20

MCDONNELL DOUGLAS

SPACE TUG SYSTEMS STUDY (CRYOGENIC)
SEPTEMBER DATA DUMP

VOLUME 8 Programmatics and Cost
Book 1 Option 1

SEPTEMBER 1973

PREPARED BY: SPACE TUG STUDY TEAM

APPROVED BY: L. Q. Westmoreland

L. Q. WESTMORELAND
STUDY MANAGER

(NASA-CR-179114) SPACE TUG SYSTEMS STUDY (CRYOGENIC). VOLUME 8: PROGRAMMATICS AND COST, BOOK 1, OPTION 1 Data Dump, Sep. 1973 (McDonnell-Douglas Astronautics Co.) 505 p Avail: NTIS

N87-70405

Unclas
00/18 0074244

PREPARED FOR NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER
UNDER CONTRACT NO. NAS8-29677

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST

5301 Bolsa Avenue, Huntington Beach, CA 92647

PREFACE

This study report for the Tug Program is submitted by the McDonnell Douglas Astronautics Company (MDAC) to the Government in partial response to Contract Number NAS8-29677.

The current results of this study contract are reported in eight volumes:

Volume 1 — Summary, Program Option 1

Volume 2 — Summary, Program Option 2

Volume 3 — Summary, Program Option 3

These three summary volumes present the highlights of the comprehensive data base generated by MDAC for evaluating each of the three program options. Each volume summarizes the applicable option configuration definition, Tug performance and capabilities, orbital and ground operations, programmatic and cost considerations, and sensitivity studies. The material contained in these three volumes is further summarized in the Data Dump Overview Briefing Manual.

Volume 4 — Mission Accomplishment. (3 Books and 1 Supplement Bound Together)

This volume contains mission accomplishment analysis for each of the three program options and includes the tug system performance, mission capture, and fleet size analysis.

Volume 5 — Systems (3 Books)

This volume presents the indepth design, analysis, trade study, and sensitivity technical data for each of the configuration options and each of the Tug systems i.e., structures, thermal, avionics, and propulsion. Interface with the Shuttle and Tug payloads for each of the three options is defined.

Volume 6 – Operations (3 Books)

This volume presents the results of orbital and ground operations trades and optimization studies for each option in the form of operations descriptions, time lines, support requirements (GSE, manpower, networks, etc.), and resultant costs.

Volume 7 – Safety (3 Books)

This volume contains safety information and data for the Tug Program. Specific safety design criteria applicable to each option are determined and potential safety hazards common to all options are identified.

Volume 8 – Programmatics and Cost (3 Books)

This volume contains summary material on Tug Program manufacture, facilities, vehicle test, schedules, cost, project management SR&T, and risk assessment for each option studied.

These volumes contain the data required for the three options which were selected by the Government for this part of the study and are defined as:

A. Option 1 is a direct development program (I.O.C.: Dec 1979). It emphasizes low DDT&E cost; the deployment requirement is 3500 pounds into geosynchronous orbit, it does not have retrieval capability, and it is designed for a 36-hour mission. MDAC has also prepared data for an alternative to Option 1 which deviates from certain requirements to achieve the lowest practicable DDT&E cost.

B. Option 2 is also a direct development program (I.O.C.: 1983). It emphasizes total program cost effectiveness in addition to low DDT&E cost. The deployment requirement is 3500 pounds minimum into geosynchronous orbit and 3500 pounds minimum retrieval from geosynchronous orbit.

C. Option 3 is a phased development program (I.O.C.: 1979 phased to I.O.C. 1983). It emphasizes minimum initial DDT&E cost and low total program cost. The initial Tug capability will deploy a minimum of

3500 pounds into geosynchronous orbit without retrieval capability, however, through phased development, it will acquire the added capability to retrieve 2200 pounds from geosynchronous orbit. The impact of increasing the retrieval capability to 3500 pounds is also provided.

CONTENTS

1 SCHEDULES
2 VEHICLE TEST PROGRAM
3 FACILITIES PLAN
4 VEHICLE MANUFACTURING
5 SPECIAL PROGRAMMATICS
6 COST DATA
7 FLIGHT SCHEDULES
8 COST SENSITIVITIES FOR THE PROGRAM OPTION
9 RISK ASSESSMENT
10 SUPPORTING RESEARCH AND TECHNOLOGY (SR&T)
11 SPECIAL COST SENSITIVITIES
12 DOD ACQUISITION APPROACH (AFSCP 800-3)
13 COST ESTIMATING METHODOLOGY
14 OTHER SENSITIVITIES AS DEFINED

INTRODUCTION AND SUMMARY

This report contains detail programmatics and cost data, sensitivies, and trades analyses pertinent to the Space Tug (Cryogenic) Program Option 1. This option, a direct developed Tug with IOC in December 1979, emphasizes minimum DDT&E cost with low peak year funding as a primary objective. The data presented is organized in accordance with the Government-furnished outline. Data covering the programmatic areas of schedules, vehicle testing, facilities, manufacturing, and attendant costs are presented. The cost data are reported in accordance with the basic requirements of Data Requirement Document No. MF003M, dated dated 1 May 1971, as modified by study guidelines received from the Government in the course of the study. Additional data is given in the areas of program management plans and risk assessment.

Results of the Option 1 analyses indicate that this version of the Tug can be developed within the study groundrules for a total DDT&E cost of $197.1 million. The peak annual funding requirement is $76.7 million occurring in Government fiscal year 1978. Production phase cost for an operational fleet of 13 vehicles plus 9 auxiliary (kick) stages required to satisfy the flight schedule, including contingency for expected reliability losses, totals $179.6 million. First unit production cost for this vehicle is $14.44 million. Total operations phase cost, for a total of 225 flights, is $200.8 million, yielding an average cost per flight of $0.90 million for the basic reusable Tug flight mode.

Special attention is called to Section 6.12, Cost Data Adjustments, in which the basic cost model output data has been corrected at the summary level to offset an error in the inputting of ground launch operations data to the cost model. This error, which affects only the launch operations cost estimates and subsequent total project summary costs, was found after the Option 1 cost run had been made and time did not permit a complete recycle. It is believed that the basic data presented coupled with the cost adjustments reported in Section 6.12 will suffice for this data dump.

Section 1
SCHEDULES

This section presents schedules developed for the Tug Option 1 based on the requirement for a nominal IOC December 31, 1979 (actual first operational flight in April 1980). An additional constraint was that the earliest ATP for the DDT&E phase was October 1975. The schedules were derived by iterative analysis of design and development requirements for subsystems and the vehicle main stage, test and evaluation requirements, manufacturing requirements and production rate considerations, as well as operational flight schedule requirements and fleet size.

1.1 SUMMARY SCHEDULE

The project summary schedule for Option 1 is shown in Figure 1.1-1. It features an ATP for the Phase C/D design development in October 1975. Required supporting research and technology for the vehicle design is assumed to have been initiated approximately eight months prior to project ATP. Design, development, test and evaluation (DDT&E) requires 54 months up to the first flight on April 1, 1980. This first flight is used to place an operational payload in orbit, having only secondary test objectives associated with monitoring critical subsystem functions by means of added test instrumentation. No dedicated flight test is planned for this Tug option. Subsequent to the first flight, a total of 225 mission flights will have been flown through 1990. One hundred ninety three flights are launched from ETR and thirty two from WTR.

Completion of Preliminary Design Review (PDR) is scheduled for March 1977 to establish firm vehicle configurations. A Critical Design Review (CDR) will be completed in December 1977 to assure that design requirements have been met.

The ground test program, discribed in detail in Section 2, will use subsystem models for concept and design development and qualification. Qualification of subsystems will be complete in January 1979, 39 months after ATP. System level test articles will be used in the ground test program for subsystem integration and interface verification activities. Two Tug vehicles are required at IOC to support the initial requirement of three flights in the first year of operation. A total of 13 vehicles are produced over a period of three years. Included are 3 vehicles procured as contingency for expected reliability losses. Vehicles are stored at the launch facility and used as required to support the flight utilization schedule (Reference Section 7).

Table 1.1-1 identifies symbols and acronyms used on the summary schedule.

Figure 1.1-1 Space Tug Option 1 Project Summary Schedule

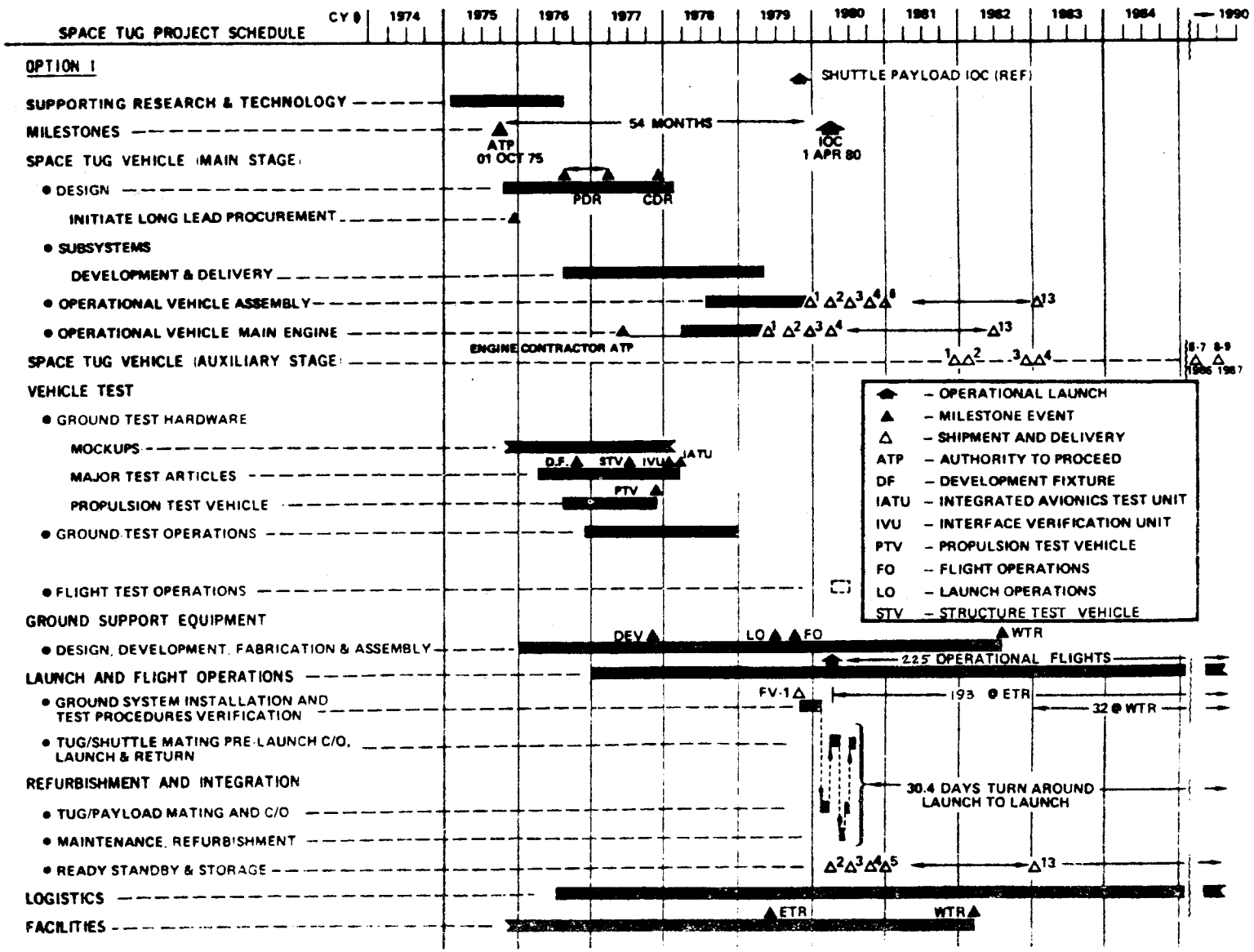


Table 1.1-1 SPACE TUG PROJECT SCHEDULES LEGEND:

▬▬▬	INCREMENT I ACTIVITY
▥▥▥	INCREMENT II ACTIVITY
⬟	– OPERATIONAL LAUNCH
▲	– MILESTONE EVENT
△	– SHIPMENT AND DELIVERY
ATP	– AUTHORITY TO PROCEED
DF	– DEVELOPMENT FIXTURE
DTU	– DYNAMICS TEST UNIT
IATU	– INTEGRATED AVIONICS TEST UNIT
IVU	– INTERFACE VERIFICATION UNIT
PTV	– PROPULSION TEST VEHICLE
FO	– FLIGHT OPERATIONS
LO	– LAUNCH OPERATIONS
STV	– STRUCTURE TEST VEHICLE
INCR	– INCREMENT

A logic network for Option 1 is provided in Figure 1.1-2 supplementing the project summary schedule. This summary network was developed in consonance with the work breakdown structure, the project summary schedule and required flight schedules. It contains a sufficient number of major milestones and key events to insure satisfactory accounting of program requirements, interrelating activities and limiting constraints. The level of detail is governed by the need to account for the key events and identify critical actions or decision points. Event orientation and constraint lines indicate project feasiblity and timely execution.

Depicted on the calendar-oriented network are design, development, test and evaluation of the first flight vehicle, followed by delivery to the launch site, Tug/payload mating, Tug/Shuttle mating and vehicle launch at IOC. Also shown are the related events of procurement, ground support equipment, facilites and tooling. Interface events locate delivery and/or receipt of major hardware and software items critical to the project implementation. Vehicle deliveries to storage at the launch site, site activations at ETR and WTR, vehicle turnaround, and initial launch of each vehicle are indicated in relation to the flight profile requirements and refurbishment activity.

1.2 DEVELOPMENT SCHEDULES

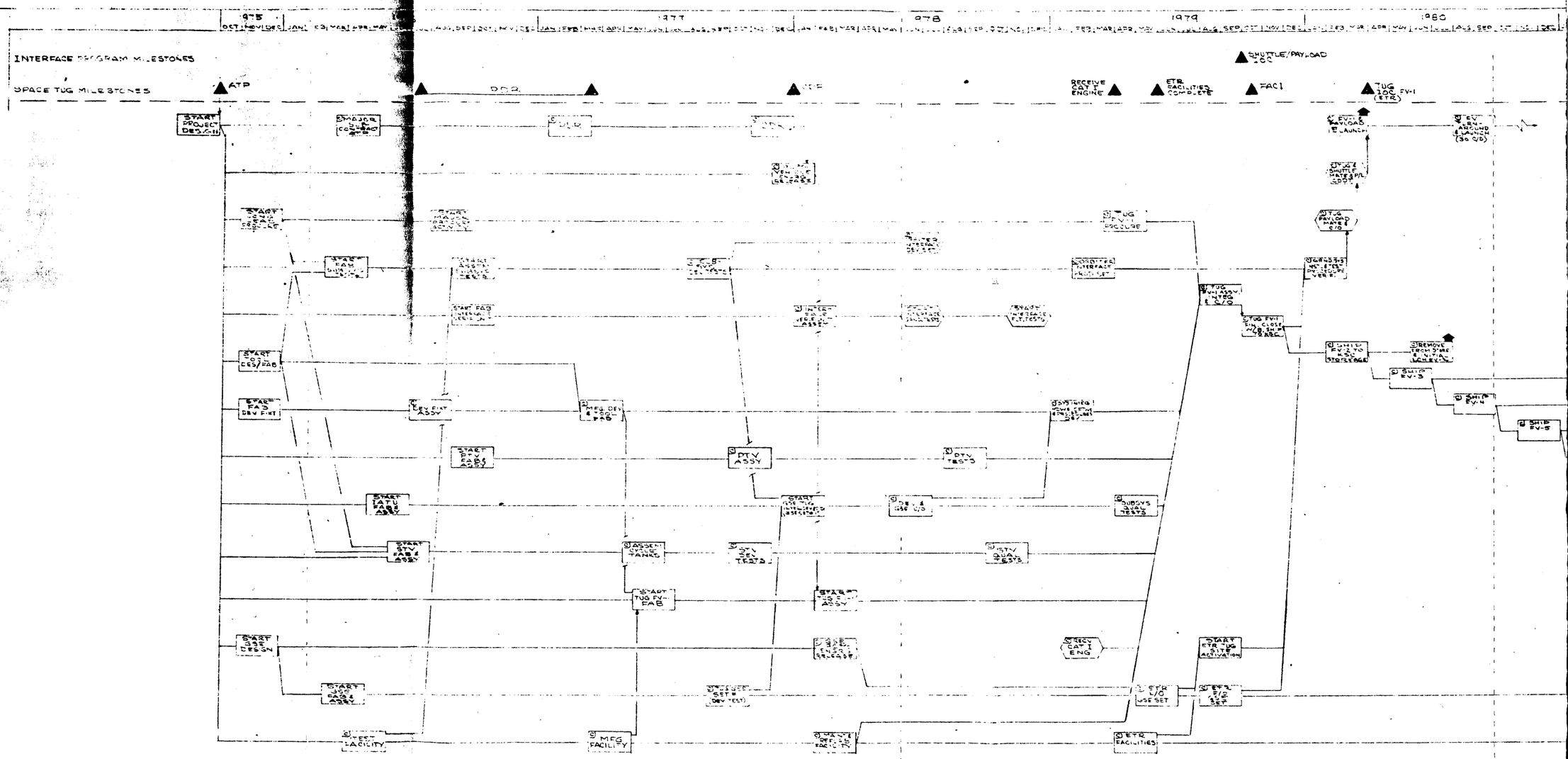
Development schedules are presented in two forms: an overall development shhedule interrelating the various project element and test/evaluation activities; and detail subsystem schedules.

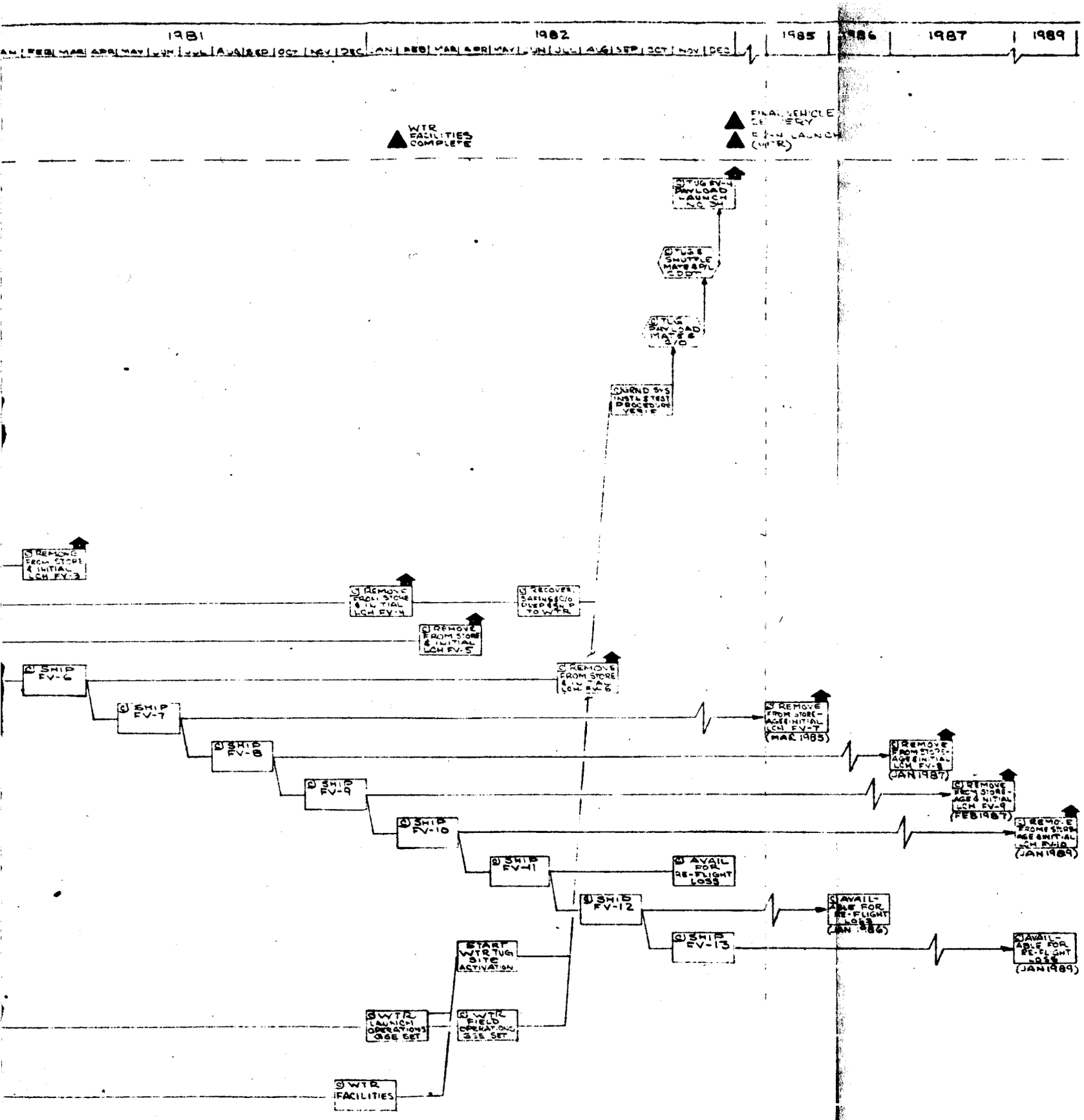
1.2.1 Development Schedule

Figure 1.2-1 is the planned overall development schedule for Tug Option 1. It reflects major engineering development tests, qualification tests, ground support equipment (GSE) development, and software development. Main engine and auxiliary kick stage requirements are reflected in the project summary schedule, Figure 1.1-1. The scheduled activities reflect test planning requirements which are described in detail in Section 2.

1.2.2 Subsystem Schedules

Figures 1.2-2 through 1.2-12 provide development schedules for critical subsystems of the vehicle main stage. The schedules are developed primarily at Level 5 of the WBS except for critical avionics elements which are shown at Level 6.


1975
1977
1978
1979
1980
INTERFACE PROGRAM MILESTONES
SPACE TUG MILESTONES
ATP
PDR
RECEIVE CATT ENGINE
ETR FACILITIES COMPLETE
FAC1
SHUTTLE/PAYLOAD IOC
START PROJECT DES/CON
START FAB DEV FIXT
START STV FAB & ASSY
START ETR TUG SITE ACTIVATION
ETR FACILITIES
MFG FACILITY
SUBSYS QUAL TESTS
SECT CATT ENG



GLOSSARY & SYMBOLS

ATP	AUTHORITY TO PROCEED
CDR	CRITICAL DESIGN REVIEW
CDDT	COUNTDOWN DEMONSTRATION TEST
C/O	CHECKOUT
D/F	DEVELOPMENT FIXTURE
ER	ENGINEERING RELEASE
ETR	EASTERN TEST RANGE
F/O	FIELD OPERATIONS
FV	FLIGHT VEHICLE
GSE	GROUND SUPPORT EQUIPMENT
IATU	INTEGRATED AVIONICS TEST UNIT
IVU	INTERFACE VERIFICATION UNIT
IOC	INITIAL OPERATIONAL CAPABILITY
LCH	LAUNCH
L/O	LAUNCH OPERATIONS
PDR	PRELIMINARY DESIGN REVIEW
P/L	PAYLOAD
PTV	PROPULSION TEST VEHICLE
STV	STRUCTURE TEST VEHICLE
W/B	WEIGH & BALANCE
WTR	WESTERN TEST RANGE

= COMPLETE

= INTERFACE EVENT

= OPERATIONAL LAUNCH

= MILESTONE

SPACE TUG OPTION [illegible]
FIGURE NO. 1.2-1

2

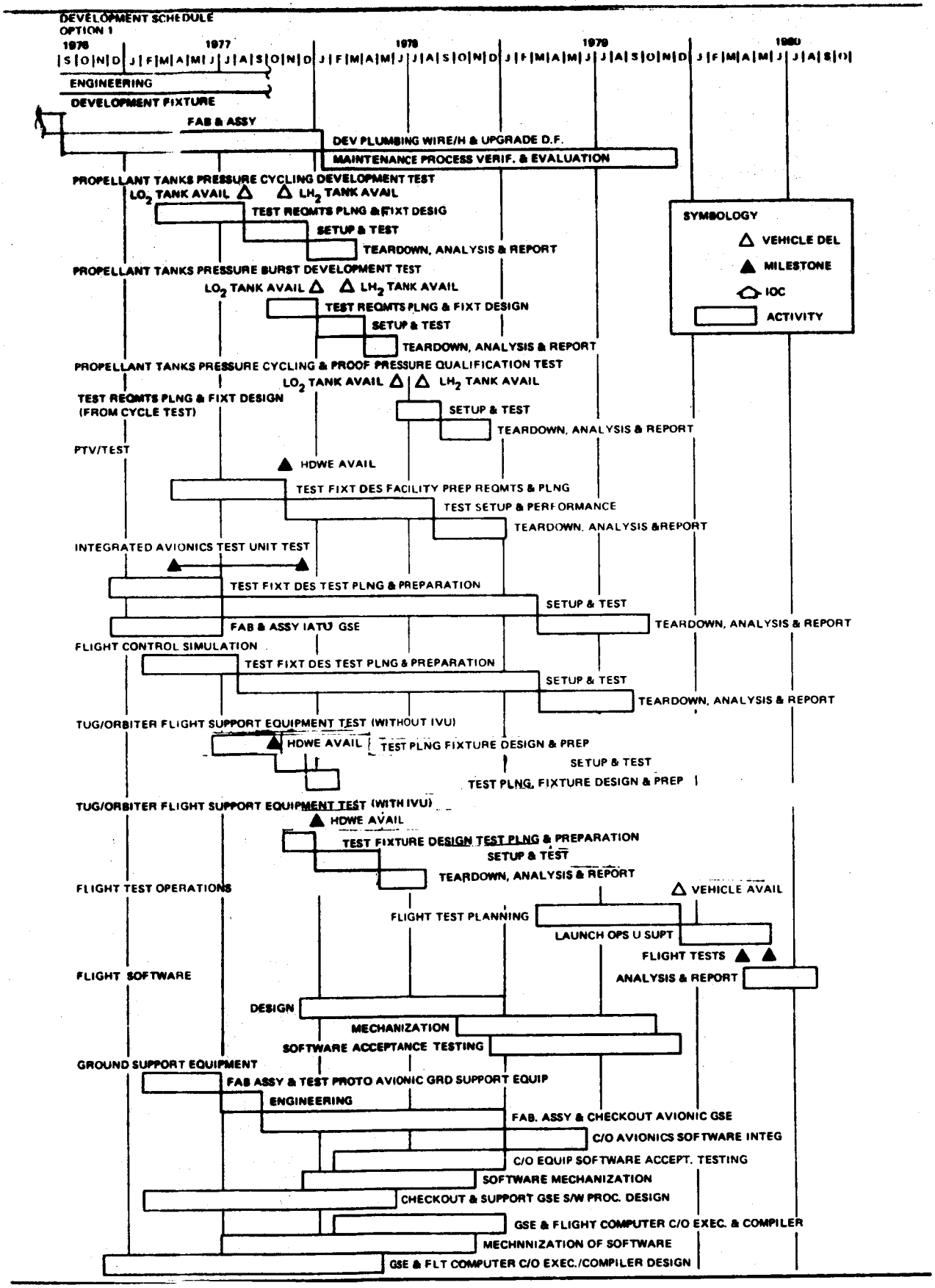


Figure 1.2-1 Development Schedule, Option 1

Figure 1.2-2

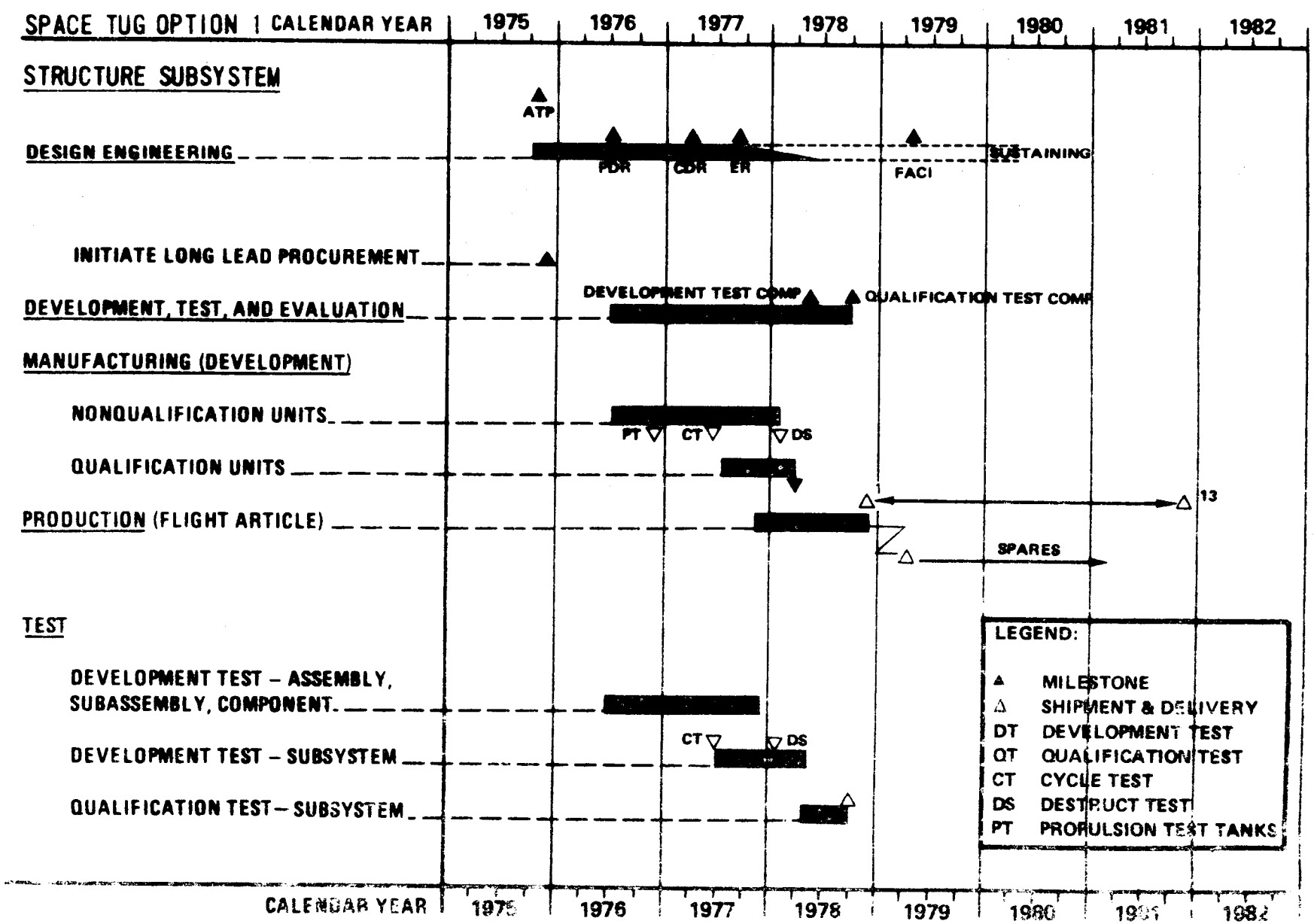

SPACE TUG OPTION 1 CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982
STRUCTURE SUBSYSTEM
ATP
DESIGN ENGINEERING
PDR
CDR
ER
FACI
SUSTAINING
INITIATE LONG LEAD PROCUREMENT
DEVELOPMENT TEST COMP
QUALIFICATION TEST COMP
DEVELOPMENT, TEST, AND EVALUATION
MANUFACTURING (DEVELOPMENT)
NONQUALIFICATION UNITS
PT
CT
DS
QUALIFICATION UNITS
PRODUCTION (FLIGHT ARTICLE)
13
SPARES
TEST
DEVELOPMENT TEST – ASSEMBLY, SUBASSEMBLY, COMPONENT
DEVELOPMENT TEST – SUBSYSTEM
CT
DS
QUALIFICATION TEST – SUBSYSTEM
LEGEND:
MILESTONE
SHIPMENT & DELIVERY
DT DEVELOPMENT TEST
QT QUALIFICATION TEST
CT CYCLE TEST
DS DESTRUCT TEST
PT PROPULSION TEST TANKS
CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982

