31 MARCH 1977

MDC G6741

(NASA-CR-150234) INTEGRATED PAYLOAD AND MISSION PLANNING, PHASE 3. VOLUME 4: OPTIMUM UTILIZATION OF SPACELAB RACKS AND PALLETS Final Report (McDonnell-Douglas Astronautics Co.) 90 p HC A05/MF A01

N77-21182

Unclas

G3/16 24931

INTEGRATED PAYLOAD AND MISSION PLANNING, PHASE III

FINAL REPORT

VOLUME IV

Optimum Utilization of Spacelab Racks and Pallets

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

MCDONNELL DOUGLAS CORPORATION

MCDONNELL DOUGLAS

INTEGRATED PAYLOAD AND MISSION PLANNING, PHASE III

FINAL REPORT, VOLUME IV
Optimum Utilization of Spacelab Racks and Pallets

CONTRACT NO. NAS8-31146
DPD NO. 535
DR MA-04

31 MARCH 1977

MDC G6741

PREPARED BY:

R. G. LOGSTON
TASK LEADER

G. D. BUDRIS

APPROVED BY:

R. P. DAWSON
STUDY MANAGER

APPROVED BY:

F. C. RUNGE
PROGRAM MANAGER
SPACE PAYLOADS

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST
5301 Bolsa Avenue, Huntington Beach, CA 92647

PREFACE

This report documents the results of a study conducted by the McDonnell Douglas Astronautics Company (MDAC) from 1 June 1976 to 31 March 1977 for the NASA George C. Marshall Space Flight Center (MSFC) related to integrated payload and mission planning for Space Transportation System (STS) payloads. This Phase III effort is a continuation of the Shuttle payload planning studies initiated by NASA/MSFC in October 1974.

An executive summary of this phase is reported in MDC-6740. Final detailed technical results of this study phase are reported in the following volumes of MDC G6741.

Volume I - Integrated Payload and Mission Planning Process Evaluation

Volume II - Logic/Methodology for Preliminary Grouping of Spacelab and Mixed Cargo Payloads

Volume III - Ground Data Management Analysis
Onboard versus Ground Real-Time Mission Operations

Volume IV - Optimum Utilization of Spacelab Racks and Pallets

This Volume IV presents the results of an analysis of the first 18 Spacelab missions directed toward optimizing the use of Spacelab racks and pallets. Included are a description of the general approach, estimates of baseline flow dwell times and costs, an assessment of the effects of rack dedication to selected payloads, a discussion of the applicability of results to varying degrees of Level IV integration, and general observations and recommendations.

Requests for additional information should be directed to the following personnel:

- Mr. R. E. Valentine, Study COR
  NASA George C. Marshall Space Flight Center
  Huntsville, Alabama 35812
  Telephone: 205-453-3437

- Mr. R. P. Dawson, Study Manager
  McDonnel Douglas Astronautics Company
  Huntington Beach, California 92647
  Telephone: 714-896-3205

- Mr. R. D. Nichols, Field Office Representative
  McDonnell Douglas Astronautics Company
  Huntsville, Alabama 35812
  Telephone: 205-881-0611

ACKNOWLEDGMENTS

MDAC wishes to acknowledge the management and technical assistance given by the following NASA personnel throughout the course of this study:

R. E. Valentine - Study COR

W. A. Emanuel

R. E. Lavender

J. H. Sims

J. W. Price

CONTENTS

FIGURES

TABLES

SUMMARY

Spacelab experiment operations are expected to generate demands for pallets and racks to the extent that the available inventory must be processed in an optimum manner in order to properly utilize the equipment as well as minimize the labor involved in Level IV integration activities and postflight refurbishment activities. The objective of this task was to develop the methodology to optimize the utilization of Spacelab racks and pallets and to apply this methodology to the early STS Spacelab missions.

Initially, a review was made of Spacelab Program requirements and flow plans, generic flow plans for racks and pallets were examined, and the principal optimization criteria and methodology were established. The review addressed interactions between schedule, inventory, and key optimization factors; schedule and cost sensitivity to optional approaches; and the development of tradeoff methodology. This methodology was then applied to early Spacelab missions (1980-1982). Rack and pallet requirements and duty cycles were defined, a utilization assessment was made, and several trade studies performed involving varying degrees of Level IV integration, inventory level, shared versus dedicated Spacelab racks and pallets, and potential adjustments in mission schedules.

The key findings from the analysis are:

1. Baseline inventory is adequate with minor delivery adjustments required.
2. Rack dedication to selected payloads is cost effective.
3. Five payloads were identified for rack dedication.
4. Cost effective options were identified for rack usage.
5. Pallet dedication is not practical.
6. Methodology for above derivation developed for possible future application.

Section 1
INTRODUCTION AND SUMMARY

This Volume IV represents the final report of all tasks relating to Task 2.2C, Optimum Utilization of Spacelab Racks and Pallets. The overall effort began in July 1976 and extended through February 1977 with the bulk of the analysis and findings occurring from September to December of 1976.

As background, it should be noted that Spacelab experiment operations are expected to generate demands for pallets and racks to the extent that the available inventory must be processed in an optimum manner in order to properly utilize the equipment as well as minimize the labor involved in Level IV integration activities and postflight refurbishment activities. The objectives of this task (summarized in Figure 1-1) were to develop the criteria and methodology to optimize the utilization of Spacelab racks and pallets and to apply this methodology to the early STS Spacelab missions.

Figure 1-1 28221

STUDY OBJECTIVES

- PERFORM SYSTEMS ENGINEERING ANALYSES OF SPACELAB PROGRAM HARDWARE, PAYLOADS, AND OPERATIONS DIRECTED TOWARD OPTIMIZING THE USE OF RACKS AND PALLETS
  - ESTABLISH OPTIMIZATION CRITERIA FOR USE IN THE SUBSEQUENT DEVELOPMENT OF THE METHODOLOGY
  - DEVELOP THE METHODOLOGY TO OPTIMIZE USE OF SPACELAB RACKS AND PALLETS
  - APPLY THE METHODOLOGY TO THE EARLY STS MISSIONS* AND FORMULATE RECOMMENDATIONS RESULTING THEREFROM

*STUDY BASED ON EARLY STS MISSIONS PLAN DATED JUNE 22, 1976 AS AMENDED BY IP&MP OFFICE

Initially, a review was made of Spacelab program requirements and flow plans, generic flow plans for racks and pallets were examined, and the principal optimization criteria and methodology were established. The review addressed interactions between schedule, inventory, and key optimization factors; schedule and cost sensitivity to optional approaches; and the development of tradeoff methodology. This methodology was then applied to early Spacelab missions (1980-1982). Rack and pallet requirements and duty cycles were defined, a utilization assessment was made, and cost and flow estimates derived. In the process of application to these early missions, the methodology was further developed.

Considerable effort was expended toward understanding and/or developing baseline flows and costs. For example, a clear definition of the scope or degree of Level IV integration was not available for the study. Therefore, three possible modes of operation for Level IV were defined which spanned the range of probable program choices. Described more fully in Section 3, the modes of operation are:

Mode A - Flight Ready integrated systems
Mode B - Integration to subsystem level
Mode C - Installation verification only.

For convenience, flow and cost estimates were derived primarily for the Mode B approach as a nominal case for this study, with Mode A and C cases also developed for certain payloads of interest. General conversion factors were derived parametrically to convert study results, where applicable, to the ultimate program choice for Level IV integration mode.

After establishing baselines for flow, costs, inventory, rack and pallet sharing, and the interrelationships involved, alternatives were explored to identify possible cost savings in the rack and pallet area. The most notable finding was that dedicating Spacelab racks to selected payloads is cost effective. Payloads were selected as candidates for dedication after reiterative consideration of the following:

A. Number of reflights in early STS missions
B. Percentage of rack consumed
C. Technical/operational advantages
D. Probable cost savings.

Candidate payloads so chosen were subjected to detailed analysis comparisons of shared and dedicated approaches. The analysis indicates (for the nominal study case) a possibility of a net savings of about $800,000 in the early missions by dedicating six double racks and one single rack, requiring the purchase of only two double racks beyond the inventory now planned (see Section 7 for additional details). Alternate options involving schedule and inventory interactions were derived by detailed analysis, indicating several cost-effective approaches requiring only minor mission schedule changes or shifts in rack delivery schedules. These are discussed in Section 8.

Other findings included the fact that pallet dedication does not appear to be cost effective due to its high cost. In addition, methodology was developed for later use when better payload and flow definitions are available. It was concluded, however, that even though study results were based on preliminary data and estimates, the basic findings and trend information will probably remain valid as later payload and program definitions firm up. The sensitivity analyses discussed in Section 7 tend to support this conclusion. Overall study results and recommendations are summarized briefly in Figures 1-2 and 1-3.

29348

Figure 1-2

SUMMARY OF RESULTS
GENERAL

- CONFIRMED VALIDITY OF BASELINE INVENTORY PLANNING; HOWEVER MINOR DELIVERY ADJUSTMENTS MAY BE REQUIRED
- CONCLUDED THAT RACK DEDICATION IS COST EFFECTIVE
- IDENTIFIED 5 PAYLOAD CANDIDATES FOR RACK DEDICATION $805K SAVINGS POSSIBLE IN EARLY STS MISSIONS
- IDENTIFIED VIABLE OPTIONS FOR OPTIMIZING RACK USAGE
- CONCLUDED THAT PALLET DEDICATION IS NOT PRACTICAL
- DEVELOPED METHODOLOGY FOR ABOVE TO BE USED IN FUTURE
- CONCLUDED THAT DEDICATION DATA, ALTHOUGH PRELIMINARY, WILL PROBABLY REMAIN FIRM AS ADDITIONAL DEFINITION TAKES PLACE

Figure 1-3

29347

RECOMMENDATIONS

DIRECT ACTION

- CONSIDER DEDICATION OF RACKS TO SELECTED PAYLOADS
- **SELECT AND IMPLEMENT OPTIONS FOR RACK USAGE**
- ACCELERATE DELIVERY OF TWO PALLETS IN MID 1981
  i.e., NASA BUY - THREE ON LINE JUNE 1, TWO ON AUGUST 1

FOLLOW-ON STUDIES

- APPLY/EXTEND THIS METHODOLOGY TO:
  - NEWLY OR BETTER DEFINED PAYLOADS
  - PAYLOADS BEYOND EARLY STS MISSIONS
- INVESTIGATE FEASIBILITY OF LOW-COST RACK CONFIGURATION
- CONDUCT ANALYSIS TO REGROUP/RESCHEDULE PAYLOADS TO OPTIMIZE TOTAL STS RESOURCES
- EVALUATE DEDICATION OF RACKS/PALLETS TO PAYLOAD DISCIPLINES

Section 2
STUDY PLAN

The study was initiated in July 1976 with MDAC providing the systems engineering and analyses to perform the following three major tasks.

A. Establish the optimization criteria to be used for the subsequent development of the methodology. During this task, the contractor shall devote adequate attention to tradeoff considerations relative to minimizing the inventory of racks and pallets required, minimizing the Level IV integration effort, and minimizing the postflight disassembly and refurbishment effort.

B. Develop the methodology to optimize utilization of Spacelab racks and pallets. This methodology shall permit proper consideration to be given to the relationship between STS mission planning and resultant demands on Level IV integration and postflight refurbishment. The methodology shall permit the determination of changes to the STS mission planning which would be required to optimize utilization of Spacelab racks and pallets.

C. Apply the methodology developed to the early STS Spacelab missions and formulate, from the results of such application, recommendations regarding changes to the STS mission plans which would be required to optimize utilization of Spacelab racks and pallets.

Initial exploratory effort focused on conceptual and generic approaches to a broad spectrum of program elements contributing to rack and pallet utilization. This effort identified areas of interest (summarized in Figure 2-1) from which to choose those thought to be most productive for further study. With MSFC guidance, the field of interest was focused on Level IV integration flow, the concept of rack and pallet dedication to selected payloads, inventories, mission schedules, KSC time lines, and the interrelationships of all five.

Figure 2-1

OPTIMIZATION FACTORS

FACTORS AFFECTING RACK/PALLET REQUIREMENTS

- MISSION DURATION
- MISSION FREQUENCY
- ✓✓ MISSION SCHEDULES
- MISSION/PAYLOAD COMPLEXITY
- PAYLOAD CONFIGURATION & QUANTITY REQMTS
- ✓✓ KSC TIMELINE ALLOCATIONS
- ✓✓ REFURBISH REQUIREMENTS/DEDICATION
- USER LOCATION TIMELINES
- ✓✓ LEVEL IV REQUIREMENTS
- ✓ TRANSPORTATION TIME
- ✓ SHIPPING CONTAINER/EQUIPMENT AVAILABILITY
- ✓ LINE MODIFICATIONS
- ✓✓ INVENTORY
- ✓ OPERATIONAL PROBLEMS
- ✓ MANAGEMENT TECHNIQUES

✓ DENOTES POTENTIALLY PRODUCTIVE AREA FOR OPTIMIZING

✓✓ DENOTES AREA CHOSEN FOR DETAILED STUDY

2.1 TASK DESCRIPTIONS

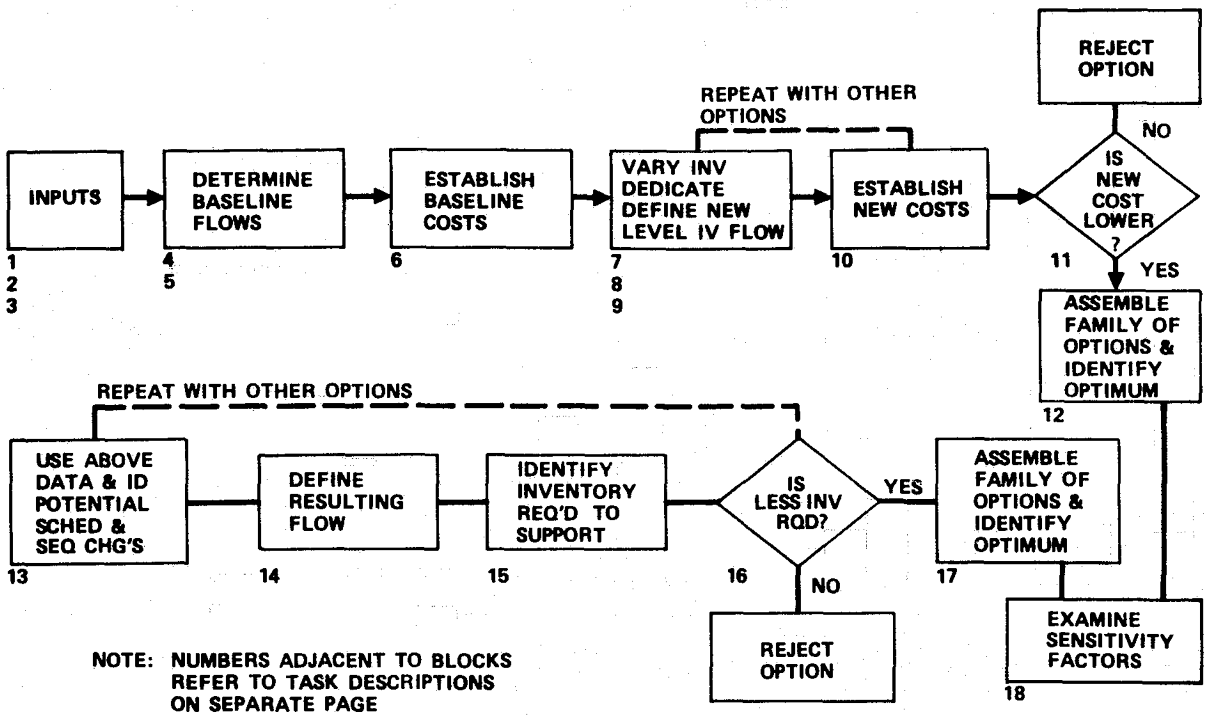
The basic flow logic for the detailed tasks which evolved is presented in Figure 2-2; numbers shown at the corner of each block correspond to the numbers of the following detailed tasks.

1. Define payloads for each mission.
2. Identify number of racks and pallets for each mission.
   - A. Identify planned delivery schedule.
3. Identify planned launch dates.
4. Determine probable user and Level IV baseline flow time.
   - A. Estimate complexity, learning curves, etc.
   - B. Assume all racks and pallets rotating (nondedicated).
5. Schedule all mission flow to support planned launches.
   - A. Determine number of racks and pallets required if different from baseline inventory planned.
6. Convert above to baseline costs for Level IV, inventory, and Kennedy Space Center (KSC) refurbishment.
7. Identify candidate payloads and missions for dedicated racks and pallets.
   - A. Permanent or as scheduled.
   - B. Identify groundrules, assumptions.

Figure 2-2

23081

TASK LOGIC FLOW



NOTE: NUMBERS ADJACENT TO BLOCKS REFER TO TASK DESCRIPTIONS ON SEPARATE PAGE

8. Determine new user and Level IV flow times.
   A. Determine reduction in KSC refurbishment requirements.

9. Reschedule all mission flow (hold launch dates).
   A. Determine number of racks and pallets required.
10. Convert tasks 8 and 9 to new program costs.
    A. Level IV, inventory, KSC refurbishment.
11. Compare baseline and new program costs (tasks 6 and 10).
12. Repeat tasks 7 through 11 with differing inventories and candidate payloads, seeking minimum program costs (optimum inventory).
13. Identify candidate changes in mission schedule and sequence which would appear to reduce inventory requirements.
14. Reschedule all mission flow to support candidate change.
15. Determine number of racks and pallets required.
16. Compare task 15 with task 12.
17. Assemble family of options and identify optimum.
18. Examine sensitivities of savings to variable parameters.

Significant questions addressed by the study are listed in Figure 2-3 and task schedules are presented in Figure 2-4.

Figure 2-3

QUESTIONS ADDRESSED DURING STUDY

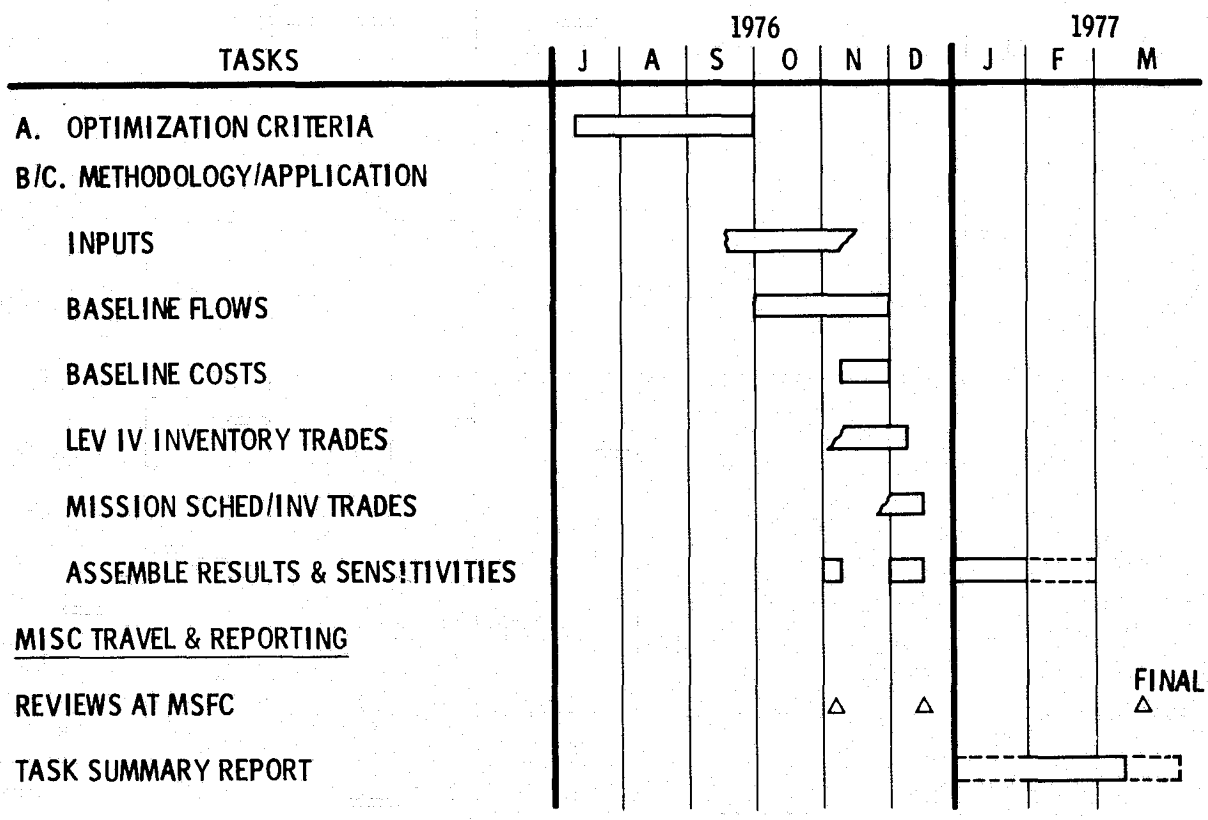
28223

- INTEGRATION REQUIREMENTS AND TIMELINES
    - WHAT IS THE SCOPE OF LEVEL IV INTEGRATION?
    - WHAT ARE THE DWELL TIMES AND COSTS OF INTEGRATION?
    - WHAT ARE THE BASELINE REQUIREMENTS VS INVENTORY?
    - WHAT TRADE-OFFS ARE POSSIBLE?
- COST TRADES OF DEDICATING RACKS/PALLETS TO GIVEN PAYLOADS
    - CAN COSTS BE REDUCED BY DEDICATION?
    - HOW DO WE SELECT PAYLOAD CANDIDATES FOR DEDICATION?
    - WHAT IS THE OVERALL EFFECT OF DEDICATION?
- INTERACTION OF MISSION SCHEDULES AND RESOURCES
    - CAN MINOR RESCHEDULING REDUCE INVENTORY REQUIREMENTS?
    - WHAT MISSION RESCHEDULING SHOULD BE CONSIDERED?

