General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.
NASA TECHNICAL MEMORANDUM

NASA TM X-73349

SPACELAB EXPERIMENT COMPUTER STUDY
VOL 1: EXECUTIVE SUMMARY (PRESENTATION) (NASA) 68 p HC
A04/MF A01

CSCL 2-8 G3/15 56997

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
This is Volume I of five volumes.

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).
SPACELAB EXPERIMENT COMPUTER STUDY

TABLE OF CONTENTS

VOLUME I  EXECUTIVE SUMMARY

Presentation Charts - April 1976
Backup Charts - April 1976

VOLUME II  STUDY ELEMENTS AND APPROACH

Section 1  Introduction

Section 2  Groundrules and Assumptions

Section 3  Options and Cost Elements
   A. Options
   B. Cost Elements

Section 4  Summary of Software Requirements Analysis Study

Section 5  Cost Analysis
   A. Spacelab Costs
   B. Spacelab User Costs

Section 6  Cost Data Matrix

Section 7  Costing Rationale
   A. Minicomputers
   B. Computer Interface Device (CID) and Real Time Simulation Test Set (RTSTS)
   C. Costs Per Statement/Costs Per Instruction
   D. Software Sizing
   E. Central Experiment Computer Functions
   F. Consumable Stock
   G. Central Site Computer Additions
   H. Equipment Maintenance
   I. Miscellaneous Supporting Data
VOLUME III

SPACELAB COST DATA

Section 1. Costing Method
Section 2. Cost Data

VOLUME IV

SPACELAB USER COST DATA (CENTRAL EXPERIMENT COMPUTER)

Section 1. Option IA1 - Central With Mini, Central Software Development by Central Group.

1.1 Costing Method
1.2 Cost Data

Section 2. Option IA2A - Central With Mini, Central Software Development by PI at Central Facility.

2.1 Costing Method
2.2 Cost Data

Section 3. Option IA2B - Central With Mini, Central Software Development by PI at Central Facility Remote.

3.1 Costing Method
3.2 Cost Data

Section 4. Option IA3A - Central With Mini, Software Development by PI at His Facility. Real Time Simulation at Central Facility.

4.1 Costing Method
4.2 Cost Data

Section 5. Option IA3B - Central With Mini, Software Development by PI at His Facility. Real Time Simulation at His Facility for DEP.

5.1 Costing Method
5.2 Cost Data
Section 6. Option IA4 - Central With Mini, Software Development by PI at His Facility. Not Compatible With Central Facility (This Option Not Included - Excessive Cost).

6.1 Costing Method
6.2 Cost Data

Section 7. Option IB1 - Central with Standard Mini, Central Software Development by Central Group.

7.1 Costing Method
7.2 Cost Data

Section 8. Option IB2A - Central With 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


10.1 Costing Method
10.2 Cost Data

Section 11. Option IB3B - Central With Standard Mini, Software Development by PI on His Facility. Real Time Simulation at His Facility.

11.1 Costing Method
11.2 Cost Data
Section 12. Option IB4 - Central With Standard Mini, Software Development by PI at His Facility. Not Compatible with Central Facility (This Option not included - Excessive Cost).

12.1 Costing Method
12.2 Cost Data

Section 13. Option IC1 - Central No Mini, Central Software Development Central Group.

13.1 Costing Method
13.2 Cost Data

Section 14. Option IC2A - Central No Mini, Central Software Development by PI at Central Facility Local.

14.1 Costing Method
14.2 Cost Data

Section 15. Option IC2B - Central No Mini, Central Software Development by PI at Central Facility Remote.

15.1 Costing Method
15.2 Cost Data

Section 16. Option IC3A - Central No Mini, Software Development by PI at His Facility. Real Time Simulation at Central Facility.

16.1 Costing Method
16.2 Cost Data

Section 17. Option IC3B - Central No Mini, Software Development by PI at His Facility. Real Time Simulation at His Facility.

17.1 Costing Method
17.2 Cost Data
Section 18. Option 1C4 - Central No Mini
Software Development by PI
at His Facility. Not Compatible
with Central Facility (This Option
Not Included - Excessive Cost).

18.1 Costing Method
18.2 Cost Data
VOLUME V

SPACELAB USER COST DATA (DISTRIBUTED COMPUTER)

Section 1. Option IIAl - Distributed Non-
Standard Mini, Central Software Development by Central Group.
(Not Priced - Option Not Feasible).

1.1 Costing Method
1.2 Cost Data

Section 2. Option IIAlA2A - Distributed Non-
Standard Mini, Central Software Development by PI at Central Facility Local.
(Not Priced - Option Not Feasible).

2.1 Costing Method
2.2 Cost Data

Section 3. Option IIAlA2B - Distributed Non-
Standard Mini, Central Software Development by PI at Central Facility Remote.
(Not Priced - Option Not Feasible).

