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LIFE SCIENCES PAYLOAD DEFINITION AND INTEGRATION STUDY

VOLUME IV • APPENDIX, COSTS, AND DATA MANAGEMENT REQUIREMENTS OF THE DEDICATED 30-DAY LABORATORY

GENERAL DYNAMICS
Convair Division

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VOLUME IV • APPENDIX, COSTS, AND DATA MANAGEMENT REQUIREMENTS OF THE DEDICATED 30-DAY LABORATORY

August 1974

Submitted to
National Aeronautics and Space Administration
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

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FOREWORD

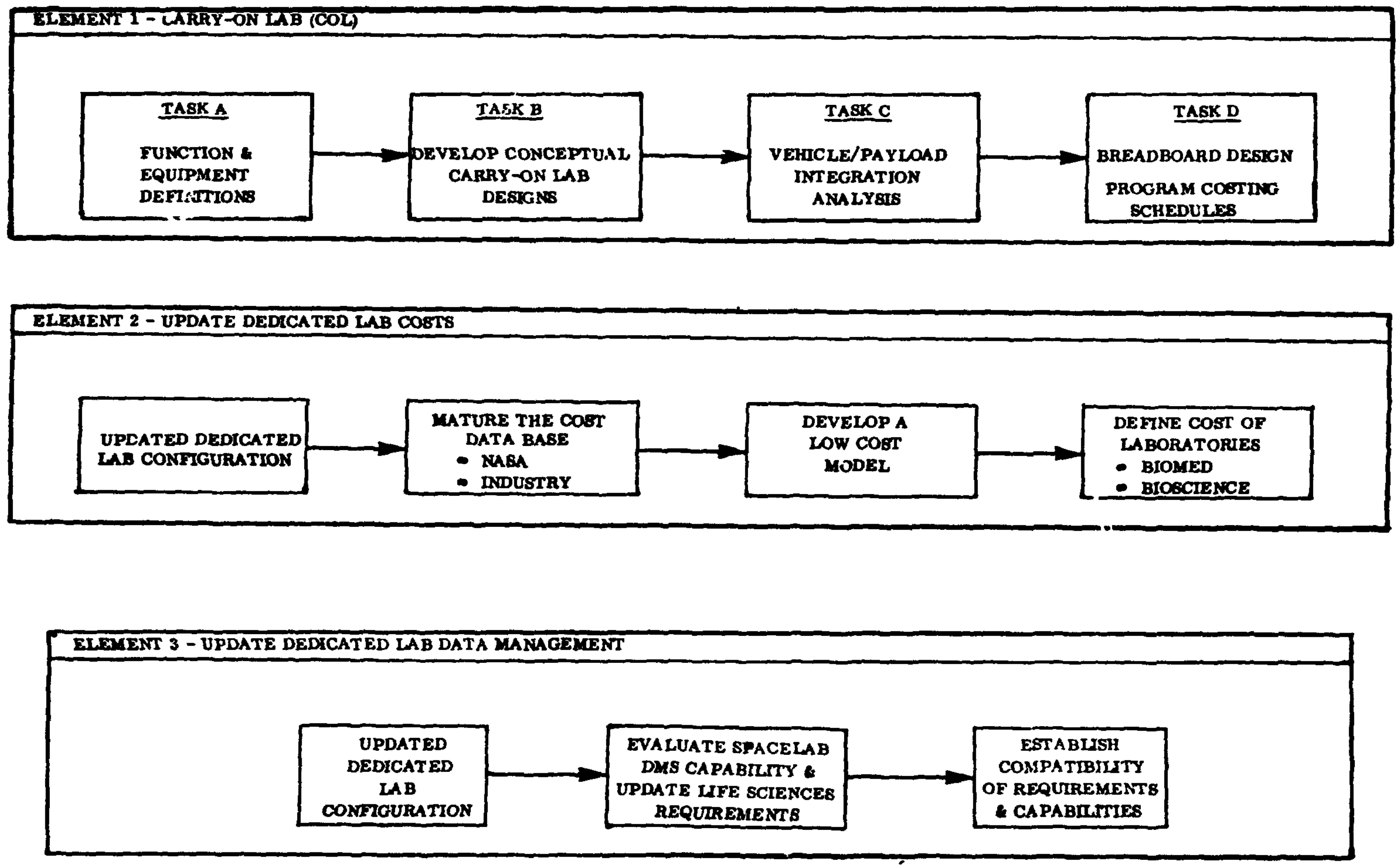
Recent NASA planning activity has been directed toward the definition of Life Science payloads for the Space Shuttle vehicle system. This study, the third in the series, was funded under NASA contract NAS8-30288. The two prior studies are summarized below.

1. Oct. 1970 - March 1972 — Life Sciences Payload Definition and Integration Study (Task A&B), Contract NAS8-26468. This contract established a comprehensive inventory of functional and equipment requirements to perform unlimited life sciences research in space. It also examined life sciences laboratory concepts of extensive capability which might be suitable for incorporation in large future space station complexes.

2. July 1972 - August 1973 — Life Sciences Payload Definition and Integration Study (Task C&D), Contract NAS8-29150. This contract utilized the research functions and equipment requirements established in the preceding contract. Laboratory concepts were more limited in scope than the preceding study and were intended to fit within the Shuttle/Sortie Module (Spacelab). The major life sciences laboratory concept resulting from this study was designated the 30-Day Dedicated Laboratory, which would completely fill the Sortie Module. Preliminary Carry-On Laboratory concepts were also investigated.

The present study contained three separate work element tasks as shown in the following figure. The first delt with Carry-On Laboratory design concepts as reported in Volume II. The second and third dealt with updating the cost and data management studies performed on the previous contract, NAS8-29150. The results of the second and third task elements are presented in Part I and Part II, respectively, of this volume.

NAS8-30288 TASK ELEMENT OVERVIEW



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PART II

PART I

UPDATE OF THE DEDICATED 30-DAY LIFE SCIENCES LABORATORY COSTS

SECTION 1

INTRODUCTION

This study was performed as an adjunct to the costing study accomplished during Task C&D of Contract NAS8-29150. The initial reporting was presented in report CASD-NAS73-003, Volume II dated August 1973.

1.1 SUMMARY

This report documents the results of the updated 30-Day Life Sciences Dedicated Laboratory scheduling and costing activities. It includes a discussion of the "Low Cost" methodology used to establish individual equipment item costs. This approach allows the consideration of equipment that is commercial off-the-shelf, modified commercial, laboratory prototypes, etc., which significantly lower the program costs. The costs generated include estimates for the non-recurring development, recurring production, and recurring operations costs. It should be noted that these estimates do not include such major elements as the space shuttle vehicle, the SPACELAB, or Principal Investigator costs.

A cost for a Biomedical Emphasis Laboratory and a Δ cost to provide a Bioscience and Technology Laboratory were generated. The costs reported are commensurate with the design and schedule definition available, with the understanding that the estimates are for budgetary and planning purposes.

Table 1-1 is a summary of the laboratory costs generated, in 1974 dollars.

TABLE 1-1. LABORATORY COST SUMMARY (K$)

	Non-Recurring Development	Recurring Production	Recurring Operations	Total
Biomedical Emphasis	19,137	2,809	35,425	57,371
Bioscience and Technology Laboratory Cost Δ	2,318	358	3,416	6,092

The basic cost element for the overall Dedicated Laboratory costs is the equipment unit (EU) costs. These costs are summarized in Table 4-1. Composition of EU costs includes individual equipment item costs plus the wraparound cost factors which are detailed in Section 6 of this part.

As a result of cost studies performed on the Dedicated Laboratories, certain programmatic and technical factors became apparent. The more significant factors are:

1. The laboratory development schedule required to support an August 1980 mission is extremely tight and contains no contingency time.
2. Certain SRT areas require that the Phase A/B program activity begin in January 1975 and that the Phase C&D begin by mid-1976. This would provide SRT equipment items to the principal investigators for baseline experiments prior to the space mission.
3. The confidence level for the majority of equipment item cost estimates ranges from medium-high to medium. This means that cost estimates at the equipment level would be subject to change when requirements changed or equipment definition become more detailed.
4. The major contribution to program costs, approximately 60 percent, is the recurring operations during the 12-year program.
5. The wraparound cost factors such as system test, system engineering and integration, M&A, fee, and initial spares, are based on historical data where available and estimated allowances in the other cases. These factors could vary considerably depending on the guidelines used. Cost based on these factors amounted to about 9 percent of the total Dedicated Laboratory cost esti[illegible].
6. The use of available Skylab equipment can be very effect[illegible] the Life Science missions. Caution, however, should be exercised with r[illegible] to its availability to support a 12-year program.
7. Cost reduction guidelines are needed to control future program costs. Design-to-cost approaches with performance goals and thresholds should be established for hardware development. Other cost reductions can be achieved by minimizing changes in design criteria, relaxing reliability requirements, and reducing test requirements.

SECTION 2

LABORATORY DEVELOPMENT SCHEDULES

Dedicated laboratory development schedules were generated for the Biomedical Emphasis Mission only The Bioscience and Advanced Technology Laboratory schedule can be accommodated without any impacts, based upon the present level of definition.

The development is paced initially by the first flight date of August 1980 (Reference 1). Subsequently, the development schedule is paced by the development of each equipment item (EI). Two classes of EIs were identified. These are Supporting Research and Technology (SRT) items and all other EIs.

2.1 SRT EQUIPMENT ITEMS

The SRT items exhibit the highest development risk and some, like the common holding unit and its inserts, require extensive evaluation in the Principal Investigator's (PIs) laboratory. The initiation of SRT Phase C&D is required approximately 1½ years before the other equipment items. To accomplish this within the available time span, the SRT Phase B must be initiated before the end of the Phase A study for the total dedicated laboratory. Following is a list of SRT items with their indicated development time.

Common Holding Unit, Inserts and Camera Drive System (EI 99, 98A, 30A & 38A)	30 Months
Freezers and Refrigerators (EI 77B, 81 & 83)	24 Months
Monkey Cages (EI 28A)	30 Months
Centrifuge (EI 43)	30 Months
Environmental Control System	30 Months

2.2 NON-SRT EQUIPMENT ITEMS

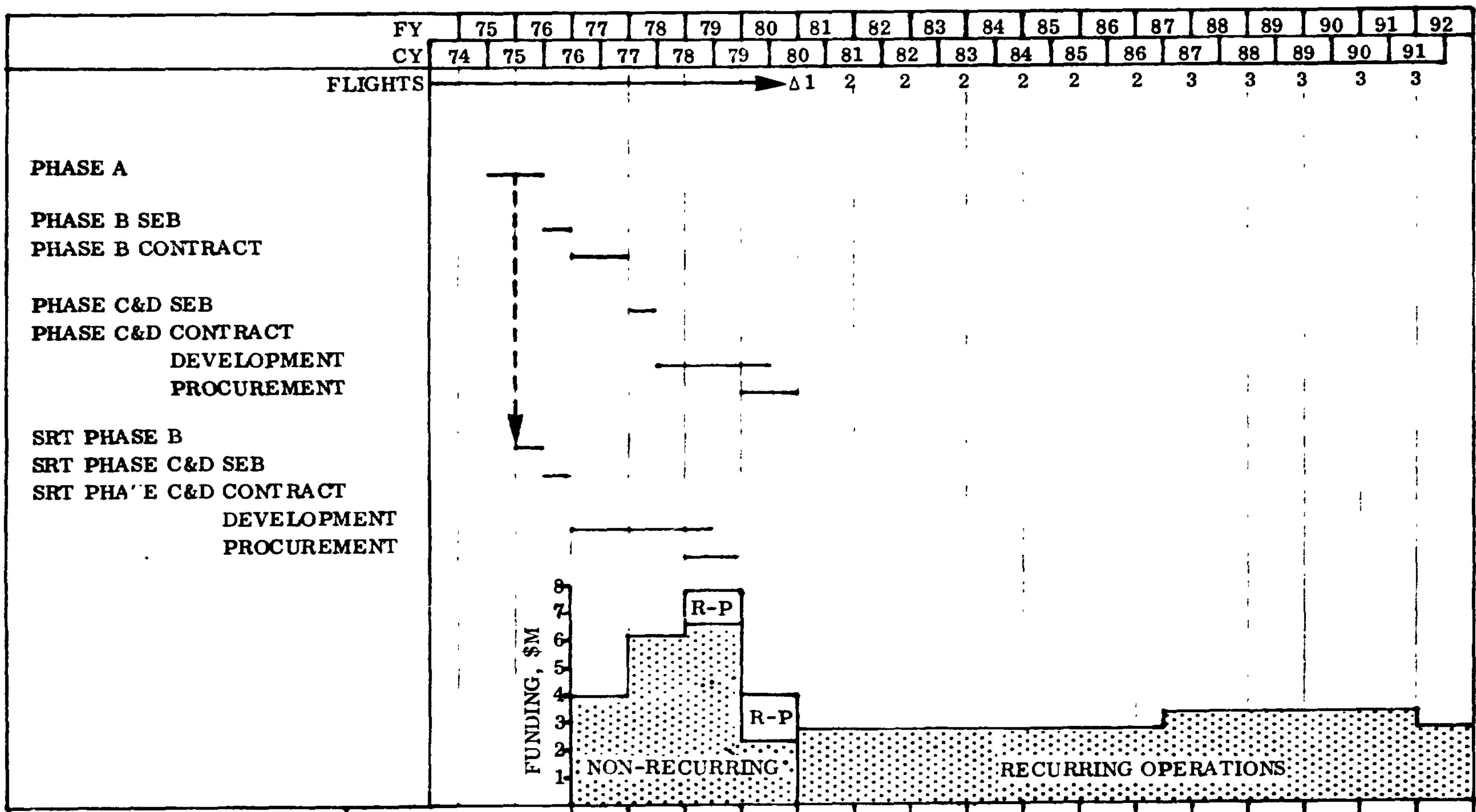
The other class of equipment items represents all those not in the SRT category. The development time of each equipment unit (EU) was estimated based on its longest EI development time. The total Phase C&D development time span is two years. Figure 2-1 shows the development time spans of the different EUs. The procurement

DEVELOPMENT TIMES			
6 MONTHS	12 MONTHS	18 MONTHS	24 MONTHS
EU-1	EU-3	EU-2	EU-4
EU-6/7	EU-40/41/42	EU-80	EU-5
EU-60/61	EU-50/51/70		EU-26
EU-23	EU-91/93		EU-12/31

Figure 2-1. EU Development Time Span
(Assumes 1 January 1978 Start)

phase is initiated six months before the completion of the development phase for all non-SRT items. This is required to permit checkout and installation time for the laboratory. A minimum risk is anticipated by initiating procurement prior to completion of the development phase since the last development tasks represent EU and Life Sciences Lab System Tests. The amount of changes which would impact production is expected to be at a minimum during this phase of development.

Figure 2-2 shows the Biomedical Laboratory schedule, including the funding spread which is discussed in Par. 3.3.2.



NON-REC. K$	3933	6203	6697	2303												Σ = 19136
REC.-PROD. K$	0	0	1121	1688												Σ = 2809
REC.-OPER. K$					2818	2818	2818	2818	2818	2818	2818	3219	3219	3219	3219	2818 = 35420

Figure 2-2. Dedicated Biomedical Emphasis Lab Schedule & Funding.

SECTION 3

COST ANALYSIS

An overview of the cost analysis approach is shown in Figure 3-1. Guidelines reflecting the NASA low cost philosophy as described in References 2, 3 and 4 were used to develop the program cost elements. The basic costing methodology was developed for both the large Dedicated Life Sciences Laboratory and the COL. A description of this costing methodology is detailed in Par. 3.2.

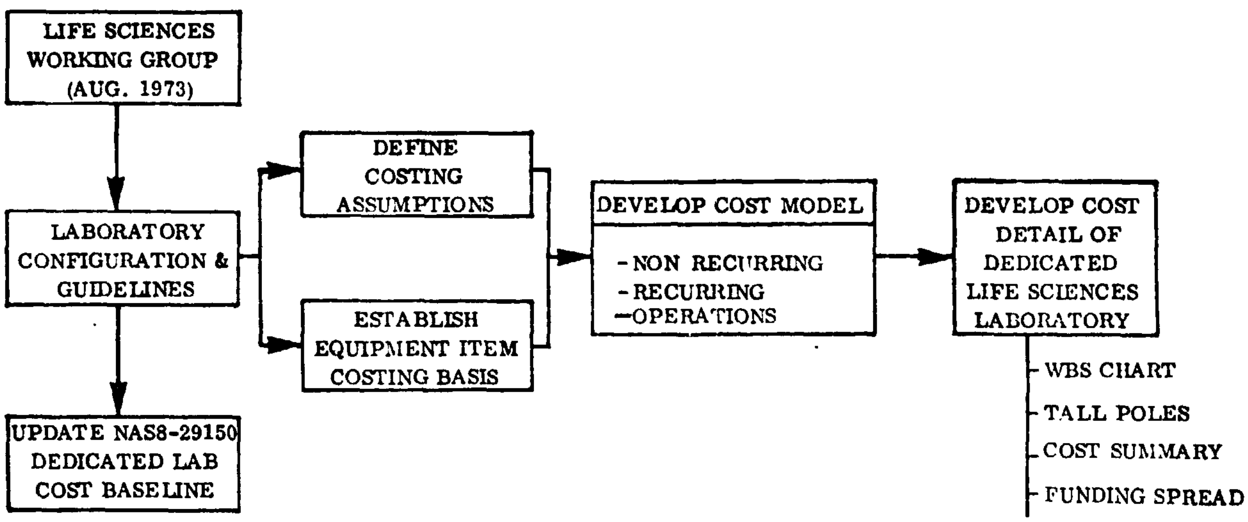


Figure 3-1. Costing Activity Overview.

3.1 COST ANALYSIS GROUND RULES AND ASSUMPTIONS

The following is a list of the general ground rules used in the cost estimating.

1. Costs are estimated in 1974 dollars and reported by government fiscal year.

2. Only phase C&D and recurring operations are costed.

3. GFE - non-recurring costs are excluded. (These costs, however, are utilized as inputs for cost elements estimated on the basis of hardware costs, etc.).

4. Supporting Research and Technology Items (SRT) are included in the costs.

5. All equipment items were included under prime development category because subcontract items have not been identified at this time.

6. All G&A and other overheads except Management and Administration are included in each of the equipment item cost elements.

7. The cost methodology selected provides costs commensurate with early payload definition information. The cost estimates are for preliminary budgetary and planning purposes.

8. No equipment items were costed for the EU Systems Test (WBS Level 3). It was assumed that test specimens from individual qualification tests are available. For the L/S Laboratory System Test (WBS Level 2), 50 percent of the required hardware is assumed available from EU Level Systems Test programs and refurbishment costs (10 percent) for these items is included in the EU Level, System Test Costs. Costs for the remaining 50 percent of thehardware are included in the L/S Laboratory Systems Test.

9. A 25 percent factor was added to vendor purchased unit costs to account for prime contractor off-site procurement inspection, receiving inspection, and general and administrative costs.

10. For certain commercial equipment which requires minimum modification, development units were not included and any development tasks required are accomplished on the production unit.

11. A 28 flight, 12 year operational program was assumed.

The cost estimates based upon these ground rules are further defined by the summary of included and excluded items shown in Table 3-1.

