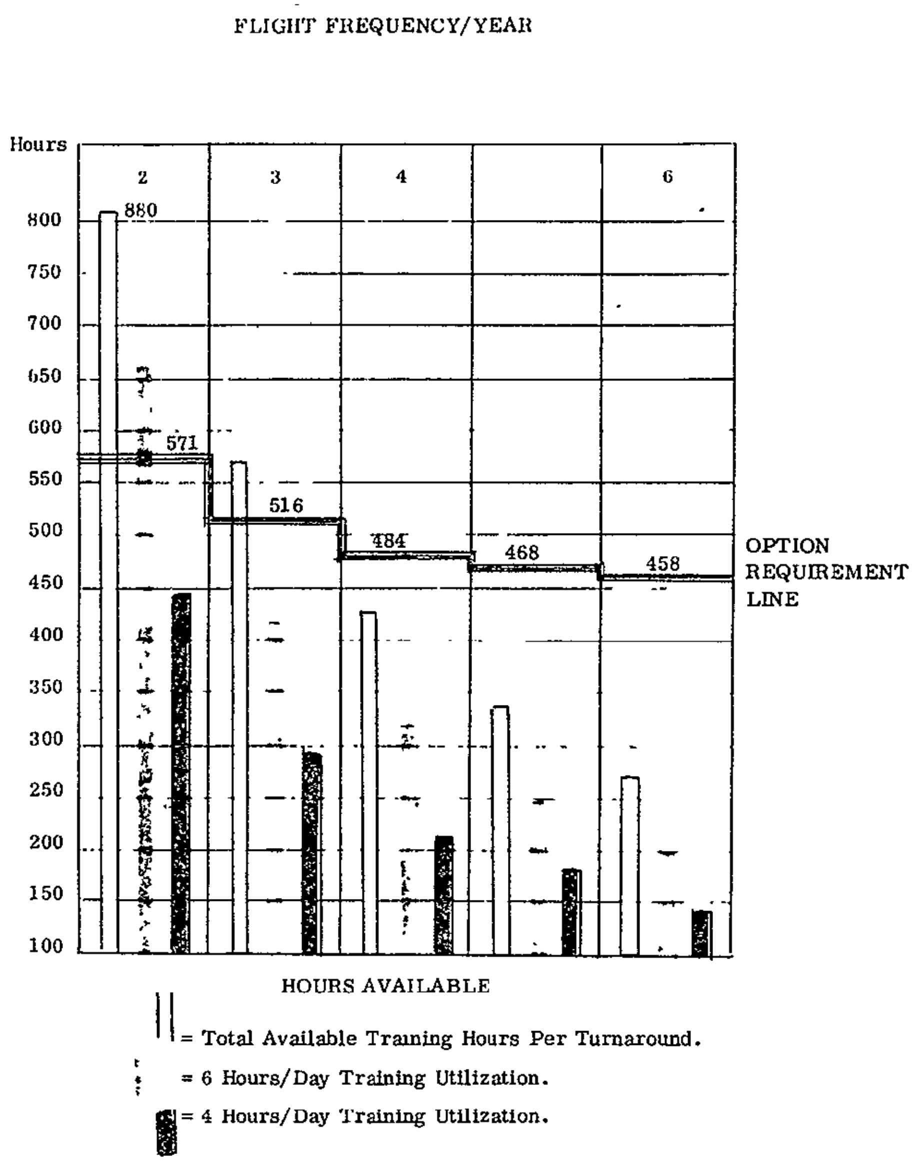

FIGURE 4 - TRAINING HOUR REQUIREMENT VRS. AVAILABILITY - OPTION II

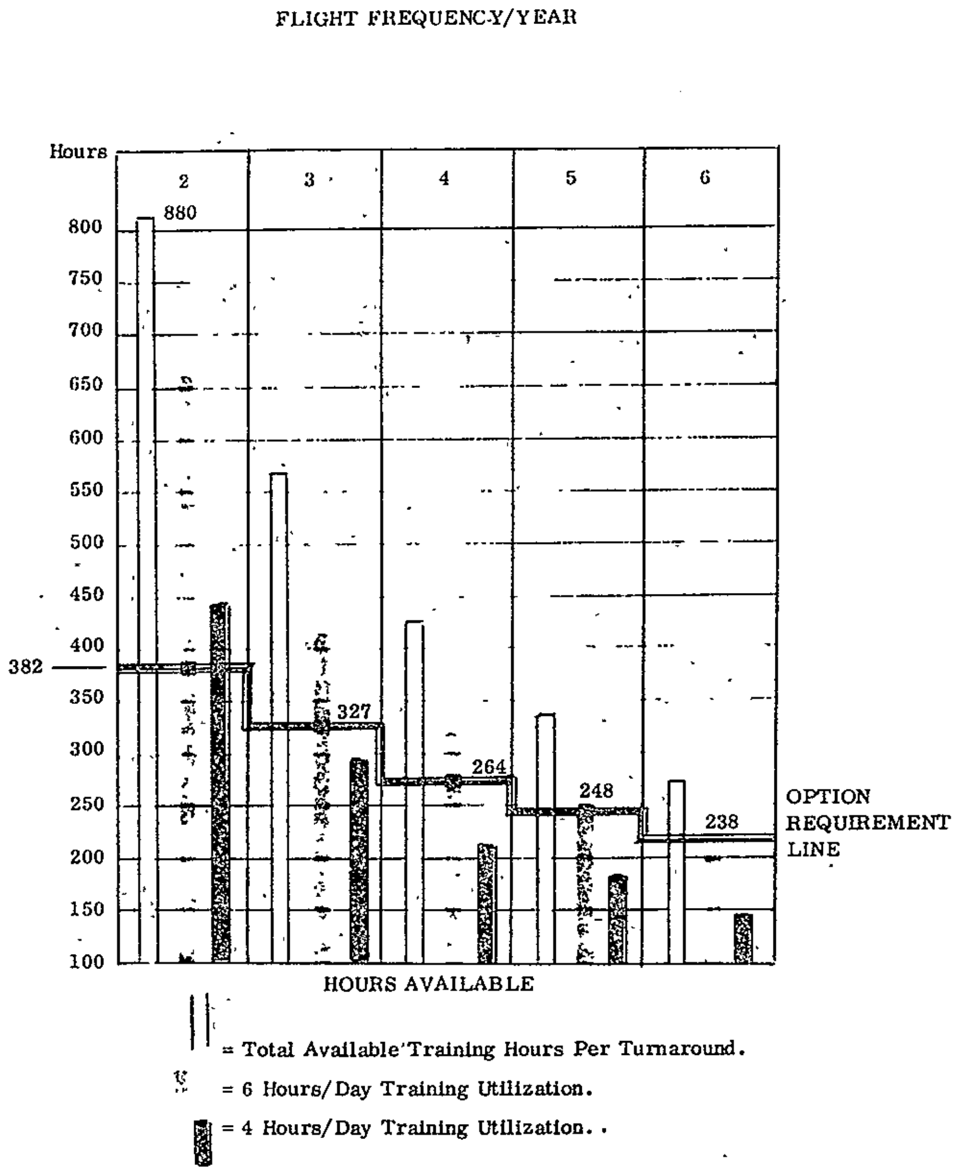

FIGURE 5 - TRAINING HOUR REQUIREMENT VRS. AVAILABILITY - OPTION III

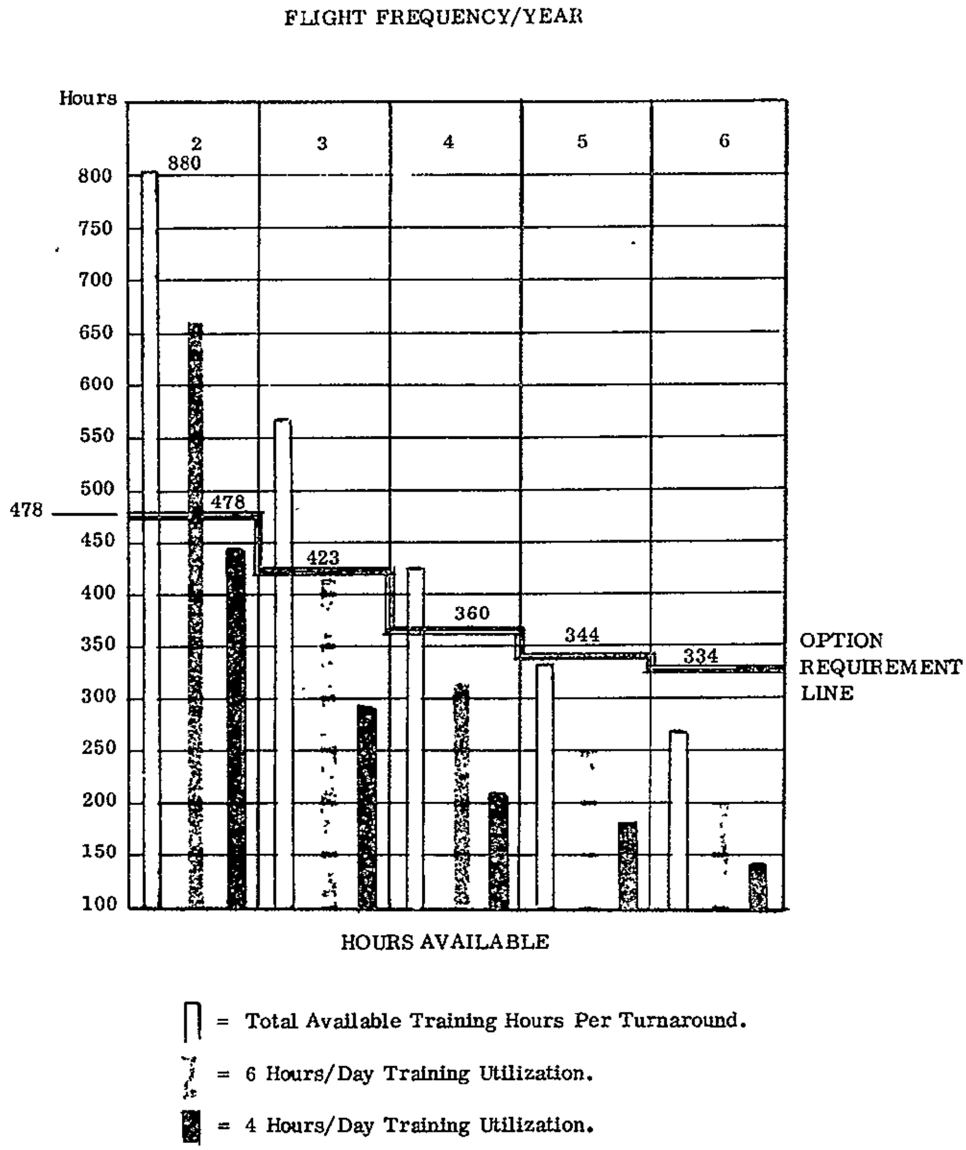

FIGURE 6 - TRAINING HOUR REQUIREMENT VRS. AVAILABILITY - OPTI ON IV

G. CONCLUSIONS AND RECOMMENDATIONS

1. Discussion - Assessment of data developed in this study indicates that Commander/Pilot participation in on-orbit payload operation is not only feasible but from the standpoint of effective crew utilization is desirable. The large number of Commander/Pilot man hours available during the on-orbit phase of flight can contribute substantially to the accomplishment of overall mission objectives and on some flights reduce the size of the crew. Reduction of the number of crew members is particularly important on long flights when considering the weight and endurance of life support, power generation, and other onboard expendables.

   The most significant constraint affecting crew participation in payload operation is available training time between flights. The fixed hours required for Flight Specific training programmed during each turnaround consumes the majority of the available training time. It is the opinion of this study that once the detailed Orbiter and payload functions are clearly defined and the operatonal tasks identified and analyzed the projected training hours assigned each functional task in current JSC training documentation may be reduced. A systems approach to training operational procedures will identify those tasks necessary to operate the equipment and eliminate irrelevant information that does not contribute to the overall operation. The objectives of the training curriculum should only contain those items with which the crew has an interface, and the condition or stimulus which generate a required crew response are identified. Applying the systems approach to the development of training objectives may reduce the current projected training requirements.

   This in turn will reduce the Flight Specific and Recurring training hour baseline developed in this study and provide time for additional Payload Specific training, attaining higher crew payload involvement or allowing increased crew turnaround rates, which will reduce the number of required crews.

   Another conclusion identified in this study which affects training capability is utilization of available training hours. Four hours training in an eight hour day will not support the training requirements of any of the four options for more than one flight a year (except Option 3, which will support two flights a year). Crew requirements to satisfy the STS mission model at this rate are unrealistic.

Training hours required to qualify the Commander and Pilot for Option I, Generalized Crew with low payload involvement and Option IV, Specialized Crew with high payload involvement are relatively the same. However, because of the higher payload involvement specified for Option IV, more effective utilization of their on-orbit available manhours can be achieved.

As Figures 3 through 6, Training Hour Requirements vrs. Availability, indicate specialization of crews by payload category will reduce the on going training hours necessary to qualify the Commander and Pilot to participate in payload operation. Quantitative factors developed to compute training hour requirements reflect the training advantages gained by utilizing the Specialized Crew concept. Reduction of required training hours will relieve pressure on simulator schedules and allow for higher crew flight frequencies. Increased flight frequencies will reduce operating costs and by the same token increase flight crew proficiency without increasing training requirements.

Data generated in this study supports a crew flight frequency of 4 flights a year. This frequency achieves the best reduction of crews required to accomplish the projected mission model each year along with the most accommodating training hour availability necessary to accomplish turnaround training. This rate would favor using a Specialized Crew concept as training hour requirements are comparable to training hour availability.

2. <u>Summary of Conclusions</u>

* TIME IS AVAILABLE FOR COMMANDER/PILOT PARTICIPATION IN ON-ORBIT PAYLOAD OPERATION.

* FROM A UTILIZATION STANDPOINT, COMMANDER/PILOT PARTICIPATION IN SELECTED PAYLOAD OPERATIONAL SEQUENCES WILL REDUCE PAYLOAD SPECIALIST REQUIREMENTS.

* COMMANDER/PILOT INVOLVEMENT IN PAYLOAD OPERATION IS FEASIBLE FOR CERTAIN FLIGHT FREQUENCIES.

* COMMANDER/PILOT INVOLVEMENT IN PAYLOAD OPERATION IS ATTAINABLE FOR CERTAIN OPTIONS DEFINED IN THIS STUDY (Assuming 6 hour training utilization per day)

    OPTION I - GENERALIZED/LOW-3 FLIGHTS A YEAR.
    OPTION II - GENERALIZED/HIGH - 1 FLIGHT A YEAR.
    OPTION III - SPECIALIZED/LOW - 5 FLIGHTS A YEAR.
    OPTION IV - SPECIALIZED/HIGH - 3 FLIGHTS A YEAR.

* REQUIRED RECURRING AND FLIGHT SPECIFIC TRAINING HOURS BEFORE EACH FLIGHT, SEVERELY LIMITS TRAINING TIME AVAILABLE TO QUALIFY THE COMMANDER AND PILOT FOR PAYLOAD OPERATION.

* OPTION I AND OPTION IV CONTAIN COMPARABLE TOTAL TRAINING HOUR REQUIREMENTS. HOWEVER, MORE ON-ORBIT OVERALL CREW UTILIZATION CAN BE ACHIEVED WITH OPTION IV.

