SPACE TUG ECONOMIC ANALYSIS STUDY
NAS 8-27709

FINAL REPORT
DR MA-04
VOLUME II: TUG CONCEPTS ANALYSIS
APPENDIX - TUG DESIGN & PERFORMANCE DATA BASE

Prepared for
National Aeronautics & Space Administration
George C. Marshall Space Flight Center

Lockheed Missiles & Space Company, Inc.
Sunnyvale, California
and
Mathematica Inc.
Princeton, New Jersey
SPACE TUG
ECONOMIC ANALYSIS STUDY

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FOREWORD

This report summarizes work accomplished under the Space Tug Economic Analysis Study on Contract NAS8-27709. This study was performed for the NASA Marshall Space Flight Center by Lockheed Missiles & Space Company, Inc. of Sunnyvale, California, and Mathematica, Inc. of Princeton, New Jersey. The period of technical performance was nine months, starting July 26, 1971.

The NASA Contracting Officer's Representatives for this program were Lieutenant Commander William C. Stilwell (USN) and Mr. Richard L. Klan. The study team was led by Mr. Charles V. Hopkins of Lockheed and Dr. Edward Greenblat of Mathematica. Task leaders on the Lockheed team were as follows:

- John P. Skratt - Data Integration and Interpretation
- William T. Eaton - Payload Data and Payload Effects Analysis
- Richard T. Parmley - Tug Definition

Other key team members included:

- Anthony G. Tuffo - Data Mechanization and Evaluation
- Zoe A. Taulbee - Computer Programming
- Jolanta B. Forsyth - Payload Costs and Benefits; Tug Cost Model
- Kenneth J. Lush - Program Costing Logic

This report is organized as follows:

- Volume I - Executive Summary
- Volume II - Tug Concepts Analysis
  - Part 1: Overall Approach and Data Generation
  - Part 2: Economic Analysis
- Appendix: Tug Design and Performance Data Base
- Volume III - Cost Estimates

Volume II contains detailed discussions of the methods used to perform this study, and the major findings that have resulted. For convenience Volume II has been further divided into three parts. This Appendix supplements the results presented in the first two parts by documenting the detailed Tug design and performance information that forms part of the Tug data base.
Chapter 1
INTRODUCTION

A sizeable data base of Space Tug vehicle characteristics, costs, and performance capabilities was generated as a basis from which to compare concepts on this study. This Appendix to Volume II is a compendium of the detailed design and performance information from the data base. Comparable cost data are incorporated into a separate volume as specified in Data Requirement Description number MA-04; the cost volume is Volume III of the final report.

The design data are parametric across a range of reusable Space Tug sizes, whereas the performance curves were generated for selected point designs of expendable orbit injection stages and reusable Tugs. The Appendix is divided into two principal chapters. Chapter 2 contains the design data and Chapter 3 presents the performance data.
Chapter 2
REUSABLE TUG DESIGN DATA

This chapter presents parametric design data on reusable ground-based Space Tug concepts developed during the study. As explained at length in Part 1 of Volume II, the reusable Tugs were defined using a set of design estimating relationships (DERs). These relationships, extrapolated from Lockheed-generated point designs for the Space Tug, take the form of equations that characterize vehicle dimensions and weights down to major assembly level; the equations relate Tug design concept and propellant weight and type to specific parameters of interest. The DERs are automated in the Lockheed Space Transportation Analysis Routine (STAR) computer program which synthesizes weight statements and dimensional data across a range of propellant loadings from 20,000 to 70,000 pounds.

Chapter 2 comprises graphs of key Tug parameters; these graphs were plotted directly by computer. Information is presented in a data book format with minimum text. The sequence of Tug concepts presented in this chapter is as follows:

- LO₂/LH₂ Single Stage
- LF₂/LH₂ Single Stage
- FLOX/CH₄ Single Stage
- LO₂/LH₂ Drop Tanks (for Stage-and-one-half configurations)

To help locate data in Chapter 2, a roadmap matrix of Tug concepts and design data has been generated. This matrix, presented as Table 2-1, lists the figure references for all design graphs in Chapter 2.
<table>
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<th>Expendable</th>
<th>Reusable</th>
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Figure 2-2

Figure 2-3
AVIONICS AND ELECTRICAL POWER
20000 LBS. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPellant
460.0 SEC. SPECIFIC IMPULSE

Figure 2-4

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-3

Figure 2-6
REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

**Figure 2-8**
LAMBDAPRIMEBASEDONTOTAALGROSSSTAGEWEIGHT
20,000 LBS. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

Figure 2-9

2-9

LOCKHEED MISSILES & SPACE COMPANY
LAMBOA 4:1 ME. BASED ON BURNOUT HEIGHT AND IMPULSE PROP. REUSEABLE Mode
20000 LBS. THRUST  NUMBER OF ENGINES EQUAL 1.
LOX HYDROGEN PROPELLANT  460.0 SEC. SPECIFIC IMPULSE

Figure 2-10

2-10

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-11

PROPELLANT WEIGHT *LBS*

LENGTH

DIAMETER

2-11

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-12

2-12

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-13

2-13

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-14
Figure 2-15

2-15

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-16

LOCKHEED MISSILES & SPACE COMPANY
EXPENDABLE MODE

LOX HYDROGEN PROPELLANT

NUMBER OF ENGINES EQUAL 1.