3.2 COST METHODOLOGY AND RATIONALE. A cost model using a work breakdown structure (WBS), including categories of hardware, services and other cost tasks, was developed for the Dedicated 30-Day Lab. The WBS, including Levels 1, 2, and 3, is shown in Table 3-2.

3.2.1 COST MODEL. The model includes a set of individual equipment item cost estimating relationships (CERs), cost factors or point estimates. In addition, the model established a mathematical procedure for the proper accumulation of the

TABLE 3-1. SUMMARY OF COST ELEMENTS

INCLUDED ITEMS	EXCLUDED ITEMS
NON-RECURRING DEVELOPMENT - DESIGN & DEVELOPMENT - QUALITY ASSURANCE & RELIABILITY - SYSTEM ENGINEERING - MISSION ANALYSIS - EU SYSTEMS TEST - L/S LAB SYSTEMS TEST - INTEGRATION - GSE - INITIAL SPARES RECURRING PRODUCTION - MANUFACTURE - QUALITY CONTROL - ACCEPTANCE TEST - SUSTAINING ENGINEERING RECURRING OPERATIONS - CONSUMPTION SPARES - REFURBISHMENT - LAUNCH OPERATIONS - MISSION OPERATIONS GENERAL AND ADMINISTRATIVE MANAGEMENT & ADMINISTRATION FEE	NASA INTERNAL MANAGEMENT PRINCIPAL INVESTIGATOR SUPPORT EXPERIMENT SPECIFIC EQUIPMENT GROUND-BASED LAB ARTICLES FOR CONTROL EXPERIMENTS TRAINING ARTICLES BACKUP LABS GROUND MOCKUP DEDICATED SPACELAB COST SPACE SHUTTLE "USER CHARGES" PHASE A & B COSTS FLIGHT CREW COSTS GROWTH OR CONTINGENCY COSTS FACILITIES COSTS

individual elements together with the overall program or mission factors (where defined) such as operational lifetime, number of launches, etc. The model was used to organize the procedures for determining all of the individual cost "pieces" making up the total Dedicated 30-Day Lab program costs.

The model derived an equipment unit hardware cost. This cost was then employed where necessary during the derivation of non-recurring (development) and recurring (production and operational) costs. These were then accumulated to provide the required total program cost. A discussion of the individual equipment cost methodology and the application of the different item factors and their application follows.

TABLE 3-2

LIFE SCIENCES 30-DAY DEDICATED LABORATORY

COST WORK BREAKDOWN STRUCTURE

	NR	R-P	R-O
LEVEL 1 - LABORATORY PROJECT			
Laboratory Hardware	x	x	x
Spacelab		x	x
Integration			
Life Sciences Lab to Spacelab	x		x
Spacelab to Shuttle	x	x	x
LEVEL 2 - LABORATORY HARDWARE			
EU-1 (see Level 3)	x	x	
EU-2 (see Level 3)	x	x	
EU-N (see Level 3)	x	x	
ECS	x	x	
* SPARES			
Initial Spares	x		
Consumption Spares			x
*LAB SYSTEM TEST			
Engineering Test Operations	x		
Test Hardware	x		
*SYSTEM ENGR'G/SYSTEM INTEG			
EU - EU	x		
Man-EU	x		
*FLIGHT OPERATIONS			
Launch Operations			x
Mission Operations			x
Refurbishment			x
MGMT & ADMIN (ITEMS ONLY)	x	x	x
FEE (*ITEMS ONLY)	x	x	x
PI SUPPORT	x	x	x
NASA INTERNAL MGT SYSTEM (IMS)	x	x	x

TABLE 3-2 (Cont'd)

	NR	R-P	R-O
LEVEL 3 - EU HARDWARE			
EI-1	x	x	
EI-2	x	x	
⋮			
EI-n	x	x	
Structure/Mechanical	x	x	
Electrical Power	x	x	
Data Handling	x	x	
Cabling	x	x	
SYSTEMS TEST			
Hardware	x		
Operations	x		
Refurbishment	x		
SYSTEMS ENGR'G & INTEGRATION	x		
GSE	x		
MGMT & ADMIN	x	x	
FEE	x	x	

The cost methodology for the individual equipment items was tailored to obtain the highest confidence cost estimate with the information available. Table 3-3 shows the six methods of costing used and the percentage of the items included under each category.

TABLE 3-3. LABORATORY COST ESTIMATING TECHNIQUES

PERCENT OF ITEMS	COSTING METHODS
36	BASED ON SSPDA DEVELOPED CER'S
23	BASED ON UNOFFICIAL NASA SKYLAB COSTS
18	BASED ON VENDOR CATALOG OR TELECON QUOTES
8	BASED ON ENGINEERING ESTIMATES
9	BASED ON UNOFFICIAL NASA COST DATA FOR PROGRAMS OTHER THAN SKYLAB
6	BASED ON DESIGN MANLOADING & PARAMETRIC ANALYSIS

A significant portion (36 percent) of the items were costed using Space Shuttle Payload Development Activity (SSPDA) (Reference 5) developed cost estimating relationships for "low cost" SPACELAB payloads. A typical example of a cost data backup sheet is shown in Figure 3-2.

The SSPDA CERs were generated for general types of experiment equipment. These CERs were further refined with complexity factors for all of the equipment items. The sources for the CERs include historical data, mission equipment studies, vendor contact, commercial catalogs, and in-house experiment programs. The amount of applicable historical data was sparse. As a result, a wide variety of cost data was collected from manned and unmanned spacecraft programs, aircraft and balloon programs, and commercial laboratory equipment to augment the data base. The data was displayed on a cost versus weight graph and technological families identified. Log-linear CERs were then derived using standard curve fitting techniques with weight as the driving parameter. Figure 3-2 includes typical CER equations developed for mechanical devices and electrical components. SSPDA CERs were used to estimate costs where no higher confidence method was available. In some cases, SSPDA CER costs were reduced to account for savings expected because existing commercial equipment can be modified to meet the requirements.

The second highest percentage of items was estimated based on unofficial Skylab cost information. The data was obtained by contacting cognizant technical and management personnel at NASA. The majority of the items included were kits whose costs were estimated based on Skylab experience with the Inflight Medical Support System Kit development.

INFRARED GAS ANALYZER

Contact: Lou Shaver, Infrared Industries, Inc., Santa Barbara, CA 805/684-4181

Development Cost

Total Unit Weight = 25#
65% of Weight = 16.3#
SSPDA CER 42d Mechanical/Mechanism - Low Complexity

$* \; C_D = K_D \times 19.68 \times W^{.5}$

$C_D = (.232)\,(19.68)\,(16.3)^{.5} = \$18.4K.$

35% of Weight is Electrical - Nom Complexity - 8.7#
SSPDA CER 21m

$* \; C_D = K_D \times 51.8 \; W^{.5}$

$C_D = (1)\,(51.8)\,(8.7)^{.5} = \$153K$

∴ Total Development = \$171.2K × 1.06 (1974 \$) = \$181.5K

Commercial equipment is available and developed. Vendor contacts and engineering analysis indicates ~ 1/3 of new development cost required for space rating.

∴ $C_D = \$61K.$

Unit Cost

Commercial unit cost - IR Industries Series 700 ~ \$2K.
Eng. Estimate & Vendor Contact $C_u = \$10K$ (5× commercial).

Confidence Level - Medium High

*These equations for development cost are of the form:

$$C_D = K_D \times A\,(W)^B$$

where:

C_D = development cost   A = log linear equation coefficient
K_D = complexity factor   W = independent parameter (weight)
B = log linear equation exponential power

Figure 3-2. Backup Example - CER Costed Item.

Other costing methodology involved obtaining vendor catalog costs and vendor telecon quotes for commercial modified equipment. The remaining equipment item costs (23 percent) were based upon engineering estimates, NASA cost data other than Skylab, and design manloading and parametric analysis.

3.2.2 COST ANALYSIS FLOW CHART. Figure 3-3 shows the Cost Analysis Flow Chart which traces the cost buildup through WBS Level 3, 2 and 1. A discussion of the application of the different cost factors and their rationale follows.

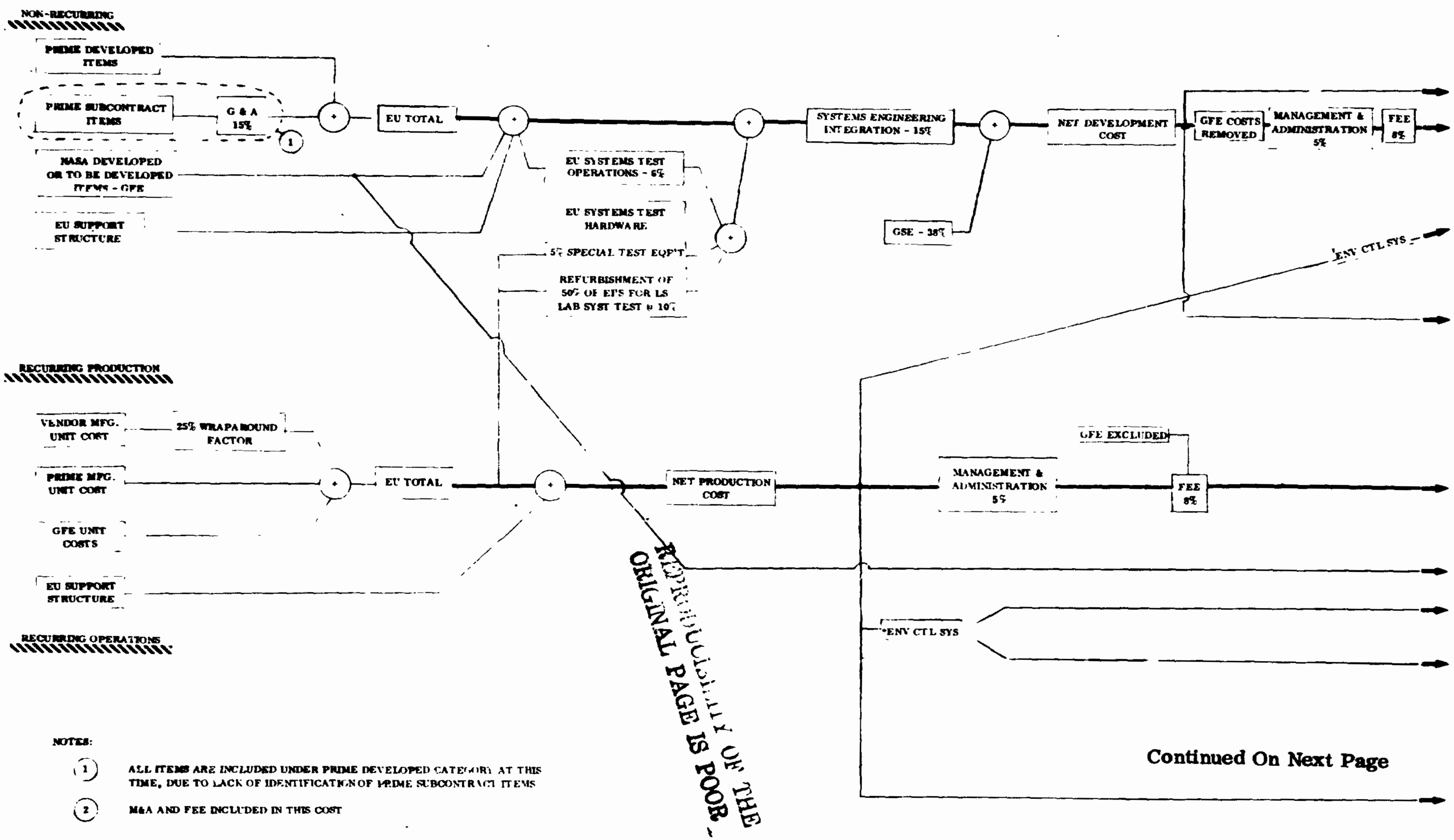
Test Operations: The EU systems test operations cost is estimated at 6 percent of the total non-recurring cost (including estimated GFE development costs). This includes all test hardware, test operations, and test support at the system level but excludes development or qualification tests of individual equipment items and test facilities. The study results from the RAM study (Reference 6) were 6.8 percent and the Large Space Telescope Phase A study were 6.5 percent (Reference 7). From these results, a slightly lower factor of 6 percent was selected for a low cost approach. For the L/S Lab System Test (WBS Level 2), test operations cost is estimated at 3 percent of the total non-recurring cost (WBS Level 3).

Special Test Equipment & Test Equipment Refurbishment: The special test equipment (5 percent) and refurbishment (10 percent) percentages were selected based on engineering esdimates because no directly applicable historical data existed. The refurbishment is required to permit the use of 50 percent of the equipment in the L/S Lab Systems Test (WBS Level 2).

Management & Administration: Project Management and Administration includes all tasks associated with planning, organizing, directing and controlling the development, production and operations of the laboratory. A 5 percent allowance is used for this cost element and is typical of many NASA programs. (In the Centaur NAS3-3232 contract, program management was 5.37 percent.)

Systems Engineering and Integration: Systems Engineering and Integration includes system analysis performance and operational requirements, interface requirements, design and control, system effectiveness analysis (reliability, QA, maintainability, human factors, safety, value engineering, etc.), integration requirements, test and checkout philosophies, specification maintenance, design reviews, technical performance measurements and special studies. A total of 15 percent of non-recurring was used for EI to EI integration within an EU at WBS Level 3. At WBS Level 2, 5 percent of non-recurring was used for each of the EU to EU and Man to EU integration tasks. At WBS Level 1, 5 percent was used to account for L/S Laboratory to SPACELAB payload integration tasks. The total integration percentage used is 30 percent. Centaur data, although not directly applicable, shows 21 percent and other study data shows up to 32 percent.

Ground Support Equipment: The GSE cost element includes all of the engineering design and development, test and evaluation, and manufacture of all equipment required to support the lab. This category includes handling and transport, servicing, maintenance and auxiliary equipment. Little or no historical data is available which is applicable to payload equipment of the type under consideration. Accordingly, the



NOTES:

1. ALL ITEMS ARE INCLUDED UNDER PRIME DEVELOPED CATEGORY AT THIS TIME, DUE TO LACK OF IDENTIFICATION OF PRIME SUBCONTRACT ITEMS
2. M&A AND FEE INCLUDED IN THIS COST

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Figure 3-3. Cost Analysis Flow Chart.

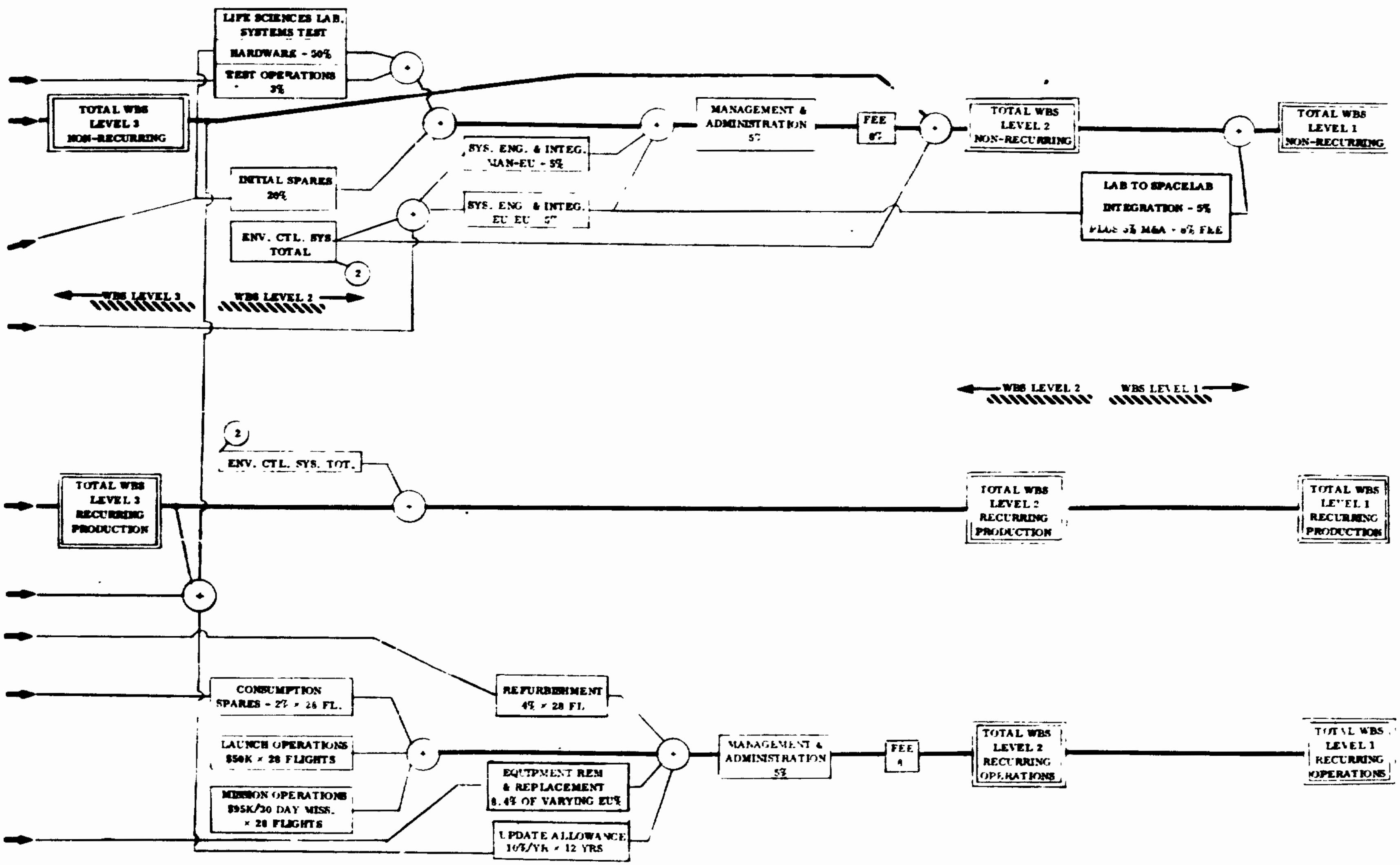


Figure 3-3. Cost Analysis Flow Chart (Cont'd).

results of the SSPDA studies which selected an austere allowance of 38 percent of recurring production costs were used.

Spares: Initial spares cost based on 20 percent of recurring production and consumption spares is calculated at 2 percent recurring production cost per flight. Little or no historical data is available for specific Shuttle/SPACELAB payload applications. Studies have shown a spares requirement of from less than 1 percent to numbers approaching 10 percent per flight for the Apollo program. SSPDA cost analysis used a 5 percent consumption spares allowance without any allocation for initial spares. Accordingly, the values have been selected as an allowance pending a detailed sparing study.

Equipment Removal and Replacement: This cost element only includes equipment removal, equipment reinstallation and compatibility verification. All other costs are included under refurbishment. An estimate of the percentage of each EU equipment subject to removal after each flight is shown in Table 3-4; 8.4 percent of the recurring unit cost of the equipment removed is used. This is based on the results of an analysis performed for the RAM Study (Reference 6).

TABLE 3-4

EU EQUIPMENT REMOVAL & REINSTALLATION PERCENTAGES

EU 1	25%	EU 26	5%
EU 2	40%	EU 12/31	35%
EU 3	40%	EU 40/41/42	35%
EU4	40%	EU 50/51/70	20%
EU 5	40%	EU 60/61	5%
EU 6/7	10%	EU 80/91/93	40%
EU 23	5%	ECS	25%

Refurbishment: Equipment refurbishment includes all labor and support for post-flight cleanup, maintenance and refurbishment. This includes scheduled maintenance, failure diagnosis and repair, equipment storage, equipment replacement and reassembly, and functional checkout and calibration. Not included is equipment removal and replacement, which is treated as a separate cost element.