* SPECIALIZATION OF CREWS BY PAYLOAD CATEGORY WILL REDUCE TRAINING HOURS AND ALLOW HIGHER FLIGHT FREQUENCIES PER CREW. NO SIGNIFICANT INCREASE IN THE NUMBER OF CREWS RESULTS.

* THE GREATEST EFFECT IN DECREASING THE NUMBER OF CREWS OCCURS AT 4 FLIGHTS A YEAR.

3. Recommendations - As a result of this study the following recommendations are offered as a way to achieve effective utilization of the Commander and Pilot on-orbit available man hours for payload operation.

Flight Specific training required before each flight consumes the largest part of the turnaround training requirements. Application of an operationally oriented systems approach to development of this training may identify areas where this training hour requirement may be reduced to provide more time for payload training.

Specialization of crews into some designated payload category will achieve a saving in turnaround training time by eliminating a requirement to achieve recurrency qualifications for all STS payload desciplines. Specializing will assure the crew flies with the same category of payload each flight which increases the association with the payload and helps maintain proficiency. Changing payload categories frequently between each flight introduces additional training requirements imposed by the different types of payloads.

Training utilization of 6 hours a day should be planned for Orbiter crews in order to satisfy all training requirements and still maintain an acceptable crew flight rate. There may be exceptions during certain phases of training depending upon the media selected; however, for scheduling purposes our airline experience shows a six hour training day (actual involvement in training) ideal.

As Table 9, Average Crews Required, shows, specialization does not significantly effect the number of crews required to fulfill the mission model. The table also shows a crew flight rate of about 4 flights a year is the most ideal rate as far as reducing the required number of crews is concerned. The curve flattens as the rate exceeds four flights a year and the loss of available training time precludes any option consideration other than a low payload involvement using the Specialized Crew concept.

FLIGHT FREQUENCY	Average Crews Required by Payload Involvement Concept (1982 thru 1991)	
	GENERALIZED	SPECIALIZED
2/yr.	17	18
3/yr.	12	13
4/yr.	9	10
5/yr.	8	9
6/yr.	6	8

TABLE 9 - AVERAGE CREWS REQUIRED

This study has identified estimated training hour requirements necessary to qualify the Commander and Pilot to operate payloads as defined in the four selected options. No attempt was made to identify utilization of available training aids or simulators necessary to fulfill the training hour requirements outlined. Simulator utilization and scheduling to satisfy training requirements for the number of crews finally selected should justify additional study in the methods and media areas.

4. Summary of Recommendations

* USE A SYSTEMS APPROACH TO DEVELOPMENT OF ORBITER CREW TRAINING PROGRAMS IN AN ATTEMPT TO REDUCE PROJECTED TRAINING HOURS. (PARTICULARLY FLIGHT SPECIFIC TRAINING).

* SPECIALIZE ORBITER CREWS BY SOME METHOD OF PAYLOAD CATEGORIZATION.

* DEVELOP TRAINING PROGRAMS BASED ON 6 HOURS A DAY TRAINING UTILIZATION.

* ATTEMPT TO ATTAIN A CREW FLIGHT RATE OF 4 TIMES A YEAR TO REDUCE CREW REQUIREMENTS. THIS APPEARS TO BE THE MOST EFFECTIVE FLIGHT RATE FOR REDUCING THE NUMBER OF CREWS WHILE RETAINING ACCEPTABLE TURN-AROUND TRAINING HOUR AVAILABILITY.
* ADDITIONAL STUDY TO DETERMINE MOST EFFECTIVE UTILIZATION OF AVAILABLE TRAINING AIDS AND SIMULATORS TO SUPPORT TRAINING FOR THE NUMBER OF CREWS INVOLVED.

APPENDIX I - COMMANDER/PILOT PAYLOAD PARTICIPATION OPTIONS

A. GENERAL

The objective of this study is to identify use of Commander/ Pilot on-orbit time for involvement in payload operation. Participation of the Commander and Pilot in payload operation will take full advantage of available crew man-hours and may even reduce overall crew size and the resultant demand for consumables and life support equipment. To evaluate this participation it was decided to investigate two crew operational concepts with two levels of payload involvement. The concepts pertain to "Generalized Crews" with a high and low payload involvement and to "Specialized Crews" with high and low payload involvement. Table I-1, Commander/Pilot Payload Options, displays a matrix of the involvement generated by four parameters evaluated in this study. This illustration identifies the four options of Commander/Pilot payload involvement used in this study.

All Crews (Commander and Pilot) regardless of the designated option will be trained to participate in payload activities that affect safety of flight or could jeopardize safe accomplishment of the mission objectives.

CONCEPT	PAYLOAD INVOLVEMENT	
	LOW	HIGH
Generalized Crew	Option I Operates Orbiter on any STS Flight and provides Minimal Payload Support	Option II Operates Orbiter and Payloads on any STS Flight.
Specialized Crew	Option III Operates Orbiter on STS Flights in Designated Mission Category. Provides Minimal Payload Support.	Option IV Operates Orbiter and Payloads on STS Flight in Designated Mission Category

Table I-1 - COMMANDER/PILOT PAYLOAD OPTIONS

This is obviously the lowest acceptable level of payload involvement from a flight safety point of view, but for the purposes of this study it falls short of a desirable and practical minimum involvement. Low payload involvement in this study includes the following generic tasks:

1. Deploy and activate payloads.
2. Recover and de-activate payloads.
3. Act as subject for experiments.
4. Support payload contingencies.
    a. Simple repair/trouble shooting.
    b. Recycle/restart.
    c. Confirm cable connections.
    d. Component exchange.
    e. Assist in accomplishment of checklists.

High payload involvement, as defined in this study, assumes the Commander and Pilot may be qualified and certified to operate specified subsets of experiment or payload operations on any STS flight. This level of involvement represents the highest possible participation in payload operation and may be unrealistic when highly complex payloads are involved, particularly when the Generalized crew concept in considered. Generic tasks identified with high payload involvement of pre-determined experiments in this study include:

1. Operation of individual experiments/payloads or pre-determined sequences.
2. Act as subject and/or observer of experiments.
3. Operation of pre-determined sub-set of experiments. (Up to approx. 25% of Payload, i.e., not necessary to operate all experiments on payload.)
4. Perform payload contingencies.
    a. Perform involved repair/trouble shooting of experiments.
    b. Accomplish contingency checklists.

High payload involvement generates a high level of qualification training hours which will be treated in detail in this study.

Primary and backup orbiter crew responsibilities shown in Table I-2, Orbiter Crew Functional Responsibilities, are fixed and are not intended to be affected by the results of this study. A Generalized crew with low payload involvement will be trained to perform payload support functions in all of these areas of responsibility. A Specialized crew with low payload involvement will only be trained to provide payload support in the functions associated with the designated payload category.

In contrast, high payload involvement will encompass detailed payload operation of all STS payloads for the Generalized concept. High involvement for the Specialized Crew concept will require detailed payload operation in those functions that pertain to the Specialized category.

Function / Crew Member	Orbiter Operation And Maneuvering	Orbiter Systems Operation	RMS Operation (1)	Rendezvous and Docking	EVA (2)	Experiment Operation (Payload) (3)	Safety of Flight Emergencies and Contingency Operation
COMMANDER	Primary	Primary		Primary			Primary
PILOT	Back-up	Back-up	Primary	Back-up	Back-up		Back-up

(1) Mission Specialist - Backup.

(2) Mission Specialist - Primary.

(3) Payload Specialist - Primary
Mission Specialist - Backup.

TABLE I-2 - ORBITER CREW FUNCTIONAL RESPONSIBILITIES

B. GENERALIZED CREW CONCEPT

The Generalized Crew concept assumes the Commander and Pilot are qualified to fly any STS flight. Required training has been accomplished to qualify the crew for performance of mission objectives associated with each flight. Training will include certain pre-determined payload support including on-orbit operation of payloads. The degree of participation will range from a low level of payload support to a high level of actual payload operation.

1. Low Involvement - A Generalized crew with low payload involvement will be expected to provide orbiter pointing and attitude control, rendezvous and docking maneuvers, deployment and retrieval of payloads, emergency and contingency procedures including EVA, if necessary to insure safety of flight and safe accomplishment of the mission objectives. Some payload support, such as participating as an experiment subject, trouble shooting or assisting the mission or payload specialist would be involved. The crew will be trained in basic orbiter support functions necessary to operate any planned payload.

2. High Involvement - A Generalized Crew with high payload involvement represents the opposite end of the scale. This concept requires that the Commander and the Pilot be trained and qualified to operate or support a subset of the on-orbit payload experiments on any STS flight. They will be trained to act as Payload Specialists for specified on-orbit payload functions. This option represents the highest degree of Commander/Pilot participation and a requirement for the most training. It transcends a broad spectrum of scientific disciplines and generates difficult training demands peculiar to each STS flight. The impact of drivers identified in Appendix II, are magnified with the various disciplines involved and complexity of the payloads on each flight.

C. SPECIALIZED CREW CONCEPT

The Specialized Crew concept assumes that the Commander and Pilot are trained and qualified to fly only certain categories of STS payloads. Reference Appendix III. Four categories of payloads are identified in this study as applicable to the Specialized Crew concept. They are:

Spacelab - Module or pallet/module combinations
Spacelab - Pallet only
Free Flyer
IUS/TUG

Commanders and Pilots assigned under this concept would fly only STS flights in one of these four designated categories. Crews will be trained to perform mission objectives associated with their payload category. The degree of payload participation will range from a support function at the lower end to actual payload operation at the higher end.

1. Low Involvement - A Specialized Crew with low payload involvement will be trained to accomplish payload functions that relate to safety of flight or affect safe completion of the mission objectives for payloads in their designated category. Payload operational support functions provided by the crew will also pertain to the designated payload specialization category. This option represents the smallest payload training impact upon crew turnaround training requirements of the four options identified in this study.

2. High Involvement - Specialized Crews with high payload involvements will be responsible for the same payload functions as stated in the low involvement option. In addition, they will be trained and qualified to perform on-orbit operation of experiments and payloads in their designated payload category. These crews will be thoroughly familiar with the operational requirements of payloads and experiments in their specialty and will perform necessary operational tasks to meet payload objectives. They should be trained to perform selected on-orbit payload tasks with the same degree of proficiency as payload specialists or operate certain experiments in lieu of payload specialists on some flights.

APPENDIX II - DRIVERS - CONSTRAINTS AND CONSIDERATIONS AFFECTING COMMANDER/PILOT TRAINING FOR PARTICIPATION IN ON-ORBIT PAYLOAD OPERATIONS

A. GENERAL

This Appendix contains constraints and considerations which affect training necessary to qualify the Commander and Pilot to perform on-orbit operation of payloads carried aboard the STS Orbiter. These drivers do not consider any basic policies (if any) developed by NASA which would limit involvement of the Commander and Pilot in payload operation. It is assumed that no prohibition exists between the flight crew and the host payload center that will prevent the Commander and Pilot for operating payloads, provided they are properly trained and certified.

The list may not be complete and each consideration may not apply to all types of payloads or missions, however, the impact with training requirements needed to qualify the Commanders and Pilots for inflight operation of payloads are identified. The most significant factors vary considerably with the type of mission, and Commander/Pilot backgrounds. Crews schooled in the scientific discipline of the payload will require much less training to qualify for payload operation than those who possess little background in the discipline. For this reason any Commander/Pilot on-orbit payload training should be operationally oriented to avoid prolonged and extensive training beyond operational requirements.

Considering Orbiter Recurring training requirements between flights, available training time is probably the most critical driver affecting crew qualification for on-orbit payload operation. The second driver producing significant impact on training requirements and costs is the number of crews to be trained. Higher flight frequencies require fewer crews and lessen the demand for high trainer and simulator utilization. It also cuts the availability of training time between flights limiting possible crew payload involvement because of insufficient training time to qualify them for payload operation.

B. AVAILABLE TRAINING TIME - NUMBER 1 DRIVER

The most significant driver affecting the Commander and Pilot's participation in on-orbit payload operation is finding the necessary time to train them to operate payloads. Recurrent, Flight Specific and Payload Specific training necessary to maintain crew proficiency and qualifications must be accomplished between flights. Payload training will have to be in addition to the established recurrent and specific requirements. One of the objectives of this study is to establish a planning baseline for Commander/Pilot Recurrent and Flight Specific training requirements. Establishment of a turnaround training hour baseline is necessary to identify training time available to train for payload operation. Flight crew flight rates, obviously have a direct impact on the number of crews required to support the STS program, as discussed in para. C, below.

Because there is a great amount of similarity between Orbiter crew training in the STS program and flight crew training in commercial aviation, the baseline Orbiter Recurrent training hour requirements were developed using the experiences of United Airlines who has a continuing need to maintain recurrency qualification of over 5000 pilots. A correlation between transition training conducted by the airline industry and the planned Orbiter advanced training was made. Airline recurrent training requirements were identified and applied to the Orbiter training to establish a baseline recurrent training requirement for Orbiter crews. Some modification will undoubtedly be required after the STS initial training programs are firmly established. Training hour requirements for initial Orbiter crew qualification was obtained from a JSC training document outlining Basic, Advanced, and Flight Specific Training requirements, dated March 19, 1976.

1. Available Training Hours Between Flights

Available training time between Orbiter flights is inversely proportional to the frequency that the Commander and the Pilot fly. The higher the frequency, the less time is available for training between flights. After vacations and holidays are counted, Orbiter crews will be available for flying and training approximately 46 weeks each year. Using this assumption the number of weeks available to train based upon flight frequency is determined by using the following computation:

$$\frac{46 - \text{Weeks in Flight}}{\text{Flight Frequency}} = \text{Available weeks for training}$$

Applying this formula, available training weeks for each flight rate is identified as:

2 flights/year	-	22 weeks
3 flights/year	-	14 weeks
4 flights/year	-	10.5 weeks
5 flights/year	-	8.2 weeks
6 flights/year	-	6.6 weeks

Table II-1, Available Training Hours, converts weeks into hours used in computations for training hour availability in this study. Total hours available based upon an 8 hour day are identified along with training hours available using four and six hour a day utilization.

Training hour requirements were determined to accomplish Recurrent, Flight Specific, and Payload Specific training between flights. From this determination, a baseline was established for each category of turnaround training.

TURNAROUND TRAINING AVAILABILITY (Hours)

Flights Per Year	Available Weeks	Available Days	Available Hours	Utilization	
				6 Hrs/Day	4 Hrs/Day
2	22	110	880	660	440
3	14	70	560	420	280
4	10.5	52.5	420	315	212
5	8.2	41	328	246	164
6	6.6	33	264	198	132

TABLE II-1 - AVAILABLE TRAINING HOURS

2. Baseline Turnaround Training Hour Requirements

Three general types of training programs must be accomplished by the Commander and Pilot between flights to maintain their currency and prepare them for Orbiter and payload involvement. The objective of this appendix is to baseline the required training hours in each category of training. The three training categories required are:

- Orbiter Recurrent Training
- Flight Specific Training
- Payload Specific Training

a. Orbiter Recurrent Training - Training requirements for Orbiter Recurrent Training, were baselined using comparable airline experience with this type of training, as described below. This training is an established fixed requirement and is not subject to weighted factors explained in Appendix V, when determining required turnaround training requirements for the options described in this study.

b. Flight Specific Training - Development of the Flight Specific required training hours baseline is described below. Flight Specific training hours are subject to the weighted factors described in Appendix V, when computing option turnaround training hour requirements.

c. Payload Specific Training - Development of a Payload Specific Training hour requirement baseline is described below. Training hour requirements for Payload Specific training is subject to the weighted factors described in Appendix V, when computing option turnaround training hour requirements.