460.0 SEC. SPECIFIC IMPULSE

Figure 2-18

2-18

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-19
20000 LBS. THRUST

EXPEDEABLE MODE

NUMBER OF ENGINES EQUAL 1.

4500.0 SEC. SPECIFIC IMPULSE

THERMAL PROTECTION

**TOTAL THERMAL PROTECTION**
THERMAL CONTROL COATING
OXIDIZER TANK INSULATION
FUEL TANK INSULATION

Figure 2-20

PROPULSION

**TOTAL PROPULSION**
PNEUMATICS
REACTION CONTROL SYSTEM
ZERO-G VENT SYSTEM
FILL AND DRAIN, FEED, VENT
PRESSURIZATION (INCL HE)
PROPELLANT MANAGEMENT
PROPELLANT ORIENTATION
THRUST VECTOR CONTROL
MAIN ENGINE

PROPELLANT WEIGHT *LBS*

Figure 2-21

2-20

LOCKHEED MISSILES & SPACE COMPANY
AVIONICS AND ELECTRICAL POWER
20000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.
460.0 SEC. SPECIFIC IMPULSE

LOX HYDROGEN PROPELLANT

Figure 2-22

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LOCKHEED MISSILES & SPACE COMPANY
Figure 2-24

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Figure 2-26
Figure 2-27
LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP.: EXPENDABLE MODE

PROP. LBS. THRUST  NUMBER OF ENGINES EQUAL 1.

460.0 SEC. SPECIFIC IMPULSE

Figure 2-28
Figure 2-29

2-27

LOCKHEED MISSILES & SPACE COMPANY
**TOTAL STRUCTURE**

AVIONICS SUPPORT RING

P/L DOCKING MECHANISM

DOCKING CUBE

FUll TANK SUPPORTS

OXIDIZER TANK SUPPORTS

ENGINE THRUST STRUCTURE

TRUSS STRUCTURE FRAME

SLUSH BAFFLES

OXIDIZER TANK

FUEL TANK

PROPELLANT HEIGHT "LBS"
Figure 2-31

Figure 2-32
Figure 2-33
Figure 2-36

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LOCKHEED MISSILES & SPACE COMPANY
Figure 2-37
Figure 2-38

PROPELLANT WEIGHT *LBS*
Figure 2-39

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LOCKHEED MISSILES & SPACE COMPANY
Figure 2-40

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LOCKHEED MISSILES & SPACE COMPANY
Figure 2-41

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LOCKHEED MISSILES & SPACE COMPANY
Figure 2-42

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LOCKHEED MISSILES & SPACE COMPANY
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LOCKHEED MISSILES & SPACE COMPANY
Figure 2-44

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LOCKHEED MISSILES & SPACE COMPANY
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LOCKHEED MISSILES & SPACE COMPANY
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LOCKHEED MISSILES & SPACE COMPANY
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LOCKHEED MISSILES & SPACE COMPANY
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LOCKHEED MISSILES & SPACE COMPANY
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LOCKHEED MISSILES & SPACE COMPANY
Figure 2-57

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LOCKHEED MISSILES & SPACE COMPANY
Figure 2-58

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LOCKHEED MISSILES & SPACE COMPANY
20000 LBS. THRUST

**TOTAL THERMAL PROTECTION**
THERMAL CONTROL COATING
OXIDIZER TANK INSULATION
FUEL TANK INSULATION

Figure 2-59

**TOTAL PROPULSION**
REACTION CONTROL SYSTEM
ZERO-G VENT SYSTEM
FILL AND DRAIN, FEED, VENT
PRESSURIZATION (INCL. HE)
PROPELLANT MANAGEMENT
PROPELLANT ORIENTATION
THRUST VECTOR CONTROL
MAIN ENGINE

Figure 2-60

LOCKHEED MISSILES & SPACE COMPANY
AVIONICS AND ELECTRICAL POWER
20000 LBS. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

FLOW METHANE PROPELLANT
414.0 SEC. SPECIFIC IMPULSE

Figure 2-61
Non-Useable Fluids

Figure 2-62

Non-Impulse Consumables

Figure 2-63
ADVANCED TUG SYSTEM WEIGHTS

20,000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

**TOTAL BURNOUT HEIGHT**

NON-CONSUMABLE FLUIDS

**TOTAL DRY WEIGHT**

CONTINGENCY

ELECTRICAL POWER

AVIONICS

PROPULSION

THERMAL PROTECTION

STRUCTURE

PROPELLANT WEIGHT *LBS*
Figure 2-65
LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

Figure 2-66
LAMDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP.  REUSABLE MODE  FLOX METHANE PROPELLANT

20000 LBS. THRUST  NUMBER OF ENGINES EQUAL 1.  414.0 SEC. SPECIFIC IMPULSE

Figure 2-67

PROPELLANT WEIGHT *LBS*

2-59
Figure 2-68

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LOCKHEED MISSILES & SPACE COMPANY
Figure 2-69

2-61

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-70

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-71

2-63

LOCKHEED MISSILES & SPACE COMPANY
FLOX METHANE PROPELLANT

NUMBER OF ENGINES EQUAL 1

414.0 SEC. SPECIFIC IMPULSE

Figure 2-72

LOCKHEED MISSILES & SPACE COMPANY
FULL TANK
20,000 LBS. THRUST
NUMBER OF ENGINES EQUAL 1.
414.0 SEC. SPECIFIC IMPULSE

FUEL METHANE PROPELLANT

PROPELLANT WEIGHT, LBS.