Figure 2-4

23080

TASK SCHEDULE



2.2 GROUND RULES AND ASSUMPTIONS

Key ground rules and assumptions are presented in Figure 2-5. The detailed ground rules and assumptions are delineated below.

1. All pallets are the same basic configuration.
2. All 1m racks are the same basic configuration and interchangeable left and right.
3. All 0.5m racks are the same basic configuration and interchangeable left and right.
4. Standard subsystem support equipment installations will be performed at KSC.
5. Experiment installation and all nonstandard support equipment installations will be performed at user site and/or Level IV integration site.
6. Experiment removal, nonstandard support equipment removal, and standard subsystem support equipment removal will be performed offline at KSC.
7. Dedicated racks and pallets will deviate from ground rules and assumptions 4, 5, and 6, as required.

28245

Figure 2-5

KEY GROUND RULES AND ASSUMPTIONS

- MISSIONS 1 THRU 6 DEFINED BY IP&MP OFFICE
- MISSIONS 7 THRU 18 DEFINED IN EARLY STS MISSIONS PLAN DATED 6-22-76
- RACK COSTS — SINGLE $127K, DOUBLE $154K
- PALLET COST — $1.79M
- RACK & PALLET INVENTORY & DELIVERY SCHEDULED SUPPLIED BY MFSC
- LEVEL IV FLOW & COSTS TO BE ESTIMATED BASED ON BEST AVAILABLE DATA
- PRIMARY STUDY EMPHASIS DIRECTED AT SPECIFIC APPLICATION TO EARLY STS MISSIONS AND PROVIDING RECOMMENDATIONS THEREFROM

8. All KSC timeline information used in this study is extracted from KSC Spacelab Operational Turnaround Assessment, dated 16 April 1976, or represents MDAC estimates which are consistent therewith.
9. The schedule intervals remain the same whether one or more units (racks or pallets) is being processed, i.e., assumes manpower, facilities, and other resources can handle simultaneous processing without delay.
10. One 3m pallet segment cost is $1.79 million. This includes power distribution equipment, power and signal wiring, average 2.5 RAUs, coldplates, and plumbing.
11. One 0.5m rack cost is $127K, one 1m rack is $154K. This includes power distribution equipment, power and signal wiring, and air ducts.
12. KSC postflight operations manhours for a nominal mission are:

	Shared	Dedicated
Racks	1280	220 (man hours)
Pallets	776	193

13. Level IV integration costs are to be estimated, based on best available information.
14. NASA/MSFC will supply baseline data (or specific references to already existing data) for the following:
    - A. Identification of individual payloads for each mission.
    - B. Hardware and/or flow definition of each payload, as available.
    - C. Number of racks and pallets required for each mission.
    - D. Delivery dates for racks and pallets.
    - E. Mission launch dates.
    - F. Cost data for Level IV, inventory, and KSC refurbishment.
15. Cargo grouping and mission planning processes will minimize the number of racks and pallets required for each mission.
16. The primary emphasis for this study will be directed at specific application to the early phases of the Spacelab program currently being planned.
17. Determination of user/Level IV flow will be based on best available baseline data from MSFC (ground rule 14) and MDAC estimates (learning curves, payload complexity, repeat missions, etc.), where required.

Section 3
ESTABLISHING BASELINES

Before attempting to define alternate approaches intended to optimize the use of Spacelab hardware, the primary planned baseline had to be understood. Where clear plans, definitions, and criteria did not exist or were not available, they had to be obtained, developed, and/or synthesized. The following subsections summarize the noted baseline data and the data source or derivation method.

3.1 BASELINE INVENTORY

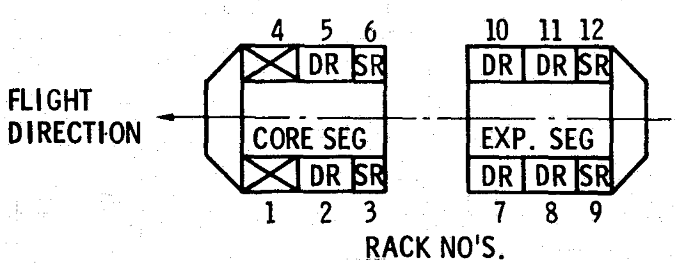
Baseline inventory was obtained from the MSFC Spacelab Program Office through the Integrated Payload and Mission Planning (IP&MP) Office and was last updated and input to this study on 17 December 1976. The number and delivery schedule for racks and pallets are listed on Figure 3-1 which shows

Figure 3-1

28233

BASELINE INVENTORY

- **FULL SPACELAB EXPERIMENT RACK COMPLEMENT- 6 DOUBLES, 4 SINGLES**



- **MAXIMUM FLIGHT COMPLEMENT FOR PALLETS IS FIVE**
- **BASELINE INVENTORY PLANNED & ON-LINE SCHEDULE***

	6-79	8-79	12-80	6-81	8-81	TOTALS
DBL RACK	6		+8			=14
SGL RACK	4		+8			=12
PALLET	1	+4		+1	+4	=10

*PER MSFC SPACELAB PROGRAM THRU IP&MP, 12-17-76 a total of 12 single racks, 14 double racks, and 10 pallets, which will be available for use by August 1981.

The core segment of the Spacelab has fewer racks available for experiment installation, because it requires two double racks (No. 1 and No. 4) for Spacelab operational subsystems and controls. The core segment, then, has two double racks (No. 2 and No. 5) and two single racks (No. 3 and No. 6) which can be used to install experiments and the controls for experiments mounted on pallets. The experiment segment of the long Spacelab configuration provides all of its four double racks (No. 7, No. 8, No. 10, and No. 11) and two single racks (No. 9 and No. 12) for experiment installation.

One of the primary references used to obtain rack and pallet data is the Early STS Missions Plan, FY 1980-1982, Cargo Manifest, dated 22 June 1976. For rack inventory accounting purposes, this document recorded the number of racks as equivalent single racks. In other words, double racks were accounted for as two single racks. Therefore, a long module Spacelab, which is made up of a core and experiment segment, is recorded as having 16 equivalent single racks. This method of accounting for racks is not appropriate for detailed investigations of rack availability and dedication, since double racks physically cannot be converted to single racks and vice versa. The actual number and type of racks, the online dates, the inventory and the schedule used in these investigations is shown in the table in Figure 3-1. The quantities and schedule dates shown in the table differ from those shown in the Early STS Mission Plan because it reflects the latest information obtained from NASA/MSFC. This data, obtained in December 1976, was provided by the NASA/MSFC Spacelab Project Office. Their inputs modified the quantity of double and single racks contained in the NASA initial buy to the numbers shown. All of these data are used in subsequent rack and pallet utilization investigations. Online dates differ from delivery dates in that three months are added by NASA to delivery dates to account for preparation of hardware prior to it being available online for service.

3.2 MISSION REQUIREMENTS

Mission requirements for racks and pallets, as shown in Figure 3-2, were

. Figure 3-2

MISSION REQUIREMENTS FOR RACKS AND PALLETS

28244

FLIGHTS NO.		LAUNCH DATE	PAYLOAD	NO. OF RACKS AND PALLETS		
				RACKS		
SHUTTLE	SPACELAB			DOUBLE	SINGLE	PALLETS
8	1	JUL 1980	1ST SPACELAB	6	4	1
10	2	OCT 1980	2ND SPACELAB	0	0	4
12	3	JAN 1981	MULTI-USER	4	2	1
14	4	MAR 1981	LIFE SCIENCE	6	4	1
17	5	JUN 1981	MULTI-USER	2	2	3
19	6	AUG 1981	ATL EMPH	2	2	2
21	7	SEP 1981	LIFE SCIENCE	6	4	1
23	8	OCT 1981	COMB ASTR	0	0	5
25	9	NOV 1981	MULTI-USER	5	1	1
27	10	DEC 1981	MULTI-USER	2	2	3
30	11	FEB 1982	LIFE SCIENCE	6	4	1
34	12	APR 1982	AMPS	2	2	3
36	13	MAY 1982	MULTI-USER	5	4	1
38	14	JUN 1982	ATL*	2	2	2
40	15	JUL 1982	EVAL**	2	2	3
42	16	AUG 1982	MULTI-USER	6	4	1
44	17	SEP 1982	LIFE SCIENCE	6	4	1
46	18	OCT 1982	ASTR/HI ENG	0	0	5

*ESTIMATE BASED ON S/L 6
**ASSUMED REQUIREMENTS

derived from the Spacelab mission and payload descriptions contained in the following two documents.

A. Missions 1 through 6 are defined by the IP&MP Office in informal document received on October 8, 1976.

B. Missions 7 through 18 are defined by the MSFC Early STS Missions Plan document, dated 22 June 1976.

The number of racks and pallets required for the early Spacelab missions is shown in Figure 3-2 which also includes estimates where data were lacking. The number of pallets used per mission reflects an input from NASA/MSFC that recommends that every early Spacelab mission should include at least one pallet. This table also reflects the elimination of a multi user payload that was previously scheduled to be launched in September 1981. Because of this elimination, all subsequent payload launch dates are advanced to fill the vacant launch date, and the total number of missions is reduced from 19 to 18.

3.3 LEVEL IV INTEGRATION

Level IV integration was not well defined in terms of operational flow plans and depth of testing on which to base estimates of individual payload element flows and costs. Recognizing that a wide range of possibilities exist from which NASA could choose, three Level IV integration modes were defined which spanned the range of probable program choices. These were then used as bases for payload flow and cost estimating. The three modes are defined in Figure 3-3 and are listed below:

Mode A - provides flight ready integrated systems
Mode B - provides integration to subsystem level
Mode C - provides installation verification only.

For convenience, Mode B was chosen as the nominal case for this study on which to base estimates for each payload element examined. Mode A and Mode C flow and cost estimates were also derived for certain payloads of interest, i.e., the dedication candidates. The cost relationships among the three modes were examined and established parametrically with factors

Figure 3-3 29346

BASELINE LEVEL IV CONCEPTS

- LEVEL IV SCOPE NOT YET DEFINED. HOW TO COST & SCHEDULE?
- DEFINED 3 MODES FOR STUDY
  - MODE A LOW RISK (1.44 X MODE B) — PROVIDES FLIGHT READY, INTEGRATED SYSTEMS; COMPATIBILITY DEMONSTRATED; INCLUDES FULL SOFTWARE C/O, COMBINED SYSTEMS TESTS AND LIMITED MISSION SIMULATION
  - MODE B MED. RISK (STUDY NOMINAL) — PROVIDES INTEGRATION TO THE SUBSYSTEM LEVEL USING INTERFACE SIMULATORS; NO COMPATIBILITY TESTING; INCLUDES RAU'S, LIMITED EXP-TO-CDMS SIMULATOR SOFTWARE, INTERNAL EXP FUNCTIONAL C/O & CALIBRATION
  - MODE C HIGH RISK (0.37 X MODE B) — PROVIDES INSTALLATION VERIFICATION ONLY; NO RAU'S, PWR DISTRI EQUIP, ETC; INCLUDES CONTINUITY, GROUNDING TESTS, MECHANICAL FIT & FUNCTION, LEAK TESTS
- CHOOSE CONCEPT B FOR EMPHASIS AS STUDY "NOMINAL"
- STUDY RESULTS APPLICABLE TO ANY MODE BY CONVERSION FACTORS

derived from actual estimates of schedule flow and manpower required for each mode. Cost relationships are:

Mode A = 1.44 x Mode B

Mode B = 1 (nominal)

Mode C = 0.37 x Mode B.

It is emphasized that these mode conversion factors are considered a gross average based on the payload elements examined for Spacelab Missions 1 and 2 and may not be representative for a selected payload. They should be helpful, however, for approximations.

3.4 LEVEL IV ESTIMATES

Level IV estimates for payload flow, manpower, and costs were assembled using experience and judgement based on the available Spacelab program data and synthesized considerations, where required. Level IV operations were expected to include less rigorous operational disciplines than previous programs such as Skylab; minimal inspection requirements, probably limited to installations and safety items; and a resident team of experienced personnel who integrate payload representatives and hardware into the operational flow. Included in the manpower estimates was a 30% allowance for routine contingencies, those problems which are an inevitable part of technical operations but which are solved with relative ease within the overall scheduled period, e.g., removing, replacing, and retesting a malfunctioning part. This 30% factor does not include time to solve major design problems or other kinds of major problems which would abort a calendar sequence and require major rescheduling. Also included in the manpower estimates were a 150% allowance for direct-support of the first echelon of personnel who have their hands-on the hardware. These direct-support personnel would include, for examples, the gas systems specialist who takes and analyzes a gas sample, a liaison engineer who helps solve a fit problem, and a specialist called out to bond-on a temperature sensor. The 150% factor does not include facility operating expenses, management, and administrative support. These 2 factors (30% and 150%) have been used in previous aerospace applications and are believed to be realistic for Spacelab Level IV integration. Figure 3-4 summarizes the preceeding baseline flow estimates.

Figure 3-4 28222

BASELINE FLOW ESTIMATING

- LEVEL IV EXPECTATIONS
  - LESS RIGOROUS DISCIPLINES THAN SKYLAB
  - MINIMAL INSPECTION REQUIREMENTS
  - RESIDENT TEAM INTEGRATING OPERATIONS
  - 30% CONTINGENCY, 150% DIRECT SUPPORT ALLOWANCES
- FLOW ESTIMATES S/L 1 & 2 (MODE B)
  - INDIVIDUAL P/L FLOWS GENERATED
  - COMPOSITE MISSION P/L FLOW & DWELL TIME
- LATER MISSION PROJECTIONS
  - 85% LEARNING CURVE FOR DWELL/80% FOR COST
  - MODES A, B, & C BASELINES

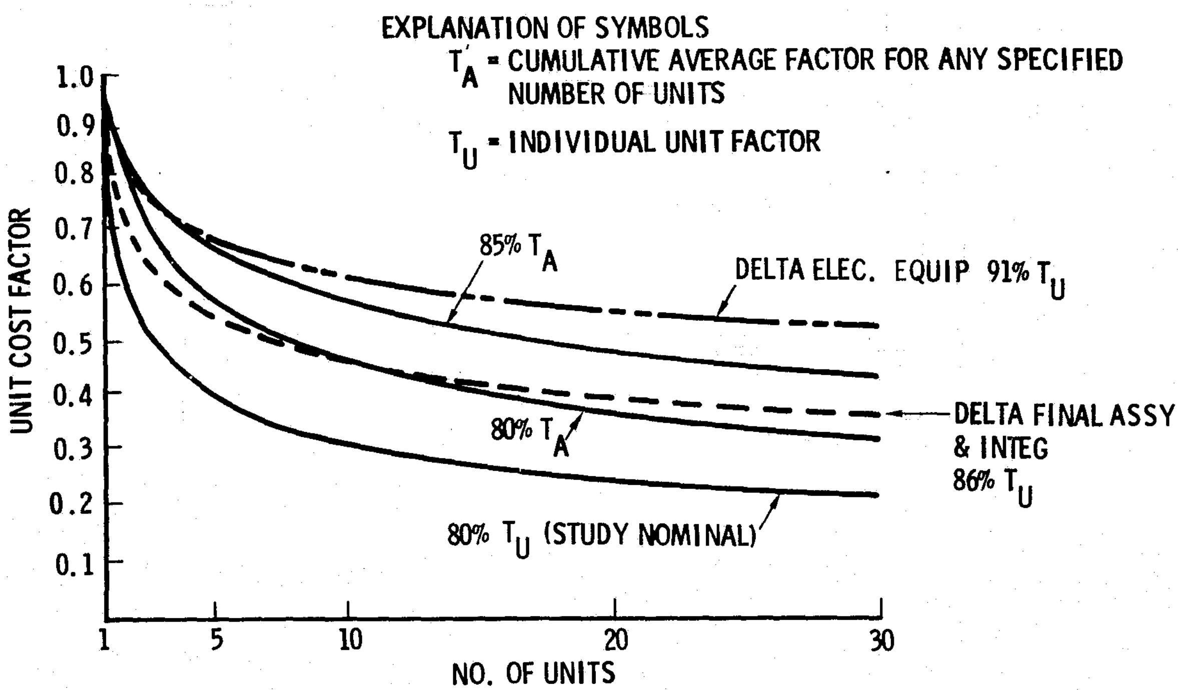
3.5 LEARNING CURVES

Learning curves were used in projecting schedule and cost improvements for subsequent operations. An 80% curve was used to project cost reductions due to learning on those payload elements flying a multiple number of times and which were candidates for rack dedication. An 80% curve defines unit cost reductions which cause the average cost to drop 20% every time the production is doubled. This 80% curve produced conservative study results as can be seen later in this report since the actual learning rate is expected to be slower and nearer to 85%. Figure 3-5 presents learning curve examples.

Figure 3-5

23280

LEARNING CURVE EXAMPLES



3.6 FLOW DWELL TIMES

Flow dwell times were assembled by first estimating the flow sequence and dwell time of individual payload elements through a Mode B Level IV operation as if there were no other payloads with which to be concerned. Individual flows were developed for 40 payload elements to gain insight into overall flow plans and costs. Figure 3-6 is a typical example. The individual flows for Spacelab Mission 1 were then integrated into a combined Mode B flow which included a logical sequence of events based on certain required sequences and certain optional parallel activities.

An attempt was made to smooth out manpower loads by avoiding excessive parallel operations. This provided the nominal study baseline dwell time depicted in Figure 3-7. Similarly, this was extended to provide Mode A dwell time, and reduced to provide Mode C dwell time. These dwell times became the basis for projecting subsequent mission Level IV dwell times based on an 85% learning curve which was thought to be a realistic possibility. See Figure 3-8 for a summary of Level IV dwell times and a delineation of KSC and mission dwell time goals. These dwell times appear to be reasonably consistent with Spacelab Program plans.

Figure 3-6 28275

LEVEL IV BASELINE FLOW EXAMPLE
INDIVIDUAL P/L ELEMENT (MODE B)

ST-31-S DROP DYNAMICS (1-1/2 SINGLE RACKS)

- – DROP GENERATION/SAMPLE INJECTIONS SYSTEM
- – ACOUSTIC POSITIONING SYSTEM
- – LIGHTING SYSTEM
- – OBSERVATION SYSTEM
- – CAMERA/DATA SYSTEM
- – CONTROL SYSTEM

- – SELF CONTAINED
- – NEED ACCEL & TIMING
- – 15 DISPLAY MEASUREMENTS
- – O_2/N_2 PURGE
- – WATER SUPPLY
- – FILM

MODE B LEVEL IV ESTIMATES

ELAPSED DAYS 1 2 3 4 5 6 7 8 9 10 11 12 13

RCV & INSP.