3. Definition of Training Hour Requirements

A comparison between the planned Initial JSC crew training requirements and airline flight crew training requirements was made by categorizing airline training into comparable groupings and identifying ratios between initial and recurrency airline training requirements. This ratio was then applied to the initial JSC training projection and recurrent requirements estimated. Comparative airline and Orbiter training categories used to establish Orbiter Recurrent training requirements for this study are as follows:

Airline Training	Orbiter Training
Basic	Basic
Transition and Upgrade	Advanced

a. Basic Training - Basic Training in both cases refers to prerequisite training of a general nature required to qualify pilots to perform duties within their areas of responsibility. It includes environmental, technical, scientific, physiological and regulatory aspects of flying an airplane or the Orbiter. Objectives of this type of training can be directly related in both programs and rather straight forward comparisons are made.

b. Advanced Training - Advanced Training for the Orbiter Commander and Pilot can be similarly compared to the Transition and Upgrade training of an airline pilot. This is where the airline pilot learns to fly a specific type of airplane as either Pilot In Command or First Officer. Operational requirements and technical knowledge necessary to operate systems are covered from an operational inflight behavioral approach. Flight profiles and applicable techniques are flown in simulators and airplanes. Normal operating procedures of systems are practiced in procedures trainers and simulators. Emergency and contingency procedures applicable to the airplane are also practiced.

c. Flight Specific Training - Flight Specific training for the Orbiter program is construed to apply to the training required to upgrade a qualified Commander and Pilot to fly the succeeding Orbiter flight. Some of the training activity items associated with Flight Specific training will require full programmed training hours prior to each flight. Other activities will not be part of the next flight and some training may be considered recurrent training for activities previously accomplished in the Advanced training phase.

d. Payload Specific Training - Payload Specific training is training required to qualify the Commander and Pilot in on-orbit payload operations. This training requirement will vary greatly with the degree of involvement and the Generalized/Specialized crew concept.

4. Determination of Orbiter Recurrent Training Hour Requirements - This paragraph describes the procedures and rationale used to determine the baseline turnaround training requirements for the study. A recurring training requirement was developed for the Orbiter Advanced training and a Flight Specific turnaround training requirement was identified. Payload Specific training requirements were developed using documentation obtained from the Life Sciences Test II, Simulation.

   a. Orbiter/Recurring Advanced Training Activities - Table II-2, Commander/Pilot Basic and Advanced Training Hours, generally lists the training activities developed for Basic and Advanced training by JSC to qualify crews to fly STS missions. Programmed training hours are grouped into four media categories, (1) Classroom (CLRM), (2) Part Task and procedures trainers (TRNR), (3) Simulators (SIMS), and (4) Airplane. This grouping corresponds to similar training accomplished by airline training departments to qualify flight crews.

      1) United Training Activities - Table II-3, UA Captain/First Officer Basic and Transition Training Hours, represents comparative United Airlines Training requirements grouped into the same media categories. Hours listed represent average hours for all types of airplanes operated by United. Airplane flying hour averages are obtained from empirical data generated over a 12 month period. This was necessary because UA airplane requirements are to train to proficiency without any consideration for specific programmed flying hour requirements.

      2) United Recurrent Training - Table II-4, UA Captain/First Officer Recurrent Training Hour Requirements. Recurrency requirements in this table reflect annual

TABLE II-2 - COMMANDER/PILOT BASIC AND ADVANCED TRAINING HOURS

JSC TRNG. DOCUMENT
3/19/76

COMMANDER/PILOT STS TRAINING HOUR REQUIREMENTS

BASIC TRN	CLRM	TRNS	SIMS	STA, T38, KC-135 AIRPLANE	SUB TOTAL	TOTAL TRN HRS.
FUNDAMENTALS	276				276	
WIF		26			26	
SUB TOTAL	276	26			302	302
ADVANCED TRAINING						
ORBITER SYSTEMS	172	155	54		381	
HABITAT & EMER.	21	21			42	
EVA	19	76	19		114	
RMS	14	13	36		63	
SPACELAB	65	38	61		164	
IUS	26		16		42	
PHASE TRAINING			34		34	
FLIGHT PROFILES	59	172	288	68	587	
STD. ORB. OPS. (1)	18	87	113		218	
SUB TOTAL	394	562	621	68	1645	1645
TOTAL BASIC AND ADVANCED	670	588	621	68	1947	1947

(1) TRANSFERRED FROM FLIGHT SPECIFIC PROGRAMMING

TABLE II-3 - UA CAPTAIN/FIRST OFFICER BASIC AND TRANSITION TRAINING HOURS

UA CAPTAIN/FIRST OFFICER TRAINING HOUR REQUIREMENTS

UA BASIC PREPARATION TRAINING (CAPT/FO)

COURSE	BRIEFING AND CLRM	TRNS	SIMS	AIRPLANE	SUB TOTAL	TOTAL TRN HRS
BASIC TURBINE	30				30	
INITIAL S/O	70				70	
INITIAL F/O	48				48	
BASIC CAPTAIN	32				32	
RADAR	8				8	
TOTAL	188				188	188

UA TRANSITION TRAINING (CAPT/FO)

INITIAL DITCHING	8	4			12	
EMERGENCY PROC	5	4			9	
LINE QUALIFICATION QUALIFICATION				25	25	
TRANSITION - AVERAGE	*42	23.6	23.2	2.9	91.7	
TOTALS	55	31.6	23.2	27.9	137.7	137.7

* Includes 2 hours briefing time for each simulator period.

BASIC AND TRANSITION TOTALS	243	31.6	23.2	27.9	325.7	325.7

TABLE II-4 - UA CAPTAIN/FIRST OFFICER RECURRENT TRAINING HOUR REQUIREMENTS

- LESS THAN 90 DAYS

COURSE	BRIEFING AND CLRM	TRNS	SIMS	AIRPLANE	SUB TOTAL
RECURRENT SYS	25				25
PROFICIENCY TRNG	2		2		4
PROFICIENCY CHECK	4		4		8
EMERGENCY PROC	4	4			8
LESS THAN 90 DAYS				3 Takeoffs (1 Hr) and Landings	1
TOTALS	35	4	6	1	46

- OVER 90 DAYS LESS THAN 12 MONTHS

RECURRENT SYS	25				25
PROFICIENCY TRNG	2		2		4
PROFICIENCY CHECK	4		4		8
EMERGENCY PROC	4	4			8
REQUAL TRNG.	7			2	9
TOTALS	42	4	6	2	54

recurrency training accomplished by flight crews. If breaks between flights do not exceed 90 days flight crews must receive on an annual basis training identified in the upper chart. If a break period between a flight exceeds 90 days and not more than 12 months, crews will receive training listed in the lower chart.

The majority of this training is normally accomplished in two separate training periods spaced about six months apart. A two day program consisting of Emergency Procedures training and simulator practice of approach and landing profiles and airplane emergency and irregular procedures is accomplished as Proficiency Training (PT). Approximately six months later a two day program consisting of a simulator warm-up period which includes approach and landing profiles and airplane emergency and irregular procedures is accomplished, followed by a check of these maneuvers by a Flight Standards Manager in a visual simulator on the second day. This training period is consider a Proficiency Check (PC). The PC also includes an oral examination covering the airplane systems and airline operating procedures and a review of Category II operational requirements. The airplane time indicated in Table II-4, is normally satisfied during day to day flying activities, however, if not, three takeoff and landings must be accomplished within a 90 day period, or an actual check out must be accomplished if no takeoffs or landings are made for over 90 days and less than 12 months.

Most of the required maneuvers accomplished during the PC and PT simulator periods and emergency procedures training are established by Federal Aviation Regulations (FAR). Table II-5, Annual Pilot Recurrent Training, lists a generic breakdown of recurrent training tasks required. The airplane systems reviews are accomplished with individualized training carrels using slide/tape audio visual review packages. This training hour requirement is also established by FAR's.

Failure of a crew member to satisfactorily perform maneuvers or display adequate knowledge of required operating procedures will result in additional training. This training is individually programmed to correct only the specific deficiencies noted.

TRAINING	DESCRIPTION OF TASK	MEDIA	FAA REQ
RECURRENT SYS	Review of airplane systems and Irregular and Emergency flight manual procedures.	Individualized Carrel w/slide tapes	YES
PROFICIENCY TRAINING AND PROFICIENCY CHECK	. Flight planning and pre-takeoff procedures. . Steep turns and approaches to stalls. . Area departures and arrivals. . Category II requirements review. . Approach and missed approach profiles and procedures. . Irregular and emergency procedures.	Briefings, Oral Exam, Simulator	YES
EMERGENCY PROCEDURES TRAINING	. Emergency assignments and crew coordination. . Location, function and operation of emergency equipment. . Coping with emergency situations. . Operation and use of emergency exits, slides, life vests and rafts. . Evacuation drills. . Emergency oxygen systems and use. . Ditching techniques and procedures. . INS and dead reckoning review.	Classroom, Training, Aids, and Mock-ups	YES

TABLE II-5 - ANNUAL PILOT RECURRENT TRAINING

Except for selected special emphasis items such as, hijacking procedures, wind shear on final approach, new Air Traffic Control procedures, etc., that are required to keep flight crews abreast of the latest developments, all subject matter is a review of previously accomplished training. Pilots have demonstrated end level proficiency or knowledge of equipment, systems, or procedures before completing basic, transition, or upgrading training requirements which is comparable to the STS advanced training requirements. The objective of recurrency training is to monitor and check pilot skills and proficiencies to insure desired airline standards of performance are maintained and FAA requirements are satisfied.

3) Recurrency Training in Percent of Total - Table II-6, Recurrent Training Hours in % of Total Hours. This figure identifies the percent of total training hours that are represented by recurrency training hours in each media category accomplished yearly by United Airlines pilots. Again the chart includes over and under 90 day flight frequencies.

4) Training Subject to Recurrency Requirements - Table II-7, Commander/Pilot Total Training Hours Subject to Recurrency, identifies the basic training hours used to determine recurrent training hour requirements. Basic training classroom hours have been reduced 50% to accommodate differences between the entry level performance of pilots entering airline training and entry level performance of astronauts entering the STS program. Crew members entering airline pilot training programs are pilots who possess airplane and instrument ratings, therefore, the depth of basic training is shallow. Background and enrichment information relating to the tasks of flying an airplane and interpreting instrument presentations or discussions of basic navigational aids and communications are practically eliminated. By contrast, the added dimensions involved in space flight will demand more emphasis on aspects of the STS program that are foreign to the newly hired trainee. Much of the training offered in the Basic phase of the STS training program is not subject to recurrency training once end level course objectives are obtained. To compensate for this consideration 50% of the Basic Training classroom hours are used as a basis for computing recurrent training hour requirements from United Airlines experience.

UNITED AIRLINES CURRENCY TRAINING REQUIREMENTS
VS TOTAL QUALIFICATION TRAINING HOURS

LESS THAN 90 DAYS

COURSE	BRIEFING AND CLRM	TRNS	SIMS	AIRPLANE	SUB TOTAL
TOTAL TRNG HOURS(1)	243	31.6	23.2	27.9	325.7
RECURRENT HOURS(2)	35	4	6	1	46
% OF TOTAL	14	12.5	26	3.5	14

OVER 90 DAYS LESS THAN 12 MONTHS

TOTAL TRNG HOURS(1)	243	31.6	23.2	27.9	325.7
RECURRENT HOURS(2)	42	4	8	2	56
% OF TOTAL	17	12.5	26	7	17

(1) From Table II-3
(2) From Table III-4

TABLE II-6 - RECURRENT TRAINING HOURS IN % OF TOTAL HOURS

BASIC HOURS FOR RECURRENT COMPUTATIONS

TRAINING PHASE	CLRM	TRNR	SIMS	AIRPLANE	TOTAL
BASIC	138 (1)	26			164
ADVANCED	376	476	508	68	1427
FLIGHT SPECIFIC (2)	18	87	113		218
TOTAL HOURS RECURRENT BASE	532	588	621	68	1809

(1) Total Basic Classroom Hours Reduced 50%.

(2) Transferred from Flight Specific Program.

TABLE II-7 - COMMANDER/PILOT TOTAL TRAINING SUBJECT TO RECURRENCY

5) Orbiter Recurrent Training Requirement Baseline - Table II-8, Orbiter Recurrent Training Hour Requirements. Applying United Airlines recurrent training percentages developed in Table II-6 to the baseline Orbiter Basic and Advanced training hour requirements identified in Figure 6, an estimate of the required Recurrent training hour requirements can be made for the STS program. Training hour requirements identified in Table II-8, represents an annual requirement and only a certain percentage need to be accomplished during turnaround training. A flight frequency of 3 times a year will require one third of the total recurrent training hours to be accomplished between flights. Detailed task analysis of Orbiter duties and flight histories of crew performance will be required to satisfactorily develop crew qualifications for future Orbiter flights.

5. Determination of Flight Specific Training Hour Requirements Table II-9, Commander/Pilot Flight Specific Training Hour Requirements, lists the generic training activities for Flight Specific Training as defined in the JSC training document dated 3/19/76. The training activities were evaluated in an effort to establish a baseline training hour requirement for Flight Specific training. Full training is required for Habitat and Emergency considerations, and flight profiles prior to each scheduled flight.

Standard Orbiter operations referred to are Orbiter maneuvering and control techniques required to support Orbiter and payload flight requirements. Crews should be trained

COMPUTING NASA RECURRING TRAINING HOUR REQUIREMENTS

FLIGHT FREQUENCY LESS THAN 90 DAYS.

ADVANCED RECURRING TRAINING HOUR REQUIREMENTS					
COURSE	CLRM	TRNR	SIMS	AIRPLANE	SUB TOTAL
TRAINING HOUR BASE (1)	532	588	621	68	1809
UA RECURRENT % (2)	14	12.5	26	3.5	
RECURRING HOURS	74	73	162	2	311

FLIGHT FREQUENCY MORE THAN 90 DAYS LESS THAN 12 MONTHS

ADVANCED RECURRING TRAINING HOUR REQUIREMENTS					
COURSE	CLRM	TRNR	SIMS	AIRPLANE	SUB TOTAL
TRAINING HOUR BASE (1)	532	588	621	68	1809
UA RECURRENT % (2)	17	12.5	26	7	
RECURRING HOURS	90	73	162	5	330

(1) - Table II-7
(2) - Table II-6

TABLE II-8 - ORBITER RECURRENT TRAINING HOUR REQUIREMENTS

TABLE II-9 - COMMANDER/PILOT FLIGHT SPECIFIC TRAINING HOUR REQUIREMENTS

FLIGHT SPECIFIC TRAINING

	TRAINING ACTIVITY	CLRM	TRNR	SIMS	STA	TOTAL	ACTION
Fixed	HABITAT AND EMERGENCIES	9	10			19	Required for all flights.
Fixed	PHASE TRAINING		7	20		27	Required for all flights.
Fixed	FLIGHT PROFILES	15	34	40	10	99	Required for all flights.
	SUB TOTAL	24	51	60	10	145	145 HOURS - FIXED
	STANDARD ORBITER OPERATIONS	(18)	(87)	(113)		(218)	Transferred to Advanced Training and Recurrency Factor applied.
Adjusted	EVA	4	31			35	Activities not required
Adjusted	RMS	6	6	29		41	For all flights.
Adjusted	SPACELAB	36	37	45		118	Approximately 1/3 of total
Adjusted	IUS/TUG	15		16		31	training hours required for
Adjusted	SPACE TELESCOPE	6	24			30	each flight.
	SUB TOTAL	67	98	90		255	$\frac{255}{3}$ = 85 HOURS - ADJUSTED

FLIGHT SPECIFIC BASELINE HOUR 230 HOURS

( ) = HOURS ADDED TO ADVANCED TRAINING AND REFLECTED IN RECURRENT TRAINING HOUR REQUIREMENTS to proficiency in these maneuvers during the Advanced phase of training and only recurrency requirements accomplished prior to each flight. Using this rationale, these requirements are transferred to the Advanced training phase and a recurrent training factor applied to determine between flight training hour requirements.