The costs were calculated as 4 percent of recurring production per flight. This included 2 percent for refurbishment and 2 percent for functional checkout and calibration. No directly applicable historical precedent exists for the type of mission operations envisioned in the Shuttle/SPACELAB era. Accordingly, the values used are based on study results derived from manloading of similar type study vehicles.

Update Allowance: An update allowance of 10 percent of recurring production plus non-recurring development cost was used for each year of the flight program. This cost element includes all sustaining engineering effort to perform modification and procurement of existing equipment, and the development and acquisition of new and undefined equipment.

Launch Operations Support: This cost element includes all supporting activities directly related to the payload itself between the time of the completion of the payload integration task (including all integration test and checkout and the flight readiness certification) and the time of orbit attainment. It includes transportation to the launch site, onboard fluids and gases (expendables), launch operations, GSE maintenance, and all support (labor) during this period including loading into the shuttle, launch preparations and launch operations monitoring.

No directly applicable historical precedent exists for the type of operations envisioned in the Shuttle area. Accordingly, the results of the RAM study were used (Reference 6). The average allowance of $50K/launch is derived from a brief manloading study of an austere payload launch operations concept.

Mission Operations Support: This cost element includes all supporting activities directly related to the payload itself between the time of orbital attainment and the time of completion of orbital activities and space shuttle return. It includes all mission monitoring/control fault diagnostics and other operational support required by the payload itself.

No directly applicable historical precedent exists for the type of mission operations envisioned in the Shuttle Sortie era. Accordingly, the RAM study results were utilized. The average allowance of $95,000 for a 30-day flight is based on a 12-hour day and is derived from a brief manloading study of an austere payload mission operations concept.

3.3 COST SUMMARY

Table 3-5 shows a WBS Level 1 and 2 Cost Summary of the Biomedical Emphasis Laboratory. Table 3-6 shows the Level 1 and 2 Bioscience and Advanced Technology Laboratory Cost Delta WBS Summary. The WBS Level 3 Cost Summary for both laboratories is shown in Table 3-7. Figure 3-4 shows the details of the recurring operations costs and the impact of the update allowance on the total costs. Table 3-8 shows a typical example of an EU Cost Summary Sheet. All the EU cost summary sheets are presented in Section 6.0

The delta costs for EU 23, bioresearch centrifuge, are as follows:

Recurring Production	Non-Recurring Development	Recurring Operations (28 Flights, 12 Years)	Total
$315K	$1648K	$2458K	$4421K

3.3.1 HIGH COST ITEMS. Table 3-9 lists all equipment items with non-recurring development costs above $100K and Table 3-10 lists all equipment items with recurring production costs above $50K. All costs shown are only at the equipment item level, they do not include EU level wraparound costs.

For the non-recurring items, three cost groups exist. The first includes only the common holding unit. Its cost estimate confidence level is rated as medium high and no significant cost reduction is possible without changing the scope of the system.

The second group of items ranges from $615 to $977K. The items in this category have a medium confidence level and further detailed definition of the design characteristics could reduce the costs. The bioresearch centrifuge cost, however, could be increased significantly if the design required a non-stoppable centrifuge approach.

All other items are in the $100 to $200K development cost range. The cost of the majority of these can possibly be reduced with more detailed definition of design requirements as would occur during a Phase A program.

Table 3-10 lists the equipment items with recurring unit cost above $50K. Two groups are apparent, those with costs below $100K and the bioresearch centrifuge with a unit cost of $277K. The centrifuge cost, as discussed above, can be subject to significant change depending on its further definition. Of the remaining items, approximately a third of which are GFE, the majority of the costs can be subject to reduction with more detailed definition of design and production requirements.

TABLE 3-5. LIFE SCIENCES BIOMEDICAL EMPHASIS
30-DAY DEDICATED LABORATORY

COST WORK BREAKDOWN STRUCTURE (K$)

	NR	R-P	R-O
LEVEL 1 - LABORATORY PROJECT			
Laboratory Hardware	18270	2809	35425
Spacelab		-	-
Integration			
Life Sciences Lab to Spacelab	867		
Spacelab to Shuttle	-	-	-
LEVEL 2 - LABORATORY HARDWARE			
EU-1 - EU-7 (CORE)	4372	1317	
EU-40/41/42	3019	352	
EU 60/61	126	135	
EU 26	332	74	
EU 12/31	1092	301	
EU 23	1263	315	
ECS	3845	315	
*SPARES			
Initial Spares	495		
Consumption Spares			1387
*SYSTEM TEST			
Test Operations	459		
Test Hardware	1238		
*SYSTEM ENGR'G/SYSTEM INTEG			
EU - EU	765		
Man-EU	765		
*FLIGHT OPERATIONS			
Launch Operations			1400
Mission Operations			2666
Refurbishment			25786
MGMT & ADMIN (ITEMS ONLY)	186	0	1562
FEE (*ITEMS ONLY)	313	0	2624
PI SUPPORT	-	-	-
NASA INTERNAL MGT SYSTEM (IMS)	-	-	-

TABLE 3-6. 30-DAY DEDICATED LABORATORY BIOSCIENCE AND ADVANCED TECHNOLOGY LAB COST Δ TO BIOMEDICAL EMPHASIS LAB COST

COST WORK BREAKDOWN STRUCTURE

	NR	R-P	R-O
LEVEL 1 - LABORATORY PROJECT			
Laboratory Hardware	2230	358	3416
Spacelab		-	-
Integration			
Life Sciences Lab to Spacelab	88		
Spacelab to Shuttle	-	-	-
LEVEL 2 - LABORATORY HARDWARE			
EU 50/51/70	354	141	
EU 80/91/93	1421	217	
* SPARES			
Initial Spares	63		177
Consumption Spares			
* LAB SYSTEM TEST			
Engineering Test Operations	47		
Test Hardware	135		
* SYSTEM ENGR'G/SYSTEM INTEG			
EU - EU	78		
Man-EU	78		
* FLIGHT OPERATIONS			
Launch Operations			0
Mission Operations			0
Refurbishment			2835
* MGMT & ADMIN (*ITEMS ONLY)	20	0	151
* FEE (*ITEMS ONLY)	34	0	253

TABLE 3-7. SPACE SHUTTLE/SPACELAB LIFE SCIENCES 30-DAY DEDICATED LABORATORY PAYLOAD

WBS LEVEL 3 EQUIPMENT UNIT SUMMARY (K$)

BIOSCIENCE & BIOMEDICAL LAB EU'S

CORE EU'S	Non-Recurring	Recurring Production	Total
EU 1 Vis. Records & Microscopy	412	191	603
EU 2 Data Management	483	191	674
EU 3 LS Experiment Unit	403	96	499
EU 4 Preparation & Preservation	1418	222	1640
EU 5 Biochem & Biophys. Analysis	1413	564	1977
EU 6/7 Maint/Repair/Storage	243	53	296
	4372	1317	5689
BIOSCIENCE & BIOMEDICAL COMMON EU'S			
EU 40/41/42 Vertebrates	3019	352	3371
EU 60/61 Cells & Tissues	126	135	261
EU 26 Radiobiology Support	332	74	406
	3477	561	4038
BIOMEDICAL LAB EU			
EU 12/31 Behav. Support	1092	301	1393
EU 23 Bioresearch Centrifuge	1263	315	1578
BIOSCIENCE LAB EU'S			
EU 50/51/70 Plants & Invertebrates	354	141	495
EU 80/91/93 Life Sup/Behavioral	1421	217	1638
	1775	358	2133
BIOMEDICAL EMPHASIS LABORATORY	10204	2494	12698
BIOSCIENCE & ADVANCED TECHNOLOGY LABORATORY COST Δ	1775	358	2133

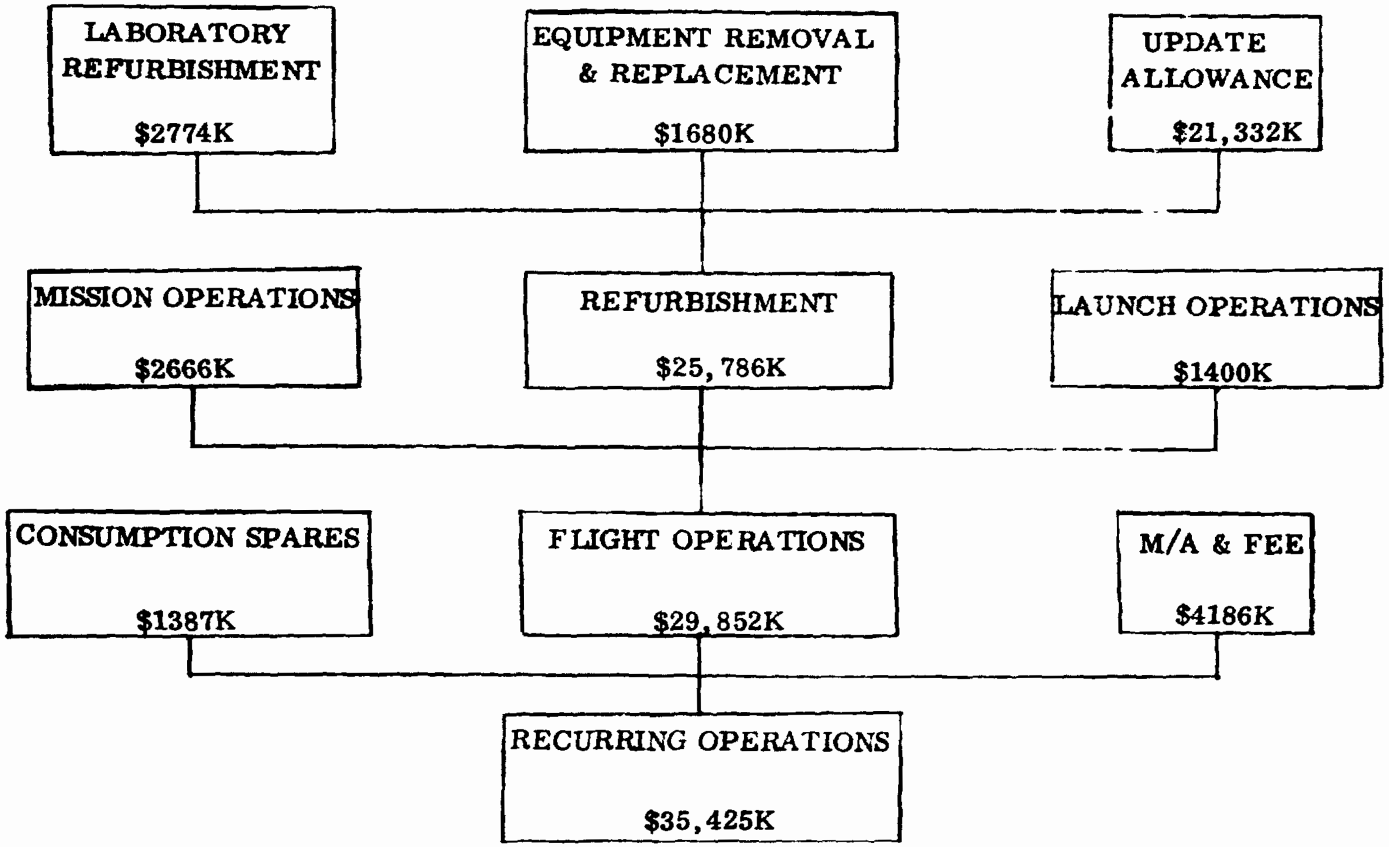


Figure 3-4. 30-Day Dedicated Biomedical Emphasis Laboratory - WBS Level 1 - Recurring Operations.

TABLE 3-8

TYPICAL EU COST SUMMARY –
EU 4 – PREPARATION AND PRESERVATION

EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
14	Anesthetizer, Invert.	1	2	4	6	ERR 1630, CER & Vendor Cost
18	Glove Box	1	19	2	21	SSPDA CER & Vendor Cost
18A	Glove Box Liners	60	5	<.1	7	ENG ROM
18B	Glove Box Insert - Radiochemical	1	-	-	-	Deleted. Badges eliminate need for inserts.
41	Centrif. Frig. Hi-Spd	1	124	7	131	SSPDA CER & Vendor Cost
44	Chemicals	1	2.4	.2	3	Δ
44A	Chemicals - Radioactive	1	2.4	.5	3	Δ
48	Cleaner, Vacuum	1	46	2	48	MDAC Study & Vendor Cost
70	Electrophoresis, Appar.	1	45	3	48	SSPDA CER & Vendor Cost
77B	Freezer, Cryo	1	105	20	125	Parametric detailed manloading
81	Freezer, Lo Temp	1	122	12	134	SSPDA CER
83	Frig.	1	65	5	70	SSPDA CER
105	Kit, Bench Chem. Anal.	1	74	6	80	Δ
106	Kit, Hematology	1	74	6	80	Δ
108	Kit, Histology	1	8	.7	9	Δ
110	Kit, Microbiology	1	17.7	1.5	19	Δ
114A	Kit, Microdissection	1	13	1	14	Δ
121	Mass Meas., Macro	1	(300)	8	8	Refurbish existing Skylab backup unit. GFE. New unit cost - $84K.
122	Mass Meas., Micro	1	(225)	5	5	Refurbish existing Skylab backup unit. GFE. New unit cost - $50K.
136A	Microscope, Dissecting	1	1	2	3	Vendor Cost.
159	Stain Sys., Bacteriological	1	(100)	13	13	Use unit developed for Skylab by Beckman. GFE.
179	Temp. Block	2	15	.5	16	SSPDA CER & Vendor Cost
186	Volumetric Meas., Liq.	1	(300)	75	75	Use unit developed for ASTP. GFE.
	TOTAL EIs		741	177	918	
	Structure/Mechanical Supports		37	25	62	SSPDA CER
	Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab.
	Systems Test: Hardware 0; Operations 102; Refurbishment 20	Total	122	-	122	
	System Engineering & Integration		274	-	274	
	GSE		77	-	77	
	Management & Administration		62	10	72	
	TOTAL		1313	212	1525	
	Fee		105	10	115	
	TOTAL		1418	222	1640	

Δ NASA Skylab detailed estimate.

TABLE 3-9

30-DAY DEDICATED LABORATORY PAYLOAD EQUIPMENT ITEMS WITH NON-RECURRING COSTS ABOVE $100K

NO.	EU	EI	NAME	NON-REC.* K$
1	-	99	COMMON HOLDING UNIT	1544
2	23	43	BIORESEARCH CENTRIFUGE	977
3	80	115F	LSS TEST BENCH	670
4	41	28A	CAGE, MONK, MACAC	615
5	5	89	GAS ANALYZER, GC COMPLEX	276
6	91	144C	PSYCHOMOTOR, PERF. CONSOLE	233
7	12	51D	CONT. CONSOLE, EXPMTR.	233
8	40	30A	CAGE, RAT/HAMP/QUAIL	224
9	26	150	RADIATION SOURCE STORAGE	208
10	1	38A	CAMERA, X-Y DRIVE	200
11	60	98A	HOLDING UNIT, PLANT	184
12	5	148	BENCH, GEN. EXP.	148
13	2	63B	DISPLAY KEYBOARD	128
14	4	41	CENTRIFUGE, FRIG. HI-SPEED	124
15	4	81	FREEZER, LOW TEMP.	122
16	4	77B	FREEZER, CRYO	105
17	5	91	GAS ANALYZER, MASS SPEC.	100

*THESE COSTS DO NOT INCLUDE EU LEVEL COSTS, I.E., SYSTEM TEST, SE&I, GSE, M&A, & FEE.

TABLE 3-10

30-DAY DEDICATED LABORATORY PAYLOAD EQUIPMENT ITEMS
WITH RECURRING PRODUCTION UNIT COSTS ABOVE $50K

NO.	EU	EI	NAME	REC-PROD.* $K
1	23	43	BIORESEARCH CENTRIFUGE	277
2	5	91	GAS ANALYZER, MASS SPEC.	100
3	1	38	CAMERA, VIDEO COLOR	100
4	91	144C	PSYCHOMOTOR PERF. CONSOLE	97
5	12	51D	CONT. CONSOLE EXPMTR.	97
6	80	115F	LSS TEST BENCH	86
7	41	28A	CAGE, MONK, MACAC	84
8	4	186	VOLUMETRIC, MEAS. LIQUID	75 (GFE)
9	5	7	GEMSAEC	75 (GFE)
10	26	150	RADIATION SOURCE STORAGE	60
11	-	99	COMMON HOLDING UNIT	55
12	5	85	GAS ANALYZER, AUTO PHYSIO.	50 (GFE)
13	12	153A	ROTATING LITTER CHAIR	50 (GFE)
14	31	76M	ULTRASONASCOPE	50 (GFE)

*THESE COSTS DO NOT INCLUDE EU LEVEL COSTS, I.E., SYSTEMS TEST, SE&I, GSE, M&A, & FEE.

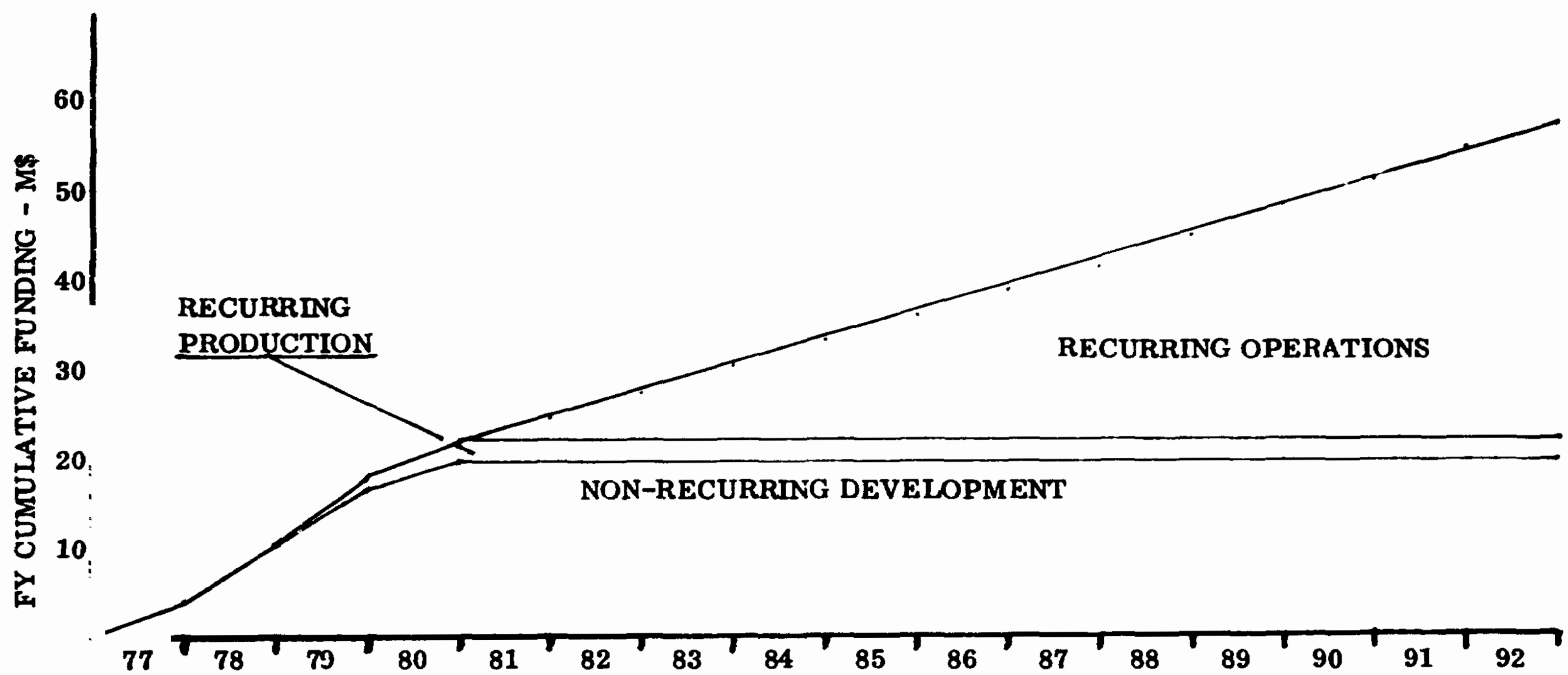
3.3.2 ANNUAL FUNDING REQUIREMENTS. Funding spreads were generated only for the Biomedical Emphasis Laboratory and are shown in Figure 2-2 in conjunction with the schedule. Idealized cost distribution curves, as defined in NASA Data Requirements MF003M18, March 18, 1973, were used. The cost distribution curve selected for the non-recurring and recurring production phases is based upon 60 percent of the funds expended at 50 percent of the program time. This distribution has historically been found reasonable because it reflects the manpower buildup early in a program and the tailoff toward the end.