INSTALL

C/O PREPS.

PWR & DATA

SOFTWARE

EXP. C/O

SECURE & PREPS. TO SHIP

DWELL TIME (DAYS) = 13

HAND-ON MEN
3 TECH + 2 ENG + 1 MISC = 6

HANDS ON MAN HRS (6 MEN X 8 HRS X 1.7 SHIFTS X 13 DAYS) = 1061

TOTAL DIRECT MAN HRS
1061 X 1.3 X 2.5 = 3448

Figure 3-7 28230

LEVEL IV BASELINE FLOW EXAMPLE
SPACELAB NO. 1 COMPOSITE LEVEL IV (MODE B)

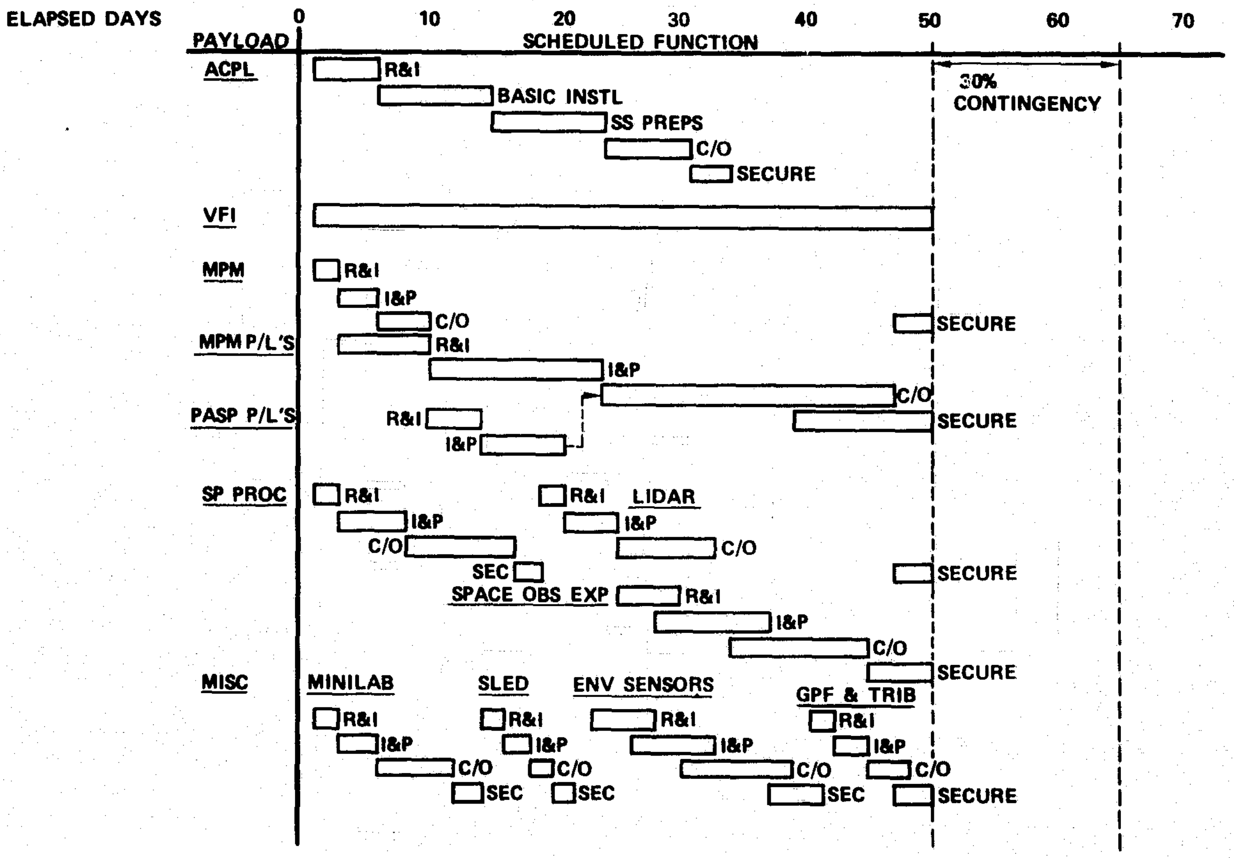


Figure 3-8 28281

BASELINE FLOW DWELL TIME PROJECTIONS (DAYS)

S/L NO.	LEVEL IV - 85% LEARNING MODE A	MODE B	MODE C	LEV III/II/I/MISSION/SHIP KSC GOALS
1	113	64	24	161
•2	93	51	19	161
3	64	45	17	88
4	57	40	15	71
5	53	37	14	56
6	50	35	13	47
7	47	33	12	42
•8	45	32	12	42
9	44	31	11	42
10	43	30	11	42
11	42	29	11	42
12	41	28	11	42
13	40	28	10	42
14	39	27	10	42
15	38	27	10	42
16	38	26	10	42
17	37	26	10	42
•18	37	26	10	42

*PALLET ONLY

3.7 RACK AND PALLET INVENTORY

Rack and pallet inventory utilization assessments were conducted to explore the interrelationships involved and to determine the adequacy of planned inventories to meet baseline requirements. The analysis indicated no problems supporting Modes A, B, or C in the early STS missions with the latest planned inventory of 14 double racks, 12 single racks, and 10 pallets. However, two pallets may need to be delivered two months earlier than now planned to support Spacelab Mission 8.

Rack and pallet availability was determined for each mission based on mission launch schedule, rack and pallet requirements for the mission, and rack and pallet inventory and online schedule. The purpose of this investigation was to determine if an adequate number of double and single racks and pallets has been ordered and if adequate hardware processing time exists.

Figures 3-9 through 3-11 show the results of these investigations for single racks, double racks, and pallets, respectively. On each figure is shown

Figure 3-9 28277

BASELINE FLOW

SINGLE RACK AVAILABILITY

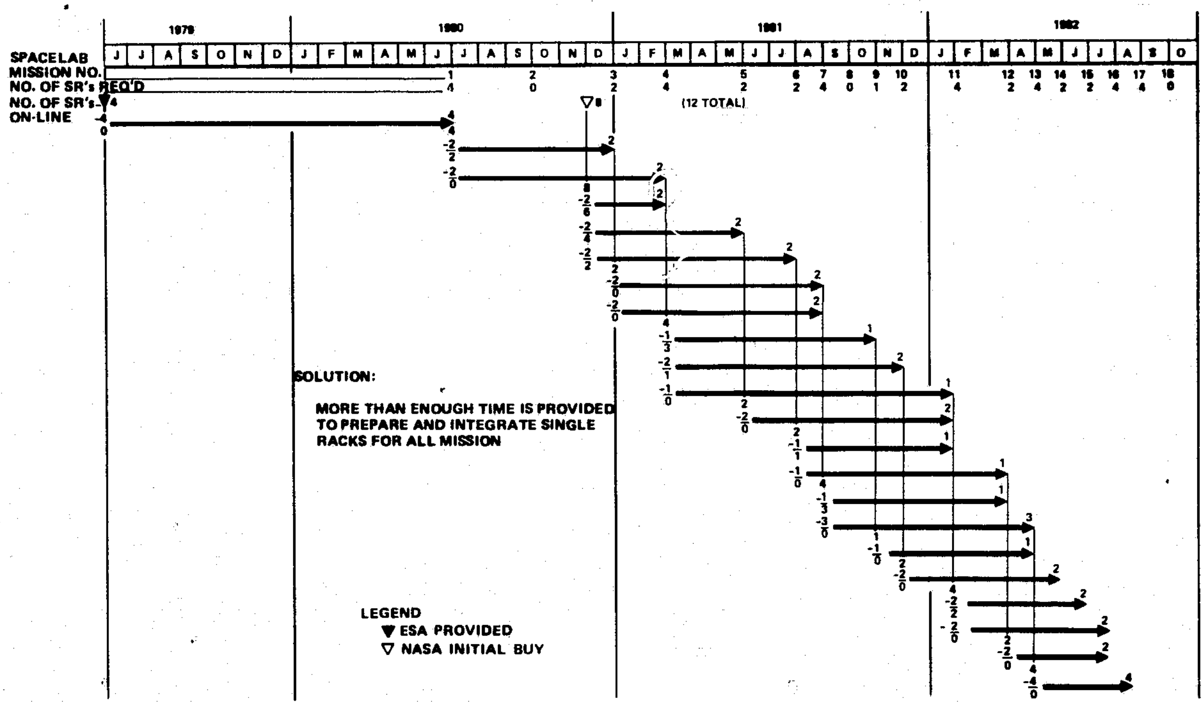


Figure 3-10. 28278

BASELINE FLOW

DOUBLE RACK AVAILABILITY

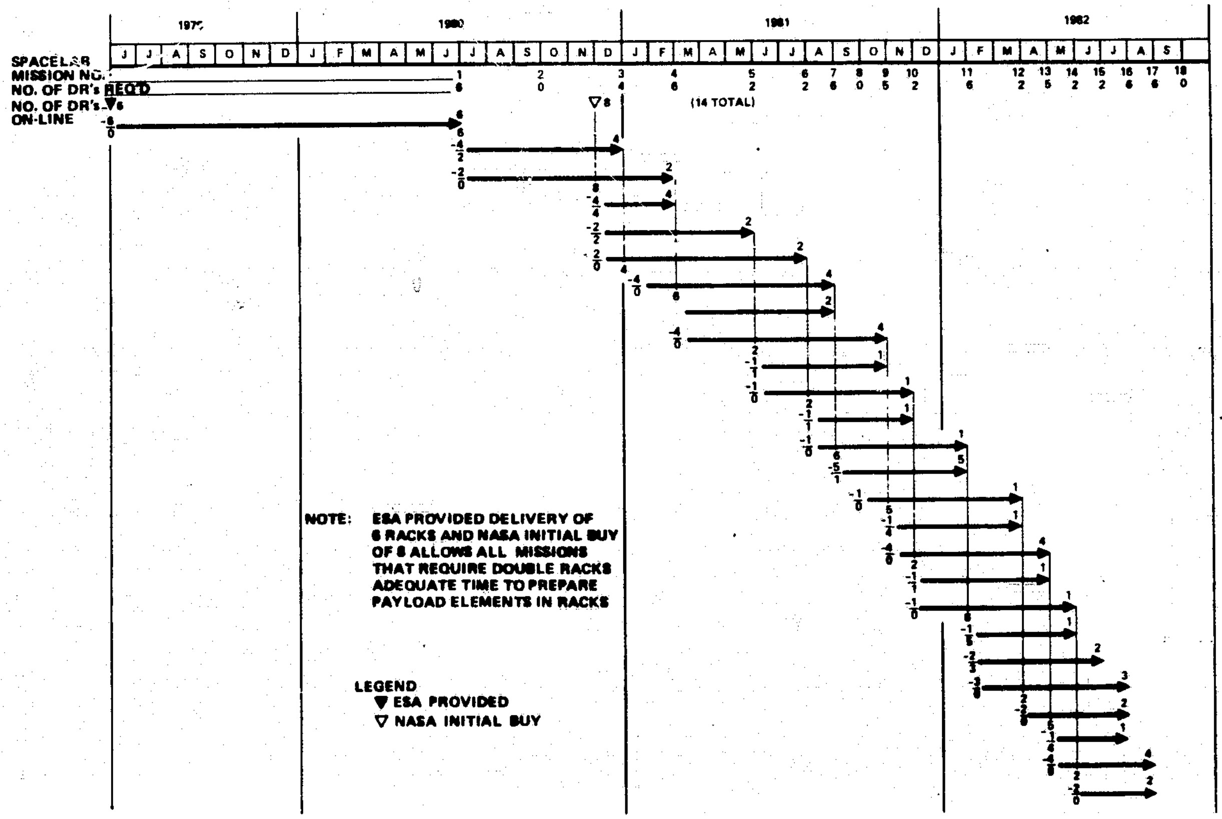
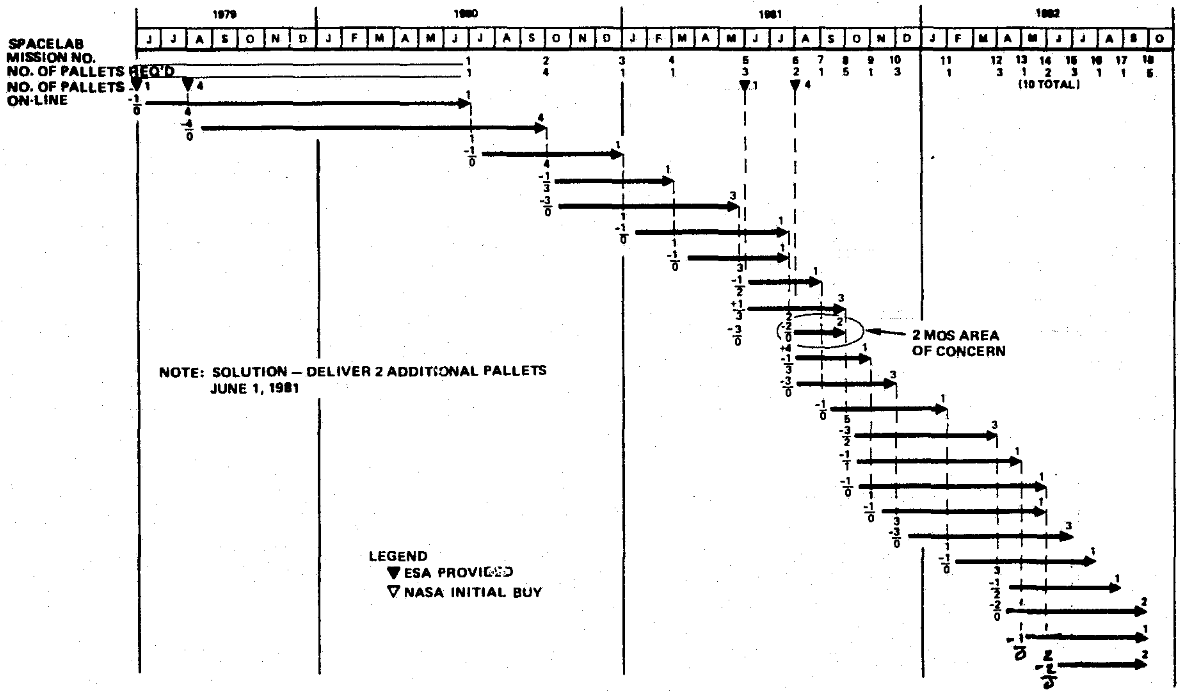


Figure 3-11
BASELINE FLOW
PALLET AVAILABILITY



the mission number, its launch date, and how many hardware items are required to perform that mission as defined in Figure 3-2. Hardware online availability dates and quantities delivered are placed on the charts consistent with the data shown in Figure 3-1.

A total of 14 double racks are being procured for the Spacelab missions. Six are provided by the European Space Agency (ESA) to be online in July 1979, and eight are ordered by NASA in their initial buy to be delivered in September 1980 and online by December 1980. This analysis of the utilization of these 14 double racks assumes that all racks are shared and that they will be assigned for use again in another mission as soon as they become available at the end of a mission. The objective of the analysis of double rack availability shown on Figure 3-10 is to determine if all of the first 18 Spacelab missions requiring double racks can be accommodated with the racks required and that the dwell time between each use is sufficient to allow all levels of payload integration and all operational functions to occur. As can be seen in Figure 3-10, all missions are provided with their required complement of double racks from the 14 double rack inventory.

The dwell time between reuses is also sufficient to allow all functions to occur that are necessary to prepare a rack for reuse.

The technique used in these analyses can be described by explaining how the double rack analysis was performed.

A. Mission 1 requires six double racks; six racks from the basic inventory are used with a 13-month dwell time.

B. Mission 2 does not require racks.

C. Mission 3 requires four double racks; four racks used in Mission 1 are assigned to this mission with a 6-month dwell time.

D. Mission 4 requires six double racks; two of the remaining racks used in Mission 1 are assigned with an eight-month dwell time, and four racks from the NASA initial buy are assigned with a three-month dwell time.

E. Mission 5 requires two double racks; two racks are from the four remaining NASA initial buy racks with a six-month dwell time.

F. Mission 6 requires two double racks; the last two racks of the NASA initial buy are assigned to this mission. The dwell time is eight months.

G. Mission 7 requires six double racks; four racks are obtained from Mission 3 and two from Mission 4 with dwell time of eight and six months respectively.

H. Mission 8 does not require double racks.

I. Mission 9 requires five double racks; four are obtained from Mission 4 with an eight-month dwell time, and one is obtained from Mission 5 with a five-month dwell time.

J. Mission 10 requires two double racks; one is obtained from Mission 5 and one from Mission 6, with six and four-month dwell times, respectively.

K. Mission 11 requires six double racks; one is obtained from Mission 6 and five are assigned from Mission 7; minimum dwell time is five months.

L. Mission 12 requires two double racks; one is obtained from Mission 7 and one is obtained from Mission 9. Minimum dwell time is five months.

M. Mission 13 requires five double racks; four are assigned from Mission 9 and one comes from Mission 10. The minimum time between reuses is five months.

N. Mission 14 requires two double racks; one comes from Mission 10 and one from Mission 11 with a four-month dwell time.

O. Mission 15 requires two double racks; they are obtained from Mission 11 with a five-month dwell time.

P. Mission 16 requires six double racks; three come from Mission 11, two from Mission 12, and one from Mission 13. The minimum dwell time is three months.

Q. Mission 17 requires six double racks; four are assigned from Mission 13 and two from Mission 14. Minimum dwell time is three months.

R. Mission 18 does not require double racks.

As a check to determine if all racks have been accounted for at the end of the analysis, all racks that have not been assigned to a mission are summed:

Mission 15	2 racks
Mission 16	6 racks
Mission 17	6 racks
	14 racks

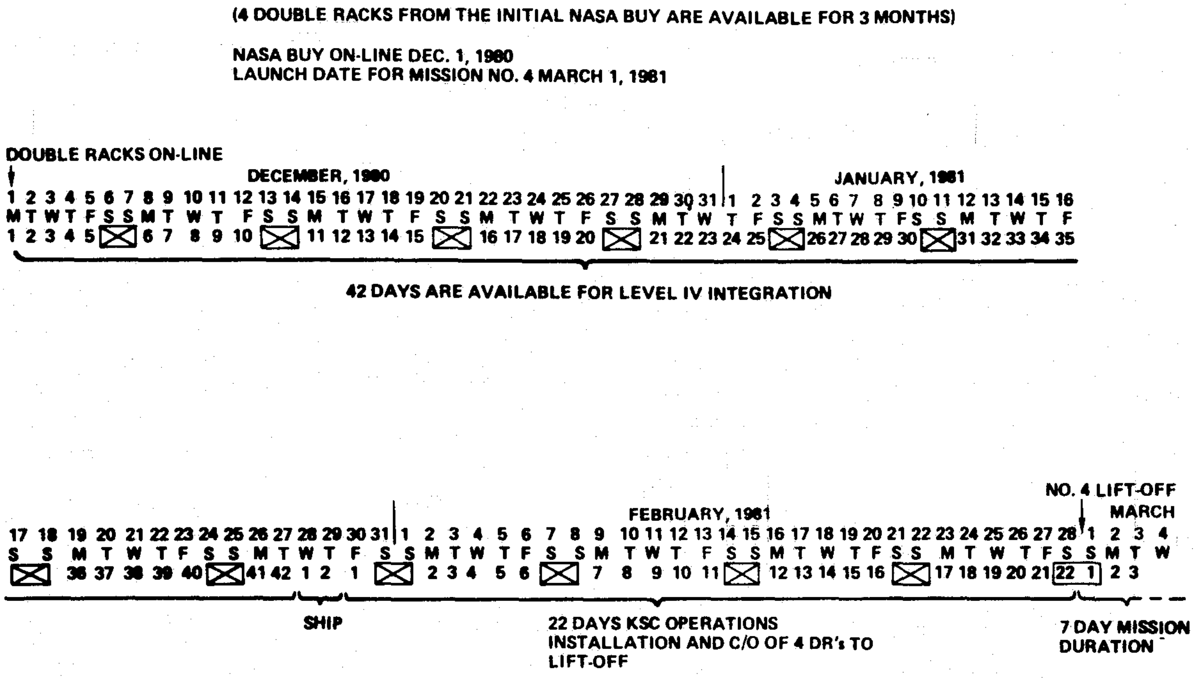
This checks with the total number of racks procured; therefore, all double racks have been accounted for. Single rack and pallet availability were analyzed in a similar manner.