20000 24000 28000 32000 36000 40000 44000 48000 52000 56000 60000 64000 68000

200 210 220 230 240 250 260 270

50 100 150 200 250 300 350 400

AREA, FT.

Figure 2-73

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-74

2-66

LOCKHEED MISSILES & SPACE COMPANY
STAGE LENGTH

EXPENDABLE MODE

FLOX METHANE PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

414.0 SEC. SPECIFIC IMPULSE

Figure 2-75

LOCKHEED MISSILES & SPACE COMPANY
20000 lbs. thrust

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Figure 2-76

LOCKHEED MISSILES & SPACE COMPANY
AVIONICS AND ELECTRICAL POWER
20000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT
414.0 SEC. SPECIFIC IMPULSE

Figure 2-79

2-70

LOCKHEED MISSILES & SPACE COMPANY
EXPENDABLE MODE

20000 LBS. THRUST

NON - USEABLE FLUIDS

**TOTAL NON-USEABLE FLUIDS**

TRAPPED LIQUIDS

OUTAGE

OXIDIZER GAS RESIDUALS

FUEL GAS RESIDUALS

**TOTAL NON-USEABLE FLUIDS**

CHILLDOWN SI

NON-IMPULSE CONSUMABLES

**TOTAL NON-IMPULSE CONSUMABLES**

RCS PROPELLANT

VENTED PROPELLANT

ENGINE CHILDDOWN S/S

Figure 2-10

Figure 2-81

2-71

LOCKHEED MISSILES & SPACE COMPANY
ADVANCED TUG SYSTEM WEIGHS

20000 LBS. THRUST

EXPEDEABLE NOOE

NUMBER OF ENGINES EQUAL 1

FLOX METHANE PROPELLANT

414.1 SEC. SPECIFIC IMPULSE

Figure 2-82

2-72

LOCKHEED MISSILES & SPACE COMPANY
BURNOUT AND TOTAL GROSS STAGE HEIGHT
20000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT
414.0 SEC. SPECIFIC IMPULSE

TOTAL GROSS STAGE HEIGHT

SUMMED WEIGHT

20000 24000 28000 32000 36000 40000 44000 48000 52000 56000 60000 64000 68000

PROPPELLANT WEIGHT - LBS

Figure 2-83

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-84

2-74

LOCKHEED MISSILES & SPACE COMPANY
Lambda Prime Based on Burnout Height and Impulse Prop. Expendable Mode

20000 Lbs. Thrust

Number of Engines Equal 1

Methane Propellant

414.0 Sec. Specific Impulse

Figure 2-85
Figure 2-86
Figure 2-87

DROP TANK THERMAL PROTECTION

Figure 2-88

DROP TANK PROPULSION

Figure 2-89

DROP TANK NON-CONSUMABLES

2-77

LOCKHEED MISSILES & SPACE COMPANY
Figure 2-90
Chapter 3
PERFORMANCE DATA

This chapter presents detailed data on the performance characteristics and sensitivities associated with expendable orbit injection stages and reusable Space Tugs analyzed during the Space Tug Economic Analysis Study. The Tug concepts for which performance data are presented in this chapter are all point designs of primary interest in the study, namely the four candidate orbit injection stages (Agena, Large Tank Agena, D-1T Centaur, and Growth Tank Centaur), and single-stage ground-based reusable Tugs with LO$_2$/LH$_2$, LF$_2$/LH$_2$ and FLOX/CH$_4$ propellants. The reusable Tugs are generally sized to about 50,000 lb propellant loading, except that a smaller (36,300 lb) LO$_2$/LH$_2$ concept is included to show the performance variation with decreased stage size.

The performance data were generated automatically within the STAR computer program and directly plotted by the computer. The equations and methodology used to derive the performance data are presented in Part 1 of Volume II.

To assist the reader in locating any particular performance data in Chapter 3, a roadmap matrix of Tug concepts and performance data has been formatted; this matrix references specific figure numbers in the pages following. The matrix is presented as Table 3-1.