The SRT development items were funded separately because of their earlier start and then combined with the other development items to obtain the total non-recurring funding spread. Figure 3-5 shows the cost distribution curves for cumulative funding requirements.

3.4 COST REDUCTION GUIDELINES

There are several cost reduction areas that should be emphasized in addition to making maximum use of commercial equipment technology. The first and most important is the use of cost performance trade studies, together with a design to cost approach. Historically, the performance requirements for a design have been established with minimum if any consideration for their effect on cost. Due to this, large cost penalties are incurred for small or unnecessary increases in performance. In the design to cost approach, a balance between performance and cost is accomplished. In order to achieve a low cost program, the marginal cost increase to achieve a given change in performance must be known. Figure 3-6 shows a general cost-performance relationship with thresholds and goals established. These thresholds and goals must be set by the cognizant engineers and scientists so that different configurations can be analyzed to arrive at a cost/performance relationship. To control the total program costs, a "design to cost" approach is recommended. This approach should be used during the development and production programs in conjunction with a broad range of technical tradeoff options built in as a means of cost control. These cost control approaches should include limitations on cost escalation with specific items or systems subject to removal from the program if the price rises beyond set limits. This type of costing approach has been successful in military programs and is being incorporated into the European SPACELAB development program.

An area which resulted in high costs on past programs is frequent design criteria iterations. This causes redesign and retesting in many cases, with consequent schedule and cost impacts. Design criteria, once established, should not be changed, even if some performance degradation will result. Similarly, if interface parameters are not firm until late in a program, there will be a similar effect resulting in large cost increases. These criteria, therefore, should be firmly established early in a program and limited as to change.



DEV	3.9	10.1	16.8	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
PROD	0	0	1.1	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
OPER	0	0	0	0	2.8	5.6	8.4	11.2	14.1	16.9	19.8	23.0	26.2	29.5	32.7	35.5
TOTAL	3.9	10.1	17.9	21.9	24.7	27.5	30.3	33.1	36.0	38.8	41.7	44.9	48.1	51.4	54.6	57.4

Figure 3-5. Cumulative Funding.

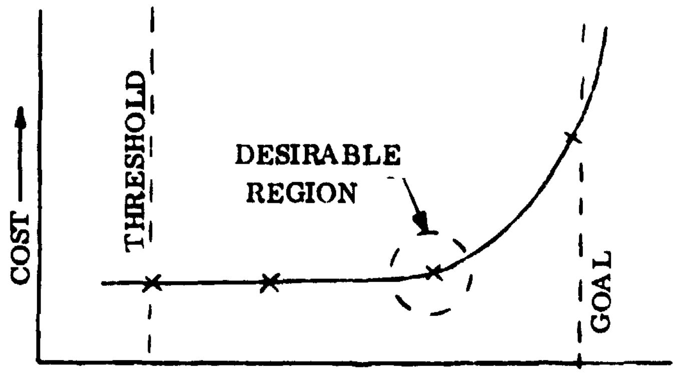


Figure 3-6. Cost Performance Relationship.

Significant cost reductions can be achieved in the area of reliability by relaxing requirements in areas where crew safety is not involved. Payload reliability requirements can be further reduced because of the many flight opportunities in the mission and the capability to do on-board maintenance. The use of off-the-shelf and custom commercial equipment with inherent high reliability will also tend to reduce costs associated with reliability.

Commonality of equipment associated with the various scientific disciplines scheduled for the Shuttle/SPACELAB operation provides an opportunity for cost savings. Equipment such as cameras and recorders are likely candidates for this cost reduction.

SECTION 4

COMPARISON OF PREVIOUS AND NEW LIFE SCIENCES LAB COSTS

The previous Life Sciences Payload Definition and Integration Study (Task C&D), included a cost analysis of a 30-Day Dedicated Life Sciences Laboratory. A summary comparison of these previous costs and the new costs generated in this study is shown in Table 4-1.

TABLE 4-1. SPACE SHUTTLE/SPACELAB LIFE SCIENCES 30-DAY DEDICATED LABORATORY PAYLOADS

BIOMEDICAL EMPHASIS LABORATORY

	TOTAL COSTS, $K	
	PREVIOUS	NEW
EU 1	3904	603
EU 2	739	674
EU 3	576	499
EU 4	6424	1640
EU 5	3867	1977
EU 6	176	296 (EU 6 + EU 7)
EU 7	37	
TOTAL CORE	15723	5689
EU 40	5210	3371 (EU 40–42)
EU 41	450	
EU 42	636	
EU 12	572	1393 (EU 12 + EU 31)
EU 31	1032	
EU 60	20	261 (EU 60 + EU 61)
EU 61	2	
EU 26	417	406
EU 23	400	1578
	24455	12698

NOTES: The above previous costs are based on the GDCA task C&D study results. The totals are updated to reflect the changes in quantity as established by the L.S. Working Group in August 1973.

A comparison of the costs at the total laboratory level was not possible because of the different ground rules in effect for the two studies. The only reasonable comparison was at the WBS Level 3, which includes the total EU development. The prior study totals were updated to reflect equipment item inventory changes made by the Life Sciences Working Group in August 1973.

Table 4-2 shows the cost differences and categorizes the reason for the changes. The largest percentage change (22 percent) was due to scope changes in the equipment items. This includes items whose complexity was reduced and also those which were treated from a low cost approach.

Skylab and other NASA program-developed items reduced the costs by 17 percent. Other programs included ASTP, ARC and JSC independent development areas. A more detailed estimating approach resulted in 9 percent cost reduction. These were equipment items for which more detailed engineering information was available, thereby permitting a better estimate.

TABLE 4-2

COST COMPARISON OF DEDICATED LIFE SCIENCES LABORATORIES
(NAS8-29150 vs. NAS8-30288)

NAS8-29150 (PREVIOUS)	$24.5M
NAS8-30288 (NEW)	$12.7M

COST DIFFERENCE EXPLANATION

EQUIPMENT ITEM SCOPE CHANGE	22%
SKYLAB DEVELOPED	10%
OTHER NASA DEVELOPED	7%
MORE DETAILED ESTIMATE	9%
TOTAL REDUCTION	48%

4.1 DETAIL EQUIPMENT ITEM COST COMPARISONS

This section contains a tabularion of all the equipment item costs grouped into the appropriate EU. Tables 4-3 through 4-15 present both the old and new costs at the WBS Level 3. The new costs also include the WBS Level 2 costs.

TABLE 4-3. EU #1 - VISUAL RECORDS AND MICROSCOPY

EU#	EI #	NAME	NOTES	QTY.	OLD COSTS, $K Dev.	OLD COSTS, $K Unit	OLD COSTS, $K Total	NEW COSTS, $K Dev.	NEW COSTS, $K Unit	NEW COSTS, $K Total
1	3C	Adapter, TV-microscope		1	1	1	2	0	.5	.5
	32A	Camera, Cine	Scope Change	2	150	20	190	10	6	22
	32A	Camera Controller	Scope change, part of EI 37	1	3000	150	3150	Eliminated		
	34	Camera, 35 mm		2	0	1	2	0	1	2
	37	Camera, Video, B/W		2	0	10	20	1	13	27
	38	Camera, Video, Color	GFE, NASA Dev.	1	300	100	400	0	100	100
	38A	Camera, X-Y Drive		2	100	1	102	200	10	220
	76C	Film, 35 mm		4	0	0	0	0	0	0
	76E	Filters, Video		1	0	1	1	0	.5	.5
	116	Log Books		11	0	0	0	0	0	0
	126	Microscope, Compound		1	20	12	32	.5	3.5	4
	126G	Monitor, Video		1	0	5	5	12	6	18
	181E	Video I.D. Date Time Sys.		1	-	-	-	-	-	-
*	35	Camera, Polaroid		1	0	0.5	0.5	0	.5	.5
		TOTAL			3571	333.5	3904.5	224	171	396
		Structure/Mechanical Supports						6.2	4.2	10.4
		Systems Test						30	0	30
		Systems Engineering & Integration						38	0	38
		GSE						65	0	65
		Management & Administration						18	9	27
		Fee						30	7	37
		EU #1 TOTAL			3571	333.5	3904.5	411	191	603

*New EI #

TABLE 4-4

EU #2 - DATA MANAGEMENT

EU#	EI#	NAME	NOTES	QTY.	OLD COSTS, $K Dev.	OLD COSTS, $K Unit	OLD COSTS, $K Total	NEW COSTS, $K Dev.	NEW COSTS, $K Unit	NEW COSTS, $K Total
2	141	Antennas, Assorted		1	20	1	21	1	.5	1.5
	51	Computer, Digital		-	-	-	-	-	-	-
	56A	Data Mgmt. Sys. Buses		1	-	-	-	-	-	-
	58A	Data Mgmt. Sys.		1	-	-	-	-	-	-
	58B	Data Mgmt. Sys.		4	-	-	-	-	-	-
	63B	Display Keyboard		1	50	30	80	128	43	171
	64	ECG Coupler		12	5	1	17	10	1.2	24
	65	EEG Coupler		4	5	1	9	10	1.2	15
	66	EMG Coupler		6	5	1	11	10	1.2	17
	132	Oscilloscope		1	150	20	170	54	14.6	69
	138A	Photocells		12	7	1	19	-	-	-
	138B	Phototransistor (PLR)		12	7	1	19	10	1.2	24
	143G	Coupler-Press. Transducer		4	5	1	9	10	1.2	15
	150D	Receivers, dc-5MHZ	Scope change	1	200	10	210	27	6.6	34
	153	Recorder, Voice		1	35	5	40	11	.5	16
	156	Signal Cond. Coupler		35	15	3	120	10	1	45
	176	Tape, Video		1	0	0	0	0	<.1	0
	180	Timer, Event		2	2	1	4	0	.2	.5
	181I	Transducer, Pressure		9	1	1	10	0	2	18
		TOTAL			507	232	739	281	169	450
	Systems Test							34	-	34
	Systems Engineering & Integration							47	-	47
	GSE							64	-	64
	Management & Administration							21	8	29
	Fee							36	14	50
	EU #2 TOTAL				507	232	739	483	191	674

TABLE 4-5

EU #3 - LIFE SCIENCES EXPERIMENT UNIT

EU#	EI#	NAME	NOTES	QTY.	OLD COSTS, $K			NEW COSTS, $K		
					Dev.	Unit	Total	Dev.	Unit	Total
3	1	Accelerometer Activity		3	1	1	4	1.5	.5	3
	1A	Accelerometer Coupler		3	20	2	26	.5	.1	[illegible]
	55A	Crew Mobility Aids	Skylab	6	50	1	56	2	.2	3
	55B	Crew Restraints	Skylab	3	50	1	53	2	.7	4
	76J	Flowmeter, Gas		6	10	1	16	13	.8	18
	93A	Gas Supply, Assorted		6	200	2	212	50	5.3	82
	187A	Waste Storage Device	Scope change	4	100	20	180	20	.5	20.5
*	143	Power Conditioning Equip.		1	0	5	5	64	24	88
*	93C	Gas Conditioning Equip.		1	0	5	5	50	9	59
*	188	Water Conditioning Equip.		1	0	5	5	25	2.8	28
	118I	Manifold Vacuum		1	12	2	14	30	6.9	37
		TOTAL			443	133	576	258	85	344
		Systems Test						23	0	23
		Systems Engineering & Integration						42	-	42
		GSE						32	-	32
		Management & Administration						18	4	22
		Fee						30	7	37
		EU #3 TOTAL			443	133	576	403	96	499

*New EI #

TABLE 4-6

EU #4 - PREPARATION AND PRESERVATION

EU#	EI#	NAME	NOTES	QTY.	OLD COSTS, $K Dev.	OLD COSTS, $K Unit	OLD COSTS, $K Total	NEW COSTS, $K Dev.	NEW COSTS, $K Unit	NEW COSTS, $K Total
4	14	Anesthetizer, Invert.		1	35	5	40	2	4	6
	18	Glove Box	Scope change	1	2000	25	2025	19	2	21
	18A	Glove Box Liners	Scope change	60	100	1	160	5	<.1	7
	18B	Glove Box Insert - Rad. Chem.	Deleted	1	-	6	6	-	-	-
	41	Centrif. Frig. Hi-Spd		1	175	25	200	124	7	131
	44	Chemicals	Skylab	1	100	10	110	2.4	.2	3
	44A	Chemicals - Radioactive		1	-	10	10	2.4	.5	3
	48	Cleaner, Vacuum		1	200	50	250	46	2	48
	70	Electrophoresis, Appar.		1	50	5	55	45	3	48
	77B	Freezer, Cryo		1	500	25	525	105	20	125
	81	Freezer, Lo Temp		1	200	10	210	122	12	134
	83	Frig.		1	50	5	55	65	5	70
	105	Kit, Bench Chem. Anal.		1	100	10	110	74	6	80
	106	Kit, Hematology		1	7	1	8	74	6	80
	108	Kit, Histology		1	20	3	23	8	.7	9
	110	Kit, Microbiology		1	40	5	45	17.7	1.5	9
	114A	Kit, Microdissection		1	40	5	45	13	1	14
	121	Mass, Meas., Macro	Skylab	1	20	10	30	(225)	5	5
	122	Mass, Meas., Micro	Skylab	1	2000	20	2020	(300)	8	8
	126A	Microscope, Dissecting		1	10	5	15	1	2	3
	159	Stain Sys., Bacteriological	Skylab	1	400	20	420	(100)	13	13
	179	Temp. Block		2	5	1	7	15	.5	16
	186	Volumetric Meas., Liq.	ASTP developed	1	50	5	55	(300)	75	75
		TOTAL			6102	322	6424	741	177	918
Structure/Mechanical Supports								37	25	62
Systems Test								122	-	122
Systems Engineering & Integration								274	-	274
GSE								77	-	77
Management & Administration								62	10	72
Fee								105	10	115
EU #4 TOTAL					6102	322	6424	1418	222	1640

TABLE 4-7

EU #5 - BIOCHEMICAL AND BIOPHYSICAL ANALYSIS

EU#	EI#	NAME	NOTES	QTY.	OLD COSTS, $K Dev.	OLD COSTS, $K Unit	OLD COSTS, $K Total	NEW COSTS, $K Dev.	NEW COSTS, $K Unit	NEW COSTS, $K Total
5	6	Air Particle Sample Coll.		1	28	4	32	11	1	12
	7	GEMSAEC	GFE, JSC Dev.	1	700	100	800	(175)	75	75
	50A	Commutator, Gas Mnfld		1	200	20	220	20	1.7	22
	54	Counter Colony, Manual		1	10	2	12	2	.5	2.5
	76L	Fibrometer, Blood Clot		1	100	10	110	47	3.4	50
	85	Gas Analyzer, Auto Physio.	GFE, JSC Dev.	1	200	50	250	(200)	50	50
	89	Gas Analyzer, GC Complex		1	850	120	970	276	83	359
	91	Gas Analyzer, Mass Spec.	Viking Mod.	2	800	100	1000	100	100	300
	125B	Meters, Assorted		4	150	1	154	4	1	8
	125C	Meter, AOTS		1	3	1	4	.5	.5	1
	138	pH Meter		1	150	20	170	90	26.5	117
	137	Sound Level Meter		1	30	5	35	10	6	16
	15A	Atmospheric, Manifold Sys.		1	-	-	-	13	3.5	17
	19	Bench, Gen. Exp.		1	100	10	110	148	27	175
		TOTAL			3321	546	3867	720	485	1205
		Structure/Mechanical Supports						31	21	52
		Systems Test						116	-	116
		Systems Engineering & Integration						187	-	187
		GSE						192	-	192
		Management & Administration						62	25	87
		Fee						105	33	138
		EU #5 TOTAL			3321	546	3867	1413	564	1977

TABLE 4-8

EU #6/7 - MAINTENANCE/REPAIR/STORAGE

EU#	EI#	NAME	QTY.	OLD COSTS, $K Dev.	OLD COSTS, $K Unit	OLD COSTS, $K Total	NEW COSTS, $K Dev.	NEW COSTS, $K Unit	NEW COSTS, $K Total
6	16E	Bags, Plastic Permeable	250	0	0	0	3.4	3.8	7
	49A	Hand Wipes, Betadyne	250	5	1	6	2.4	2	4
	50B	LSPS Compactor, Solids	1	14	2	16	5	1	6
	106A	Kit, Cleanup	1	5	1	6	40	4	44
	109	Kit, Linear Meas.	1	0	0	0	1	.1	1
	110B	Kit, Org. Hold. & Mgmt.	1	25	3	28	13	1.1	14
	113	Kit, General Tool	1	40	5	45	16	1.4	17
	165	Sterilizer, Tool	1	40	10	50	5	1	6
	168A	Tags, ID, Organism	2	0	0	0	0	0	0
	181G	Trash Can	1	10	1	11	2	.5	3
	185	Voltmeter (DVM)	1	12	2	14	22	4	26
		EU #6 TOTAL		151		176	110	18	128
7	45	Chemical Storage Cabinet	1	20	10	30	22	12	34
	167B	Storage, General	1	1	4	5	3	2	5
	167C	Storage, Film	1	1	1	2	3	1	4
		EU #7 TOTAL		22		37	28	15	43
		TOTAL EU #6 & EU #7		173	40	213	138	33	171
		Structure/Mechanical Supports					19	13	32
		Systems Test					14	-	14
		Systems Engineering & Integration					26	-	26
		GSE					17	-	17
		Management & Administration					11	2	13
		Fee					18	4	22
		EU #6/7 TOTAL		173	40	213	243	53	296

TABLE 4-9

EU #12/31 - BEHAVIORAL SUPPORT

BIOMEDICAL SUBLAB ONLY

EU#	EI#	NAME	NOTES	QTY.	OLD COSTS, $K Dev.	OLD COSTS, $K Unit	OLD COSTS, $K Total	NEW COSTS, $K Dev.	NEW COSTS, $K Unit	NEW COSTS, $K Total
12	51D	Cont. Console Expmtr.		1	150	50	200	233	97	330
	65B	Electrophysiology Backpack		1	100	25	125	27	6.6	34
	65C	Electrophysiology Receiver		1	100	25	125	38	11	49
	144B	Psychogalvanometer GSR	Part of EI 65B	2	1	1	2	-	-	-
	153A	Rotating Litter Chair	Skylab, GFE	1	20	100	120	(300)	50	50
		EU #12 TOTAL			371	201	572	298	165	463
31	18C	Exercise Physiology Equip.	Skylab, GFE	1	5	5	10	(339)	18	18
	76K	Flowmeter, Doppler		2	5	1	7	10	.4	11
	110C	Kit, Physiology		1	100	10	110	19	2	21
	125P	Metabolic Analyzer, Fixed	GFE	1	20	100	120	(379)	5	5
	139	Plethysmograph, Limb		1	10	10	20	37	1	38
	181B	Transducer-Plethysmo.	Part of EI 139	4	35	5	55	-	-	-
	182J	Coupler, Vectorcardiogram		1	5	1	6	10	1	11
*	76M	Ultrasonoscope	ARC, GFE	1	500	4	504	(400)	50	50
	117	LBNP	Skylab, GFE	1	100	100	200	(181)	18	18
		EU #31 TOTAL			780	252	1032	76	96	172
		EU #12/31 TOTAL			1151	453	1604	374	261	635
		Structure/Mechanical Supports						19	13	32
		Systems Test						146	-	146
		Systems Engineering & Integration						320	-	320
		GSE						104	-	104
		Management & Administration						48	13	61
		Fee						81	14	95
		EU #12/31 TOTAL			1151	453	1604	1092	301	1393

*NEW EI NUMBER.