3.1 Costing Method
3.2 Cost Data

Section 4. Option IIAlA3A - Distributed Non-
(Not Priced - Option Not Feasible).

4.1 Costing Method
4.2 Cost Data

Section 5. Option IIAlA3B - Distributed Non-
Standard Mini, Software Development by PI at His Facility. Real Time Simulation Testing on RTSTS.
(Not Priced - Option Not Feasible).

5.1 Costing Method
5.2 Cost Data
Section 6. Option IIA4 - Distributed Non-Standard Mini, Software Development by PI at His Facility. Not compatible with Central Facility.

6.1 Costing Method
6.2 Cost Data

Section 7. Option IIB1 - Distributed Standard Mini, Central Software Development by Central Group.

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


10.1 Costing Method
10.2 Cost Data

Section 11. Option IIB3B - Distributed Standard Mini, Software Development by PI at His Facility. Real Time Simulation at His Facility.

11.1 Costing Method
11.2 Cost Data
Section 12. Option IIb4 - Distributed Standard Mini, Software Development by PI at His Facility. Not Compatible With Central Facility. (Same as Option IIb3B)

12.1 Costing Method
12.2 Cost Data

Section 13. Option IIb3B (Variation I)

13.1 Costing Method
13.2 Cost Data

Section 14. Option IIb3B (Variation II)

14.1 Costing Method
14.2 Costing Data
**PRESENTATION OUTLINE**

**STUDY DEFINITION**

**OBJECTIVE**

**APPROACH**

**METHOD**

**SOFTWARE REQUIREMENTS DEVELOPMENT**

**COSTING**

**SUMMARY**
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
<table>
<thead>
<tr>
<th>STUDY METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Derive computation requirements for Spacelab payload elements (experiments) by detailed analysis of three missions - extrapolation to 226 missions in mission model.</td>
</tr>
<tr>
<td>- Speed</td>
</tr>
<tr>
<td>- Memory - main and bulk</td>
</tr>
<tr>
<td>- Statements to be coded</td>
</tr>
<tr>
<td>- Estimate size of European delivered software and the expected change rate</td>
</tr>
<tr>
<td>- Define options to be evaluated</td>
</tr>
<tr>
<td>- Develop comprehensive set of assumptions and ground rules</td>
</tr>
<tr>
<td>- Define method of costing for each element</td>
</tr>
<tr>
<td>- Combine costs to determine yearly and total costs</td>
</tr>
<tr>
<td>- Maintain separation of costs - Spacelab and user</td>
</tr>
<tr>
<td>- Examine major cost elements for sensitivity to assumptions and ground rules</td>
</tr>
<tr>
<td>- Maintain traceability for all cost elements</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>PRESENTATION OUTLINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUDY DEFINITION</td>
</tr>
<tr>
<td>OBJECTIVE</td>
</tr>
<tr>
<td>APPROACH</td>
</tr>
<tr>
<td>METHOD</td>
</tr>
<tr>
<td>SOFTWARE REQUIREMENTS DEVELOPMENT</td>
</tr>
<tr>
<td>COSTING</td>
</tr>
<tr>
<td>SUMMARY</td>
</tr>
</tbody>
</table>
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 GROUNDRULES

- 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

<table>
<thead>
<tr>
<th>79</th>
<th>80</th>
<th>81</th>
<th>82</th>
<th>83</th>
<th>84</th>
<th>85</th>
<th>86</th>
<th>87</th>
<th>88</th>
<th>89</th>
<th>90</th>
<th>91</th>
<th>92</th>
<th>93</th>
<th>94</th>
<th>95</th>
<th>96</th>
<th>97</th>
<th>98</th>
<th>99</th>
<th>00</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