The remainder of Flight Specific training activities are identified with specific type of payloads. Since three basic payload categories exist, the total of training hours represented by these activities is divided by three to provide an averaged approximation for each flight preparation. Approximately one third of the requirements will apply to the payload scheduled for the next flight.

This rationale establishes the baseline for Flight Specific training hour requirements as follows:

a. Fixed hours for all flights.

CLRM	TRNR	SIMS	STA	TOTAL
24	51	60	10	145 Hours

b. Total Specific Payload adjusted hours:

CLRM	TRNR	SIMS	STA	TOTAL ADJUSTED HOURS
67	98	90	0	255

It is assumed that approximately one third of the adjusted hours, or 85 hours, will be the required training hours for turnaround training prior to the next flight. The Flight Specific training hour baseline established for this study utilizing the above rationale is:

Fixed	145 Hours
Adjusted	85 Hours
Flight Specific Baseline	230 Hours

6. Determination of Payload Specific Training Hour Baseline - A baseline training hour requirement for Payload Specific training must be established in addition to the Flight Specific and Orbiter recurrent training baselines to determine the impact of turnaround training time on payload involvement training.

As reasonable estimates for payload training are difficult to obtain in this time frame the training plan for the Life

Sciences Test II Simulation was selected to provide a representative approximation for Payload Specific training requirements. The requirements of this plan were modified to comply with the definitions of crew involvement utilized in this study. Certain areas of the training plan requirements had previously been included in this study under Orbiter recurrent or Flight Specific and were therefore excluded. Additionally, the definitions used here for low and high crew involvement led to the decision to reduce the Test II training plan requirement for Experiment Training Exercise by 75%. It is assumed for this study that a Commander or Pilot would only be responsible for involvement in a subset of total experiment operations (no more than 25%) regardless of his level of involvement in those operations. It was felt that the pilot training requirements in the Test II plan most nearly approximated a low involvement training requirement while the Payload Specialist requirements (when modified as previously noted) represented a high involvement level for the purposes of this study.

Table II-10, Payload Specific Training Hour Baseline, lists the modified training requirements and shows the established baseline of 80 hours required for Payload Specific Training that will be used in this study. This total represents the low involvement definition. The total for high involvement supports our assumption in the weighted methodology section that high involvement will require approximately twice the training level of low involvement for Payload Specific training.

7. Total Baseline Training Requirements - Table II-11, Baseline Turnaround Training Requirements, identified the total training requirements baselines developed and used in this study. Data is generated from projected training requirements obtained from JSC Training Document dated 19 March 1976 (which outlined Commander/Pilot, Basic, Advanced, and Flight Specific training), the Life Sciences Test II, Mission Simulation, United Airlines, Flight Operations Training Manual, and other United Airlines training records. Quantitative data developed in Appendix V, is developed from applicable baseline training hour requirements listed in Table II-11.

C. CONSTRAINTS AND CONSIDERATIONS AFFECTING TRAINING HOURS:

Considering availability of training time as a major impact driver affecting qualification of the Commander and Pilot to operate payloads, a brief look at the constraints and considerations that affect training time should be made. Six impact items have been identified in this study and a numerical factor applied to each in an attempt to quantify the total effect of all items applicable to any given payload. Computations for development of training hour

PAYLOAD SPECIFIC TRAINING HOUR BASELINE

TRAINING ACTIVITY	LOW INVOLVEMENT		HIGH INVOLVEMENT	
	CLRM	TRNR	CLRM	TRNR
INITIAL PI BRIEFING	16		32	
EXPERIMENT PROCEDURE BRIEFING	4		40	
EXPERIMENT TRAINING EXERCISE		23		66
SAFETY BRIEFING	1		1	
FLIGHT PLAN BRIEFING & REVIEWS	16		16	
CONTINGENCY PROCEDURES BRIEFING	2		4	
DATA SYSTEMS BRIEFING	2		2	
WET RUN SIMULATION		16		16
SUB TOTAL	41	39	95	82
BASELINE TOTALS	80 Hours		177 Hours	

TABLE II-10 - PAYLOAD SPECIFIC TRAINING HOUR BASELINE

TRAINING REQUIREMENT		MEDIA				TOTAL
		CLRM	TRNR	SIMS	AIRPLANE	
RECURRING ORBITER	Less than 90 days	74	73	162	2	311
	More than 90 days	90	73	162	5	330
FLIGHT SPECIFIC	Fixed	24	51	60	10	145
	Adjusted	22.4	32.6	30	0	85
PAYLOAD SPECIFIC	High Involvement	95	82			177
	Low Involvement	41	39			80

TABLE II-11 - BASELINE TURNAROUND TRAINING REQUIREMENTS

requirements utilizing the weighted factors assigned to these impact items for various payload options is contained in Appendix V, to this report.

The six impact items identified are:

- Crew Specialization or Generalization
- Payload Involvement by the Crew.
- Payload Complexity.
- Multi-Discipline Payload Requirements.
- Contingency Operation of Payloads.
- Training Locations.

Training methods also impact training time. A proper mix of classroom type training combined with part task or procedures training and high fidelity simulators can significantly reduce time required for trainees to reach end level performance

1. Crew Specialization or Generalization: The Specialized concept of designating the Commander and Pilot to fly only specified categories of payloads requires less training time than to train the crew on a generalized concept and qualify them to operate any payload. This is reflected in the weighted factor applied to each concept identified in Appendix V.

   Specialization reduces training requirements for Initial, Recurrent and flight specific training. When the total training requirements to qualify the Commander and Pilot for STS operation are analyzed and turnaround training considered the incentives to apply the specialized concept of crew assignment is compelling. In all probability a generalized crew would not fly the same payload category more than once in a single year while the specialized crew definitely would. Recurrency considerations alone rule strongly in favor of specialization.

2. Payload Involvement by Crew: A high or low payload involvement by the crew presents a straight line impact on training requirements. Payload involvement considerations are described in Appendix I to this report.

3. Payload Complexity: More difficult payload operations require more training time to train to end level proficiency, more sophisticated trainers or simulators, or a combination of both. Automated payloads or free flyer delivery and retrieval present the least involvement with payload operation itself. Orbiter rendezvous and docking, installation and removal of experiments from the orbiter bay and possible activation and deactivation of the payload in most

cases is the extent of payload specialist involvement. Other payloads may require monitoring only while some may require extensive manipulation or procedural operation to accomplish the experiment objectives. The latter type of payloads will require more training time to qualify the operator and probably higher fidelity simulators.

Payloads requiring manual dexterity or motor skills to operate would be more suitable for high fidelity type of simulation which would allow the operator to develop skills and techniques necessary to perform the payload operation. Using the Remote Manipulator System is an example of this type of training.

Part task or procedures trainers can be used to train procedural skills. Procedures may be performed by use of a checklist or by performing sequential steps initiated by a condition/action chain of events. Training devices needed for this type of training will require adequate logic to provide highly reqlistic stimuli to trigger the proper succeeding action or response. Operating a switch or control must produce a realistic indication on a gauge instrument, or CRT that will verify that the previous action was correct and to provide the stimulus or condition for the next action.

All operational on-orbit payload training that would involve the Commander and Pilot will be accomplished in trainers, or simulators, or by ground operation of the experiment, if practical. Training to end level proficiency will be done without benefit of actual on-orbit operation. This consideration identifies a requirement to develop high fidelity simulators such as the Shuttle Mission Simulator, Spacelab Simulator, Orbiter and Spacelab Neutral Buoyancy Trainers, RMS simulator, etc. to develop crew skills and techniques.

Part task trainers such as the Orbiter and Spacelab One-G trainers where training of habitability procedures, power and consumables management, payload check out procedures, and applicable contingency procedures may be accomplished provide adequate simulation of the real equipment as high fidelity simulators.

4. Multi-Discipline: Multi-discipline payloads may consist of experiments and equipment provided from more than one payload center. It is conceivable that all centers may contribute experiments for a single STS mission. The designated lead center will provide necessary on-orbit operational training to qualify the Commander and Pilot to participate in payload operation. This introduces an

additional training location and time constraint in overall turnaround or recurrent training that must be accomplished between flights.

Perhaps the most significant training impact presented by multi-discipline payloads is the possible difference in scientific discipline of the experiments and equipment that constitute the payload. The Commander's and Pilot's scientific background will determine to a great extent the training difficulty experienced in qualifying them for payload operation. It is not likely that the Orbiter crew will possess requisite knowledge and training in all disciplines involved. Those experiments which require extensive knowledge and experience in a discipline foreign to the Commander's and Pilot's backgrounds will require excessive training and should be eliminated from consideration for on-orbit involvement.

5. <u>Contingency Operation of Payloads</u>: All Orbiter crews will be trained to perform emergency and contingency operation of payloads that will affect Orbiter safety. Malfunctions which require payload deactivation, jettison, fuel dumping, safing, etc., should be performed with the aid of applicable emergency and contingency action checklists and accomplished or monitored by the Commander and the Pilot. These safety of flight payload malfunction checklists will normally include ground interfaces with MCC but in extreme cases of emergency may be accomplished unilaterally by the crew. Other less serious payload contingencies that will affect mission accomplishment will be corrected by or with assistance of the Orbiter crew. Representative contingencies in this category include:

   a. Incapacitation of the Payload Specialist or Mission Specialist. The Commander and Pilot would be trained to fill in with experiment operation in the event the primary crew member(s) become incapacitated.

   b. Failure of automated payload features. The Commander and Pilot would be trained to operate automated payload features manually if such provisions are incorporated into the design.

   c. Repair experiment/payload malfunctions. This refers to actions related to servicing and repair not included in the normal flight planning sequence. The Commander and Pilot would be trained to utilize available onboard equipment and with ground furnished instruction or experiment payload knowledge and checklists perform servicing or repair to the payload to insure mission accomplishment.

6. Training Location: The location where payload training is to be accomplished will present a significant scheduling constraint to Commanders and Pilots fulfilling recurrency or turnaround training requirements. Time consumed in travel will reduce available training time and present scheduling difficulties when arranging for several training requirements at a number of locations all within specified time frames, some of which may overlap other training requirement schedules. Establishing on-orbit operational payload training at JSC could reduce the impact of this driver. Lead payload centers will normally develop trainers for their payloads, if practical; however, payload training may also be accomplished at JSC, and the launch site.

   Some training can only be accomplished at a certain time interval before launch. Operational payload training accomplished during integration testing is a typical example, i.e., Integration of the payloads with the Spacelab and the Spacelab with the orbiter. These activities will take place on a timeline of events based upon the launch time. Any payload training programmed during this time will have to be accomplished to accommodate the integration schedule. Crewmen requiring payload training will have to be available during the integration process. This consideration not only infers a time constraint but also a location constraint since integration will probably be conducted at the launch site. In the case of the Commander and Pilot other training will have to be scheduled around this type of payload training that is restricted to inflexible time frames.

   Trainers and devices built for payload training may be located at the lead payload center, the launch site, or at JSC. Location of these training devices will partially determine where specific payload training will have to take place.

7. Training Methodology: The training methodology used to train for payload operation will affect the training time needed to reach established end of course objectives defined for operational payload tasks. The most effective way to achieve these objectives would be to put the entire crew in a high fidelity simulator and practice a specific mission. This method would produce a qualified crew in the shortest possible time. It is impractical and uneconomical to consider such an approach for many reasons, some of which are:

   - Cost of high fidelity simulators.
   - Utilization of simulators (only one crew could be trained at a time unless several simulators were available).

- Many tasks and procedures can be trained adequately in less sophisticated training devices.
- Only one crew can be in training at a time.
- All training must be done at simulator site.

A well designed training program that meets the needs of the end of course performance objectives should utilize a mix of training media. Detailed task analysis of the job and development of specific behavioral objectives will identify what media will best satisfy the training requirements necessary to satisfy course criteria. Some of the advantages of using a well rounded mix of training media are:

- Economical use of high fidelity simulation.
- Provides scheduling flexibility.
- Can accommodate larger student population.
- Exposes trainee to a larger cross-section of expertise.
- Training can be accomplished at more than one location.

Training required for some payload operation can be accomplished without using training media other than some classroom orientation identifying experiment objectives. Operating procedures are so minimal or the experiment is automated to the extent that flight crew operational participation is not required. This training could be accomplished during integration of the experiment with the total payload. By contrast more complex payloads may require use of high fidelity simulators. Proper use of accepted training development procedures and application of a systems approach to training will identify media requirements. The following media are currently used in pilot training programs in the airline industry:

a. High fidelity simulators equipped with:

    - Visual systems.
    - Performance comparison capability.
    - Programmed malfunction and fault analysis.
    - Six degrees of freedom motion base.
    - Automatic feedback
    - Record/playback.

b. Cockpit procedures trainers equipped with audio/visual projection systems

c. System mock-ups.

d. Individualized training carrels with audio/visual programmed instruction.

e. Classrooms with responder systems and audio/visual presentation equipment.

Availability and utilization of different media selected for training payload operation will impact the selection of Commander/ Pilot payload options.

D NUMBER OF CREWS TO BE TRAINED - NUMBER 2 DRIVER

Flight frequency is the major factor affecting crew requirements for the STS program. Lower frequencies greatly increase the number of crews required to fly the missions scheduled for the program. Higher flight frequencies reduce the number of required crews and also the turnaround time available to train them for payload operation. More payload training can be accomplished and crews can become more involved with payload operation with lower flight frequencies, however more crews will have to be trained to meet mission model requirements. Higher flight frequency turnaround rates preclude all but minimal payload training during the available training time between flights.

A second factor affecting crew requirements is the Generalized Crew Concept versus the Specialized Crew Concept. Although the type of payloads planned for the STS flights are evenly distributed, use of the Specialized concept generates a slight increase in the number of crews required to fly the mission schedule. The total training impact remains relatively constant with either concept. Generalization requires more training hours per crew and Specialization requires less training hours but more crews to train. Scheduling conflicts are more likely to occur when more crews are involved. The Specialized crews need only be trained in their designated payload specialty while Generalized crews require training in all payload categories. Table II-12, Generalized versus Specialized Crew Requirements, identifies the number of crews to be trained in each concept based upon flight frequencies of two through six flights a year. Data compiled refers to 341 planned seven day flights from the TRW371 mission model. Thirty, 30-day missions are also planned but not included in the totals represented.