Figure 1.2-3

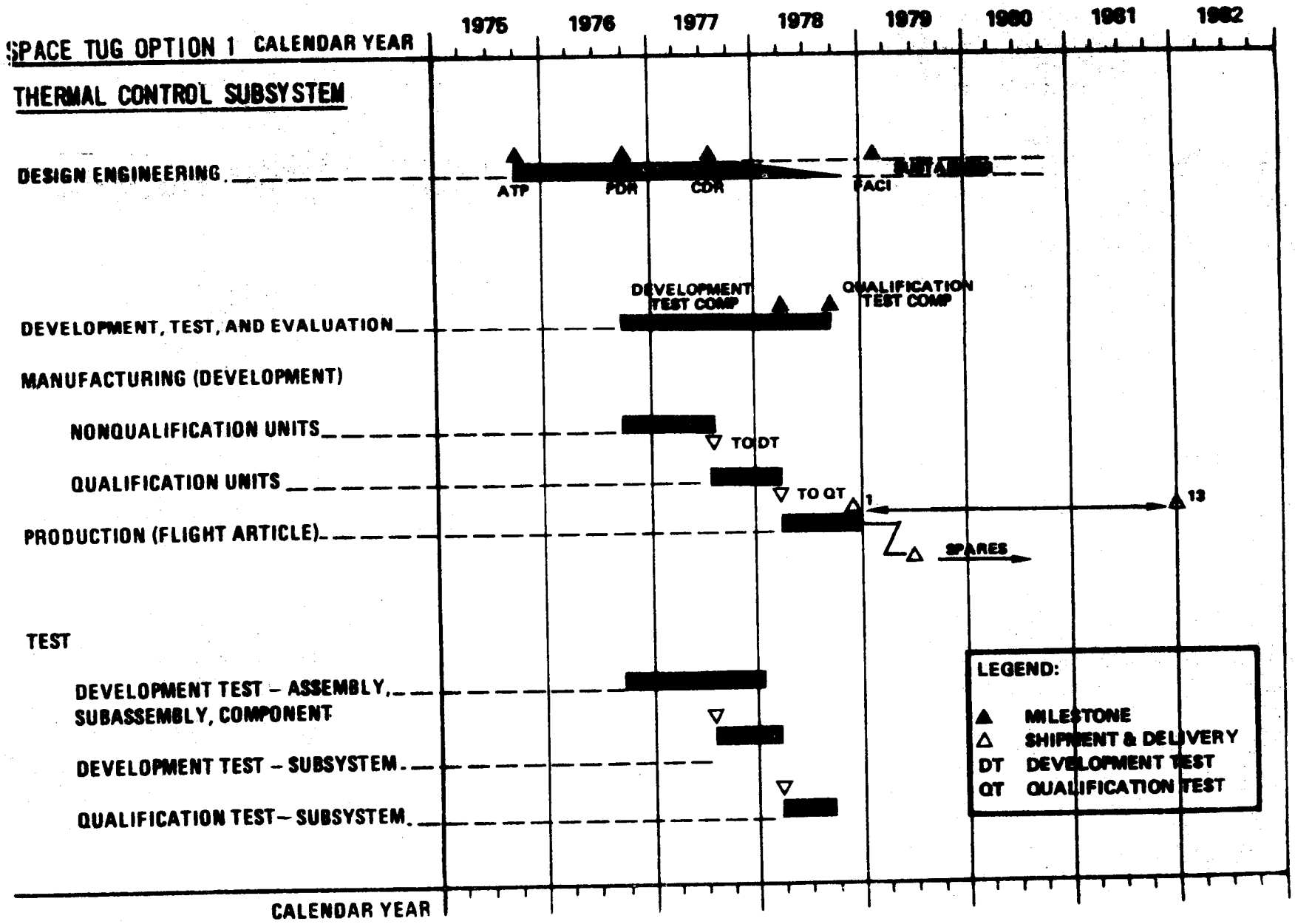

SPACE TUG OPTION 1 CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982
THERMAL CONTROL SUBSYSTEM
DESIGN ENGINEERING
ATP
PDR
CDR
FACI
DEVELOPMENT, TEST, AND EVALUATION
DEVELOPMENT TEST COMP
QUALIFICATION TEST COMP
MANUFACTURING (DEVELOPMENT)
NONQUALIFICATION UNITS
TO DT
QUALIFICATION UNITS
TO QT
1
13
PRODUCTION (FLIGHT ARTICLE)
SPARES
TEST
DEVELOPMENT TEST – ASSEMBLY, SUBASSEMBLY, COMPONENT
DEVELOPMENT TEST – SUBSYSTEM
QUALIFICATION TEST – SUBSYSTEM
LEGEND:
MILESTONE
SHIPMENT & DELIVERY
DT DEVELOPMENT TEST
QT QUALIFICATION TEST
CALENDAR YEAR

Figure 1.2-4

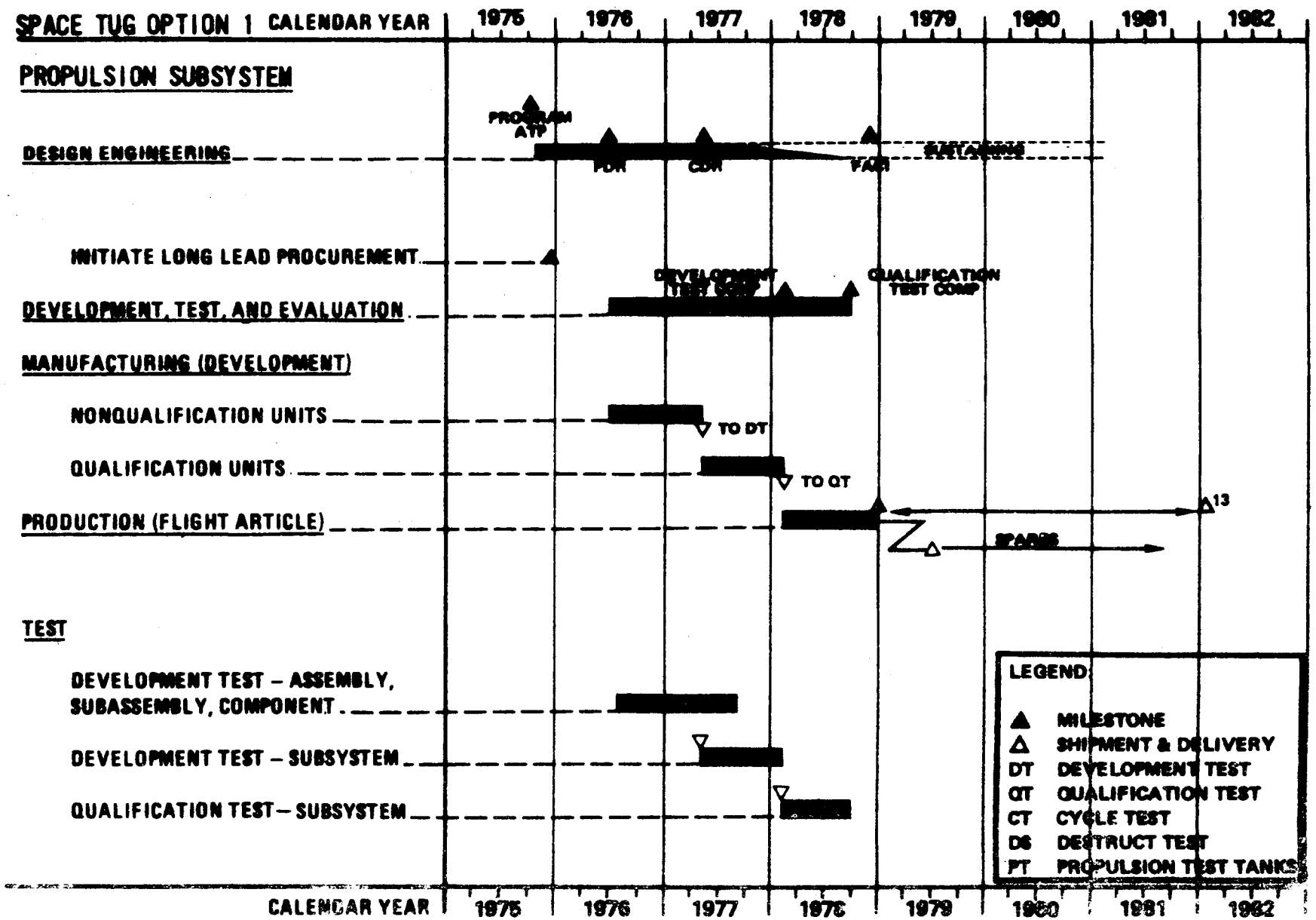

SPACE TUG OPTION 1 CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982
PROPULSION SUBSYSTEM
PROGRAM ATP
DESIGN ENGINEERING
PDR
CDR
FAR
SUSTAINING
INITIATE LONG LEAD PROCUREMENT
DEVELOPMENT TEST COMP
QUALIFICATION TEST COMP
DEVELOPMENT, TEST, AND EVALUATION
MANUFACTURING (DEVELOPMENT)
NONQUALIFICATION UNITS
TO DT
QUALIFICATION UNITS
TO QT
PRODUCTION (FLIGHT ARTICLE)
13
SPARES
TEST
DEVELOPMENT TEST – ASSEMBLY, SUBASSEMBLY, COMPONENT
DEVELOPMENT TEST – SUBSYSTEM
QUALIFICATION TEST – SUBSYSTEM
LEGEND
MILESTONE
SHIPMENT & DELIVERY
DT DEVELOPMENT TEST
QT QUALIFICATION TEST
CT CYCLE TEST
DS DESTRUCT TEST
PT PROPULSION TEST TANKS
CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982

Figure 1.2-5

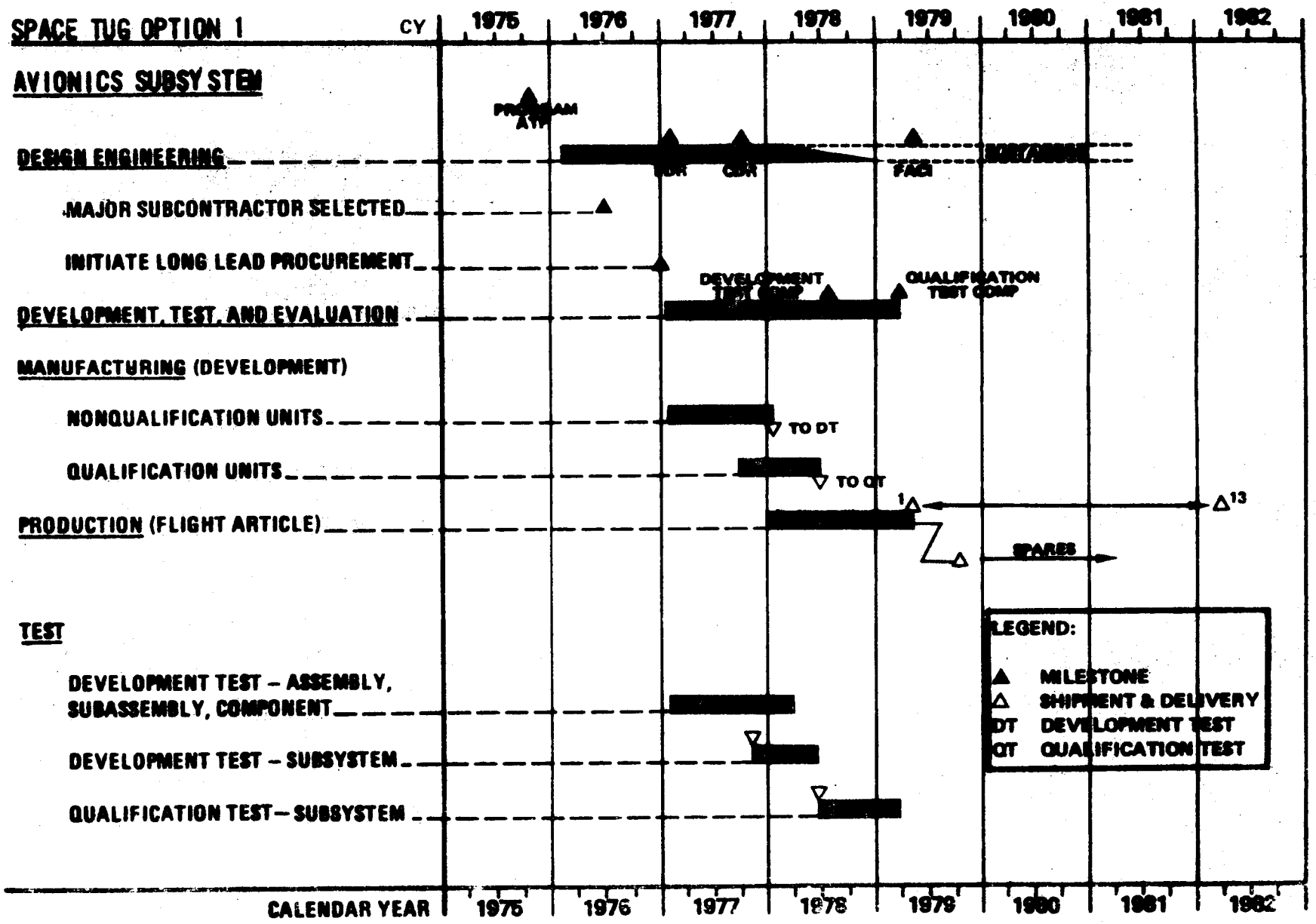
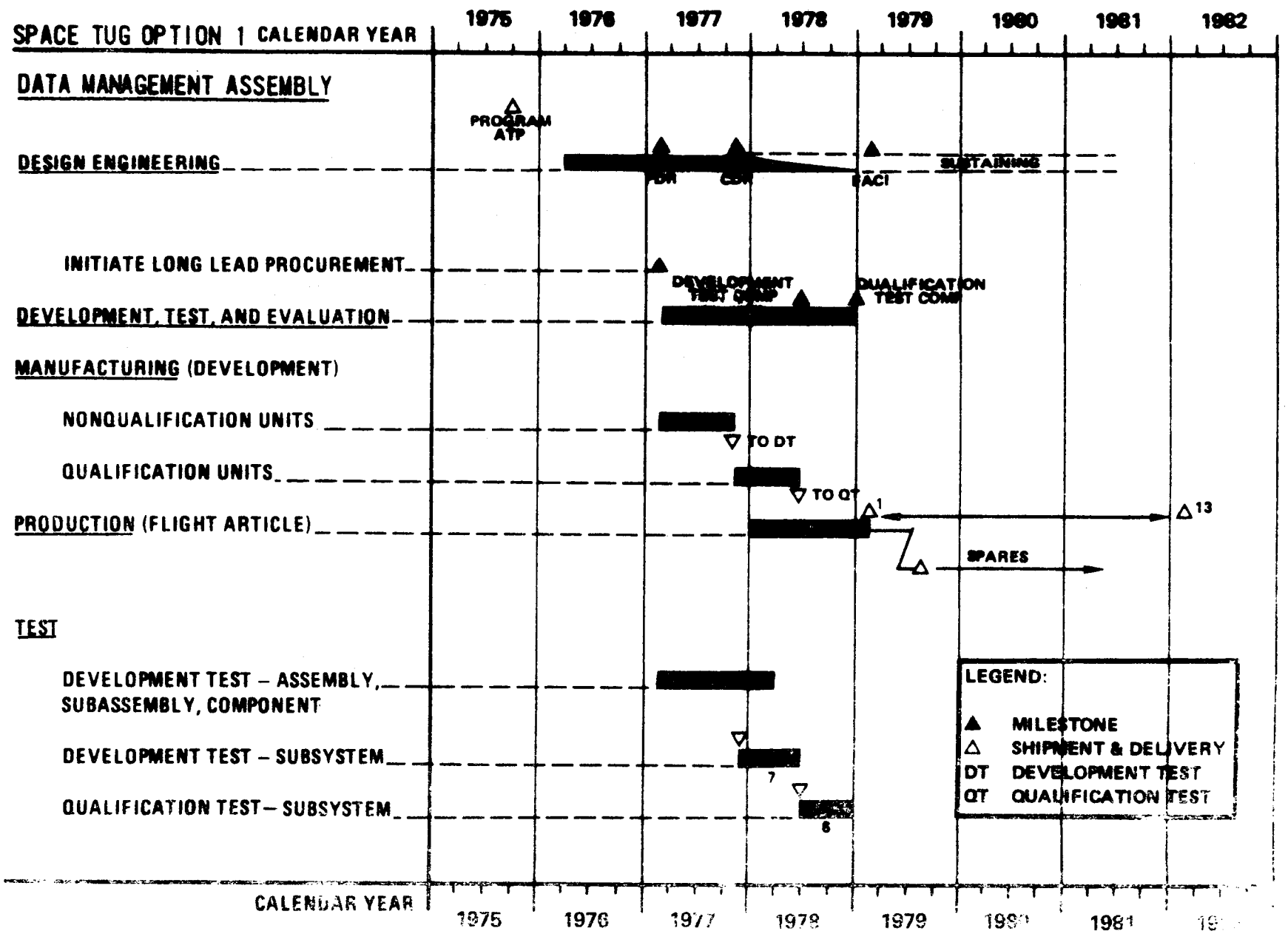

SPACE TUG OPTION 1
CY
1975
1976
1977
1978
1979
1980
1981
1982
AVIONICS SUBSYSTEM
PROGRAM ATP
DESIGN ENGINEERING
PDR
CDR
FACI
MAJOR SUBCONTRACTOR SELECTED
INITIATE LONG LEAD PROCUREMENT
DEVELOPMENT TEST COMP
QUALIFICATION TEST COMP
DEVELOPMENT, TEST, AND EVALUATION
MANUFACTURING (DEVELOPMENT)
NONQUALIFICATION UNITS
TO DT
QUALIFICATION UNITS
TO QT
PRODUCTION (FLIGHT ARTICLE)
1
13
SPARES
TEST
DEVELOPMENT TEST – ASSEMBLY, SUBASSEMBLY, COMPONENT
DEVELOPMENT TEST – SUBSYSTEM
QUALIFICATION TEST – SUBSYSTEM
LEGEND:
MILESTONE
SHIPMENT & DELIVERY
DT DEVELOPMENT TEST
QT QUALIFICATION TEST
CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982

Figure 1.2-6



1/12

Figure 1.2-7

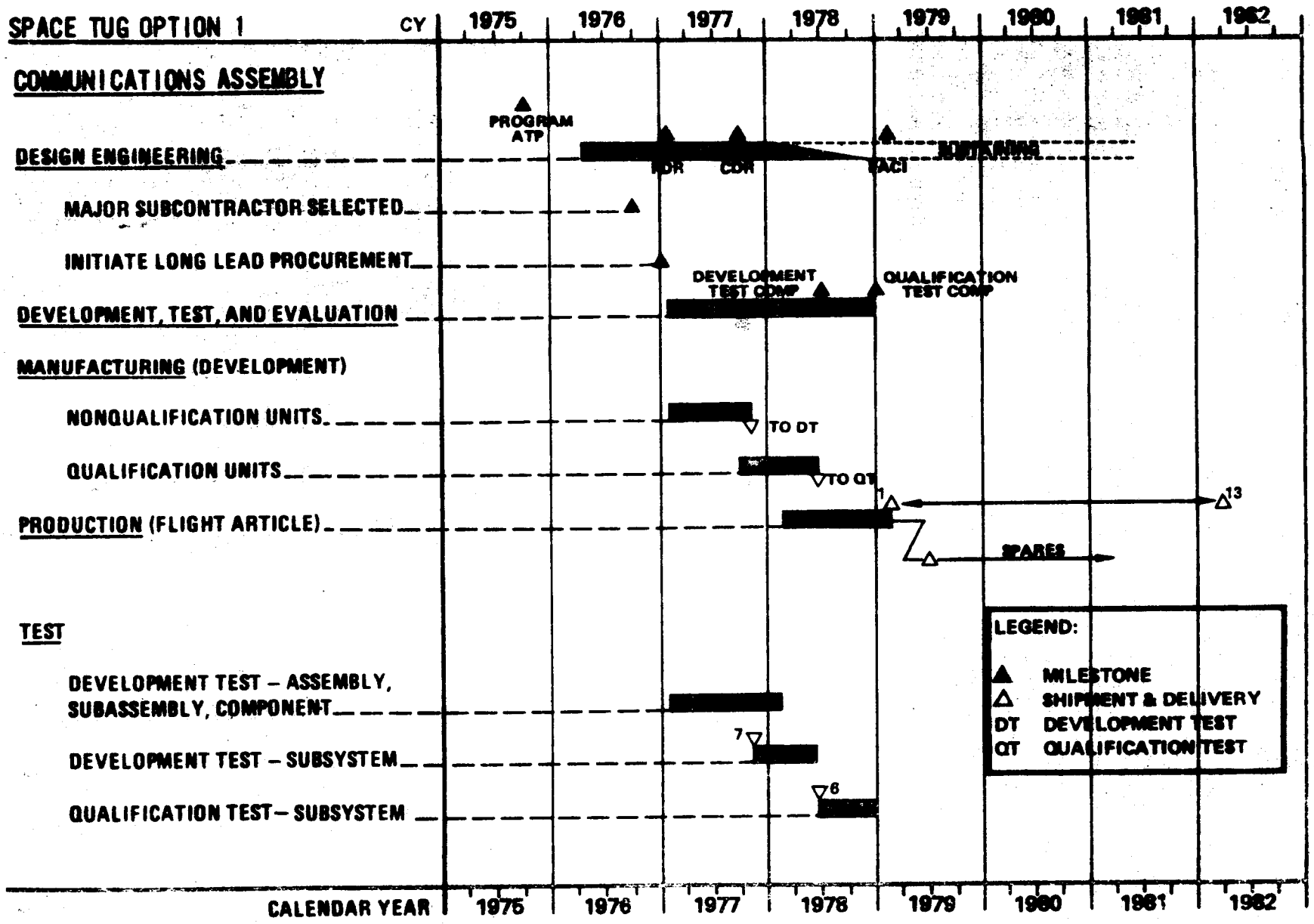

SPACE TUG OPTION 1
CY
1975
1976
1977
1978
1979
1980
1981
1982
COMMUNICATIONS ASSEMBLY
PROGRAM ATP
DESIGN ENGINEERING
SDR
CDR
FACI
MAJOR SUBCONTRACTOR SELECTED
INITIATE LONG LEAD PROCUREMENT
DEVELOPMENT TEST COMP
QUALIFICATION TEST COMP
DEVELOPMENT, TEST, AND EVALUATION
MANUFACTURING (DEVELOPMENT)
NONQUALIFICATION UNITS
TO DT
QUALIFICATION UNITS
TO QT
1
13
PRODUCTION (FLIGHT ARTICLE)
SPARES
TEST
DEVELOPMENT TEST – ASSEMBLY, SUBASSEMBLY, COMPONENT
7
DEVELOPMENT TEST – SUBSYSTEM
6
QUALIFICATION TEST – SUBSYSTEM
LEGEND:
MILESTONE
SHIPMENT & DELIVERY
DT DEVELOPMENT TEST
QT QUALIFICATION TEST
CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982

Figure 1.2-8

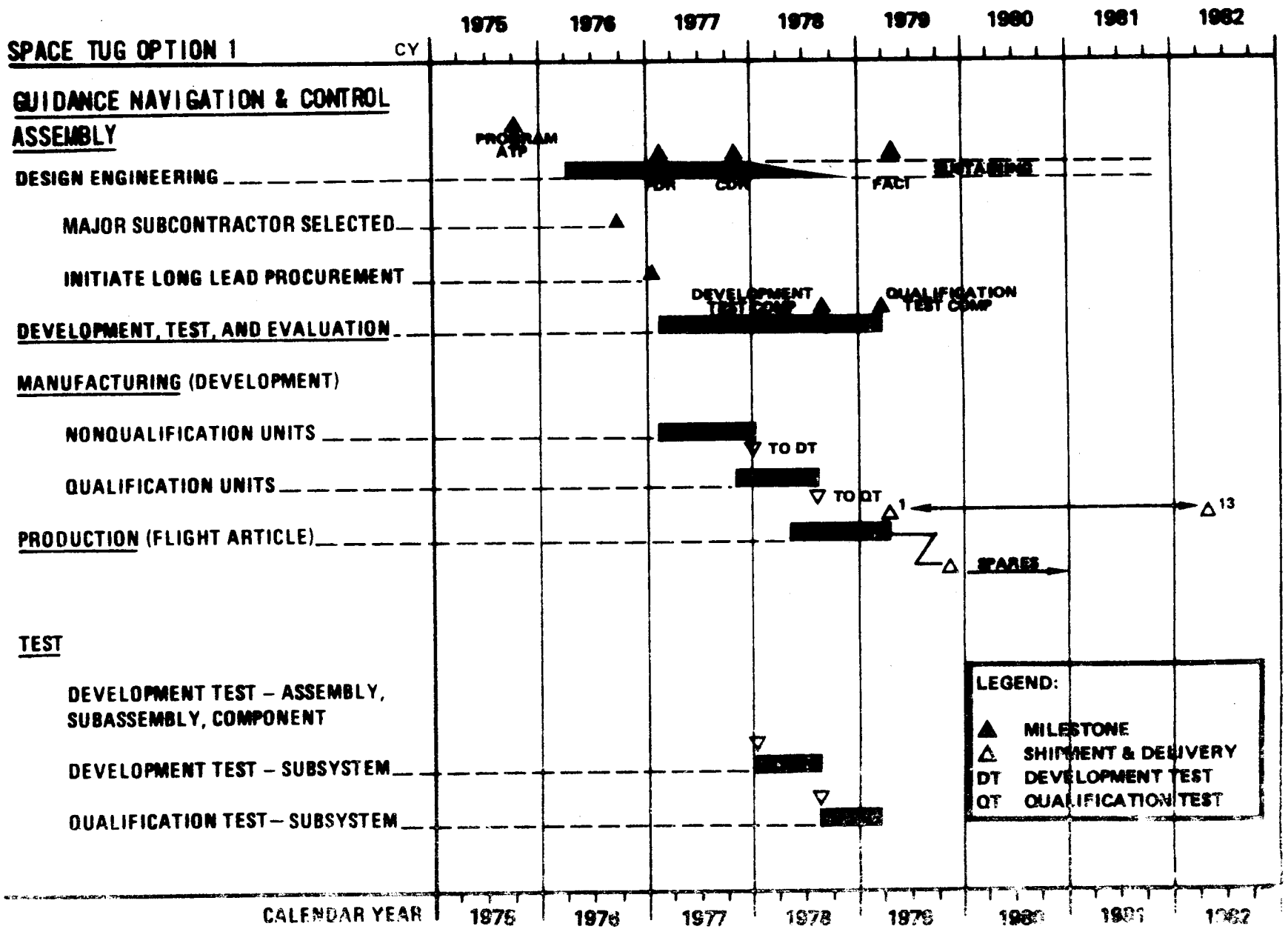

SPACE TUG OPTION 1
CY
1975
1976
1977
1978
1979
1980
1981
1982
GUIDANCE NAVIGATION & CONTROL ASSEMBLY
PROGRAM ATP
DESIGN ENGINEERING
FACT
MAJOR SUBCONTRACTOR SELECTED
INITIATE LONG LEAD PROCUREMENT
DEVELOPMENT TEST COMP
QUALIFICATION TEST COMP
DEVELOPMENT, TEST, AND EVALUATION
MANUFACTURING (DEVELOPMENT)
NONQUALIFICATION UNITS
TO DT
QUALIFICATION UNITS
TO QT
1
13
PRODUCTION (FLIGHT ARTICLE)
SPARES
TEST
DEVELOPMENT TEST – ASSEMBLY, SUBASSEMBLY, COMPONENT
DEVELOPMENT TEST – SUBSYSTEM
QUALIFICATION TEST – SUBSYSTEM
LEGEND:
MILESTONE
SHIPMENT & DELIVERY
DT DEVELOPMENT TEST
QT QUALIFICATION TEST
CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982

Figure 1.2-9

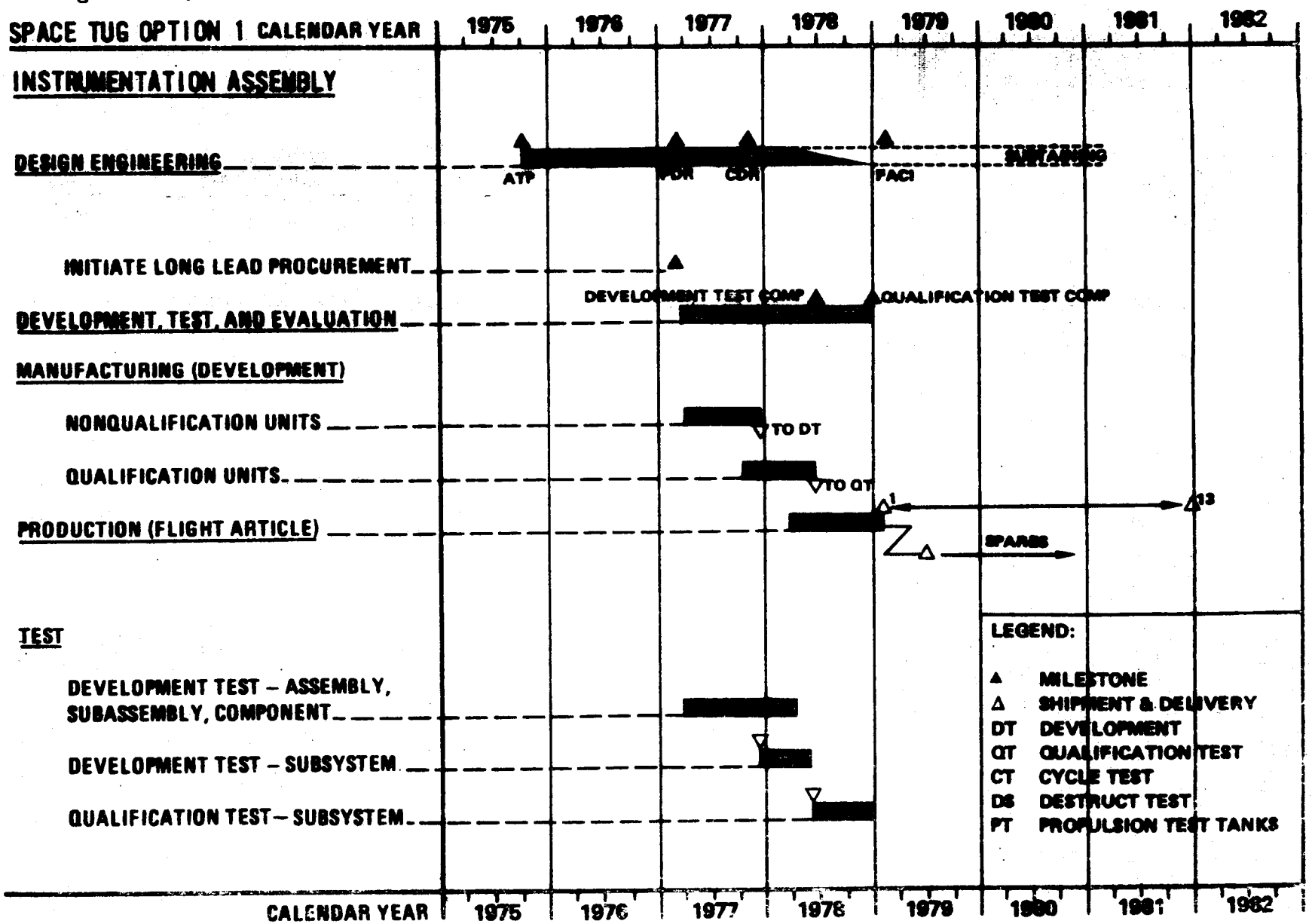

SPACE TUG OPTION 1 CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982
INSTRUMENTATION ASSEMBLY
DESIGN ENGINEERING
ATP
PDR
CDR
FACI
INITIATE LONG LEAD PROCUREMENT
DEVELOPMENT TEST COMP
QUALIFICATION TEST COMP
DEVELOPMENT, TEST, AND EVALUATION
MANUFACTURING (DEVELOPMENT)
NONQUALIFICATION UNITS
TO DT
QUALIFICATION UNITS
TO QT
1
13
PRODUCTION (FLIGHT ARTICLE)
SPARES
TEST
DEVELOPMENT TEST – ASSEMBLY, SUBASSEMBLY, COMPONENT
DEVELOPMENT TEST – SUBSYSTEM
QUALIFICATION TEST – SUBSYSTEM
LEGEND:
MILESTONE
SHIPMENT & DELIVERY
DT DEVELOPMENT
QT QUALIFICATION TEST
CT CYCLE TEST
DS DESTRUCT TEST
PT PROPULSION TEST TANKS
CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982

Figure 1.2-10

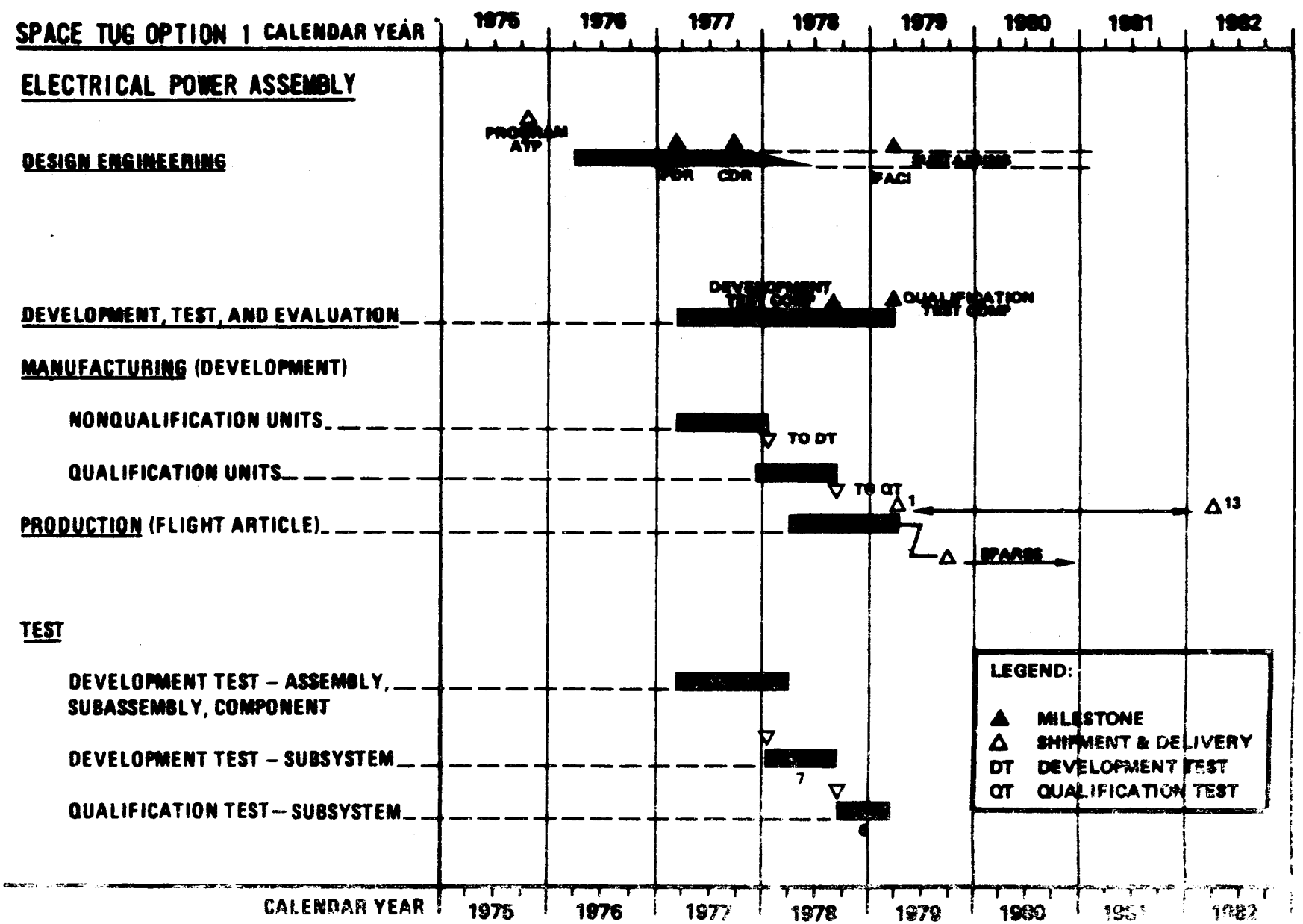

SPACE TUG OPTION 1 CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982
ELECTRICAL POWER ASSEMBLY
DESIGN ENGINEERING
PROGRAM ATP
PDR
CDR
PACI
DEVELOPMENT, TEST, AND EVALUATION
DEVELOPMENT TEST COMP
QUALIFICATION TEST COMP
MANUFACTURING (DEVELOPMENT)
NONQUALIFICATION UNITS
TO DT
QUALIFICATION UNITS
TO QT
PRODUCTION (FLIGHT ARTICLE)
1
13
SPARES
TEST
DEVELOPMENT TEST – ASSEMBLY, SUBASSEMBLY, COMPONENT
DEVELOPMENT TEST – SUBSYSTEM
7
QUALIFICATION TEST – SUBSYSTEM
LEGEND:
MILESTONE
SHIPMENT & DELIVERY
DT DEVELOPMENT TEST
QT QUALIFICATION TEST
CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982