### Description

- **AST-10A**: 200 Mission 21
- **AST-10B**: 200 Stellar Astronomy
- **AST-10C**: 200 Stellar Astronomy
- **AST-1000X**: 200 Stellar Astronomy (28.5 Deg Orbit)
- **AST-1000Y**: 200 Stellar Astronomy (30 Deg Orbit)
- **AST-1000Z**: 200 Stellar Astronomy (28 Deg Orbit)
- **AST-10F**: 200 Stellar Astronomy
- **AST-10G**: 200 Stellar Astronomy
- **AST-10J**: 200 Stellar Astronomy
- **AST-10K**: 200 Stellar Astronomy
- **AST-10L**: 200 Stellar Astronomy
- **AST-10M**: 200 Stellar Astronomy
- **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
- **LS-2A**: 200 Life Sciences Shuttle Laboratory (Mod 1)
- **LS-2B**: 200 Life Sciences Shuttle Laboratory (Mod 2)
- **MD-1A**: 200 First Spacelab Mission (Mission A)
- **MD-1B**: 200 Multi-User Mission (10)
- **NN/15**: 200 Space Manufacturing
- **NN/16A**: 200 Earth Observations (ESA 28.5 Deg Orbit)
- **NN/16B**: 200 Earth Observations (ESA 30 Deg Orbit)
- **NN/16C**: 200 Solar Physics
- **OA-1A**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1B**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1C**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1D**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1E**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1F**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1G**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1H**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1I**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1J**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1K**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1L**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1M**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1N**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1O**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1P**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1Q**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1R**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1S**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1T**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1U**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1V**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1W**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1X**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1Y**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **OA-1Z**: 200 Multidiscipline Applications (ISSH 14/25 Deg)
- **PH-1A**: 200 High Energy (X-Ray/Mass Spectrometer)
- **PH-1B**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1C**: 200 High Energy (X-Ray/Cosmic Ray Survey)
- **PH-1D**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1E**: 200 High Energy (X-Ray/Cosmic Ray Survey)
- **PH-1F**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1G**: 200 High Energy (X-Ray/Cosmic Ray Survey)
- **PH-1H**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1I**: 200 High Energy (X-Ray/Cosmic Ray Survey)
- **PH-1J**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1K**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1L**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1M**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1N**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1O**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1P**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1Q**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1R**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1S**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1T**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1U**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1V**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1W**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1X**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1Y**: 200 High Energy (X-Ray/Space Telescope)
- **PH-1Z**: 200 High Energy (X-Ray/Space Telescope)

**Notes:**
- **X, Y** distinguish different orbits or misnomer duration for same mission payload.
## PAYLOADS USED FOR DETAILED ANALYSIS

<table>
<thead>
<tr>
<th>MISSION 8 (JOINT NASA/ESA)</th>
<th>MISSION 14 (MULTIDISCIPLINE APPLICATIONS)</th>
<th>MISSION 21 (COMBINED STELLAR ASTRONOMY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>APE-01 LIDAR/LASER SOUNDER</td>
<td>CN-04-S ELECTROMAGNETIC ENVIRONMENT</td>
<td>AS-01-S 1.5 M IR TELESCOPE</td>
</tr>
<tr>
<td>AP-09-S ELECTRON ACCELEROMETER</td>
<td>CN-08-S TWT OPEN ENVELOPE</td>
<td>AS-04-S 1.0 M UV/OPTICAL TELESCOPE</td>
</tr>
<tr>
<td>AP-13-S LOW LIGHT LEVEL TV</td>
<td>EO-20-S IMAGING RADAR</td>
<td></td>
</tr>
<tr>
<td>APE-07 PASSIVE ATMOSPHERE SOUNDER</td>
<td>OP-03-S MICROWAVE RADIO-METRY</td>
<td></td>
</tr>
<tr>
<td>SPE-01 FREE-FLOW ELECTROPHORESIS FACILITY</td>
<td>SP-31-S BIOLOGICAL/FURNACE SUBELEMENTS AND CORE</td>
<td></td>
</tr>
<tr>
<td>SPE-80/85 ISOTHERMAL MULTIPLE HEATING FACILITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO-01-S ZERO G CLOUD PHYSICS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST-31-S DROP DYNAMICS FACILITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STE-10 ADVANCED HEAT PIPE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LS-13-S LIFE SCIENCE PAYLOAD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASE-01 WIDE-FIELD CAMERA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EOE-01 METRIC CAMERA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO-19-S MK II INTERFEROMETER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN-08-S OPEN TWT EXPERIMENTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VERIFICATION FLIGHT INSTRUMENTATION</td>
<td></td>
</tr>
</tbody>
</table>
# Example Integrated Payload Computer Processing Timeline

**Mission:** 14  
**Payload Element:** All-Summary  

<table>
<thead>
<tr>
<th>HOURS FROM LAUNCH</th>
<th>24</th>
<th>25</th>
<th>26</th>
<th>27</th>
<th>28</th>
<th>29</th>
<th>30</th>
<th>31</th>
<th>32</th>
<th>33</th>
<th>34</th>
<th>35</th>
<th>36</th>
<th>37</th>
<th>38</th>
<th>39</th>
<th>40</th>
<th>41</th>
<th>42</th>
<th>43</th>
<th>44</th>
<th>45</th>
<th>46</th>
<th>47</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PAYLOAD ELEMENT OPERATIONS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN-01-S EM EXPERIMENT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO-2S-S RADAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP-03-S RADIOMETER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN-09-S TWT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP-31-S B10/FURNACE*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(*Includes Experiments 101, 102, 201, 203, 207, &amp; 209)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Computer Loading**  