The minimum dwell time between double rack reuses is three months. The first time this occurs is for Mission 4, which receives four double racks from the NASA buy. Figure 3-12 shows a detailed day-by-day investigation of the tasks and functions that occur to prepare the four racks and their payload of experiments for use in Mission 4. To determine the number of days available for Level IV integration; i. e., from the time the racks are online at the Level IV integration site until the time they are shipped to KSC, spacelab operational turnaround times at KSC were studied to obtain the number of days that racks are required at KSC prior to liftoff. The time required at KSC and other operational functions such as shipping and receiving are then subtracted from the total number of days a rack will be available.

Figure 3-12

INVESTIGATION OF DOUBLE RACK AVAILABILITY FOR MISSION NO. 4

28282



The remaining number of days are allocated to Level IV integration. An assessment of KSC dwell times for payload integration is shown in Figure 3-8. A breakdown of Mission 4 requirements is shown in Table 3-1. Since the four racks were from the initial NASA buy, there was no mission time,

Table 3-1

KSC DWELL TIMES, IN DAYS, FOR PAYLOAD INTEGRATION

	Spacelab Mission						
Function	1	2	3	4	5	6	7
Prelaunch*	110	110	55	44	33	26	22
Mission	7	7	7	7	7	7	7
Postlanding*	20	20	11	8	6	5	5
Refurbishment*	20	20	11	8	6	5	4
Ship to and from	4	4	4	4	4	4	4
	161	161	88	71	56	47	42

*Based on a two-shift operation.

postlanding refurbish time, or shipment to the Level IV integration site to account for. Shipping time from the Level IV integration site was accounted for and was considered to be two days. The 44 days shown for prelaunch is the time required to integrate all payload elements into all racks and on a pallet. On this mission there are six double racks, four single racks and one pallet. To obtain the number of days to integrate four double racks, a ratio of total racks to these four is used. This is on the conservative side, for the pallet integration time is not considered. The four single racks are converted to two equivalent double racks; therefore, the ratio to obtain the time required to integrate payload elements at KSC into four double racks is 4 divided by 8 or 1:2. Application of this ratio and total days required for KSC integration is shown in Table 3-2. As shown in Figure 3-12, this leaves 42 days available for Level IV integration. Dwell time estimates for the fourth mission Level IV integration shown in Figure 3-8 shows 57 days are required. Applying the same ratio of 1/2 to this number yields 29 days required to perform Level IV integration on four double racks. Since 42 days are available as shown in Figure 3-12, the three-month time period from online to liftoff provides an adequate amount of time to use these four racks in Mission 4.

Table 3-2

*NUMBER OF DAYS TO INTEGRATE FOUR RACKS AT KSC - MISSION 4

Function	Days	
Prelaunch	44 x 1/2 = 22	
Mission	N/A	
Postlanding	N/A	
Refurbishment	N/A	
Ship to Level IV	N/A	
Ship from Level IV	2	= 2
	Total	24 Days

The next time the minimum dwell time of three months occurs is for Mission 16. One rack from Mission 13 is available for three months. Mission 16 uses six double racks and four single racks or the equivalent of eight double racks; therefore, the ratio to determine integration times for one double rack is 1:8. This one rack is reused from a prior mission; therefore, the KSC dwell time must include mission duration, postlanding, refurbishment time and shipping to the Level IV site. The 1:8 factor is only applied to prelaunch days and refurbishment time, since mission duration, postlanding operations, and shipping are the same for all racks. Therefore, the dwell time at KSC for this one rack is shown in Table 3-3. These values are obtained from KSC dwell time data shown in Table 3-1. Mission 7 is used because KSC is said to reach production dwell times for racks at the seventh mission. Level IV integration dwell time for one rack is obtained from Figure 3-8 with the 1:8 ratio applied; therefore, it is 38 x 1/8 = 5 days. Total integration dwell time is 20 + 5 = 25 days. This fits in a three-month time period with several days to spare.

Table 3-3

NUMBER OF DAYS TO INTEGRATE ONE RACK
KSC – MISSION 16

Function	Days	
Prelaunch	22 x 1/8 =	3
Mission		7
Postlanding		5
Refurbishment	4 x 1/8 =	1
Ship to Level IV		2
Ship from Level V		2
	Total	20

Single rack investigations result in the conclusion that the 12 single racks (4 ESA provided and 8 initial NASA buy) provide more than enough time to perform Level IV integration and subsequent integration tasks at KSC of payload elements into single racks.

Pallet availability investigations found that for Mission 8, which uses five pallets only, two pallets from Mission 6 are available for a two-month time period. This is shown in Figure 3-11. All other missions that require pallets have pallets available prior to liftoff for significantly longer periods of time. Two months does not allow sufficient time to prepare and integrate payload elements on these two pallets. KSC dwell times shown for Mission 8 use the ratio of 2:5 for prelaunch integration activities and refurbishment times. The application of this ratio is shown in Table 3-4. Level IV integration time is obtained using the same ratio; therefore, from Figure 3-8, 45 x 2/5 = 18 days. Total integration and operational time required to prepare two racks for Mission 8 is 27 + 18 = 45 days. Considering 22 working days per month and a two-shift operation (2 x 22 = 44 days), two months does not provide adequate time for these racks to be used on Mission 8. The solution to this problem is not to buy more pallets, but to schedule an early delivery of two pallets of the NASA initial buy such that three of the NASA initial buy are online 1 June 1981. This early delivery of two pallets provides four months (88 days) for pallet preparation which is adequate.

Table 3-4

NUMBER OF DAYS TO INTEGRATE TWO PALLETS AT KSC – MISSION 8

Function	Days
Prelaunch	22 x 2/5 = 9
Mission	7
Postlanding	5
Refurbishment	4 x 2/5 = 2
Ship to and from Level IV	4
	Total 27

Section 4
DEDICATION SEARCH AND ANALYSIS

The concept of dedicating racks or pallets to individual payload elements as a means of reducing refurbishing or turnaround effort between missions drew interest in the study based on both the logical relationships shown in the establishment of baselines as well as on the judgment of experienced personnel indicating it should be a fruitful area to pursue. Having developed the baseline data and understandings in Section 3, this section will now address the overall area of defining the differences between the baseline sharing of racks and pallets and their dedication to individual payload elements.

4.1 FLOW PATH DIFFERENCES

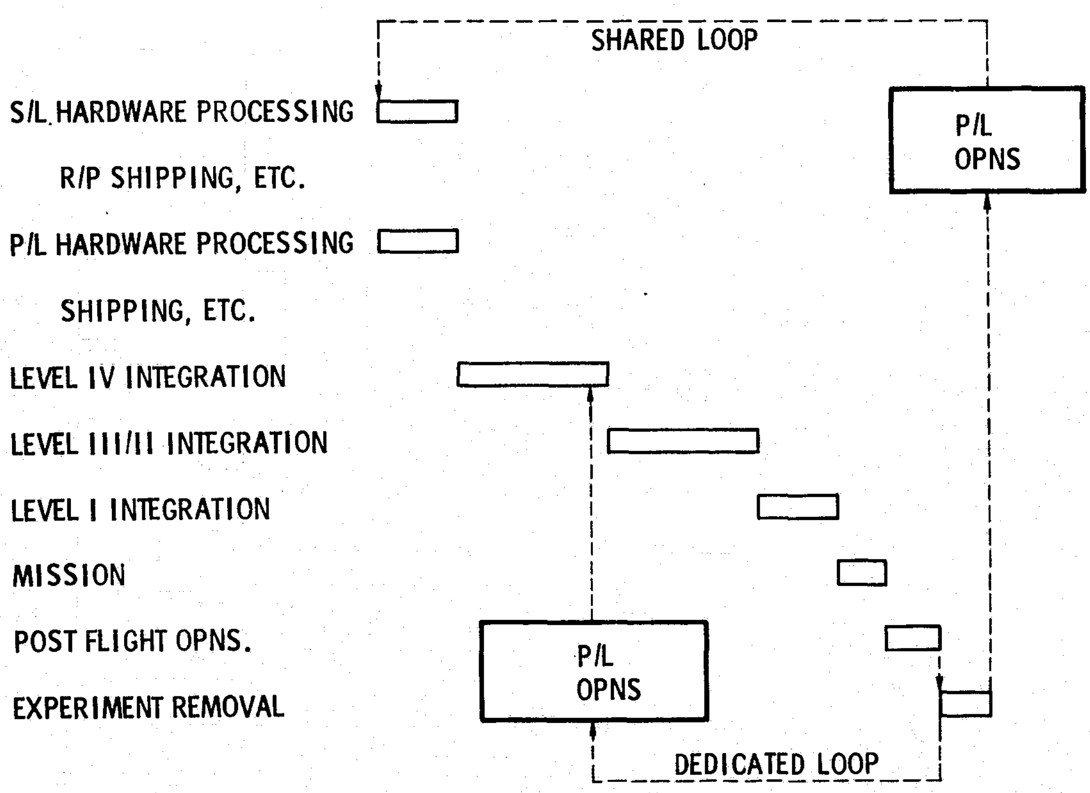
Flow path differences between the shared and dedicated approaches to rack usage were examined in detail. In the shared (baseline) flow, the payload elements are removed from the racks and pallets at KSC in the Spacelab operations and checkout (O&C) facility. The racks and pallets are refurbished and reconfigured for the next payload element to use them in a subsequent mission. The racks and pallets then reenter an integration flow at KSC or are packaged and shipped to the user or Level IV site for integration. Those payload elements which will fly again have, in the meantime, been disassembled and in some cases would be stored at KSC until refurbished and integrated there for a subsequent mission. Other payload elements would be shipped to the user or Level IV site for postflight checks, storage, refurbishment, etc., until needed again to begin the reintegration effort with another rack or pallet.

In the case of dedicated flow, the payload elements would remain installed in the rack or pallet. After the necessary postflight checks at KSC, the integrated payload and rack (or pallet) combination would be stored, in some cases, at KSC until needed to reenter integration flow at Level III/II for the intended mission. In other cases, the combination would be shipped to the user or Level IV site for postflight checks, storage, refurbishment, etc., until needed again to reenter integration flow at Level III/II for the intended mission. In some cases, depending on the integration mode selected, the combination would reenter integration flow at Level IV for compatability testing. In actual practice, even dedicated payload/rack (or pallet) combinations will require limited removals and reinstallations of components for repairs, refurbishment, or modifications. It is anticipated that such removals and reinstallations can be easily accomplished and retesting performed off-line or in conjunction with normally planned Level III/II tests (cost allowances were included for this).

Operational similarities exist for both shared and dedicated flow in the areas of payload modifications, refurbishing, servicing, calibrations, payload-peculiar handling, etc. Although only limited data were available on individaul payloads, it was concluded that such potential costs tend to balance each other or are slightly greater in the shared flow. Therefore, the primary area of cost differences explored was the flow sequence differences discussed above and displayed in Figure 4-1.

Figure 4-1 28219

SHARED VS DEDICATED FLOW SEQUENCE



4.2 CANDIDATE PAYLOAD SELECTION CRITERIA

To choose from the long list of payloads being planned, a technique is necessary to select candidate payloads for dedication of racks or pallets. After a review of the anticipated Spacelab Program flow sequences, four relatively simple selection criteria emerged, as follows:

A. Number of Reflights - Obviously a payload must fly more than once to be a candidate. If dedication is to save money, then the greater the number of reflights, the greater would be the savings. Until a full-cost trade analysis is performed, the break-even point cannot be determined. Therefore, any payload was considered a candidate if it flew two or more times.

B. Rack and Pallet Consumption - If a payload element consumed an entire rack or pallet it was assumed to be a candidate. If it consumes a significant portion of a rack or pallet, it was retained as a candidate until evaluation of other criteria was completed.

C. Technical and Operational Advantages - Based on a review of payload hardware and operations for handling, installing and testing, a subjective evaluation was made to identify possible advantages to dedication. Any reasonable advantage, so identified, caused the payload to be considered a candidate for dedication.

D. Cost Savings - A cursory estimate of Level IV integration complexity and cost factors was made and if a judgmental assessment indicated a probable cost savings from dedication, the payload was considered to be a candidate.

A collective review and reiteration of the above criteria was performed on each candidate prior to final candidate selection. Failure to meet any single criterion was not cause for candidate rejection until all other criteria had been rereviewed in concert for reasonable justification to dedicate. The selection criteria and the selected candidates are summarized on Figures 4-2 and 4-3, respectively.

4.3 DETAILED ANALYSES

Detailed analyses were conducted for the selected candidates to determine the cost differences between shared and dedicated flow. The results would confirm (or negate) the candidate selection and provide quantitative cost data from which decisions might be made.

Figure 4-2

28235

DEDICATION CANDIDATE SELECTION CRITERIA

CANDIDATE PAYLOADS SELECTED BY REITERATIVE CONSIDERATION OF:

- NUMBER OF RE-FLIGHTS IN EARLY MISSIONS
- WHOLE OR PARTIAL RACK/PALLET CONSUMED
- TECHNICAL/OPERATIONAL ADVANTAGES OF DEDICATION
- CURSORY COST COMPARISON OF SHARED VS. DEDICATED

CANDIDATES SO SELECTED SUBJECTED TO DETAILED EXAMINATION

- SHARED VS. DEDICATED COSTS (MAN HOURS)
- DISTRIBUTION OF THOSE COSTS
- PROGRAM EFFECTS OF DEDICATION

Figure 4-3

28234

CANDIDATES IDENTIFIED BY SELECTION PROCESS

EO-01-S	ATMOSPHERIC CLOUD PHYSICS LABORATORY
LS-09-S	LIFE SCIENCES SPECIMEN HOLDING FACILITIES
SP-31-S	SPACE PROCESSING (US)
SP-80/85	SPACE PROCESSING (ESA)
ST-31-S	DROP DYNAMICS

The quick-look data on how the candidates survived the dedication screening test and the results of the detailed analysis for each candidate are shown on Figures 4-4 through 4-13.

Each candidate was examined in detail regarding Level IV integration flow plans or requirements which would affect flow plans. A waterfall of Level IV integration activities was constructed based on MDAC estimates and payload developer inputs, where available. The types of functions required and their distribution within the integration sequence were identified, evaluated, and costed in order to assess integration costs for each of the three Level IV operating modes discussed in Section 3, Establishing Baselines. The types of functions fell into the following four general categories for estimating purposes.

1. Installations and preparations (common to Modes A, B, and C).
2. Subsystem checkout (common to Modes A and B).
3. Systems compatibility tests (Mode A requirements only).
4. KSC postflight operations (common to Modes A, B, and C).

Figure 4-4 28236

CANDIDATE QUICK LOOK

EO-01-S ATMOSPHERIC CLOUD PHYSICS LABORATORY

RE-FLIGHTS

- FLIES 4 TIMES IN FIRST 12 SPACELAB FLIGHTS
- ADDITIONAL FLIGHTS PROJECTED

WHOLE/PARTIAL RACK

- CONSUMES 1 FULL DOUBLE RACK

TECHNICAL/OPERATIONAL ADVANTAGES OF DEDICATION

- AVOID EXTENSIVE RETEST/RE-CALIBRATIONS
- SYSTEM OPERATION SENSITIVE (TUBE BEND RADIUS, ETC)
- LENGTHY RACK DWELL TIME FOR RE-INSTALLATIONS

CURSORY COST COMPARISONS

- MDAC EXPERIENCE/JUDGMENT INDICATES PROBABLE SAVINGS

Figure 4-5 28283

CANDIDATE DETAIL LOOK-MODE B

EO-01-S ATMOSPHERIC CLOUD PHYSICS LABORATORY (1 DOUBLE RACK)

MODE A "HANDS-ON" ESTIMATE FROM MSFC PERSONNEL IN MAN HOURS

- RACK ASSEMBLY AND INTEGRATION AT CONTRACTOR = 2728
- ADDITIONAL INTEGRATION AT LEVEL IV SITE = 528
- DISASSEMBLY IF NOT DEDICATED (INCLUDES SPECIAL HANDLING) = 1672

MODE B LEVEL IV DERIVED FROM ABOVE

- HANDS ON = (2728 + 528) ÷ 1.44 = 2261
- TOTAL DIRECT = 1.3 x 2.5 x 2261 = 7348
- 60% INSTAL/40% C/O = 4409/2939
- KSC POST FLT (DEDICATED) = 220 x 1.3 x 2.5 x 0.1 = 72

	SHARED			DEDICATED			SAVINGS (MAN HOURS)	
NO. FLTS	INSTL.	C/O	POST FLT.	INSTL.	C/O	POST FLT	PER FLT	CUM
1	4409	2939	1672	4409	2939	72	1600	1600
2	2645	1763	1000	265	176	43	4924	6524
3	2249	1499	853	450	300	37	3814	10,338
4	1984	1323	752	198	132	32	3697	14,035
*5	1852	1234	702	185	123	30	3450	17,485

*FLIGHT NO. 5 NOT NOW PLANNED IN EARLY STS MISSIONS

Figure 4-6 28228

CANDIDATE QUICK LOOK

LS-09-S LIFE SCIENCES SPECIMEN HOLDING FACILITIES

RE-FLIGHTS

- FLIES 4 TIMES IN FIRST 17 SPACELAB FLIGHTS
- ADDITIONAL FLIGHTS PROJECTED

WHOLE/PARTIAL RACK

- EACH HOLDING FACILITY CONSUMES 1 FULL DOUBLE RACK

TECHNICAL/OPERATIONAL ADVANTAGES OF DEDICATION

- AVOID SIGNIFICANT REMOVAL, REINSTALLATION AND RETEST OF LIFE SUPPORT, DATA AND CONTROL SYSTEMS

CURSORY COST COMPARISONS (3 DOUBLE RACKS)

- MDAC EXPERIENCE/JUDGMENT INDICATES PROBABLE SAVINGS

Figure 4-7 28243

CANDIDATE DETAIL LOOK - MODE B

LS-09-S LIFE SCIENCES SPECIMEN HOLDING FACILITIES (3 DOUBLE RACKS)

MODE B LEVEL IV ESTIMATES BY MDAC IN MAN HOURS

- HANDS ON = (3 x 914) = 2742
- TOTAL DIRECT = 1.3 x 2.5 x 2742 = 8910
- 80% INST/20% C/O = 7128/1782
- KSC POST FLT SHARED = 1280 x 1.3 x 2.5 x 0.3 = 1248
- KSC POST FLT DEDICATED = 220 x 1.3 x 2.5 x 0.3 = 215

	SHARED			DEDICATED			SAVINGS (MAN HOURS)	
FLT NO.	INSTL	C/O	POST FLT	INSTL	C/O	POST FLT	PER FLT	CUM
1	7128	1782	1248	7128	1782	215	1033	1033
2	4277	1069	749	854	215	129	4897	5930
3	3635	909	636	364	91	110	4615	10,545
4	3208	802	562	320	80	97	4075	14,620
* 5	2994	748	524	600	150	90	3426	18,046
* 6	2780	695	487	278	70	84	3530	21,576
* 7	2637	659	462	260	66	79	3353	24,929
* 8	2495	624	437	250	62	75	3169	28,098

* NOT NOW PLANNED IN EARLY STS MISSIONS

Figure 4-8 28237

CANDIDATE QUICK LOOK

SP-31-S SPACE PROCESSING (US)

RE-FLIGHTS

- FLIES 2 TIMES IN FIRST 9 SPACELAB FLIGHTS
- ADDITIONAL FLIGHTS PROJECTED

WHOLE/PARTIAL RACK

- CONSUMES 1 FULL DOUBLE RACK

TECHNICAL/OPERATIONAL ADVANTAGES OF DEDICATION

- AVOID REMOVAL, REINSTALLATION AND RETEST OF FLUID MEDIA, HEATING, MANIPULATOR, AUTOMATED DATA, POWER AND CONTROL SYSTEMS

CURSORY COST COMPARISONS

- MDAC EXPERIENCE/JUDGMENT INDICATES PROBABLE SAVINGS

Figure 4-9 28247

CANDIDATE DETAIL LOOK-MODE B

SP-31-S SPACE PROCESSING -US (1 DOUBLE RACK)