Figure 1.2-11

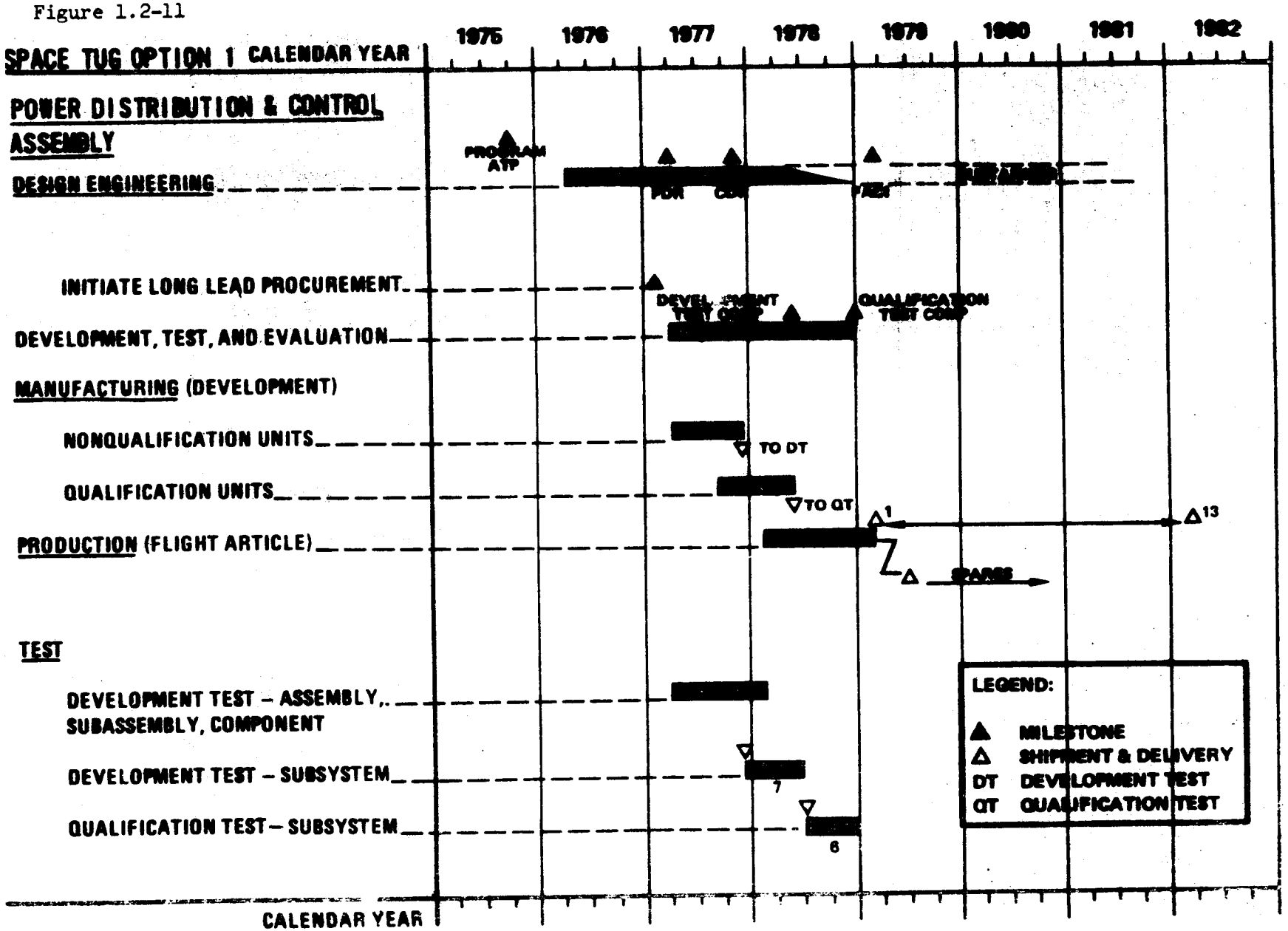
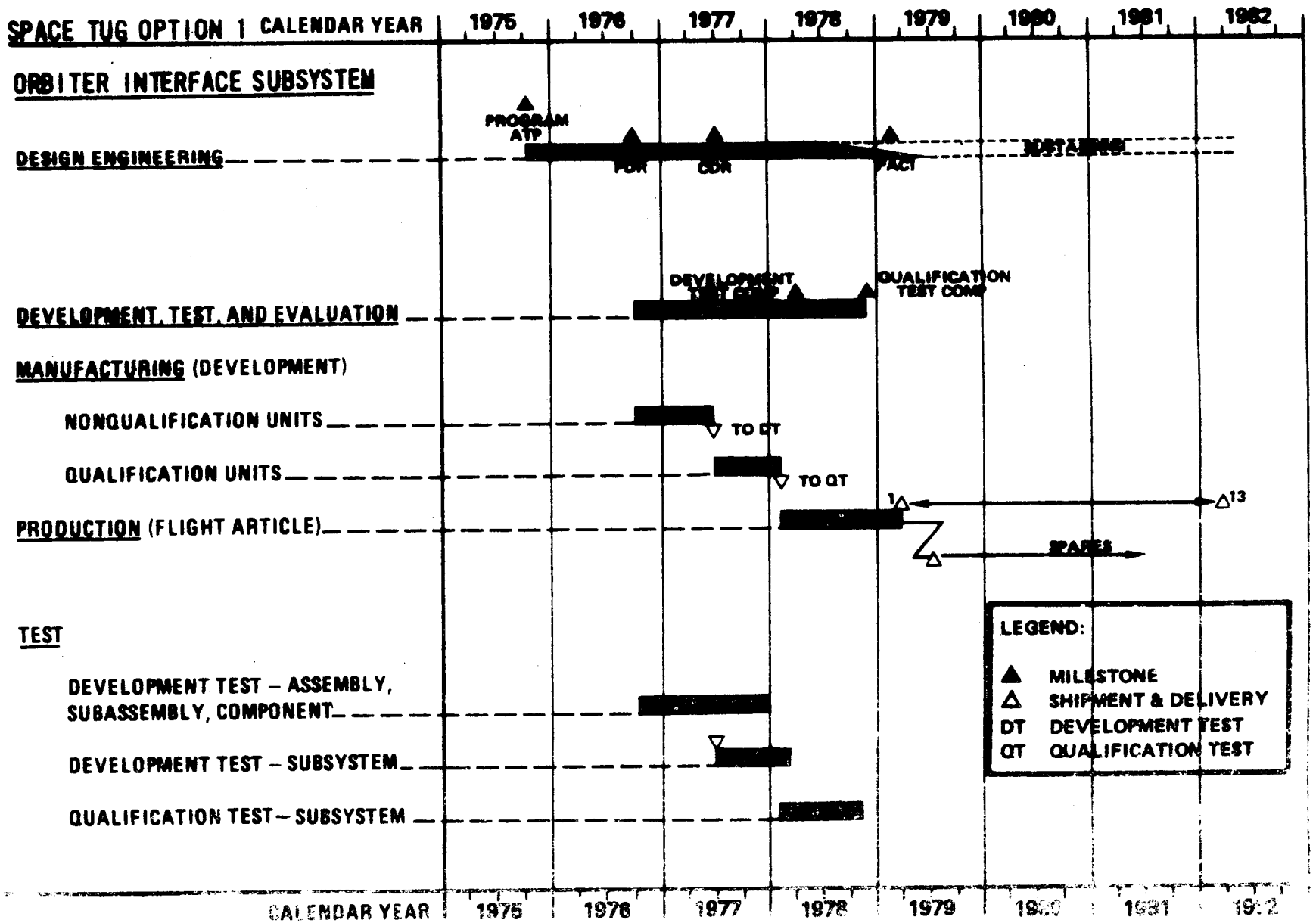

SPACE TUG OPTION 1 CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982
POWER DISTRIBUTION & CONTROL ASSEMBLY
DESIGN ENGINEERING
PROGRAM ATP
PDR
CDR
FSR
INITIATE LONG LEAD PROCUREMENT
DEVELOPMENT, TEST, AND EVALUATION
QUALIFICATION TEST COMP
MANUFACTURING (DEVELOPMENT)
NONQUALIFICATION UNITS
TO DT
QUALIFICATION UNITS
TO QT
PRODUCTION (FLIGHT ARTICLE)
1
13
SPARES
TEST
DEVELOPMENT TEST – ASSEMBLY, SUBASSEMBLY, COMPONENT
DEVELOPMENT TEST – SUBSYSTEM
7
QUALIFICATION TEST – SUBSYSTEM
6
LEGEND:
MILESTONE
SHIPMENT & DELIVERY
DT DEVELOPMENT TEST
QT QUALIFICATION TEST
CALENDAR YEAR

Figure 1.2-12


SPACE TUG OPTION 1 CALENDAR YEAR
1975
1976
1977
1978
1979
1980
1981
1982
ORBITER INTERFACE SUBSYSTEM
PROGRAM ATP
DESIGN ENGINEERING
PDR
CDR
PACT
DEVELOPMENT TEST AND EVALUATION
QUALIFICATION TEST COMP
MANUFACTURING (DEVELOPMENT)
NONQUALIFICATION UNITS
TO DT
QUALIFICATION UNITS
TO QT
PRODUCTION (FLIGHT ARTICLE)
1
13
SPARES
TEST
DEVELOPMENT TEST – ASSEMBLY, SUBASSEMBLY, COMPONENT
DEVELOPMENT TEST – SUBSYSTEM
QUALIFICATION TEST – SUBSYSTEM
LEGEND:
MILESTONE
SHIPMENT & DELIVERY
DT DEVELOPMENT TEST
QT QUALIFICATION TEST
CALENDAR YEAR

1.3 PRODUCTION SCHEDULE

The production schedule, Figure 1.3-1, reflects the vehicle manufacturing requirements and rate of production to satisfy this Tug program option within the project summary schedule. This schedule has been prepared from data developed in the manufacturing flow schedule, shown in Section 4. Data presented in Section 4 anplifies the information presented here (see Section 4.1).

1.4 OPERATIONS SCHEDULE

This schedule, Figure 1.4-1, shows the activities required to initially activate the launch site, prepare for the first vehicle launch, and prepare for the next launch. Operations activities for both ETR and WTR are indicated as are the vehicle deliveries required to support the Option 1 flight schedule. Detail operations activities, timelines and schedules are provided in Volume 6, Book 1.

1.5 FACILITIES SCHEDULE

This schedule, Figure 1.5-1, shows major events and activities required to activate factory and launch site facilities necessary to support the Option 1 program. Data used to establish these requirements is contained in the facilities description in Section 3.

1.6 EVALUATION OF MAJOR SCHEDULE DRIVERS

The 54 month DDT&E program has been determined a reasonable schedule for Program Option 1. Our analysis (based upon the design approach of minimizing design and manufacturing unknowns and of maximizing proven systems and off the shelf hardware) concludes that there are no schedule critical items. However, to meet the fabrication and assembly of three development test tank sets per the baseline schedule, Figure 1.1-1, the following activities must be accomplished in a timely manner:

- Procurement of tapered domes (spin formed domes).
- Procurement of the chem mill facilities.
- Procurement of the aging oven.
- Activation of anodizing facilities.
- Tools for the LO_2 and LH_2 tank fabrication and assembly.
- Procurement of aluminum, titanium, carbon, and stock material.

The other major items of the project, e.g., the facilities modification and actuation at ETR and WTR, and the development and integration of the GSE, are considered parallel, non-constraining activities without being major schedule drivers.

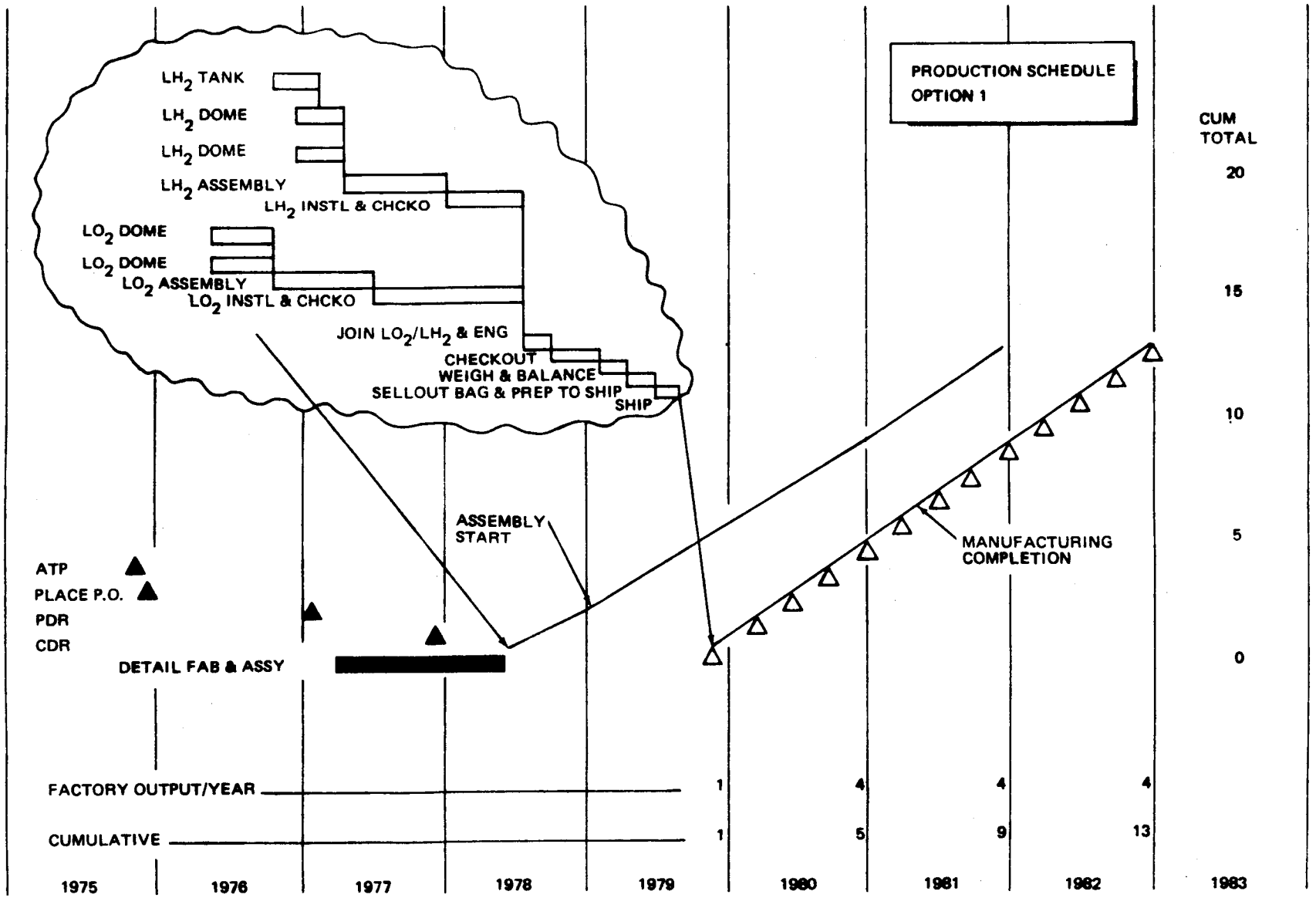


Figure 1.3-1 Production Schedule, Option 1

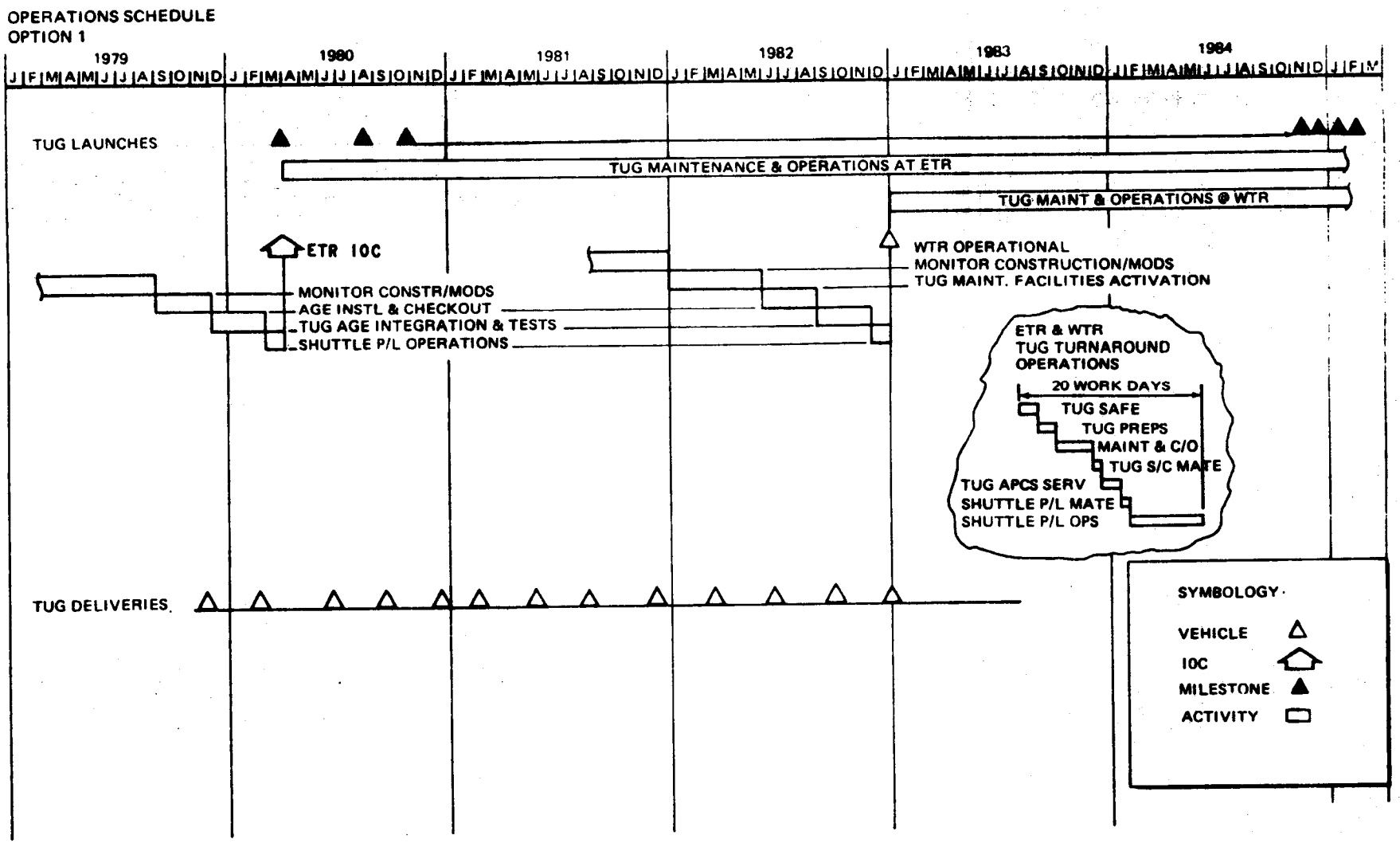


Figure 1.4-1 Operations Schedule, Option 1

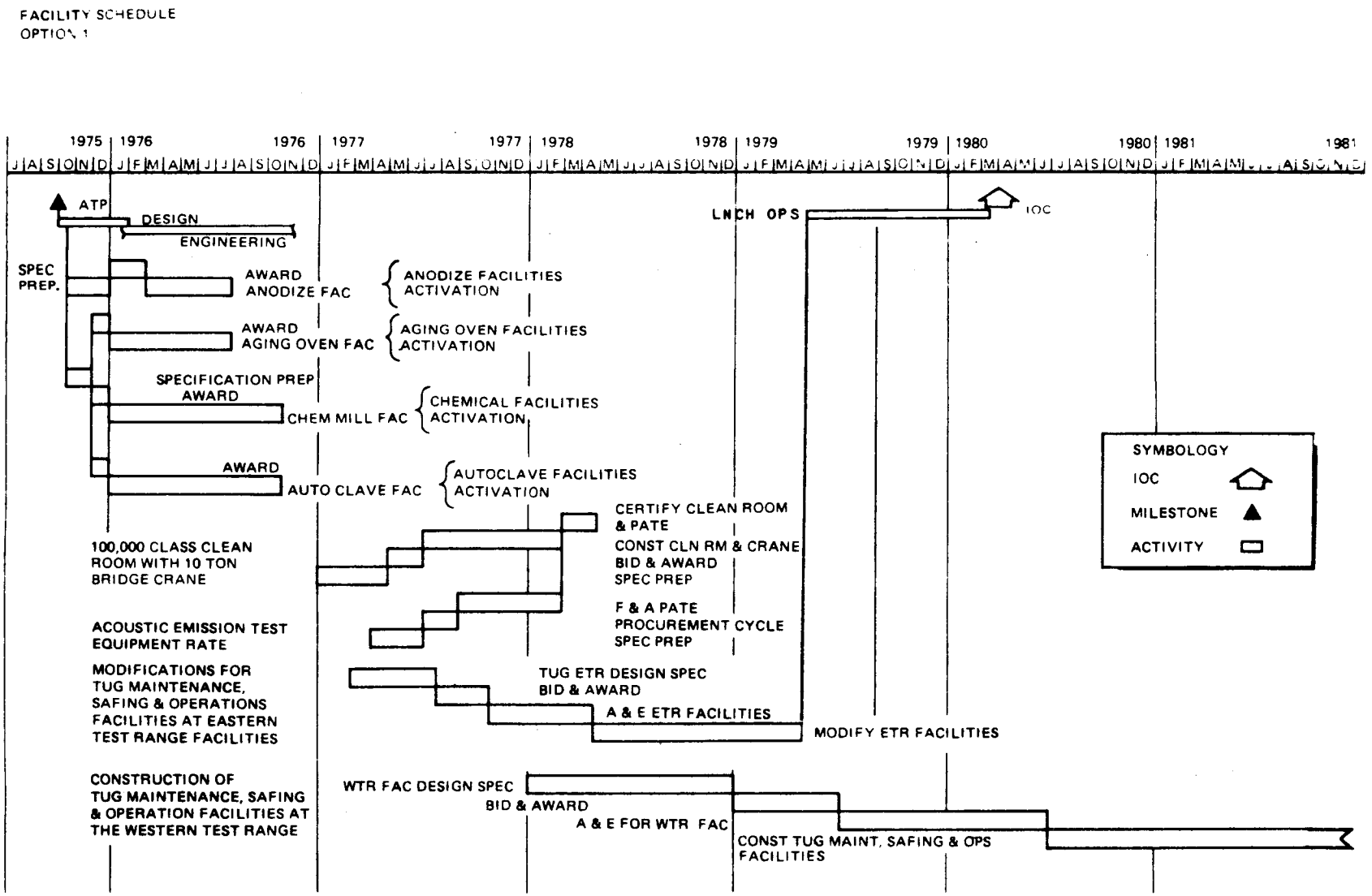


Figure 1.5-1 Facilities Schedule, Option 1

1.7 IMPACT OF OPTION SENSITIVITIES

This subsection discusses the impact on project schedules by the three sensitivities:

1. Programmatic sensitivity for a 2 year later IOC (31 December 1981).
2. DDT&E effects for 36-hour mission duration.
3. Impact to provide 300 watts to payload.

1.7.1 Impact of 2 Year Later IOC

The baseline schedule for Program Option 1 requires a 2-shift manufacturing activity to provide a delivery rate of 4 vehicles per year. Stretch out of the schedule for the full 2 years, as shown in Figure 1.7.1-1, results in a single shift manufacturing activity to provide delivery rate of 2.8 vehicle per year. We consider this uneconomical. Other alternatives to the 2 year IOC delay are provided in Volume 5, Section 9.1.1.

1.7.2 DDT&E Effects for 36-hour Mission

There is no effect on the overall vehicle schedule for Program Option 1 to provide a greater than 36-hour mission duration. However, there will be an increase in the subsystem development and test activities which can be absorbed.

1.7.3 Impact to Provide 300 Watts to Payload

There is no effect on overall project baseline schedule for Program Option 1 due to this requirement.

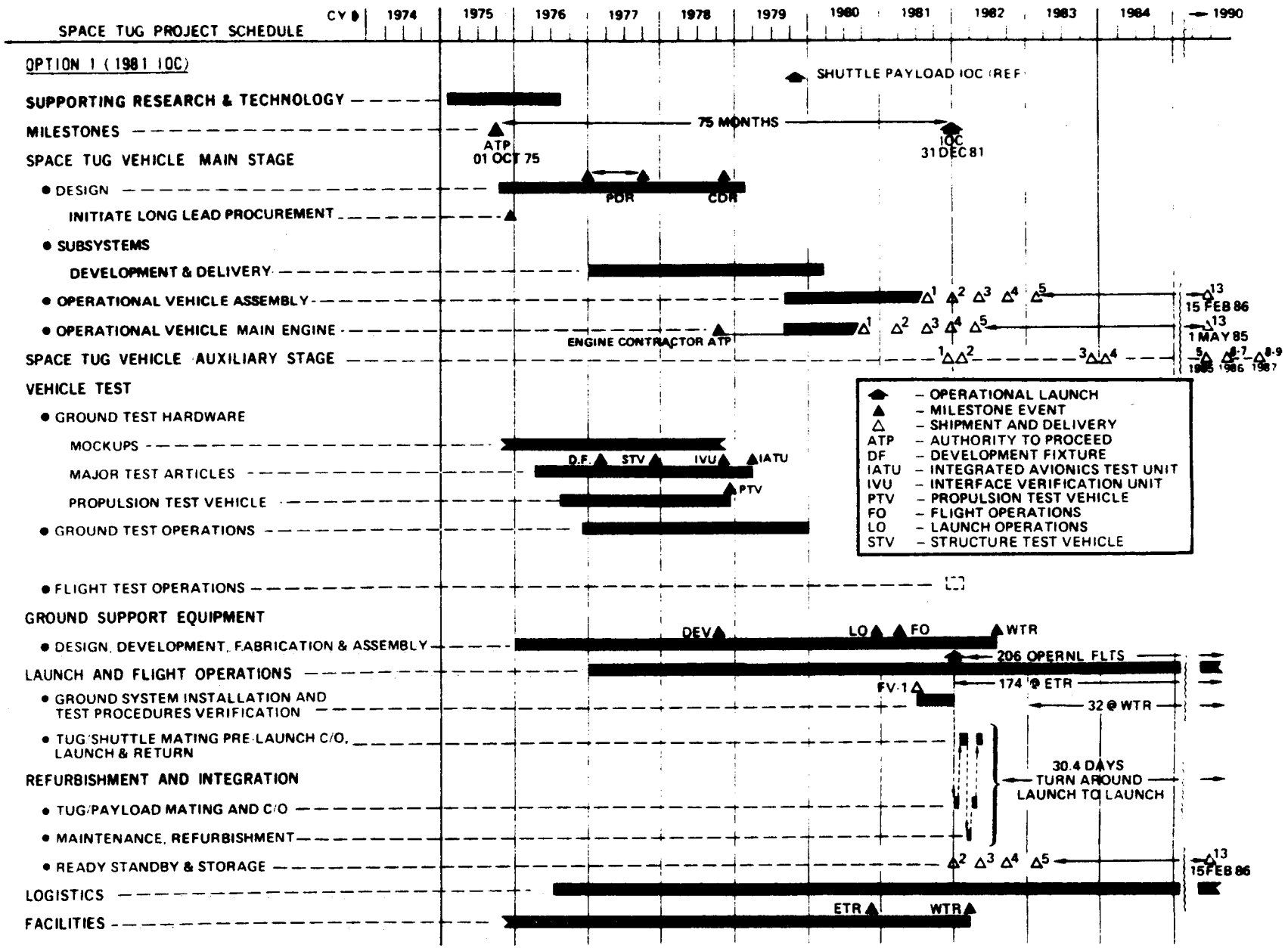
1.8 COMPARISON OF DOD AND NASA SCHEDULES

NOTE: Submittal of this data has been deferred until after the Data Dump, which has been agreed to by the Study COR.

1.9 PARALLEL DEVELOPMENTS

Concurrent activities on the baseline schedule for Program Option 1 are shown in the Project Summary Schedule, Figure 1.1-1. This concurrent development and test of the Vehicle Main Stage, the GSE, and facilities modification is considered reasonable. We have reviewed the subsystems and components on Program Option 1 for parallel developments to ensure performance and schedule achievement, and we can find no such need.

Figure 1.7.1-1


SPACE TUG PROJECT SCHEDULE
CY
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1990
OPTION 1 (1981 IOC)
SHUTTLE PAYLOAD IOC (REF)
SUPPORTING RESEARCH & TECHNOLOGY
MILESTONES
75 MONTHS
ATP
01 OCT 75
IOC
31 DEC 81
SPACE TUG VEHICLE MAIN STAGE
• DESIGN
PDR
CDR
INITIATE LONG LEAD PROCUREMENT
• SUBSYSTEMS
DEVELOPMENT & DELIVERY
• OPERATIONAL VEHICLE ASSEMBLY
15 FEB 86
• OPERATIONAL VEHICLE MAIN ENGINE
ENGINE CONTRACTOR ATP
1 MAY 85
SPACE TUG VEHICLE AUXILIARY STAGE
VEHICLE TEST
• GROUND TEST HARDWARE
MOCKUPS
D.F.
STV
IVU
IATU
MAJOR TEST ARTICLES
PTV
PROPULSION TEST VEHICLE
• GROUND TEST OPERATIONS
• FLIGHT TEST OPERATIONS
GROUND SUPPORT EQUIPMENT
• DESIGN, DEVELOPMENT, FABRICATION & ASSEMBLY
DEV
LO
FO
WTR
LAUNCH AND FLIGHT OPERATIONS
206 OPERNL FLTS
• GROUND SYSTEM INSTALLATION AND TEST PROCEDURES VERIFICATION
FV-1
174 @ ETR
32 @ WTR
• TUG/SHUTTLE MATING PRE-LAUNCH C/O, LAUNCH & RETURN
30.4 DAYS TURN AROUND LAUNCH TO LAUNCH
REFURBISHMENT AND INTEGRATION
• TUG/PAYLOAD MATING AND C/O
• MAINTENANCE, REFURBISHMENT
• READY STANDBY & STORAGE
15 FEB 86
LOGISTICS
FACILITIES
ETR
WTR
– OPERATIONAL LAUNCH
– MILESTONE EVENT
– SHIPMENT AND DELIVERY
ATP – AUTHORITY TO PROCEED
DF – DEVELOPMENT FIXTURE
IATU – INTEGRATED AVIONICS TEST UNIT
IVU – INTERFACE VERIFICATION UNIT
PTV – PROPULSION TEST VEHICLE
FO – FLIGHT OPERATIONS
LO – LAUNCH OPERATIONS
STV – STRUCTURE TEST VEHICLE

Section 2

VEHICLE TEST PROGRAM

2.1 GROUND TEST ARTICLES

Figure 2.1-1 identifies the test articles, tests associated with them and which of these tests is conducted on Option 1.

2.1.1 Test Article Descriptions

2.1.1.1 Structural Test Article

The Structural Test Article is not tested as an assembled entity. Each major element is subjected to those environments or test conditions peculiar to its operational exposure. The Structural Test Article is comprised of the following elements:

Quantity	Hardware
3	LH_2 Tanks
3	LO_2 Tanks
1	Body Structure
1	Thrust Structure
1 set	Support Elements
1 set	Joint Elements

2.1.1.2 Development Fixture

The development fixture commences with the structural subsystem upon which wiring and plumbing routing and equipment installations are developed. It can later be upgraded with higher fidelity hardware and used for Maintenance ($\overline{M}$), removal, replacement, accessibility procedure verification and Maintainability ($\underline{M}$) analyses.

2.1.1.3 Propulsion Test Vehicle

The propulsion test vehicle is not truly a vehicle (Tug). It consists of the tankage; Main Engine Support Assembly (MESA) plus a 0.2 equivalency for spares; a set of electrical and propulsion GSE, instrumentation, and sufficient quantities of propellants and pressurant and pneumatic gases to support the test. In addition, for demonstration of Tug/Orbiter interface capability, a structures assembly, interface panel assembly, purge provisions assembly, and an abort provisions assembly from the Orbiter Interface Subsystem will be provided.