<table>
<thead>
<tr>
<th>EOPS (K)</th>
<th>80</th>
<th>60</th>
<th>40</th>
<th>20</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6193</td>
<td>5793</td>
<td>51320</td>
<td>2900</td>
<td>30030</td>
</tr>
</tbody>
</table>

**Computer Main Memory**  

<table>
<thead>
<tr>
<th>16-bit Words (K)</th>
<th>30</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>38281</td>
<td>16190</td>
<td></td>
</tr>
</tbody>
</table>

**Data Bus Traffic**  

<table>
<thead>
<tr>
<th>KBPS</th>
<th>12-16</th>
<th>6-8</th>
<th>2-4</th>
<th>2-4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2544</td>
<td>11520</td>
<td>8280</td>
<td>4224</td>
</tr>
</tbody>
</table>

**Controls**  

<table>
<thead>
<tr>
<th>KBPS</th>
<th>1-2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6091</td>
</tr>
</tbody>
</table>
SPACELAB EXPERIMENT
COMPUTER STUDY

NO. OF COMPUTATIONS PER SEC.

TOTAL CAPACITY
AVAILABLE FOR EAS

SPACELAB MISSION PAYLOADS
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>
<thead>
<tr>
<th>MISSION P/L</th>
<th>P/L ELEMENTS</th>
<th>P/L ELEMENT COMPS/SEC</th>
<th>MISSION COMPS/SEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. AST 10a</td>
<td>1M UV TELESCOPE</td>
<td>167,600</td>
<td>346,300</td>
</tr>
<tr>
<td></td>
<td>1M IR TELESCOPE</td>
<td>178,700</td>
<td></td>
</tr>
<tr>
<td>2. AST 10d</td>
<td>1M UV TELESCOPE</td>
<td>167,600</td>
<td>347,600</td>
</tr>
<tr>
<td></td>
<td>3M AMBIENT TEMP. IR TELESCOPE</td>
<td>180,000</td>
<td></td>
</tr>
<tr>
<td>3. AST 10k</td>
<td>1M UV TELESCOPE</td>
<td>167,600</td>
<td>347,600</td>
</tr>
<tr>
<td></td>
<td>2.5M IR TELESCOPE</td>
<td>180,000</td>
<td></td>
</tr>
<tr>
<td>4. AST 11b/c</td>
<td>ATM SPACELAB</td>
<td>2,500,000*</td>
<td>2,500,000</td>
</tr>
<tr>
<td>5. AST 11d</td>
<td>SOLAR ACTIVITY</td>
<td>2,500,000*</td>
<td>2,500,000</td>
</tr>
<tr>
<td>6. AST 11e</td>
<td>SOLAR FINE POINTING</td>
<td>2,500,000*</td>
<td>2,500,000</td>
</tr>
<tr>
<td>7. MU-2</td>
<td>X-RAY ANGULAR STRUCTURE SOLAR ACTIVITY GROWTH MK. II INTERFEROMETER</td>
<td>2,500,000* 7,600</td>
<td>2,527,600</td>
</tr>
</tbody>
</table>

*BASED ON PROCESSING (1024 X 1024) IMAGE EVERY 10 SECONDS.*
SPACELAB EXPERIMENT
COMPUTER STUDY
RAPID ACCESS MEMORY

AVAILABLE TOTAL CAPACITY

AVAILABLE FOR EAB

RAPID ACCESS MEMORY SIZE, WORDS

SPACELAB MISSION PAYLOADS
SPACELAB MISSION PAYLOADS

BULK MEMORY SIZE, WORDS

TOTAL CAPACITY
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.
PRESENTATION OUTLINE

STUDY DEFINITION

OBJECTIVE

APPROACH

METHOD

SOFTWARE REQUIREMENTS DEVELOPMENT

COSTING

SUMMARY
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/GUIDELINES

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 HOL STATEMENTS/YR) X COST/STATEMENT

SUMMATION OF ALL COST FACTORS BY YEAR

REQUIREMENTS STUDY RESULTS

MINI-COMPUTER STUDY RESULTS
### 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 real-time simulation at central site
   