Flight modes referenced for the reusable Tugs are as follows:

Mode 1 — Delivery of a payload on the outbound leg of a roundtrip Tug flight and return with a payload of equal weight on the inbound leg
Mode 2 — Retrieval, only, of a payload on a roundtrip Tug flight
Mode 3 — Delivery, only, of a payload on a roundtrip Tug flight
Mode 4 — Delivery of a payload on a one-way Tug flight

All of the orbit injection stages are flown in Mode 4.
Table 3-1. ROADMAP OF TUG PERFORMANCE DATA IN CHAPTER 3
(All References are to Figure Numbers)

<table>
<thead>
<tr>
<th>Orbit Injection Stage</th>
<th>L.E.P. Cont. Coefficient</th>
<th>F.O. Cont. Coefficient</th>
<th>Reusable L.E.P. ( \frac{m}{W} ) Tag OP</th>
<th>Reusable L.E.P. ( \frac{m}{W} ) Tag OP</th>
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<td>3.4 3.8 3.5 3.3 3.0 2.8 2.6 2.4</td>
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LOCKHEED MISSILES & SPACE COMPANY
STANDARD
AGENA
Figure 3-1
PAYLOAD DELIVERED

13386 LBS. FIXED PROPELLANT WEIGHT

○ = FIXED IGNITION 15000 LBS.   X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS.   ▼ = FIXED IGNITION 65000 LBS.

ON ORBIT VELOCITY *FT/SEC*

Figure 3-2

3-4

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

13386 LBS. FIXED PROPELLANT WEIGHT

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-3

3-5

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

13386 LBS. FIXED PROPELLANT WEIGHT

\[ V = \text{PAYLOAD} \]

\[ \text{ON ORBIT VELOCITY *FT/SEC*} \]

**Figure 3-4**

3-6

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

13386 LBS. FIXED PROPELLANT WEIGHT

Figure 3-5

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-6

3-7
PAYLOAD DELIVERED

FIXED IGNITION WEIGHTS

\[ P = \begin{cases} 
0 & \text{FIXED IGNITION 15000 LBS.} \\
1 & \text{FIXED IGNITION 30000 LBS.} \\
2 & \text{FIXED IGNITION 65000 LBS.} \\
X & \text{FIXED IGNITION 45000 LBS.} \\
\end{cases} \]

EXPENDABLE TUG AND P/L

\[ P = \begin{cases} 
0 & \text{FIXED IGNITION 15000 LBS.} \\
1 & \text{FIXED IGNITION 30000 LBS.} \\
2 & \text{FIXED IGNITION 65000 LBS.} \\
X & \text{FIXED IGNITION 45000 LBS.} \\
\end{cases} \]

Figure 3-7
LARGE TANK AGENA

\[ W_p = 50,730 \text{ LB} \]
PAYLOAD DELIVERED
\[ 50730 \text{ LBS.} \]
\( \cdot \) FIXED PROPELLANT 50730 LBS.
\( \bigcirc \) FIXED IGNITION 55000 LBS.
\( \bigstar \) FIXED IGNITION 75000 LBS.
\( \times \) FIXED IGNITION 65000 LBS.

EXPENDABLE TUG AND P/L
\( \square \) FIXED IGNITION 50730 LBS.

ON ORBIT VELOCITY *FT/SEC*

Figure 3-8
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50730 LBS. FIXED PROPELLANT WEIGHT

FIGURE 3-9

ON ORBIT VELOCITY *FT/SEC*

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

50730 LBS, FIXED PROPELLANT WEIGHT

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-10
PAYLOAD DELIVERED

50730 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

Figure 3-11

ON ORBIT VELOCITY *FT/SEC*

3-12

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

50,730 LBS. FIXED PROPELLANT WEIGHT

Figure 3-12

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-13

3-13

LOCKHEED MISSILES & SPACE COMPANY
Figure 3-14

3-14

LOCKHEED MISSILES & SPACE COMPANY
D-1 T CENTAUR
Figure 3-15
PAYLOAD DELIVERED
30000 LBS. FIXED PROPELLANT HEIGHT

Figure 3-16

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

30000 LBS. FIXED PROPELLANT HEIGHT

ALL FIXED IGNITION HEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-17
PAYLOAD DELIVERED

30000 LBS. FIXED PROPELLANT WEIGHT

PAYLOAD DELIVERED

ON ORBIT VELOCITY *FT/SEC*

Figure 3-18
PAYLOAD DELIVERED

30000 LBS. FIXED PROPELLANT WEIGHT

Figure 3-19

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-20

3-19

LOCKHEED MISSILES & SPACE COMPANY
Figure 3-21
GT CENTAUR

\[ W_p = 45,000 \text{ LB} \]
PAYLOAD DELIVERED

- = FIXED PROPELLANT 45000 LBS.
○ = FIXED IGNITION 30000 LBS.
□ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNIITION 15000 LBS.
X = FIXED IGNITION 45000 LBS.

PAYLOAD DELIVERED

45000 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

PAYLOAD WEIGHT

ON ORBIT VELOCITY *FT/SEC*

Figure 3-22

3-21

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

$45000 \text{ LBS. FIXED PROPELLANT WEIGHT}$

$\begin{array}{c}
\text{PAYLOAD} \\
\text{ON ORBIT VELOCITY *FT/SEC*}
\end{array}$

Figure 3-23

3-22

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

45000 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

ALL FIXED IGNITION HEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-24
PAYLOAD DELIVERED

45000 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

\[ 0 = \text{FIXED IGNITION 15000 LBS.} \quad X = \text{FIXED IGNITION 45000 LBS.} \]
\[ 0 = \text{FIXED IGNITION 30000 LBS.} \quad \# = \text{FIXED IGNITION 65000 LBS.} \]

ON ORBIT VELOCITY *FT/SEC*

Figure 3-25

3-24

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

45000 LBS. FIXED PROPELLANT WEIGHT

Figure 3-26

ALL FIXED IGNITION WEIGHS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-27
Figure 3-28
MODE 1
Figure 3-29
Figure 3-30

ON ORBIT VELOCITY *FT/SEC*

LOCKHEED MISSILES & SPACE COMPANY
Figure 3-31
Figure 3-32
Figure 3-33
Figure 3-34

Figure 3-35
Figure 3-36
Figure 3-37
MODE 2
PAYLOAD RETURNED 50158 LBS. FIXED PROPELLANT WEIGHT. TUG = P/L RETRIEVAL CAPABILITY.

