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SPACELAB EXPERIMENT COMPUTER STUDY
VOL 1: Executive Summary (Presentation)

By James L. Lewis, Bobby C. Hodges, and James O. Christy
Data Systems Laboratory

April 1976

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
**Title and Subtitle:**
SPACELAB EXPERIMENT COMPUTER STUDY
Vol. I: Executive Summary (Presentation)

**Authors:**
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**Sponsoring Agency Name and Address:**
National Aeronautics and Space Administration
Washington, D. C. 20546

**Abstract:**
The purpose of this study was to provide a quantitative cost for various Spacelab flight hardware configurations, along with varied software development options. The three major conclusions reached as a result of this study are as follows:

1. Spacelab program cost for software development and maintenance is independent of experimental hardware and software options.

2. Distributed standard computer concept simplifies software integration without a significant increase in cost.

3. Decision on flight computer hardware configuration should not be made until payload selection for a given mission and a detailed analysis of the mission requirements are completed.

This report is published in five volumes: Volume I contains the Executive Summary (Presentation); Volume II, Study Elements and Approach; Volume III, Spacelab Cost Data; Volume IV, Spacelab User Cost Data (Central Experiment Computer); and Volume V, Spacelab User Cost Data (Distributed Computer).

This is Volume I: Executive Summary (Presentation).

**Keywords:**

**Distribution Statement:**
Unclassified-Unlimited

**Security Classif. (of this report):**
Unclassified

**Security Classif. (of this page):**
Unclassified

**No. of Pages:**
68

**Price:**
NTIS
SPACELAB EXPERIMENT COMPUTER STUDY

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9.1 Costing Method
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13.1 Costing Method
13.2 Cost Data

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14.1 Costing Method
14.2 Cost Data

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15.1 Costing Method
15.2 Cost Data

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1.1 Costing Method  
1.2 Cost Data

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2.1 Costing Method  
2.2 Cost Data


3.1 Costing Method  
3.2 Cost Data


4.1 Costing Method  
4.2 Cost Data


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5.2 Cost Data
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6.1 Costing Method
6.2 Cost Data

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7.1 Costing Method
7.2 Cost Data

Section 8. Option IIB2A - Distributed Standard Mini, Central Software Development by PI at Central Facility Local.

8.1 Costing Method
8.2 Cost Data


9.1 Costing Method
9.2 Cost Data

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10.1 Costing Method
10.2 Cost Data

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11.1 Costing Method
11.2 Cost Data
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12.1 Costing Method
12.2 Cost Data

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13.1 Costing Method
13.2 Cost Data

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14.2 Costing Data
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OBJECTIVE OF STUDY

- TO DEFINE, VIA ANALYSIS AND TRADE STUDIES, THE MOST COST EFFECTIVE CONFIGURATION OF FLIGHT COMPUTATIONAL RESOURCES THAT WILL SATISFY SPACELAB USER REQUIREMENTS

APPROACH

- PROJECT COSTS ASSOCIATED WITH VARIOUS OPTIONS (CENTRALIZED VS. DISTRIBUTED) THAT CAN POTENTIALLY BE ADOPTED TO SATISFY THESE REQUIREMENTS

- PROJECT TOTAL COSTS ASSOCIATED WITH SOFTWARE DEVELOPMENT INCLUDING:
  - EXPERIMENT COMPUTER(S) SOFTWARE
  - SUBSYSTEM COMPUTER SOFTWARE
  - EGSE COMPUTER SOFTWARE
  - SUPPORT SOFTWARE
  - SIMULATION SOFTWARE
  - ASSOCIATED HARDWARE
## STUDY METHOD

- Derive computation requirements for Spacelab payload elements (experiments) by detailed analysis of three missions - extrapolation to 226 missions in mission model.
  - Speed
  - Memory - main and bulk
  - Statements to be coded

- Estimate size of European delivered software and the expected change rate.

- Define options to be evaluated.

- Develop comprehensive set of assumptions and ground rules.

- Define method of costing for each element.

- Combine costs to determine yearly and total costs.

- Maintain separation of costs - Spacelab and user.

- Examine major cost elements for sensitivity to assumptions and ground rules.

- Maintain traceability for all cost elements.
STUDY APPROACH

THE OVERALL APPROACH FOR SIZING EXPERIMENT APPLICATION SOFTWARE WAS TO REVIEW ALL PAYLOAD ELEMENTS CONTAINED IN THE SPACELAB MISSION MODEL (PM01, 75-253, DATED 11/75) WHICH CONSISTS OF 226 FLIGHT OF FORTY-FIVE (45) DIFFERENT MISSIONS. OF THIS TOTAL NUMBER OF MISSIONS THREE (3) WERE SELECTED FOR DETAILED ANALYSIS. THE THREE (3) SELECTED WERE MISSIONS EIGHT (8), FOURTEEN (14), AND TWENTY ONE (21). FOR THESE THREE (3) THE DETAILED SOFTWARE REQUIREMENTS WERE DERIVED AT THE PAYLOAD ELEMENT FUNCTIONAL LEVEL. THE DERIVED REQUIREMENTS WERE STATED IN TERMS OF MAIN MEMORY, BULK MEMORY, AND EQUIVALENT ADDS PER SECOND, TEMPERED BY REALISTIC GROUND RULES APPLIED TO MINIMIZE THE TOTAL SOFTWARE JOB WHILE MAXIMIZING PAYLOAD RETURN. FOR DATA LISTED IN SPDA AS TBD, ENGINEERING ESTIMATES WERE USED. MISSION TIME LINES WERE APPLIED AND REQUIREMENTS WERE SUMMED, IF APPROPRIATE. FINALLY, THE DATA GENERATED WAS EXTRAPOLATED OVER THE MISSION MODEL AND YEARLY TOTALS GENERATED FOR SOFTWARE DEVELOPMENT, MAINTENANCE, AND DISTRIBUTION.