   B. Real-time simulation for dedicated experiment processor (DEP) experiment application software (EAS) on real-time 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>
</tr>
<tr>
<td>- SUBSYSTEM COMPUTER SOFTWARE DEVELOPMENT</td>
<td>- GROUND CHECKOUT SOFTWARE DEVELOPMENT AND ACCEPTANCE</td>
<td>- FACILITY OPERATION AND AND MAINTENANCE</td>
</tr>
<tr>
<td>AND ACCEPTANCE</td>
<td>GROUND CHECKOUT SOFTWARE MAINTENANCE</td>
<td>- HOST AND SIMULATION COMPTER SUPPORT SOFTWARE DEVELOPMENT AND ACCEPTANCE</td>
</tr>
<tr>
<td>- SUBSYSTEM COMPUTER SOFTWARE MAINTENANCE</td>
<td>GROUND CHECKOUT SOFTWARE CONFIGURATION MANAGEMENT RELEASE, AND DISTRIBUTION</td>
<td>- HOST AND SIMULATION COMPTER 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>
<td></td>
</tr>
<tr>
<td>- EXPERIMENT COMPUTER SOFTWARE DEVELOPMENT</td>
<td>EGSE COMPUTER SOFTWARE PRODUCTION SET MAINTENANCE</td>
<td></td>
</tr>
<tr>
<td>AND ACCEPTANCE</td>
<td>EGSE COMPUTER SOFTWARE PRODUCTION SET CONFIGURATION MANAGEMENT RELEASE, AND DISTRIBUTION</td>
<td></td>
</tr>
<tr>
<td>- EXPERIMENT COMPUTER SOFTWARE MAINTENANCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- EXPERIMENT COMPUTER SOFTWARE CONFIGURATION MANAGEMENT RELEASE, AND DISTRIBUTIONS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## USER COST ELEMENTS

<table>
<thead>
<tr>
<th>PI HOST COMPUTER</th>
<th>EXPERIMENT</th>
<th>DEP*</th>
<th>RTSTS*</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOST AND SIMULATION COMPUTER SUPPORT SOFTWARE MAINTENANCE</td>
<td>EAS DEVELOPMENT</td>
<td>EXPERIMENT PROCESSOR ACQUISITION</td>
<td>RTSTS ACQUISITION</td>
</tr>
<tr>
<td></td>
<td>EAS MAINTENANCE</td>
<td>EXPERIMENT PROCESSOR MAINTENANCE AND DISTRIBUTION</td>
<td>RTSTS MAINTENANCE, OPERATION, AND DISTRIBUTION</td>
</tr>
<tr>
<td></td>
<td>EAS INTEGRATION</td>
<td>DEP SOFTWARE DEVELOPMENT AND PROCUREMENT</td>
<td>RTSTS SUPPORT SOFTWARE DEVELOPMENT AND PROCUREMENT</td>
</tr>
<tr>
<td></td>
<td>EXPERIMENT PREFLIGHT CHECKOUT SOFTWARE DEVELOPMENT</td>
<td>DEP SOFTWARE MAINTENANCE AND DISTRIBUTION</td>
<td>RTSTS SUPPORT SOFTWARE MAINTENANCE AND DISTRIBUTION</td>
</tr>
<tr>
<td></td>
<td>EXPERIMENT PREFLIGHT CHECKOUT SOFTWARE MAINTENANCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EAS DEPENDENT CENTRAL SITE HARDWARE SUPPLEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EAS DEPENDENT CENTRAL SITE SOFTWARE SUPPLEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EXPERIMENT REAL-TIME SIMULATION SOFTWARE DEVELOPMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EXPERIMENT REAL-TIME SIMULATION SOFTWARE MAINTENANCE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*DEP - DISTRIBUTED EXPERIMENT PROCESSOR
RTSTS - REAL-TIME SIMULATION TEST SET
# Option/Cost Element Correlation Matrix

## Options

<table>
<thead>
<tr>
<th></th>
<th>Option Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Centralized Standard Minicomputer Configuration</td>
</tr>
<tr>
<td>A</td>
<td>Non-standard Minicomputer</td>
</tr>
<tr>
<td></td>
<td>1. Central group develops EAS at central facility</td>
</tr>
<tr>
<td></td>
<td>2. PI develops EAS at central facility</td>
</tr>
<tr>
<td></td>
<td>3. PI develops EAS at his facility which is compatible with EDSL</td>
</tr>
<tr>
<td></td>
<td>4. PI uses an EDSL</td>
</tr>
<tr>
<td>B</td>
<td>Standard Minicomputer</td>
</tr>
<tr>
<td></td>
<td>1. Central group develops EAS at central facility</td>
</tr>
<tr>
<td></td>
<td>2. PI develops EAS at central facility</td>
</tr>
<tr>
<td></td>
<td>3. PI develops EAS at his facility which is compatible with EDSL</td>
</tr>
<tr>
<td></td>
<td>4. PI uses an EDSL</td>
</tr>
<tr>
<td>C</td>
<td>No Minicomputer</td>
</tr>
<tr>
<td></td>
<td>1. Central group develops EAS at central facility</td>
</tr>
<tr>
<td></td>
<td>2. PI develops EAS at central facility</td>
</tr>
<tr>
<td></td>
<td>3. PI develops EAS at his facility which is compatible with EDSL</td>
</tr>
<tr>
<td></td>
<td>4. PI uses an EDSL</td>
</tr>
<tr>
<td>D</td>
<td>Distributed Minicomputer Configuration</td>
</tr>
<tr>
<td>A</td>
<td>Non-standard Minicomputer</td>
</tr>
<tr>
<td></td>
<td>1. Central group develops EAS at central facility</td>
</tr>
<tr>
<td></td>
<td>2. PI develops EAS at central facility</td>
</tr>
<tr>
<td></td>
<td>3. PI develops EAS at his facility which is compatible with EDSL</td>
</tr>
<tr>
<td></td>
<td>4. PI uses an EDSL</td>
</tr>
<tr>
<td>B</td>
<td>Standard Minicomputer</td>
</tr>
<tr>
<td></td>
<td>1. Central group develops EAS at central facility</td>
</tr>
<tr>
<td></td>
<td>2. PI develops EAS at central facility</td>
</tr>
<tr>
<td></td>
<td>3. PI develops EAS at his facility which is compatible with EDSL</td>
</tr>
<tr>
<td></td>
<td>4. PI uses an EDSL</td>
</tr>
</tbody>
</table>
## Option/Cost Element Correlation Matrix