TABLE 4-10

EU #26 - RADIOBIOLOGY SUPPORT
BIOMEDICAL AND BIOSCIENCE SUBLAB

EU#	EI#	NAME	NOTES	QTY.	OLD COSTS, $K			NEW COSTS, $K		
					Dev.	Unit	Total	Dev.	Unit	Total
26	16D	Badges, Radiation		52	0	0	0	0	<.1	0
	144C	Radiation Detector	GFE, Shuttle Orb.	1	15	2	17	0	2	2
	150	Radiation Source Storage		1	350	50	400	208	60	268
		EU #26 TOTAL			365	52	417	208	62	270
		Structure/Mechanical Supports						6	4.2	10
		Systems Test						0	0	0
		Systems Engineering & Integration						19	-	19
		GSE						24	-	24
		Management & Administration						15	3	18
		Fee						25	5	30
		EU #26 TOTAL			365	52	417	332	74	406

TABLE 4-11

BIOMEDICAL & BIOSCIENCE SUBLAB

EU #40/41/42 - VERTEBRATE HOLDING & SUPPORT

				OLD COSTS, $K			NEW COSTS, $K		
EU#	EI#	NAME	QTY.	Dev.	Unit	Total	Dev.	Unit	Total
40	30A	Cage, Rat/Hamp./Quail	16	100	1	116	224	3.2	275
	76H	Flowmeter, Coupler	16	20	2	52	5	.1	6
	76F	Flowmeter, H_2O Manifold	16	1	1	17	20	.6	27
	103	Holding Unit, Small Vert. *	2	5000	10	5020	1544	55	1654
	118D	Manifold, Organism, H_2O	1	-	5	5	15	.7	16
		EU #40 TOTAL		5121		5210	1808	170	1978
41	28A	Cage, Monk Macac	2	400	25	450	615	51	717
42	115	Kit, Veterinary	1	75	10	85	35	3	38
	150B	Receiver, Exg. Cage Mod.	2	400	20	440	21	5	31
	155A	Sensor, Implanted	12	1	1	13	1	.5	7
	177	Temperature Sensors, Body	32	1	1	33	1	.5	17
	181C	Xdcer, Blood Pres.	6	35	5	65	2	.5	5
		EU #42 TOTAL		512		636	60	38	98
		EU #40/41/42 TOTAL EI'S		6033	263	6296	2483	310	2793
		Systems Test					37	-	37
		Systems Engineering & Integration					15	-	15
		GSE					118	-	118
		Management & Administration					133	16	149
		Fee					233	26	259
		EU #40/41/42 TOTAL		6033	263	6296	3019	352	3371

*Old Cost included EI 103, 30,98A, 98C & 101.
New Cost for these is approximately:
Development - 2.15M
Unit - 220K

TABLE 4-12
EI #43 - BIORESEARCH CENTRIFUGE

EU#	EI#	NAME	QTY.	OLD COSTS, $K			NEW COSTS, $K		
				Dev.	Unit	Total	Dev.	Unit	Total
	43	Bioresearch Centrifuge	1	350	50	400	977	277	1254
	50	Clinostat	1	See	EU 51		3	.7	4
		GSE					105	-	105
		Management & Administration					56	14	70
		Fee					94	23	117
		EI #43 TOTAL		350	50	400	1263	315	1578

TABLE 4-13

EU #50/51/70 - PLANT HOLDING & SUPPORT/INVERTEBRATES

BIOSCIENCE SUBLAB ONLY

EU#	EI#	NAME	QTY.	OLD COSTS, $K			NEW COSTS, $K		
				Dev.	Unit	Total	Dev.	Unit	Total
50	101	Holding Unit, Plant	1	0	10	10	184	65	249
51	50	Clinostat	1	50	7	57	See EU 43		
	111	Kit, Plant Tools	1	25	3	28	10.5	.9	11
70	98C	Holding Unit Incub. Invert.	1	-	10	10	47	59	106
	113A	Kit, Tool, Insect Manip.	1	20	3	23	7.1	.6	8
		TOTAL EU #50/51/70 EI'S		95	33	128	249	125	374
		Systems Test					13	-	13
		Systems Engineering & Integration					3	-	3
		GSE					47	-	47
		Management & Administration					16	6	22
		Fee					26	10	36
		EU #50/51/70 TOTAL		95	33	128	354	141	495

TABLE 4-14
BIOMEDICAL & BIOSCIENCE SUBLABS

EU #60/61 - CELLS & TISSUES

EU#	EI#	NAME	QTY.	OLD COSTS, $K			NEW COSTS, $K		
				Dev.	Unit	Total	Dev.	Unit	Total
60	98A	Holding Unit, Incub. Cells	2	-	10	20	47	118	165
61	124	Media, Prepared	2	0	1	2	5.8	.5	7
		EU #60/61		0	11	22	53	119	172
		Systems Test					12	-	12
		Systems Engineering & Integration					1	-	1
		GSE					45	-	45
		Management & Administration					6	6	12
		Fee					9	10	19
		EU #60/61 TOTAL		0	11	22	126	135	261

TABLE 4-15

BIOSCIENCE SUBLAB ONLY

EU #80 - LIFE SUPPORT SUBSYSTEM TEST UNIT

EU #91/93 - BEHAVIORAL MEASUREMENTS UNIT/MOBILITY UNIT

EU#	EI#	NAME	QTY.	OLD COSTS, $K			NEW COSTS, $K		
				Dev.	Unit	Total	Dev.	Unit	Total
80	115F	LSS Test Bench	1	1000	100	1100	670	86	756
91	50C	Console Behav. Measurements	-	-	-	-	-	-	-
	144C	Psychomotor Perf. Console	1	150	50	200	233	97	330
93	15	Anthropometric Grid	1	10	1	11	10	1	11
	126I	Mobility Unit, Protective Corridor	1	30	2	32	32	3	35
		TOTAL EU #80/91/93		1190	153	1343	945	187	1132
		Structure/Mechanical Supports					6	4.2	10.2
		Systems Test					76	-	76
		Systems Engineering & Integration					154	-	154
		GSE					72	-	72
		Management & Administration					63	10	73
		Fee					105	16	121
		EU #80/91/93 TOTAL		1190	153	1343	1421	217	1638

SECTION 5

SUPPLEMENTAL COST STUDIES

5.1 EQUIVALENT GROUND LABORATORY COMPARISON

A comparison of SPACELAB Life Sciences equipment unit costs to a ground laboratory of similar function was made for EU 4 and EU 5. The cost comparisons are shown in Table 5-1 and Table 5-2. A significant cost difference exists. One prime reason is that only 8 percent of the total cost is represented by non-recurring costs for the ground laboratory. For the space laboratory, the non-recurring costs represent 86 percent and 71 percent of the total cost for EU #4 and #5, respectively. Of these non-recurring costs, 45-50 percent is only due to performing system level tasks, which are almost non-existent for the ground based laboratory.

The ratio of SPACELAB to ground lab costs is 103:1 for EU #4 and 16:1 for EU #5. The explanation lies in the equipment item mix for each EU. EU #4 has a large number of kits and items like freezers and mass measurement devices which are well developed and inexpensive in a 1-g application. EU #5, however, contains rather sophisticated high cost equipment like a clinical analyzer and mass spectrometer which drive its ground lab cost almost eight times that of EU #4.

In conclusion, the SPACELAB costs increase can be attributed mainly to non-recurring development costs. A significant recurring unit cost difference also exists, but it varies in the complexity of the individual items, and in some individual cases the differences are not great.

5.2 SKYLAB EQUIPMENT APPLICABILITY

As shown in Table 3-3, the costs of 23 percent of the equipment items were based on Skylab information. There are several areas where equipment developed and flown on Skylab will meet the Life Sciences Laboratory requirements, but a limited amount of hardware for future use is available. This generally consists of a bonded flight backup unit, qualification units, and training units in the principal investigator's laboratory.

In many cases, refurbishment of an available unit was assumed possible with the remainder of the units providing a backup capability. However, it must be recognized that a limit of the spares for future operations does exist. New production of Skylab items was assumed for certain items. Two categories of items must, however, be considered for this.

TABLE 5-1

EQUIVALENT GROUND LABORATORY/SPACE LABORATORY EU COMPARISON

EU #4

Equivalent Ground Laboratory EI		Qty.	Cost, $	Space Laboratory
14	Anesthetizer, Invert.	1	400	
18C	Glove Box (Interface Box)	1		
18A	Glove Box Liners	60		
18B	Glove Box Insert - Radiochemical	1	1400	
41	Centrif. Frig. Hi-Spd	1	3300	
44	Chemicals	1	500	
44A	Chemicals - Radioactive	1	700	
48	Cleaner, Vacuum	1	25	
70	Electrophoresis, Appar.	1	300	Development &
77B	Freezer, Cryo	1	200	Unit Costs
81	Freezer, Lo Temp	1	1060	
83	Frig.	1	150	
105	Kit, Bench Chem. Anal.	1	300	
106	Kit, Hematology	1	400	
108	Kit, Histology	1	200	
110	Kit, Microbiology	1	200	
114A	Kit, Microdissection	1	150	
121	Mass, Meas., Macro	1	200	
122	Mass, Meas., Micro	1	800	
126A	Microscope, Dissecting	1	900	
159	Stain Sys., Bacteriological	1	2000	
179	Temp. Block	2	110	
186	Volumetric Meas., Liq.	1	200	
	EQUIPMENT TOTAL		13,495	$918,000
	Prime Contractor Integration (10%)		1,349	722,000
	Prime Contractor Fee (8%)		1,180	
	TOTAL		$15,934	$1,640,000
	Space/Ground Lab Ratio 103:1			

TABLE 5-2

EQUIVALENT GROUND LABORATORY/SPACE LABORATORY EU COMPARISON

EU #5

Equivalent Ground Laboratory				Space Laboratory
EI		Qty.	Cost, $	
6	Air Particle Sample Cell	1	200	
7	Dupont 700 Automatic Clinical Analyzer	1	69500	
50A	Commutator, Gas Manifold	1	600	
54	Counter Colony, Manual	1	200	
76L	Fibrometer, Blood Clot	1	500	
85	Gas Analyzer, Auto Physio.	1	3790	
89	Gas Analyzer, G.O. Complex	1	1300	Development & Unit Costs
91	Gas Analyzer, Mass Spec. (1)	2	20000	
125B	Meters, Assorted	4	100	
125C	Meter, AOTS	1	300	
138	pH Meter	1	300	
157	Sound Level Meter	1	3000	
15A	Atmospheric, Manifold Sys.	1	200	
19	Bench, Gen. Exp.	1	800	
18A	Bench Liners		50	
	EQUIPMENT TOTAL		101,140	$1,205,000
	Prime Contractor Integration (10%)		10,1[illegible]4	772,000
	Prime Contractor Fee (8%)		8,900	
	TOTAL		$120,154	$1,977,000
	Space to Ground Lab Ratio 16:1			

The first includes those items which were manufactured by commercial vendors. For these, it is considered quite feasible that the item can be produced again. Given the new low cost guidelines, the costs will probably be lower than Skylab's with the benefit of any applicable state-of-the-art advancement being included.

The other category of items are those which were developed and produced by NASA, universities or prime contractors. Attempting to procure additional Skylab hardware through these will undoubtedly result in significant non-recurring costs if feasible at all. In all probability, the technical and production team which existed during the Skylab program has been dissolved.

In summary, Skylab equipment applicability to the Life Sciences Laboratory must be investigated in detail based on the individual items under consideration. For certain items, the equipment available will satisfy the requirements while for others a cost tradeoff to determine the most viable approach is necessary.

5.3 MULTI-INTEGRATION OPTIONS

A brief analysis was made to assess the impact on recurring operations cost of alternate dedicated laboratory mission configurations. The following two options were considered:

1. Change from Biomedical Emphasis Laboratory to Bioscience and Technology Laboratory

   Remove EU 12/31 - Behavioral Support
   Remove EU 23 - Bioresearch Centrifuge
   Install EU 50/51/70 - Plants and Invertebrates
   Install EU 80/91/93 - Life Support & Behavioral

2. The same as option 1 but not removing EU 23, the Bioresearch Centrifuge.

The following breakdown of the removal and reinstallation percentage of 8.4 was applied. The breakdown is based on data from the RAM study.

Experiment Removal	.55%
Experiment Installation	2.25%
Compatibility Verification	5.6%

In addition to these costs, a 2 percent allowance was made for integration activities to account for planning, scheduling, procedures, etc., of the EU changeout. All percentages were applied to recurring unit costs.

The following recurring operations cost deltas are estimated:

	Two Flights	28 Flight Total
Option 1	$115K	$1456K
Option 2	$ 76K	$ 972K

These cost deltas represent a 4.1 percent and 2.7 percent increase in total estimated recurring operations costs, respectively.

SECTION 6

WBS LEVEL 2 EU COST SUMMARY SHEETS

This section presents all the EU equipment item summary sheets (Tables 6-1 through 6-13) for the Biomedical Emphasis and Bioscience and Technology Laboratories.

TABLE 6-1

EU #1 - VISUAL RECORDS & MICROSCOPY

			COSTS, $K			
EI#	NAME	QTY.	Non-Rec.	Rec-Prod (Unit)	Total	NOTES
3C	Adapter, TV-Microscope	1	0	.5	.5	Skylab data.
32	Camera, Cine	2	10	6	22	Vendor cost.
34	Camera, 35 mm	2	0	1	2	Vendor cost.
37	Camera, Video, B/W	2	1	13	27	Vendor cost.
38	Camera, Video, Color	1	0	100	100	GFE, camera developed by Tele-communications Dev. Div., JSC.
38A	Camera, X-Y Drive	2	200	10	220	Vendor ROM.
76C	Film, 35 mm	4	0	0	0	
76E	Filters, Video	1	0	.5	.5	Vendor & Skylab
116	Log Books	11	.5	.1	.6	Engineering Estimate
126	Microscope, Compound	1	2.0	3.5	5.5	Vendor cost
126G	Monitor, Video	1	12	6	18	Vendor cost
181E	Video I.D. Date Time Sys.	1	-	-	-	Supplied as part of Spacelab Data Management System.
35	Camera, Polaroid	1	0	.5	.5	Vendor cost
	TOTAL EIs		225	171	396	
	Structure/Mechanical Supports		6.2	4.2	10.4	SSPDA CER
	Electrical Power. Cabling, Data Handling		-	-	-	Supplied by Spacelab.
	Systems Test: Hardware 0, Operations 13, Refurbishment 17	Total	30	-	30	
	System Engineering & Integration		38	-	38	
	GSE		65	-	65	
	Management & Administration		18	9	27	
	TOTAL		392	184	566	
	Fee		30	7	37	
	TOTAL		412	191	603	

TABLE 6-2

BIOMEDICAL & BIOSCIENCE SUBLABS

EU #2 - DATA MANAGEMENT

EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
141	Antennas, Assorted	1	1	.5	1.5	ENG ROM & NASA
51	Computer, Digital	-	-	-	-	Supplied as part of Spacelab Data Management System.
56A	Data Mgmt. Sys. Buses	1	-	-	-	
58A	Data Mgmt. Sys.	1	-	-	-	
58B	Data Mgmt. Sys.	4	-	-	-	
63B	Display Keyboard	1	128	43	171	
64	ECG Coupler	12	10	1.2	24	
65	EEG Coupler	4	10	1.2	15	SSPDA CER
66	EMG Coupler	6	10	1.2	17	
132	Oscilloscope	1	54	14.6	69	
138A	Photocells	12	-	-	-	Part of EI 138B.
138B	Phototransistor	12	10	1.2	24	
143G	Coupler-Press. Transducer	4	10	1.2	15	SSPDA CER
150D	Receivers, dc-5MHZ	1	27	6.6	34	SSPDA CER & Vendor Cost
153	Recorder, Voice	1	11	.5	16	ENG ROM Commercial Mod.
156	Signal Cond. Coupler	35	10	1	45	SSPDA CER
176	Tape, Video	1	0	<.1	0	Vendor Cost
180	Timer, Event	2	0	.2	.5	GFE. ENG ROM
181I	Transducer, Pressure	9	0	2	18	Vendor Cost
	TOTAL EIs		281	169	450	
	Structure/Mechanical Supports		0	0	0	
	Electrical Power, Cabling & Data Handling		-	-	-	Supplied by Spacelab.
	Systems Test: Hardware 0, Operations 17, Refurbishment 17	Total	34	-	34	
	System Engineering & Integration		47	-	47	
	GSE		64	-	64	
	Management & Administration		21	8	29	
	TOTAL		447	177	624	
	Fee		36	14	50	
	TOTAL		483	191	674	

TABLE 6-3

EU #3 - LIFE SCIENCES EXPERIMENT UNIT

EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
1	Accelerometer, Activity	3	1.5	.5	3	Vendor Cost
1A	Accelerometer Coupler	3	.5	.1	1	Vendor Cost
55A	Crew Mobility Aids	6	2	.2	3	Skylab Data
55B	Crew Restraints	3	2	.7	4	Skylab Data
76J	Flowmeter, Gas	6	13	.8	18	*
93A	Gas Supply, Assorted	6	50	5.3	82	ERR 1360 CER
187A	Waste Storage Device	4	20	.5	20.5	ENG ROM
143	Power Conditioning Equip.	1	64	24	88	SSPDA CER & Vendor Cost
93C	Gas Conditioning Equip.	1	50	9	59	*
188	Water Conditioning Equip.	1	25	2.8	28	*
118I	Manifold Vacuum	1	30	6.9	37	*
	TOTAL EIs		258	85	344	
	Structure/Mechanical Supports		0	0	0	
	Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab.
	Systems Test: Hardware 0; Operations 15; Refurbishment 8	Total	23	-	23	
	System Engineering & Integration		42	-	42	
	GSE		32	-	32	
	Management & Administration		18	4	22	
	TOTAL		373	89	462	
	Fee		30	7	37	
	TOTAL		403	96	499	

*SSPDA CER for Unit Cost. Parametric Detailed Manloading for Development Cost.