1. Currency Requirements: Flight Frequency of the Orbiter and flight frequency of certain payloads will have an impact on recurrent training requirements. Orbiter recurrent training requirements must be baselined to identify Orbiter currency requirements based upon the flight frequency of the Orbiter. Flight frequency of payloads will not necessarily be the same as Orbiter frequencies. Recurrent payload training will apply only to those payloads scheduled to be on the next flight the crew will fly. The specific payload flight frequency may be only once or twice a year. Many experiments may only be flown one time during the entire program, although the payload category, i.e., Spacelab, Free Flyer, or IUS/TUG may be flown many times a year.

GENERALIZED VS SPECIALIZED CREW TRAINING REQUIREMENTS BASED UPON FLIGHT FREQUENCY (7 DAY MISSIONS)

		PAYLOAD SPECIALIZATION CATEGORY				NUMBER OF CREWS TO BE TRAINED									
						2 FLTS/YEAR		3 FLTS/YEAR		4 FLTS/YEAR		5 FLTS/YEAR		6 FLTS/YEAR	
Year	Flights Scheduled	Cat I Spacelab	Cat II Pallet Only	Cat III Free Flyer	Cat IV INS/TUG	Generalized	Specialized	Generalized	Specialized	Generalized	Specialized	Generalized	Specialized	Generalized	Specialized
1980	2	1	1	0	0	1	2	1	2	1	2	1	2	1	2
1981	8	4	1	1	2	4	5	3	5	2	4	2	4	2	4
1982	11	4	2	1	4	6	6	4	6	3	4	3	4	2	4
1983	19	5	4	5	5	10	11	7	8	5	7	4	4	4	4
1984	25	8	6	5	6	13	13	9	9	7	8	5	7	5	5
1985	32	8	8	7	9	16	17	11	12	8	9	7	8	6	8
1986	38	8	10	8	12	19	19	13	14	10	10	8	9	7	8
1987	41	10	11	7	13	21	22	14	16	11	12	9	10	7	9
1988	39	9	11	7	12	20	21	13	14	10	11	8	10	7	8
1989	41	9	10	7	15	21	22	14	15	11	12	9	9	7	9
1990	42	11	11	6	14	21	22	14	15	11	12	9	11	7	8
1991	43	12	12	6	13	22	22	15	15	11	12	9	11	8	9
TOTAL	341	89	87	60	105										

REFERENCE TRW 371 MISSION MODEL

TABLE II-12 - GENERALIZED VS. SPECIALIZED CREW REQUIREMENTS

Specialized crews will maintain currency on their designated payload category but will be trained for specific experiment/payload operation prior to each flight. Generalized crews would require training for both the designated payload category and specific experiment/payload operation. The Generalized crew flight frequency in a particular payload category would be lower than the Specialized crew and more training time and simulation will be required to prepare them for their next flight.

2. Projection of Training Aids and Simulators: The design and availability of training aids and simulators will have an impact on the available training hours necessary to qualify crews for STS flights. Effective use of training devices and the degree of fidelity designed into their operation will influence the overall training time required to qualify the Commander and Pilot for payload operation. Monetary budget constraints require that money spent for training be held to a minimum. Restricting procurement costs will affect the quantity of trainers and simulators available and to some degree will affect the quality and fidelity of simulation. Training requirements must be reduced as much as possible to relieve the pressure on these devices. Training must be closely scheduled and sequenced to take full advantage of training aids and to insure maximum utilization is achieved. Required training programs must be developed with a systems approach to insure that training devices are used only for relevant operational training and that trainer time is not wasted unnecessarily on non-operational tasks.

   An analysis of the tasks involved with payload operation using the systems approach will also identify those objectives that can be effectively trained in a classroom environment. Using classroom training to obtain these objectives will free the trainers for use in training more relevant tasks that require fidelity of response or simulation of the work environment.

   Trainers and simulators currently planned at JSC for payload and mission training are listed below:

   a. Shuttle Mission Simulator - Orbiter Flight Deck
   b. Spacelab Simulator - Spacelab Systems, Module and Experiment Interfaces.
   c. IUS Simulator
   d. Orbiter One-G Trainers - Orbiter Cabin, Mid-Body, Payload Bay doors.
   e. Spacelab One-G Trainer - Spacelab Module and Pallets.
   f. Orbiter Neutral Buoyancy Trainer - Cabin, Mid-Body, and Payload Bay doors.
   g. Spacelab Neutral Buoyancy Trainer - Exterior of Module and Pallets.
   h. RMS Simulator - Manipulator, Aft Cabin Orbiter Controls, Cargo Bay.

APPENDIX III - FUNCTIONAL PAYLOAD CATEGORIZATION

A. GENERAL

The first step in defining operational payload tasks for a Specialized Crew is to identify logical areas of specialization for on-orbit payload operations. Certain functions associated with certain types of payloads can be homogeneously grouped into compatible workload behaviors that lend themselves to specialization. This close look at payload operational functions was also necessary to acquire a generic picture of the workload tasks required to define the involvement of generalized crews with on-orbit payload operation.

Using the Flight/Year, Modified Payload Traffic Model and the Space Transportation System Payload Mission Control Study, a broad look at the functional operation requirements of each type of payload was made (Reference Table III-1). These functional requirements were further expanded to identify the number of times each function was scheduled to occur each year. (Reference Table III-2). This data will help identify where the major training emphasis needs to be applied each year, and when the need for this training must be accommodated.

This data also identifies areas where major training workloads occur and provides some insight into dividing the scheduled STS mission program into identifiable specialization categories for application of possible Commander/Pilot involvement with on-orbit payload operations. This information also supports training media and simulation decisions. Areas of high training loads or frequent occurrences might be best satisfied with more sophisticated training devices of high operational fidelity. For example RMS operation will be used on 201 STS missions (Reference Table III-2). It might be used several times on each mission which would increase the total number of operations significantly. Regardless, it points out a requirement for a relatively high fidelity trainer to adequately train the number of crews who will be using the remote manipulator system.

Criticality of the operational functions relevant to flight safety and mission accomplishment must also be considered when developing training devices and training requirements.

B. STS MISSION PAYLOAD CATEGORIZATION

There are three basic types of STS mission payload categories, 1) Spacelab Payloads, 2) Automated free flyer payloads, and 3) Orbit to Orbit IUS/TUG payloads. This categorization is based upon major technological concepts and mission objectives. Other factors such as 1) compatible behavioral objectives of the tasks involved,

OPERATIONAL PAYLOAD CONSIDERATIONS

Mission Control Flight Type	DISCIPLINE	Flts Sched-uled	PAYLOAD MISSION REQUIREMENTS											TYPE OF OPERATION				SPECIALIZATION CATEGORY
			SERVICE								SPACE LAB							
			W/EVA	WO/EVA	RMS	Airlock Opera-tion	Delivery	Retrieval	Multi Satelite	Plane-tary	Module Only	SL&P	P Only	Auto-mated	PS Oper	Multi Disc.	Dedi-cated	
A	Space Technology (ATL)	33				x						x			x		x	TYPE I
A	AMPS	19			x							x			x		x	
B	Astonomy, Cloud physics lab, Space processing & Tech, LS Mini-Lab	46				x	x					x		x	x	x		
C	Solar Physics	41											x		x	x		TYPE II
C	Stellar	9											x				x	
D	High energy physics Solar Physics Earth Resources radar	37											x	x	x	x		
E	EOS-LEO	8			x		x	x						x			x	TYPE III
F	LST Delivery HEAO - C	27			x		x	x (HEAO)						x			x	
G	EOS-LEO	4		x											x		x	
H	LEO/LST Servicing	7	x		x		x	x						x		x		
I	FFTO - LEO Bess Delivery	14	x	x	x	x	x	x							x	x		
J_1	Life Sciences 30 Day	10			x		x	x			x				x		x	TYPE I
J_2		11			x		x	x			x						x	
K	IUS	7			x		x		x					x			x	TYPE IV
L	IUS	7			x		x			x				x			x	
M	TUG	68			x		x	x	x					x			x	
N	TUG	23			x		x	x		x				x			x	
	TOTALS	371	21	18	201	93	226	168	75	30	21	98	87					

TABLE III-1

NUMBER OF SCHEDULED OCCURRENCES PER YEAR OF OPERATIONAL PAYLOAD CONSIDERATIONS

YEAR	NO FLTS YR	PAYLOAD MISSION REQUIREMENTS										
		SERVICE								SPACE LAB		
		W/EVA	WO/EVA	RMS	Air Lock Operation	Delivery	Retrieval	Multi-Satelite	Planetary	Module Only	SL & P	Pallet Only
1980	2				1	1					1	1
1981	8			5	2	5	1	1	1	1	3	1
1982	12			7	2	7	2	2	1	2	3	2
1983	20	2	1	13	4	14	6	3	2	2	4	4
1984	26	2	2	14	6	15	8	4	2	2	7	6
1985	34	2	3	19	8	20	16	5	4	2	8	8
1986	41	3	2	24	9	26	21	7	5	2	9	10
1987	44	3	2	24	11	26	13	7	6	2	11	11
1988	43	3	3	23	11	25	19	10	2	2	11	11
1989	46	3	2	26	12	30	23	12	3	2	12	10
1990	48	1	2	23	13	28	20	13	1	2	14	11
1991	48	2	1	23	13	29	20	11	2	2	15	12
TOTAL	371	21	18	201	93	226	149	75	29	21	98	87

TABLE III-2

2) equitable distribution and homogeneity of functional tasks, 3) frequency of task accomplishment, and 4) requisite repertory of the operator compared to the tasks involved, must also be considered when classifying payloads into specific functional categories.

The number of STS missions scheduled through 1991, in each of three categories cited above is:

1)	Spacelab	206
2)	Free Flyer	60
3)	IUS/TUG	105
	TOTAL	371

Further assessment of the Spacelab category identifies two distinctly different types of Spacelab missions. One involves utilization of a Spacelab module and the other utilizes pallet only configuration. Functionally, there is a decided difference between the two concepts from an operational view of the Commander and Pilot. Use of the Spacelab module extends the habitable environment of the Orbiter into the Spacelab. It presents an additional dimension to the sphere of responsibility and control the flight crew must exercise. The span of operation is divided into two separate experiment areas and the number of interfaces between the orbiter and the payload are substantially increased.

By contrast, a pallet only Spacelab mission will be operated and controlled from the Orbiter experiment stations much the same as other categories of payloads. Training necessary to involve the Commander and Pilot in payload operation of experiments on Spacelab missions with the Spacelab module will need to be more involved and time consuming than for payloads which are operated solely from the Orbiter. It would therefore, be logical to make a distinction of payload involvement by the Commander and Pilot on Spacelab missions between pallet only and module or module pallet combinations. The number of Spacelab missions scheduled through 1991 is 206. The breakdown is as follows:

1)	Module only or module/pallet	119
2)	Pallet only	87
	TOTAL	206

Dividing Spacelab missions into these two categories will eliminate a requirement to train the pallet only Specialized Crews in operation of the Spacelab module and certain Orbiter/Spacelab interfaces.

Based upon these considerations, four categories of STS mission payloads are developed for use in payload training utilizing a specialized crew concept. The flight frequencies developed in the payload traffic model for each of the identified categories will provide an equitable distribution of payload training requirements throughout the operational phase of the STS program. The four categories and the number of flights in each category is as follows:

1)	Category I - Spacelab Module/Pallet	119
2)	Category II - Spacelab pallet only	87
3)	Category III - Free flyers	60
4)	Category IV - IUS/TUG	105
	TOTAL	371

A generic list of payload disciplines scheduled for flight in the STS program in each category is contained in Table III-3, Summary of Payload Disciplines by Category. From this data a broad look can be made at the general type of mission and payload disciplines that are involved with each of the Mission Categories identified in this study. Analysis of the functional tasks involved with the inflight operational requirements of these payloads and the planned mission payload traffic model dictates a logical separation of the scheduled payloads into these four categories.

Table III-4, Payload Flight Frequency by Payload Category, shows the number of flights planned each year in each of the four categories. Assuming the Commanders and Pilots are specialized in each of these four categories and trained to participate in on-orbit payload operation in their specialty, the number of crews required to meet the annual scheduled program can be determined by applying the flight frequency guidelines.

SUMMARY OF PAYLOAD DISCIPLINES BY CATEGORY

CATEGORY I		CATEGORY II		CATEGORY III		CATEGORY IV	
SPACELAB MODULE/ PALLET		SPACELAB PALLET ONLY		FREE FLYER		IUS/TUG	
PAYLOAD	# FLTS	PAYLOAD	# FLTS	PAYLOAD	# FLTS	PAYLOAD	# FLTS
ATL	33	Solar Physics	41	EOS	12	Planetary Pioneer Mariner	30
Life Sciences (30 day)	10	Astronomy	9	LST	34	Multi-Satelite FAA Intel/SAT COMM/SAT Disaster Warn (NOAA)	75
AMPS	19	Multi-Discipline ATL Atmos-Physics Applications	37	FFTO LS (Bess)	14		
Multi-Discipline Space Process	46						
J_2	11						
TOTAL	119		87		60		105

TABLE III-3

TRW MISSION CONTROL STUDY, OCT. 1975

PAYLOAD FLIGHT FREQUENCY BY CATEGORY

	SPACELAB MODULE/PALLET CATEGORY I			SPACELAB PALLET ONLY CATEGORY II	FREE FLYER CATEGORY III	IUS/TUG CATEGORY IV	
YEAR	FLIGHTS	7 DAY	30 DAY	FLIGHTS	FLIGHTS	FLIGHTS	TOTAL
1980	1	1	0	1	0	0	2
1981	4	4	0	1	1	2	8
1982	5	4	1	2	1	4	12
1983	6	5	1	4	5	5	20
1984	9	8	1	6	5	6	26
1985	10	8	2	8	7	9	34
1986	11	8	3	10	8	12	41
1987	13	10	3	11	7	13	44
1988	13	9	4	11	7	12	43
1989	14	9	5	10	7	15	46
1990	16	10	5	11	6	14	47
1991	17	12	5	12	6	13	48
TOTALS	119	89	30	87	60	105	371

TABLE III-4

TRW MISSION CONTROL STUDY OCT. 15, 1975

APPENDIX IV - ON-ORBIT CREW FUNCTIONS FOR PAYLOAD OPERATION

A. GENERAL

This appendix identifies generic on-orbit functional tasks performed by the crew to accomplish objectives of an STS mission. In terms of the educational technologist, these broad based functions are in essence terminal objectives, each of which requires a number of sub-tasks or steps to accomplish. Sequences, controls, displays, and procedures must be designed or developed and the tasks elements necessary to perform these objectives identified before the behavioral objectives required to accomplish these functions can be developed. For the purpose of this study the functions are identified to evaluate the involvement of the Commander and Pilot in on-orbit payload operation. It is one step in the overall investigation of constraints and limitations generated by the participation of the Orbiter crew in experiment/payload operation.

Based upon determination formulated in Appendix III, Functional Payload Categorization, the functional tasks identified in this Appendix are divided into four categories of payload types.

Category I - Spacelab - Module/or module/pallet

Category II - Spacelab - Pallet only

Category III - Free Flyer Payloads

Category IV - IUS/TUG - Free flyers requiring a kick stage.