<table>
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<td>SPACELAB EXPERIMENT COMPUTER STUDY</td>
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<tr>
<td>LABORATORY</td>
<td>NAME: J. T. POWELL</td>
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**PRESENTATION OUTLINE**

- **STUDY DEFINITION**
- **OBJECTIVE**
- **APPROACH**
- **METHOD**
- **SOFTWARE REQUIREMENTS DEVELOPMENT**
- **COSTING**
- **SUMMARY**
SOFTWARE REQUIREMENTS
OVERALL APPROACH

SELECTION OF P/L'S FOR DETAILED ANALYSIS
- CRITERIA
- LEVEL OF CONFIDENCE

DETAILED P/L SOFTWARE REQTS FOR REPRESENTATIVE P/L'S
- 3 MISSION P/L'S
- 20 P/L ELEMENTS
- 19 FLIGHTS

SPDA LEVEL A DATA & NASA/GDC ESTIMATES

COMPUTER PROCESSING REQTS FOR MISSION MODEL P/L'S
- 45 MISSION P/L'S
- 47 PAYLOAD ELEMENTS
- 226 FLIGHTS

SPDA: SPACE SHUTTLE PAYLOAD DATA ANALYSIS
SOFTWARE REQUIREMENTS STUDY GROUND RULES

• DATA BASE USED
  
  • JULY 1975 SPDA LEVEL A PAYLOAD DATA
  • FOR MISSION 8, THE LEVEL 1 CONSTRAINTS FOR FIRST SPACELAB FLIGHT AND SPACELAB FIRST FLIGHT GUIDELINES - LEVEL II (BOTH DATED NOV. 1975)
  • SPACELAB MISSION MODEL (PM01) 75-253, DATED 11/75

• USE DETAILED ANALYSIS DATA (MISSIONS 8, 14, 21) TO REPLACE LEVEL A DATA FOR APPROPRIATE PAYLOAD ELEMENTS

• TALL POLES IDENTIFIED WILL BE FURTHER EVALUATED BY MSFC/GDC

• FUNCTIONS THAT CANNOT BE EFFICIENTLY HANDLED BY THE CREW MANUALLY SHALL BE CONSIDERED FOR AUTOMATION

• THE CREW SHOULD BE PROVIDED A LEVEL OF PAYLOAD CONTROL AND MONITORING THAT WILL YIELD HIGH CONFIDENCE OF PROPER EXPERIMENT OPERATION AND EXPERIMENT DATA QUALITY

• THROUGH MODEST INCREASES IN ON-BOARD PROCESSING, REAL-TIME TRANSMISSION REQUIREMENTS WILL BE MINIMIZED WHERE POSSIBLE

• PAYLOAD ELEMENT REQUIREMENTS WERE SUMMED FOR EACH MISSION IF POINTING REQUIREMENTS WERE COMPATIBLE
PAYLOADS USED FOR DETAILED ANALYSIS

MISSION 8 WAS SELECTED AT THE SPECIFIC REQUEST OF THE SPACELAB PROGRAM MANAGER. IT IS ATYPICAL SINCE IT IS THE FIRST SPACELAB FLIGHT, AND INCLUDES THE LARGEST NUMBER OF PAYLOAD ELEMENTS.

MISSIONS 14 AND 21 WERE SELECTED BECAUSE THEY REPRESENT A REASONABLE SPREAD OF REQUIREMENTS (LOW TO HIGH) AND BECAUSE GOOD DETAIL WAS AVAILABLE FROM PRIOR ANALYSES. THESE MISSIONS WERE ALSO COVERED IN THE CRAS STUDIES.
MISSIONS EXCEEDING CDMS CAPACITY

THE FIRST 3 MISSIONS, SHOWN OPPOSITE, SLIGHTLY EXCEED THE AVAILABLE OPERATIONS PER SECOND CAPACITY OF THE CENTRAL EXPERIMENT COMPUTER, WHEN THE OPERATING SYSTEM AND CONTINGENCY ARE CONSIDERED. IT WAS CONCLUDED THAT THESE 3 MISSIONS COULD BE ACCOMMODATED BY MINOR REVISION OF THE REQUIREMENT OR BY USING THE CONTINGENCY RESERVED.

THE LAST 4 MISSIONS LISTED EXCEED THE CURRENT AND ANTICIPATED STATE OF THE ART, IN TERMS OF OPERATIONS PER SECOND. IT WAS ASSUMED THAT THE FUNCTION COULD BE ACCOMPLISHED BY SPECIAL PURPOSE HARDWARE, YET TO BE DEFINED, AND THE SOFTWARE REQUIREMENTS WERE TREATED AS VALID. NO COSTS WERE INCLUDED FOR THE SPECIAL PURPOSE HARDWARE.

THE ATM/SPACELAB MISSION IS NO LONGER BEING CONSIDERED.
### Spacelab Mission Payload Model

#### No. of Flights Calendar Year

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#### Module Types
- 100 - Module
- 200 - Pallet
- 300 - Module + Pallet