TABLE 6-4

EU #4 - PREPARATION AND PRESERVATION

EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
14	Anesthetizer, Invert.	1	2	4	6	ERR 1630, CER & Vendor Cost
18	Glove Box	1	19	2	21	SSPDA CER & Vendor Cost
18A	Glove Box Liners	60	5	<.1	7	ENG ROM
18B	Glove Box Insert - Radiochemical	1	-	-	-	Deleted. Badges eliminate need for inserts.
41	Centrif. Frig. Hi-Spd	1	124	7	131	SSPDA CER & Vendor Cost
44	Chemicals	1	2.4	.2	3	Δ
44A	Chemicals - Radioactive	1	2.4	.5	3	Δ
48	Cleaner, Vacuum	1	46	2	48	MDAC Study & Vendor Cost
70	Electrophoresis, Appar.	1	45	3	48	SSPDA CER & Vendor Cost
77B	Freezer, Cryo	1	105	20	125	Parametric detailed manloading
81	Freezer, Lo Temp	1	122	12	134	SSPDA CER
83	Frig.	1	65	5	70	SSPDA CER
105	Kit, Bench Chem. Anal.	1	74	6	80	Δ
106	Kit, Hematology	1	74	6	80	Δ
108	Kit, Histology	1	8	.7	9	Δ
110	Kit, Microbiology	1	17.7	1.5	19	Δ
114A	Kit, Microdissection	1	13	1	14	Δ
121	Mass Meas., Macro	1	(300)	8	8	Refurbish existing Skylab backup unit. GFE. New unit cost - $84K.
122	Mass Meas., Micro	1	(225)	5	5	Refurbish existing Skylab backup unit. GFE. New unit cost - $50K.
126A	Microscope, Dissecting	1	1	2	3	Vendor Cost.
159	Stain Sys., Bacteriological	1	(100)	13	13	Use unit developed for Skylab by Beckman. GFE.
179	Temp. Block	2	15	.5	16	SSPDA CER & Vendor Cost
186	Volumetric Meas., Liq.	1	(300)	75	75	Use unit developed for ASTP. GFE.
	TOTAL EIs		741	177	918	
	Structure/Mechanical Supports		37	25	62	SSPDA CER
	Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab.
	Systems Test: Hardware 0; Operations 102; Refurbishment 20 — Total		122	-	122	
	System Engineering & Integration		274	-	274	
	GSE		77	-	77	
	Management & Administration		62	10	72	
	TOTAL		1313	212	1525	
	Fee		105	10	115	
	TOTAL		1418	222	1640	

Δ NASA Skylab detailed estimate.

TABLE 6-5

EU #5 - BIOCHEMICAL AND BIOPHYSICAL ANALYSIS

EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
6	Air Particle Sample Coll.	1	11	1	12	SSPDA CER & Vendor Cost.
7	GEMSAEC (General Medical Sciences AEC)	1	(175)	75	75	Unit being developed by JSC. GFE. Remaining cost - $175K. Non-Rec.
50A	Commutator, Gas Mnfld	1	20	1.7	22	Parametric Manloading Est.
54	Counter, Colony, Manual	1	2	.5	2.5	ENG ROM & Skylab Data
76L	Fibrometer, Blood Clot	1	47	3.4	50	SSPDA CER & Vendor Cost
85	Gas Analyzer, Auto Physio.	1	(200)	50	50	Use unit developed by O'Rion for JSC. GFE
89	Gas Analyzer, GC Complex	1	276	83	359	MDAC CER & Vendor ROM
91	Gas Analyzer, Mass Spec.	2	100	100	300	Use modified Perkin Elmer Viking unit.
125B	Meters, Assorted	4	4	1	8	ENG ROM
125C	Meter, AOTS	1	.5	.5	1	Vendor quote & ENG ROM
138	pH Meter	1	90	26.5	117	SSPDA CER & Vendor Cost
157	Sound Level Meter	1	10	6	16	Vendor Quote & ENG ROM
15A	Atmospheric Manifold Sys.	1	13	3.5	17	Parametric Manloading Estimate
19	Bench, Gen. Exp.	1	148	27	175	SSPDA CER & ENG. ROM
	TOTAL EIs		720	485	1205	
	Structure/Mechanical Supports		31	21	52	SSPDA CER
	Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab.
	Systems Test: Hardware 0; Operations 68; Refurbishment 48	Total	116	-	116	
	System Engineering & Integration		187	-	187	
	GSE		192	25	192	
	Management & Administration		62	34	87	
	TOTAL		1308	531	1839	
	Fee	-	105	33	138	
	TOTAL		1413	564	1977	

TABLE 6-6

EU #6/7 - MAINTENANCE, REPAIR/STORAGE

EU#	EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
6	16E	Bags, Plastic Permeable	250	3.4	3.8	7	Δ NASA Skylab detailed estimate
	19A	Hand Wipes, Betadyne	250	2.4	2	4	Δ
	50B	LSPS Compactor, Solids	1	5	1	6	Vendor Cost & ENG ROM
	106A	Kit, Cleanup	1	40	4	44	Δ
	109	Kit, Linear Meas.	1	1	.1	1	Δ
	110B	Kit, Org. Hold. & Mgmt.	1	13	1.1	14	Δ
	113	Kit, General Tool	1	16	1.4	17	Δ
	165	Sterilizer, Tool	1	5	1	6	Vendor Cost & ENG ROM
	168A	Tags, ID, Organism	2	0	0	0	
	181G	Trash Can	1	2	.5	3	ENG ROM
	185	Voltmeter (DVM)	1	22	4	26	SSPDA CER
		EU #6 TOTAL EIs		110	18	128	
7	15	Chemical Storage Cabinet	1	22	12	34	SSPDA CER
	167B	Storage, General	1	3	2	5	ENG ROM
	167C	Storage, Film	1	3	1	4	ENG ROM
		EU #7 TOTAL EIs		28	15	43	
		TOTAL EU #6 & #7 EIs		138	33	171	
		Structure/Mechanical Supports		19	13	32	SSPDA CER
		Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab
		Systems Test: Hardware		0	0	0	
		Operations 9	Total	14	-	14	
		Refurbishment 5					
		System Engineering & Integration		26	-	26	
		GSE		17	-	17	
		Management & Administration		11	2	13	
		TOTAL		225	49	274	
		Fee		18	4	22	
		TOTAL		243	53	296	

TABLE 6-7

BIOMEDICAL SUBLAB ONLY

EU #12/31 - BEHAVIORAL SUPPORT

EU#	EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
12	51D	Cont. Console Expmtr.	1	233	97	330	SSPDA CER
	65B	Electrophysiology Backpack	1	27	6.6	34	SSPDA CER & Vendor Cost
	65C	Electrophysiology Receiver	1	38	11	49	SSPDA CER & Vendor Cost
	144B	Psychogalvanometer GSR	2	-	-	-	Included in EI 65B
	153A	Rotating Litter Chair	1	(300)	50	50	GFE. Rework Skylab Bonded Backup. New unit - $300K.
		EU #12 TOTAL		298	165	463	
31	18C	Exercise Physiology Equipment	1	(339)	18	18	GFE. Rework Skylab Unit.
	76K	Flowmeter, Doppler	2	10	.4	11	NASA ARC Data
	110C	Kit, Physiology	1	19	2	21	Skylab Detailed Estimate
	125P	Metabolic Analyzer, Fixed	1	(379)	5	5	GFE. Rework Skylab Bonded Backup.
	139	Plethysmograph, Limb	1	37	1	38	SSPDA CER & Vendor Cost
	181B	Transducer-Plethysmo.	4	-	-	-	Included in EI 139.
	182J	Coupler, Vectorcardiogram	1	10	1	11	SSPDA CER
	76M	Ultrasonoscope	1	(400)	50	50	GFE. Use Ames unit presently under development.
	117	LBNP	1	(181)	18	18	GFE. Rework Skylab Bonded Backup
		EU #31 TOTAL		76	96	172	
		TOTAL EU #12/31 EIs		374	261	635	
		Structure/Mechanical Supports		19	13	32	SSPDA CER
		Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab.
		Systems Test: Hardware 0; Operations 120; Refurbishment 26	Total	146	-	146	
		System Engineering & Integration		320	-	320	
		GSE		104	-	104	
		Management & Administration		48	13	61	
		TOTAL		1011	287	1298	
		Fee		81	14	95	
		TOTAL		1092	301	1393	

TABLE 6-8

BIOMEDICAL AND BIOSCIENCE & ADVANCED TECHNOLOGY LABORATORY - COMMON

EU 23 - BIORESEARCH CENTRIFUGE

EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
43	Bioresearch Centrifuge (Stopped Transfer)	1	977	277	1254	SSPDA CER
50	Clinostat	1	3	.7	4	NASA ARC data.
	Structure/Mechanical Supports		0	0	0	
	Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab.
	Systems Test: Hardware 0, Operations 0, Refurbishment 28 } Total		28	-	28	Included in development cost for EI 43.
	System Engineering & Integration		0	-	0	Included in development cost for EI 43.
	GSE		105	-	105	
	Management & Administration		56	14	70	
	TOTAL		1159	292	1461	
	Fee		94	23	117	
	TOTAL		1263	315	1578	

TABLE 6-9

BIOMEDICAL AND BIOSCIENCE & ADVANCED TECHNOLOGY LABORATORY - COMMON

EU #26 - RADIOBIOLOGY SUPPORT

EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
16D	Badges, Radiation	52	0	<.1	0	
144C	Radiation Detector	1	0	2	2	GFE. Use Orbiter unit.
150	Radiation Source Storage	1	208	60	268	SSPDA CER
	TOTAL EIs		208	62	270	
	Structure/Mechanical Supports		6	4.2	10	SSPDA CER
	Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab.
	Systems Test: Hardware 0, Operations 13, Refurbishment 6	Total	19	-	19	
	System Engineering & Integration		35	-	35	
	GSE		24	-	24	
	Management & Administration		15	3	18	
	TOTAL		307	69	376	
	Fee		25	5	30	
	TOTAL		332	74	406	

TABLE 6-10

BIOMEDICAL AND BIOSCIENCE & ADVANCED TECHNOLOGY LABORATORY - COMMON

EU #40/41/42 - VERTEBRATE HOLDING & SUPPORT

EU#	EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
40	30A	Cage, Rat/Hamp./Quail	16	224	3.2	275	SSPDA CER
	76H	Flowmeter, Coupler	16	5	.1	6	*
	76F	Flowmeter, H_2O Manifold	16	20	.6	27	*
	103	Holding Unit, Small Vert.		0	0	0	EI 103 replaced by EI 99.
	99	Common Holding Unit	2	1544	55	1654	SSPDA CER & Manloading.
	118D	Manifold, Organism, H_2O	1	15	.7	16	*
		EU #40 TOTAL EIs		1808	170	1978	
41	28A	Cage, Monk Macac	2	615	51	717	SSPDA CER
42	115	Kit, Veterinary	1	35	3	38	Skylab detailed estimate
	150B	Receiver, Exg. Cage Mod.	2	21	5	31	SSPDA CER & Vendor Cost
	155A	Sensor, Implanted	12	1	.5	7	ENG Estimate & Vendor Cost
	177	Temperature Sensors, Body	32	1	.5	17	ENG Estimate & Vendor Cost
	181C	Xdcer, Blood Pres.	6	2	.5	5	ENG Estimate & Vendor Cost
		EU #42 TOTAL EIs		60	38	98	
		EU #40/41/42 TOTAL EIs		2483	310	2793	
		Structure/Mechanical Supports		0	0	0	
		Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab
		Systems Test: Hardware 0; Operations 6; Refurbishment 31	Total	37	-	37	EI 28A, 30A & 99 test costs included in their development.
		System Engineering & Integration		15	-	15	EI 28A, 30A & 99 costs included in their development.
		GSE		118	-	118	
		Management & Administration		133	16	149	
		TOTAL		2786	326	3112	
		Fee		233	26	259	
		TOTAL		3019	352	3371	

*Parametric Manloading Estimate for development & SSPDA CER for Unit Cost.

TABLE 6-11

BIOMEDICAL AND BIOSCIENCE & ADVANCED TECHNOLOGY LABORATORY - COMMON

EU #60/61 - CELLS & TISSUES

EU#	EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod	Total	NOTES
60	98A	Holding Unit, Incub. Cells	2	47	8	55	SSPDA CER
	99	Common Holding Unit	2	0*	110	110	SSPDA CER
61	124	Media, Prepared	2	5.8	1	7	Skylab Estimate
		TOTAL EU #60/61 EIs		53	119	172	
		Structure/Mechanical Supports		0	0	0	
		Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab.
		Systems Test: Hardware 0 Operations .5 Refurbishment 12	Total	12	-	12	EI 98A costs included under its development.
		System Engineering & Integration		1	-	1	EI 98A costs included under its development.
		GSE		45	-	45	
		Management & Administration		6	6	12	
		TOTAL		117	125	242	
		Fee		9	10	19	
		TOTAL		126	135	261	

*Development Cost included under EU 40 ($1544 K).

TABLE 6-12

BIOSCIENCE & ADVANCED TECHNOLOGY LABORATORY ONLY

EU #50/51/70 - PLANT HOLDING & SUPPORT/INVERTEBRATES

EU#	EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
50	101	Holding Unit, Plant	1	184	10	194	SSPDA CER
	99	Common Holding Unit	1	0*	55	55	SSPDA CER
51	111	Kit, Plant Tools	1	10.5	.9	11	Skylab Data
70	98C	Holding Unit Incub. Invert.	1	47	4	51	SSPDA CER
	99	Common Holding Unit	1	0*	55	55	SSPDA CER
	113A	Kit, Tool, Insect Manip.	1	7.1	.6	8	Skylab Data
		TOTAL EU #50/51/70 EIs		249	125	374	
		Structure/Mechanical Supports		0	0	0	
		Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab.
		Systems Test: Hardware 0; Operations 1; Refurbishment 12	Total	13	-	13	EI 101, 98C & 99 test costs included in their development costs.
		System Engineering & Integration		3	-	3	EI 101, 98C & 99 costs included in their development costs.
		GSE		47	-	47	
		Management & Administration		16	6	22	
		TOTAL		328	131	459	
		Fee		26	10	36	
		TOTAL		354	141	495	

*Development cost included under EU 40 ($1544 K).

TABLE 6-13

BIOSCIENCE SUBLAB ONLY

EU #80 - LIFE SUPPORT SUBSYSTEM TEST UNIT,

EU #91/93 - BEHAVIORAL MEASUREMENTS UNIT/MOBILITY UNIT

EU #	EI#	NAME	QTY.	COSTS, $K Non-Rec.	Rec-Prod (Unit)	Total	NOTES
80	115F	LSS Test Bench	1	670	86	756	SSPDA CER
91	50C	Console Behav. Measurements		-	-	-	Provided by EI 58A, EU #2.
	144C	Psychomotor Perf. Console	1	233	97	330	SSPDA CER
93	15	Anthropometric Grid	1	10	1	11	ENG ROM
	126I	Mobility Unit, Protective [illegible] idor	1	32	3	35	SSPDA CER
		TOTAL EU #80,91/93 EIs		945	187	1132	
		Structure/Mechanical Supports		6	4.2	10.2	
		Electrical Power, Cabling, Data Handling		-	-	-	Supplied by Spacelab.
		Systems Test: Hardware 0; Operations 57; Refurbishment 19	Total	76	-	76	
		System Engineering & Integration		154	-	154	
		GSE		72	-	72	
		Management & Administration		63	10	73	
		TOTAL		1316	201	1517	
		Fee		105	16	121	
		TOTAL		1421	217	1638	

SECTION 7

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2. NASA PD-MP-S-73-90, from Chester B. May to George Drake, Subject: Guidelines for Task A of Contract NAS8-30288, August 22, 1973.

3. PD-MP-S-73-122, from Chester B. May to Addressees, Subject: Selection of Life Sciences Commercial Equipment for Tests of Compatibility with the Spacelab, December 3, 1973.

4. "NASA Activities" publication, Vol. 3, No. 9, September 15, 1972, and Aviation Week and Space Technology dated September 25, 1972.

5. CASD-ERR-73-010, Low Cost Shuttle Payload Requirements Analysis, Convair Aerospace Division of General Dynamics, RD-1 No. 111-7119-352.

6. Research and Applications Modules (RAM) Phase B Study, GDCA-DDA72-008, Contract NAS8-27539, 12 May 1972.

7. ITEK, LST Phase A Study (NAS8-27948), Report 72-8409-4, January 8, 1973.

PART II

DATA MANAGEMENT REQUIREMENTS STUDY FOR THE DEDICATED 30-DAY LIFE SCIENCES LABORATORY

SECTION 1
INTRODUCTION

This study was performed as an adjunct to the data management subsystem (DMS) study performed in the preceding Life Sciences Payload Definition and Integration (LSPD) Study (Task C & D), NAS8-29150, Reference 1. A brief summary of the previous study is continued below.

1.1 SUMMARY OF LIFE SCIENCES PAYLOAD DEFINITION AND INTEGRATION STUDY (TASKS C & D)

The purpose of the Task C & D DMS Study was: (1) to estimate the data management requirements of the life sciences laboratories being investigated, and (2) to determine whether the SPACELAB, in which they were to be housed, contained sufficient DMS equipment for their support. The SPACELAB was referred to as the Sortie Module in the Task C & D study. At that time, the SPACELAB design included a mini-computer, a display and control console, and a digital control unit for controlling signals transmitted serially throughout the laboratory on a data bus which could handle a maximum rate of 1000 kbps. All communications to ground were provided by the Shuttle Orbiter communications system, through the manned spaceflight network (MSFN). Long-term data storage was accomplished by on-board recording, using three magnetic tape recorders—one video recorder, and two general purpose analog or digital recorders.

The life sciences laboratory requirements were estimated during Task C & D for 3 laboratories. The largest (worst-case) laboratory was the 30-Day Dedicated Laboratory, which is the subject of the current study. For the equipment within the 30-Day Laboratory, the average sampled digital data output rate was approximately 45 kbps, with a peak rate of approximately 90 kbps. These rates could readily be handled by the previously proposed SPACELAB data bus and the resulting data could be stored using the SPACELAB tape recorders. The requirements of the 30-Day Dedicated Laboratory in the area of video data recording, however, were quite large. Three recorders, in addition to those provided by SPACELAB, were needed to accommodate the video data. Also, approximately 1100 kg (2400 lb) of tape were needed for the 30-day mission duration.