### Spacelab User Cost Elements

<table>
<thead>
<tr>
<th>Options</th>
<th>4. Experiment</th>
<th>5. Off</th>
<th>6. RTSTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Non Standard Minicomputer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Central group develops EAS at central facility (cost)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Develops EAS at central facility, local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Develops EAS at his facility which is compatible with EAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Develops EAS at his facility which is not compatible with EAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Standard Minicomputer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Central group develops EAS at central facility (cost)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Develops EAS at central facility, local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Develops EAS at his facility which is compatible with EAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Develops EAS at his facility which is not compatible with EAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. No Minicomputer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Central group develops EAS at central facility (cost)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Develops EAS at central facility, local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Develops EAS at his facility which is compatible with EAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Develops EAS at his facility which is not compatible with EAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Distributed Standard Minicomputer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Central group develops EAS at central facility (cost)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Develops EAS at central facility, local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Develops EAS at his facility which is compatible with EAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Develops EAS at his facility which is not compatible with EAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Standard Minicomputer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Central group develops EAS at central facility (cost)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Develops EAS at central facility, local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Develops EAS at his facility which is compatible with EAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Develops EAS at his facility which is not compatible with EAS</td>
<td></td>
<td></td>
<td></td>
</tr>
</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 COMPILLED, 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.
<table>
<thead>
<tr>
<th>COST ELEMENT</th>
<th>FY77</th>
<th>78</th>
<th>79</th>
<th>80</th>
<th>81</th>
<th>82</th>
<th>83</th>
<th>84</th>
<th>85</th>
<th>86</th>
<th>87</th>
<th>88</th>
<th>89</th>
<th>90</th>
<th>91</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAS DEVELOPMENT</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4940</td>
<td>14596</td>
<td>8282</td>
<td>1240</td>
<td>3937</td>
<td>0</td>
<td>5183</td>
<td>4526</td>
<td>898</td>
<td>1550</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EAS MAINTENANCE</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3371</td>
<td>4443</td>
<td>7956</td>
<td>5344</td>
<td>7793</td>
<td>3969</td>
<td>5750</td>
<td>5618</td>
<td>5892</td>
<td>7217</td>
<td>7229</td>
</tr>
<tr>
<td>PREFLIGHT CHECKOUT S/W DEV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>13020</td>
<td>4650</td>
<td>13950</td>
<td>3720</td>
<td>1850</td>
<td>0</td>
<td>2790</td>
<td>2790</td>
<td>930</td>
<td>930</td>
<td>-</td>
</tr>
<tr>
<td>PREFLIGHT CHECKOUT S/W MAINT</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1302</td>
<td>558</td>
<td>2232</td>
<td>3511</td>
<td>4092</td>
<td>2790</td>
<td>4650</td>
<td>3627</td>
<td>4929</td>
<td>5022</td>
<td>5952</td>
</tr>
<tr>
<td>EXP. REAL TIME SIMULATION S/W DEV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>19600</td>
<td>7000</td>
<td>21000</td>
<td>5600</td>
<td>2800</td>
<td>0</td>
<td>4200</td>
<td>4200</td>
<td>1400</td>
<td>1400</td>
<td>-</td>
</tr>
<tr>
<td>EXP. REAL TIME SIMULATION S/W MAINT</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1960</td>
<td>840</td>
<td>3360</td>
<td>3700</td>
<td>6100</td>
<td>4200</td>
<td>7000</td>
<td>6460</td>
<td>7420</td>
<td>7560</td>
<td>8960</td>
</tr>
<tr>
<td>DEP O/F SYS DEV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>800</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DEP O/F SYS MAINT</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

| STATEMENTS TOTAL                   | -    | -  | -  | 38360| 22919| 49113| 24148| 20272| 10005| 23172| 28956| 17945| 22161| 20499| 22181 |