TEST	OPTION 01 NASA	01 DOD	01 IOC CHG	02 NASA	02 DOD	02 IOC CHG	03I NASA	03I DOD	03I IOC CHG	03F NASA	03F DOD	03F IOC CHG	03S
PRESSURE CYCLE TANKS (DEVELOPMENT)	X	X	X	X	X	X	X	X	X				
PRESSURE BURST TANKS (DEVELOPMENT)	X	X	X	X	X	X	X	X	X				
PRESSURE CYCLE/PROOF TANKS AND STATIC LOADING OF REMAINDER OF STRUCTURES SUBSYSTEMS (QUALIFICATION)	X	X	X	X	X	X	X	X	X				
MAINTENANCE (M) PROCEDURES VERIFICATION (DT&E, IOT&E) - DEVELOPMENT FIXTURE	X	X	X	X	X	X	X	X	X	X	X	X	X
MAINTAINABILITY (M) EVALUATION - DEVELOPMENT FIXTURE	X	X	X	X	X	X	X	X	X	X	X	X	X
PROPULSION TEST VEHICLE - COLD FLOW(CAT I RL10 ENGINE)	X	X	X				X	X	X				
PROPULSION TEST VEHICLE - STATIC FIRING (OTHER THAN CAT I RL10)				X	X	X							X
MAINTAINABILITY (M) EVALUATION - PTV	X	X	X	X	X	X	X	X	X				X
INTEGRATED AVIONICS TEST UNIT (IATU) (DT&E, IOT&E)	X	X	X	X	X	X	X	X	X	X	X	X	X
MAINTAINABILITY (M) EVALUATION - IATU	X	X	X	X	X	X	X	X	X	X	X	X	X
FLIGHT CONTROL SIMULATION (DEPLOYMENT ONLY)	X	X	X				X	X	X				
FLIGHT CONTROL SIMULATION (DEPLOYMENT AND RETRIEVAL)				X	X	X				X	X	X	X
TRANSPORTATION AND HANDLING PROCEDURES VERIFICATION, FLIGHT TEST ARTICLE (DT&E, IOT&E)	X	X	X	X	X	X	X	X	X				
THERMAL				X	X	X				X	X	X	

Figure 2.1-1 Vehicle Test

TEST	OPTION 01 NASA	01 DOD	01 IOC CHG	02 NASA	02 DOD	02 IOC CHG	03I NASA	03I DOD	03I IOC CHG	03F NASA	03F DOD	03F IOC CHG	03S
EMC - FLIGHT TEST ARTICLE, MANUFACTURING	X	X	X	X	X	X	X	X	X	X	X	X	X
EMC - FIRST DELIVERED TUG, ETR	X	X	X	X	X	X	X	X	X	X	X	X	X
EMC - FIRST DELIVERED TUG, WTR	X	X	X	X	X	X	X	X	X	X	X	X	X
M - FLIGHT TEST ARTICLE, ETR	X	X	X	X	X	X	X	X	X	X	X	X	X
M - FLIGHT TEST ARTICLE, ETR	X	X	X	X	X	X	X	X	X	X	X	X	X
FLIGHT SUPPORT EQUIPMENT WITH AN IVU	X	X	X	X	X	X	X	X	X				
FLIGHT SUPPORT EQUIPMENT WITH AN IVU AND THE ORBITER (EGRESS-INGRESS)	X	X	X	X	X	X	X	X	X				
FLIGHT TEST OPERATIONS EGRESS-INGRESS MANEUVER VERIFICATION USING THE IVU	X	X	X	X	X	X	X	X	X				
FLIGHT TEST OPERATIONS TWO FLIGHTS WITH OPERATIONAL MISSIONS	X		X	X		X	X		X				
FLIGHT TEST OPERATIONS - TWO FLIGHTS, DEDICATED		X			X			X					
FLIGHT TEST OPERATIONS - ONE FLIGHT WITH OPERATIONAL MISSION										X		X	X
FLIGHT TEST OPERATIONS - ONE FLIGHT, DEDICATED											X		

Figure 2.1-1 (Cont.) Vehicle Test

The propellant tanks will be fabricated and assembled on production tooling. They will be the initial tanks so produced. They are therefore the tooling "proof and complete" tanks. The major difference between these and "flight weight" tanks is that no tapering or chemical milling of the material is accomplished prior to assembly. These tanks are therefore heavier and stronger than "flight weight" tanks. These "proof and complete" tanks are a necessary "product" of the program but would not normally have further usage assigned them. As tankage for the Propulsion Test Vehicle, their usage is cost effective, relative to the non-procurement of special high pressure capability battleship tankage or extra allocation of production tankage, and they are more characteristic of Tug tanks. A block diagram of the PTV/GSE installation is shown in Figure 2.1-2. The IATU uses the factory set of GSE to develop procedures and software.

2.1.1.4 Integrated Avionics Test Unit (IATU)

This unit consists of one Avionics subsystem plus a 0.2 equivalency for spares; a set of interfacing hardware (sensors, valves) from appropriate subsystems; a set of electronic ground support equipment and associated software; and a set of interface verification units from each of the associate contractors, i.e., spacecraft, and orbiter. The test setup is designed and constructed so that access to installations is immediate, e.g., equipment is mounted on walls or benches so that both surfaces are accessible. Trouble-shooting and maintenance can be performed with minimum manhours and schedule conflicts. An important aspect of layout and installation here is that impedance match and electromagnetic compatibility be assured, or determined to be within specified limits, by adhering to wire lengths and routing proximities dictated by the flight configuration. It is highly desirable that components comprising this unit should be new, just as in a flight production Tug, with qualification at the component level complete, just as in a flight production Tug. The importance here is that the integration of the Avionics subsystem is under development and if not functionally qualified here, such qualification would have to await the first flight vehicle. Functional qualification on this unit then should not be hindered by failures induced by unqualified or used components. This is not to say that hardware originating from categories other than fully qualified or new or both cannot be used, but its functional integrity for the intended purpose must be assured. Judicious selection can accomplish this if indeed any previously tested components are available. Availability can be dependent upon program policy relative to disposition of test hardware. This policy could require all test hardware, subsequent to completion of qualification testing, to be placed in bond. A block diagram of the IATU is shown in Figure 2.1-3.

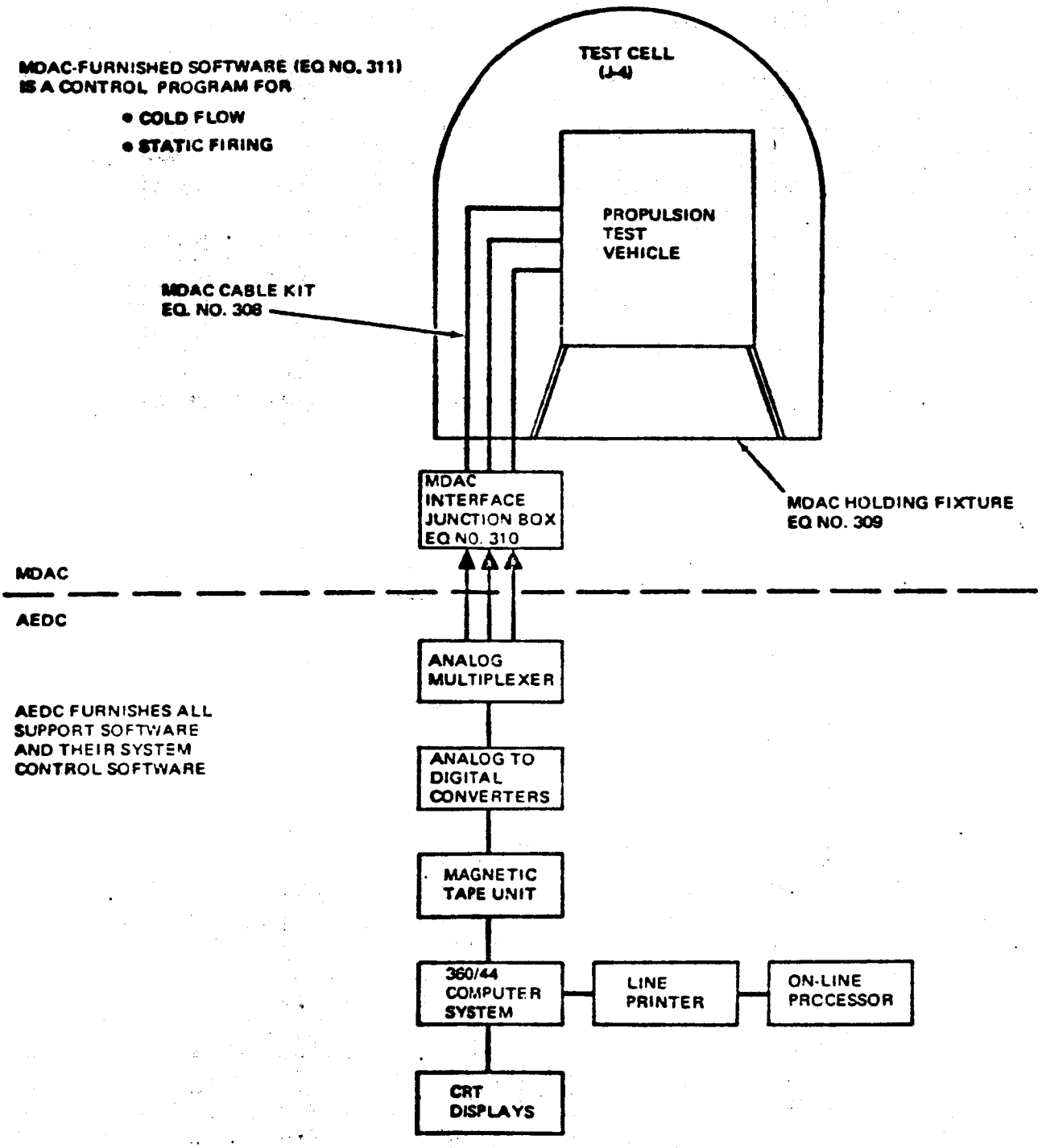


Figure 2.1-2. Propulsion Test Vehicle/Ground Support Equipment Assembly

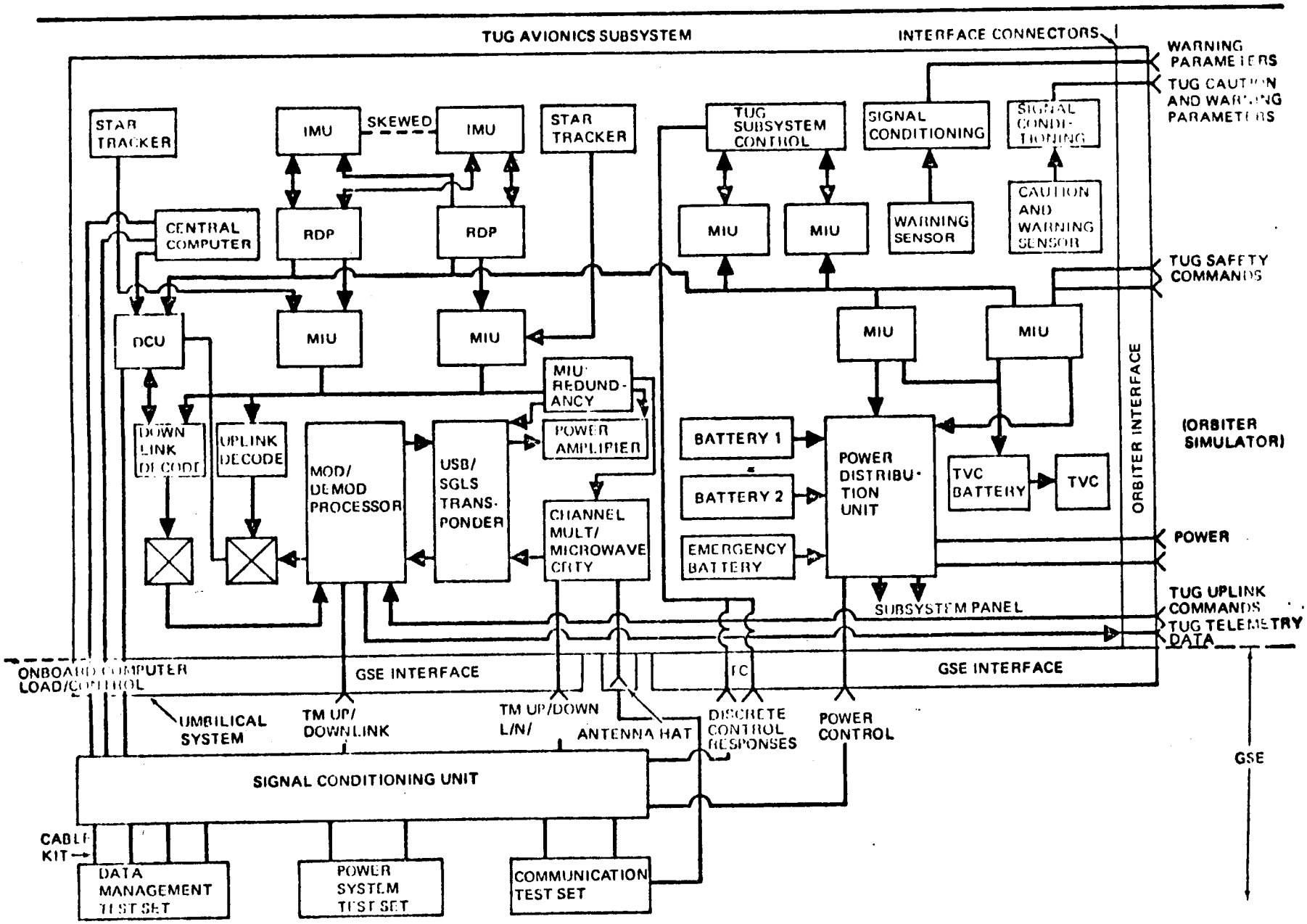


Figure 2.1-3. Integrated Avionics Test Unit

2.1.1.5 Flight Control Simulation

This test is a dynamic extension to the IATU. It will be accomplished in the On-Line Subsystem Facility (OLSF) which is co-located with the IATU. Equipment under test will be the guidance and navigation subassemblies.

2.1.1.6 Flight Support Equipment

This is that Tug flight equipment which interfaces with the orbiter and remains with the orbiter during Tug flight. It consists of the tilt table; two fluid/electrical interface panels; an abort dump interface panel; and an electrical interface panel. This equipment undergoes testing first without, then with, an Interface Verification Unit representative of a Tug.

2.1.1.7 Flight Test Article

Prior to conducting flight tests, certain ground tests will be conducted using this Tug. It is the first production Tug. The ground tests utilizing this vehicle are the verification of checkout procedures at the manufacturing site; the electromagnetic compatibility test at the manufacturing site; verification of the transportation and handling procedures; verification of checkout procedures at ETR; electromagnetic compatibility with the ETR launch complex; EMC at WTR (first delivered Tug); verification of maintenance procedures at the launch site; and maintainability testing and supporting analyses at the launch site.

2.2 FLIGHT TEST ARTICLE

The flight test article will be the first produced Tug. No special equipment will be installed specifically for flight test purposes. In addition to operational instrumentation, however, some flight test instrumentation will be carried. Flight test articles, other than a complete Tug, are not required.

2.3 GROUND TEST PROGRAM

A development test program envelopes SR&T; development and qualification testing of parts, components, subassemblies, and assemblies of subsystems; reliability testing of selected items; repairability/maintainability testing of the smaller items; development, qualification, maintenance, and maintainability testing of major or vehicle level test articles; and flight testing of the completed CEI. During the course of this Conceptual Phase study, planning emphasis has been placed on that testing conducted on major test articles and flight tests. That is not to say that testing at the lower levels of hardware has been completely ignored, only that the level of planning depth is more shallow, but sufficient to acquire costing information.

The acquisition of assurance of reusability of the cryogenic Space Tug through equipment life, maintainability, and/or refurbishment, begins with design and continues through component and vehicle level testing to mission operations. The foundation of such a goal lies with intelligent design of components and subsystems for high inherent reliability and long life. Accordingly, every economically practical means of reducing to a functional minimum the number of failures that might occur must be applied to the design effort.

In terms of reducing total maintenance hours to a minimum, it would be ideal to achieve total elimination of failures. However, even if this were functionally possible to accomplish, the cost of providing the capability of trouble free service for the projected life of a Space Tug vehicle and proving it to a high level of confidence would be prohibitive. The inevitable risk of unforeseen operational accidents, the fact that it is not feasible to totally eliminate failures, and shear economics indicate a need for supplementary approaches and techniques such as redundancy and failure-tolerant design. Design for high reliability and judiciously planned and implemented testing must be used to insure the specified reusability and service life of the Space Tug.

The most cost effective program combines four philosophies pertinent to design, analyses and test.

1. Select existing hardware which is shown to have survived space flight; reserach the history of that hardware to determine durations of missions flown and the amount of testing accomplished to assure survival to (or beyond) that duration; introduce redundancy into designs which include that hardware;

utilize maintainability (M) analyses to establish scheduled maintenance ($\overline{M}$) procedures for removal and replacement; and conduct qualification tests at higher levels of assembly, e.g., subassembly, assembly level, for Tug criteria. An example is the propellant valves.

2. Design new subsystem hardware to survive an economically reasonable portion of Tug life; conduct development and qualification tests to establish and verify that survivability and from a maintainability (M) analysis, schedule removal and refurbishment/replacement accordingly. Examples of this type of component are the propellant disconnects.

3. Determine, through reliability analyses that component reliability meets Tug requirements and that failures which may occur must be considered random failures, i.e., the probability of a failure occurring on the first flight is as great as the probability of a failure occurring on any subsequent flight; introduce redundancy into designs which include that hardware, or accept the risk of a random failure; remove and refurbish/replace as necessary in unscheduled maintenance ($\overline{M}$). An example of this type of component is the computer in the data management assembly, a single installation.

4. Determine that a component/subassembly/assembly/subsystem cannot be removed and replaced through scheduled or unscheduled maintenance; design for survival through Tug environmental criteria beyond expected life; and conduct development and qualification tests to assure survival beyond design requirements. An example of this type of hardware is the structural subsystem.

Background acquired in aircraft development programs can prove most useful to the Space Tug Program as the experience is closely related to Space Tug development. As a basic and obvious point of comparison, aircraft are designed to be operated and maintained over extensive operational lifetimes as is the Space Tug.

From the standpoint of developing a Space Tug design for inclusion of maintenance capability, it is significant to note that with each new generation of aircraft, maintainability has been more thoroughly considered as an integral part of overall system design. A related vital fact is that maintenance accounts for approximately 28 percent of the direct operating costs. This substantial cost for maintenance results in a continuing challenge to aircraft operating agencies

to minimize total maintenance hours while maximizing aircraft utilization. The operational problems are quite similar to those of the Space Tug. The broad approaches to improving this area of aircraft operations are therefore quite applicable to the Space Tug Program.

The majority of the components intended to comprise this configuration either have been developed for use in previously produced space vehicles, are standard components qualified for space vehicle applications or will require little modification to meet Space Tug specifications. For those components requiring new or further development, or requalification, an economically feasible population will be selected for the appropriate type of testing. Further, the level of hardware assembly at which verification of a given item can be adequately achieved, i.e., component, subassembly, assembly, etc., will be evaluated. To the maximum extent possible, qualification of hardware included in the design will be achieved through means other than testing, i.e., analysis, inspection, demonstration, or simulation. Emphasis will be placed on repairability within each analysis or during testing.

Combination of design selection of high reliability/long life components and parts, and the component verification approach outlined above should yield an approximate 10 percent reduction of operational maintenance and refurbishment costs. DDT&E costs will be higher due to testing and its associated population requirements to provide reliability and life; however, this cost is non-recurring and will produce a reduction in recurring costs by lowering the incidence of both scheduled and unscheduled maintenance and refurbishment.

2.3.1 Test Operations Descriptions

2.3.1.1 Structural Test Article

Tests are conducted in three categories, i.e., tankage, load carrying structure, and joint development.

Tankage -- Pressure Cycling (Development)

The first LO_2 and LH_2 tanks to be produced will be placed separately in the hydrostatic test tank at MDAC, Huntington Beach. Internal pressure will be increased to normal operating pressure, held for a nominal period of time, then relieved. This cycle will be repeated until crack propagation is in evidence or until a quantity of cycles equal to 300 percent of the quantity

expected throughout the Tug's projected life whichever occurs first. In the event the former occurs first, the propagation will be investigated and further procedure assessed. If the latter occurs first, internal pressure will then be increased incrementally to burst, establishing a burst point under fatigue conditions.

Tankage -- Burst Pressure (Development)

The second set of tanks will be placed in the same hydrostatic test tank and the internal pressure increased incrementally to burst, establishing a fresh tank burst point.

Tankage -- Pressure Cycle Plus Proof Pressure (Qualification)

With information from the development tests available for design consideration, the third set of tanks will then be subjected to 150 percent of the projected life cycle quantity with the internal pressure then increased to proof pressure, held for a sufficient length of time to establish leak integrity, then relieved. In the event development test results indicate that design and production methods meet specification requirements this test may not be required.

Load Carrying Structure

These are the thrust structure forward support fitting, yaw fitting, and the Body Structure. Under static conditions, these items will be subjected to axial, shear, and bending loads.

Joint Development

This effort consists of applying compression, bending, and shear loads to the titanium tube-to-tank joint.

2.3.1.2 Development Fixture

The development fixture commences with the structural subsystem upon which wiring and plumbing routing and equipment installations are developed. It can later be upgraded with higher fidelity hardware and used for Maintenance ($\bar{M}$), removal, replacement, accessibility procedure verification, and Maintainability ($\underline{M}$) analyses.

Maintenance Procedure Verification

Maintenance procedures are developed after the definition of maintenance requirements through maintainability and maintenance analyses. The verification of these procedures on the engineering development fixture provides an initial opportunity to determine their validity in a semi-realistic environment. The test objectives include the verification of:

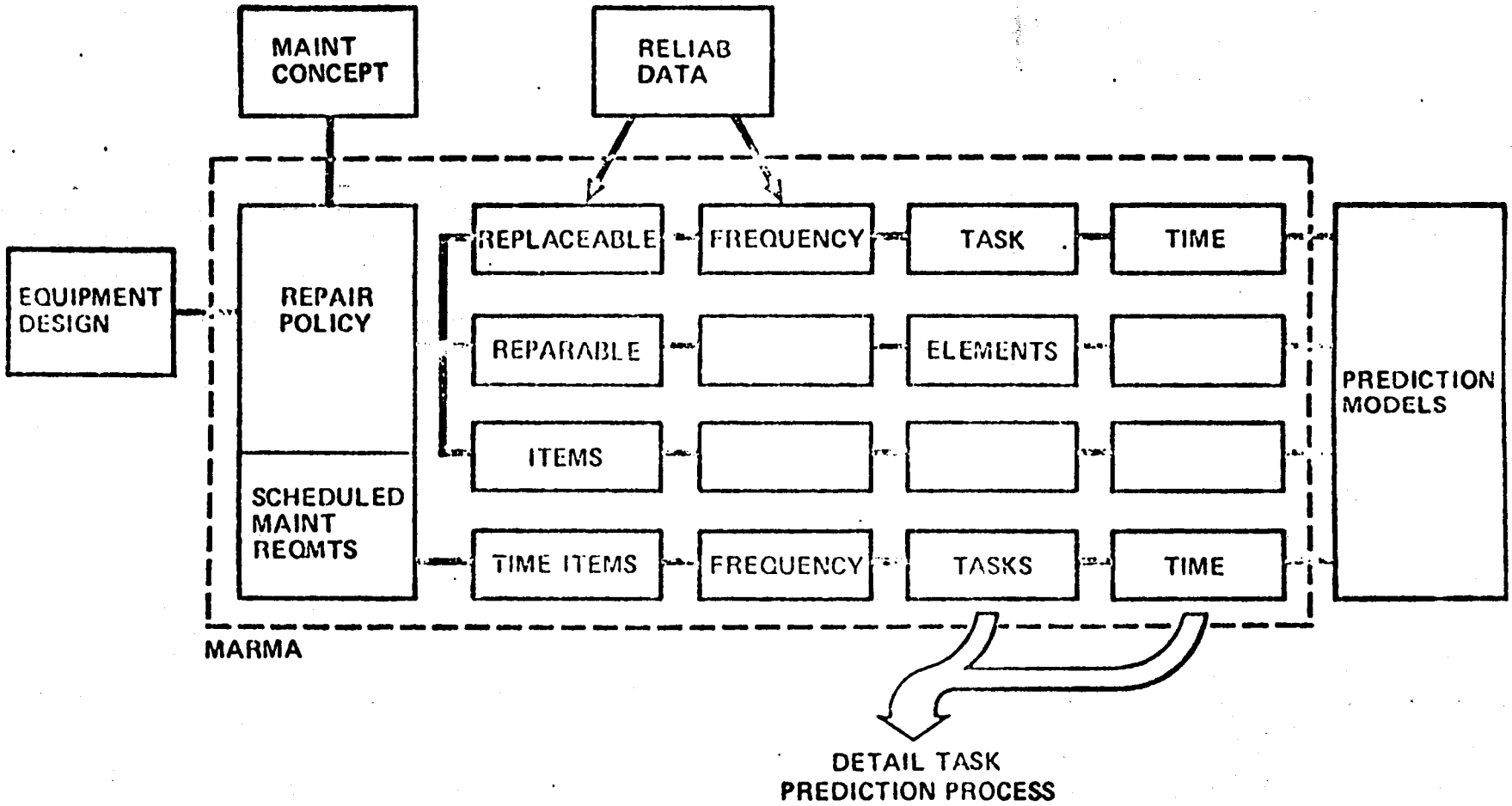
- o Satisfactory accessibility
- o Ease of LRU replacement
- o LRU handling capability
- o Potential safety hazards
- o Identification of proper tools
- o Maintenance manhours
- o Manpower requirements

This is first conducted as a contractor DT&E function and subsequently by the customer as an IOT&E effort.

Maintainability Evaluation

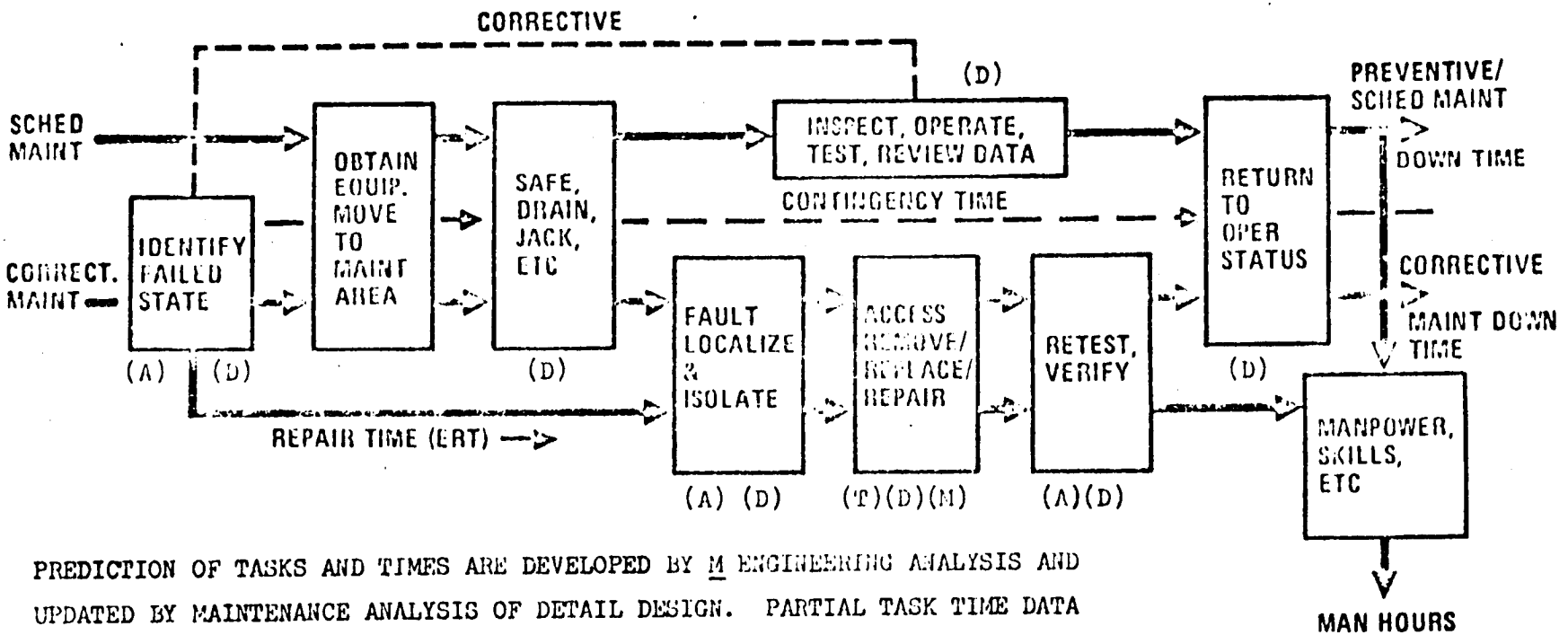
The maintainability program is dedicated to the achievement of a design that is (1) testable to maximize verification that the subsystems are unfailed and to identify what is failed or degraded, (2) repairable at a level to minimize field station equipment, time, and skills, and (3) economical with regard to refurbishment of structure and failed or wear out items. Most of the effort to achieve these objectives is encompassed in the M analysis, conducted in support of and concurrent with design development.

The M analysis provides evaluation for each item of equipment, determining its mission required preventive (scheduled) maintenance requirements and corrective maintenance methods, and selectively recommending design corrective action as required to achieve operational objectives. As each design area achieves proper M design quality, the maintenance tasks will be documented. This will show repair policy for each item, predicted frequency, and predicted task time. Figure 2.3-1, MARMA (Maintenance and Repair Method Analysis) Prediction Data Flow shows this process. The initial predictions are available at PDR. The process is iterative and the MARMA data used for system predictions are improved and verified by later data as available. The MARMA data update process is summarized in the annotated Figure 2.3-2, MARMA Detail Task Prediction Process. This shows the operations which provide the opportunities to observe and collect the required partial task time data.



(MARMA DATA DEVELOPED BY ANALYSIS AND IMPROVED BY SELECTIVE TESTS)

Figure 2.3-1 MARMA Prediction Data Flow



PREDICTION OF TASKS AND TIMES ARE DEVELOPED BY M ENGINEERING ANALYSIS AND UPDATED BY MAINTENANCE ANALYSIS OF DETAIL DESIGN. PARTIAL TASK TIME DATA ARE COLLECTED BY OBSERVATION. SOURCES CODED TO PARTIAL TASK ELEMENTS INCLUDE: IATU, PTV, AND FTA TESTING (A), TEST ON DEVELOPMENT FIXTURE (T) AND VERIFIED ON FTA, IATU, AND PTV BY COLLECTING DATA FROM ACTUAL EXPERIENCED MAINTENANCE (D) OR DURING VERIFICATION OF MAINTENANCE TECHNICAL DATA (M)

Figure 2.3-2 MARMA Detail Task Prediction Process

The key to the MDAC maintainability test program is use of maximum routinely available data to verify the predictions made in analyses and thus minimize costs of tests. The analysis identifies all repairable/replaceable items and risk or frequency of occurrence. The collected data on a number of tasks or task elements verify the accuracy of these individual predictions and demonstrate the actual access and replaceability of components when drawing analysis and visual study are inconclusive. Thus, the integrated avionics test unit (IATU) together with the development fixture (DF),flight test article (FTA), and propulsion test vehicle (PTV) will provide early opportunities to determine actual functional test and fault isolation times. These elements of the total repair time are combined with untested tasks (i.e., replace-time predictions) to update the repair-time prediction. The verification data are collected and analyzed by M engineers without introducing mechanic work tasks.

The tests on the development fixture will determine critical access problems early enough to incorporate required changes in the design prior to critical design review. These tasks will be conducted by mechanic personnel to verify access with some indication of remove/replace task time. The actual operations of acceptance test, checkout, and repair of failures for IATU, FTA, PTV, and production flight articles will provide an update of frequency and maintenance time. These data and those available from maintenance procedure verification on FTA , development fixture, or PTV will be collected by observation and analysis of actual operations rather than by scheduled M demonstrations.

The measure of M actual performance is provided by the system predictions utilizing approved models and detail task time data verified by and updated to incorporate the observed data from system tests and operations. The predictions will reflect maintenance tasks conducted according to formal procedures and the best prediction of frequency. The M predictions will identify critical tasks to achieve system operational status, down times for unscheduled maintenance during Tug turnaround, and recommended spares levels for each critical subsystem item for field station stocks. These data are integrated with the logistics studies of scheduled maintenance, servicing, and pipeline handling of repairables to form the total viable maintenance and refurbishment plan.

2.3.1.3 Propulsion Test Vehicle

The Propulsion Test Vehicle is not truly a vehicle, i.e., a Space Tug. The testing is concerned with the development and functional qualification of the main engine support assembly and associated interfaces only. The components which comprise the assembly either will have been developed and qualified on previous programs or will be developed and qualified on this program.

Leak checks using gaseous helium will be accomplished within each of the component areas, i.e., propellant feed, vent, fill and drain, pressurization, and pneumatics. Correct electronic functioning of the appropriate components will be accomplished, i.e., propellant utilization, propellant orientation, feed line thermal conditioning, thrust vector control (mechanical actuation also), and correct operation of all valves (electrical, pneumatic, and electro-pneumatic).

Propellants and gases are introduced to the test setup, chilldown procedures and operations are verified and flowing of propellants is accomplished. Several test runs are made to gain assurance that all components and interfaces are functioning within specified limits. Full duration and shutdown and restart runs are accomplished followed by mission simulations. The Category I RL10 engine is a flight operational engine. The inlet interface requirements are known. With propellants delivered to the interface within these requirements operational reliability of the engine is known. The test objective will be to assure these interface delivery requirements by "cold flowing" the propellants and acquiring the appropriate measurements at the engine inlet interface. This will be done without an engine installed.

The test will be performed in Test Cell (J4) AEDC, Tullahoma, Tennessee. This facility has altitude capability during both firing and hold and sufficient propellant and gas storage capability.

Ground support equipment and software requirements are identified in the PTV GSE Description Sheets, Table 2.3-1.

Maintainability Evaluation - PTV

The maintainability program to be conducted on the propulsion test vehicle is described in the description of the maintainability program for the engineering development test fixture, 2.3.1.2.