MODE B LEVEL IV ESTIMATE BY MDAC

- HANDS ON = 1632
- TOTAL DIRECT = 1.3 x 2.5 x 1632 = 5304
- 50% INSTL/50% C/O = 2652/2652
- KSC POST FLT-SHARED = & 1.3 x 2.5 x 1280 x 0.1 = 416
- KSC POST FLT-DEDICATED = 1.3 x 2.5 x 220 x 0.1 = 72

	SHARED			DEDICATED			SAVINGS (MAN HOURS)	
FLT NO	INSTL	C/O	POST FLT	INSTL	C/O	POST FLT	PER FLT	CUM
1								
1	2652	2652	416	2652	2652	72	344	344
2	1591	1591	250	159	159	43	3071	3415
*3	1353	1353	212	270	270	37	2341	5756
*4	1193	1193	187	119	119	32	2303	8059
*5	1114	1114	175	111	111	30	2151	10,210
*6	1034	1034	16[illegible]	103	103	28	1996	12,206

*NOT NOW PLANNED IN EARLY MISSIONS

Figure 4-10 28238

CANDIDATE QUICK LOOK

SP-80/85 SPACE PROCESSING (ESA)

REFLIGHTS

- FLIES 4 TIMES IN FIRST 16 SPACELAB FLIGHTS
- ADDITIONAL FLIGHTS PROJECTED

WHOLE/PARTIAL RACK

- CONSUMES 1 FULL DOUBLE RACK

TECHNICAL/OPERATIONAL ADVANTAGES OF DEDICATION

- AVOID REMOVAL, REINSTALLATION AND RETEST OF FLUID MEDIA, HEATING, COOLING, ACOUSTIC POSITIONING, SPECIMEN PROCESSING, TELEVISION, DATA, POWER AND CONTROL SYSTEMS

CURSORY COST COMPARISONS

- MDAC EXPERIENCE/JUDGMENT INDICATES PROBABLE SAVINGS

Figure 4-11

CANDIDATE DETAIL LOOK-MODE B

28242

SP-80/85 SPACE PROCESSING, ESA (1 DOUBLE RACK)

MODE B LEVEL IV ESTIMATES BY MDAC IN MAN HOURS

- HANDS ON = 1728
- TOTAL DIRECT = 1.3 x 2.5 x 1728 = 5616
- 50% INSTL/50% C/O = 2808/2808
- KSC POST FLT-SHARED = 1.3 x 2.5 x 1280 x 0.1 = 416
- KSC POST FLT-DEDICATED = 1.3 x 2.5 x 220 x 0.1 = 72

	SHARED			DEDICATED			SAVINGS (MAN HOURS)	
FLT NO	INSTL	C/P	POST FLT	INSTL	C/O	POST FLT	PER FLT	CUM
1	(2808	2808	416)	(2808	2808	72)	344	344
2	1685	1685	250	169	169	43	3239	3583
3	1432	1432	212	286	286	37	2467	6050
4	1264	1264	187	126	126	32	2431	8481
* 5	1179	1179	175	118	118	30	2267	10,748
* 6	1095	1095	162	110	110	28	2104	12,852
* 7	1039	1039	154	210	210	26	1786	14,638
* 8	983	983	146	98	98	25	1891	16,529

*NOT NOW PLANNED IN EARLY STS MISSIONS

Figure 4-12

CANDIDATE QUICK LOOK

28239

ST-31-S DROP DYNAMICS

REFLIGHT

- FLIES 4 TIMES IN FIRST 14 SPACELAB FLIGHTS
- ADDITIONAL FLIGHTS PROJECTED

WHOLE/PARTIAL RACK

- CONSUMES 1-1/2 SINGLE RACKS

TECHNICAL/OPERATIONAL ADVANTAGES OF DEDICATION

- FEASIBLE TO DEDICATE 1 FULL SINGLE, SHARE 1/2 SINGLE RACK
- AVOID REMOVAL REINSTALLATION AND RETEST OF PAYLOAD SELF-CONTAINED SYSTEMS FOR CAMERA, DATA, MONITOR, RECORD AND CONTROL FUNCTIONS

CURSORY COST COMPARISONS

- MDAC EXPERIENCE/JUDGMENT INDICATES PROBABLE SAVINGS

Figure 4-13

CANDIDATE DETAIL LOOK-MODE B

28246

ST-31-S DROP DYNAMICS (1-1/2 SINGLE RACKS)

MODE B LEVEL IV ESTIMATES BY MDAC IN MANHOURS

- HANDS ON FOR 1-1/2 RACKS = 1061
- HANDS ON FOR 1 RACK = 707
- TOTAL DIRECT = 1.3 x 2.5 x 707 = 2298
- 62% INSTL/38% C/O = 1414/884
- KSC POST FLT - SHARED = 1.3 x 2.5 x 1280 x 0.1 = 416
- KSC POST FLT - DEDICATED = 1.3 x 2.5 x 220 x 0.1 = 72

	SHARED			DEDICATED			SAVINGS (MAN HOURS)	
FLT NO	INSTL	C/O	POST FLT	INSTL	C/O	POST FLT	PER FLT	CUM
1	1414	884	416	1414	884	72	344	344
2	848	530	250	85	53	43	1447	1791
3	721	451	212	144	90	37	1113	2904
4	636	398	187	64	40	32	1085	3989
**5	594	371	175	120	74	30	916	4905
**6	551	345	162	55	35	28	940	5845
**7	523	327	154	52	33	26	893	6738
**8	495	309	146	100	60	25	815	7553
**9	481	301	141	48	30	24	821	8374
**10	467	292	137	47	29	24	796	9170

*BASED ON DEDICATING 1 SINGLE RACK AND SHARING 1/2 SINGLE RACK

**NOT NOW. PLANNED IN EARLY STS MISSIONS

Most estimates were made for the Mode B which represents a conservative middle-of-the-road approach. Mode B results can also be converted to other modes by means of the formulas discussed in Section 3. The operational cost savings for subsequent flights of dedicated rack/payloads was computed by subtracting dedicated flow costs from shared flow costs, both of which were derived on the basis of learning curves.

The learning curve selected for reducing subsequent integration costs was an 80% curve, defined as one which reduces the unit cost such that the average cost is lower by 20% each time the production or launch rate is doubled. For the dedicated case, an allowance is made for partial removal, replacement, and retest of payload elements based on a percentage of the shared cost. These allowances represent MDAC estimates based on payload expectations and/or inputs from payload developers. Such removals, reinstallations, and limited retests are expected to be conducted offline or in conjunction with planned Level III/II integration.

The data from the detailed analyses for the selected candidates are displayed in Figures 4-5, 4-7, 4-9, 4-11, and 4-13. It can readily be seen that significant savings can be obtained through dedication. The operational savings (not counting possible additional rack costs) are summarized for all dedication candidates in each of the three Level IV operating modes on Figure 4-14. Net program savings, considering required rack costs, are addressed in Section 7.

Figure 4-14

28284

OPERATIONAL SAVINGS THROUGH DEDICATION
CURRENTLY PLANNED MISSIONS

	RACKS			OPERATIONAL SAVINGS (MAN HOURS)		
	DBL	SGL	FLTS	MODE A	MODE B	MODE C
CLOUD PHYSICS	1		4	18408	14035	10058
LIFE SCIENCES*	3		4	19892	14620	12226
SPACE PROCESSING – US	1		2	4673	3415	1983
SPACE PROCESSING – ESA	1		4	11821	8481	4681
DROP DYNAMICS		1	4	5356	3989	2793
MAN HOUR TOTALS				60,150	44,540	31,741
TOTALS AT $25/HR				$1,503,750	$1,113,500	$793,525

*NUMBER OF DEDICATED LIFE SCIENCE RACKS REQUIRED, AND THE NUMBER OF FLIGHTS FOR EACH, ARE NOT DEFINED. THE CASE SHOWN IS THOUGHT TO BE A PROBABLE MINIMUM. ACTUALS COULD BE MORE

4.4 PALLET DEDICATIONS

Pallet dedications are not indicated by the candidate selection criteria and attendant analysis. No reasonable combination of number of flights, pallet consumption, and technical and operational advantages could be assembled from the Early STS Missions Plan. For example, one payload, the Transition Radiation Cosmic Ray Detector, consumes one pallet segment and flies twice in the early missions. At $25/hr, the integration effort saved by dedication for the two flights would have to total 71,600 manhours to pay for the cost of a pallet. This level is far in excess of what would be expected. It was concluded, therefore, that pallet dedication is not cost effective as program plans are currently understood (see Figure 4-15).

Figure 4-15

28232

PALLET FINDINGS

- NO PALLET MOUNTED PAYLOADS WERE IDENTIFIED AS CANDIDATES FOR PALLET DEDICATION

  REFLIGHTS
  - FEW MULTIPLE REFLIGHTS IN EARLY STS MISSIONS
  - ONE P/L (IECM) FLIES 4 TIMES IN FIRST 14 MISSIONS
  - TRANSITION RADIATION COSMIC RAY DETECTOR FLIES 2 TIMES

  WHOLE/PARTIAL PALLET
  - MOST INDIVIDUAL PAYLOADS CONSUME PARTIAL PALLET
  - TRANSITION RADIATION COSMIC RAY DETECTOR CONSUMES 1 PALLET
  - RELATED PAYLOAD GROUPS MAY CONSUME WHOLE PALLET

  TECHNICAL/OPERATIONAL ADVANTAGES
  - UNCERTAIN, BASED ON ABOVE

  CURSORY COST COMPARISONS
  - IF P/L INTEGRATION COST SAVINGS AVERAGED 10,000 MAN HOURS, IT WOULD TAKE MORE THAN 7 REFLIGHTS TO SAVE (AT $25/HR) THE COST OF A DEDICATED PALLET—SUCH CASES NOT EXPECTED

- PALLET DEDICATION TO A DISCIPLINE SHOULD BE STUDIED

4.5 DEDICATION ANALYSIS QUALIFICATIONS

Conservative conclusions are believed to be possible from the data results of the preceding analyses for the following reasons:

A. Learning curve of 80% used for forecasting cost reductions for subsequent mission preparations represents a faster-than-expected learning. Previous experience indicates that an 80% rate is normally achievable only if the subsequent operations are carbon-copies of the first in terms of hardware, people, test environment, and continuous flow. The Spacelab integration operations are expected to have more variables and complexities, such as differing payload groupings, than those operations which have achieved 80% in the past. More realistic estimates of Spacelab Level IV integration learning curves, actually resistance-to-learning curves, by MDAC and others, including MSFC, range from 85% to 95%, representing slower learning than the study nominal of 80%. Such slower learning would drive the cost of integration up and thus create the potential for more savings by dedication.

B. Facility operation costs for Level IV were not included in the cost trades. In practice, it would be expected that payloads would share such costs on a pro-rata basis. Thus, minimizing Level IV operations by dedication would tend to reduce facility operation costs slightly.

C. Additional flights of the selected candidates are highly probable based on preliminary plans of the payload developers and on the inherent nature of the experiment objectives, e.g., space processing is expected to remain a long term area of interest and will be flown repeatedly throughout the STS operational period.

PRECEDING PAGE BLANK NOT FILMED

Section 5
COSTING DOUBLE CHECK

The costs (manhours) shown in Section 4 for integrating payload elements into racks and on pallets were based on preliminary estimates of Level IV timelines. To obtain an independent check on these values other cost estimates and techniques were used to compare with these initial values. The main purpose for this comparison is not to verify the exact number of manhours or dollars estimated, but to determine if there existed a degree of commonality between the various estimates for performing Level IV integration on Spacelab experiments. If this commonality exists, the confidence level in the estimates would be increased, thereby lending more credence to the series of conclusions reached by using these estimates.

Two other sources for obtaining Level IV integration costs were used to compare with initial MDAC values. One is the Cost Data Synthesis Method and the other is based on data obtained from MSFC pertaining to specific experiments.

5.1 COST DATA SYNTHESIS METHOD

The Cost-Data Synthesis Method was employed to obtain Level IV integration costs for the payload elements in the first five Spacelab missions. This method was developed by NASA and reported in Report CASD-NAS-76-009, February 1976. Its prime feature is to allow cost estimates to be made for an entire spectrum of payload elements based on data generated from a detailed analysis of a few specific payload elements. From these detailed analyses of payload elements, estimating relationships were derived that utilize manhours and a complexity index. The resulting equation is shown in Figure 5-1. The term steady-state used in the equation is derived assuming the integration functions take place after approximately 60 payload elements have been flown and the integration cycle requirements and process are well established, steady-state, and austere.

Figure 5-1

COST DATA SYNTHESIS METHODOLOGY

28001

- METHOD USED DOCUMENTED IN NASA REPORT NO. CASD-NAS-76-009
- "STEADY STATE" COST ESTIMATING RELATIONSHIP

$$C = K_1 \times K_2 \times a \, (CI)^b \times R$$

		NOMINAL VALUES USED
WHERE K_1	= CONTINGENCY FACTOR	1.3
K_2	= DIRECT SUPPORT FACTOR	2.5
a	= CER EQU REGRESSION COEF, 2.5	–
b	= CER EQUATION EXPONENT, 0.9	–
R	= COMPOSITE LABOR RATE	\$25/HR
CI	= COMPLEXITY INDEX	–

- FIRST FLIGHT COST OBTAINED BY "BACKING UP" 80% LEARNING CURVE
- COSTS OF REFLIGHTS OBTAINED USING 80% LEARNING CURVE TABLE

Obtaining the complexity index is the main task performed when using the synthesis method. A description of the experiment must be available to a detailed level such as that shown in STS Payload Description Level B document. From these data a selection of an appropriate weighting factor is made for each equipment item within an experiment. An established weighting factor scale for various equipment items is shown in CASD-NAS-76-009. It is used in this analysis, but requires judgment by the estimator in matching the equipment item to the proper scale of weighting factors. A summation of all the weighting factors is the complexity index which is used in the cost equation to obtain steady-state costs. Figures 5-2 and 5-3 show an example of how the complexity index and costs for the ESA Space Processing Experiment (SPE-80/85) are obtained. From ESA Report MBB-ESP-75/01, 11 April 1975, a description and quantity of each equipment item was obtained. Using this description, judgment, and the weighting factor scale, a unit weighting factor was established. Unit weighting factor and quantity are multiplied to form total weighting factor. A total weighting factor was derived for each

Figure 5-2

28002

EXAMPLE OF LEVEL IV INTEGRATION COST ESTIMATING COST DATA SYNTHSIS METHOD

EXPERIMENT, SPE-80/85 SPACE PROCESSING (MISSION 1, DOUBLE RACK NO. 5)

EQUIPMENT ITEM	QUANTITY	UNIT WEIGHTING FACTOR	TOTAL WEIGHTING FACTOR
SPE-80 ISOTHERMAL FURNACE AND AUX. EQUIPMENT			
COOLING SYSTEM	1	6	6
THERMAL INSULATION	1	1	1
VACUUM SYSTEM	1	8	8
VACUUM GAUGE	1	8	8
POWER CONDITIONING	1	6	6
HEATING ELEMENT	1		
FURNACE CHAMBER	1	15	15
ATMOSPH. SENSOR AND CONDITIONING	1	8	8
PRESSURE CONTROL	1	20	20
INERT GAS SUPPLY	1	6	6
PROCESS CONTROL UNIT	1	20	20
TEMPERATURE CONTROL	1	20	20
CHARGE AND DISCHARGE EQUIPMENT	1	6	6
SAMPLE HOLDER	1	1	1
SAMPLE DISPLACEMENT	1	2	2
CAMERA	1	8	8
DATA ACQUISITION UNIT	1	15	15
SPE-85 ACOUSTIC POSITIONING DEVICE			
FREQUENCY CONTROLLER	1	20	20
TEMPERATURE/PRESSURE CONTROL	1	20	20
FREQUENCY GENERATOR	1	6	6
MICRO RESONATOR	1	6	6
ADJUSTABLE VALVE (HELIUM)	1	1	1
POWER AMPLIFICATION	1	6	6
TRANSDUCER	1	1	1
ARGON	1	6	6
HELIUM	1	6	6
ADJUSTABLE VALVE (ARGON)	1	1	1
		COMPLEXITY INDEX	223

Figure 5-3

28003

EXAMPLE OF LEVEL IV INTEGRATION COST ESTIMATING COST DATA SYNTHESIS METHOD

EXPERIMENT SPE-80/85, CONTINUED

- STEADY STATE LEVEL IV INTEGRATION COST

$$C = 1.3 \times 2.5 \times 2.5\ (223)^{0.9} \times 25 = \$26,400$$

- REPEAT FLT LEV IV INTEGRATION COST (80% LEARNING CURVE "BACKUP")

1ST	$C = \dfrac{26,400}{0.2676}$	= \$ 98,700	MISSION NO. 1
2ND	C = \$98,700 x .6	= 59,200	MISSION NO. 5
3RD	C = \$98,700 x .506	= 49,900	MISSION NO. 13
4TH	C = \$98,700 x .453	= 44,700	MISSION NO. 16

TOTAL: \$252,500

equipment item, and the sum of these results in the complexity index. The index can be used in any of the estimating relationships contained in Report CASD-NAS-76-009 for the various integration levels and operational functions, but, for this investigation only, the cost of Level IV integration was calculated. These calculations are shown in Figure 5-3. Steady-state costs were calculated first. For the early missions, which include the first four times this experiment is flown , this steady-state cost had to be converted to costs of the first through the fourth mission. As suggested in Report CASD-NAS-76-009, the first unit cost was obtained by backing-up the learning curve. This was done by going to the learning curve table and obtaining the unit value of the 60th unit, then dividing the steady-state cost by this value. An 80% learning curve was selected since it represents a rapid learning and, for this evaluation, was conservative.

The unit value used in Report CASD-NAS-76-009 is based on the cumulative average cost for the 60th unit and is 0. 2676 for 80% learning. This value was used to obtain the first unit cost. At MDAC, however, it has been traditional, when using the learning curves to calculate unit cost, to use the individual unit cost table. Therefore, for the second and subsequent units the individual unit cost table was used.

Summing the costs for the four space processing missions results in a cost of performing Level IV integration on a shared-rack basis, i.e., this payload element will have to be integrated into a new rack every time it is reflown.

This type of calculation was done for all payload elements defined in the first five Spacelab missions on a rack-by-rack pallet-by-pallet basis. Only the first five Spacelab missions were analyzed in detail because the level of payload definition, as to the type and location in the Spacelab, was sufficient to obtain complexity indexes while the other early missions were not defined in enough detail.

In addition to calculating the cost of Level IV integration for the experiments in the first five missions to check the MDAC cost estimates, a criterion was established to determine if certain racks might show program cost savings if they were dedicated to a specific payload element or experiment. The criterion derived was basically a simple one, i.e., if the total cost of performing

Level IV integrations for a payload element was greater than the cost of a rack, it was a candidate for dedication. Figure 5-4 summarizes the approach used in searching for dedicated racks and pallets.

Figures 5-5 through 5-8 show the results of the cost data synthesis estimating technique as applied to Missions 1 through 5. Figure 5-5 shows Level IV integration cost estimates for Mission 1 (Option 1A). Column 3 shows costs for the first flight unit for each of the racks and the pallet. These costs were calculated as described above. Column 5 shows the number of reflights the particular payload element is expected to have, based on the data available for the first 18 missions. The dashed line indicates that there are no known reflights of that experiment. Column 6 is the total Level IV integration cost for each rack including the effects of an 80% learning curve in reducing the cost of the second and subsequent reflights. Column 7 reflects the dedication selection criteria. In three cases, the total cost of Level IV integration of shared racks is higher than the cost of the rack itself. These three are marked by a check-mark to indicate that they are candidates for dedication. Column 8 shows how many dollars can be saved by dedication. This analysis assumes that Level IV integration will have to be performed on the first flight of an experiment, but if the rack is dedicated to a specific experiment there will be no Level IV integration performed for subsequent missions.

Figure 5-6 shows the cost estimates for Mission 2, a pallet only mission. None of the pallets can be justified as candidates for dedication because pallet hardware cost is high compared to Level IV integration costs and there are few reflights of pallet mounted experiments. This situation exists for all missions, therefore, it is concluded that pallets cannot be dedicated based on the information we have at the present time and the criteria used for selection. There may be technical or operational considerations in the future that would justify dedicating a pallet, but based on the results of this study, pallets are too expensive to dedicate.