**X, Y distinguish different orbits or mission duration for same mission payload**

**Note:**
- **AST-10A**: 200 Mission 21
- **AST-10B**: 200 Stellar Astronomy
- **AST-10C**: 200 Stellar Astronomy
- **AST-10D**: 200 Stellar Astronomy (28.5 deg orbit)
- **AST-10E**: 200 Stellar Astronomy (100 deg orbit)
- **AST-10F**: 200 Stellar Astronomy (50 deg orbit)
- **AST-10G**: 200 Stellar Astronomy (85 deg orbit)
- **AST-10H**: 200 Stellar Astronomy (100 deg orbit)
- **AST-10I**: 200 Stellar Astronomy (75 deg orbit)
- **AST-10J**: 200 Stellar Astronomy (100 deg orbit)
- **AST-11A**: 200 Solar Physics
- **AST-11B**: 200 Solar Physics
- **AST-11C**: 200 Solar Physics
- **AST-11D**: 200 Solar Physics
- **AST-11E**: 200 Solar Physics
- **AST-11F**: 200 Solar Physics
- **AST-11G**: 200 Solar Physics
- **AST-11H**: 200 Solar Physics
- **AST-11I**: 200 Solar Physics
- **AST-11J**: 200 Solar Physics
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- **AST-11V**: 200 Solar Physics
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- **AST-12Q**: 200 Solar Physics
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- **AST-12S**: 200 Solar Physics
- **AST-12T**: 200 Solar Physics
- **AST-12U**: 200 Solar Physics
- **AST-12V**: 200 Solar Physics
- **AST-12W**: 200 Solar Physics
- **AST-12X**: 200 Solar Physics
- **AST-12Y**: 200 Solar Physics
- **AST-12Z**: 200 Solar Physics
- **LS-2A07**: 200 Life Sciences Shuttle Laboratory (MOD 1)
- **LS-2A20**: 200 Life Sciences Shuttle Laboratory (MOD 1)
- **LU-2 (10)**: 200 Multi-User Mission (10)
- **NU-15**: 200 Space Manufacturing
- **NU-15A**: 200 Earth Observations (ESA 28.5 deg orbit)
- **NU-15A**: 200 Earth Observations (ESA 90 deg orbit)
- **NU-15E**: 200 Astronomy ESA
- **OA-1A (141 X)**: 200 Multidiscipline Applications (ISS 14-5 deg)
- **OA-1B (141 Y)**: 200 Multidiscipline Applications (ISS 14-5 deg)
- **OA-18**: 200 C1 (15 deg orbit)
- **OA-18**: 200 C1 (180 deg orbit)
- **PH-4X + 6D**: 200 High Energy (X-Ray/Gamma Ray & Cosmic Ray Survey)
- **PH-4E**: 200 High Inclination Cosmic Ray Survey
- **PH-6C**: 200 High Energy (X-Ray Angular Structure & Gamma Ray Survey)
- **PH-6G**: 200 Gamma-Ray Photometric Studies
- **PH-YX**: 300 AMPS (28.5 deg orbit)
- **PH-YA**: 300 AMPS (85 deg orbit)
- **PH-YA**: 300 AMPS (100 deg orbit)
- **PH-YA**: 300 AMPS (190 deg orbit)
- **PH-YC**: 300 AMPS (180 deg orbit)
- **PH-YC**: 300 AMPS (250 deg orbit)
- **PH-SA**: 300 Space Processing Lab (Manned & Automated IS + G + C + FP + LP + S1)
- **PH-SA**: 300 Space Processing Lab (Manned & Automated IS + G + C + FP + LP + S1)
- **PH-SA**: 300 Space Processing Lab (Manned & Automated IS + G + C + FP + LP + S1)
- **ST-2A**: 300 Advanced Technology Lab 2
- **ST-2B**: 300 Advanced Technology Lab 2
- **ST-2C**: 300 Advanced Technology Lab 3
- **ST-2D**: 300 Advanced Technology Lab 3

**Total No. of Flights:** 226
## Payloads Used for Detailed Analysis

### Mission 8 (Joint NASA/ESA)
- **APE-01**: Lidar/Laser Sounder
- **AP-09-S**: Electron Accelerometer
- **AP-13-S**: Low Light Level TV
- **APE-07**: Passive Atmosphere Sounder
- **SPE-01**: Free-Flow Electrophoresis Facility
- **SPE-80/85**: Isothermal Multi-Heating Facility
- **EO-01-S**: Zero G Cloud Physics
- **ST-31-S**: Drop Dynamics Facility
- **STE-10**: Advanced Heat Pipe
- **LS-13-S**: Life Science Payload
- **ASE-01**: Wide-Field Camera
- **EOE-01**: Metric Camera
- **EO-19-S**: MK II Interferometer
- **CN-08-S**: Open TWT Experiments
- **VERIFICATION FLIGHT INSTRUMENTATION**

### Mission 14 (Multidiscipline Applications)
- **CN-04-S**: Electromagnetic Environment
- **CN-08-S**: TWT Open Envelope
- **EO-20-S**: Imaging Radar
- **OP-03-S**: Microwave Radiometry
- **SP-31-S**: Biological/Furnace Subelements and Core

### Mission 21 (Combined Stellar Astronomy)
- **AS-01-S**: 1.5 M IR Telescope
- **AS-04-S**: 1.0 M UV/Optical Telescope
**EXAMPLE INTEGRATED PAYLOAD COMPUTER PROCESSING TIMELINE**

**MISSION:** 14  
**PAYLOAD ELEMENT:** ALL-SUMMARY

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<thead>
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<th>PAYLOAD ELEMENT OPERATIONS</th>
<th>HOURS FROM LAUNCH</th>
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<td>SP-31-S 810/FURNACE*</td>
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*INCLUDES EXPERIMENTS 101, 102, 201, 203, 207, & 209*

**COMPUTER PROCESSING TIMELINES**

(TYPICAL DAY-REPEAT FOR DAYS 3, 4, 5, & 6)

**COMPUTER LOADING**

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<td>30</td>
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</table>
SPACELAB EXPERIMENT
COMPUTER STUDY

NO. OF COMPUTATIONS PER SEC.
RAPID ACCESS MEMORY

THE AVAILABLE TOTAL RAPID ACCESS MEMORY CAPACITY, SHOWN OPPOSITE, IS THAT OF THE BASELINE SYSTEM. THE CAPACITY AVAILABLE FOR EXPERIMENT APPLICATION SOFTWARE IS LESS BECAUSE OF REQUIREMENTS FOR OPERATING SYSTEM, COMMON CENTRAL SERVICES, AND CONTINGENCY. ADDITIONAL MEMORY MODULES CAN BE ADDED WITH NO DESIGN CHANGE TO ACCOMMODATE THE INDICATED REQUIREMENTS. ESTIMATED COSTS FOR THIS WERE INCLUDED IN THE OVERALL COST ANALYSIS.
BULK MEMORY

The bulk memory capacity was exceeded by the same 7 missions which exceeded the computations per second capacity. No costs were included for modification on the basis that these missions would either be eliminated, or the requirement solved by the special-purpose hardware postulated earlier.
### MISSIONS EXCEEDING CDMS CAPACITY

<table>
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<tr>
<th>MISSION P/L</th>
<th>P/L ELEMENTS</th>
<th>P/L ELEMENT COMPS/SEC</th>
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<tr>
<td>1. AST 10a</td>
<td>1M UV TELESCOPE 1M IR TELESCOPE</td>
<td>167,600</td>
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<td>5. AST 11d</td>
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<td>6. AST 11e</td>
<td>SOLAR FINE POINTING</td>
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*BASED ON PROCESSING (1024 X 1024) IMAGE EVERY 10 SECONDS.*
SPACELAB EXPERIMENT
COMPUTER STUDY

RAPID ACCESS MEMORY

AVAILABLE TOTAL CAPACITY

AVAILABLE FOR EAB

SPACELAB MISSION PAYLOADS
ACCOMMODATION OF PAYLOAD REQUIREMENTS

- SPEED - CENTRAL EXPERIMENT COMPUTER CAN ACCOMMODATE ALL MISSIONS EXCEPT 7
  - THESE 7 HAVE STATED REQUIREMENTS THAT EXCEED STATE OF THE ART
  - MADE UP OF 4 PAYLOADS