Table 2.3-1

PTV DESCRIPTION SHEET

WBS 32A-07-01

NAME: TUG TEST CELL HOLDING FIXTURE EQUIPMENT NO. 309

FUNCTIONAL REQUIREMENT(S):

Holding fixture to mount Tug in the J4 test cell at AEDC.

EQUIPMENT DESCRIPTION:

Tubular steel holding fixture that adapt to Tug and test cell.

COST PER UNIT: $ 8,750 (NON-RECURRING)

$ 6,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW _____ MODIFIED _____ AS IS _____

1ST YEAR REQ'D _____ NUMBER AVAILABLE _____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED

TOTAL REQUIRED _____ TOTAL COST $ 14,750

Table 2.3-1 (Cont.)

PTV GSE DESCRIPTION SHEET

WBS 32A-07-01

NAME: AEDC INTERFACE JUNCTION BOX EQUIPMENT NO. 310

FUNCTIONAL REQUIREMENT(S):

Instrumentation junction box required to interface with J4 test cell at AEDC.

EQUIPMENT DESCRIPTION:

Junction box with 500 twisted shielded wire and 60 connectors.

COST PER UNIT: $ 12,500 (NON-RECURRING)

$ 16,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW _____ MODIFIED _____ AS IS _____

1ST YEAR REQ'D _____ NUMBER AVAILABLE _____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED

TOTAL REQUIRED _____ TOTAL COST $ 28,500

Table 2.3-1 (Cont.)

PTV GSE DESCRIPTION SHEET

WBS 32A-07-01

NAME: TEST SOFTWARE COMPUTER PROGRAMS EQUIPMENT NO. 311

FUNCTIONAL REQUIREMENT(S):

Test software to control the propulsion test vehicle testing in J4 test cell at AEDC.

EQUIPMENT DESCRIPTION:

Magnetic tape or disk, listing, and test procedure. (See attachment.)

COST PER UNIT: $ 20,760 (NON-RECURRING)

$ -0- (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW X MODIFIED _____ AS IS _____

1ST YEAR REQ'D _____ NUMBER AVAILABLE _____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	AEDC J4 Test Cell	1

TOTAL REQUIRED _____ TOTAL COST $ 20,760

Table 2.3-1 (Cont.)

TEST SOFTWARE REQUIREMENTS (AEDC) J4 TEST CELL

A. Define instrumentation requirements

1. Assign data channels and speeds for analog data.
2. Assign discrete channels.
3. Determine data recording requirements (tape recording, strip chart, and real time reduction via Raytheon 520 and IBM 360/50 computers).
4. Determine console real time data display requirements.
5. Determine checkout computer (IBM 360/44 data input requirements for real time test control and monitoring).

B. Define control parameters

1. Assign control functions for manual control panels in J4 test cell.
2. Assign checkout computer control functions (relay closures and logic level).

C. Define calbiration data

1. Determine calibration for facility instrumentation (use trend data from other test programs).
2. Determine calibration for the test peculiar parameters.

It is assumed that AEDC J4 test cell provides channel assignments list, calibration data, signal routing requirements from existing support software programs. MDAC will have to provide inputs to these programs through Interface Control Documents (ICD).

COLD FLOW TEST

Develop a checkout/control program to perform the Cold Flow Test. This program to be executed on the IBM 360/44 computer will provide the following:

a. Automatically accomplish facility monitoring and control.
b. Initiate, monitor, and terminate cold flow per the design parameters.
c. Secure test article and facility.
d. Provide the emergency shutdown sequences.

This program is sized at 12,000 words which include limited real time documentation via a line printer.

2.3.1.4 Integrated Avionics Test Unit

This test develops and verifies the electronics operations of the Space Tug. It is the first assembly of all avionics equipment from all the subsystems. Electrical and electromagnetic compatibility are developed and verified to be within specification. Line lengths are identical to Tug installed lengths to insure against impedance mismatch. Compatible integration with the GSE is assured and checkout and mission software is developed. Integration and compatibility with each of the major interfaces (spacecraft and orbiter) are verified through the use of Interface Verification Units (IVU) supplied by the appropriate associate contractors. Operation of the telemetry system is developed and verified including interfaces with the control transducers. Verification of redundancy management is accomplished and fault isolation methods are developed.

Maintainability Evaluation - IATU

The maintainability program to be conducted on the Integrated Avionics Test Unit is described in the description of the maintainability program for the engineering development fixture, 2.3.1.2.

2.3.1.5 Flight Control Simulation

This test is associated with the Integrated Avionics Test Unit (IATU). At MDAC, Huntington Beach, the selected facility is the On-Line Subsystem Facility (OLSF) and is co-located with the IATU. By providing the appropriate simulations (computer, optical, etc.), navigation and guidance command capability is verified. Communication is maintained with the IATU affording integration and compatibility verification with the remainder of the Avionics subsystem.

2.3.1.6 Flight Support Equipment (FSE)

This equipment will be tested in two modes to allow for capability buildup. The test conditions will be similar but will be applied first without the use of the interface verification unit (IVU) then with the IVU installed.

Without the IVU

This test is conducted in a Mechanical Test Laboratory. The objective is to develop the subsystem and verify that the equipment will accomplish the egress-ingress maneuver satisfactorily subsequent to exposure to Orbiter flight induced environments. The interfacing equipment will be stressed simulating acceleration,

vibration, bending, and torsion loads associated with ascent flight. When these loads have been terminated, the interface panels will be commanded to separate followed by the command for Tug release and tilt table actuation. The reverse process will then be accomplished with loads associated with descent flight and landing being imposed upon the equipment. This procedure will be repeated through a sufficient number of cycles to assure that the system is operable within the given conditions.

With the IVU

The IVU will be so constructed as to be able to simulate Tug/Spacecraft configurations of various c.g.'s and MOI's. The conditions of the former test will be repeated through a sufficient number of cycles and Tug/Spacecraft configurations, accompanied with appropriate scheduled and unscheduled maintenance, and removals and replacements, to qualify the system to its specification requirements of performance and reuse.

In both tests, i.e., "with" and "without the IVU", special test equipment will be employed to effect zero-g mass balancing of the hardware under test since it is designed for zero-g application.

2.3.1.7 Interface Verification Units

IVUs are fabricated from either commercial, substitute, or the actual designed and produced flight-weight Tug hardware. The one non-waiverable requirement being that the unit operate and/or respond exactly as the Tug would at the interface under test. The amount of hardware required is dependent upon how much physically and functionally is required upstream from the interface under test. The interfaces being addressed here are those between associate contractor hardware, i.e., Tug/Spacecraft, and Tug/Orbiter.

Tug/Spacecraft -- Deployment Only

These IVUs include capability for accomplishing deployment. They consist of spacecraft attachment/release mechanism.

These units are manufactured by the Tug contractor to his CEI specifications in accordance with ICDs and IFSs placed upon both contracts as a result of agreements

between the two contractors and the customer. They are shipped to the spacecraft contractors for their use in developing, qualifying, and checking out their side of the interface. A like unit is shipped to the Tug contractor for his use in the same activities.

Tug/Orbiter

This unit has the external appearance of a Space Tug. Exterior material causes no impact damage to orbiter or manipulator arms. The IVU includes mass characteristics of flight weight Tug. Interfaces are production hardware, i.e., tilt table connections, fluid-electrical interface panel, manipulator contact points, latches.

This unit is for developing, qualifying, and checking out the interfaces between the Tug and the Orbiter pertinent to the egress/ingress maneuver. Since the development of these interfaces are as important to the Orbiter contractor as to the Tug contractor, the manufacturing and testing costs of the unit may be shared. In this regard, and due to its estimated cost ($50,000), only one unit will probably be constructed between the two contractors. Either an Orbiter mockup or an operational Orbiter may be used for the test. Gravity compensation will be required in the test setup. The objective is to assure operational integrity of all interfaces, i.e., latches, disconnects, tilt, maneuvering arms grip/degrip, egress maneuver, ingress maneuver, etc. Importance of the test is emphasized by the facts that when the maneuver is performed with a live Tug, both the Tug and the Orbiter are fueled; the Orbiter is manned; if the Tug can't be recovered, this expensive vehicle must be left on-orbit; and, if the first time the maneuver is performed is deferred to the first live Tug flight only to find a fault, particularly part way through the maneuver, the Orbiter cannot accomplish atmospheric reentry aerodynamically unclean.

2.3.1.8 Electromagnetic Compatibility -- Manufacturing Site

An EMC integrated subsystems test (IST) will be performed on the first flight vehicle. The EMC IST will fulfill the requirements of MIL-E-6051C for an Electrical-Electronic Compatibility (EEC) test.

The EEC test will:

1. Verify a 6 db safety margin on all signal and control lines determined mission-critical.
2. Verify a 6 db safety margin on circuits which analysis indicates may be potential problems.
3. Verify operation within design tolerances of all subsystems when operated as a system.
4. Verify transient levels on dc power buses at the input to selected transistorized equipment do not exceed ±50 percent of nominal bus voltage.
5. Record Tug power buses to determine amplitudes of any extraneous voltages.
6. Satisfy the receiver antenna conducted interference test requirements of MIL-E-6051C for Tug on-board equipment.

The EEC test will follow post manufacturing acceptance for test of the vehicle. Tug test data obtained from the special EMC test instrumentation will be evaluated with the entire system performance data (telemetry, stripchart recordings, digital events recorder, etc.) to determine that systems are within their design and performance tolerances and that MIL-E-6051C required margin of safety is provided.

2.3.1.9 Transportation and Handling Verification

Transportation and handling procedures are developed after the definition of requirements through transportability and transportation analyses. The verification of these procedures affords an early opportunity to determine the validity of these procedures for all phases of Space Tug movement required at the assembly, test, and launch sites. The test objectives include, as a minimum, the following:

- Load/unload Tug on transporter
- Load/unload Tug on Guppy type aircraft
- Transfer from one transportation vehicle to another
- Identify, through monitoring and recording instrumentation, ground and in-transit loads and stresses.

This is first conducted as a contractor DT&E function and subsequently by the customer as an OT&E effort.

2.3.1.10 Electromagnetic Compatibility -- Launch Sites

These tests are not a complete repeat of the manufacturing site EMC test. The objective here is to verify the on-site procedures and radiated systems (vehicle/other vehicles/site) compatibility during open loop operation.

2.3.1.11 Refurbishment/Reuse Verification -- Launch Site

Launch site maintenance procedures evolve from those verified on the engineering development fixture. They are developed and verified by performing the initial appropriate ground operations on the first flight article. Subsequent to this DT&E verification, the procedures are then evaluated by customer personnel performing selected maintenance tasks on the flight test article effecting an OT&E verification. These tests demonstrate the Tug's maintainability characteristics and demonstrate that the required maintenance/refurbishment tasks can be satisfactorily performed by customer personnel using the contractor developed procedures. Furthermore, these tasks must be performed within the maintenance down times and resources allocated for these tasks.

Launch site transportation and handling procedures will be verified in both DT&E and OT&E through use of the flight test article. The validity of these procedures will be determined for all launch site movement of the Space Tug, not previously verified and will include, as a minimum, the following:

- Mate/demate with simulated/dummy spacecraft
- Mate/demate with flight support equipment.
- Load/unload Tug in Space Shuttle Orbiter.

2.3.1.12 Maintainability Evaluation -- Flight Test Article, Launch Sites

The maintainability program to be conducted on the Flight Test Article is described in the description of the maintainability program for the engineering development fixture, 2.3.1.2.

2.3.2 Test Operations Manloading Estimations

Manloading estimations employed the following steps:

a. Determine the major elements required to conduct the specific test.

b. Schedule these elements relative to each other.

c. Determine the quantities and types of key direct personnel required to accomplish each element.

d. Complete the arithmetics.

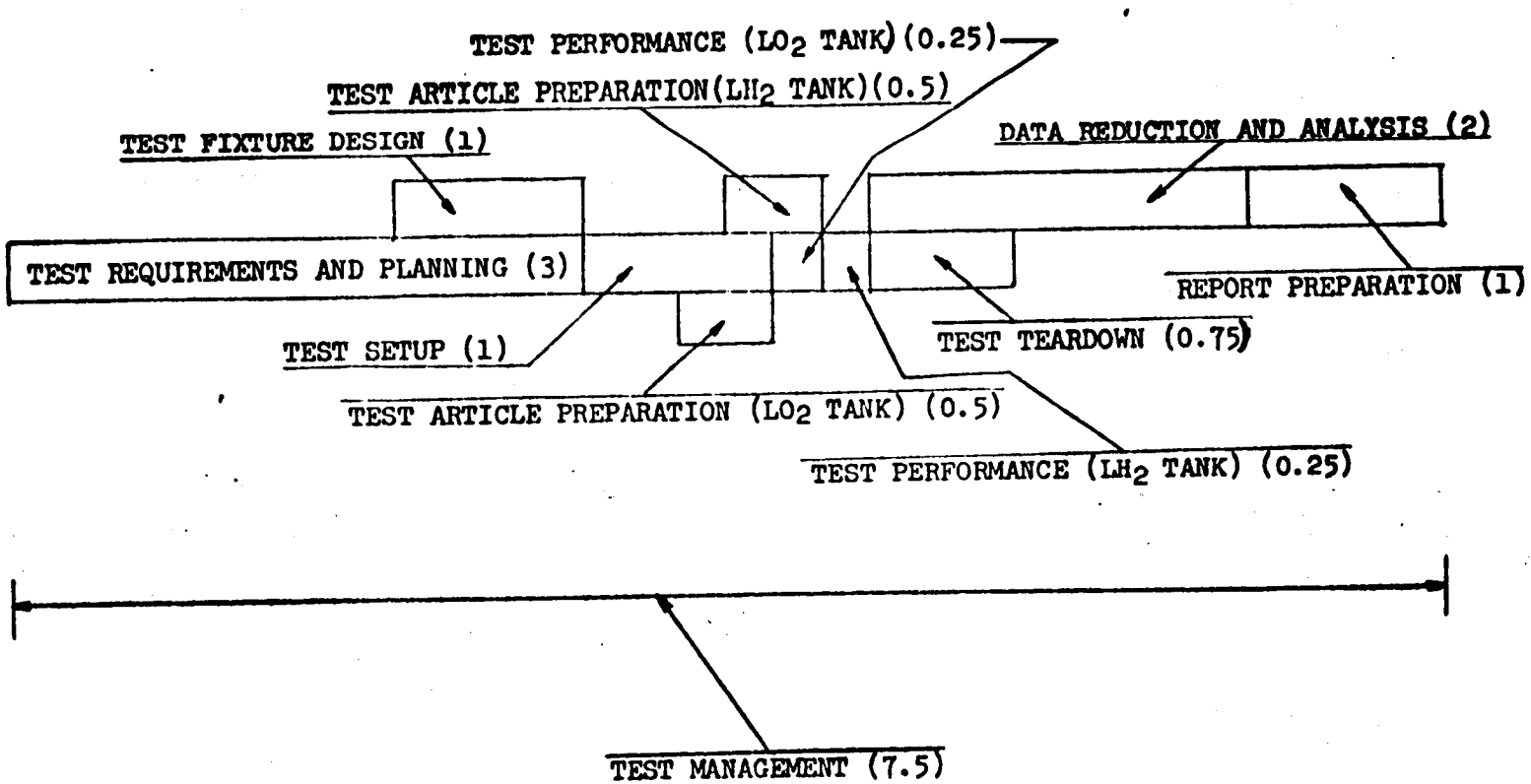
Schedules and respective personnel estimates are presented on the following pages for each of the tests within WBS element 32A-08-01.

STRUCTURAL TEST ARTICLE

PROPELLANT TANKS PRESSURE CYCLING DEVELOPMENT TEST

SCHEDULE

(MONTHS)



STRUCTURAL TEST ARTICLE

PROPELLANT TANKS PRESSURE CYCLE DEVELOPMENT TESTS

Personnel	Months	Man-Months	Type Personnel	Cumulative Personnel
Test Management 1 Manager	7.5	7.5	1 Engineer	1 Engineer
Test Requirements and Planning 1 Analyst 2 Test Engineers	3	9	3 Engineers	4 Engineers
Test Article Preparation 2 Test Engineers 1 Instrumentation Technician 1 Structural Test Technician 1 Q.C.	1	5	2 Engineers 2 Technicians 1 Q.C.	4 Engineers 2 Technicians 1 Q.C.
Test Fixture Design 2 Engineers	1	2	2 Engineers	6 Engineers
Test Setup 2 Test Engineers 2 Instrumentation Technicians 4 Structural Test Technicians 1 Q.C.	1	9	2 Engineers 6 Technicians 1 Q.C.	6 Engineers 6 Technicians 1 Q.C.
Test Performance 2 Test Engineers 3 Structural Test Technicians 2 Q.C.	0.5	3.5	2 Engineers 3 Technicians 2 Q.C.	6 Engineers 6 Technicians 2 Q.C.
Tear Down 2 Instrumentation Technicians 2 Structural Test Technicians 1 Q.C.	0.75	3.75	4 Technicians 1 Q.C.	6 Engineers 6 Technicians 2 Q.C.

STRUCTURAL TEST ARTICLE (Cont'd)

TANKS CYCLE DEV

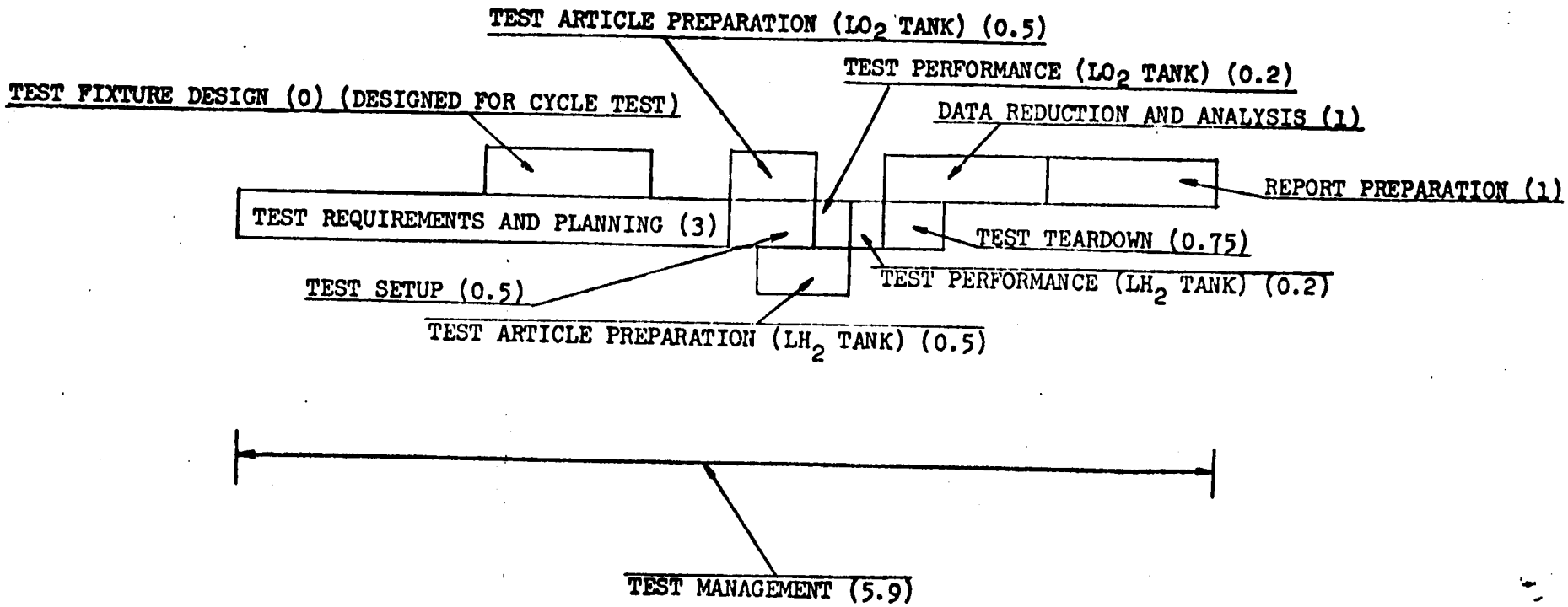
Personnel	Months	Man-Months	Type Personnel	Cumulative Personnel
Data Reduction and Analysis 1 Analyst 2 Engineers	2	6	3 Engineers	6 Engineers 6 Technicians 2 Q.C.
Report Preparation 2 Engineers	1	2	2 Engineers	6 Engineers 6 Technicians 2 Q.C.
TOTAL MAN-MONTHS:		47.75		

STRUCTURAL TEST ARTICLE

PROPELLANT TANKS PRESSURE BURST DEVELOPMENT TEST

SCHEDULE

(MONTHS)



STRUCTURAL TEST ARTICLE

PROPELLANT TANKS PRESSURE BURST DEVELOPMENT TESTS

Personnel	Months	Man-Months	Type Personnel	Cumulative Personnel
Test Management 1 Manager	5.9	5.9	1 Engineer	1 Engineer
Test Requirements and Planning 1 Analyst 2 Test Engineers	3 0(NASA)	9 0(NASA)	3 Engineers 0 (NASA - in Dev Cycle Plng)	4 Engineers 1 (NASA)
Test Article Preparation 2 Test Engineers 1 Instrumentation Technician 1 Structural Test Technician 1 Q.C.	1	5	2 Engineers 2 Technicians 1 Q.C.	4 Engineers (3 NASA) 2 Technicians 1 Q.C.
Test Fixture Design 2 Engineers	0	0	0 (Designed for Cycle Test)	4 Engineers (3 NASA) 2 Technicians 1 Q.C.
Test Setup 2 Test Engineers 2 Instrumentation Technicians 4 Structural Test Technicians 1 Q.C.	0.5	4.5	2 Engineers 6 Technicians 1 Q.C.	4 Engineers (3 NASA) 5 Technicians 1 Q.C.
Test Performance 2 Test Engineers 3 Structural Test Technicians 2 Q.C.	0.4	2.8	2 Engineers 3 Technicians 2 Q.C.	4 Engineers (3 NASA) 5 Technicians 2 Q.C.
Tear Down 2 Instrumentation Technicians 2 Structural Test Technicians 1 Q.C.	0.75	3.75	4 Technicians 1 Q.C.	4 Engineers (3 NASA) 5 Technicians 2 Q.C.

STRUCTURAL TEST ARTICLE (Cont'd)

TANKS BURST DEV

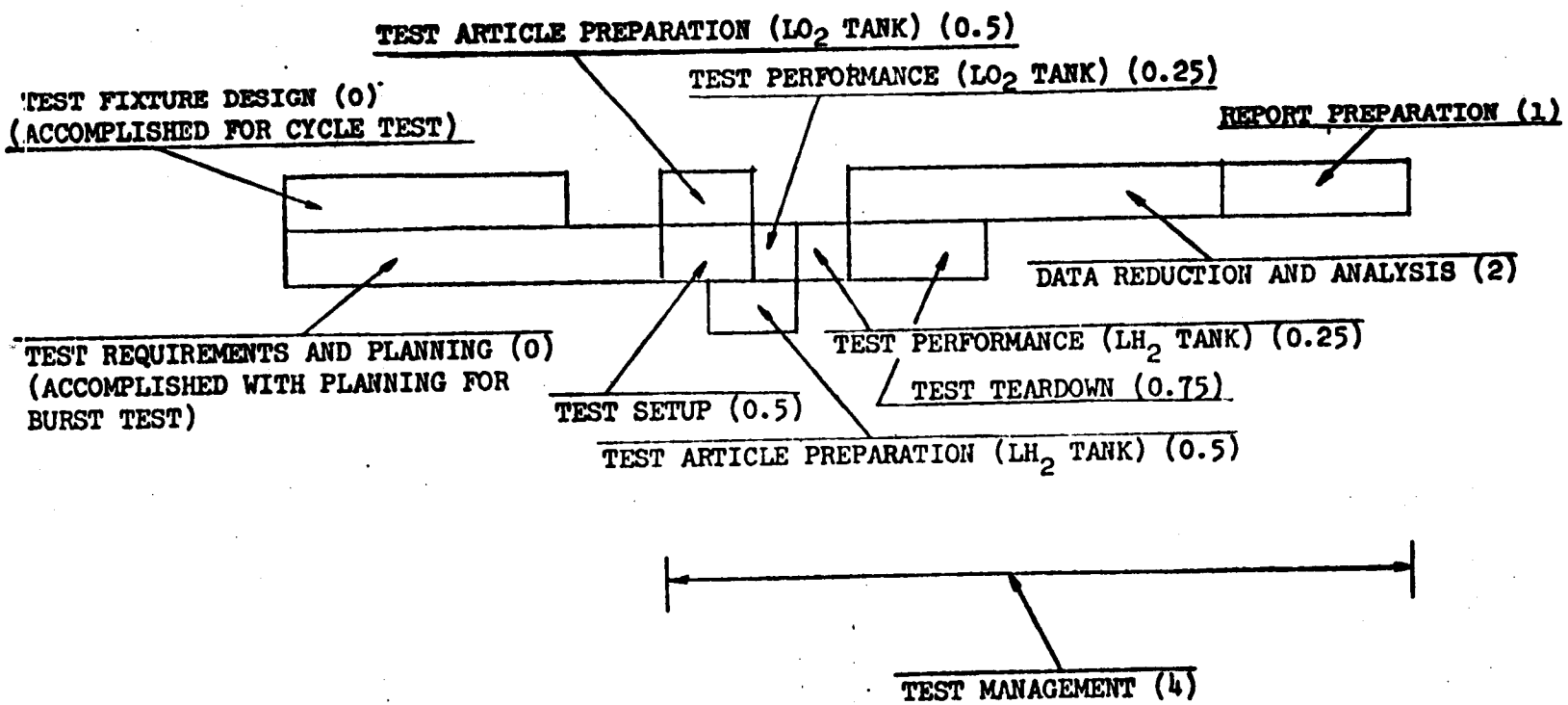
Personnel	Months	Man-Months	Type Personnel	Cumulative Personnel
Data Reduction and Analysis 1 Analyst 2 Engineers	1	3	3 Engineers	4 Engineers 5 Technicians 2 Q.C.
Report Preparation 2 Engineers	1	2	2 Engineers	4 Engineers 5 Technicians 2 Q.C.
TOTAL MAN-MONTHS:		35.95 26.95 (NASA)		

STRUCTURAL TEST ARTICLE

PROPELLANT TANKS PRESSURE CYCLING AND PROOF PRESSURE QUALIFICATION TEST

SCHEDULE

(MONTHS)



STRUCTURAL TEST ARTICLE

PROPELLANT TANKS PRESSURE CYCLE/PROOF QUALIFICATION TESTS

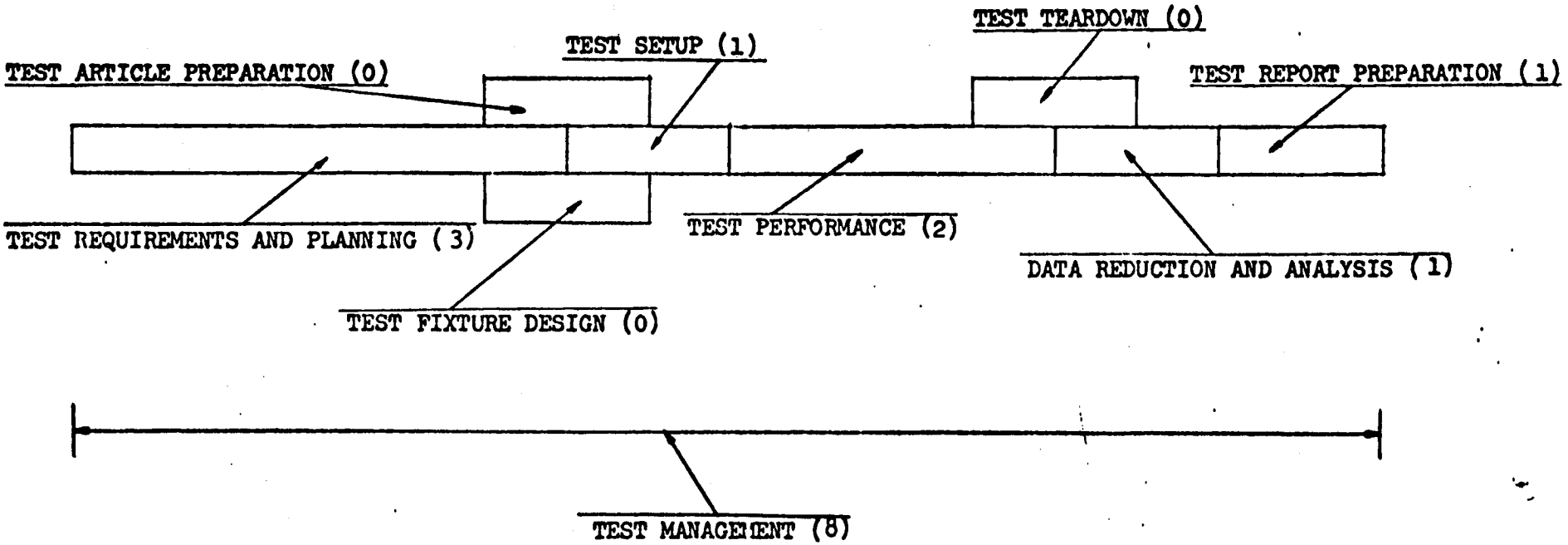
Personnel	Months	Man-Months	Type Personnel	Cumulative Personnel
Test Management 1 Manager	4	4	1 Engineer	1 Engineer
Test Requirements and Planning 1 Analyst 2 Test Engineers	0	0	0 (in Dev or Burst Plng)	1 Engineer
Test Article Preparation 2 Test Engineers 1 Instrumentation Technician 1 Structural Test Technician 1 Q.C.	1	5	2 Engineers 2 Technicians 1 Q.C.	3 Engineers 2 Technicians 1 Q.C.
Test Fixture Design 2 Engineers	0	0	0 (Designed for Cycle Test)	3 Engineers 2 Technicians 1 Q.C.
Test Setup 2 Test Engineers 2 Instrumentation Technicians 4 Structural Test Technicians 1 Q.C.	0.5	4.5	2 Engineers 6 Technicians 1 Q.C.	3 Engineers 5 Technicians 1 Q.C.
Test Performance 2 Test Engineers 3 Structural Test Technicians 2 Q.C.	0.5	3.5	2 Engineers 3 Technicians 2 Q.C.	3 Engineers 5 Technicians 2 Q.C.
Tear Down 2 Instrumentation Technicians 2 Structural Test Technicians 1 Q.C.	0.75	3.75	4 Technicians 1 Q.C.	3 Engineers 5 Technicians 2 Q.C.