Functional payload tasks identified correspond to these four categories. Table IV-1, represents the Spacelab module/pallet combination and module only payloads. Table IV-2, identified Spacelab Pallet only functions, Table IV-3, lists the Free Flyer and EOS functions and Table IV-4, identifies functions involved with the interim upper stage and TUG planetary and military free flyer payloads utilizing the kick stage to achieve outer orbits. Functions identified in Tables IV-1 through IV-4 are applied to the four crew involvment options utilized for evaluation in this study.

B. GENERALIZED CREW CONCEPT

As with all other phases of STS flights, on-orbit functions which involve flight safety should be either performed by the Commander or Pilot or performed with their cognizance. The primary objective or rule should be "Safety", and the Commander must

TABLE IV-1 CATEGORY I - PAYLOAD FUNCTIONS

CATEGORY I - SPACELAB MODULE/PALLET ON-ORBIT OPERATIONAL PAYLOAD FUNCTIONS

SPACELAB OPERATIONS	MODULE/PALLET	MODULE ONLY
• C&W monitoring for Spacelab.	• Payload checkout.	• C & W and safing.
• Critical Spacelab activation parameter monitoring and verification(1).	• Payload activation sequence.	• Rendezvous.
• Orbiter systems configuration to support Spacelab operations(2).	• Antenna and boom deployment.	• Docking.
• State vector and timing update as required for specific experiments.	• Experiment calibration and alinement.	• Berthing.
• Spacelab deactivation.	• Experiment operations.	• Servicing.
• Monitor safety of flight C&W.	• Detached subsatellite deployment.	• Payload checkout (preingress to Spacelab).
	• Experiment repair.	• Deployment.
	• Extravehicular activity (EVA).	• Retrieval.
	• Rendezvous.	• Experiment operations.
	• Subsatellite retrieval.	• Experiment-related EVA or IVA.
	• Subsatellite berthing.	• C & W.
	• Antenna and boom stowing.	
	• Experiment deactivation sequence.	

(1) Examples are oxygen or carbon dioxide pressure, emergency power status, and so forth.

(2) Examples are bus configurations, environmental control systems configuration, and so forth.

TABLE IV-2 CATEGORY II - PAYLOAD FUNCTIONS

CATEGORY II - SPACELAB PALLET ONLY ON-ORBIT OPERATIONAL PAYLOAD FUNCTIONS

SPACELAB OPERATION	EXPERIMENT/PAYLOAD OPERATION
. C & W monitoring for Spacelab. . Critical Spacelab activation parameter monitoring and verification(1). . Orbiter systems configuration to support spacelab operations(2). . State vector and timing update as required for specific experiments. . Spacelab deactivation. . Monitor safety of flight C & W.	. Activation. . Mechanical structures - deploying elements. . Manipulator. . Orbiter maneuvering, attitude control. . Orbiter pointing. . Experiment pointing. . Power management. . Experiment - critical C & W. . Command and control (including change capability). . EVA . Direct viewing. . Remote (TV) viewing. . Data display. . Onboard data storage control. . Control data transmit to ground. . Active and passive thermal control management. . Contamination monitoring and dumping.

(1) i.e., Oxygen or cabin dioxide pressure, emergency power status, etc.

(2) i.e., Bus configurations, environmental control systems configuration, etc.

TABLE IV-3 CATEGORY III - PAYLOAD FUNCTIONS

CATEGORY III - FREE FLYER ON-ORBIT OPERATIONAL PAYLOAD FUNCTIONS

CHECKOUT AND DEPLOYMENT	POST RELEASE OPERATION	RETRIEVAL	SERVICING	EOS OPERATION
• Monitor and control resources provided by orbiter to payloads (electrical power and data interface). • Perform visual inspections. • Monitor C&W for flight safety. • Control safing functions. • Remove onboard inhibit of ground commands to payload. • Initiate, monitor, and control payload checkout sequence. • Activate and verify manipulator system. • Release payload retention system. • Erect payload in payload bay. • Monitor and control resources provided by orbiter to payload. • Monitor C&W for flight safety. • Disconnect and retract payload/orbiter umbilical. • Deploy payload to release position and release payload.	• Initiate, monitor, and control payload sequence. • Contingency support.	• Configure payload for capture. • Capture payload with remote manipulator subsystem. • Hard interface with orbiter for servicing. • Redeploy into space or lock into payload bay. • Mate and check orbiter/payload umbilical. • Monitor C&W for flight safety. • Control safing functions. • Monitor and control resources provided by orbiter to payloads. • Configure for deorbit and return (retrieval only).	BY EVA - • Perform EVA Translate to payload. Repair or exchange payload. Return to orbiter. BY SELF CONTAINED MANIPULATOR - • Activate and verify payload provided manipulator. • Perform repair or exchange. • Terminate servicing.	CHECKOUT AND DEPLOYMENT- • Monitor C&W. • Monitor orbit position. • Operate manipulator. SERVICING AND RETRIEVAL - • Monitor C&W. • Capture and operate manipulator. • Operate mission-peculiar mechanisms (MEM, flying spot scanner). • Secure spacecraft in orbiter orbiter for contingency return. • Perform pyro/propellant safing.

TABLE IV-4 CATEGORY IV - PAYLOAD FUNCTIONS

CATEGORY IV - IUS/TUG ON-ORBIT OPERATIONAL PAYLOAD FUNCTIONS

CHECKOUT AND DEPLOYMENT	POST RELEASE OPERATION	RENDEZVOUS AND DOCKING	RETRIEVAL
• Inspect visually.	• Activate Tug and update G&N.	• Track for navigation.	• Insert safety locks.
• Open payload bay doors.	• Perform activation and checkout.	• Vent main propulsion system.	• Stow Tug/ payload in bay.
• Control environmental contamination.	• Commit to main propulsion system burn.	• Verify safety status of Tug and payload.	• Connect umbilicals.
• Commit to deploy.	• Arm pyros and pressurize propellants.	• Deactivate Tug and payload and give GO for capture.	• Monitor and control C&W.
• Connect manipulator	• Monitor and control C&W.	• Make terminal closing maneuver.	
• Release latches.	• Open contamination shroud.	• Visual inspection and flyaround.	
• Extend OOS/spacecraft.	• Perform engineering housekeeping readout.	• Deploy manipulator arm and capture.	
• Activate spacecraft.	• Perform limited science sequences.	• Deactivate Tug auxiliary propulsion system.	
• Check payload rf system.	• Remove RTG cooling.	• Dock.	
• Commit to release.			
• Remove safety interlocks.			
• Release Tug.			
• Perform separation maneuver.			

be the primary crew member to insure that all tasks performed by any crew member conforms to this primary rule. This concept extends into many Orbiter/Payload interface functions. If these functions are identified as safety of flight oriented, the Commander/Pilot crew members should be involved with the operation. The following functional tasks listed for Commander and Pilot payload participation incorporate this philosophy.

1. <u>Low Payload Involvement Crew Functions (Option 1)</u> - The generalized Crew Commander and Pilot will be trained and qualified to perform the following functional tasks. These tasks represent those generic functions that a Generalized Crew with low payload involvement would be expected to perform.

   - Monitor/Control resources provided by the Orbiter to payloads (EPDS, ECS, CDMS, and data and communications interfaces).
   - Systems Housekeeping.
   - Monitor C & W.
   - Control data transmissions to the ground.
   - Control onboard data storage.
   - Open and close Orbiter payload bay doors.
   - Activate and verify manipulator system (RMS)
   - Operate RMS to remove and install payloads in Orbiter bay.
   - Display and release payloads.
   - Verify and maintain orbital positioning.
   - Maintain required payload pointing requirements.
   - Perform orbital maneuvering to accommodate payload.
   - Perform rendezvous and docking maneuvers to capture payloads.
   - Perform backup contingency EVA requirements.
   - Assist in payload operation when requested.
   - Act as experiment subject when required.
   - Perform Orbiter contingency procedures.
   - Assist in payload trouble shooting.

Training and certification of Commander and Pilots to perform these tasks will be accomplished at JSC and at the launch site during Pre-launch testing and checkout, Reference Table IV-5, Commander/Pilot Payload Training Requirements (Option I). Training requirements for Spacelab, Free flyer, and IUS/TUG Space flight missions are identified together with the planned training location. These requirements represent minimum training necessary to qualify a low involvement crew for the Generalized Crew concept. Payload testing and checkout training at the launch site will involve mission simulation and includes participation by the Payload Operations Center (POC), if applicable, and the Mission Control Center (MCC) at JSC.

2. High Payload Involvement Crew Functions (Option II) - A Generalized Crew with high payload involvement will be trained and qualified to participate in on-orbit operation of any STS payload. This concept requires training in all disciplines involved in STS missions and detailed operational training between each flight for payloads that the crew is scheduled to operate. Functional tasks identified for a Generalized Crew with low payload involvement also apply to a Generalized Crew with a high payload involvement. All functional tasks identified in Tables IV-1 through IV-4 are applicable to this payload involvement option. Functions identified are abbreviated and broad based objectives with little or no definition of the total job requirements involved. These generic functional descriptions tend to camouflage the enormity of the training requirements actually involved with this option.

   Table IV-6, Commander/Pilot Payload Training Requirements (Options II), identifies additional training requirements generated by this option. High involvement in payload operation introduces additional training requirements at the lead payload center. Commanders and Pilots will be trained to proficiency in selected payload operation and certified to perform on-orbit experiments and operational requirements necessary to accomplish the payload objectives.

C. SPECIALIZED CREW CONCEPT

Categorization of operational STS payloads into specialized functional areas as previously defined will apply to the identification of the following generic tasks. The on-orbit functions listed are logically separated into four specialized flight type categories identified in Paragraph A of this appendix.

These specialized categories provide logical training blocks for the functional tasks identifed in Tables IV-1 through IV-4. The Orbiter Commander and Pilot flying STS missions under the Special-

GENERALIZED CREW CONCEPT (LOW PAYLOAD INVOLVEMENT)

		SPACELAB	FREE FLYER	IUS/TUG	
JSC	Flight Crew Selection Basic and Advanced Training	1. Mission Independent 2. Spacelab Habitability 3. Spacelab EVA 4. Spacelab Subsystems 5. Recurrent and Flight Specific 6. Contingency Operation 7. Safety 8. Integrated Flight Crew Operations.	1. Mission Independent 2. Backup EVA 3. Rendezvous and docking 4. Contingency operation 5. Payload removal and stowage 6. Recurrent and Flight Specific 7. Safety 8. Integrated Flight Crew Operations	1. Mission Independent 2. Rendezvous and Docking. 3. Contingency Operation 4. Payload Removal and Stowage 5. Recurrent and Flight Specific 6. Safety 7. Integrated Flight Crew Operations	
LAUNCH SITE		1. Spacelab/Orbiter Testing and Checkout POC and MCC Interaction Required	1. Orbiter/Payload Testing and Checkout POC and MCC Interaction Required	1. Orbiter/Payload Testing and Checkout. POC and MCC Interaction Required	LAUNCH

TABLE IV-5 - COMMANDER/PILOT PAYLOAD TRAINING REQUIREMENTS (OPTION I)

GENERALIZED CREW CONCEPT (HIGH PAYLOAD INVOLVEMENT)

		SPACELAB	FREE FLYER	IUS/TUG	
JSC	Flight Crew Selection Basic and Advanced Training	1. Mission Independent 2. Spacelab Habitability 3. Spacelab EVA 4. Spacelab Subsystems 5. Contingency Operation 6. Safety 7. Integrated Flight Crew Operational Training 8. Recurrent and Flight Specific	1. Mission Independent 2. EVA 3. Rendezvous & docking 4. Contingency Operation 5. Payload Removal and Stowage 6. Safety 7. Integrated Flight Crew Operational Training 8. Recurrent and Flight Specific	1. Mission Independent 2. Rendezvous and docking 3. Contingency Operation 4. Payload Removal and Stowage 5. Safety 6. Integrated Flight Crew Operational Training 7. Recurrent and Flight Specific	
USER PI OR SYSTEMS CONTRACTOR	Lead Center GSFC MSFC	1. Mission Dependent 2. Payload Checkout and Activation 3. Experiment operation 4. Payload servicing 5. Safety 6. Orbiter/Spacelab/ Payload Interfaces	1. Mission Dependent 2. Payload Checkout and Activation 3. Payload Operation 4. Payload Servicing 5. Safety 6. Orbiter/Payload Interfaces		
	Lead Center JPL ARC			1. Mission Dependent 2. Payload Checkout and Activation 3. Payload Operation 4. Payload Deactivation and Safing 5. Safety 6. Orbiter/Payload Interfaces	
LAUNCH SITE	KSC or Vandenberg AFB	1. Spacelab/Experiment Operational Training POC and MCC Interaction Required	1. Orbiter/Payload Testing and Checkout Training POC and MCC Interaction Required	1. Orbiter/Payload Testing and Checkout Training POC and MCC Interaction Required	LAUNCH

TABLE IV-6 - COMMANDER/PILOT PAYLOAD TRAINING REQUIREMENTS (OPTION II) ized Crew concept will be trained to perform payload tasks in one of these four categories. They will fly missions in their specialization only. Advanced training will include functional tasks identified for low payload involvement. If high payload involvement is required specific on-orbit payload operational training for the succeeding mission will be accomplished as Flight Specific and Payload Specific training between flights (Turnarounds).

1. Low Payload Involvement Crew Functions (Option III) - Specialized Crew concept with a low payload involvement will basically require only Advanced and Flight Specific training for the Commander and Pilot to qualify for payload support functions. This training will include system familiarization, housekeeping, habitability, waste management, food management, emergency and contingency procedures, and common orbiter/payload interfaces that occur on every STS mission in the designated mission category. The following list of functional tasks is the same as for a Generalized Crew with low payload involvement, however, not all would be applicable to every flight for a Specialized Crew. Only those functions applicable to the Specialized payload category will be included in Flight Specific training as indicated in Table IV-7, Specialized Crew Functions (Option III).

   The concept of Specialized Crews with low payload involvement is the simplest option in terms of training time.

   This option will accommodate quick turnaround times created by limited crew availability and/or high flight frequencies. Functions defined in Table IV-7 represent minimum acceptable payload training requirements for Specialized Crews in each specialized payload category. Payload center planning assumes JSC will provide most of the training required to qualify STS crews for the low payload involvement concept.

2. High Payload Involvement Crew Functions (Option IV) - The Specialized Crew concept with high payload involvement assumes the Commander and Pilot will be trained to operate on-orbit payload experiments on STS flights in their specialized payload categories. This option requires accomplishment of payload training at the sponsoring or lead payload center in addition to the training identified under the low payload involvement option.

   This additional training will increase the required training time between flights and will reduce the frequency at which the crews will be qualified to fly. Identification of generic functions involved in each specialization category is contained in Tables IV-1 through IV-4, paragraph A, of this Appendix.