- RAPID ACCESS MEMORY - MUST BE EXPANDED FOR SOME PAYLOADS
  - CAPABILITY INHERENT IN MACHINE - NO REDESIGN

- BULK MEMORY - CENTRAL MASS STORAGE CAN ACCOMMODATE ALL MISSIONS EXCEPT 7
  (SAME 7 AS ABOVE)
COSTING APPROACH

The costing approach consisted of establishing a costing method for each cost factor that was identified as applicable to the cost element within a given option. The costing method equation for each cost factor was then applied, yielding a result in terms of: one time cost, cost per flight, cost per year, user cost, or Spacelab cost as applicable. This derived cost by factors was then summed by year, escalated, and a total cost per option established. The total cost for each option was then analyzed for sensitivity to the costing rules such as rate of change, cost per statement, and mission model. Delta totals for each option were derived thus giving visibility as to sensitivity effects.
<table>
<thead>
<tr>
<th>PRESENTATION OUTLINE</th>
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</thead>
<tbody>
<tr>
<td>STUDY DEFINITION</td>
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<tr>
<td>OBJECTIVE</td>
</tr>
<tr>
<td>APPROACH</td>
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<tr>
<td>METHOD</td>
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<tr>
<td>SOFTWARE REQUIREMENTS DEVELOPMENT</td>
</tr>
<tr>
<td>COSTING</td>
</tr>
<tr>
<td>SUMMARY</td>
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</table>
OPTIONS CONSIDERED

THE TWO BASIC OPTIONS CONSIDERED FOR THIS STUDY ARE: EMPHASIS ON USE OF CENTRAL ONBOARD COMPUTING RESOURCES WITH OVERFLOW TO MINI'S, AS REQUIRED, AND EMPHASIS ON USE OF DISTRIBUTED MINI'S WITH CENTRAL RESOURCES PROVIDING STANDARD SERVICES. SUB-OPTIONS WITHIN EACH OPTION CONSIDERED SUCH ITEMS AS STANDARD MINI'S, AND VARIOUS EXPERIMENT APPLICATION SOFTWARE DEVELOPMENT OPTIONS. IN ALL, THIRTY (30) OPTIONS WERE IDENTIFIED AND A PRELIMINARY ANALYSIS MADE OF EACH. NINE (9) OF THE THIRTY (30) WERE ELIMINATED FROM FURTHER DETAIL ANALYSIS DUE TO EXCESSIVE COSTS, OR DUE TO THEIR BEING TOTALLY IMPractical TO IMPLEMENT AS WELL AS CONTAINING EXCESSIVE COST ELEMENTS. THE REMAINING TWENTY-ONE (21) WERE ANALYZED IN DETAIL AND THE RESULTS ARE INCLUDED IN VOLUME 2, BOOK 2, APPENDIX B1 THRU B30.
COSTING APPROACH

OPTIONS/GROUND RULES

COST ELEMENTS

EXAMPLE: EXPERIMENT APPLICATION SOFTWARE DEVELOPMENT

COST FACTORS

EXAMPLE: (1) SOFTWARE DEVELOPMENT
(2) COMMON SOFTWARE
(3) HOST COMPUTER TIME
(4) SIMULATION COMPUTER TIME
(5) HOST COMPUTER TIME FOR DEP SOFTWARE
(6) SIMULATION COMPUTER TIME FOR DEP SOFTWARE

COSTING METHODS

EXAMPLE: (1) COST/yr-(NO. OF HOLL STMTS/yr) X COST/STMT

SUMMATION OF ALL COST FACTORS BY YEAR

REQUIREMENTS STUDY RESULTS

MINI-COMPUTER STUDY RESULTS
OPTIONS CONSIDERED

1. CENTRAL GROUP DEVELOPS EXPERIMENT APPLICATION SOFTWARE (EAS) AT CENTRAL SITE

2. PRINCIPAL INVESTIGATOR (PI) EXPERIMENT APPLICATION SOFTWARE (EAS) AT CENTRAL SITE
   
   A. LOCAL TO CENTRAL SITE
   
   B. UTILIZING REMOTE TERMINALS

3. PRINCIPAL INVESTIGATOR (PI) DEVELOPS EXPERIMENT APPLICATION SOFTWARE (EAS) ON HIS HOST THAT IS COMPATIBLE WITH CENTRAL SITE
   
   A. ALL REALTIME SIMULATION AT CENTRAL SITE
   
   B. REALTIME SIMULATION FOR DEDICATED EXPERIMENT PROCESSOR (DEP) EXPERIMENT APPLICATION SOFTWARE (EAS) ON REALTIME SIMULATION TEST SET (RTSTS) AT PRINCIPAL INVESTIGATOR (PI) FACILITY