STRUCTURAL TEST ARTICLE (Cont'd)

TANKS CYCLE/PROOF QUAL

Personnel	Months	Man-Months	Type Personnel	Cumulative Personnel
Data Reduction and Analysis 1 Analyst 2 Engineers	2	6	3 Engineers	4 Engineers 5 Technicians 2 Q.C.
Report Preparation 2 Engineers	1	2	2 Engineers	4 Engineers 5 Technicians 2 Q.C.
TOTAL MAN-MONTHS:		28.75		

REFURBISHMENT/REUSE VERIFICATION
ENGINEERING DEVELOPMENT FIXTURE
MAINTENANCE (M) PROCEDURES VERIFICATION
(PHASED INITIAL AND DIRECT DEVELOPED)



REFURBISHMENT/REUSE VERIFICATION

ENGINEERING DEVELOPMENT FIXTURE

MAINTENANCE ($\bar{M}$) PROCEDURES VERIFICATION

(PHASED INITIAL AND DIRECT DEVELOPED)

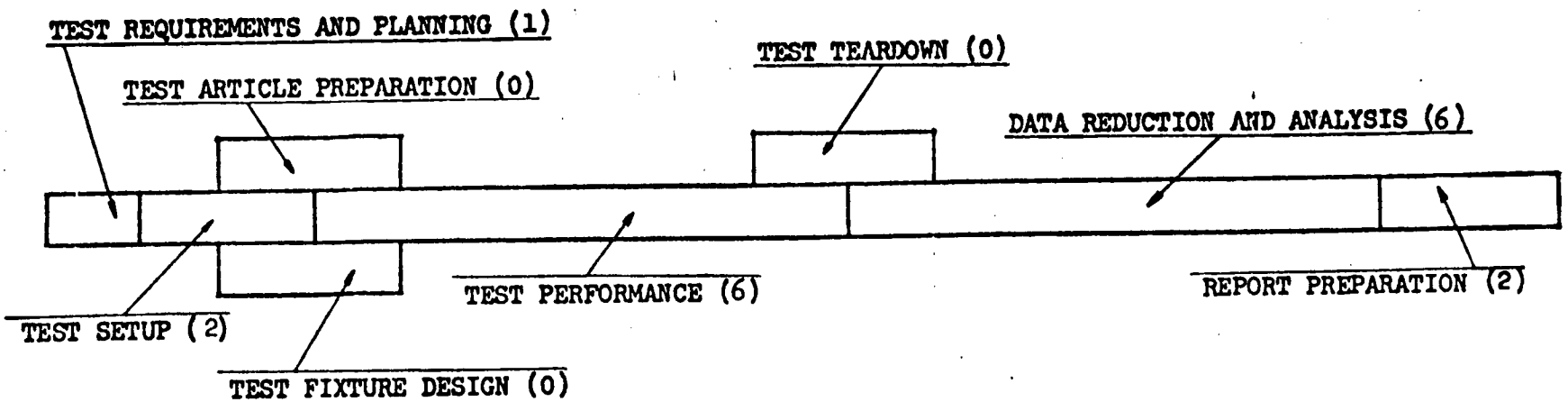
PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management	8	8	1 Engineer	1 Engineer
1 Supervision				
Test Requirements and Planning	3	9	3 Engineers	4 Engineers
1 $\bar{M}$ Engineer - Avionics 1 $\bar{M}$ Engineer - Propulsion 1 $\bar{M}$ Engineer - Struct/Mech				
Test Article Preparation	0	0		
Test Fixture Design	0	0		
Test Setup	1	3	3 Engineers	4 Engineers
1 $\bar{M}$ Engineer - Avionics 1 $\bar{M}$ Engineer - Propulsion 1 $\bar{M}$ Engineer - Struct/Mech				
Test Performance	2	26	4 Engineers 6 Technicians 3 Q.C.	5 Engineers 6 Technicians 3 Q.C.
1 $\bar{M}$ Engineer - Avionics 1 $\bar{M}$ Engineer - Propulsion 1 $\bar{M}$ Engineer - Struct/Mech 2 Technicians - Avionics 2 Technicians - Propulsion 2 Technicians - Struct/Mech 3 Quality Control 1 Safety Engineer				
Tear Down	0	0		
Data Reduction and Analysis	1	3	3 Engineers	5 Engineers 6 Technicians 3 Q.C.
1 $\bar{M}$ Engineer - Avionics 1 $\bar{M}$ Engineer - Propulsion 1 $\bar{M}$ Engineer - Struct/Mech				
Report Preparation	1	3	3 Engineers	5 Engineers 6 Technicians 3 Q.C.
1 $\bar{M}$ Engineer - Avionics 1 $\bar{M}$ Engineer - Propulsion 1 $\bar{M}$ Engineer - Struct/Mech				
TOTAL MAN MONTHS:		52		

REFURBISHMENT/REUSE VERIFICATION

ENGINEERING DEVELOPMENT FIXTURE

MAINTAINABILITY (M) EVALUATION

(PHASED INITIAL AND DIRECT DEVELOPED)



TEST MANAGEMENT (0)

REFURBISHMENT/REUSE VERIFICATION
ENGINEERING DEVELOPMENT FIXTURE
MAINTAINABILITY (M) EVALUATION
(PHASED INITIAL AND DIRECT DEVELOPED)

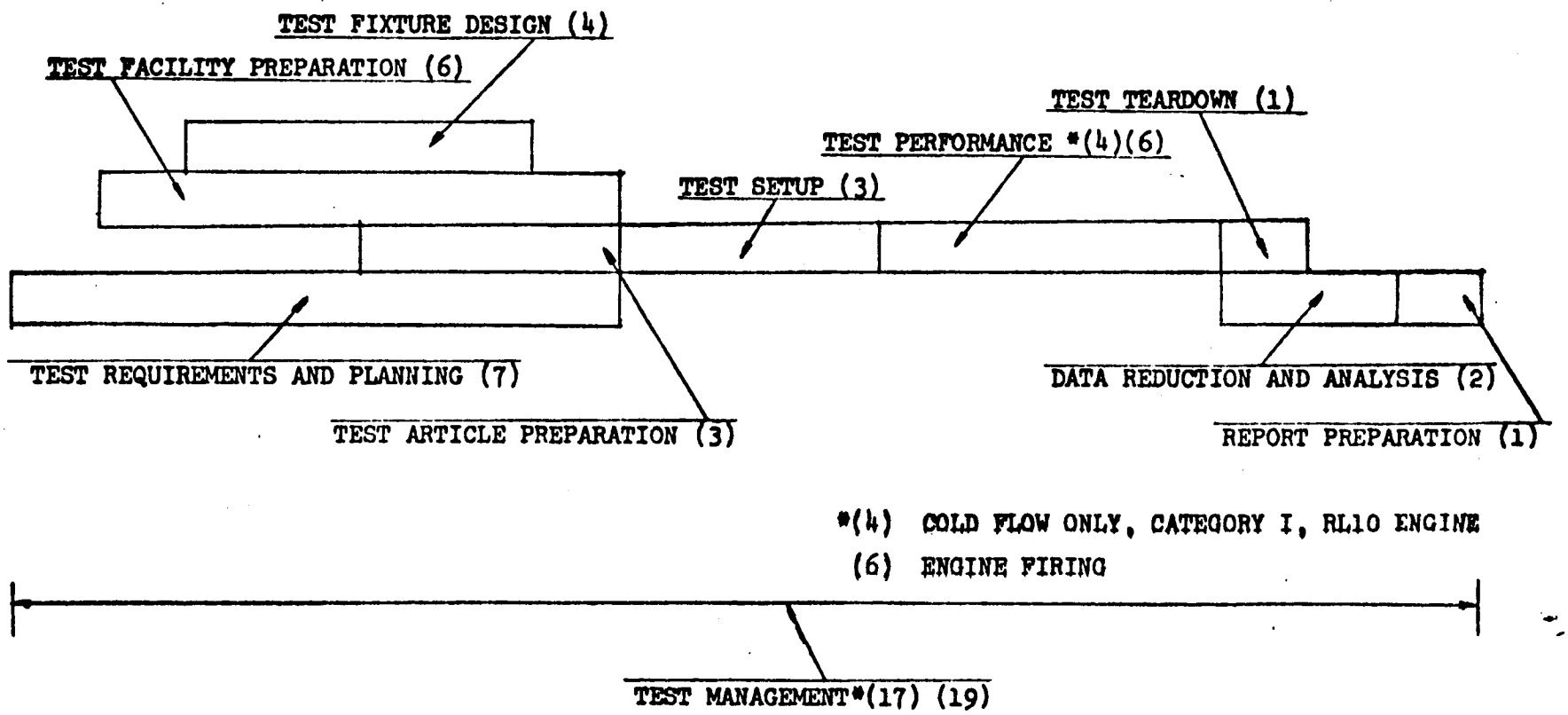
PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management	0	0		
Test Requirements and Planning	1	1	1 Engineer	1 Engineer
1 M Engineer				
Test Article Preparation	0	0		
Test Fixture Design	0	0		
Test Setup	2	1	.5 Engineer	. Engineer
.5 M Engineer				
Test Performance	6	6	1 Engineer	1 Engineer
1 M Engineer				
Tear Down	0	0		
Data Reduction and Analysis	6	2	.33 Engineer	1 Engineer
.33 M Engineer				
Report Preparation	2	1	.5 Engineer	1 Engineer
.5 M Engineer				
TOTAL MAN MONTHS:		11		

PROPULSION TEST VEHICLE

SCHEDULE

(MONTHS)

(PHASED INITIAL AND DIRECT DEVELOPED CONFIGURATIONS)



PROPULSION TEST VEHICLE

(Phased Initial and Direct Developed)

Personnel	Months	Man-Months	Type Personnel	Personnel-Cumulative
Test Management	17	59	3.5 Engineers	3.5 Engineers
1 Manager 0.5 Branch Manager (Propellant Feed) 0.5 Branch Manager (Fill & Drain) 0.5 Branch Manager (Vent & Relief) 0.5 Branch Manager (Pressurization) 0.5 Branch Manager (Pneumatics/TVC)	(19)	(66)		
Test Requirements and Planning	7	42	6 Engineers	9.5 Engineers
5 Propulsion Engineers (Feed, F&D, V&R, Press., Pneum/TVC) 0.5 Propulsion GSE Engr. 0.25 Electrical GSE Engr. 0.25 Instrumentation Engr.				
Test Article Preparation	3	42	4 Engineers 8 Technicians 2 Q.C.	13 Engineers 8 Technicians 2 Q.C.
1 Engineer, 2 Technicians — Feed 1 Engineer, 2 Technicians — F&D 0.5 Engineers, 1 Technician — V&R 1 Engineer, 2 Technicians — Press. 0.5 Engineers, 1 Technician — Pneu/TVC 2 Quality Control (Q.C.)				
Test Fixture Design	4	8	2 Engineers	15 Engineers 8 Technicians 2 Q.C.
2 Engineers				

PROPULSION TEST VEHICLE (CONT'D)

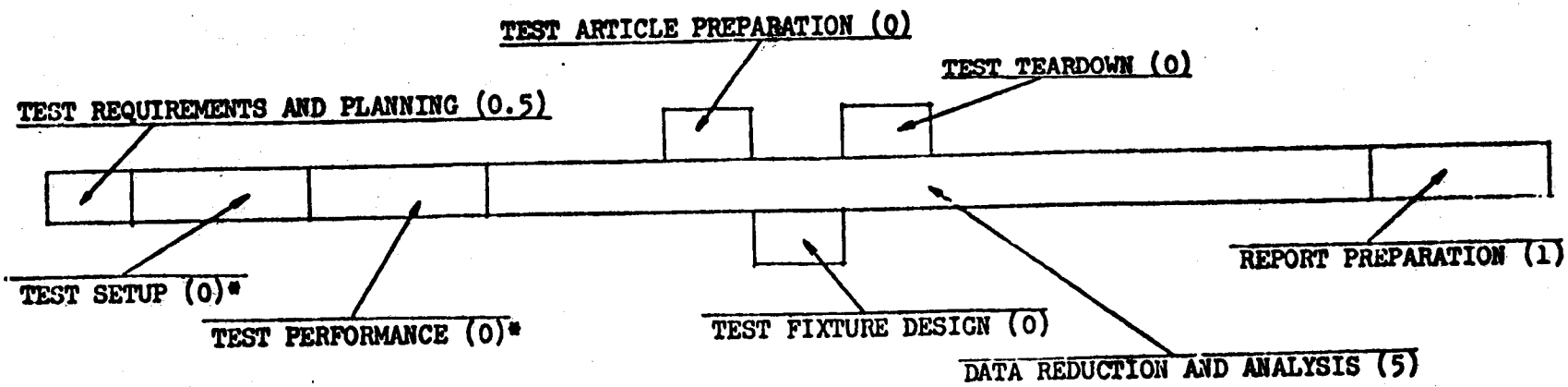
(Phased Initial and Direct Developed)

Personnel	Months	Man-Months	Type Personnel	Personnel-Cumulative
Test Setup 1 Engineer } LH_2 3 Technicians } 1 Engineer } LO_2 3 Technicians } 1 Engineer } Press. 5 Technicians } Pneu/TVC 2 Engineers } GSE 4 Technicians } 3 Q.C.	3	69	5 Engineers 15 Technicians 3 Q.C.	15 Engineers 15 Technicians 4 Q.C.
Test Performance 4 Engineers (See Test Art. Prep.) 3 Engineers-Facility 15 Technicians (See Test Setup) 1 Engineer } Data 1 Technician } Acquisition 3 Q.C.	4 Cold Flow (6) (Firing)	108 (162)	8 Engineers 16 Technicians 3 Q.C.	16 Engineers 16 Technicians 4 Q.C.
Test Teardown 3 Engineers 10 Technicians 1 Q.C.	1	14	3 Engineers 10 Technicians 1 Q.C.	16 Engineers 16 Technicians 4 Q.C.
Data Reduction and Analysis 5 Engineers (Propulsion) 1 Engineer (Data Acquisition) 3 Engineering Aids	2	18	9 Engineers	16 Engineers 16 Technicians 4 Q.C.
Report Preparation 5 Engineers	1	5	5 Engineers	16 Engineers 16 Technicians 4 Q.C.
TOTAL MAN-MONTHS:	Cold Flow (Firing)	367 (428)		

REFURBISHMENT/REUSE VERIFICATION TEST

PROPULSION TEST VEHICLE

MAINTAINABILITY (M) EVALUATION



TEST MANAGEMENT (0)

*MAINTAINABILITY ENGINEER ACTS AS AN OBSERVER ONLY

REFURBISHMENT/REUSE VERIFICATION

PROPULSION TEST VEHICLE

MAINTAINABILITY (M) EVALUATION

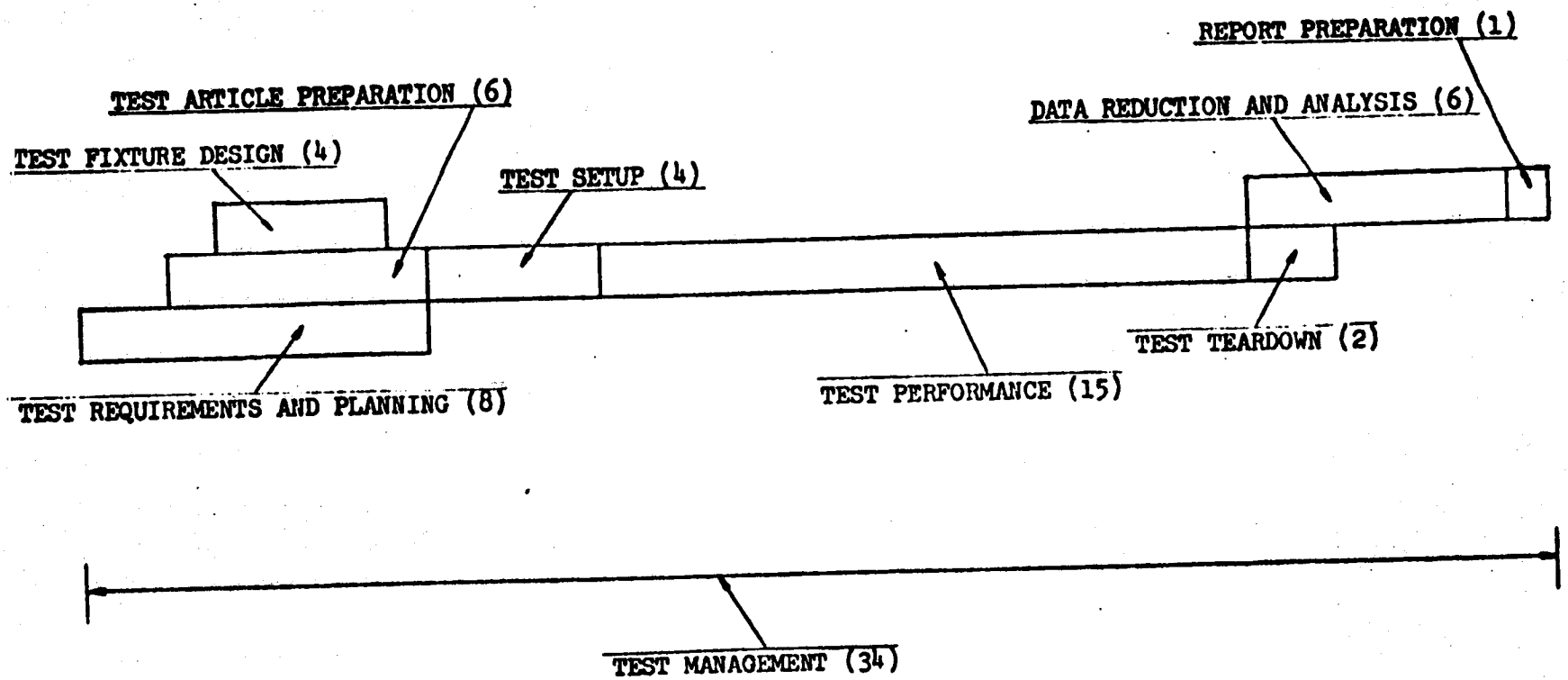
PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management	0	0		
Test Requirements and Planning	.5	.25	.5 Engineer	.5 Engineer
.5 M Engineer				
Test Article Preparation	0	0		
Test Fixture Design	0	0		
Test Setup*	0	0		.5 Engineer
Test Performance*	0	0		.5 Engineer
Tear Down	0	0		
Data Reduction and Analysis	5	1	.2 Engineer	.7 Engineer
.2 M Engineer				
Report Preparation	1	.5	.5 Engineer	1.2 Engineer
.5 M Engineer				
TOTAL MAN MONTHS:		1.75		

*Acts as observer only

INTEGRATED AVIONICS TEST UNIT (IATU)

SCHEDULE

(MONTHS)



INTEGRATED AVIONICS TEST UNIT

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management	34	136	4 Engineers	4 Engineers
1.0 Manager 0.5 Branch Manager (Data Mgmt Assy) 0.5 Branch Manager (Guid.,Nav. & Cont.) 0.5 Branch Manager (Communications) 0.5 Branch Manager (Instrumentation) 0.5 Branch Manager (Pwr & Distribution) 0.5 Branch Manager (GSE)				
Test Requirements and Planning	8	56	7 Engineers	11 Engineers
1 DMA Engineer 1 GN&C Engineer 1 Comm. Engineer 1 Instr. Engineer 1 Pwr & Dist. Engineer 1 GSE Engineer				
Test Article Preparation	6	192	12 Engineers 13 Technicians 7 Q.C.	12 Engineers 13 Technicians 7 Q.C.
2 DMA Engineers 2 GN&C Engineers 3 Comm. Engineers 1 Instr. Engineer 2 Pwr & Dist. Engineer 1 GSE Engineer 1 Propulsion Engineer 12 Electronic Technicians 1 Mechanical Technician 7 Quality Control (Q.C.)				
Test Fixture Design	4	16	4 Engineers	16 Engineers 13 Technicians 7 Q.C.
4 Engineers				
Test Setup	4	84	4 Engineers 15 Technicians 2 Q.C.	16 Engineers 15 Technicians 7 Q.C.
3.5 Elect Engineers 0.5 Prop. Engineers 12 Elect. Technicians 3 Mech. Technicians 2 Q.C.				

INTEGRATED AVIONICS TEST UNIT
(Continued)

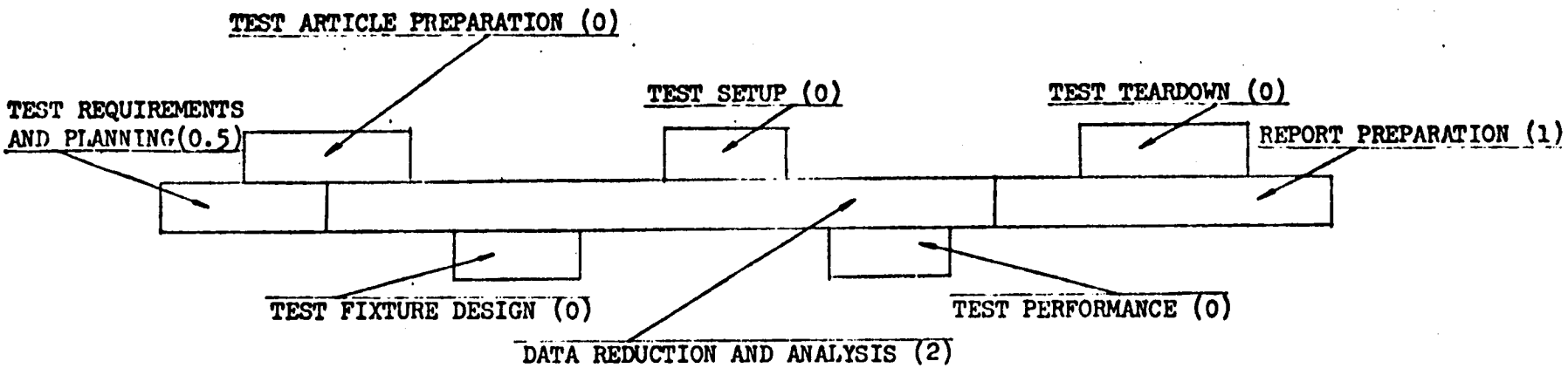
PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Performance 7 Elect. Engineers 9 Elect. Technicians 1 Mech. Technician 2 Q.C.	15	285	7 Engineers 10 Technicians 2 Q.C.	16 Engineers 15 Technicians 7 Q.C.
Test Teardown 1.25 Elect Engineers 0.75 Prop. Engineers 6 Elect. Technicians 1 Mech. Technician 1 Q.C.	2	20	2 Engineers 7 Technicians 1 Q.C.	16 Engineers 15 Technicians 7 Q.C.
Data Reduction and Analysis 11 Elect. Engineers (See Test Art. Prep.) 4 Engrg. Assts.	6	90	15 Engineers	16 Engineers 15 Technicians 7 Q.C.
Report Preparation 7 Engineers (See Test Rqmts & Plng)	1	7	7 Engineers	16 Engineers 15 Technicians 7 Q.C.
TOTAL MANMONTHS:		886		

REFURBISHMENT/REUSE VERIFICATION

INTEGRATED AVIONICS TEST UNIT

MAINTAINABILITY (M) EVALUATION

(PHASED INITIAL AND DIRECT DEVELOPED)



TEST MANAGEMENT (0)

REFURBISHMENT/REUSE VERIFICATION

INTEGRATED AVIONICS TEST UNIT

MAINTAINABILITY (M) EVALUATION

(PHASED INITIAL AND DIRECT DEVELOPED)

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management	0	0		
Test Requirements and Planning	1	.5	.5 Engineer	.5 Engineer
.5 M Engineer				
Test Article Preparation	0	0		
Test Fixture Design	0	0		
Test Setup*	0	0		.5 Engineer
Test Performance*	0	0		.5 Engineer
Tear Down	0	0		
Data Reduction and Analysis	10	2	.2 Engineer	.7 Engineer
.2 M Engineer				
Report Preparation	2	1	.5 Engineer	1.2 Engineers
.5 M Engineer				

TOTAL MAN MONTHS: 3.5

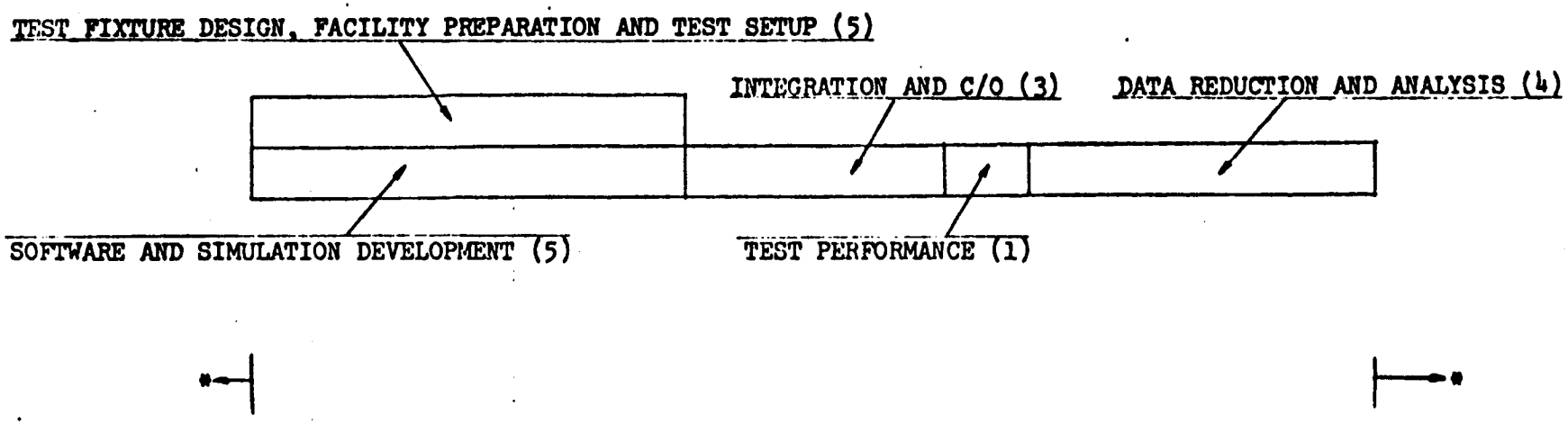
*Acts as observer only

FLIGHT CONTROL SIMULATION

SCHEDULE

(MONTHS)

(DEPLOYMENT CAPABILITY ONLY)



*TEST MANAGEMENT IS ASSOCIATED WITH THE IATU

FLIGHT CONTROL SIMULATION
(DEPLOYMENT CAPABILITY ONLY)

PERSONNEL		MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management (in IATU)					
Test Requirements and Planning (in IATU)					
Test Article Preparation (in IATU)					
Test Fixture Design/ Facility Preparation/ Test Setup 2 Engineers 1.5 Technicians		5	17.5	2 Engineers 1.5 Technicians	2 Engineers 1.5 Technicians
Test Performance					
Software & Simulation Dev	1.5 Engr	5	7.5	1.5 Engineers	4 Engineers 3 Technicians
Integ. & C/O	3.5 Engr 1.5 Tech	3	15.0	3.5 Engineers 1.5 Technicians	
Test	4 Engr 3 Tech	1	7.0	4 Engineers 3 Technicians	
			29.5		
Test Teardown (in Test Performance)					
Data Reduction and Analysis 2 Engineers		4	8.0	2 Engineers	4 Engineers 3 Technicians
Report Preparation (in IATU)					
	TOTAL MANHOURS:		55.0		

TUG/ORBITER FLIGHT SUPPORT EQUIPMENT (FSE)

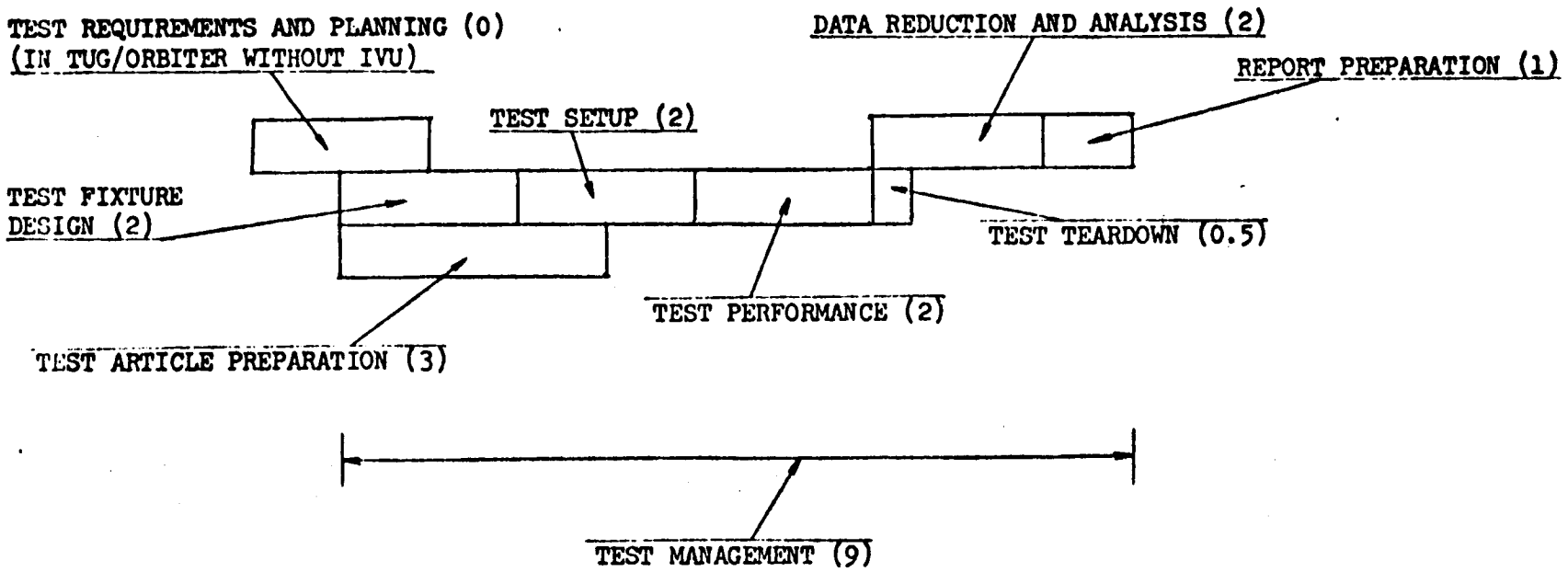
TEST OPERATIONS

SCHEDULE

(MONTHS)

(WITH THE INTERFACE VERIFICATION UNIT [IVU])

(WITH THE IVU AND AN ORBITER)



FLIGHT SUPPORT EQUIPMENT TEST OPERATIONS
(WITH THE IVU)

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management 1 Manager	9	9	1 Engineer	1 Engineer
Test Requirements and Planning (in FSE w/o IVU)	0	0	(in FSE w/o IVU)	1 Engineer
Test Article Preparation 1 Interface Engr 1 Instrumentation Engr 1 Mechanical Engr 1 Mass Properties Engr 0.5 Structural Engr 2.5 Technicians 1 Q.C.	3	24	4.5 Engineers 2.5 Technicians 1 Q.C.	5.5 Engineers 2.5 Technicians 1 Q.C.
Test Fixture Design 2 Engineers	2	4	2 Engineers	7.5 Engineers 2.5 Technicians 1 Q.C.
Test Setup 0.5 Interface Engr 0.5 Instrumentation Engr 1 Mechanical Engr 2 Technicians 1 Q.C.	2	10	2 Engineers 2 Technicians 1 Q.C.	7.5 Engineers 2.5 Technicians 1 Q.C.
Test Performance 1 Interface Engr 0.5 Instrumentation Engr 0.5 Mechanical Engr 0.5 Mass Properties Engr 0.5 Structural Engr 2 Technicians 2 Q.C.	2	14	3 Engineers 2 Technicians 2 Q.C.	7.5 Engineers 2.5 Technicians 2 Q.C.
Test Teardown 1 Interface Engr 0.5 Instrumentation Engr 2.5 Technicians 0.5 Mechanical Engr 0.5 Structural Engr 1 Q.C.	0.5	3	2.5 Engineers 2.5 Technicians 1 Q.C.	7.5 Engineers 2.5 Technicians 1 Q.C.

FLIGHT SUPPORT EQUIPMENT TEST OPERATIONS

(WITH THE IVU)

(CONT.)

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Data Reduction and Analysis 1 Interface Engr 1 Mechanical Engr 0.5 Data Engr 0.5 Data Tech 1 Mass Properties Engr	2	8	3.5 Engineers 0.5 Technicians	8 Engineers 3 Technicians 1 Q.C.
Report Preparation 1 Interface Engr 1 Mechanical Engr 1 Mass Properties Engr 1 Instrumentation Engr 1 Structural Engr	1	5	5 Engineers	8 Engineers 3 Technicians 1 Q.C.
TOTAL MAN MONTHS:		77		

FLIGHT SUPPORT EQUIPMENT TEST OPERATIONS
(WITH THE IVU AND AN ORBITER)

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management 1 Manager	9	9	1 Engineer	1 Engineer
Test Requirements and Planning (in FSE w/o IVU)	0	0	(in FSE w/o IVU)	1 Engineer
Test Article Preparation 1 Interface Engr 1 Instrumentation Engr 1 Mechanical Engr 1 Mass Properties Engr 0.5 Structural Engr 2.5 Technicians 1 Q.C.	3	24	4.5 Engineers 2.5 Technicians 1 Q.C.	5.5 Engineers 2.5 Technicians 1 Q.C.
Test Fixture Design 2 Engineers	2	4	2 Engineers	7.5 Engineers 2.5 Technicians 1 Q.C.
Test Setup 0.5 Interface Engr 0.5 Instrumentation Engr 1 Mechanical Engr 2 Technicians 1 Q.C.	2	10	2 Engineers 2 Technicians 1 Q.C.	7.5 Engineers 2.5 Technicians 1 Q.C.
Test Performance 1 Interface Engr 0.5 Instrumentation Engr 0.5 Mechanical Engr 0.5 Mass Properties Engr 0.5 Structural Engr 2 Technicians 2 Q.C.	2	14	3 Engineers 2 Technicians 2 Q.C.	7.5 Engineers 2.5 Technicians 2 Q.C.
Test Teardown 1 Interface Engr 0.5 Instrumentation Engr 2.5 Technicians 0.5 Mechanical Engr 0.5 Structural Engr 1 Q.C.	0.5	3	2.5 Engineers 2.5 Technicians 1 Q.C.	7.5 Engineers 2.5 Technicians 1 Q.C.

FLIGHT SUPPORT EQUIPMENT TEST OPERATIONS
(WITH THE IVU AND AN ORBITER)
(CONT.)

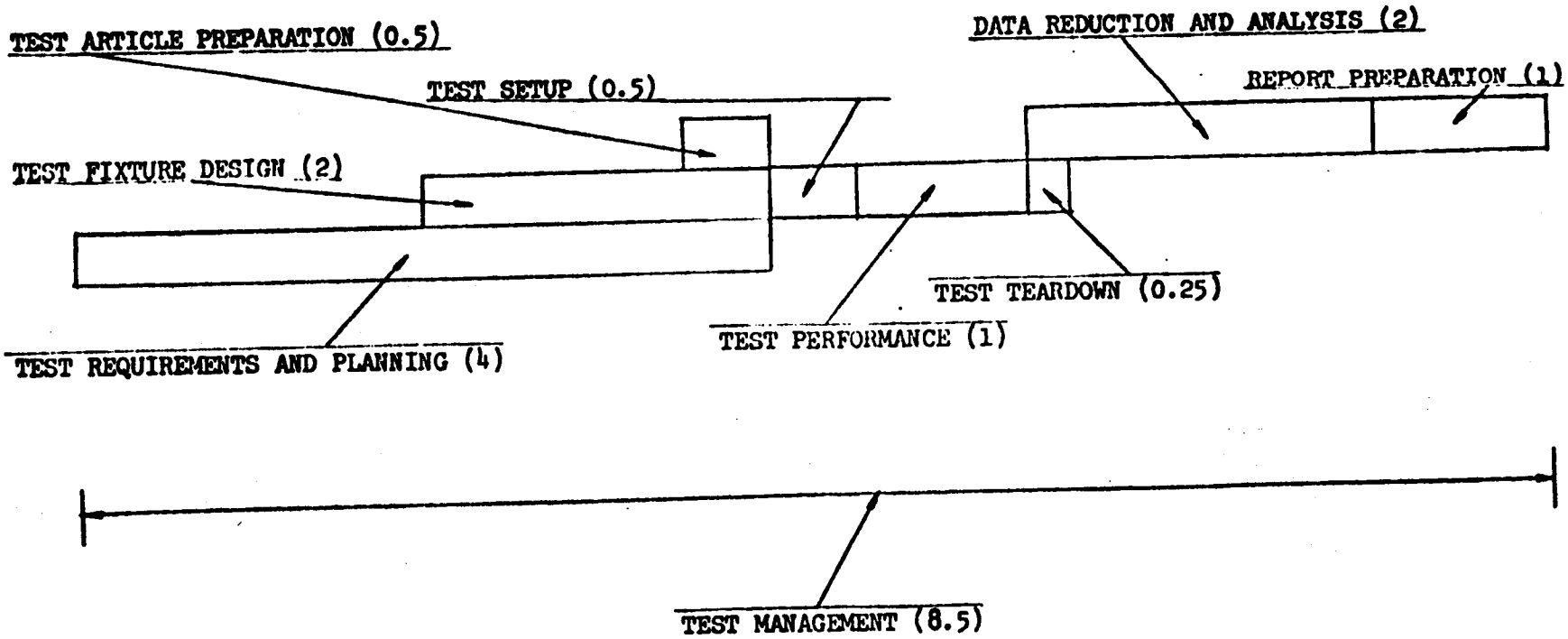
PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Data Reduction and Analysis 1 Interface Engr 1 Mechanical Engr 0.5 Data Engr 0.5 Data Tech 1 Mass Properties Engr	2	8	3.5 Engineers 0.5 Technicians	8 Engineers 3 Technicians 1 Q.C.
Report Preparation 1 Interface Engr 1 Mechanical Engr 1 Mass Properties Engr 1 Instrumentation Engr 1 Structural Engr	1	5	5 Engineers	8 Engineers 3 Technicians 1 Q.C.
TOTAL MAN MONTHS:		77		

ELECTROMAGNETIC COMPATIBILITY

(FLIGHT TEST ARTICLE - MANUFACTURING SITE)

SCHEDULE

(MONTHS)



ELECTROMAGNETIC COMPATIBILITY
(FLIGHT TEST ARTICLE - MANUFACTURING SITE)

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management 1 Manager	8.5	8.5	1 Engineer	1 Engineer
Test Requirements and Planning 1 EMC Engineer 0.5 DMA Engr 0.5 GN&C Engr 0.5 Comm. Engr 0.5 Instr. Engr 0.5 Pwr and Dist Engr 0.5 GSE Engr	4	16	4 Engineers	5 Engineers
Test Article Preparation 1 EMC Engineer 0.25 DMA Engr 0.25 GN&C Engr 0.25 Comm. Engr 0.5 Instr. Engr 0.25 Pwr and Dist Engr 0.25 GSE Engr 3 Technicians 2 Q.C.	0.5	3.875	2.75 Engineers 3 Technicians 2 Q.C.	5 Engineers 3 Technicians 2 Q.C.
Test Fixture Design 1 Engineer	2	2	1 Engineer	6 Engineers 3 Technicians 2 Q.C.
Test Setup 1 EMC Engr 3 Technicians 1 Q.C.	0.25	1.25	1 Engineer 3 Technicians 1 Q.C.	6 Engineers 3 Technicians 2 Q.C.
Test Performance 2 EMC Engineers 3 Technicians 1 Q.C.	1	6	2 Engineers 3 Technicians 1 Q.C.	6 Engineers 3 Technicians 2 Q.C.
Test Teardown 1 EMC Engineer 3 Technicians 1 Q.C.	0.25	1.25	1 Engineer 3 Technicians 1 Q.C.	6 Engineers 3 Technicians 2 Q.C.