MSFC Form 3304 (Rev October 1973)
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 II A4, IS THE EFFECT OF PARTIAL STANDARDIZATION OF MINICOMPUTERS; I.E., EACH OF 12 DISCIPLINES WOULD USE THE SAME TYPE OF COMPUTER.
<table>
<thead>
<tr>
<th>OPTIONS CONSIDERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>CENTRAL (I)</td>
</tr>
<tr>
<td>DISTRIBUTED (II)</td>
</tr>
<tr>
<td>NON STANDARD MINI FOR OVERFLOW (A)</td>
</tr>
</tbody>
</table>

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 COST/STATEMENT

$ MILION

ALL OPTIONS

SPACELAB COST

USER COST

MARSHALL SPACE FLIGHT CENTER
SPACELAB EXPERIMENT
COMPUTER STUDY

ORGANIZATION
DATA SYSTEMS LABORATORY

NAME
J. T. POWELL
DATE
APR' 76

STD. MINI FOR EACH OF 12 DISCIPLINES

NON STANDARD MINI FOR OVERFLOW

STANDARD MINI FOR OVERFLOW

NO MINI

NON STD MINI

S-D MIN

DISTRIBUTED
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
ESCALATED VS. UNESCALATED

S MILLION

ALL OPTIONS

SPACELAB COST

CENTRAL AND MINI

CENTRAL STD MINI

CENTRAL ONLY

NON STD

DISTRIBUTED STD MINI

USER COST

110
100
90
80
70
60
50
40
30
20
10
0
REQUIREMENTS FOR NO. OF COMPUTATIONS PER SEC

226 FLIGHTS
FROM 1979 THROUGH 1991

45 SPACELAB MISSION PAYLOADS

MISSION 21
MISSION 8
MISSION 14
BULK MEMORY

225 FLIGHTS
FROM 1979 THROUGH 1991

45 SPACELAB MISSION PAYLOADS

MISSION 8
MISSION 14
MISSION 21

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

BULK MEMORY SIZE, WORDS

10^3  10^4  10^5  10^6  10^7  10^8  10^9
RAPID ACCESS MEMORY REQUIREMENTS

- 226 FLIGHTS
FROM 1979 THROUGH 1991

- MISSION 21
- MISSION 14
- MISSION 8

- 45 SPACELAB MISSION PAYLOADS

CUM. % 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
SELECTED MISSIONS FOR DETAILED ANALYSIS
EARLY SHUTTLE MISSION CANDIDATES

<table>
<thead>
<tr>
<th>MISSION NO.</th>
<th>CRITERIA FOR SELECTION</th>
<th>LIFE SCIENCES</th>
<th>MULTIDISCIPLINE APPLIC.</th>
<th>AMPS</th>
<th>COMBINED ASTRONOMY</th>
<th>LIFE SCIENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>CRITERIA FOR SELECTION</td>
<td>LIFE SCIENCES</td>
<td>MULTIDISCIPLINE APPLIC.</td>
<td>AMPS</td>
<td>COMBINED ASTRONOMY</td>
<td>LIFE SCIENCES</td>
</tr>
<tr>
<td></td>
<td>FEASIBILITY ESTABLISHED</td>
<td>IMAP</td>
<td>IMAP</td>
<td>IMAP</td>
<td>IMAP (DRM)</td>
<td>IMAP (DRM)</td>
</tr>
<tr>
<td></td>
<td>ANTICIPATED LEVEL</td>
<td>MEDIAN</td>
<td>LOW</td>
<td>LOW</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
<tr>
<td></td>
<td>OF COMPUTER PROCESSING</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td>REQUIREMENTS</td>
<td>LOW</td>
<td>LOW</td>
<td>HIGH</td>
<td>HIGH</td>
<td>LOW</td>
</tr>
<tr>
<td></td>
<td>AVAILABILITY OF</td>
<td>AVAILABLE</td>
<td>DERIVABLE</td>
<td>NEAR</td>
<td>NEAR</td>
<td>NEAR</td>
</tr>
<tr>
<td></td>
<td>EXISTING OR</td>
<td>GDC</td>
<td>FROM GDC</td>
<td>TERM</td>
<td>TERM</td>
<td>TERM</td>
</tr>
<tr>
<td></td>
<td>NEAR TERM SUPPORTING</td>
<td>DATA MGT.</td>
<td>DATA MGT.</td>
<td>DATA MGT.</td>
<td>DATA MGT.</td>
<td>DATA MGT.</td>
</tr>
<tr>
<td></td>
<td>STUDY</td>
<td>PH. A STUDY</td>
<td>PH. A STUDY</td>
<td>PH. A STUDY</td>
<td>PH. A STUDY</td>
<td>PH. A STUDY</td>
</tr>
<tr>
<td></td>
<td>OTHER COMPUTER PROCESSING</td>
<td>CRASS</td>
<td>CRASS</td>
<td>CRASS</td>
<td>CRASS</td>
<td>CRASS</td>
</tr>
<tr>
<td></td>
<td>STUDIES</td>
<td>CRASS</td>
<td>CRASS</td>
<td>CRASS</td>
<td>CRASS</td>
<td>CRASS</td>
</tr>
<tr>
<td></td>
<td>OTHER CONSIDERATIONS</td>
<td>CLOSE</td>
<td>GDC</td>
<td>GDC</td>
<td>PAYLOAD COMPLEMENT</td>
<td>GDC COMPLEMENT</td>
</tr>
<tr>
<td></td>
<td>MSFC</td>
<td>EXPECTED TO</td>
<td>REVIEWED</td>
<td>CURRENT PH.</td>
<td>CURRENT PH.</td>
<td>CURRENT PH.</td>
</tr>
<tr>
<td></td>
<td>I/F</td>
<td>CHANGE SOON</td>
<td>IMAP</td>
<td>B FOR REDEFINITION</td>
<td>B FOR REDEFINITION</td>
<td>B FOR REDEFINITION</td>
</tr>
</tbody>
</table>