Mission 3 cost data show that the Atmospheric Cloud Physics Laboratory (ACPL) EO-01-S should have a dedicated rack. This experiment was also designated as a candidate in Mission 1, therefore, the total cost reduction due to dedication was not accounted for twice (cost reduction for ACPL is subtracted from the total reduction).

Figure 5-4

SELECTION OF CANDIDATES FOR DEDICATION COST DATA SYNTHESIS METHOD

28004

SELECTION CRITERIA

- RACKS OR PALLETS SELECTED AS CANDIDATES FOR DEDICATION IF TOTAL LEV IV INTEG COST WITH SHARED HDWE IS GREATER THAN HDWE COST

METHODOLOGY

- 1ST FLIGHT LEV IV INTEG COST OBTAINED FROM DETAILED ANALYSIS OF EACH P/L
- PAYLOAD DEFINITION AVAILABLE FOR THE FIRST 5 SPACELAB MISSIONS
- NUMBER OF REFLIGHTS OF A PAYLOAD
- COST OF LEV IV INTEG FOR REPEAT MISSIONS USES 80% LEARNING
- TOTAL LEV IV INTEG COST IS THE SUM OF EACH MISSION LEV IV COSTS
- IF TOTAL LEV IV INTEG $ EXCEEDS HDWE $, ELEMENT IS CANDIDATE FOR DEDICATION

Figure 5-5

LEVEL IV INTEGRATION COST VS HARDWARE COST COST DATA SYNTHESIS METHOD

28005

MISSION 1 (OPTION 1A) (80% LEARNING)

1 HARDWARE	2 EXPERIMENT	3 FIRST FLIGHT INTEG COST, $	4 HARDWARE COST, $	5 NO. OF REFLIGHTS	6 TOTAL LEV IV COST, $	7 Δ COST, $ 6 - 4	8 COST REDUCTION, $ 6 - 3
RACK #2 (DR)	VFI	47,900	154,000	-	47,900	-106,100	0
RACK #3 (SR)	2 P/L'S	47,900	127,000	-	47,900	-79,100	0
RACK #5 (DR)	SPE 80/05	98,700	154,000	4	252,500	95,500 ✓	153,800
RACK #6 (SR)	LSE-03	72,700	127,000	2	116,300	-10,700	0
RACK #7 (DR)	3 P/L'S	85,300	154,000	-	85,300	-68,700	0
RACK #8 (DR)	4 P/L'S	64,800	154,000	-	64,800	-89,200	0
RACK #9 (SR)	ESA Add-On	47,900	127,000	-	47,900	-79,100	0
RACK #10 (DR)	ACPL	135,300	154,000	4	346,200	192,200 ✓	210,900
RACK #11 (DR)	LS-13-S	75,200	154,000	4	192,300	38,300 ✓	117,500
RACK #12 (SR)	ESA Add-On	47,900	127,000	-	47,900	-79,100	0
PALLET	12 P/L'S	526,600	1,790,000	-	526,600	-1,263,400	0
		1,250,200					TOTAL = 482,200 *

CANDIDATES FOR DEDICATION ARE:

RACK #5 SPE-80/85, SPACE PROCESSING
RACK #10 EO-01-S, ACPL
RACK #11 LS-13-S, MINILAB

*ASSUMES NO LEVEL IV INTEGRATION OF EXPERIMENTS IN DEDICATED RACKS BEYOND THE FIRST FLIGHT

NOTE: ✓ INDICATES SELECTED AS CANDIDATE FOR DEDICATION

Figure 5-6

LEVEL IV INTEGRATION COST VS HARDWARE COST COST DATA SYNTHESIS METHOD

28006

MISSION 2 (80% LEARNING)

① HARDWARE	② EXPERIMENT	③ FIRST FLIGHT INTEG COST, $	④ HARDWARE COST, $	⑤ NO. OF REFLIGHTS	⑥ TOTAL LEV IV COST, $	⑦ Δ COST, $ ⑥-④	⑧ COST REDUCTION, $ ⑥ - ③
PALLETS #1 & #2	5 P/L's	247,400	3,580,000	-	247,400	-3,332,600	0
PALLET #3	6 P/L's	295,400	1,790,000	-	295,400	-1,494,600	0
PALLET #4	7 P/L's	303,500	1,790,000	-	303,500	-1,486,500	0
		846,300					

NO CANDIDATES FOR DEDICATION

MISSION 3 (80% LEARNING)

① HARDWARE	② EXPERIMENT	③ FIRST FLIGHT INTEG COST, $	④ HARDWARE COST, $	⑤ NO. OF REFLIGHTS	⑥ TOTAL LEV IV COST, $	⑦ Δ COST, $ ⑥-④	⑧ COST REDUCTION, $ ⑥ - ③
RACK #3 (SR)	ST-31-S	68,200	127,000	4	174,400	47,400 ✓	106,200
RACK #5 (DR)	EO-01-S	135,300	154,000	4	346,200	192,200 ✓	210,900
RACK #7 & #8 (DR'S)	LS-13-S	75,200	308,000	4	192,300	-115,700	0
RACK #9 (SR)	FILM	2,600	127,000	-	2,600	-124,400	0
RACK #10 (DR)	SP-31-S	98,600	154,000	2	157,700	3,700 ✓	59,100
		379,900				TOTAL =	376,200
							-210,900*
							165,300

CANDIDATES FOR DEDICATION ARE:

RACK #3 ST-31-S, DROP DYN
RACK #5 EO-01-S, ACPL (SAME AS RACK #10 MISSION 1)*
RACK #10 SP-31-S, U.S. SPACE PROCESSING

NOTE: ✓ INDICATES SELECTED AS CANDIDATE FOR DEDICATION

Figure 5-7 shows the cost analysis results for Mission 4. The Life Sciences payloads in Rack 5 show the cost increment (column 7) to be slightly negative, but the increment was so close to being zero that it was also selected as a candidate for a dedicated rack. This selection was justified when considering the cost savings by dedication ($93,400).

Figure 5-8, Mission 5 cost data, shows Space Processing should be dedicated. Space Processing was also accounted for in Mission 1, therefore, it is not accounted for again in the total cost reduction.

A summary of racks that are candidates for dedicated use, as determined using the Cost Data Synthesis Method, is shown in Figure 5-9. These candidates were selected on a cost basis only and do not reflect any technical or operational considerations that might prevent them from being dedicated to an experiment. Most are scheduled to be flown four times in the first 18 missions and comprise a mixture of double and single racks. Life science experiments make up the bulk of dedicated payload elements primarily

Figure 5-7

28007

LEVEL IV INTEGRATION COST VS HARDWARE COST
COST DATA SYNTHESIS METHOD

MISSION 4 (80% LEARNING)

(1) HARDWARE	(2) EXPERIMENT	(3) FIRST FLIGHT INTEG COST, $	(4) HARDWARE COST, $	(5) NO. OF REFLIGHTS	(6) TOTAL LEV IV COST, $	(7) Δ COST, $ (6) - (4)	(8) COST REDUCTION, $ (6) - (3)
RACK #2 (DR)	LS-09-S	55,900	154,000	4	143,000	-11,000	0
RACK #3 (SR)	LS-09-S	82,600	127,000	4	211,400	84,400 ✓	128,800
RACK #7 (DR)	LS-09-S	25,400	154,000	4	64,900	-89,100	0
RACK #8 (DR)	LS-09-S	57,900	154,000	4	148,100	-5,900	0
RACK #9 (SR)	LS-09-S	15,900	127,000	4	40,800	-86,200	0
RACK #5 (DR)	LS-09-S	59,900	154,000	4	153,300	-700 ✓	93,400
RACK #6 (SR)	LS-09-S	19,000	127,000	4	48,700	-78,300	0
RACK #10 (DR)	LS-09-S	145,100	154,000	4	371,200	217,200 ✓	226,100
RACK #11 (DR)	LS-09-S	85,800	154,000	4	219,600	65,600 ✓	133,800
RACK #12 (SR)	LS-09-S	45,600	127,000	4	116,800	-10,200	0
PALLET	HE-25-S	76,100	1,790,000	-	76,100	-1,713,900	0
		669,200				TOTAL =	582,100

CANDIDATES FOR DEDICATION ARE:

RACK #3 LS-09-S, LIFE SCIENCE DEDICATED LAB
RACK #5 LS-09-S, LIFE SCIENCE DEDICATED LAB
RACK #10 LS-09-S, LIFE SCIENCE DEDICATED LAB
RACK #11 LS-09-S, LIFE SCIENCE DEDICATED LAB

NOTE: ✓ INDICATES SELECTED AS CANDIDATE FOR DEDICATION

Figure 5-8

28008

LEVEL IV INTEGRATION COST VS HARDWARE COST
COST DATA SYNTHESIS METHOD

MISSION 5 (80% LEARNING)

(1) HARDWARE	(2) EXPERIMENT	(3) FIRST FLIGHT INTEG COST, $	(4) HARDWARE COST, $	(5) NO. OF REFLIGHTS	(6) TOTAL LEV IV COST, $	(7) Δ COST, $ (6) - (4)	(8) COST REDUCTION, $ (6) - (3)
RACK #2 (DR)	SPE-80/85	144,800	154,000	4	370,700	216,700 ✓	225,900
RACK #3 (SR)	4 P/L'S	39,200	127,000	2	62,700	-64,300	0
RACK #5 (DR)	3 P/L'S	44,400	154,000	-	44,400	-109,600	0
RACK #6 (SR)	2 P/L'S	30,200	127,000	2	48,400	-78,600	0
PALLET #1	ANTENNA	47,900	1,790,000	2	76,600	-1,713,400	0
PALLETS #2 & #3	8 P/L'S	416,900	3,580,000	-	416,900	-3,163,100	0
		723,400				TOTAL =	226,000
							- 225,900*
							0

CANDIDATE FOR DEDICATION:

RACK #2 SPE 80/85 AND SPE-01 (ACCOUNTED FOR IN MISSION 1)*

NOTE: ✓ INDICATES SELECTED AS CANDIDATE FOR DEDICATION

Figure 5-9

28009

SUMMARY OF DEDICATED HARDWARE CANDIDATES-COST DATA SYNTHESIS METHOD

HARDWARE ELEMENT	MISSION NO.	EXPERIMENT NO. AND NAME		LEVEL IV INTEGRATION COST SAVED BY DEDICATION
DOUBLE RACK	1, 5, 13, 16	SPE 80/85	SPACE PROCESSING	153,800
DOUBLE RACK	1, 3, 9, 12	EO-01-S	ACPL	210,900
DOUBLE RACK	1, 3, 9, 13	LS-13-S	MINILAB	117,500
SINGLE RACK	3, 6, 9, 14	ST-31-S	DROP DYN.	106,200
SINGLE RACK	4, 7, 11, 17	LS-09-S	LIFE SCIENCE	128,800
DOUBLE RACK	4, 7, 11, 17	LS-09-S	LIFE SCIENCE	93,400
DOUBLE RACK	4, 7, 11, 17	LS-09-S	LIFE SCIENCE	226,100
DOUBLE RACK	4, 7, 11, 17	LS-09-S	LIFE SCIENCE	133,800
DOUBLE RACK	3, 9	SP-31-S	U.S. SPACE PROCESSING	59,100
			TOTAL:	$1,229,600

because they are, as a group, reflown more often than any other class of experiment and tend to use the complete volume of a rack. The Level IV integration cost savings shown do not include the cost of the additional hardware that must be acquired to support the dedicated mode of rack utilization. In obtaining these values, it was also assumed that Level IV integration occurs during the first use of the rack and that subsequent reuses do not require Level IV integration and related costs. This may be slightly unconservative, and some Level IV integration costs should be considered. However, for this analysis, it was assumed that these were second-order factors and not significant in determining rack dedication. By dedicating seven double racks and two single racks to these experiments, approximately $1 million can be saved in Level IV integration costs. To obtain net program savings, the additional rack purchases needed to support dedicated operations must be subtracted from Level IV integration cost savings. The fact that racks are dedicated to specific payload elements does not necessarily imply that a rack must be added to the baseline inventory for each candidate. When a rack is dedicated to a particular payload element, it is used for that purpose and not assigned to other experiments, therefore, an availability investigation was made to determine the inventory necessary to support this number of dedicated racks. It was found that the addition of two more double racks to the inventory was required to dedicate seven double racks. The inventory of single racks is sufficient to support the shared and dedicated rack utilization.

Figure 5-10 shows net program savings because of dedicating seven double and two single racks. The cost of two additional double racks is subtracted from the Level IV integration cost saving resulting in a savings of over $900,000. This compares favorably with the findings of the MDAC estimating method described in Subsection 7.3.

5.2 MSFC COST ESTIMATES

To further check validity of the cost estimating performed by MDAC for Spacelab payload elements, NASA/MSFC provided Level IV manhour estimates of certain experiments in Spacelab Mission 1. These were compared with similar values derived by MDAC and by the Cost Data Sythesis Method. Figure 5-11 shows this comparison. The experiments shown in Figure 5-11 were based on an assumed Spacelab Mission 1 experiment complement which is not the same as the definition of Mission 1 experiments provided to us for study purposes, but this is incidental. However, the comparison of Level IV integration costs for the same specific payload elements made by NASA and MDAC is the significant point. The available MSFC estimates for Level IV integration are based on the Mode A definition of Level IV integration and included man-hours for preparation of test procedure writing. MDAC Level IV integration hours do not include estimates for procedure writing, and therefore, the man-hours MSFC had estimated for this function were removed from their totals, i.e., the man-hours shown for the MSFC estimates of Level IV integration include installation and test and direct support, but they do not include test preparation (procedure writing, etc.). The MDAC and Cost Data Synthesis Method estimates were originally calculated based on Mode B integration, but for comparison with MSFC estimates, they are converted to Mode A (applying the 1.44 factor). Further, since the Cost Data Synthesis Method requires backing up a learning curve to obtain first unit costs, an 85% learning curve was used to obtain the values shown in Figure 5-11. The 85% learning curve selection is consistent with MSFC's learning curve preference.

As can be seen, the costs (manhour estimates) are comparable, with both the MDAC and Cost Data Synthesis Method being somewhat lower than the

Figure 5-10

28010

NET PROGRAM COST SAVINGS-COST SYNTHESIS METHOD

AVAILABILITY

- DEDICATED RACKS ARE USED FOR ASSIGNED EXPERIMENT AND MISSIONS ONLY.
- 16 DOUBLE RACKS REQUIRED, 9 SHARED AND 7 DEDICATED.
- 12 SINGLE RACKS ADEQUATE, 10 SHARED AND 2 DEDICATED.

COST

TOTAL COST REDUCTION BECAUSE OF DEDICATION IS:

RACK TYPE	SHARED RACKS		DEDICATED RACKS	
	BASELINE	COST	REQUIRED	COST
SINGLE	12	1,524,000	12	1,524,000
DOUBLE	14	2,156,000	16	2,464,000
		$3,680,000		$3,988,000

ADDED RACK COST
3,988,000
-3,680,000
$ 308,000

TOTAL COST REDUCTION =	$ REDUCED LEV IV	$1,229,600
	-$ ADDED RACKS	-308,000
		$ 921,600

Figure 5-11

25798A

COMPARISON OF ESTIMATES - LEVEL IV INTEGRATION MODE A COSTS (MANHOURS)

PAYLOAD	COST SYNTHESIS	MSFC	MDAC
AP-09-S	7180	4908	4044
AP-13-S	2530	4588	1750
APE-01	3600	5636	5391
APE-07	1220	4499	3370
ASE-01	-	3585	2190
EO-01-S	5450	4133	3706 *
EOE-01	2360	3350	2097
LS-13-S	3030	5197	3650
SPE-01	2250	3760	2696
SPE-80/85	3970	5862	8087
ST-31-S	2740	4112	4965
STE-10	690	4309	1572

NOTE: ESTIMATES ABOVE DO NOT INCLUDE PROCEDURE PREPARATION

* MSFC PAYLOAD DEVELOPER ESTIMATES WERE USED IN COST TRADE STUDIES.

MSFC estimates. The significant conclusion reached from this comparison was that cost savings will be amplified if the costs of Level IV integration of individual experiments is increased as shown by the MSFC estimates. This point is further explained in the sensitivity analysis discussed in Section 7.

5.3 OVERALL COMPARISONS

Comparisons between the MDAC approach to selecting candidate payload elements for dedication and the Cost Data Synthesis Method are shown in Figure 5-12. There is concurrence in selecting Cloud Physics, Life Science, European and U.S. Space Processing and Drop Dynamics as candidates. The Life Sciences Minilab was also selected by the synthesis method as a candidate for a dedicated rack because it is reflown four times. The MDAC method rejected this selection because, in discussions with the payload developers, it was found that this experiment would undergo significant modifications after each flight. This would require a complete Level IV integration activity to occur before each reflight; therefore, even though the experiment is reflown many times, Level IV integration costs cannot be reduced. The one single rack for Life Sciences was also rejected by the MDAC analysis for the same reason.

A cost comparison of Level IV integration first flight costs is shown for the MDAC selected payload elements in Figure 5-13. Even though the dollar values are not exact, as would be expected, they are close enough to indicate credibility.

The general conclusion reached by these comparisons is that the costs of Level IV integration and the selection of experiments for dedicated racks by the MDAC method is credible. There may be differences in specific values between estimating techniques or selection criteria, but overall there is good agreement among the techniques, particularly when considering the maturity of the input data and the diversity of the estimating techniques.

Figure 5-12 28011

COMPARISON OF SELECTED CANDIDATES

MDAC SELECTION METHOD	COST SYNTHESIS METHOD
1. EO-01-S CLOUD PHYSICS (DR)	1. EO-01-S CLOUD PHYSICS (DR)
2. LS-09-S LIFE SCIENCES (3 DRs)	2. LS-09-S LIFE SCIENCES (3 DRs + 1 SR)
3. SP-31-S SPACE PROCESSING-US (DR)	3. SP-31-S SPACE PROCESSING-US (DR)
4. SP-80/85 SPACE PROCESSING-ESA (DR)	4. SPE-80/85 SPACE PROCESSING (DR)
5. ST-31-S DROP DYNAMICS (SR)	5. ST-31-S DROP DYNAMICS (SR)
	6. LS-13-S MINILAB (DR)

TOTAL NUMBER OF RACKS SELECTED AS CANDIDATES FOR DEDICATION

MDAC SELECTION METHOD	COST SYNTHESIS METHOD
6 DOUBLE RACKS	7 DOUBLE RACKS
1 SINGLE RACK	2 SINGLE RACKS

NOTE: SEE TEXT FOR RATIONALE FOR ULTIMATE SELECTION OF CANDIDATES

Figure 5-13 28012

COMPARISON OF LEVEL IV COSTS SELECTED CANDIDATE PAYLOADS

PAYLOAD DESCRIPTION		*FIRST FLIGHT COSTS ($) MDAC METHOD	SYNTHESIS METHOD
EO-01-S	ATMOSPHERIC CLOUD PHYSICS LAB	183,700	135,300
LS-09-S	LIFE SCIENCES SPECIMEN HOLDING FAC	74,200**	85,800
SP-31-S	SPACE PROCESSING-US	132,600	98,700
SPE-80/85	SPACE PROCESSING-ESA	140,300	98,700
ST-31-S	DROP DYNAMICS (1 1/2 RACKS)	86,100	68,200

*MODE B INTEG WORK LOAD, POST-FLIGHT COSTS NOT INCLUDED
**AVERAGE OF THREE DOUBLE RACKS

PRECEDING PAGE BLANK NOT FILMED

Section 6
DEDICATION EFFECTS ON INVENTORY

Two more double racks must be added to the rack inventory in order to dedicate six double racks. This will make the total NASA buy ten double racks instead of eight. The current inventory of twelve single racks is sufficient to allow dedication of one single rack. Therefore, in order to dedicate six double racks and one single rack, all that is required is the purchase of two additional double racks.