4. PRINCIPAL INVESTIGATOR (PI) DEVELOPS EXPERIMENT APPLICATION SOFTWARE (EAS) ON HIS HOST THAT IS NOT COMPATIBLE WITH CENTRAL SITE.
<table>
<thead>
<tr>
<th>CDMS</th>
<th>EGSE</th>
<th>CENTRAL SITE</th>
</tr>
</thead>
<tbody>
<tr>
<td>• HARDWARE MODIFICATIONS</td>
<td>• HARDWARE MODIFICATIONS</td>
<td>• FACILITY ACQUISITION</td>
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<tr>
<td>• SUBSYSTEM COMPUTER SOFTWARE DEVELOPMENT</td>
<td>• GROUND CHECKOUT SOFTWARE DEVELOPMENT AND ACCEPTANCE</td>
<td>• FACILITY OPERATION AND MAINTENANCE</td>
</tr>
<tr>
<td>AND ACCEPTANCE</td>
<td>• GROUND CHECKOUT SOFTWARE MAINTENANCE</td>
<td>• HOST AND SIMULATION COMPUTER SUPPORT SOFTWARE DEVELOPMENT AND ACCEPTANCE</td>
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<tr>
<td>• SUBSYSTEM COMPUTER SOFTWARE MAINTENANCE</td>
<td>• GROUND CHECKOUT SOFTWARE CONFIGURATION MANAGEMENT RELEASE, AND DISTRIBUTION</td>
<td>• HOST AND SIMULATION COMPUTER SUPPORT SOFTWARE MAINTENANCE</td>
</tr>
<tr>
<td>• SUBSYSTEM COMPUTER SOFTWARE CONFIGURATION MANAGEMENT RELEASE, AND DISTRIBUTION</td>
<td>• EGSE COMPUTER SOFTWARE PRODUCTION SET DEVELOPMENT AND ACCEPTANCE</td>
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<td>• EXPERIMENT COMPUTER SOFTWARE DEVELOPMENT AND ACCEPTANCE</td>
<td>• EGSE COMPUTER SOFTWARE PRODUCTION SET MAINTENANCE</td>
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<tr>
<td>• EXPERIMENT COMPUTER SOFTWARE MAINTENANCE</td>
<td>• EGSE COMPUTER SOFTWARE CONFIGURATION MANAGEMENT RELEASE, AND DISTRIBUTION</td>
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</tr>
<tr>
<td>• EXPERIMENT COMPUTER SOFTWARE CONFIGURATION MANAGEMENT RELEASE, AND DISTRIBUTION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PI HOST COMPUTER</td>
<td>EXPERIMENT</td>
<td>DEP*</td>
</tr>
<tr>
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<td>------------</td>
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</tr>
<tr>
<td>HOST AND SIMULATION COMPUTER SUPPORT SOFTWARE MAINTENANCE</td>
<td>EAS DEVELOPMENT</td>
<td>EXPERIMENT PROCESSOR ACQUISITION</td>
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<tr>
<td>EAS MAINTENANCE</td>
<td>EXPERIMENT PROCESSOR MAINTENANCE AND DISTRIBUTION</td>
<td>RTSTS MAINTENANCE, OPERATION, AND DISTRIBUTION</td>
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<tr>
<td>EAS INTEGRATION</td>
<td>DEP SOFTWARE DEVELOPMENT AND PROCUREMENT</td>
<td>RTSTS SUPPORT SOFTWARE DEVELOPMENT AND PROCUREMENT</td>
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<td>EXPERIMENT PREFLIGHT CHECKOUT SOFTWARE DEVELOPMENT</td>
<td>DEP SOFTWARE MAINTENANCE AND DISTRIBUTION</td>
<td>RTSTS SUPPORT SOFTWARE MAINTENANCE AND DISTRIBUTION</td>
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<td>EXPERIMENT PREFLIGHT CHECKOUT SOFTWARE MAINTENANCE</td>
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<td>EAS DEPENDENT CENTRAL SITE HARDWARE SUPPLEMENT</td>
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<tr>
<td>EAS DEPENDENT CENTRAL SITE SOFTWARE SUPPLEMENT</td>
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</tbody>
</table>
| EXPERIMENT REAL-TIME SIMULATION SOFTWARE DEVELOPMENT | | | *
| EXPERIMENT REAL-TIME SIMULATION SOFTWARE MAINTENANCE | | | RTSTS - REAL-TIME SIMULATION TEST SET

*DEP - DISTRIBUTED EXPERIMENT PROCESSOR
# Option/Cost Element Correlation Matrix

**Organization:**
- Data Systems Laboratory
- Marshall Space Flight Center

**Name:** J. T. Powell

**Date:** April 1976

## Spacelab Cost Elements

<table>
<thead>
<tr>
<th>1. CODE</th>
<th>2. EQIE</th>
<th>3. STIL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

## Options

1. **Centralized Standard Minicomputer Configuration**
   - A. Non-Standard Minicomputer
     - 1. Central Group develops EAS at central facility ($\text{EAS}$)
     - 2. Pile develops EAS at local ($\text{FL}$)
     - 3. Pile develops EAS at his facility which is compatible with $\text{EAS}$
     - 4. Pile develops EAS at his facility which is not compatible with $\text{EAS}$

2. **Standard Minicomputer**
   - 1. Central Group develops EAS at central facility ($\text{EAS}$)
   - 2. Pile develops EAS at local ($\text{FL}$)
   - 3. Pile develops EAS at his facility which is compatible with $\text{EAS}$
   - 4. Pile develops EAS at his facility which is not compatible with $\text{EAS}$

3. **No Minicomputer**
   - 1. Central Group develops EAS at central facility ($\text{EAS}$)
   - 2. Pile develops EAS at local ($\text{FL}$)
   - 3. Pile develops EAS at his facility which is compatible with $\text{EAS}$
   - 4. Pile develops EAS at his facility which is not compatible with $\text{EAS}$

4. **Distributed Standard Minicomputer Configuration**
   - A. Non-Standard Minicomputer
     - 1. Central Group develops EAS at central facility ($\text{EAS}$)
     - 2. Pile develops EAS at local ($\text{FL}$)
     - 3. Pile develops EAS at his facility which is compatible with $\text{EAS}$
     - 4. Pile develops EAS at his facility which is not compatible with $\text{EAS}$

5. **Standard Minicomputer**
   - 1. Central Group develops EAS at central facility ($\text{EAS}$)
   - 2. Pile develops EAS at local ($\text{FL}$)
   - 3. Pile develops EAS at his facility which is compatible with $\text{EAS}$
   - 4. Pile develops EAS at his facility which is not compatible with $\text{EAS}$

---

MSFC Form 2304 (Rev October 1972)
<table>
<thead>
<tr>
<th>OPTIONS</th>
<th>1. CENTRALIZED MINICOMPUTER</th>
<th>1. NON-STANDARD MINICOMPUTER</th>
<th>2. STANDARD MINICOMPUTER</th>
<th>3. NO MINICOMPUTER</th>
<th>4. DISTRIBUTED MINICOMPUTER</th>
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</thead>
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<tr>
<td></td>
<td>1. CENTRAL GROUP DEVELOPS EAS AT CENTRAL FACILITY SITE.</td>
<td>1. CENTRAL GROUP DEVELOPS EAS AT CENTRAL FACILITY SITE.</td>
<td>1. CENTRAL GROUP DEVELOPS EAS AT CENTRAL FACILITY SITE.</td>
<td>1. CENTRAL GROUP DEVELOPS EAS AT CENTRAL FACILITY SITE.</td>
<td>1. CENTRAL GROUP DEVELOPS EAS AT CENTRAL FACILITY SITE.</td>
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<tr>
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<td>2. DEVELOPS EAS AT CENTRAL FACILITY, LOCAL.</td>
<td>2. DEVELOPS EAS AT CENTRAL FACILITY, LOCAL.</td>
<td>2. DEVELOPS EAS AT CENTRAL FACILITY, LOCAL.</td>
<td>2. DEVELOPS EAS AT CENTRAL FACILITY, LOCAL.</td>
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<td>3. DEVELOPS EAS AT HIS FACILITY WHICH IS COMPATIBLE WITH EAS.</td>
<td>3. DEVELOPS EAS AT HIS FACILITY WHICH IS COMPATIBLE WITH EAS.</td>
<td>3. DEVELOPS EAS AT HIS FACILITY WHICH IS COMPATIBLE WITH EAS.</td>
<td>3. DEVELOPS EAS AT HIS FACILITY WHICH IS COMPATIBLE WITH EAS.</td>
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<table>
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<tr>
<th>SPACELAB USER COST ELEMENTS</th>
<th>4. EXPERIMENT</th>
<th>5. DDF</th>
<th>6. RTIDS</th>
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<td>1. CENTRAL FACILITY SITE.</td>
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<td>2. LOCAL.</td>
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<td>3. COMPATIBLE WITH EAS.</td>
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<tr>
<td>4. NOT COMPATIBLE WITH EAS.</td>
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</tbody>
</table>
### MAJOR COSTING RULES