- = FIXED PROPELLANT 50158 LBS.
O = FIXED IGNITION 55000 LBS.
X = FIXED IGNITION 65000 LBS.

PAYLOAD WEIGHT

ON ORBIT VELOCITY *FT/SEC*

Figure 3-38
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

50158 LBS. FIXED PROPELLANT HEIGHT

Figure 3-39
Figure 3-40
Figure 3-41

ON ORBIT VELOCITY *FT/SEC*

LOCKHEED MISSILES & SPACE COMPANY
Figures 3-42 and 3-43 illustrate the payload returned and on-orbit velocity for fixed propellant height.
NOTE

Offloaded propellant in Mode 2 is not a function of $\Delta V$
MODE 3
Figure 3-45
PAYLOAD DELIVERED

EXPENDABLE P/L • REUSEABLE TUG

PAYLOAD DELIVERED

PAYLOAD DELIVERED

ON ORBIT VELOCITY *FT/SEC*

Figure 3-46

3-42

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

50158 LBS. FIXED PROPELLANT WEIGHT

ALL FIXED IGNITION HEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-47

3-43
ON ORBIT VELOCITY \( \text{FT/SEC} \)

Figure 3-48

3-44

LOCKHEED MISSILES & SPACE COMPANY
50158 LBS. FIXED PROPELLANT WEIGHT

Figure 3-49

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-50
Figure 3-51

3-46

LOCKHEED MISSILES & SPACE COMPANY
MODE 4
Figure 3-52
PAYLOAD DELIVERED

50156 LBS. FIXED PROPELLANT WEIGHT

\[ \theta = \text{FIXED IGNITION 15000 LBS.} \quad \times = \text{FIXED IGNITION 45000 LBS.} \]
\[ \circ = \text{FIXED IGNITION 30000 LBS.} \quad \blacksquare = \text{FIXED IGNITION 65000 LBS.} \]

ON ORBIT VELOCITY *FT/SEC*

Figure 3-53

3-48

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

50150 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P.L

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-54

3-49

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED
50158 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

Figure 3-55

3-50

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

50158 LBS. FIXED PROPELLANT WEIGHT

Figure 3-56

ALL FIXED IGNITION HEIGHS

Figure 3-57

LOCKHEED MISSILES & SPACE COMPANY
Figure 3-58

3-52

LOCKHEED MISSILES & SPACE COMPANY
MODE 1
PAYLOAD DELIVERED 36295 LBS. FIXED PROPELLANT WEIGHT
-
FIXED PROPELLANT 36295 LBS.

= FIXED IGNITION 30000 LBS.

D = FIXED IGNITION 15000 LBS.

X = FIXED IGNITION 45000 LBS.

ROUND TRIPPED P/L CAPABILITY

Figure 3-59

3-53

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT

\[ \text{Payload} \times \text{ISP} = \text{LBS.} \times \text{SEC.} \]

- \( \text{ISP} \) = FIXED IGNITION 15000 LBS.
- \( \text{ISP} \) = FIXED IGNITION 30000 LBS.
- \( \text{ISP} \) = FIXED IGNITION 45000 LBS.
- \( \text{ISP} \) = FIXED IGNITION 60000 LBS.

ON ORBIT VELOCITY \( \text{FT/SEC} \)

Figure 3-60

3-54

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

36295 LBS. FIXED PROPELLANT WEIGHT

ROUND TRIPPED P/L CAPABILITY

ON ORBIT VELOCITY *FT/SEC*

Figure 3-61

3-55

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT

ON ORBIT VELOCITY *FT/SEC*

Figure 3-62
PAYLOAD DELIVERED

36295 LBS. FIXED PROPELLANT WEIGHT

ROUND TRIPPED P/L CAPABILITY

Figure 3-63

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

36295 LBS. FIXED PROPELLANT WEIGHT

Figure 3-64

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-65

3-58

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

36295 LBS. FIXED PROPELLANT WEIGHT

ROUND TRIPPED P/L CAPABILITY

Figure 3-66
PAYLOAD DELIVERED = FIXED IGNITION 30000 LBS.
FIXED IGNITION 65000 LBS.
= FIXED IGNITION 15000 LBS.
X = FIXED IGNITION 45000 LBS.