This conclusion was obtained by investigating the availability of both single and double racks, assuming that the dedicated racks can only be assigned to specific experiments. Figure 6-1 shows the results of this investigation

28018

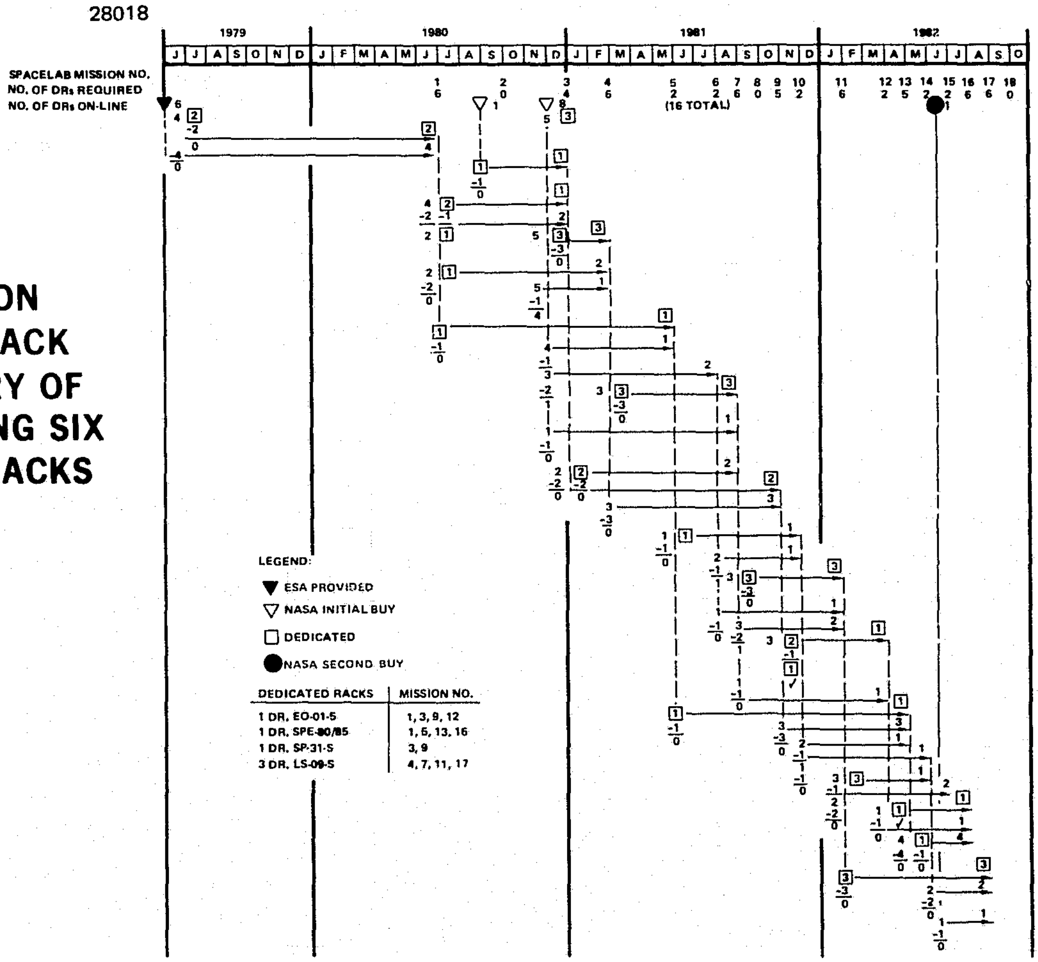


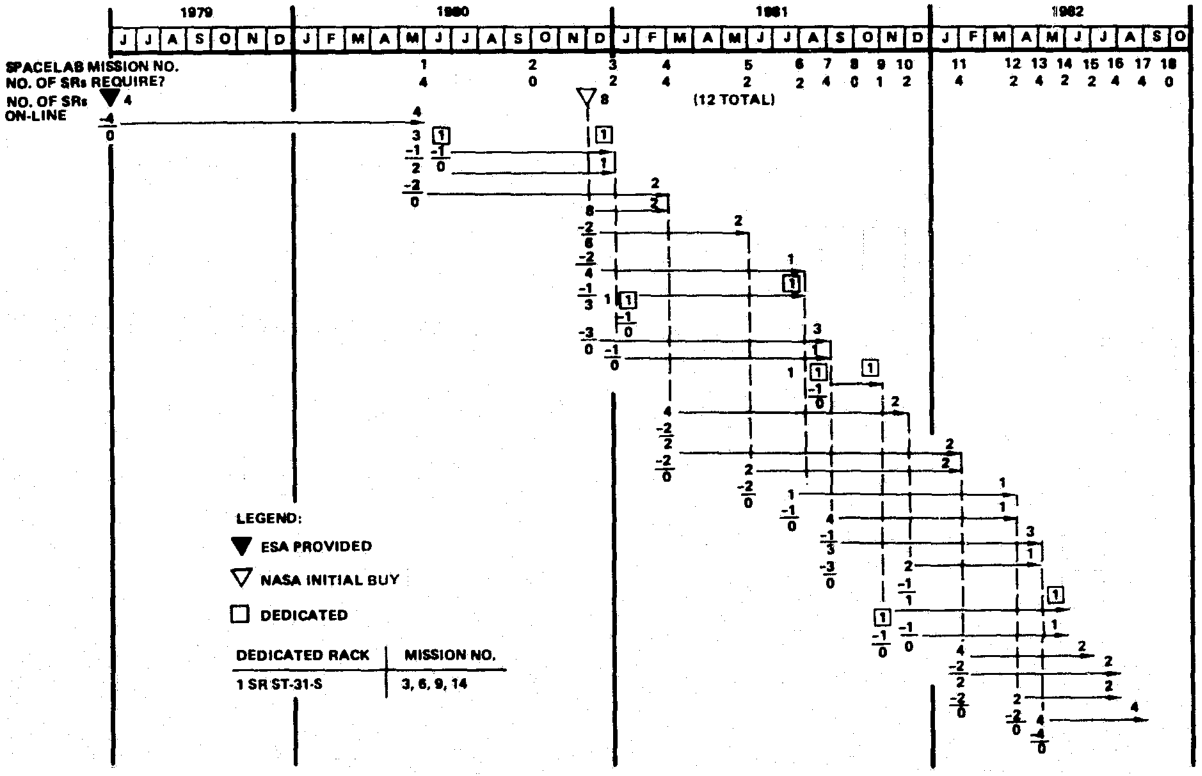
Figure 6-1
EFFECTS ON DOUBLE RACK INVENTORY OF DEDICATING SIX DOUBLE RACKS

for double racks. To provide two dedicated double racks (one for EO-01-S and one for SPE-80/85), two racks from the ESA-provided inventory must be assigned as dedicated racks. For SP-31-S, which is flown in Mission 3, an additional rack must be purchased and delivered such that its online date will be 1 September 1980. Three racks from the eight NASA initial buy inventory must be assigned to the Life Sciences payload elements in LS-09-S. Thus, in order to provide enough time to prepare a rack for Mission 17, another rack must be purchased. This rack can remain in the shared rack mode for it is not required to contain any particular payload.

The availability investigation of single racks is shown in Figure 6-2. To perform all the missions and provide a dedicated rack for payload element ST-31-S, a shared rack from Mission 1 must be converted to a dedicated rack after it has flown and been refurbished. This should not cause a problem or conflict, for there are seven months between Missions 1 and 3, which is more than adequate to perform all integration levels and operational

Figure 6-2 28019

EFFECT ON SINGLE RACK INVENTORY OF DEDICATING ONE SINGLE RACK



MCDONNELL DOUGLAS

requirements. A breakdown of functions and time requirements to prepare a rack for flight is shown below:

1.	Time required to perform a mission	=	7 days
2.	Rack removal from Spacelab	=	11 days
3.	Refurbish and prepare to ship	=	11 days
4.	Ship to Level IV site	=	2 days
5.	Level IV integration	=	64 days (Mode A)
6.	Ship to KSC	=	2 days
7.	Receive and inspect	=	2 days
8.	KSC operations	=	55 days
	Total		154 days

The total number of days shown to perform all required functions relates to the total complement of racks for Mission 3. Only one shared single rack from Mission 1 is required to be converted to dedicated use. Therefore, calculating the number of days required to get one single rack ready for dedicated use is determined by converting all racks into equivalent single racks and applying a ratio to the appropriate function shown above.

Equivalent single racks in Mission 3 = 10

Ratio = 1/10

Function ratio applies to (2, 3, 5, 8)

Total day for one single rack = (7+1+1+2+7+2+2+6) = 28 days.

Considering there are 22 working days in a month, the number of days available to convert one shared single rack into a dedicated use is 7 x 22 = 154 days. Therefore, there is more than enough time to allow a shared single rack to be converted to be used in Mission 3 and as a dedicated rack.

Section 7
PROGRAM EFFECTS, SAVINGS AND SENSITIVITY FACTORS

The concept of dedicating racks to the selected payload elements was evaluated to determine the combined effects on the overall program. This section summarizes the effects discussed previously, identifies the savings sensitivities to key factors involved in the estimates, and discusses additional advantages which were not included in the cost trades.

7.1 INDIVIDUAL PAYLOAD ELEMENTS

Payload elements can be considered individually, if desired, for purposes of assessing the program savings from rack dedication. If the cost savings from dedication for the expected number of flights approach or exceed the cost of the required rack(s), then it would be cost effective to purchase an additional rack(s) for that specific payload without considering the overall inventory effect. Such a condition exists for several of the cases studied. For example, the Atmospheric Cloud Physics payload in Mode B still has a net savings of $196,875 after purchasing a double rack for $154,000. The net savings for each candidate selected was derived for each integration Mode (A, B, and C) for the planned early STS missions, along with the required number of additional flights to permit savings to approach or exceed the cost of the dedicated rack(s). These data are summarized on Figure 7-1.

7.2 COMBINED EFFECT ON INVENTORY

Combined effect on inventory which was discussed in Section 6 is an important factor in overall program planning. As noted, the combined effect of rack dedications to the candidate payloads is to reduce the total demand for the remaining shared racks since the candidates were a part of the total demand in the baseline (all shared). The net effect is that six double racks from the baseline inventory can be dedicated to the selected candidates while generating a need for only two additional double rack purchases. The results of the rack usage analyses thus indicate a collective savings benefit which is substantial. Rack requirements are summarized on Figure 7-2.

Figure 7-1

28276

DEDICATION TRADES FOR INDIVIDUAL PAYLOADS

P/L's	RACKS DBL	RACKS SGL	PLANNED FLTS	SAVINGS AT $25/HR LABOR RATE — EARLY STS MISSIONS A	B	C	ADD'L FLTS REQD/SAVINGS A	B	C
ACPL	1		4	306,200	196,875	97,450	0	0	0
LS	3		4	35,300	-96,500	-156,350	0	1/-10,850 2/77,400	2/-13,025 3/55,975
SP-US	1		2	-37,175	-68,625	-104,425	1/50,100	1/-10,100 2/47,475	3/-13,550 4/13,075
SP-ESA	1		4	141,525	58,025	-36,975	0	0	1/-6,825 2/21,150
DROP DYN		1	4	6,900	-27,275	-57,175	0	1/-4,375 2/19,125	4/-7,625 5/6,125

NOTES: 1. SAVINGS EXPRESSED IN DOLLARS AND BASED ON OPTIMISTIC 80% LEARNING CURVE, DOUBLE RACK COST $154,000, SINGLE RACK COST $127,000, AND PURCHASING ADDITIONAL RACK FOR EACH DEDICATED RACK

2. NUMBER OF DEDICATED LIFE SCIENCE RACKS REQUIRED, AND THE NUMBER OF FLIGHTS FOR EACH, ARE NOT DEFINED. THE CASE SHOWN IS THOUGHT TO BE A PROBABLE MINIMUM. ACTUALS COULD BE MORE

Figure 7-2

28227

DEDICATION EFFECTS ON INVENTORY

OBSERVATIONS:

1) DETAILED SCHEDULE ANALYSIS WAS REQUIRED TO ASSESS INTERACTION
2) DEDICATION REDUCES TOTAL DEMAND FOR REMAINING UNDEDICATED HARDWARE
3) DEDICATION DOES NOT REQUIRE A RACK-FOR-RACK TRADE

RESULTS:	SINGLE RACKS	DOUBLE RACKS
BASELINE RQMTS (SHARED)	10	14
BASELINE INVENTORY PLANNED	12	14
DEDICATED INVENTORY RQMTS	11	16
ADDED RACKS REQUIRED	0	2
APPROX. COSTS	0	$308,000 ($154.000 EACH)

7.3 NET PROGRAM SAVINGS

Net program savings were calculated for the five candidate payloads for dedication, taking into account the operational manhour savings, the effects on total inventory, and rack purchase costs. The operational savings were calculated at $25/hour for each payload for each Level IV integration mode. The additional rack hardware costs were subtracted from the operational savings to obtain the net program savings. It should be noted that the Life Science payloads are still at a flexible point in their development and that exact flight complements and numbers of flights for given payload elements are unknown. The number of specimen-holding facilties (three) and their number of flights (four) were chosen as a study nominal because this was thought to be a probable minimum combination. Specimen-holding facilities were noted to be planned for both dedicated Life Sciences Missions as well as for Minilab applications on multiuser missions. The actual number of facilities deserving rack dedication and the number of flights for each could be higher than the selected study nominal.

The net program savings for each Level IV integration mode were calculated on the basis of the data, listed below, which is defined as the study nominal. See Figure 7-3 for a summary.

- Labor Rate - $25/hour
- Level IV Cost Reduction Learning Curve - 80%
- Level IV Schedule Reduction Learning Curve - 85%
- Double Rack Cost - $154,000
- Single Rack Cost - $127,000
- Allowance for Routine Contingencies - 30% (K_1 = 1.3)
- Allowance for Direct Support of Hands On - 150% (K_2 = 2.5)

7.4 SENSITIVITIES

Sensitivities to variations of the estimating factors listed above in the study nominal were examined for data to determine possible effects on overall study results. The data indicates that, in general, any trend which drives the cumulative cost of Level IV integration up or down will drive the potential program savings up or down, respectively. Rack cost is an inverse function, with an increase in cost driving net program savings down. The sensitivity of net program savings to other estimating factors is shown on Figure 7-4. These factors include labor rate, rack costs, learning curve and support/contingency factors. For the nominal estimates, a labor

Figure 7-3

28225

NET PROGRAM SAVINGS FROM DEDICATION

CURRENTLY PLANNED MISSIONS

PAYLOADS	RACKS DBL	RACKS SGL	FLTS	OPERATIONAL SAVINGS AT$25/HR MODE A	MODE B	MODE C
CLOUD PHYSICS	1		4	$460,200	$350,875	$251,450
LIFE SCIENCES	3		4	497,300	365,500	305,650
SPACE PROCESSING (US)	1		2	116,825	85,375	49,575
SPACE PROCESSING (ESA)	1		4	295,525	212,025	117,025
DROP DYNAMICS		1	4	133,900	99,725	69,825
OPERATIONAL SAVINGS				$1,503,750	$1,113,500	$793,525
-ADDITIONAL RACK COSTS				308,000	308,000	308,000
NET PROGRAM SAVINGS				$1,195,750	$805,500	$485,525

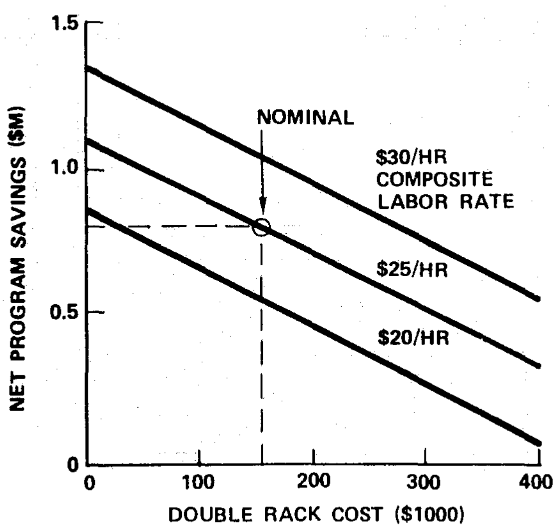
BASED ON:
1. LABOR RATE $25/HR
2. 80% LEARNING CURVE, INTEGRATION COSTS
3. 85% LEARNING CURVE, SCHEDULE DWELL TIME
4. DOUBLE RACK COST $154,000

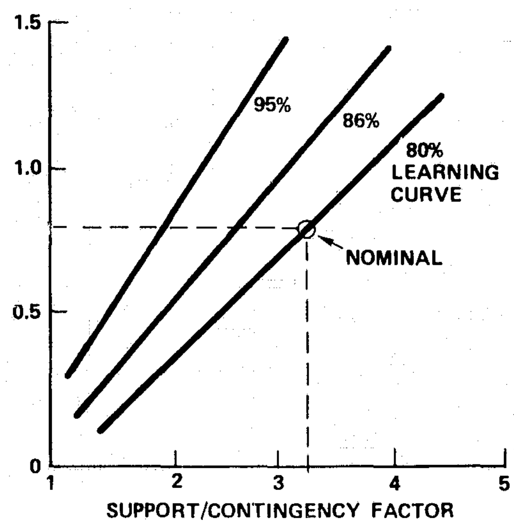
28231

Figure 7-4

SAVINGS SENSITIVITY TO ESTIMATING FACTORS

FACTOR	NOMINAL	TREND	SAVINGS
LEARNING CURVE	80%	INCREASE (SLOWER LEARNING)	INCREASE
SUPPORT FACTOR	3.25	INCREASE	INCREASE
RACK COST (DBL)	154,000	INCREASE	DECREASE
LABOR COST	$25/HR	INCREASE	INCREASE
LEVEL IV COSTS	–	INCREASE	INCREASE
NO. OF REFLIGHTS	–	INCREASE	INCREASE





rate of \$25/hour was assumed. If a lower rate (i.e., \$20/hour) is assumed, the net program savings decrease, however, the savings are still substantial (over \$0.5 million). Actually in the 1980's, higher labor rates are expected than the nominal, which would further increase program savings. Rack costs will also directly affect net program savings. As indicated on Figure 7-4, rack costs would have to increase substantially (more than triple) before net savings would be reduced to zero for the nominal case. Since the racks are fairly simple structural shells, lower rack costs than the nominal might be expected with follow-on buys, which further increases program savings. Also shown on Figure 7-4 is the affect of a support factor (150%) which was used to factor the initial estimate of hands-on Level IV integration hours to total direct hours which include other integration support activities such as technical support from laboratory technicians, design specialists, liaison engineers, shop skills specialists, etc. Management, administration, safety, and reporting activities which were not included in this factor were assumed to be covered by the standard labor rate (burden costs). Also included in the nominal support factor was a 30% allowance for contingencies. The resulting nominal factor of 3.25 is considered to be consistent with standard aerospace practices. As indicated on Figure 7-4, the net program savings from rack dedication are fairly sensitive to this factor because it has a direct bearing on the final manhour estimates. However, if the factor is reduced from 3.25 to 2.5, the net program savings still justify rack dedication. The sensitivity to the learning curve applied is also shown. In the nominal estimates fairly rapid learning (80%) was applied which is a fairly conservative estimate. Higher (slower) learning curves are probably more realistic, especially early in STS program operations. This has the effect of increasing the manhours saved and thus increasing net program savings. It has been concluded from all the sensitivity analyses that the estimates of net program savings by dedicating racks for certain payloads result in a conservatively low estimate of the savings possible. Greater savings than shown are expected.

7.5 OTHER ADVANTAGES

Other advantages, in addition to the potential cost savings from rack dedication, exist which favor rack dedication, as shown on Figure 7-5. Integration and turnaround time should be considerably reduced which should help achieve the high launch rates scheduled for the STS program, and provide the convenience of less lead time required for schedule decisions. There would be less payload and subsystem handling which should lessen the chances for payload damage. By avoiding payload removal, the activities associated with procedures, inspection, scheduling, and paperwork should be minimized which saves time and dollars. Consequently, the technical and operational confidence of a payload/rack combination should be improved, thus reducing program risks. Another possible advantage is that the payload developer can make certain internal modifications to his dedicated rack to augment payload interface without necessarily restoring the rack to its original configuration after each flight. The payload/rack combination is also available as an entity between missions to support special ground tests, evaluations, development, etc. It should also be noted that the rack is not irrevocably committed to a given payload and can be recalled for other applications at the end of a series of missions or if the program develops different priorities.