**EXPERIMENT APPLICATION SOFTWARE CHANGE RATE:**
- 40% FIRST REFLY
- 30% SECOND REFLY
- 20% THIRD REFLY
- 10% EACH SUCCEEDING REFLY

**EGSE SOFTWARE CHANGE RATE:**
- 5% EACH NEW FLIGHT
- 1% EACH REFLIGHT

**SUBSYSTEM COMPUTER SOFTWARE CHANGE RATE:**
- 5% PER FLIGHT FOR 1ST THREE YEARS
- 10% PER YEAR THEREAFTER

- ALL COSTS ESCALATED - 7% PER YEAR, COMPOUNDED ANNUALLY

**COST PER HIGHER ORDER LANGUAGE STATEMENT FOR EAS:**
- REQUIREMENTS ANALYSIS $15.00
- DESIGN, CODE, VERIFICATION $30.00
- TOTAL $45.00

**COST PER STATEMENT FOR INTEGRATION AND VERIFICATION IF IN CENTRAL COMPUTER**
- (NOT APPLICABLE TO EAS IN DISTRIBUTED COMPUTER OPTIONS) $15.00

**COST PER CHECKOUT STATEMENT**
- $30.00

**COST PER ASSEMBLY LANGUAGE INSTRUCTION**
- $100.00

- ONE HIGHER ORDER LANGUAGE STATEMENT, WHEN COMPILED, RESULTS IN FIVE COMPUTER INSTRUCTIONS
- ONE MAN-YEAR OF EFFORT IS EQUIVALENT TO $50,000 IN 1976
SPACELAB AND USER COST

THE TOTAL SPACELAB AND USER COSTS ARE SHOWN TO INDICATE DELTA COSTS BETWEEN OPTIONS. OPTION IIa4 is shown for comparison and is an indicator of the high costs associated with options Ia4, Ib4, Ic3b, Ic4, Iia1, Iia2a, Iia2b, Iia3a, and Iia3b which are not included.
### Marshall Space Flight Center
#### Spacelab Experiment
##### Computer Study

### Statements to Be Coded
#### Option 11B2A

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</table>

**Total Costs:** 38360, 23919, 49113, 24148, 20272, 10085, 23172, 28956, 17945, 22161, 20489, 22181
SENSITIVITY TO COST PER STATEMENT

AN ANALYSIS OF SENSITIVITY TO COST PER STATEMENT WAS EXERCISED FOR EACH OPTION USING, AS A BASE, 50% OF THE ORIGINAL ESTIMATED COST PER INSTRUCTION OR LANGUAGE STATEMENT AS APPLICABLE. THE RESULTING DELTA COSTS FOR COMPARABLE USER OPTIONS AS WELL AS SPACELAB DELTA COSTS ARE SHOWN. DELTA COSTS FOR ALL OPTIONS DUE TO COST PER STATEMENT SENSITIVITY ARE INCLUDED IN VOLUME 1, EXECUTIVE SUMMARY.

ALSO SHOWN, ON OPTION IIA4, IS THE EFFECT OF PARTIAL STANDARDIZATION OF MINICOMPUTERS; i.e., EACH OF 12 DISCIPLINES WOULD USE THE SAME TYPE OF COMPUTER.
OPTIONS CONSIDERED

CENTRAL (I)
- NON STANDARD MINI FOR OVERFLOW (A)
- STANDARD MINI FOR OVERFLOW (B)
- NO MINI (C)

DISTRIBUTED (II)
- NON STANDARD MINI (A)
- STANDARD MINI (B)

HARDWARE OPTIONS
- EAS SOFTWARE DEVELOPMENT OPTIONS

1. CENTRAL GROUP DEVELOPS EXPERIMENT APPLICATION SOFTWARE (EAS) AT CENTRAL SITE
2. PRINCIPAL INVESTIGATOR (PI) EXPERIMENT APPLICATION SOFTWARE (EAS) AT CENTRAL SITE
   A. LOCAL TO CENTRAL SITE
   B. UTILIZING REMOTE TERMINALS
3. PRINCIPAL INVESTIGATOR (PI) DEVELOPS EXPERIMENT APPLICATION SOFTWARE (EAS) ON HIS HOST THAT IS COMPATIBLE WITH CENTRAL SITE
   A. ALL REALTIME SIMULATION AT CENTRAL SITE
   B. REALTIME SIMULATION FOR DEDICATED EXPERIMENT PROCESSOR (DEP) EXPERIMENT APPLICATION SOFTWARE (EAS) ON REALTIME SIMULATION TEST SET (RTSTS) AT PRINCIPAL INVESTIGATOR (PI) FACILITY
4. PRINCIPAL INVESTIGATOR (PI) DEVELOPS EXPERIMENT APPLICATION SOFTWARE (EAS) ON HIS HOST THAT IS NOT COMPATIBLE WITH CENTRAL SITE.
SENSITIVITY TO MISSION RATE

IN ORDER TO INDICATE THE SENSITIVITY TO MISSION RATE AN EXERCISE WAS CONDUCTED USING A TWELVE (12) YEAR MISSION MODEL CONSISTING OF SEVENTY-SEVEN (77) TOTAL FLIGHTS. DELTA COSTS FOR THIS REDUCED MISSION MODEL ARE SHOWN FOR SPACELAB COST AND USER COSTS FOR SIX (6) COMPARABLE OPTIONS.
SENSITIVITY TO MISSION RATE