Figure 3-67

3-60

LOCKHEED MISSILES & SPACE COMPANY
MODE 2
Figure 3-68
PAYLOAD RETURNED

36295 LBS. FIXED PROPELLANT WEIGHT

Figure 3-69
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT

Figure 3-70

3-63

LOCKHEED MISSILES & SPACE COMPANY
36295 LBS. FIXED PROPELLANT WEIGHT

ON ORBIT VELOCITY *FT/SEC*

Figure 3-71
PAYLOAD RETURNED

36295 LBS. FIXED PROPELLANT WEIGHT

Figure 3-72

ALL FIXED IGNITION HEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-73

3-65

LOCKHEED MISSILES & SPACE COMPANY
NOTE

Offloaded propellant in Mode 2 is not a function of \( \Delta V \)

Figure 3-74

3-66

LOCKHEED MISSILES & SPACE COMPANY
MODE 3
PAYLOAD DELIVERED

36295 LBS. FIXED PROPPELLANT WEIGHT

EXPENDABLE P/L ** REUSEABLE TUG

\* \* \* \* \* \* \* \* \*

FIGURE 3-75

3-67

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

36295 LBS. FIXED PROPELLANT WEIGHT

Figure 3-76

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

36295 LBS. FIXED PROPELLANT WEIGHT

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-77

3-69

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

36295 LBS. FIXED PROPELLANT WEIGHT

Figure 3-78
PAYLOAD DELIVERED

36295 LBS. FIXED PROPELLANT WEIGHT

Figure 3-79

ALL FIXED IGNITION WEIGHTS

Figure 3-80

3-71
Figure 3-81

3-72

LOCKHEED MISSILES & SPACE COMPANY
MODE 4
Figure 3-82

3-73
Fig. 3-83
PAYLOAD DELIVERED

36295 LBS. FIXED PROPELLANT WEIGHT

ALL FIXED IGNITION HEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-84

3-75

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

36295 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

Figure 3-85
PAYLOAD DELIVERED

35295 LBS. FIXED PROPELLANT HEIGHT

Figure 3-86

ALL FIXED IGNITION HEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-87

3-77

LOCKHEED MISSILES & SPACE COMPANY
Figure 3-88

3-78

LOCKHEED MISSILES & SPACE COMPANY
MODE 1
PAYLOAD DELIVERED

- = FIXED PROPellant 47830 LBS.
O = FIXED IGNITION 30000 LBS.
D = FIXED IGNITION 15000 LBS.
X = FIXED IGNITION 45000 LBS.

47830 LBS. FIXED PROPellant WEIGHT

ROUND TRIPPED P/L CAPABILITY

= FIXED IGNITION 65000 LBS.

PAYLOAD WEIGHT

- LBS -

ON ORBIT VELOCITY FT/SEC

Figure 3-89

3-79

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

47830 lbs. fixed propellant weight

ROUND TRIPPED P/L CAPABILITY

Figure 3-90

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

7830 LBS. FIXED PROPELLANT WEIGHT

ROUND TRIPPED P/L CAPABILITY

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY \(*FT/SEC*)

Figure 3-91
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT

\[ \text{PAYLOAD} \]

\[ \text{ON ORBIT VELOCITY} \quad \text{FT/SEC} \]

\[ \begin{align*}
\text{O} &= \text{FIXED IGNITION 15000 LBS.} \\
\text{X} &= \text{FIXED IGNITION 45000 LBS.} \\
\text{D} &= \text{FIXED IGNITION 30000 LBS.} \\
\text{M} &= \text{FIXED IGNITION 65000 LBS.}
\end{align*} \]

Figure 3-92

3-82

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT

Figure 3-93

3-83

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

47830 LBS. FIXED PROPELLANT WEIGHT

Figure 3-94

ALL FIXED IGNITION HEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-95

3-84

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

47830 LBS. FIXED PROPELLANT WEIGHT

ON ORBIT VELOCITY *FT/SEC*

Figure 3-96

3-85

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

FIXED IGNITION WEIGHTS

ROUND TRIPPED P/L CAPABILITY

\[\square = \text{Fixed Ignition} \ 15000 \text{ LBS.}\]

\[\odot = \text{Fixed Ignition} \ 30000 \text{ LBS.}\]

\[\times = \text{Fixed Ignition} \ 45000 \text{ LBS.}\]

\[\star = \text{Fixed Ignition} \ 65000 \text{ LBS.}\]
MODE 2
PAYLOAD RETURNED

- = FIXED PROPELLANT 47830 LBS.
* = FIXED IGNITION 30000 LBS.
O = FIXED IGNITION 15000 LBS.
X = FIXED IGNITION 45000 LBS.