Figure 7-5

28226

ADDITIONAL ADVANTAGES OF RACK DEDICATION

- MINOR P/L-TO-RACK INTERFACE MODS CAN BE RESPONSIBILITY OF PAYLOAD DEVELOPER
- P/L IS AVAILABLE AS ENTITY FOR SPECIAL GROUND TESTS, EVALUATIONS, DEVELOPMENT
- AVOID EXPENSE OF PLANNING AND PROCEDURE MAINTENANCE FOR REMOVAL AND RE-INTEGRATION OF PAYLOAD/RACK.
- AVOID EXTRA PAYLOAD HANDLING & RELATED DAMAGE POTENTIAL
- CONVENIENCE OF LESS LEAD TIME REQUIRED FOR SCHEDULE DECISIONS.
- TECHNICAL & OPERATIONAL CONFIDENCE LEVELS HIGHER; LESS PROGRAM RISK
- RACK CAN BE RECALLED FOR SHARED USE IF PROGRAM DEVELOPS DIFFERENT PRIORITIES.

Section 8
SCHEDULE/INVENTORY TRADE

The investigation of rack and pallet availability performed and reported on in an earlier section indicates that the current inventory is adequate to perform all missions when all hardware is shared. When six double racks are dedicated, two more double racks must be added to the inventory to keep the launch schedule from slipping. Dedicating one single rack does not increase the inventory or slip the launch schedule. These analyses were done keeping the launch schedules intact and adding hardware items when required or in the case of pallets adjusting the delivery (online) schedule. These were specific studies to determine if the current inventory was adequate. To obtain a broader view of inventory and launch schedule interrelationships, other possibilities of schedule adjustments and hardware quantities were studied. Pallet inventory was deleted from this phase of the inventory/schedule study.

Figure 8-1 shows double rack inventory utilization options that were investigated. The findings and cost savings are summarized in the table and expanded upon below.

A. With the currently planned inventory of double racks (14), the launch schedule for the first 18 flights can be maintained and four double racks can be dedicated. One rack can be dedicated to the Atmospheric Cloud Physics Laboratory (ACPL), and three racks can be dedicated to the Life Sciences (LS) Specimen-Holding Facilities.

B. In order to dedicate five racks and keep the same inventory, Mission 17 must be rescheduled to 1 October 1982. This represents a one-month schedule slip. If this is done, one more rack can be added to the four mentioned in A. above and dedicated to the European Space Processing Experiment (SPE 80/85).

   Mission 18 does not have racks, therefore, it may not have to slip in series with Mission 17. There may be a conflict, however, with

Figure 8-1 29349

SCHEDULE VS INVENTORY OPTIONS - DOUBLE RACK

	INVENTORY	CONDITION/SCHEDULE IMPACT	NET SAVINGS* MODE B
A.	PLANNED INVENTORY	4 DEDICATED (ACPL, LS)/NO SCHEDULE SLIP	$ 716,400
B.	PLANNED INVENTORY	5 DEDICATED (ACPL, LS, SP-ESA)/ONE MONTH SCHEDULE SLIP OF MISSION #17, & 18	928,400
C.	ONE ADDITIONAL DR (ON LINE JUNE 1982)	5 DEDICATED (ACPL, LS, SP-ESA)/NO SCHEDULE SLIP	774,400
D.	PLANNED INVENTORY	6 DEDICATED/RESCHEDULE MISSIONS AS REQUIRED; MISSIONS #3, 6, 9, 16, 17 & 18 AFFECTED BY UP TO 6 MONTHS SLIP	1,013,800
E.	TWO ADDITIONAL DRs (ON LINE SEPT 1980 & JUNE 1982)	6 DEDICATED/NO SCHEDULE SLIP. (CURRENT DELIVERY DATES CAN BE RELAXED)	705,800
F.	PLANNED INVENTORY BUT ACCELERATE NASA BUY 3 TO 6 MONTHS	6 DEDICATED/MINOR SCHEDULE SLIPS FOR MISSIONS #16, 17, & 18	1,013,800

*POSSIBLE COSTS OF RESCHEDULING MISSIONS AND DELIVERIES NOT CONSIDERED

pallet integration between these two missions, and with launch facilities; therefore, Mission 18 may have to slip one month along with Mission 17.

C. Five racks can be dedicated without schedule slip if one more rack is added to the inventory. Do not dedicate one double rack to SP-31-S for Missions 3 and 9; consider it a shared rack. This allows the current NASA buy schedule to remain the same. One additional rack is needed in mid-June 1982. This can be obtained in a follow-on order if necessary.

D. To perform all missions with six dedicated double racks and the current inventory of 14 double racks (6 ESA provided and 8 NASA initial buy, online June 1979 and December 1980, respectively):

1. Payload element SP-31-S, US Space Processing, must be moved from Mission 3 to Mission 6. Mission 6 is the first available mission for this change. Mission 4 is a Life Sciences dedicated mission. Mission 5 uses a short Spacecraft module and does not have spare space, plus it has the European Space Processing payload element onboard. It is doubtful that another

space processing experiment should be introduced as a replacement for it or the experiment in the other double rack.

2. To make room for SP-31-S, on Mission 6, Payload Element Geophysical Fluid Flow must be moved to a later date. Mission 9 seems to be a logical candidate because it has a spare double rack. Mission 7 is dedicated to Life Sciences and Mission 8 is a pallet only mission.
3. Missions 16, 17, and 18 must be delayed one month each.

E. Dedicating six double racks (1 to SPE-80/85, 1 to EO-01-S, 1 to SP-31-S, and 3 to LS-09-S) and maintaining the launch schedule requires that two additional double racks be purchased. This is the recommended approach and the mode of operation that the cost analyses was based upon. One of the two racks is required online 1 September 1980 and will be used for SP-31-S. The other can be online as late as 15 June 1982 and can be assigned to the shared rack inventory.

F. Accelerating the initial NASA buy by three to six months will permit the planned 14 double racks to support all six dedications with only minor schedule impacts of approximately 1 month each for Missions 16, 17, and 18.

Figure 8-2 shows a summary of the additional trade studies performed for single rack inventory and schedule options. A discussion of each of these investigations follows:

A. The currently planned inventory of single racks is adequate to perform all missions and dedicate one single rack to Mission 3 for ST-31-S. This is the recommended approach to rack utilization. It is discussed in some detail in Section 6.

B. If for some reason a single rack used in Mission 1 cannot be converted to dedication usage, one rack from the NASA initial buy must be delivered early so that its online date is July 1980. No schedule slippage will occur and the early delivery date of the one single rack will provide adequate dwell time to integrate the payload element.

Figure 8-2

SCHEDULE VS INVENTORY OPTIONS - SINGLE RACK

	INVENTORY	CONDITION/SCHEDULE IMPACT	NET SAVINGS* MODE B
A.	PLANNED INVENTORY	1 DEDICATED DROP DYN/NO SCHEDULE SLIP DEDICATING THE RACK AFTER IT HAS BEEN USED ONE TIME AS A SHARED RACK FOR OTHER P/L'S	$ 99,700
B.	PLANNED INVENTORY BUT ACCELERATED DELIVERY OF 1 SR	1 DEDICATED/NO SCHEDULE SLIP. REQUESTING ONE RACK OF THE INITIAL BUY TO BE DELIVERED EARLY	99,700
C.	REDUCE NASA BUY TO 7	1 DEDICATED/NO SCHEDULE SLIP. DEDICATING THE RACK AFTER IT HAS BEEN USED ONE TIME AS A SHARED RACK	226,700
D.	REDUCE NASA BUY TO 6	1 DEDICATED/REQUIRES MISSIONS #17 & #18 SCHEDULE SLIP OF ONE MONTH, OR UNDEDICATING A RACK AFTER MISSION #14 IS COMPLETED. ALSO DEDICATING A RACK AFTER IT HAS BEEN USED ONE TIME AS A SHARED SHARED RACK	353,700

*POSSIBLE COSTS OF RESCHEDULING MISSIONS AND DELIVERIES NOT CONSIDERED

C. One single rack can be dedicated and the NASA initial buy can be reduced to seven instead of eight. No schedule slip will occur and a cost reduction can be realized.

D. Dedicating one single rack and reducing the NASA initial buy to six single racks will cause a dwell time problem for Level IV integration of one single rack in Mission 17. This situation can be rectified by slipping the launch dates of Missions 17 and 18 one month each. Another solution that would not require a schedule slip would be to reassign the dedicated rack after Mission 14 and use it as a shared rack in Mission 17.

Section 9
SUMMARY OF METHODOLOGY FOR DEDICATION

Optimizing methodology for rack and pallet utilization was developed for dedication cost trades. This methodology can be applied to Spacelab operations and payloads by inserting new data as it becomes available, thus providing an ongoing tool for use in the future.

Generally, if an experiment consumes a full rack and flies two or more times, it will be a candidate for obtaining a dedicated rack providing there are no technical nor operational considerations against it.

Selection Criteria

1. Determine the number of reflights of the experiment.
2. Determine if the experiment uses all or part of a rack, and what type (double or single) rack is required.
3. Determine if there are any technical or operational advantages in dedicating a rack or for not dedicating a rack.
4. Perform a cost analysis comparing the cost of Level IV integration for shared and dedicated modes of operation.
5. Determine the cost of double and single racks.
6. Determine if the cost saved by dedication is greater than the cost of a rack, or if the cumulative effect of dedication results in a net program savings. If either case prevails, the payload is a candidate for dedication.

Cost Comparison

To determine whether a rack should be dedicated or not on the basis of cost, a cost analysis must be performed that will show how much money or man-hours can be saved if a rack is dedicated to a particular payload element. Application of an analysis of this type can be reduced to an equation of the following form:

$$\Delta C = K_1 K_2 R \left[\Sigma_1^n (X_s + Y_s) - \Sigma_1^n (X_D + Y_D \lambda) \right], \text{ where}$$

ΔC = Difference in cost of Level IV integration and post-flight operations between shared and dedicated racks.

n = Number of experiment reflights

K_1 = Contingency Factor, 1.3

K_2 = Direct support factor, 2.5

X_S = Shared rack hands-on Level IV manhours

Y_S = Shared rack postflight KSC ops. manhours

R = Composite labor rate

X_D = Dedicated rack "hands-on" Level IV manhours

Y_S = Dedicated rack postflight KSC ops manhours

It should be noted that X_S, Y_S, Y_D, and Y_S are subjected to learning curve reductions based on the number of reflights. This is the reason for summing the costs as opposed to multiplying costs by the number of reflights.

As can be seen from the equation, the key terms are the cost of Level IV integration and postflight KSC operations. These will vary from payload element to payload element and be based on the complexity of the experiment. To obtain these values, a detailed description of the payload equipment and plans should be available for an estimator to derive costs.

It has been found in this study that credible costs can be estimated by scheduling the tasks that must be performed and estimating the appropriate manhours, or by the cost data synthesis method. Either method of cost estimating has given results that, although they did not match exactly when comparing dollar values, yielded similar selections of candidates for dedication.

If ΔC is equal to or greater than the cost of a rack, then that payload is clearly a candidate for rack dedication independent of other accumulative program advantages, effects, or savings. If ΔC is less than the cost of a rack, dedication may still be justified by a detailed analysis of the net cumulative effects on inventory, schedules, and costs. Such detailed analyses are warranted in either case.

Section 10
CONCLUSIONS AND RECOMMENDATIONS

This study represented an exploratory analysis based on limited available data and synthesized data to provide initial insight, methodology development, and, if possible, some preliminary approaches to optimize utilization of Spacelab racks and pallets. The study proved to be fruitful, with the objectives achieved within the limits of time and budget available. Valuable insight was gained in the interrelationships of many factors affecting rack and pallet use. The basic criteria and methodology were developed for selecting candidate payloads for dedication and for conducting the cost trades to verify the cost effectiveness of such dedication. In addition, preliminary recommendations were possible regarding inventory and dedication of racks to specific payload elements. The key findings, results, and conclusions are summarized on Figures 10-1 and 10-2, and are reviewed below.

Figure 10-1 28241

SUMMARY OF RESULTS
SPECIFIC

- DEVELOPED CRITERIA FOR SELECTING DEDICATION CANDIDATES
  - 2 OR MORE FLIGHTS
  - 100% RACK CONSUMED
  - TECH/OPNL ADVANTAGES EXIST
  - COST SAVINGS POSSIBLE
- IDENTIFIED CANDIDATE PAYLOADS FOR RACK DEDICATION
  - ATMOSPHERIC CLOUD PHYSICS LABORATORY (EO-01-S)
  - LIFE SCIENCE SPECIMEN-HOLDING FACILITIES (LS-09 & LS-13-S)
  - SPACE PROCESSING – US (SP-31-S)
  - SPACE PROCESSING – ESA (SPE-80/85)
  - DROP DYNAMICS (ST-31-S)
- DEDICATING 6 DOUBLE AND 1 SINGLE RACK(S) TO ABOVE SAVES $

• OPERATIONAL SAVINGS	$1,113,500
• ADDITIONAL RACK COSTS (2 DBL)	308,000
• NET SAVINGS (STUDY NOMINAL)	$ 805,500

Figure 10-2

SUMMARY OF RESULTS GENERAL

- CONFIRMED VALIDITY OF BASELINE INVENTORY PLANNING; HOWEVER MINOR DELIVERY ADJUSTMENTS MAY BE REQUIRED
- CONCLUDED THAT RACK DEDICATION IS COST EFFECTIVE
- IDENTIFIED 5 PAYLOAD CANDIDATES FOR RACK DEDICATION $805K SAVINGS POSSIBLE IN EARLY STS MISSIONS
- IDENTIFIED VIABLE OPTIONS FOR OPTIMIZING RACK USAGE
- CONCLUDED THAT PALLET DEDICATION IS NOT PRACTICAL
- DEVELOPED METHODOLOGY FOR ABOVE TO BE USED IN FUTURE
- CONCLUDED THAT DEDICATION DATA, ALTHOUGH PRELIMINARY, WILL PROBABLY REMAIN FIRM AS ADDITIONAL DEFINITION TAKES PLACE

A. Baseline flow options and dwell times were defined (see Section 3) in such a way as to permit application of study results to a wide range of possible program options (i. e., Level IV integration Modes A, B, and C).

B. Baseline inventory now planned was confirmed to be adequate to support baseline flow (all racks shared) in all option modes, with some reservation retained regarding the pallet delivery schedule in mid-1981 and the required turnaround time for the Atmospheric Cloud Physics Laboratory being accommodated in the schedule flow if forced to share its rack.

C. Dedication criteria were developed to use in identifying those payload elements which appear to be candidates for dedicated racks and which should undergo a more detailed analysis to determine the cost savings, if any, of such dedication (see Section 4).

D. Candidate payloads for dedicated racks were identified by use of the selection criteria and subjected to detailed cost-trade analysis. Preliminary resulting data indicate significant savings are possible from these dedications with the nominal study case indicating operational savings of $1, 113, 500 for Mode B. These candidates are listed below:

Racks	Flights	Payloads
1DR	4	Atmospheric Cloud Physics Lab
3DR	4	Life Science Specimen Holding Facilities
1DR	2	Space Processing (US)
1DR	4	Space Processing (ESA)
1SR	4	Drop Dynamics

E. Inventory required to support the flow resulting from the above dedications was determined. Only 2 additional double racks are required beyond the 14 needed to support the baseline shared flow. This would result in an expenditure of $308, 000.

F. Net program savings were determined by subtracting the cost of additional racks from the operational savings, yielding an $805, 500 savings for the Mode B study-nominal case. The range of net savings in all three modes was from approximately $0. 5 million to $1. 2 million.

G. No pallet dedications were indicated by the analysis since the cost of a single pallet segment is so high ($1. 79 million). Offsetting cost savings would not be expected to accumulate to this value based on the early STS missions payloads currently identified. It should be noted, however, that better payload definitions and mission plans in the future could lead to possible dedications by application of the methodology contained in this report.

H. Optimizing methodology for rack and pallet utilization was developed for dedication cost trades (see Sections 4 and 9). This methodology can be applied to Spacelab operations and payloads by inserting new data as it becomes available, thus providing an ongoing tool for use in the future.

I. Mission schedules effects on inventory requirements were evaluated by trial case methods to determine the relationships of mission schedule and sequence, intervals between missions, flow dwell times, and the missions requirements for racks and pallets. The resultant effects on inventory requirements of these relationships can only be determined by detail examination of given cases. In the study, this was done manually. An automatic approach could be considered for future applications. Several attractive options were identified, each one of which would provide net positive savings. See Section 8, Figures 8-1 and 8-2 for details.

J. Peripheral advantages of dedication were identified which included higher confidence levels, avoidance of extra payload handling and related risks, convenience of less lead time required to support STS schedules, and others as discussed in Section 7. Although some of these would be expected to have a dollar value which would be additive to savings, no attempt was made to include estimates of these, preferring instead to leave them as factors adding to conservatism in study results.

K. Conservative study results were obtained by leaning in the conservative direction at each point in the costing of shared vs dedicated flow in Section 4. Examination of the sensitivity factors discussed in Section 7 tends to support this conclusion since substantial margins exist for variations from the nominal case to occur before the net program savings would approach zero or become negative. Thus, the general trends in the study results are expected to survive the rigors of the future when better data on payloads, missions, and spacelab flow requirements are available.

L. Follow-up actions and studies, summarized on Figure 10-3, are recommended for the following areas of interest:

1. NASA should adopt the concept of rack dedication as a cost-effective program technique. In addition, the specific payload candidates identified by this study should be considered for dedication of racks. The actual decision to commit to the designated dedications can be deferred until actual hardware flow plans are being firmed up.
2. NASA should, in conjunction with 1, above, select from the various options discussed in Section 8, the necessary ingredients for an optimum plan for rack utilization.
3. NASA should resolve the apparent incompatibility in mission schedules and pallet deliveries by accelerating two of the NASA-buy pallets as indicated on Figure 10-3. An alternate approach would be to reschedule the missions to alleviate the conflict.

Figure 10-3 29347

RECOMMENDATIONS

DIRECT ACTION

- CONSIDER DEDICATION OF RACKS TO SELECTED PAYLOADS
- **SELECT AND IMPLEMENT OPTIONS FOR RACK USAGE**
- ACCELERATE DELIVERY OF TWO PALLETS IN MID 1981
  i.e., NASA BUY - THREE ON LINE JUNE 1, TWO ON AUGUST 1

FOLLOW-ON STUDIES

- APPLY/EXTEND THIS METHODOLOGY TO:
  - NEWLY OR BETTER DEFINED PAYLOADS
  - PAYLOADS BEYOND EARLY STS MISSIONS
- INVESTIGATE FEASIBILITY OF LOW-COST RACK CONFIGURATION
- CONDUCT ANALYSIS TO REGROUP/RESCHEDULE PAYLOADS TO OPTIMIZE TOTAL STS RESOURCES
- EVALUATE DEDICATION OF RACKS/PALLETS TO PAYLOAD DISCIPLINES

4. Low Cost Rack Configuration. A major portion of the expense for Level IV payload-to-rack integration was found to be in the handling, inspection, installation, and installation verifications of payload elements. Most such expenses may be avoided by providing (dedicating) the flight rack structural shell, less power distribution and CDMS components, as a holding fixture to maintain remaining interfaces. A detailed study could perhaps validate this theory and provide additional insight which could be helpful in planning Spacelab program operations.
5. Dedication of Racks and Pallets to Payload Groups or Disciplines. Many payload elements, considered by themselves, do not warrant dedication of racks or pallets. If it were possible to group, retain, and schedule mission — compatible payloads in a given rack(s) or pallet(s), then the savings of dedication for a series of missions could be realized. A variation on this concept would be to dedicate a rack or pallet to a given discipline if partial justification for dedication existed (e. g. , rack partially

consumed by payload flying several times and cost savings possible). The payload discipline could then be responsible for filling the rack with compatible payload equipment for each mission and for minimizing the disruption of interfaces with changing requirements. A detailed study could provide validation and/or data for the two areas discussed.

6. The methodology developed in this study should be applied as appropriate to new or better defined payloads as the Spacelab Program develops and as changes in the mission model occur. It is probable that additional candidates for rack dedication will be identified as more payloads or better defined payloads enter the planning processes.