$ MILLION

SPACELAB COST

ALL OPTIONS

IA1

IA2A

IA2B

IA3A

IA3B

IB1

IB2A

IB2B

IB3A

IB3B

IC1

IC2A

IC2B

IC3A

IIA4

IIB1

IIB2A

IIB2B

IIB3A

IIB3B

IIA4

IIB1

IIB2A

IIB2B

IIB3A

IIB3B

NON STANDARD MINI FOR OVERFLOW

STANDARD MINI FOR OVERFLOW

NO MINI

NON STD MINI

STD MINI

DISTRIBUTED

CENTRAL

USER COST
PRESENTATION OUTLINE

STUDY DEFINITION
OBJECTIVE
APPROACH
METHOD
SOFTWARE REQUIREMENTS DEVELOPMENT
COSTING
SUMMARY
SUMMARY

- SPACELAB SOFTWARE DEVELOPMENT AND MAINTENANCE COST IS INDEPENDENT OF OPTIONS

- COST IS NOT A SIGNIFICANT DRIVER BETWEEN CENTRAL AND DISTRIBUTED COMPUTER CONFIGURATIONS

- DISTRIBUTED COMPUTER CONCEPT SIMPLIFIES INTEGRATION WITHOUT SIGNIFICANT COST INCREASE

- STANDARD MINI HAS COST ADVANTAGES WHEN DEDICATED EXPERIMENT PROCESSOR IS SELECTED

- CENTRALIZED EXPERIMENT APPLICATION SOFTWARE DEVELOPMENT IS LEAST COST FOR ALL HARDWARE CONFIGURATIONS

- DECISION ON CENTRAL OR DEDICATED EXPERIMENT PROCESSOR SHOULD BE BASED ON ANALYSIS OF EACH MISSION REQUIREMENTS AFTER FINAL PAYLOAD SELECTION
ASSUMED CDMS FUNCTIONAL CAPABILITIES

- CRT HAS REFRESH CAPABILITY
- SYSTEM SOFTWARE ACCEPTS & ACCUMULATES CONTROL DATA VIA KEYBOARD ENTRY
- SPACELAB PROVIDES CAPABILITY TO INITIATE AND SCHEDULE P/L APPLICATION SOFTWARE AT DISCRETE MISSION ELAPSED TIMES
- SPACELAB PROVIDES TRANSFER OF TIME AND STATE VECTORS FROM ORBITER TO EXPERIMENT COMPUTER
- P/L APPLICATION SOFTWARE NOT REQUIRED TO SCHEDULE AND CONTROL SPACELAB MAGNETIC RECORDERS
- SPACELAB PROVIDES TRANSFER OF UPLINK COMMANDS FROM ORBITER TO EXPERIMENT COMPUTER
- SPACELAB PROVIDES FOR INPUT OF HIGH RATE P/L DATA TO EXPERIMENT COMPUTER
- SPACELAB TRANSFERS IPS STATE VECTORS FROM SPACELAB SUBSYSTEM COMPUTER TO EXPERIMENT COMPUTER
- ALL APPLICATION PROGRAMS, DATA CONSTANTS AND DISPLAY FORMATS STORED IN BULK MEMORY
- ALL APPLICATION PROGRAMS, DATA CONSTANTS, DISPLAY FORMATS AND BUFFER DATA MEMORY FOR ACTIVE PROGRAMS ARE INCLUDED IN THE ESTIMATE OF RAPID ACCESS MEMORY
# SPACELAB EXPERIMENT

## COMPUTER STUDY

<table>
<thead>
<tr>
<th>ORGANIZATION</th>
<th>MARSHALL SPACE FLIGHT CENTER</th>
<th>NAME: J. T. POWELL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATA SYSTEMS LABORATORY</td>
<td>SPACELAB EXPERIMENT</td>
<td>DATE: MARCH 1976</td>
</tr>
</tbody>
</table>

**Graph: Escalated vs. Unescalated**

**SPACELAB COST**

<table>
<thead>
<tr>
<th>Option</th>
<th>1A1</th>
<th>1A2A</th>
<th>1A3A</th>
<th>1A3B</th>
<th>1B1</th>
<th>1B2A</th>
<th>1B3A</th>
<th>1B3B</th>
<th>1C1</th>
<th>1C2A</th>
<th>1C3A</th>
<th>1C3B</th>
<th>1C3B</th>
<th>1C2B</th>
<th>1C1A</th>
<th>1B1</th>
<th>1B2A</th>
<th>1B3A</th>
<th>1B3B</th>
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<td>44</td>
<td>52</td>
<td>63</td>
<td>64</td>
<td>48</td>
<td>51</td>
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<td>51</td>
<td>51</td>
<td>63</td>
<td>48</td>
<td>51</td>
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**USER COST**

<table>
<thead>
<tr>
<th>Option</th>
<th>1A1</th>
<th>1A2A</th>
<th>1A3A</th>
<th>1A3B</th>
<th>1B1</th>
<th>1B2A</th>
<th>1B3A</th>
<th>1B3B</th>
<th>1C1</th>
<th>1C2A</th>
<th>1C3A</th>
<th>1C3B</th>
<th>1C3B</th>
<th>1C2B</th>
<th>1C1A</th>
<th>1B1</th>
<th>1B2A</th>
<th>1B3A</th>
<th>1B3B</th>
<th>1B3B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>34</td>
<td>39</td>
<td>43</td>
<td>45</td>
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<td>43</td>
<td>43</td>
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<td>43</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td>43</td>
</tr>
</tbody>
</table>
Requirements for No. of Computations per Sec

- 226 Flights
- From 1979 through 1991

45 Spacelab Mission Payloads

Mission 8

Mission 14

Cum. % of P/L or P/L Flights

No. of Computations per Sec.
BULK MEMORY

225 FLIGHTS
FROM 1979 THROUGH 1981

45 SPACELAB MISSION PAYLOADS

MISSION 21

MISSION 14

MISSION 8

CUM. O/P OF P/L OR P/L FLIGHTS

BULK MEMORY SIZE, WORDS

10^3 10^5 10^7 10^9
RAPID ACCESS MEMORY REQUIREMENTS

- 226 FLIGHTS
  FROM 1979 THROUGH 1991

- MISSION 21
- MISSION 14
- MISSION 8

- 45 SPACELAB MISSION PAYLOADS

CUM. 0/D OF P/L OR P/L FLIGHTS

RAPID ACCESS MEMORY SIZE, WORDS

$10^3$ $10^4$ $10^5$
REAL TIME SIMULATION TEST SET
(RTSTS)