ON ORBIT VELOCITY  *FT/SEC*

Figure 3-98
Figure 3-99

3-88

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD RETURNED

47830 LBS. FIXED PROPELLANT WEIGHT

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-100
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT

\[ \text{Payload} \times \frac{v^2}{2} \times \text{LBS/FT-SEC}^2 \]

\[ \text{Fixed Ignition} \times 15000 \text{ LBS.} \]
\[ \text{Fixed Ignition} \times 30000 \text{ LBS.} \]
\[ \text{Fixed Ignition} \times 45000 \text{ LBS.} \]
\[ \text{Fixed Ignition} \times 65000 \text{ LBS.} \]

ON ORBIT VELOCITY *FT/SEC*

Figure 3-101

3-90

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD RETURNED

47830 LBS. FIXED PROPELLANT WEIGHT

**Figure 3-102**

ALL FIXED IGNITION HEIGHTS

**Figure 3-103**

ON ORBIT VELOCITY *FT/SEC*

3-91

LOCKHEED MISSILES & SPACE COMPANY
NOTE

Offloaded propellant in Mode 2 is not a function of ΔV

Figure 3-104
MODE 3
PAYLOAD DELIVERED 47830 LBS. FIXED PROPELLANT WEIGHT EXPENDABLE P/L ** REUSEABLE TUG
\[ \text{PAYLOAD DELIVERED} = 47830 \text{ LBS.} \]
\[ \text{FIXED PROPELLANT} = 47830 \text{ LBS.} \]
\[ \text{EXPENDABLE P/L} = \text{REUSEABLE TUG} \]

- = FIXED PROPELLANT 47830 LBS.
\[ \text{O} = \text{FIXED IGNITION 30000 LBS.} \]
\[ \text{D} = \text{FIXED IGNITION 15000 LBS.} \]
\[ \text{X} = \text{FIXED IGNITION 45000 LBS.} \]

Figure 3-105

ON ORBIT VELOCITY "FT/SEC"

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

47830 LBS. FIXED PROPELLANT WEIGHT

ON ORBIT VELOCITY *FT/SEC*

Figure 3-106
PAYLOAD DELIVERED

47830 LBS. FIXED PROPELLANT WEIGHT

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-107

3-95

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

47830 LBS. FIXED PROPELLANT WEIGHT

2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000 19000 20000

Y = FIXED IGNITION 15000 LBS.  X = FIXED IGNITION 45000 LBS.
D = FIXED IGNITION 30000 LBS.  M = FIXED IGNITION 65000 LBS.

ON ORBIT VELOCITY *FT/SEC*

Figure 3-108

3-96

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED
47830 LBS. FIXED PROPELLANT WEIGHT

Figure 3-109

ALL FIXED IGNITION WEIGTS

ON ORBIT VELOCITY FT/SEC

Figure 3-110

3-97
PAYLOAD DELIVERED  FIXED IGNITION WEIGHTS  EXPENDABLE P/L ** REUSEABLE TUG

O = FIXED IGNITION 30000 LBS.  
X = FIXED IGNITION 45000 LBS.

Figure 3-111

ON ORBIT VELOCITY *FT/SEC*

3-98

LOCKHEED MISSILES & SPACE COMPANY
MODE 4
PAYLOAD DELIVERED
- = FIXED PROPELLANT 47830 LBS.
□ = FIXED IGNITION 15000 LBS.
○ = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

PAYLOAD WEIGHT

ON ORBIT VELOCITY *FT/SEC*

Figure 3-112

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

47,830 LBS. FIXED PROPELLANT HEIGHT

EXPENDABLE TUG AND P/L

ON ORBIT VELOCITY *FT/SEC*

Figure 3-113
PAYLOAD DELIVERED

47830 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-114

3-101
PAYLOAD DELIVERED

47830 LBS. FIXED PROPELLANT WEIGHT

EXPELLABLE TUG AND P/L

ON ORBIT VELOCITY *FT/SEC*

Figure 3-115
PAYLOAD DELIVERED

47830 LBS. FIXED PROPELLANT WEIGHT

Figure 3-116

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-117
Figure 3-118

LOCKHEED MISSILES & SPACE COMPANY
MODE 1
PAYLOAD RETURNED 51994 LBS. FIXED PROPELLANT WEIGHT = FIXED PROPELLANT 51994 LBS.
O = FIXED IGNITION 30000 LBS.  X = FIXED IGNITION 45000 LBS.
□ = FIXED IGNITION 15000 LBS.  ![Graph](image)

ON ORBIT VELOCITY *FT/SEC*

Figure 3-119

3-105

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD RETURNED

51994 LBS. FIXED PROPELLANT WEIGHT

ROUND TRIPPED P/L CAPABILITY

FIGURE 3-120

3-106

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

51994 LBS. FIXED PROPELLANT WEIGHT

PAYLOAD DELIVERED - ANI

ALL FIXED IGNITION HEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-121

3-107

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

51994 LBS. FIXED PROPELLANT WEIGHT

ROUND TRIPPED P/L CAPABILITY

\[ F_i = \text{FIXED IGNITION 15000 LBS.} \]
\[ X = \text{FIXED IGNITION 45000 LBS.} \]
\[ O = \text{FIXED IGNITION 30000 LBS.} \]
\[ I = \text{FIXED IGNITION 65000 LBS.} \]