1.2 STUDY OBJECTIVES

The current study was intended to further investigate the data management requirements of the 30-Day Dedicated Life Sciences Laboratory. This included updating the digital data rates and video requirements per the reductions in the 30-day laboratory equipment which were made by NASA's Life Sciences Working Group subsequent to the Task C & D study. The current study was also intended to investigate the need for alternative data handling techniques. These included the use of manual versus automatic data handling and the use of downlinking versus on-board storage for the purpose of long-term data preservation. The current SPACELAB proposals utilize the Tracking and Data Relay Satellite (TDRS) for downlinking all data rather than on-board storage. Therefore, this mode of long-term preservation was the one primarily considered in this study. Because of the reduced equipment in the Dedicated 30-Day Laboratory and the increased capability of the current SPACELAB command and data management subsystem (CDMS), manual data handling techniques were not needed from the standpoint of reducing the load on the CDMS. However, the philosophy used in formulating the life sciences laboratory requirements was that of using manual techniques whenever this was compatible with the equipment and such equipment was being attended to by a crewman.

SECTION 2
UPDATED SPACELAB DMS DEFINITION

The SPACELAB is currently being studied by two potential major contractors in Europe. Its detailed design and characteristics have yet to be finalized, and it is therefore not possible to determine the final properties of the Command and Data Management Subsystem (CDMS). The latest information on the design proposed by MMB/Convair/Martin is described herein. A block diagram outlining the major features of the SPACELAB CDMS is shown in Figure 1. The following paragraphs contain a description of this system.

Acquisition and distribution of low-rate sampled data is performed by two data buses, one for subsystems and another for payloads.

The data buses interface with subsystem and payload instrumentation through multiplexer-demultiplexer units (MDUs), each capable of transferring data to and from up to 256 channels each. Each bus consists of two shielded pair cables, one dedicated to command and data transfer to the MDUs, and the other dedicated to response and data transfer from the MDU. Each bus can transmit data at a rate of 1 Mbps.

The bus controller in Figure 1 is a programmable digital sequencer, capable of generating synchronous patterns of commands for the MDUs and routing the incoming responses to the appropriate experiment. It drives the two buses and distributes data to the maintenance recorder, to the low-rate telemetry (25 Kb/s), and to the on-board computers. Dialogue between the bus controller and the on-board computers takes place on program-controlled input/output channels and on Direct Memory Access (DMA) channels. The bus controller also receives the 2 Kb/s command line from the Orbiter and routes the commands to their destinations. Storage of low-rate data is performed by a maintenance recorder having the capability to store selected bus data up to a rate of 1 Mbps.

On-board processing is performed by two identical, general purpose computers, with a third included as a back-up. One computer is dedicated to subsystems and the other to payloads. The advantage of such an arrangement is to keep payload software completely separate from that of subsystems and to allow the users (scientists) to write their application programs freely, without having to worry about interferences with subsystem software. The following processing task will be handled by the payload devoted computer.

- Experiment data handling
- Experiment data processing
- P/L housekeeping, status monitoring and checkout
- Operator interface (via video terminals)
- Supervision of P/L bus control.

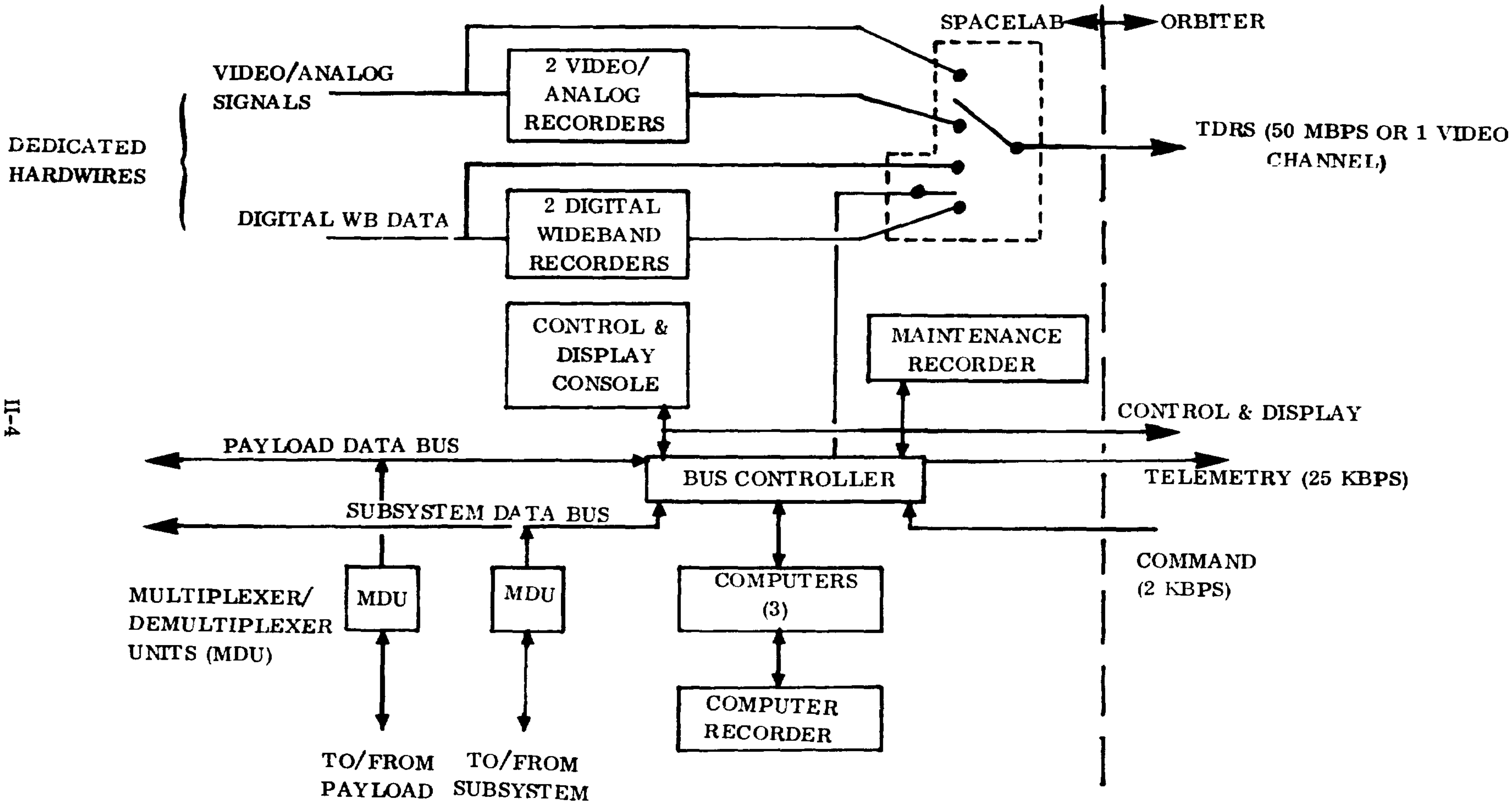

Figure 1. SPACELAB CDMS Block Diagram.

The type of computer proposed for SPACELAB would be an existing process control computer which will be rebuilt and repackaged in a low power, low weight configuration. Its major characteristics will be similar to those shown below.

- Word length: 16 bits
- Instruction Set: 32 basic functions (including all four arithmetic operations), more than 200 variants
- Floating point: provided as an add-on to basic processor
- Memory speed
  - cycle time: 1 μs
  - access time: 0.4 μs
  - memory words: 48 k
- Physical characteristics (48 k by 16 bits core)
  - volume: 55 dm^3 (1.9 ft^3)
  - weight: 20 to 30 kg (44 to 66 lb)
  - power: 80 watts (memory access rate: 500 kw/s)

One computer recorder plus another for back-up will be carried on-board to store all flight software, i.e., that which is to reside permanently in the core memories (for reloading), plus programs which do not normally reside in the core memories but are recalled during some mission phases.

For high rate data acquisition and storage, hardlines are used to interconnect the data sources to the wideband digital and analog (including video) recorders or to the TDRS link to ground. This data can also be routed to the computer direct memory access channels for processing. Equipment is available to multiplex and format high rate digital data into a serial bit stream of up to 30 Mbps (expandable to 50 Mbps). Since the TDRS coverage will not be continuous, but will be available for approximately 85 percent of the time, the wideband digital recorders will be used to store the high rate data in between periods of transmission to ground.

Another use of the recorders which may be applicable to the Dedicated 30-Day Laboratory is a mode of operation where low-rate data is recorded at low recorder speed and subsequently transmitted to ground at maximum recorder speed. This would avoid tying up the TDRS link for long periods at less than full utilization. The digital wideband recorders can be used to record data from the bus as well as from hardwired high rate sources if this is required. This also might be a preferable mode of operation for the Dedicated 30-Day Laboratory since very few high rate digital data sources are anticipated.

The digital wideband recorders currently being considered for SPACELAB will be similar if not identical to the Odetics DDS-2200. The characteristics of this recorder are listed below.

Data storage	4×10^{10} bits
Tape length	2930 m (9600 ft)
Tape width	2.54 cm (1.0 inch)
Data tracks	26 (plus 2 servo edge tracks)
Input data rates	10/15/20/25/50 MB/S
Record speeds	74.2/111/148/185/371 cm/sec (29.2/43.8/58.4/73/146 ips)
Packing density per track	5.2 KB/cm (13.2 KB/in.), (Delay Modulation)
Error rate	1 in 10^6
Output data rate	50 MB/S
Output stability	1% (Dejittered)
Reproduce speed	371 cm/S (146 ips)
Record power	35–40 watts (28 VDC nom)
Reproduce power	135 watts
MTBF	5000 hours
Size	Transport 55 × 37.5 × 16 cm (21.7 × 14.8 × 6.3 in.) Electronics 19.5 × 19.5 × 16 cm (7.7 × 7.7 × 6.3 in.)
Weight	29.5 kg (65 lb)

At the lowest recording speed of 74.2 cm/sec (29.2 ips), a single 2,930 meter reel of tape would last approximately one hour. Playback of this data for downlinking would take only 13 minutes.

Video or analog data are recorded on two Odetics VRS-3000 recorders. These have the following characteristics:

Input signal	DC - to 6 MHz
SNR	≥ 35 db
Recording Time	30 minutes (for payload video)
Power	90 watts
Weight	25 kg (55 lb)
Dimensions	Transport: 37.5 × 47.5 × 18.5 cm (14.8 × 18.7 × 7.3 in.) Electronics: 18.5 × 47.5 × 18.5 cm (7.3 × 18.7 × 7.3 in.)
MTBF	≥ 5000 hours

The SPACELAB control and display (C&D) console provides for crew interaction with the CDMS. It provides the capability for monitoring and control of subsystem and payload operations, as well as voice and visual communications within the SPACELAB and between the SPACELAB and the Orbiter. The C&D console includes:

- Two independent alphanumeric display systems (38 cm CRTs)
- Two independent alphanumeric functional keyboards
- TV monitor (13 × 18 cm display)
- A 2-axis joystick controller for CCTV camera control
- Digital readouts and timers
- Microfilm viewer
- Intercom panel
- Subsystem and experiment dedicated equipment
- Caution & Warning display

The 2 black and white closed circuit TV (CCTV) cameras will be similar to the Orbiter camera and can be plugged into connectors at various locations within the SPACELAB. They will have the following characteristics:

- Diagonal field of view: Variable from 54° to 9°
- Iris variation: 10 to 1 minimum ratio, automatically controlled
- Sensitivity: T.B.D.
- Linearity: 5% maximum non-linearity
- Image characteristics: 525 lines per frame, 30 frames per second, 60 fields per second, 2 to 1 interlace, 4 to 3 aspect ratio.
- Position control: Pan angle ± 170°, tilt angle +85° to −45° minimum.

SECTION 3

LIFE SCIENCES LABORATORY REQUIREMENTS

3.1 SAMPLED DATA HANDLING REQUIREMENTS

The sampled data handling requirements for the major data generating equipment items aboard the Dedicated 30-Day Laboratory were estimated based upon the analysis of the data requirements of these items performed during the LSPD Task C&D effort. In some cases, this data was updated based upon better information which became available on the individual equipment items. The pertinent results of this work are summarized in Table 1.

The table contains the name and number of each equipment item (E.I.) and describes the measurement to be made. Continuous (24-hour) sampling of data is required for some of the E.I.s and this is listed in the table in terms of the bits per second sampling rate. Also listed is the total daily estimated number of bits to be handled by the CDMS from each E.I. These total daily values may be made up of intermittent bursts of relatively high rate data or continuous low rate data. The sum of all these total daily values indicates the total preservation requirement for the Dedicated 30-Day Laboratory. In all cases, 100 percent preservation was assumed in the event that later data analysis on the ground was desirable. Preservation can be accomplished by either storing the data on-board or by downlinking all data to the ground. In the event that all data is stored on board (not presently proposed for SPACELAB), a certain proportion would still have to be downlinked in order to satisfy the research requirements of the principal investigators. This proportion has been estimated for each equipment item and entered in Table 1. This downlinking would generally not need to be in real time. The display required for each E.I. is indicated in the table and may include a numeric readout device, CRT, and a warning device.

Several types of simple computer processing of the data are also qualitatively described in the table. These include wave form analysis, out-of-limits comparison, rate-of-change analysis, etc. Some wave form analysis would be desirable for the electrophysiological signals, such as analysis of ECG signals to obtain heart rate. Complicated wave form analysis such as the analysis of the QRS complex of the ECG is not expected to be required on board. Such complex analysis would more likely be performed by the principal investigators on the ground. Another type of wave form analysis might be performed on the output of the gas chromatograph to determine peak heights versus time for the identification of various gaseous constituents. Out-of-tolerance analysis would be performed on some signals in order to ensure that various parameters within the laboratory are being maintained within operational limits.

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TABLE 1. DEDICATED 30-DAY LABORATORY SAMPLED DATA HANDLING REQUIREMENTS

EQUIPMENT UNIT (EU NO.) & EQUIPMENT ITEM (E.I. NO.)	MEASUREMENT DESCRIPTION OR COMMENT	SAMPLED DATA REQUIREMENTS: Sampling Rate bps	Sampling Duration min/day	Total kbits per day	DOWNLINK REQMTS. %	kbits/day	DISPLAY REQUIRED	PROCESSING REQUIRED BY CONTROL COMPUTER OR LOCAL ELECTRONICS
Data Management Unit (EU2)								
Display/Keyboard, Portable (63B)	Provides crew guidance at the experiment site. Includes alphanumeric & CRT displays and control keyboard. This device was assumed to be hard wired to the DMS.	0	0	0	0	0	None	The portable display keyboard will require considerable software specific to the experiments being supported.
Couplers, ECG (64), EEG (65), and EMG (66)	Conditions electrophysiological signals from organisms or man. Assumed 6 continuous and 16 intermittent signals.	21,000 56,000	cont. 10 (typical)	1,814,000 33,600	0.1 5	1814 1680	Numeric, CRT, & Warning	Wave form analysis and comparison.
Oscilloscope (132)	Portable unit for display at the experiment site - hard wired to couplers (above) or other sensors which provide the interface to the DMS.	0	0	0	0	0	None	None other than that provided internal to the oscilloscope.
Photocell Couplers (138B)	Monitors light levels in various cages and cage modules including those for plants.	84	cont.	7,260	0	0	Numeric & Warning	Out-of-tolerance comparison.
Pressure Sensor Couplers (143G)	For blood pressure measurements.	2,800	17	2,856	1	28	Numeric & CRT	None.
Signal Conditioners (156)	For miscellaneous physical and physiological measurements.	2,450	21	3,087	1	31	Numeric & CRT	Out-of-tolerance comparison.
	TOTALS	21,084 61,250	cont. intermitt.	1,860,803		3553		
Life Sciences Support Unit (EU 3)								
Accelerometer Coupler (1A)	Measures crew body accelerations.	10,500	60	37,800	1	378	Numeric & CRT	Simple wave form analysis.
Gas Supplies (93A)	Monitors gas vessel pressures.	1	cont.	60	0	0	Numeric & Warning	Rate-of-change analysis.
Power Conditioning Equipment (143)	Includes 6 voltage and amperage monitors.	1	cont.	60	0	0	Numeric & Warning	Out-of-tolerance comparison.
Water Conditioning Equipment (188)	Includes water tank expulsion bladder pressure monitors.	negl.	cont.	40	0	0	Numeric & Warning	Out-of-tolerance comparison.
	TOTALS	2 10,500	cont. intermitt.	37,960		378		
Preparation & Preservation Unit (EU4)								
Freezer, Cryogenic (77B)	Monitor freezer temp. and pressure.	negl.	cont.	14	0	0	Numeric & Warning	Out-of-tolerance comparison.
Freezer, Low Temp. (81)	Monitor temperature.	negl.	cont.	1	0	0	Numeric & Warning	Out-of-tolerance comparison.
Frig. (Refrigerator) (83)	Monitor temperature.	negl.	cont.	1	0	0	Numeric & Warning	Out-of-tolerance comparison.
	TOTALS	0		16		0		
Biochemical/Biophysics Analysis Unit (EU 5)								
Autoanalyzer (7)	Data entered includes specimen I.D., type of analysis, and measured value.	negl.	33	5	5	negl.	Numeric	Processing assumed to be done internal to the autoanalyzer.
Commutator, Gas Manifold (50A)	Monitor commutation valve position to determine source of gas being analyzed.	negl.	cont.	6	0	0	Numeric	None.
Fibrometer, Blood Clot (76L)	Data entered includes specimen I.D. and clotting time.	1	4	negl.	5	negl.	Numeric	Processing is performed internal to the automatic fibrometer.
Blood Gas Analyzer (85)	Based on use of NASA's Automated Potentiometric Electrolyte Analyzer. measurements could include pH, CO_2, O_2, K, Ca, Na, Cl, and glucose.	6	15	5	30	2	Numeric	Linear interpolation program required.
Gas Chromatograph (89)	Monitor GC parameters during operation and measure gas concentration values.	37	240	532	1	5	Numeric, CRT, Warning	Wave form analysis.
Mass Spectrometer (91)	Monitors digital output for matter/buffer containing information on mass number and peak heights of gases found during mass scans to detect trace constituents as well as major atmospheric components.	600	cont.	51,840	1	518	Numeric, CRT, Warning	Complex computer processing involving matrix manipulations may be required depending upon experiment requirements.
Sound Level Meter	Monitor laboratory sound levels.	14	cont.	1,210	0	0	Numeric	None.
	TOTALS	614 44	cont. intermitt.	53,598		525		

TABLE 1 (CONT'D)