ELECTROMAGNETIC COMPATIBILITY

(FLIGHT TEST ARTICLE - MANUFACTURING SITE)

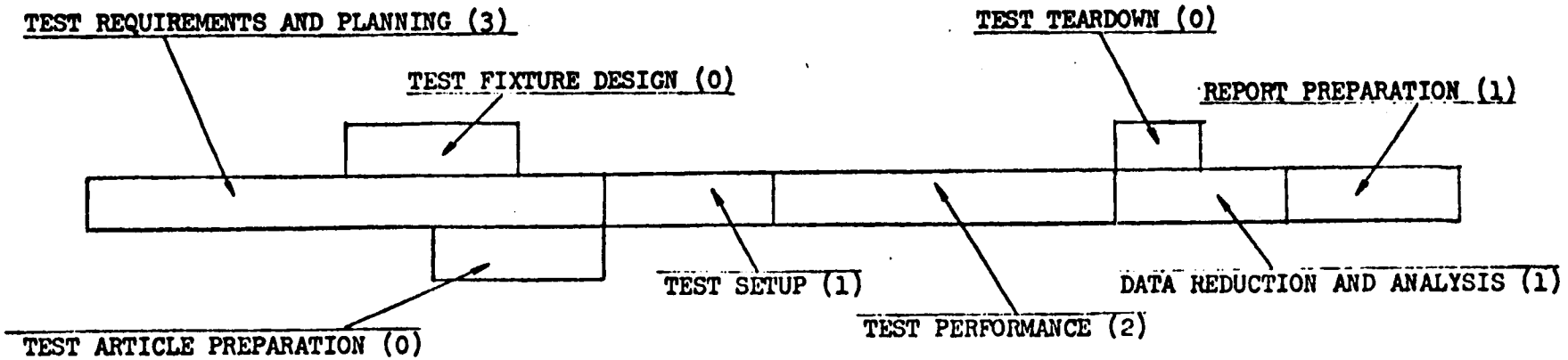
PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Data Reduction and Analysis 2.75 Engineers (See Test Art. Prep.) 1 Data Engrg Engr 1 Data Technician	2	9.5	3.75 Engineers 1 Technician	7 Engineers 4 Technicians 2 Q.C.
Report Preparation 4 Engineers (See Test Requirements and Planning)	1	4	4 Engineers	7 Engineers 4 Technicians 2 Q.C.

TOTAL MAN MONTHS: 52.375

REFURBISHMENT/REUSE VERIFICATION

FLIGHT TEST ARTICLE

TRANSPORTATION AND HANDLING PROCEDURES VERIFICATION



TEST MANAGEMENT (0)

REFURBISHMENT/REUSE VERIFICATION

FLIGHT TEST ARTICLE

TRANSPORTATION AND HANDLING PROCEDURES VERIFICATION

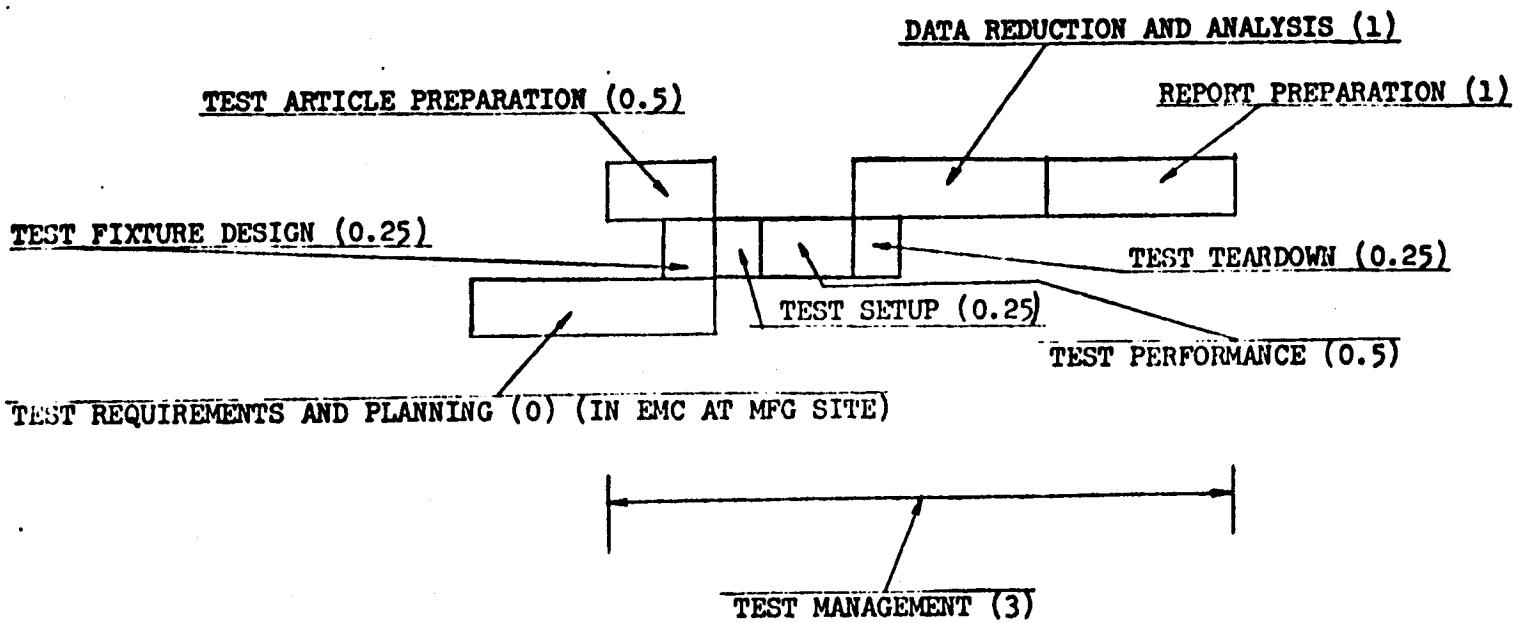
PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management	0	0		
Test Requirements and Planning 2 Transportation and Handling Engrs	3	6	2 Engineers	2 Engineers
Test Article Preparation	0	0		
Test Fixture Design	0	0		
Test Setup 2 Transportation and Handling Engrs	1	2	2 Engineers	2 Engineers
Test Performance 2 Transportation and Handling Engrs 1 Crane Operator 4 Technicians - Struct/Mech 1 Driver 1 Quality Control 1 Safety Engineer	2	20	3 Engineers 1 Crane Op. 4 Technicians 1 Driver 1 Q.C.	3 Engineers 1 Crane Op. 4 Technicians 1 Driver 1 Q.C.
Tear Down	0	0		
Data Reduction and Analysis 2 Transportation and Handling Engrs	1	2	2 Engineers	3 Engineers 1 Crane Op. 4 Technicians 1 Driver 1 Q.C.
Report Preparation 2 Transportation and Handling Engrs	1	2	2 Engineers	3 Engineers 1 Crane Op. 4 Technicians 1 Driver 1 Q.C.
TOTAL MAN MONTHS:		32		

ELECTROMAGNETIC COMPATIBILITY

(FIRST DELIVERED TUG - LAUNCH SITES)

SCHEDULE

(MONTHS)



ELECTROMAGNETIC COMPATIBILITY

(FIRST DELIVERED TUG - LAUNCH SITES)

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management 1 Manager	3	3	1 Engineer	1 Engineer
Test Requirements and Planning 1 EMC Engineer 0.5 DMA Engr 0.5 GN&C Engr 0.5 Comm. Engr 0.5 Instr. Engr 0.5 Pwr and Dist Engr 0.5 GSE Engr	0	0	(In Mfg Site Planning)	1 Engineers
Test Article Preparation 1 EMC Engineer 0.25 DMA Engr 0.25 GN&C Engr 0.25 Comm. Engr 0.5 Instr. Engr 0.25 Pwr and Dist Engr 0.25 GSE Engr 3 Technicians 2 Q.C.	0.5	3.875	2.75 Engineers 3 Technicians 2 Q.C.	3.75 Engineers 3 Technicians 2 Q.C.
Test Fixture Design 1 Engineer	0.25	0.25	1 Engineer	4.75 Engineers 3 Technicians 2 Q.C.
Test Setup 1 EMC Engr 3 Technicians 1 Q.C.	0.25	1.25	1 Engineer 3 Technicians 1 Q.C.	4.75 Engineers 3 Technicians 2 Q.C.
Test Performance 2 EMC Engineers 3 Technicians 1 Q.C.	0.5	3	2 Engineers 3 Technicians 1 Q.C.	4.75 Engineers 3 Technicians 2 Q.C.
Test Teardown 1 EMC Engineer 3 Technicians 1 Q.C.	0.25	1.25	1 Engineer 3 Technicians 1 Q.C.	4.75 Engineers 3 Technicians 2 Q.C.

ELECTROMAGNETIC COMPATIBILITY

(FIRST DELIVERED TUG - LAUNCH SITES)

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Data Reduction and Analysis 2.75 Engineers (See Test Art. Prep.) 1 Data Engrg Engr 1 Data Technician	1	4.75	3.75 Engineers 1 Technician	5.75 Engineers 4 Technicians 2 Q.C.
Report Preparation 4 Engineers (See Test Requirements and Planning)	1	4	4 Engineers	5.75 Engineers 4 Technicians 2 Q.C.

TOTAL MAN MONTHS: 21.375

REFURBISHMENT/REUSE VERIFICATION

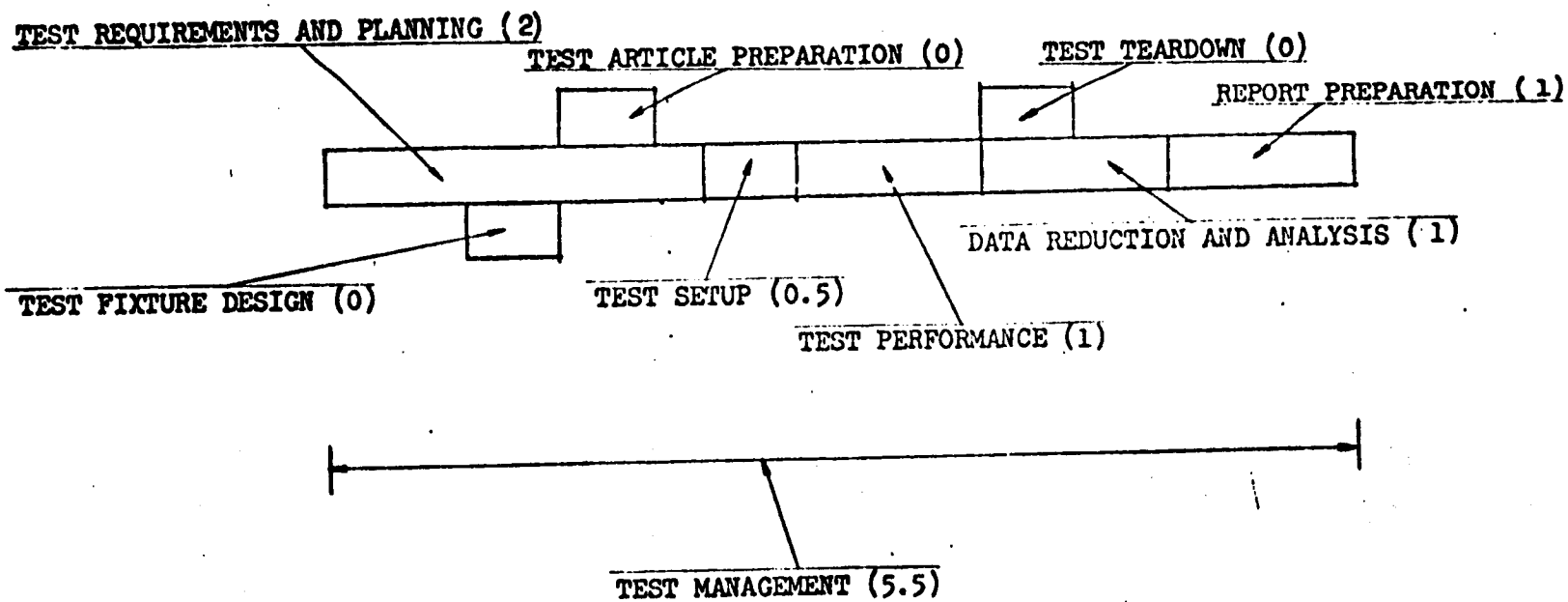
(FLIGHT TEST ARTICLE - ETR)

MAINTENANCE (M) PROCEDURE EVALUATION

SCHEDULE

(MONTHS)

(PHASED INITIAL AND DIRECT DEVELOPED)



REFURBISHMENT/REUSE VERIFICATION

(FLIGHT TEST ARTICLE - ETR)

MAINTENANCE ($\overline{M}$) PROCEDURE EVALUATION

(PHASED INITIAL AND DIRECT DEVELOPED)

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management 1 Supervision	5.5	5.5	1 Engineer	1 Engineer
Test Requirements and Planning 1 $\overline{M}$ Engineer - Avionics 1 $\overline{M}$ Engineer - Propulsion 1 $\overline{M}$ Engineer - Struct/Mech	2	6	3 Engineers	4 Engineers
Test Article Preparation	0	0		
Test Fixture Design	0	0		
Test Setup 1 $\overline{M}$ Engineer - Avionics 1 $\overline{M}$ Engineer - Propulsion 1 $\overline{M}$ Engineer - Struct/Mech	.5	1.5	3 Engineer	4 Engineers
Test Performance 1 $\overline{M}$ Engineer - Avionics 1 $\overline{M}$ Engineer - Propulsion 1 $\overline{M}$ Engineer - Struct/Mech 2 Technicians - Avionics 2 Technicians - Propulsion 2 Technicians - Struct/Mech 3 Quality Control	1	12	3 Engineer 6 Technicians 3 Q.C.	4 Engineers 6 Technicians 3 Q.C.
Tear Down	0	0		
Data Reduction and Analysis 1 $\overline{M}$ Engineer - Avionics 1 $\overline{M}$ Engineer - Propulsion 1 $\overline{M}$ Engineer - Struct/Mech	1	3	3 Engineers	4 Engineers 6 Technicians 3 Q.C.
Report Preparation 1 $\overline{M}$ Engineer - Avionics 1 $\overline{M}$ Engineer - Propulsion 1 $\overline{M}$ Engineer - Struct/Mech	1	3	3 Engineers	4 Engineers 6 Technicians 3 Q.C.
TOTAL MANMONTHS:		31		

REFURBISHMENT/REUSE VERIFICATION

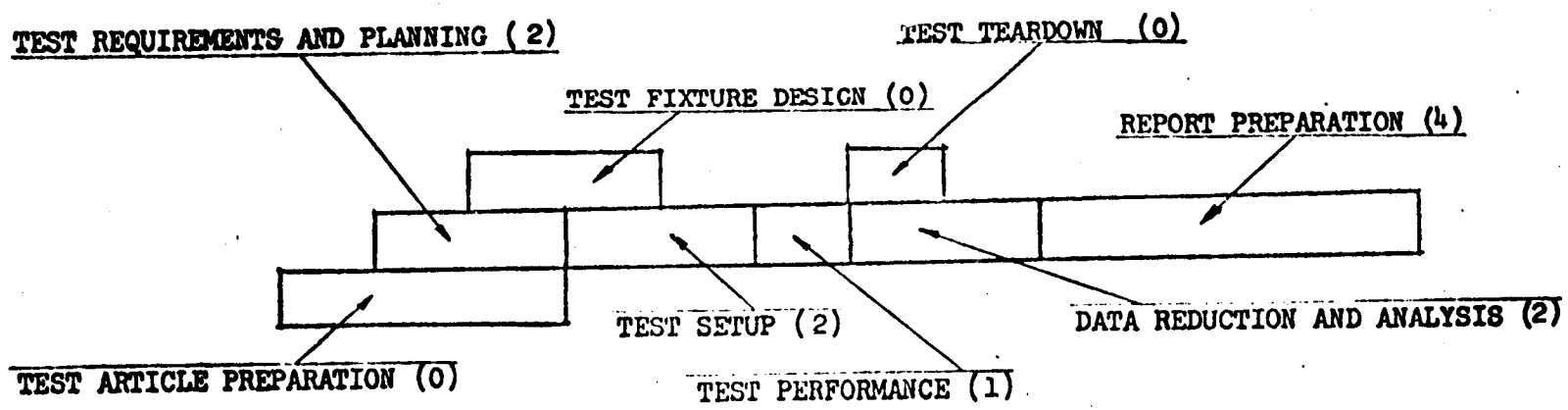
(FLIGHT TEST ARTICLE - ETR)

MAINTAINABILITY (M) DEMONSTRATION

SCHEDULE

(MONTHS)

(PHASED INITIAL AND DIRECT DEVELOPED)



TEST MANAGEMENT (0)

REFURBISHMENT/REUSE VERIFICATION

FLIGHT TEST ARTICLE (ETR)

MAINTAINABILITY (M) DEMONSTRATION

(PHASED INITIAL AND DIRECT DEVELOPED)

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Test Management	0	0		
Test Requirements and Planning	2	2	1 Engineer	1 Engineer
1 M Engineer				
Test Article Preparation	0	0		
Test Fixture Design	0	0		
Test Setup	2	1	.5 Engineer	1 Engineer
.5 M Engineer				
Test Performance	1	1	1 Engineer	1 Engineer
1 M Engineer				
Tear Down	0	0		
Data Reduction and Analysis	2	2	1 Engineer	1 Engineer
1 M Engineer				
Report Preparation	4	3	.75 Engineer	1 Engineer
.75 M Engineer				
TOTAL MAN MONTHS:		9		

2.4 FLIGHT TEST PROGRAM

The development process culminates in the flight test program. It has been a goal during this study to conduct as little flight testing as possible commensurate with demonstration of mission performance to a high degree of confidence. The two major variables involved are amount of ground development testing conducted prior to committing the first Space Tug to flight, and amount of risk to be accepted by program management. To arrive at a prudent balance, technical complexity of a subsystem, related experience, and cost were considered in formulating a ground test plan directed at minimization of flight testing. As a result flight test objectives are associated primarily with the zero-g aspects of space flight.

2.4.1 Flight Test Objectives

Objectives are aimed at verifying that the Space Tug can accomplish assigned missions within the specified mission envelope of performance and time requirements.

2.4.1.1 Propulsion Subsystem

The use of liquid hydrogen and liquid oxygen as propellants is no longer a new technology. Before the end of the Saturn-Apollo program the practice of acceptance firing each S-IVB stage was terminated. Injection into earth orbit of Apollo 17 was the first firing experienced by S-IVB stage #512. Skylab 2 and 3 launches were performed by S-IVB stages which were acceptance fired many years earlier. Subsequent to their firings stages 206 and 207 logged extensive hours of storage, transportation, modifications, inspections and an additional factory checkout. This activity (or lack of it) emphasizes the fact that with sufficient development testing and proper adherence to quality control procedures some operational testing can be reduced.

Calling on this related experience the first firing of a Space Tug will be on-orbit. Ground testing of the main engine support assembly (MESA) is considered adequate to provide the required confidence. The objectives for flight testing then are:

- propellant settling in a zero-g environment
- propellant utilization
- propellant feedline and engine thermal conditioning

propellant conditioning

2.4.1.2 Avionics Subsystem

This subsystem is of sufficient complexity and importance to Tug flight operations that strong emphasis is placed on its development through the use of the Integrated Avionics Test Unit. Information will be obtained through operational instrumentation as to performance of the assemblies of the subsystem as missions are performed. As a consequence the only flight test instrumentation will be in support of the following objective:

Avionics cold plate temperature stabilization.

2.4.1.3 Thermal Insulation Subsystem

Both ground and flight test data verify analytical predictions of heat transfer and resulting LH_2 boil-off rates. For Options 1 and 3I this flight test commands even more importance because of the lack of conduct of the ground test. The flight test objective for the subsystem is:

Zero-g heat transfer.

2.4.1.4 All Subsystems

Components and assemblies of the subsystems attach either to primary or secondary structure. Components developed on the Tug program will be exposed to vibration and shock along with their attaching structure and backup structure. Some of this testing will be accomplished at higher levels of assembly. In the absence of a dynamics test of the total system it is adviseable to obtain this information in flight. The resulting objective:

Vibration levels of selected critical installations.

2.4.2 Flight Test Instrumentation

Instrumentation for the purpose of obtaining data relative to the above objectives will be installed on the first flight vehicle. At the termination of the flight program (2 flights) the instrumentation will be removed and the Tug processed through a normal turnaround cycle. The vehicle will then continue normal operations within the fleet.

2.4.2.1 Propulsion Subsystem

Specific equipment and/or sensors and signal conditioning equipment are required for each of the objectives.

Propellant Settling

A short LH_2 capacitance probe will be installed in the LH_2 tank such that the upper end will be 3 ft (0.914 m) above the feed outlet. This probe will indicate the reduction in amount, or the lack, of bubbles.

Propellant Utilization

This objective can be satisfied by operational instrumentation.

Propellant Feedline and Engine Thermal Conditioning and Propellant Conditioning

Temperature probes will be installed in the propellant feedlines; four in the LH_2 feedline and three in the LO_2 feedline.

2.4.2.2 Avionics Subsystem

Fifteen temperature patches placed in selected locations will allow evaluation of the stability of the cold plate temperature.

2.4.2.3 Thermal Insulation Subsystem

Selectively positioned thermocouples are used to determine heat transfer losses; four on each feedline, four on the insulation tank, four on the shroud and four at other critical locations. In addition, two pressure transducers will monitor purge bag operation.

2.4.2.4 Vibration Measurements

Either a three axis or a one axis accelerometer will be placed in the locations analyzed to be critical.

2.4.3 Flights

Flight test information will be acquired on the first two flights. These flights will carry selected spacecraft for orbital placement. Obtaining this information as a secondary mission objective presents a challenge to the flight scheduling effort, the result of which will be a balance between mission/spacecraft and flight test objectives.

The objectives, instrumentation, and flights discussed above pertain to Tug subsystems. An objective and flight test to be performed in addition to these is the on-orbit verification of the egress-ingress maneuver. This is an Orbiter/Tug interface flight test. Equipment will consist of an Orbiter and a Tug/Orbiter Interface Verification Unit (IVU). This unit is for developing, qualifying, and checking out the interfaces between the Tug and the Orbiter pertinent to the egress/ingress maneuver. Since the development of these interfaces are as important to the Orbiter contractor as to the Tug contractor, the manufacturing and testing costs of the unit may be shared. In this regard, and due to its estimated cost ($50,000), only one unit will probably be constructed between the two contractors. For the flight test, if the IOC is December 1979, an "empty bay" Shuttle flight test may be utilized; if the IOC is later, a dedicated Shuttle flight would be required. Objective of the test is to assure operational integrity of all interface, i.e., latches, disconnects, tilt, maneuvering arms grip/degrip, egress maneuver, ingress maneuver, etc. Importance of the test is emphasized by the facts that when the maneuver is performed with a live Tug, both the Tug and the Orbiter are fueled; the Orbiter is manned; if the Tug can't be recovered, this expensive vehicle must be left on-orbit; and, if the first time the maneuver is performed is deferred to the first live Tug flight only to find a fault, particularly part way through the maneuver, the Orbiter cannot accomplished atmospheric reentry aerodynamically unclean.

2.4.4 Manloading Per Test

Manloading estimates employed the following steps:

a. Determine major elements required to conduct the specific test.

b. Schedule these elements relative to each other.

c. Determine the quantities and types of key direct personnel required to accomplish each element.

d. Complete the arithmetics.

2.4.4.1 Schedules and Estimates

Schedules and respective personnel estimates are presented on the following pages for each of the tests within WBS element 32A-08-04.

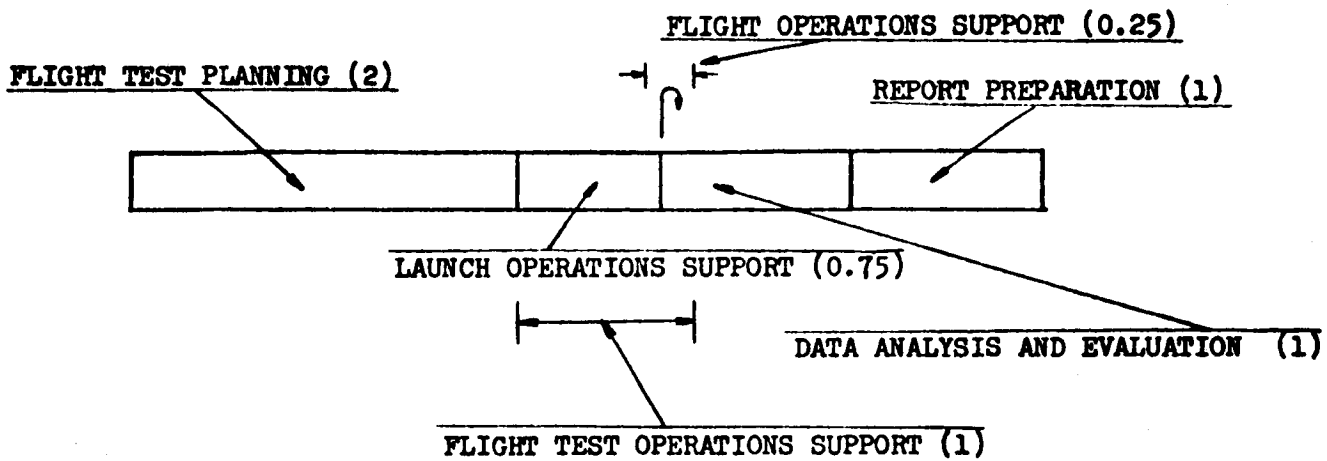
FLIGHT TEST OPERATIONS

(INTERFACE VERIFICATION UNIT)

EGRESS-INGRESS MANEUVER

SCHEDULE

(MONTHS)



FLIGHT TEST OPERATIONS

IVU

(EGRESS-INGRESS)

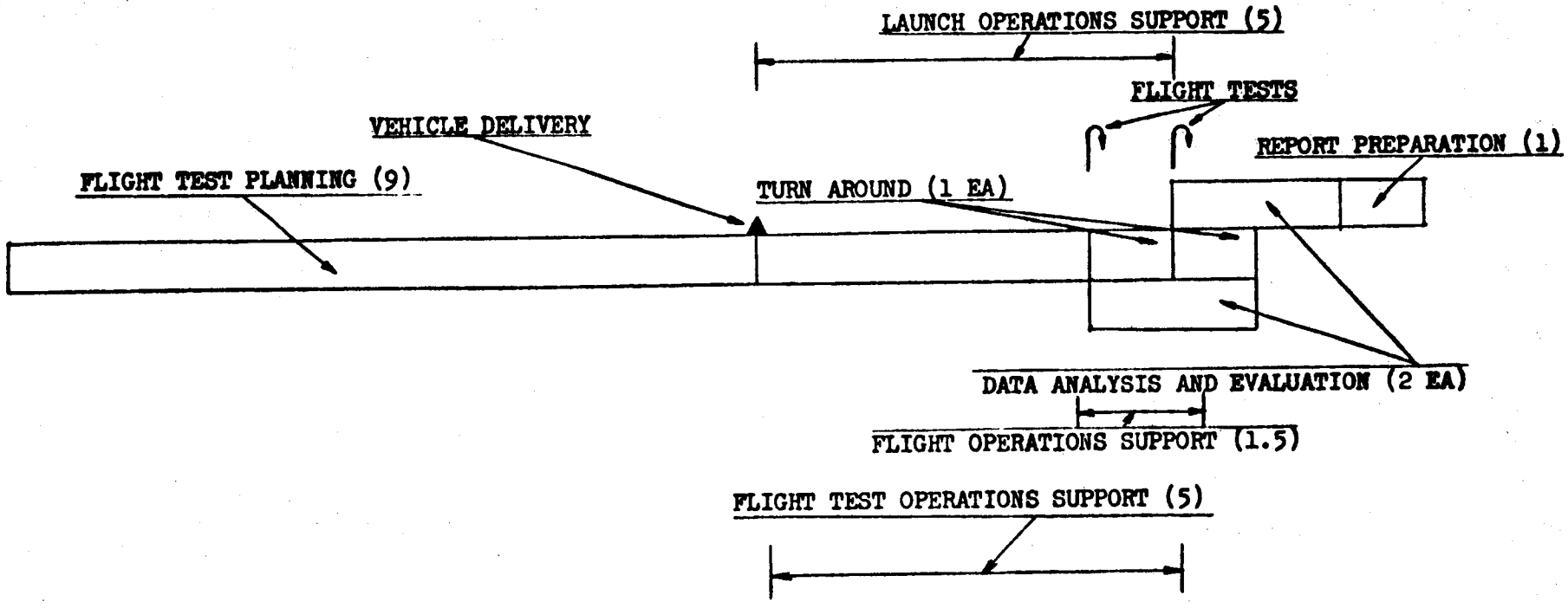
PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Flight Test Planning	2	16	8 Engineers	8 Engineers
1 Electrical Engr 1 Propulsion Engr 1 Struct/Mech Engr 1 Thermo Engr 1 Instrumentation Engr 1 Interface Engr 1 Project Engr 1 Mass Properties Engr				
Launch Operations Support (WBS 32C-09/10)	0.75	0	0 Engineer	8 Engineers
35 Engineers 80 Technicians				
Flight Operations Support (WBS 32C-11/12)	0.25	0	0 Engineer	8 Engineers
30 Engineers				
Flight Test Operations Support	1	5	5 Engineers	6 Engineers
1 Project Engineer 1 Interface Engineer 1 Struct/Mech Engineer 1 Mass Properties Engr 1 Instrumentation Engr		5		
Data Analysis and Evaluation	1	10	9 Engineers 1 Technician	7 Engineers 1 Technician
8 Engineers (See Flight Test Plng) 1 Data Acquisition Engr 1 Data Technician				
Report Preparation	1	5.5	5.5 Engineers	7 Engineers 1 Technician
1 Project Engr 1 Interface Engr 1 Instrumentation Engr 0.5 Electrical Engr 0.5 Propulsion Engr 0.5 Struct/Mech Engr 0.5 Thermo Engr 0.5 Mass Properties Engr				
TOTAL MAN MONTHS:		36.5		

FLIGHT TEST OPERATIONS

SCHEDULE

(MONTHS)

(PHASED INITIAL AND DIRECT DEVELOPED)



FLIGHT TEST OPERATIONS

(Conducted Concurrently with Operational Flights--Phased Initial and Direct Developed)

(2 FLIGHTS)

PERSONNEL	MONTHS	MANMONTHS	TYPE PERSONNEL	PERSONNEL-CUM.
Flight Test Planning	9	81	9 Engineers	9 Engineers
2 Elec. Engineers 2 Prop. Engineers 1 Struct./Mech. Engineer 1 Thermodynamics Engineer 1 Effectiveness Engrg Engr 2 Project Engineers				
Launch Operations Support (WBS 32C-09/10)	5	0		9 Engineers
Flight Operations Support (WBS 32C-11/12)	1.5	0		9 Engineers
Flight Test Operations Support	5	35	7 Engineers	9 Engineers
2 Elect. Engineers 2 Prop. Engineers 1 Struct./Mech. Engineer 1 Thermodynamics Engineer 1 Project Engineer		35		
Data Analysis and Evaluation	4	56	12 Engineers 2 Technicians	12 Engineers 2 Technicians
9 Engineers (See Flt. Test Plng.) 3 Data Acquisition Engrs 2 Data Acquisition Techs				
Report Preparation	1	9	9 Engineers	12 Engineers 2 Technicians
9 Engineers (See Flt. Test Plng.)				
TOTAL MANHOURS:		181		

Instrumentation: $100,000 - 0.006 vehicle cost

ESTIMATED FLUID USAGES

(LBM)

TEST / PROPELLANT	M/R = 5:1	M/R = 6:1	HELIUM				
			OPTION 1	OPTION 2	OPTION 3I	OPTION 3F	OPTION 3S
1 Flight Test							
LO_2	4.7×10^4	4.8×10^4	N/A	N/A	N/A	164	112
LH_2	1.0×10^4	8.7×10^3					
2 Flight Tests							
LO_2	9.4×10^4	8.4×10^4	224	112	224	N/A	N/A
LH_2	2.0×10^4	1.7×10^4					
Thermal (Propellants Recoverable)							
LO_2	9.4×10^4	9.6×10^4	N/A	213	N/A	213	213
LH_2	2.0×10^4	1.7×10^4					
Propulsion Test Vehicle (Cold Flow)							
LO_2	1.44×10^6	4.0×10^5	2.8×10^3	N/A	2.8×10^3	N/A	N/A
LH_2	2.56×10^5	6.0×10^4					
Propulsion Test Vehicle (Firing)							
LO_2	1.8×10^6	2.0×10^6	N/A	224	N/A	N/A	224
LH_2	3.2×10^5	3.0×10^5					

2.4.4.2 Flight Test Costs

Instrumentation:	$0.104 M
Flight Test Operations:	$0.750 M
Total:	$0.854 M

Flight test operations cost includes the egress-ingress maneuver interface flight test using the IVU and two Tug flight tests performed as secondary mission operations on spacecraft carrying flights.