ON ORBIT VELOCITY *FT/SEC*

Figure 3-122
PAYLOAD DELIVERED

51994 LBS. FIXED PROPELLANT WEIGHT

ROUND TRIPPED P/L CAPABILITY

\[ \Delta \text{PAYLOAD} - \Delta \text{V}_2 \]

\[ \text{LBS. FT/SEC}^* \]

\[ \text{2000} \quad \text{3000} \quad \text{4000} \quad \text{5000} \quad \text{6000} \quad \text{7000} \quad \text{8000} \quad \text{9000} \quad \text{10000} \quad \text{11000} \quad \text{12000} \quad \text{13000} \quad \text{14000} \quad \text{15000} \quad \text{16000} \quad \text{17000} \quad \text{18000} \quad \text{19000} \quad \text{20000} \]

\[ \text{O} = \text{FIXED IGNITION 30000 LBS.} \]
\[ \text{\textbullet} = \text{FIXED IGNITION 45000 LBS.} \]
\[ \text{\textbullet} = \text{FIXED IGNITION 65000 LBS.} \]

\[ \text{\textbullet} = \text{FIXED IGNITION 15000 LBS.} \]

ON ORBIT VELOCITY *FT/SEC*

Figure 3-123

3-109

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED
51994 LBS, FIXED PROPELLANT WEIGHT

Figure 3-124

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-125
51994 LBS. FIXED PROPELLANT WEIGHT

Figure 3-126
Figure 3-127

LOCKHEED MISSILES & SPACE COMPANY
MODE 2
PAYLOAD RETURNED
5199.4 LBS. FIXED PROPELLANT WEIGHT
TUG - P/L RETRIEVAL CAPABILITY
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.
D = FIXED IGNITION 15000 LBS.
X = FIXED IGNITION 45000 LBS.

PAYLOAD WEIGHT
ON ORBIT VELOCITY  *FT/SEC*

Figure 3-128

3-113
51994 LBS. FIXED PROPELLANT WEIGHT

Figure 3-129

3-114
PAYLOAD RETURNED

51994 LBS. FIXED PROPELLANT WEIGHT

TUG - P/L RETRIEVAL CAPABILITY

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-130

3-115

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT

\[ \text{PAYLOAD RETURNED} \]

\[ \text{PAYLOAD - \( \Delta V \)} \]

\[ \text{LBS. - FT-SEC} \]

\[ \text{ON ORBIT VELOCITY - FT/SEC} \]

\[ D = \text{FIXED IGNITION 15000 LBS.} \]
\[ X = \text{FIXED IGNITION 45000 LBS.} \]
\[ D = \text{FIXED IGNITION 30000 LBS.} \]
\[ \text{M = FIXED IGNITION 85000 LBS.} \]

Figure 3-131

3-116

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD RETURNED

51994 LBS. FIXED PROPELLANT WEIGHT

Figure 3-132

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-133

3-117

LOCKHEED MISSILES & SPACE COMPANY
NOTE

Offloaded propellant in Mode 2 is not a function of $\Delta V$
MODE 3
PAYLOAD DELIVERED  51994 LBS. FIXED PROPELLANT WEIGHT  EXPENDABLE P/L ** REUSEABLE TUG
- = FIXED PROPELLANT 51994 LBS.  O = FIXED IGNITION 30000 LBS.  W = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.  X = FIXED IGNITION 45000 LBS.

ON ORBIT VELOCITY  *FT/SEC*

Figure 3-135

3-119

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

51994 LBS. FIXED PROPELLANT WEIGHT

EXEMPLARY P/L ** REUSEABLE TUG

PAYLOAD DELIVERED

Figure 3-136

3-120

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

51994 LBS. FIXED PROPELLANT WEIGHT

ALL FIXED IGNITION WeIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-137

3-121

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

51994 LBS. FIXED PROPELLANT WEIGHT

ON ORBIT VELOCITY *FT/SEC*

Figure 3-138

3-122

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

51994 LBS. FIXED PROPellant WEIGHT

Figure 3-139

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY FT/SEC

Figure 3-140

3-123

LOCKHEED MISSILES & SPACE COMPANY
Figure 3-141
MODE 4
PAYLOAD DELIVERED 51994 LBS. FIXED PROPELLANT WEIGHT

* = FIXED PROPELLANT 51994 LBS.
O = FIXED IGNITION 30000 LBS.
□ = FIXED IGNITION 15000 LBS.
X = FIXED IGNITION 45000 LBS.

ON ORBIT VELOCITY *FT/SEC*

Figure 3-142
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

51994 LBS. FIXED PROPELLANT WEIGHT

Figure 3-143
PAYLOAD DELIVERED

51994 LBS. FIXED PROPellant WEIGHT

ALL FIXED IGNITION WEIGHTS

ON ORBIT VELOCITY FT/SEC

Figure 3-144

3-127
PAYLOAD DELIVERED

51994 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

Figure 3-145

ON ORBIT VELOCITY *FT/SEC*

LOCKHEED MISSILES & SPACE COMPANY
PAYLOAD DELIVERED

51994 LBS. FIXED PROPELLANT WEIGHT

Figure 3-146

ALL FIXED IGNITION HEIGHTS

ON ORBIT VELOCITY *FT/SEC*

Figure 3-147

3-129
PAYLOAD DELIVERED

FIXED IGNITION HEIGHTS

- O = FIXED IGNITION 15000 LBS.
- X = FIXED IGNITION 45000 LBS.
- M = FIXED IGNITION 65000 LBS.

ON ORBIT VELOCITY *FT/SEC*

Figure 3-148

3-130

LOCKHEED MISSILES & SPACE COMPANY