SPECIALIZED CREW LOW PAYLOAD INVOLVEMENT FUNCTIONS

CREW FUNCTION	APPLICABLE SPECIALIZATION CATEGORY			
	I	II	III	IV
• Monitor/Control resources provided by the Orbiter to payloads (EPDS, ECS, CDMS, and data and communications interfaces.	x	x	x	x
• Systems Housekeeping	x	x	x	x
• Control data transmittion to the ground	x			
• Control onboard data storage	x	x		
• Open and Close Orbiter payload bay doors	x	x	x	x
• Activate and verify manipulator System (RMS)		x	x	x
• Deploy and release payloads			x	x
• Operate RMS to remove and install payloads in Orbiter bay			x	x
• Verify and maintain orbital positioning	x	x	x	x
• Maintain required payload pointing requirements	x	x		
• Perform orbital maneuvering to accommodate payload	x	x	x	x
• Perform rendezvous and docking maneuvers to capture payloads			x	x
• Perform backup contingency EVA requirements	x	x	x	x
• Assist in payload operation on request	x	x	x	x
• Act as experiment subject when required	x	x	x	x
• Perform Orbiter/payload contingency procedures	x	x	x	x
• Assist in payload trouble shooting	x	x	x	x

TABLE IV-7 - SPECIALIZED CREW FUNCTIONS (OPTION III)

a. Category I - Spacelab Module/Pallet Payloads. - Table IV-1, identifies the generic on-orbit payload functions involved with operation of Spacelab Module/Pallet combination payloads. High payload involvement by the Commander and Pilot will require qualification in the functional tasks listed on this table for this specialized payload category. Training and qualification in specified subsets of these functions is in addition to the functional tasks identified for low payload involvement listed in Table IV-7, Specialized Crew Functions. Training for high payload involvement will normally be accomplished at the lead payload center responsible for the payload.

b. Category II - Spacelab Pallet Only Payloads - Table IV-2, identifies the generic on-orbit payload functions involved with operation of pallet only Spacelab payloads. Items listed represent additional qualification requirements for high payload involvement in this specialization category in addition to those denoted in Table IV-7.

c. Category III - Free Flyer Payloads - Table IV-3, identifies the generic on-orbit payload functions involved with operation of free flyer payloads. With the high payload involvement concept, Commanders and Pilots flying STS flights in this specialization category will be trained and qualified to perform functions listed on this table in addition to functional tasks identified in Table IV-7.

d. Category IV - IUS/TUG Payloads - Table IV-4, identifies the generic on-orbit payload functions involved with operation of free flying payloads utilizing a kick stage to achieve orbits beyond the capability of the shuttle. High payload involvement will require the Commander and Pilot to be trained and qualified to perform these functions in addition to functional tasks listed in Table IV-7.

APPENDIX V - WEIGHTED METHODOLOGY

A. GENERAL

The intent of this Appendix is to utilize the available training hours and required training hours determined in Appendix II to develop a methodology for weighting each consideration of training and establish baseline training requirements for each option. These data will provide an example of training requirements based upon the tentative inputs currently available. The methodology presented will allow certain assumptions to be factored into the baseline training requirement and will provide a method for ready comparison of training for the four crew options.

B. APPROACH

For this study several factors were found to influence the hours required to train the Commander and Pilot. These factors are:

- Generalized vs. Specialized Crew
- High of Low Payload Involvement
- Payload Complexity
- Multiple Payload Disciplines
- Contingency Operation Involvement
- Training Locations

These factors are applied only to Flight Specific and Payload Specific requirements as it is believed that the Orbiter Recurrency training is a firm requirement not subject to the impact of payload involvement.

Generalized vs. Specialized Crew - The baseline option for this study is considered to be a generalized-low involvement crew and any deviation from that baseline will be a factor of influence on the final training hour requirement. The Generalized factor, hence, will have no impact. Specialization, however, is considered to have a reduction effect on both Flight Specific and Payload Specific training. Although these training categories are intended to consist of delta training between missions, it is thought that significant reduction of training requirements will occur as the result of greater retention of similar activities in flight categories from one flight to the next, (i.e., similarities of different experiments within the same scientific discipline will streamline the training for new experiments within that discipline).

It is difficult to quantify the savings in training time because of specialization, however, it is generally agreed that savings will occur. Hence we have assumed that a specialized crew would require only 70% as much training between flights as a generalized crew for flights rates of three a year or less. We have further assumed that an additional 10% is gained by increased retention of similar activities for flight rates over three a year. Hence, a factor of (.7) will appear for specialized crew factors of three flights a year or less and (.6) for specialized factors over three flights a year. These factors will apply both to Flight Specific and Payload Specific.

High or Low Payload Involvement - As the low involvement is our baseline option, a factor of (1.0) will be used. No impact is assumed to Flight Specific training as a result of additional payload operation involvement, however, we have assumed that a factor of (2.0) or twice the hours will be required for Payload Specific to train for a higher level of payload operation involvement.

Payload Complexity - As the complexity of the payload will have obvious affect on training both for the Flight Specific activities (attitude profile, maintenance, maneuvers, etc.) and the Payload Specific activities, three factors were assumed applied to both - a no-impact factor of (1.0) for normal, a (.8) impact factor for low complexity, and a (1.5) factor for high complexity. More precise methods of analysis can be applied as specific training requirements are defined, however, for the generic analysis being performed in this study, this approach should be sufficient.

Multiple Payload Disciplines - A dedicated discipline payload was considered the norm and multiple disciplines were considered to increase the training complexity by 10% for each additional discipline.

Contingency Operation Involvement - The training requirements utilized in the analysis for Flight Specific and Payload Specific were felt to include enough contingency training to satisfy the study definition of low involvement. A factor of (1.0) was therefore applied for low involvement options. It was felt that high involvement would require additional Payload Specific training for contingency payload operations and a factor of (1.2) was applied to increase by 20% the training period.

Training Locations - It was assumed that for each training location used in addition to JSC, some additional training, travel, and logistics would be involved to justify an increase of 5%

for each center added.

With these groundrules, each option was evaluated by including Orbiter Recurrency hours, factored Flight Specific hours, and factored Payload Specific hours to estimate the total training hours required between flights for each option at all flight rates from one to six per year. These data are then compared with the hours available for training developed in Appendix II.

C. GENERALIZED CREW CONCEPT

Table V-1, Weighted Factors for Generalized Crews, depicts the weighting factors assumed for the generalized crew concept having both low and high Commander/Pilot involvement in payload operations. Each of the factors shown is the result of the groundrules defined in B. APPROACH, above. The following will present examples of the methodology using available tentative training requirements to estimate the impacts on training. To simplify the process normal payload complexity, dedicated payloads, and single training locations (all having factors of 1.0) will be utilized in the numerical example.

1. Low Payload Involvement (Option I)

Orbiter Recurrent Hours

The base number utilized in all the examples that follow will be the Orbiter Recurrent hours required between flights. From Appendix II we have the annual Orbiter Recurrent hours of 330 annual hours for flight rates of 1, 2, and 3 per year and 311 annual hours for flight rates of 4, 5, and 6 per year. When these annual hours are divided by the appropriate flight rate the following Orbiter Recurrent hours between flights result:

Annual Orbiter Recurrent - 330 hours

Flight Rate - one/year = 330 hours between flights

" " - two/year = 165 hours between flights

" " - three/year = 110 hours between flights

Annual Orbiter Recurrent - 311 hours

Flight Rate - four/year = 78 hours between flights

" " - five/year = 62 hours between flights

" " - six/year = 52 hours between flights

GENERALIZED CREW CONCEPT

CONSIDERATIONS	OPTION I - LOW PAYLOAD INVOLVEMENT: Flight Spec	OPTION I - LOW PAYLOAD INVOLVEMENT: Payload Spec	OPTION II - HIGH PAYLOAD INVOLVEMENT: Flight Spec	OPTION II - HIGH PAYLOAD INVOLVEMENT: Payload Spec
I OPTION INFLUENCES CREW: GENERALIZED	1	1	1	1
PAYLOAD INVOLVEMENT				
LOW	1	1		
HIGH			1	2.0
II PAYLOAD FACTORS				
PAYLOAD COMPLEXITY				
LOW	.8	.8	.8	.8
NORMAL	1	1	1	1
HIGH	1.5	1.5	1.5	1.5
MULTIPLE PAYLOAD FACTORS				
DEDICATED	1	1	1	1
MULTIPLE	1+(.1)(# of additional disciplines)	1+(.1)(# of additional disciplines)	1+(.1)(# of additional disciplines)	1+(.1)(# of additional disciplines)
III TRAINING FACTORS				
CONTINGENCY OPERATION	1	1	1	1.2
TRAINING LOCATION				
JSC	1	1	1	1
MULTI-CENTER	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)

TABLE V-1 - WEIGHTED FACTORS FOR GENERALIZED CREWS

These hours of Orbiter Recurrent training required between flights, although not subject to the weighted factors, will be added to the Flight Specific and Payload Specific to arrive at the total between flight training hours required for all options.

Flight Specific Hours

Referring to Table V-1, note that no factors impact this case and the base training hours of 230 determined in Appendix II remain for Flight Specific Hours.

Payload Specific Hours

Again referring to Table V-1 note that no factors impact the base of 80 hours developed in Appendix II.

Total Training Hours Required Between Flights for Option 1

TRAINING HOURS	FLIGHTS PER YEAR					
	ONE	TWO	THREE	FOUR	FIVE	SIX
ORBITER RECURRENT	330	165	110	78	62	52
FLIGHT SPECIFIC	230	230	230	230	230	230
PAYLOAD SPECIFIC	80	80	80	80	80	80
TOTAL	640	475	420	388	372	362

These resulting data are plotted in Figure V-1 to illustrate the required vs. available training hours. Two background plots are depicted - one to show total hours available between flights for a six hour per day training schedule and the other for a four hour per day training schedule. These background plots will be the same for all options.

The resulting data are then overlaid to indicate which flight rates can be accommodated utilizing the existing training groundrules for this option. The Required points coincident or below the Available lines represent feasible cases. The delta that Required is below Available represents additional training hours that could be utilized for increased payload involvement training.

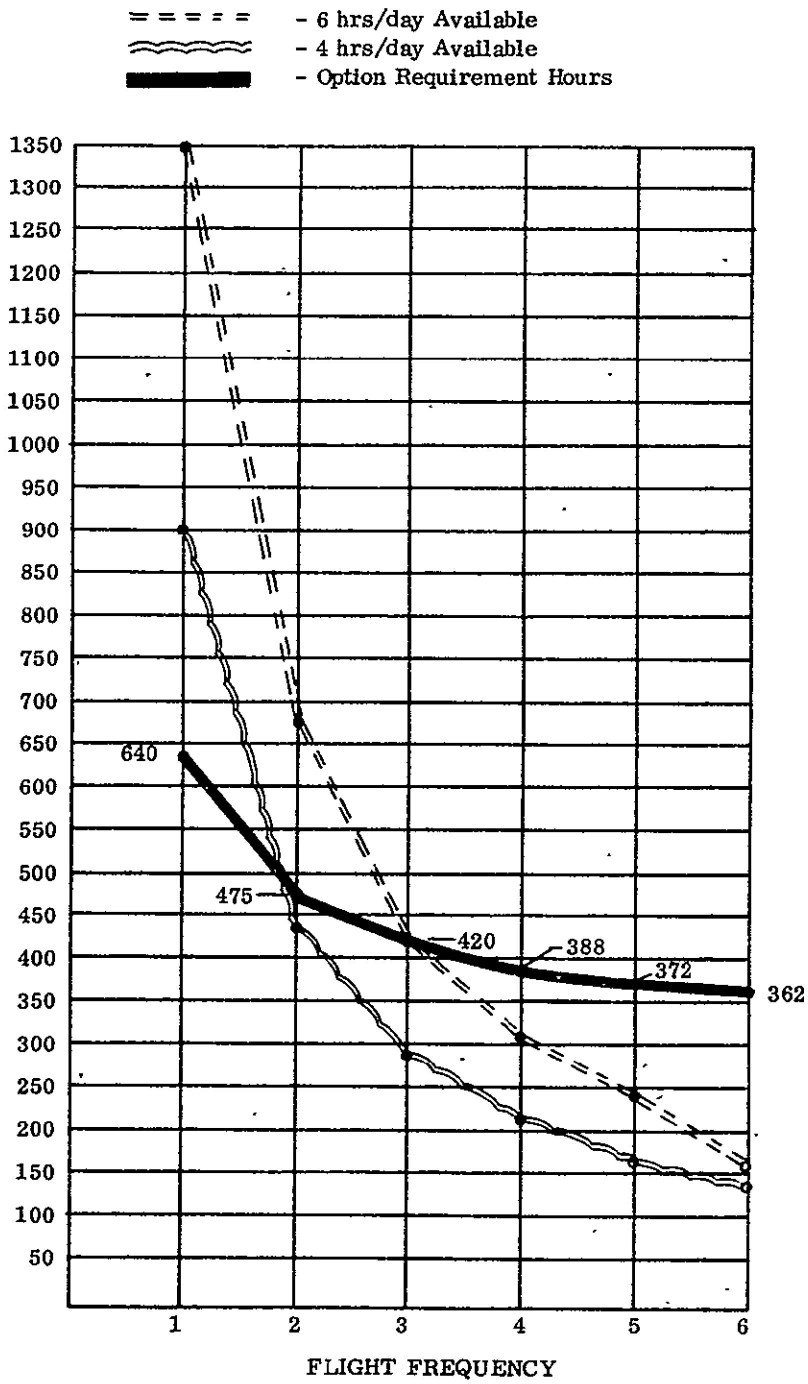

FIGURE V-1 - AVAILABLE VS. REQUIRED TRAINING HOURS (OPTION I)

2. High Payload Involvement (Option II)

Orbiter Recurrent Hours

Refer to Section C.1

Flight Specific Hours

No factors impact the base number of 230 (Table V-1).

Payload Specific Hours

Referring to Table V-1 we see factors impacting Payload Specific Hours to be the high payload involvement and the contingency operations.

Base	=	80 hours
Factor - High Involvement (2.0) - add 100%	=	80 hours
Factor - Contingency (1.2) -add 20%	=	16 hours
Payload Specific	=	170 hours

Total Training Hours Required Between Flights for Option II

TRAINING HOURS	FLIGHTS PER YEAR					
	One	Two	Three	Four	Five	Six
ORBITER RECURRENT	330	165	110	78	62	52
FLIGHT SPECIFIC	230	230	230	230	230	230
PAYLOAD SPECIFIC	176	176	176	176	176	176
TOTAL	736	571	516	516	484	458

These resulting data are applied in Figure V-2, Available vs. Required Training Hours (Option II), for your reference.

D. SPECIALIZED CREW CONCEPT

Table V-2, Weighted Factors for Specialized Crews, depicts the weighting factors assumed for the Specialized crew concept having both low and high Commander/Pilot involvement in payload operations. Each of the factors shown are the result of the groundrules defined above in B. Approach. The numerical examples for specialized crew options follow.

1. Low Payload Involvement (Option III)

Orbiter Recurrent Hours

Refer to Section C.1.