REQUIRED FOR USE BY PI'S DEVELOPING DEP SOFTWARE

- PERFORMS REAL TIME EXPERIMENT SIMULATIONS
- PERFORMS REAL TIME CDMS SIMULATIONS
  - CENTRAL STANDARD SERVICES
  - DISPLAY
  - MASS STORAGE
- SERVES AS HOST COMPUTER FOR:
  - ASSEMBLY
  - COMPILATION
  - LINK EDIT
  - POST PROCESSING OF REAL TIME SIMULATIONS
# Spacelab Experiment Computer Study

## Selection of Missions for Detailed Analysis
### Early Shuttle Mission Candidates

<table>
<thead>
<tr>
<th>Mission No.</th>
<th>Name</th>
<th>Criteria for Selection</th>
<th>Space Science</th>
<th>Life Sciences</th>
<th>Multi-Discipline Science</th>
<th>Combined Astronomy</th>
<th>Life Sciences</th>
</tr>
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<tbody>
<tr>
<td>8</td>
<td>JOINT NASA/ESA</td>
<td>Preliminary Mission Feasibility Established</td>
<td>IMAP</td>
<td>IMAP DRM (PH A)</td>
<td>IMAP DRM</td>
<td>(DRM)</td>
<td>Low</td>
</tr>
<tr>
<td>10</td>
<td>MULTI-DISCIPLINE</td>
<td>Anticipated Level of Computer Processing Requirements</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>(IMAP)</td>
<td>Low</td>
</tr>
<tr>
<td>12</td>
<td>LIFE SCIENCES</td>
<td>Availability of Existing or Near Term Supporting Data</td>
<td>Available - GDC</td>
<td>Derivable from GDC</td>
<td>Near Term - GDC</td>
<td>Derivable from GDC</td>
<td>Low</td>
</tr>
<tr>
<td>14</td>
<td>Multi-Discipline Applic.</td>
<td>Other Computer Processing Studies Control</td>
<td>CRASS</td>
<td>CRASS</td>
<td>CRASS</td>
<td>CRASS</td>
<td>CRASS</td>
</tr>
<tr>
<td>19</td>
<td>AMPS</td>
<td>Other Considerations</td>
<td>Close MSFC I/F</td>
<td>Payload Complement</td>
<td>GDC Wrote DRM, Reviewed IMAP</td>
<td>Extremely Complex, Current Ph. B for Redefinition</td>
<td>-</td>
</tr>
<tr>
<td>21</td>
<td>COMBINED ASTRONOMY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>LIFE SCIENCES</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- **Selected for detailed analysis**
- **( )** Study has close relation to mission
CENTRAL EXPERIMENT COMPUTER FUNCTIONS

- NEEDED EVEN IF DISTRIBUTED COMPUTER CONFIGURATION IS ADOPTED
- EXECUTES STANDARD TASKS THAT ARE REQUIRED BY ALL PAYLOADS
- EXAMPLES ARE
  - DISPLAY
  - KEYBOARD
  - ORBITER COMMUNICATION
  - DISTRIBUTION OF UPLINK COMMANDS
  - PCM FORMATTING
OPTIONS NOT COSTED

• 1A4 IMPractical to develop support software for central computer to run on each non standard host

• 1B4 1C4

• 1C3B No dedicated experiment processor (DEP) in this option - therefore no DEP software simulation required

• 11A1 11A2A 11A2B IMPractical for central site to maintain support facilities for every non standard DEP

• 11A3A IMPractical for central site to furnish simulation facilities for every non standard DEP

• 11A3B Cost is the same as option 11A4
SPACELAB COSTS
($ - ESCALATED)

YEAR


MAN YRS

3,500
3,000
2,500
2,000
1,500
1,000

$ K
OPTION I CI
($ - ESCALATED)

$ K

78 79 80 81 82 83 84 85 86 87 88 89 90 91

MSFC - Form 3304 (Rev October 1972)
OPTION II B1
($ - ESCALATED)

$ K

78 79 80 81 82 83 84 85 86 87 88 89 90 91
### CENTRAL SITE COSTS FOR EAS DEVELOPMENT

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST</th>
<th>COSTED TO</th>
<th>USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Memory (1 Megabyte)</td>
<td>$393K</td>
<td>Spacelab</td>
<td>Allow 360-65 to Accommodate Throughout Requirements</td>
</tr>
<tr>
<td>Central Site Operation, Maintenance, and Consumables</td>
<td>$123.22/Hr.</td>
<td>User</td>
<td></td>
</tr>
<tr>
<td>Display Terminals (Qty. 8)</td>
<td>$7,912 Total</td>
<td>User</td>
<td>Local Programmer Coding, Functional Simulation EAS Checkout</td>
</tr>
<tr>
<td>Display Terminals Maintenance</td>
<td>$528/Yr.</td>
<td>User</td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remote Job Entry Terminal</td>
<td>$43,45K Each</td>
<td>User</td>
<td>Remote Programmer Coding, Functional Simulation EAS Checkout</td>
</tr>
<tr>
<td>Telecommunications Rental</td>
<td>$15.72K/Yr./Terminal</td>
<td>User</td>
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<tr>
<td>Terminal Maintenance</td>
<td>$3,180/Yr.</td>
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### Central Site Facility

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>360/65 and peripherals</td>
<td>$2,460 K</td>
</tr>
<tr>
<td>Simulation computer</td>
<td>137 K</td>
</tr>
<tr>
<td>Computer interface device (CID)</td>
<td>186 K</td>
</tr>
<tr>
<td>Command and data management system (CDMS)</td>
<td>1,920 K</td>
</tr>
<tr>
<td></td>
<td>$4,703 K</td>
</tr>
</tbody>
</table>

**Operations and Maintenance**

- $511 K per year
- ($245 per hour)
SPACELAB COSTS

($ - ESCALATED)
<table>
<thead>
<tr>
<th>SPACELAB</th>
<th>All Options</th>
<th>Escalated Average Cost/Flight ($K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAS</td>
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<tr>
<td>IA1</td>
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<tr>
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<tr>
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<td>IB1</td>
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</table>
APPROVAL

SPACELAB EXPERIMENT COMPUTER STUDY
Volume I: Executive Summary

By James L. Lewis, Bobby C. Hodges, and James O. Christy

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

[Signature]

J. P. POWELL
Director, Data Systems Laboratory

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