Selected for detailed analysis

( ) Study has close relation to mission
<table>
<thead>
<tr>
<th>CENTRAL EXPERIMENT COMPUTER FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• NEEDED EVEN IF DISTRIBUTED COMPUTER CONFIGURATION IS ADOPTED</td>
</tr>
<tr>
<td>• EXECUTES STANDARD TASKS THAT ARE REQUIRED BY ALL PAYLOADS</td>
</tr>
<tr>
<td>• EXAMPLES ARE</td>
</tr>
<tr>
<td>• DISPLAY</td>
</tr>
<tr>
<td>• KEYBOARD</td>
</tr>
<tr>
<td>• ORBITER COMMUNICATION</td>
</tr>
<tr>
<td>• DISTRIBUTION OF UPLINK COMMANDS</td>
</tr>
<tr>
<td>• PCM FORMATTING</td>
</tr>
</tbody>
</table>
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**  IMPractical for central site to maintain support facilities for every non-standard DEP
- **11A2A**
- **11A2B**
- **11A3A**  IMPractical for central site to furnish simulation facilities for every non-standard DEP
- **11A3B**  COST is the same as option 11A4
OPTION I CI
($ - ESCALATED)

$ K

5,000

4,500

4,000

3,500

3,000

2,500

2,000

1,500

78 79 80 81 82 83 84 85 86 87 88 89 90 91
OPTION II B1
($ - ESCALATED)
<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 Throughput 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></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>
<td></td>
</tr>
<tr>
<td>Terminal Maintenance</td>
<td>$3,180/Yr.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SPACELAB EXPERIMENT COMPUTER STUDY

CENTRAL SITE FACILITY

360/65 AND PERIPHERALS $2,460 K

SIMULATION COMPUTER 137 K

COMPUTER INTERFACE DEVICE (CID) 186 K

COMMAND AND DATA MANAGEMENT SYSTEM (CDMS) 1,920 K

$4,703 K

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>
<td></td>
<td>153</td>
</tr>
<tr>
<td>IA1</td>
<td>196</td>
<td></td>
</tr>
<tr>
<td>IA2A</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>IA2B</td>
<td>273</td>
<td></td>
</tr>
<tr>
<td>IA3A</td>
<td>214</td>
<td></td>
</tr>
<tr>
<td>IA3B</td>
<td>301</td>
<td></td>
</tr>
<tr>
<td>IB1</td>
<td>178</td>
<td></td>
</tr>
<tr>
<td>IB2A</td>
<td>191</td>
<td></td>
</tr>
<tr>
<td>IB2B</td>
<td>204</td>
<td></td>
</tr>
<tr>
<td>IB3A</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>IB3B</td>
<td>238</td>
<td></td>
</tr>
<tr>
<td>IC1</td>
<td>147</td>
<td></td>
</tr>
<tr>
<td>IC2A</td>
<td>182</td>
<td></td>
</tr>
<tr>
<td>IC2B</td>
<td>225</td>
<td></td>
</tr>
<tr>
<td>IC3A</td>
<td>177</td>
<td></td>
</tr>
<tr>
<td>IIA4</td>
<td>891</td>
<td></td>
</tr>
<tr>
<td>IIB1</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>IIB2A</td>
<td>176</td>
<td></td>
</tr>
<tr>
<td>IIB2B</td>
<td>217</td>
<td></td>
</tr>
<tr>
<td>IIB3A</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td>IIB3B</td>
<td>414</td>
<td></td>
</tr>
<tr>
<td>IIB4</td>
<td>414</td>
<td></td>
</tr>
</tbody>
</table>