DEDICATED 30-DAY LABORATORY SAMPLED DATA HANDLING REQUIREMENTS

EQUIPMENT UNIT (EU NO.) & EQUIPMENT ITEM (E.I. NO.)	MEASUREMENT DESCRIPTION OR COMMENT	SAMPLED DATA REQUIREMENTS Sampling Rate bps	Sampling Duration min/day	Total kbits per day	DOWNLINK REQMTS %	kbits/day	DISPLAY REQUIRED	PROCESSING REQUIRED BY CONTROL COMPUTER OR LOCAL ELECTRONICS
Biomedical/Behavioral Research Support Unit (EU 12)								
Electrophysiological Receiver (65C)	Monitors electrophysiological signals from man and vertebrates.	14,000	53	44,520	1	445	CRT	Wave form analysis.
Rotating Litter Chair (153A)	Measure experimental data such as subject responses, and monitor operational parameters such as rpm and acceleration.	2753	158	26,100	1	261	Numeric & Warning	Out-of-tolerance comparison.
	TOTALS	0 16,753	cont. intermitt.	70,620		706		
Biomedical Research Support Unit (EU 31)								
Exercise Equipment (bicycle ergometer used as a basis of data reqm'ts (18C)	Monitor ergometer parameters such as energy output.	13	37	29	5	1	Numeric	To be determined.
Flowmeter, Doppler (76K)	Measures instantaneous blood velocity in peripheral vessels.	700	31	1,302	1	13	CRT	To be determined.
Ultrasonoscope (76M)	Displays cross-sectional view of the heart on an oscilloscope which is included as part of the E.I. Video camera will be used to document the image.	0	N.A. (not applicable)	0	N.A.	N.A.	None	None.
Metabolic Analyzer (125D)	Data readouts include O_2 consumed, CO_2/O_2 ratio, respiratory minute volume, vital capacity, % CO_2, % H_2O, and % O_2. Processing to yield this data is performed internal to the E.I.	25	77	116	1	1	Numeric	Processing, if required, will depend upon specific experiments.
Coupler, Vectorcardiogram (182J)	Converts VCG signals to a format usable by the DMS interface units.	21,000	5	20,951	1	209	CRT	Probable processing will include matrix manipulation & wave form analysis.
	TOTALS	0 21,738	cont. intermitt.	22,398		224		
Small Vertebrate Holding Unit (EU 40)								
2 Cage Modules (103)	Monitor temp., air flow, humidity, pressure & feeder.	7	cont.	605	1	6	Numeric & Warning	Out-of-tolerance comparison & simple computations.
Primate Holding Unit (EU 41)								
2 Cages, Primate (28A)	Monitor temp., air flow, humidity, pressure & feeder.	7	cont.	605	1	6	Numeric & Warning	Out-of-tolerance comparison & simple computations.
Vertebrate Research Support Unit (EU 42)								
Couplers, Flowmeter (76H)	Monitors water flow at various points in the laboratory.	28	cont.	2,419	0	0	Numeric	Possible integration.
Transducer, Blood Pressure (181C)	Measure vertebrate blood pressure wave contour.	50	27	567	5	28	CRT	Possible wave form analysis.
	TOTALS	28 50	cont. intermitt.	2,986		28		

TABLE 1 (CONT'D)

DEDICATED 30-DAY LABORATORY SAMPLED DATA HANDLING REQUIREMENTS

EQUIPMENT UNIT (EU NO.) & EQUIPMENT ITEM (E.I. NO.)	MEASUREMENT DESCRIPTION OR COMMENT	SAMPLED DATA REQUIREMENTS: Sampling Rate bps	Sampling Duration min/day	Total kbits per day	DOWNLINK REQMTS.: %	kbits/day	DISPLAY REQUIRED	PROCESSING REQUIRED BY CONTROL COMPUTER OR LOCAL ELECTRONICS
Plant Holding Unit (EU 50) Holding Unit, Plants (101)	Monitor temp., air flow, humidity, and pressure.	2	cont.	173	1	2	Numeric & Warning	Out-of-tolerance comparison.
Plant Research Support Unit (EU 51) Clinostat (50)	Monitor rotation rate.	negl.	cont.	10	0	0	Numeric	None.
Cells & Tissues Holding Unit (EU 60) 2 Holding Units, C/T (98A)	Monitor temperature, air flow, and humidity.	3	cont.	259	1	3	Numeric	Out-of-tolerance comparison.
Invertebrate Holding Unit (EU 70) Holding Unit, Invertebrates (98C)	Monitor temperature, air flow, humidity.	1	cont.	86	1	1	Numeric	Out-of-tolerance comparison.
Life Support Subsystem Test Unit (EU 80) LSS Test Bench (115F)	Monit r data from a typical test item such as Bosch reactor t, p, flow, etc.	24	cont.	2,074	1	21	Numeric	Out-of-tolerance comparison. Various performance calculations.
MSI Measurements Unit (EU 91) Psychomotor Performance Console (144)	Monitor sensor outputs which measure crews ability to perform various psychomotor tasks such as tracking, steadiness, pattern recognition, etc.	20	12	1,728	5	86	Numeric	Unknown but could be substantial.
Bioresearch Centrifuge (EU 23) Bioresearch Centrifuge (43)	Monitor vertebrate environmental parameters and centrifuge operational parameters.	11	cont.	1,210	0	0	Numeric	Out-of-tolerance comparison.
	TOTALS (FOR ALL EU'S)	21,786	cont.	2,055,131		5,539		

The couplers (ECG, EEG & EMG) shown in Table 1 are important sources of data. They are used to condition electrophysiological signals for input in the CDMS MDUs. A total of 22 couplers are specified for the Dedicated 30-Day Laboratory. It was assumed that 16 of these couplers would be used only intermittently with an average use time of 10 minutes per day. This was based on the use times of these items developed during the previous Task C&D contract (as were most of the sampling durations shown in Table 1). The remainder of the couplers, 6 in number, were assumed to be on continuously, as would be the case if these couplers were receiving signals from sensors permanently attached to organisms in the laboratory. This is an important assumption since electrophysiological data constitutes the major source of relatively high rate data to be handled within the Dedicated 30-Day Laboratory. Out of 21,786 bps total data rate which must be handled on a continuous basis, 21,000 bps result from the assumed 6 continuously monitored electrophysiological couplers. Thus, changes in assumptions concerning electrophysiological data acquisition can produce major impacts on the life sciences laboratory data requirements. This statement applies not only to E.I.s 64, 65 & 66 but also to other electrophysiological data sources such as the electrophysiological receiver (EU 12, E.I. 65C), the vector-cardiogram coupler (EU 31, E.I. 172J), etc. Other potential sources of high rate data are the accelerometer couplers (EU 3, E.I. 1A) but these will generally operate only intermittently. They are used to monitor accelerations experienced by human subjects undergoing various tests. They were estimated to be used only 1 hour per day.

Another important type of data acquisition typical of the life sciences laboratory is that associated with the holding units. For example, the small vertebrate holding unit requires monitoring of temperatures, air flow, relative humidity, pressure, and possibly feeder status. Most of this data was assumed to be monitored at the relatively low rate of 1 sample every 10 seconds. Although this is conservatively fast with respect to the monitoring requirements, it is negligible with respect to the overall capability of the SPACELAB data handling capability. Considering all the monitored parameters, the average continuous bit rate of two small vertebrate cage modules is 7 bits/second, as shown in Table 1. It was estimated that about 1 percent of this data would be of interest to principal investigators on the ground. Displays which are required include a numeric read-out on which any desired parameter could be read out, and a warning device to warn of life endangering or experiment invalidation conditions existing within the small vertebrate cage module. Computer processing could include out-of-tolerance comparisons for some of the parameters as well as simple computations such as counting, integration, etc. All such computations can be performed by local special processing electronics rather than by the control computer if desired.

A summary of the sampled acquisition requirements of the Dedicated 30-Day Laboratory is contained in Table 2. For each equipment unit, the continuous, total daily, and downlinked data requirements are tabulated. By far the largest portion of the data comes from the data management unit and results from the electrophysiological

TABLE 2

LIFE SCIENCES LABORATORY SAMPLED DATA REQUIREMENTS SUMMARY

E.U. NO.	EQUIPMENT UNIT NAME (NO. & NAME OF HIGH RATE E.I.'S)	E.U. SAMPLED DATA RATES			HIGH RATE E.I.'S	
		CONTINUOUS BPS	TOTAL DAILY KBITS	DOWNLINKED KBITS	SAMPLING RATE, KBPS	SAMPLING DURATION, MIN.
2	DATA MANAGEMENT	21,084	1,860,803	3553		
	(64, 65, & 66, COUPLERS, ECG, EEG, & EMG)				56 (16 Couplers)	10
3	LIFE SCIENCES EXPERIMENT SUPPORT	2	37,960	378		
	(1A, COUPLER, ACCELEROMETER)				11	60
4	PREPARATION & PRESERVATION	NEGL.	16	0		
5	BIOCHEMICAL/BIOPHYSICS ANALYSIS	614	53,598	525		
12	BIOMEDICAL/BEHAVIORAL RESEARCH SUPPORT	0	70,620	706		
	(65C, ELECTROPHYSIOL. RECEIVER)				14	53
31	BIOMEDICAL RESEARCH SUPPORT	0	22,398	224		
	(182J, COUPLER, VCG)				21	5
40	SMALL VERTEBRATE HOLDING	7	605	6		
41	PRIMATE HOLDING	7	605	6		
42	VERTEBRATE RESEARCH SUPPORT	28	2,986	28		
50	PLANT HOLDING UNIT	2	173	2		
51	PLANT RESEARCH SUPPORT	NEGL.	10	0		
60	CELLS/TISSUES HOLDING	3	259	3		
70	INVERTEBRATE HOLDING	1	86	1		
80	LIFE SUPPORT SUBSYSTEM TEST	24	2,074	21		
91	M.S.I. MEASUREMENTS	0	1,728	86		
23	BIORESEARCH CENTRIFUGE	14	1,210	0		
	TOTALS	21,786	2,055,131	5539		
	APPROXIMATE CONTINUOUS DATA RATE	22 KBPS				
	50% OVERHEAD FACTOR	11 KBPS				
	AVERAGE CONTINUOUS DATA RATE	33 KBPS				
	INTERMITTENT DATA RATE (8 COUPLERS)	~ 28 KBPS				
	TYPICAL MAXIMUM DATA RATE	61 KBPS				

couplers. The approximate total continuous data rate for the laboratory is 22 Kbps. Adding a 50 percent overhead factor to account for scheduling loss and transmission of parity, synchronization and I.D. information results in an average continuous rate of 33 Kbps.

Superimposed upon this average rate will be short periods of relatively high rate data from several E.I.s throughout the laboratory. These E.I.s are also shown in the table along with their maximum data rates and sampling durations. The highest rate results from the 16 electrophysiological couplers which are on an average duration of 10 minutes each. It is unlikely that all couplers would be operating simultaneously. Therefore, it was assumed that about half of them might be operating, thus adding 28 Kbps to the average continuous data rate. Thus, a typical maximum data rate is 61 Kbps for the Dedicated 30-Day Laboratory.

The values shown in Table 2 and discussed above may be compared with those estimated for the Dedicated Laboratory during the Task C&D study, Reference 1. The Task C&D average continuous data rate was 45 Kbps and the maximum rate was 90 Kbps. Thus, the current figure represents reductions of 27 percent and 32 percent, respectively.

3.2 VIDEO DATA REQUIREMENTS

The updated Dedicated 30-Day Laboratory contains two black and white video cameras and one color video camera (exclusive of those provided as part of the CDMS equipment). An operations model was used to determine the data management requirements to support these cameras. This model, as well as some of the resulting data management characteristics, are shown in Table 3.

The model assumes that black and white camera #1 is used for intermittent monitoring of experiment events for a total of 60 min./day. An on-board monitor is sometimes required for this mode of camera operation. The resulting video signal could be recorded on video tape during the monitoring periods. This data could be preserved by means of storing video tape on-board or by means of downlinking, depending upon the mode of operation of the SPACELAB CDMS. The CDMS system described in Section 2.0 used downlinking rather than on-board storage of video data. On-board storage is only provided for short periods (approximately 30 minutes) in the event that the TDRS downlink is not immediately available. As an option to downlinking, the video data could be preserved on video tape. For this type of preservation, Table 3 gives the estimated quantity of tape required for storage. For black and white camera #1, this amounts to about 5.7 kg/day. It was estimated that 10 percent of this data would need to be downlinked to the principal investigators in the event that long-term preservation was by means of on-board storage.

TABLE 3

TELEVISION CAMERA DATA REQUIREMENTS

	B/W VIDEO CAMERA #1	B/W VIDEO CAMERA #2	COLOR VIDEO CAMERA
	E.U. 1, E.I. 37	E.U. 1, E.I. 37	E.U. 1, E.I. 38
PURPOSE	INTERMITTENT MONITORING OF EXPERIMENT PHENOMENA	TIME LAPSE MONITORING OF ORGANISMS & OCCASIONAL EVENT MONITORING	MONITORING & DOWN LINKING OF COLOR DATA INCLUDING MICROSCOPIC EXAMINATIONS
DURATION OF USE (ASSUMED TIMES)	60 MIN/DAY	12 HR/DAY @ 1 FRAME PER 20 SECONDS	30 MIN/DAY
ANALOG BANDWIDTH OR DIGITAL BIT RATE	6 MHZ	55 KBPS AVERAGE DIGITAL RATE DURING TIME LAPSE	6 MHZ
DISPLAY	ON-BOARD MONITOR REQ'D	ON-BOARD MONITOR REQ'D	ON-BOARD MONITOR DESIRABLE
LONG TERM PRESERVATION (ON-BOARD STORAGE OR DOWN-LINKING)	STORE 100% FOR SUBSEQUENT GROUND ANALYSIS	STORE 100% FOR SUBSEQUENT GROUND ANALYSIS	STORE 100% FOR SUBSEQUENT GROUND ANALYSIS
TAPE REQUIRED FOR ON-BOARD STORAGE	1380 M/DAY (4530 FT/DAY), WT. ≅ 5.7 KG/DAY (12.6 LB/DAY)	WT. ≅ 0.3 KG/DAY (0.66 LB/DAY) (FOR 100% EFFICIENT DATA PACKING)	690 M/DAY (2265 FT/DAY), WT. ≅ 2.85 KG/DAY (6.3 LB/DAY)
DOWNLINK PERCENTAGE REQ'D IF LONG TERM PRESERVATION IS BY MEANS OF ON-BOARD STORAGE	10% (6 MIN/DAY OF VIDEO COVERAGE)	5% (APPROX. 1.2×10^8 BITS/DAY)	10% (3 MIN/DAY OF COLOR VIDEO COVERAGE
PROCESSING	NONE. DIRECT RECORDING ON VIDEO TAPE RECORDER.	TIME LAPSE VIDEO MUST BE DIGITIZED, PROCESSED & RECORDED.	NONE. DIRECT RECORDING ON VIDEO TAPE RECORDER.

The second black and white video camera contained in the life sciences Dedicated 30-Day Laboratory was assumed to be devoted to time lapse video monitoring at a rate of one frame every 20 seconds for 12 hours per day. This type of monitoring is used to monitor critical test organisms on a continuous but time lapse basis. It was assumed that this data would be digitized and processed in order to facilitate its handling at a relatively low and steady rate rather than in bursts of high rate video data. In this case, the average data rate would be approximately 55 Kbps during 12 hours per day. This data could be transmitted by the SPACELAB data bus, or could be hardwired to the digital high rate data recorders. The amount of tape needed to record this data would be about 0.3 kg/day (0.66 lb/day) assuming 100 percent efficient packing of data. This efficiency will not be possible but the weight value serves as a reference to which efficiency factors can be applied. It was assumed that 5 percent of the time lapse data should be downlinked to the principal investigators. This is equivalent to 1.2×10^8 bits/day. If all the time lapse data were transmitted to ground, the total amount would be 2.4×10^9 bits.

The third video camera on the Dedicated 30-Day Life Sciences Laboratory is a color camera, as shown in Table 3 . It was assumed that this camera was on for 30 min./day. Data from this camera would be hardwired to the video recorder for storage or subsequent in-orbit playback for transmission to the ground.

SECTION 4

COMPARISON OF LIFE SCIENCES LABORATORY REQUIREMENTS WITH SPACELAB CAPABILITY

In general, the SPACELAB has data management capability in excess of that required by the Dedicated 30-Day Life Sciences Laboratory. A comparison of the life sciences requirements and the SPACELAB capability is summarized in Table 4-1. The data bus can handle data at 1 mbps whereas the life sciences laboratory will require up to 0.116 mbps. This requirement is comprised of 61 Kbps for various life sciences laboratory parameters and measurements and 5.5 Kbps for the time lapse video. The digital wide band storage recorders can be used to record data bus signals and other hardwired signals up to a rate of 50 mbps. Selected data bus signals can also be stored on the maintenance recorder. The SPACELAB CCTV provides continuous video monitoring and the control and display console provides 2 CRT displays, function and alphanumeric keyboards, a number of digital readouts, and warning lights and alarms. These capabilities more than satisfy the life sciences requirements which have been identified to date.

The digital computer requirements of the life sciences laboratory are difficult to predict before specific research protocols have been established. Although such protocols were unavailable for the Dedicated 30-Day Laboratory, several straw man protocols were postulated during the IMBLMS study and investigated with respect to their requirements for digital computer capacity, Ref. 2. It was estimated that a worse case load would result in 494,233 machine cycles/sec., or an approximate 2 μsec. cycle time requirement, as shown in Table 4. This would be equivalent to using about one-half the dynamic capacity of a central processor with a 1 μs cycle time, such as the processor proposed for SPACELAB.

The same reference also quoted an estimated worst case main storage requirement for the central processor of 12,962 words. This may be compared to the SPACELAB computer's nominal memory capability of 48,000 words. From the above comparisons, it may be concluded that the proposed SPACELAB computer will probably satisfy typical life sciences processing requirements.

With regard to downlinked data, SPACELAB plans currently call for the downlinking of data via TDRS rather than on-board storage. The capability of TDRS is 50 mbps of digital data or one 6 mHz video signal, but not simultaneously. Thus, for the calculation of comparative values for Table 4, it was assumed that the TDRS link was equally shared between digital and video date downlinking. Further, since TDRs will be available for only about 85 percent of the time for SPACELAB use, this factor was also used to calculate the the SPACELAB downlinking capability. The above assumptions result in the values shown in Table 4 of 1.84×10^{12} bits/day of digital downlink capability and 10.2 hrs of video. These values are much greater than the requirements currently identified for the Dedicated 30-Day Laboratory.

TABLE 4

COMPARISON OF DEDICATED 30-DAY LABORATORY
MANAGEMENT REQUIREMENTS AND SPACELAB CDMS CAPABILITY

	DEDICATED 30-DAY LAB REQUIREMENTS	SPACELAB CDMS CAPABILITY*
ON-BOARD DATA HANDLING		
Data Bus Maximum Data Rate, Mbps	0.116	1
Digital Wide Band Storage Rate, Mbps	0.116	50 (hardwired)
Video Monitoring by CCTV, Hrs/Day	<1.5	Continuous
Displays (other than Video)	CRT, Numeric & Warning	2 CRTs (Alphanumeric Capability), Digital Readouts, Warning Lights & Audible Alarms
Computer: Cycles/second	500K } IMBLMS estimates	1000K
Main Memory Storage, words	13K } IMBLMS estimates	48K
DOWN-LINKED DATA HANDLING		
Digital Transmission To Ground, bits/day	2×10^9 (all data down-linked for preservation)	1.84×10^{12} (assuming 85% availability of TDRS and 50% time-sharing with video data)
Video Transmission To Ground, Hrs/Day	1.5 (primarily for purposes of preservation)	10.2 (assuming 85% availability of TDRS and 50% time-sharing with digital downlinked data)

*Control & Data Management Subsystem, based on preliminary studies by Messerschmitt, Bolkow-Blohm (MBB) and General Dynamics/Convair.

SECTION 5

REFERENCES

1. Life Sciences Payload Definition and Integration Study (Task C&D), Report No. CASD-NAS73-003, Contract NAS8-29150, General Dynamics Convair Aerospace Division, San Diego, CA, August 1973.

2. IMBLMS, Phase B4, Final Project Definition Study, Final Report, GE No. 70SD5386, Contract NAS9-10741, General Electric Space Co., Systems Division, no date.