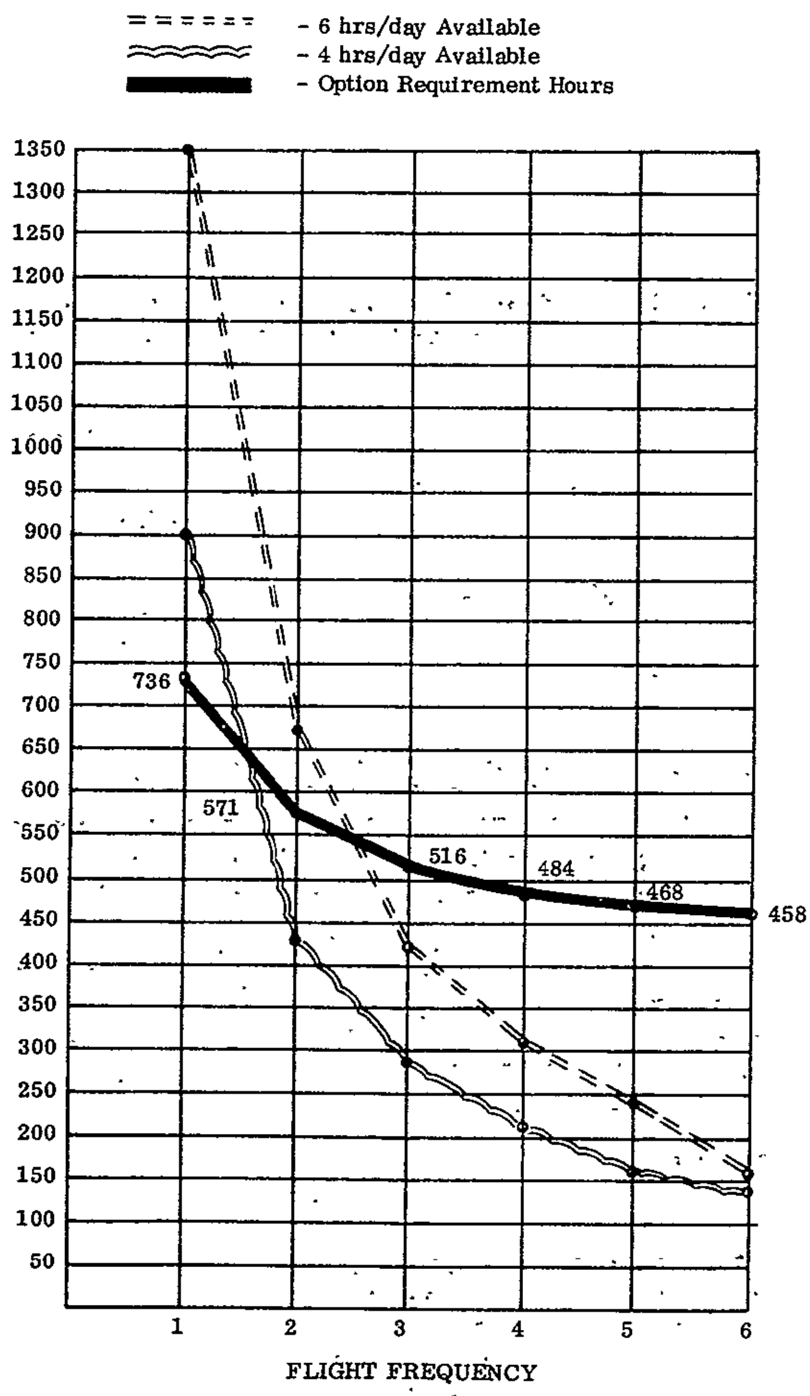

FIGURE V-2 - AVAILABLE VS. REQUIRED TRAINING HOURS (OPTION II)

Flight Specific Hours

Referring to Table V-2, note that factors impacting the base number of 230 are imposed by crew specialization. A reduction of 30% is indicated for flight rates of three a year and below and 40% for flight rates over three a year.

Flight Rates - 1, 2, and 3 per year

Base	=	230 hours
Factor - Crew Specialization (.7) decrease 30%	=	-69 hours
Flight Specific	=	161 hours

Flight Rates - 4, 5, and 6 per year

Base	=	230 hours
Factor - Crew Specialization (.6) - decrease 40%	=	-92 hours
Flight Specific	=	138 hours

Payload Specific Hours

Table V-2, indicates factors impacting the base number of 80 to be only crew specialization.

Flight Rates - 1, 2, and 3 per year

Base	=	80 hours
Factor-Crew Specialization (.7) - decreased 30%	=	-24 hours
Payload Specific		56 hours

Flight Rates - 4, 5, and 6 per year

Base	=	80 hours
Factor-Crew Specialization (.6) - decreased 40%	=	-32 hours
Payload Specific		48 hours

SPECIALIZED CREW CONCEPT

	OPTION III - LOW PAYLOAD INVOLVEMENT		OPTION IV - HIGH PAYLOAD INVOLVEMENT	
CONSIDERATIONS	Flight Spec	Payload Spec	Flight Spec	Payload Spec
I OPTION INFLUENCES				
CREW (3 Flts or Less)	.7	.7	.7	.7
(Over 3 Flts/Year)	.6	.6	.6	.6
PAYLOAD INVOLVEMENT:				
LOW	1.0	1.0		
HIGH			1.0	2.0
II PAYLOAD FACTORS				
PAYLOAD COMPLEXITY				
PAYLOAD CATEGORY				

	I	II	III	IV
Low			.8	.8
Normal		1		
High	1.5			

CONSIDERATIONS	Flight Spec	Payload Spec	Flight Spec	Payload Spec
MULTIPLE PAYLOAD FACTORS				
DEDICATED	1	1	1	1
MULTIPLE	1+(.1)(# of additional disciplines)	1+(.1)(# of additional disciplines)	1+(.1)(# or additional disciplines)	1+(.1)(# of additional disciplines)
III TRAINING FACTORS				
CONTINGENCY OPERATION	1.0	1.0	1.0	1.2
TRAINING LOCATION				
JSC	1.0	1.0	1.0	1.0
MULTI-CENTER	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)	1+(.05)(# of additional locations)

TABLE V-2 - WEIGHTED FACTOR FOR SPECIALIZED CREWS

Total Training Hours Required Between Flights for Option III

TRAINING HOURS	FLIGHTS PER YEAR					
	One	Two	Three	Four	Five	Six
ORBITER RECURRENT	330	165	110	78	62	52
FLIGHT SPECIFIC	161	161	161	138	138	138
PAYLOAD SPECIFIC	56	56	56	48	48	48
TOTAL	547	382	327	264	248	238

These resulting data are plotted in Figure V-3, Available vs. Required Training Hours (Option III), for your reference.

2. High Payload Involvement (Option IV)

Orbiter Recurrent Hours

Refer to Section C.1.

Flight Specific Hours

Reference to Table V-2 shows that factors impacting the base number are imposed by crew specialization. A reduction of 30% is indicated for flight rates of three per year and below and 40% for flight rates above three per year.

Flight Rates - 1, 2, and 3 per year

Base	=	230 hours
Factor - Crew Specialization (.7) - decreased 30%	=	-69 hours
Flight Specific	=	161 hours

Flight Rates - 4, 5, and 6 per year

Base	=	230 hours
Factor - Crew Specialization (.6) - decreased 40%	=	-92 hours
Flight Specific		138 hours

Payload Specific Hours

Table V-2 indicates factors impacting the base number of 80 to be crew specialization, increased payload involvement, and increased contingency operations.

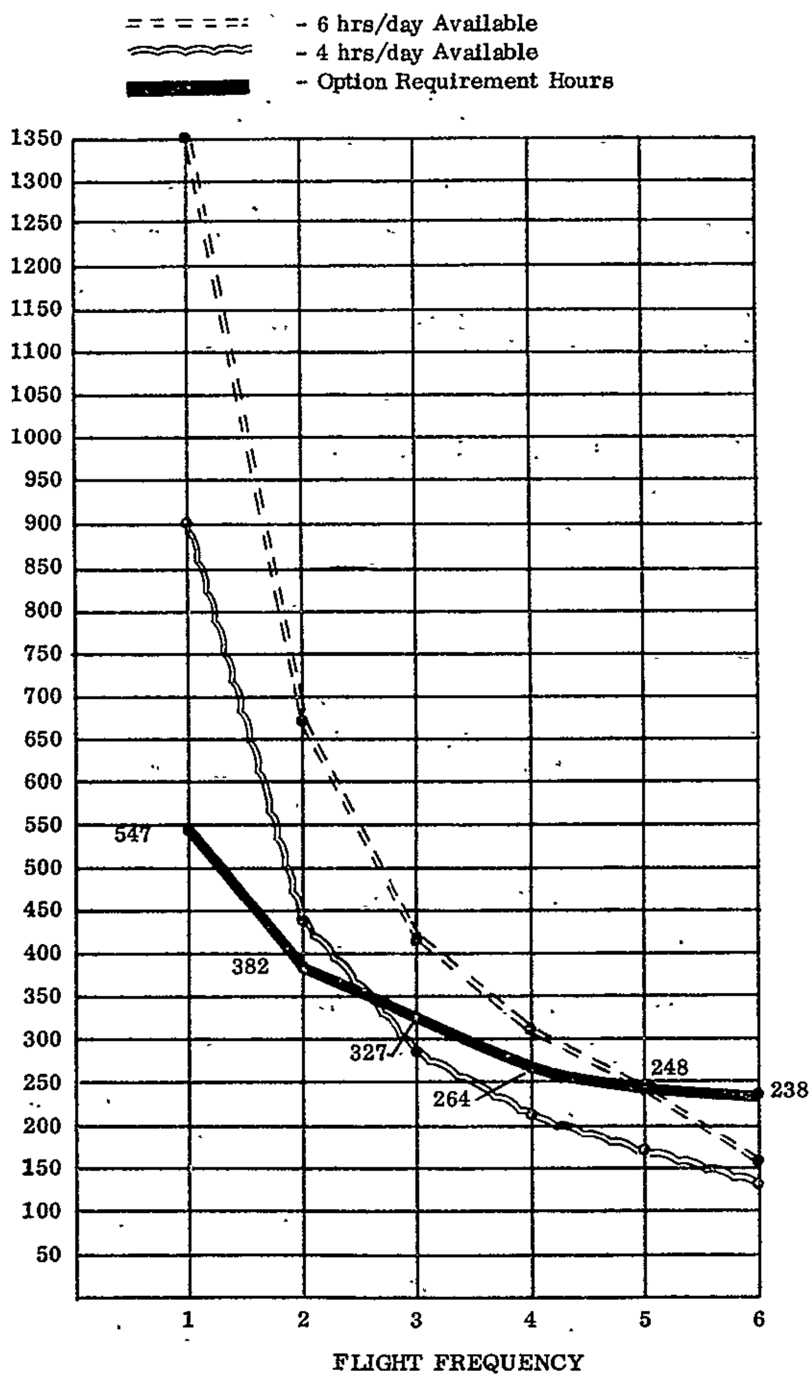

FIGURE V-3 - AVAILABLE VS. REQUIRED TRAINING HOURS (OPTION III)

Flights Rates - 1, 2, and 3 per year

Base	=	80 hours
Factor - Crew Specialization (.7) - decreased 40%	=	-24 hours
Factor - High Involvement (2.0) Increase 100%	=	80 hours
Factor - Contingency Operations (1.2) - increased 20%	=	16 hours
Payload Specific	=	152 hours

Flight Rates - 4, 5, and 6 per year

Base	=	80 hours
Factor - Crew Specialization (.6) - decreased 40%	=	-32 hours
Factor - High Involvement (2.0) - increased 100%	=	80 hours
Factor - Contingency Operations (1.2) - increased 20%	=	16 hours
Payload Specific	=	144 hours

Total Training Hours Required Between Flights for Option IV

TRAINING HOURS	FLIGHTS PER YEAR					
	One	Two	Three	Four	Five	Six
ORBITER RECURRENT	330	165	110	78	62	52
FLIGHT SPECIFIC	161	161	161	138	138	138
PAYLOAD SPECIFIC	152	152	152	144	144	144
TOTAL	643	478	423	360	344	334

These resulting data are plotted in Figure V-4, Available vs. Required Training Hours (Option IV), for your reference.

Any modification of assumptions and groundrules needed to assign weighting factors or in the base training hours numbers can significantly change the data and hence the conclusions.

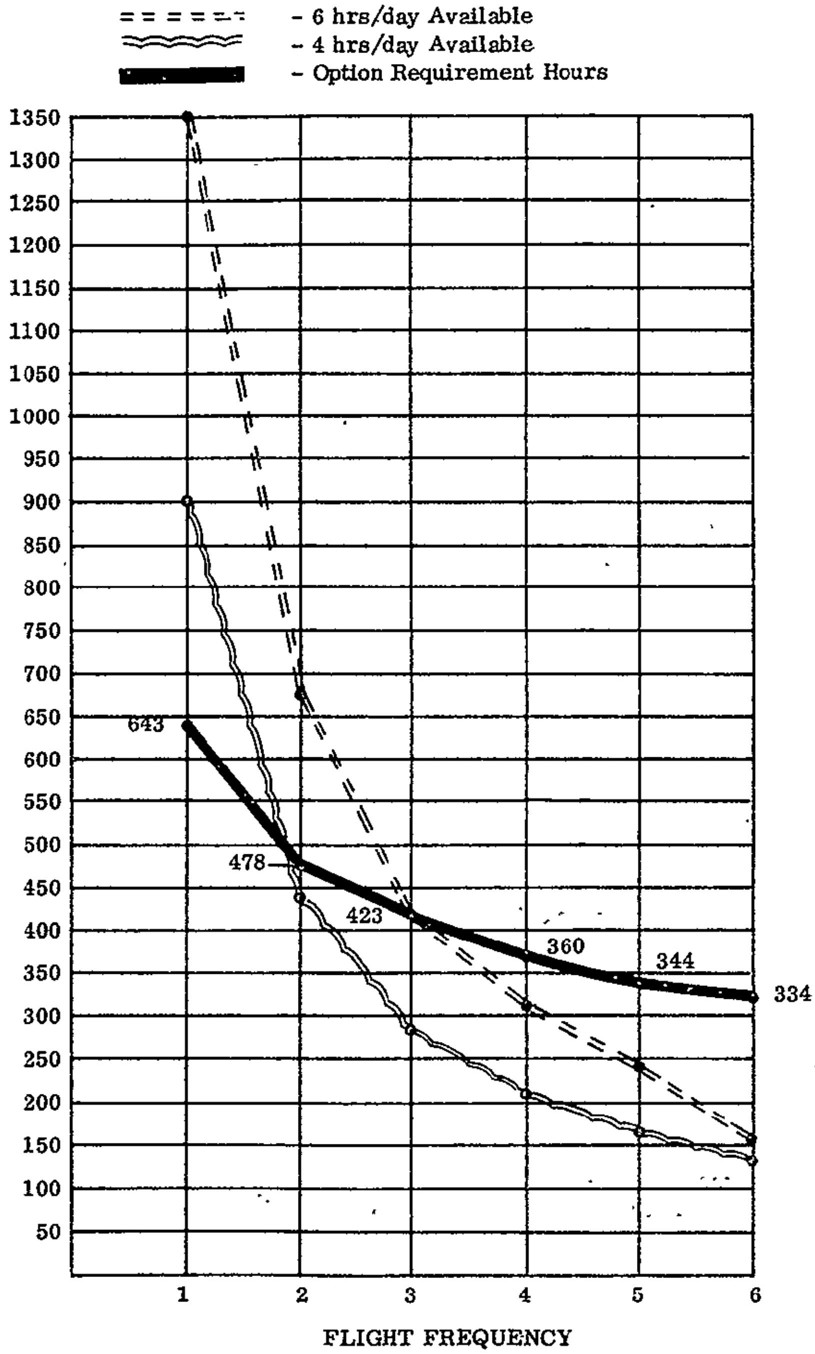

FIGURE V-4 - AVAILABLE VS. REQUIRED TRAINING HOURS (OPTION III)