2.5. IMPACT OF OPTION SENSITIVITIES

Vehicle test is affected lightly or not at all by the differences from the principal emphases.

2.5.1 Programmatic Sensitivity for a Two Year Later IOC (Dec. 31, 1981)

A later IOC results in no impact on the vehicle test program. To maintain minimum DDT&E cost, no tests would be added, and a later IOC offers no opportunity to reduce an already minimum program. For cost and funding impact refer to Section 8, Volume 8.

2.5.2 DDT&E Effects for >36 Hour Mission Duration

A greater mission duration would not affect the vehicle test program but some effect would be reflected in lower assembly level hardware DDT&E (WBS) 32A-03, reference Section 9, Volume 5.

2.5.3 Impact to Provide 300 Watts to Payload

Provision of power to the spacecraft would not affect the vehicle test program but some effect would be reflected in lower assembly level hardware DDT&E (WBS) 32A-03, reference Section 9, Volume 5.

2.6 ANALYSIS OF TEST PROGRAM

Elements of a test program normally include:

- Supporting Research and Technology (SR&T)
- Development and qualification testing of the lower hardware assembly levels, i.e., parts, components, subassemblies, and assemblies
- Reliability testing of selected items
- Repairability/maintainability testing at the Line Replaceable Unit (LRU) level
- Development, qualification, maintenance, and maintainability testing of major or vehicle level test articles
- Acceptance testing of the lower level hardware
- Acceptance testing of the completed Tug
- Prelaunch testing
- Flight testing of the completed CEI

For purposes of this study, these elements have been organized into their associated operational areas.

2.6.1 Supporting Research and Technology (SR&T)

Depending upon the option,some subsystems require preceding SR&T. The testing program is based, however, upon the assumption that all required SR&T is completed prior to ATP of the Tug Phase C-D. Therefore, SR&T discussions are found in Section 8, Volume 5, and Section 10, Volume 8.

2.6.2 Development and Qualification Testing

This testing is accounted for at two levels; components and assemblies, and vehicle test.

2.6.2.1 Component and Assembly Testing

A goal in this study was to identify as many of the selected components as possible which could be qualified to Tug requirements by means other than testing, i.e.,

A - Analysis

I - Inspection

D - Demonstration

S - Simulation

For those items, identifiable in a conceptual study, achievement of that goal has been reached.

2.6.2.2 Vehicle Test

The bulk of the test program is comprised in this activity, and properly so. When assembly reaches this level, it is approaching, or has become, the Space Tug. This is the first time the lower level hardware has been assembled into the Tug configuration. This is where true Tug development takes place. Discussion of test hardware and operations is located in Section 2.1 and 2.3, respectively. The test programs have been formulated to comply with Tug program requirements of minimum/low DDT&E, demonstrate reusability, etc. It is always possible that less testing can be performed. But it is also a

fact of product development life that as the activity which proves that the design/manufacturing process meets the design requirements, i.e., test, is lowered, the risk that the product will perform as required raises. Another view is that as dollars are shoved out of development, they pop up in operations. There is, therefore, a cross over point where further reductions in development/qualification costs are not sound reductions. At the level of design definition available from a conceptual study, the test program described in the foregoing sections reflect an adequate balance between technical assurance and budgetary limitations.

2.6.3 Reliability Testing

As a result of the component selection process, reliability analyses, development and qualification test design, and cost limitations no specific reliability testing is identified for this option.

2.6.4 Reusability Demonstration

Demonstration of the reusability of the Space Tug, and therefore the components of which it consists, bears close resemblance to that of any reusable equipment. Such a demonstration really spans three separate but allied activities: the overall design/test philosophy; component/subassembly level development and qualification testing; and repairability/maintainability testing at all levels of assembly.

2.6.4.1 Design/Test Philosophy

This is a combination of four approaches and is discussed in Section 2.3.

2.6.4.2 Component Testing

Where applicable, critical test conditions or environments are imposed in accelerated life modes or in repeated cycles to assure their survivability within the limits to be specified.

2.6.4.3 Maintenance/Maintainability Testing

This testing is commenced early in the program at the component level on the bench and carried through the program utilizing the development fixture, the propulsion test vehicle, the Integrated Avionics Test Unit, and the flight test article. The activity is designed to assure the repairability/maintainability of the line replaceable hardware,

accessibility of LRUs within the Tug design and adequacy and effectiveness of procedures. The latter is accomplished first in the development mode by the contractor, followed in the operational test and evaluation mode by the customer.

2.6.5 Acceptance Testing

Items acquired from vendors and subcontractors will be conducted at their facilities under MDAC and customer Q.C. direction. Post manufacturing acceptance testing of the completed CEI will be conducted in the Vehicle Checkout Laboratory (VCL) at MDAC, Huntington Beach. These activities are discussed in Section 4.

2.6.6 Prelaunch Testing

This testing consists of receiving inspections, pre and post mate tests (both spacecraft and orbiter), propellant loading preparations, launch readiness tests and maintenance/refurbishment checkouts. These tests have been formulated to blend within launch site operations procedures, Tug/Spacecraft and Tug/Orbiter interface compatibility, maximum reuse capability, and cost constraints. The activity is discussed in Section 11.3, Volume 6.

2.6.7 Flight Testing

Flight testing has been held to a minimum in terms of engineering information acquisition and of cost. Maximum use must be made of ground test results through analysis emphasizing flight application. Identified flight test objectives are concentrated on those subsystem operations specifically affected by a zero-g environment. Satisfaction of these objectives coupled with the analyses of ground test results will assure verification of the Tug's capability to accomplish assigned missions within the mission envelope, to be specified, of performance and time requirements. While the objectives are not considered of minor significance, the flight tests can be flown on spacecraft-carrying flights, which is beneficial from a cost standpoint.

In addition to the subsystem oriented flight test objectives, one further mission objective is associated with the egress-ingress maneuver, i.e., getting the Tug and its spacecraft out of and back into the orbiter cargo bay. This objective, the subsystem objectives, and the flight test requirements are discussed in Section 2.4.

Section 3
FACILITIES PLAN

The requirements developed by operations analysis in the areas of manufacturing, test, integration, C/O, launch, recovery, refurbishment, and storage were matched against existing, modified, and new facilities on the basis of availability, compatibility, and cost.

It was determined that facilities are not configuration sensitive; cost is not a determinate factor in selection; existing facilities can be utilized for most requirements; and horizontal mating is a preferred method.

3.1 MANUFACTURING FACILITIES

Manufacture and checkout of the Space Tug will be accomplished at the McDonnell Douglas Astronautics Company, Huntington Beach, California, facility.

The Huntington Beach facility was planned and designed from inception to provide fully integrated facility capabilities for space vehicles. Its buildings consist of engineering and administration offices, a Systems Integration Laboratory, Structural Test Laboratory, Space Simulation Laboratory, Production Test Laboratory, Manufacturing and Assembly Building, Insulation Building, Final Assembly and Checkout Building, and other service and support buildings.

Maximum utilization will be made of the existing MDAC and government owned facilities used on the Saturn SIVB Orbital Workshop and other programs in the development and production of the Space Tug. This will include but not be limited to such MDAC facilities as the existing machine shops, sheet metal shops, process shops, electrical/electronic fabrication and assembly, and supporting inspection and test laboratories.

A preliminary list of additional facility requirements identified at this time, for each of the configurations are shown in Table 3.1-1 along with ROM cost and procurement lead time estimates also shown in Vol. 6, Book 1, Section 11.5 and Section 4.3 of this Book.

3.2 TEST FACILITIES

Production testing (and checkout) will be done at Huntington Beach in existing laboratories of the McDonnell Douglas Astronautics Company facilities. These

laboratories, designed and used for space vehicles, will require little or no modification for use in the Space Tug Program.

Vehicle PTV tests will be conducted in test cell J4 of the AEDC facility at Tullahoma. Test cell J4 provides an altitude simulation capability lacking in the test facilities at Huntsville. Thermal tests of the vehicle will be accomplished in the NASA High Vacuum facility utilizing an existing scaled down and instrumented tank that will fit the 15 foot diameter chamber. These government facilities are available at no cost or at a nominal fee depending on the using agency (see Table 3.1-1). See also Volume 6, Book 1, Section 11.5.1 and Section 2 of this Book.

3.3 OPERATIONS FACILITIES

The requirement for Tug launch facilities at ETR will be satisfied with construction of one new building, by modification and refurbishment of existing buildings and by use of Orbiter facilities that can be expanded or adapted to include Tug service.

At WTR,construction of a new Payload Processing facility together with use of programmed Shuttle facilities expanded to satisfy Tug needs will provide the support required. A tabulation of these facilities' status and cost is presented in Table 3.3-1. Additional information is available in Volume 6, Book 1, Sections 11.5.2 and 11.5.3.

New construction and modification to existing buildings (the first three items of Table 3.3-1) is shown in Tables 3.3-3 and 3.3-4.

3.4 IMPACT OF OPTION SENSITIVITIES

3.4.1 Option 1

- Programmatic sensitivity for a two year earlier IOC (Dc. 31, 1983) will have a schedule effect in terms of facilities need dates as described in Section 1.7 of this Book.
- DDT&E effects for >36 hour mission duration will not have an impact on facilities.
- Impact to provide 300 watts to payload will not have an impact on facilities.

Table 3.1-1

MANUFACTURING AND TEST FACILITIES

MANUFACTURING FACILITIES

	DESCRIPTION	LEAD TIME	ROM COST OPTION 1 & 3	ROM COST OPTION 2
1.	AGING OVEN 20 FT X 20 FT x 8 FT (325°F)	6 MONTHS	30,000	
2.	AUTOCLAVE 16 FT DIA X 12 FT LONG (600°F)	10 MONTHS	130,000	
3.	CHEM-MILL FACILITY 2 TANKS 20 FT X 20 FT X 12 FT	10 MONTHS	200,000	
4.	ANODIZE FACILITY 20 FT X 20 FT X 10 FT TANKS	4 MONTHS	200,000	
5.	CLEAN ROOM/10 TON BRIDGE CRANE 5000 SQ FT (100,000 CLASS)	8 MONTHS	250,000	
6.	ACOUSTIC EMISSION TEST EQUIPMENT (PATE)		150,000	
7.	ACOUSTIC EMISSION TEST EQUIPMENT (PATE)		75,000	
				1,035,000
8.	CURING OVEN 16 FT X 16 FT X 8 FT (600°F)	6 MONTHS		60,000
		T O T A L	1,035,000	1,095,000

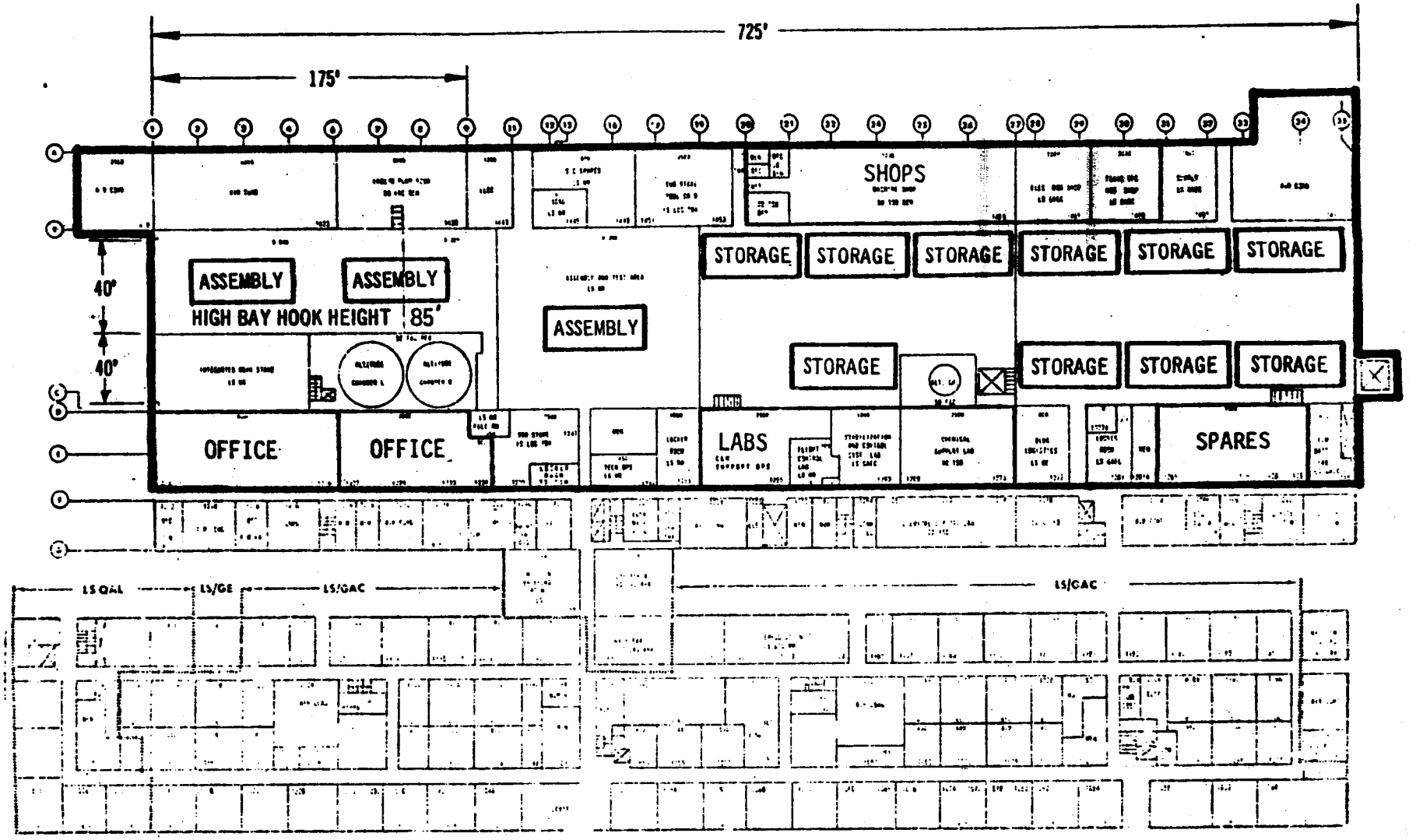
TEST FACILITIES

		NASA	DOD
1.	MDAC HUNTINGTON BEACH LABS	-0-	-0-
2.	NASA HUNTSVILLE HIGH VACUUM FACILITY	-0-	250,000
3.	AEDC TULLAHOMA MARK 4 CHAMBER	1,250,000	-0-

Table 3.3-1

OPERATIONAL FACILITIES SUMMARY

FACILITY	ORIGIN	KSC	WTR
Tug Processing Facility	Modified KSC Bldg M7-355	500,000	
DOD Payload Processing Facility	New	500,000	
Payload Processing Facility	New		750,000
Maintenance and CO Facility	Modified Shuttle Facility	10,000	
Maintenance and CO Facility	Modified Shuttle Facility		10,000
Launch Service Structure	Modified Shuttle Facility	350,000	
Launch Service Structure	Modified Shuttle Facility		350,000
Launch Control Center	Modified Shuttle Facility	10,000	
Launch Control Center	Modified Shuttle Facility		-0-
Safing Facility	Modified Shuttle Facility	-0-	
Safing Facility	Modified Shuttle Facility		-0-
Storable Propellant Facility	Modified Shuttle Facility	-0-	
Storable Propellant Facility	Modified Shuttle Facility		-0-
Vertical Assembly Building	Modified Shuttle Facility	10,000	
Vertical Assembly Building	Modified Shuttle Facility		10,000
		1,380,000	1,120,000



O & C BUILDING FIRST FLOOR, KSC M7-355

SERVICE AREA	24,736 SQ. FT.
A&T AREA	48,750 SQ. FT.
A&E AREA	159,790 SQ. FT.
LSC AREA	123,170 SQ. FT.
TUNNEL AREA	12,026 SQ. FT.
TOTAL	368,312 SQ. FT.

NORTH

Table 3.3-2 Tug Processing Facility

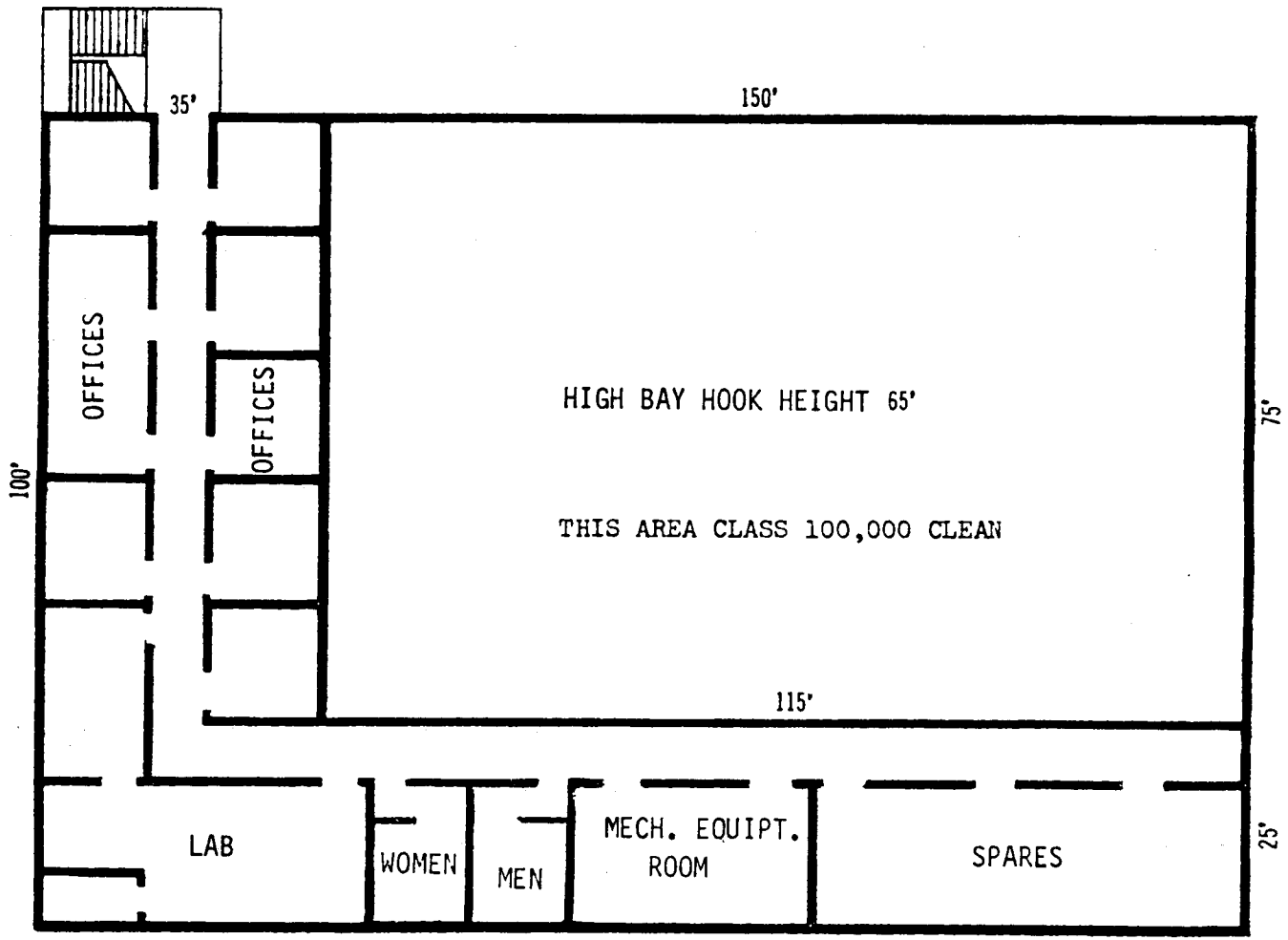


Table 3.3-3 PAYLOAD PROCESSING FACILITY KSC

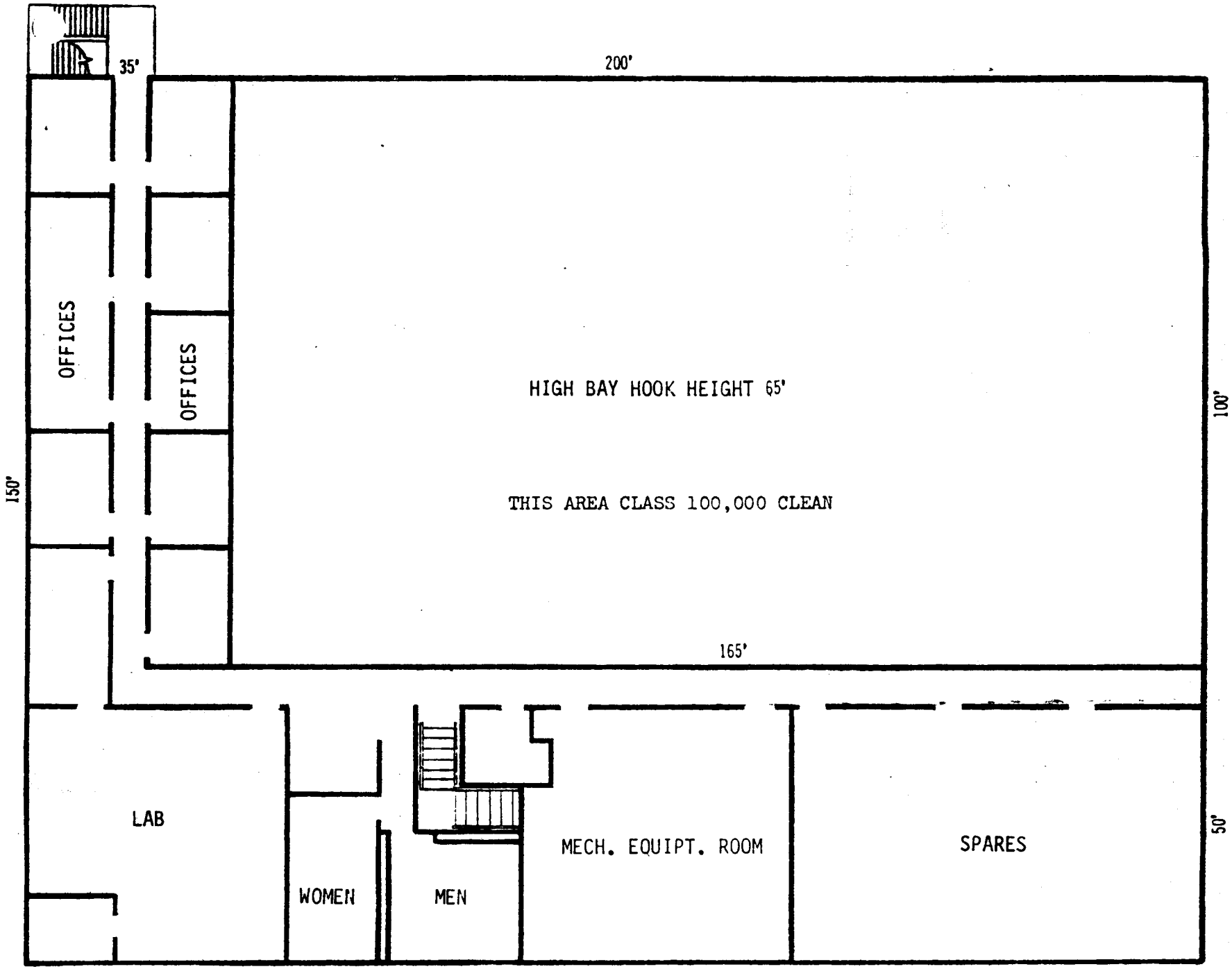


Table 3.3-4 PAYLOAD PROCESSING FACILITY WTR

Section 4
VEHICLE MANUFACTURING

The vehicle manufacturing plan of the Space Tug (see Figure 4-1) contains the Space Tug manufacturing support of the DDT&E requirements, the Space Tug production manufacturing plan, including Peak Rate charts, Manufacturing Flow Plans, tooling required to manufacture the Space Tug per the prescribed rate and the facilities that will be required to accomplish the task. Also included in this section are the problem areas, special processes required, summary analysis and manufacturing philosophy engendered into the manufacturing plan. The impact of the options and the sensitivity to these options are delineated in this section. Factory GSE lists have been made and are also included.

4.1 PLAN/FLOW/TIME

The manufacturing plan/flow/time elements used for the manufacture of the Space Tug are based on the following key factors:

- Low Production requirements
- Minimum DDT&E costs
- Low Production Manufacturing Costs
- Low Early Year Funding
- Low Manufacturing Rate Requirement
- Test Article Requirements Support
- Utilization of existing Capital Equipment, GSE, and facilities
- High Reliability and Reuseable requirements of the Space Tug.

The above noted key factors were considered and incorporated into the Manufacturing plan with the principal motivating factor being the high reliability and reuseability requirement.

4.1.1 Manufacturing Requirements

This section has been divided into two parts to separate the manufacturing requirements for major test articles from those needed for the production of flight articles. No dedicated flight test articles are planned for this program. Schedule requirements for the major test articles are presented in

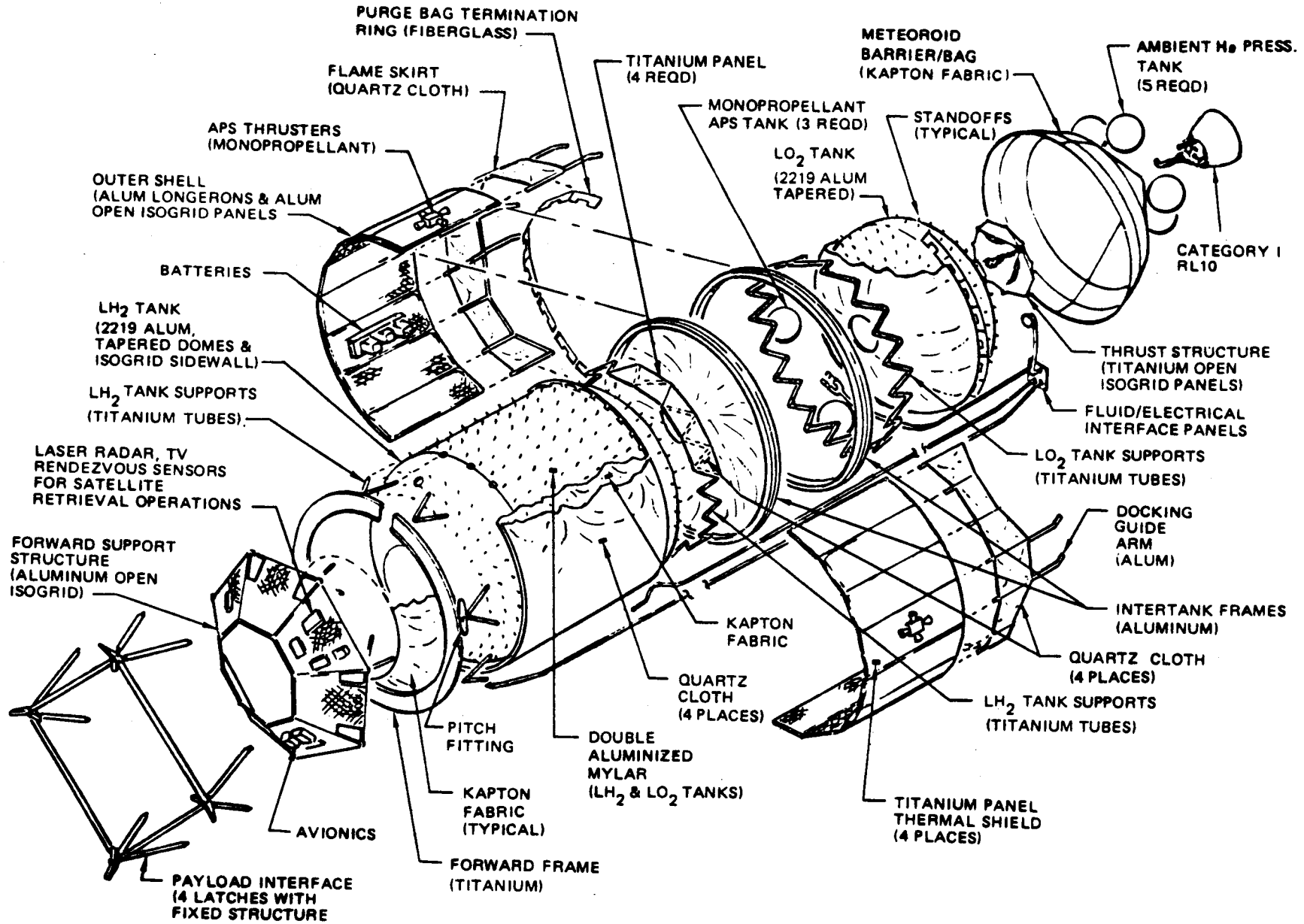


Figure 4-1. Space Tug Configuration – Option 1

Section 1.2. Wherever practical or feasible from a schedule standpoint, manufactured test components will be fabricated during tool proofing to provide lower program cost, reduce Planning effort, provide a greater lead time, and reduce Tooling setup times for test components.

4.1.1.1 Major Test Articles

A. Structural Test Articles

Manufacturing will support the development testing and the qualification testing of structural test hardware by producing one tank set for each of three tests. A tank set consists of an LO_2 tank and an LH_2 tank, as the structural test article is not tested as an assembled entity. Two tank sets will be used during development testing, one for the hydrostatic pressure cycle and one for the hydrostatic pressure burst test. One set of weldment/joining joints will also be produced for development testing.

The third tank set produced will be used for qualification testing during a hydrostatic pressure cycle. One body structure, a thrust structure, and a set of support elements will be produced by manufacturing for qualification testing under static loads: axial, shear and bending. One set of joints will be manufactured also for qualification testing of compression and bending under static loads.

B. Propulsion Test Vehicle (PTV)

Hardware produced by manufacturing for the PTV test includes one each of the following articles: main engine support assembly, structures assembly, interface panel assembly, purge provisions assembly, abort provisions assembly, and one set of electrical and propulsion GSE. The main engine will be GFE for this test. As a cost reduction consideration the LO_2 and the LH_2 tank used in this test will be the previously fabricated Tooling Proof tanks developed to "prove and complete" the tooling required in tank manufacture. Cost savings to the program by using these tanks is consistent with MDAC's policy of low cost and high reliability. Use of these existing tanks is

reflected in the hardware usages schedule for the time-phased production of test articles.

Although the PTV is not a true Space Tug vehicle, being used only to develop and qualify the main engine support assembly and associated interfaces, the components which comprise the PTV will be of production quality to assure that components and interfaces function within the specified limits. The propellant tanks will be fabricated and assembled on production tooling, but will not have the tapered or chemical milled skins used for regular "flight weight" tanks.

C. Integrated Avionics Test Unit (IATU)

Items of test hardware produced to support the IATU test include one avionics subsystem "set" plus spare equivalencies; one set of interfacing hardware (sensors, valves) from such typical subsystems as thermal control, propulsion, and orbiter interface; and one set of electronic GSE and associated software. Associate contractors will supply, in addition, interface verification units for such systems as spacecraft, orbiter, and launch processing. Components comprising this IATU will be of flight production Tug quality, with complete qualification of parts at the component level to assure functional integrity.

D. Flight Control Simulation (Deployment Only)

Test hardware to be produced by manufacturing in support of this test will be one set of the navigation and guidance command (GN&C) subsystem.

E. Flight Support Equipment (FSE)

For the Tug/Orbiter FSE with an Interface Verification Unit (IVU), manufacturing will provide: one tilt table, two fluid/electrical interface panels, one abort dump interface panel, and one electrical interface panel. Special test equipment will also be provided to effect zero g mass balancing of the hardware under test.

Interfaces identified are those between associate contractor hardware or customer hardware. Interface hardware furnished to MDAC by an associate contractor for the IVU will be controlled to assure functional fit and alignment by interface master tooling. This master will be produced, controlled and maintained by MDAC to exact specifications, and supplied to the associate contractor for interface control.

4.1.1.2 Flight Articles

MDAC does not plan to provide dedicated flight test articles, as the high reliability and reusability stressed in the initial design, and proven in development tests, will assure flight-worthy hardware. Thirteen vehicles will be the total Tug. See Mission Accomplishment, Volume 4 for flight vehicle requirements. Manufacture of the flight articles is described in Section 4.1.2, together with the production flow for test, integration, insulation and checkout.

4.1.2 Manufacturing Schedule and Flow

The manufacturing schedule is based on the Production Schedule, shown in Section 1.3, which is the basis also for the manufacturing flow charts, lead time set-back charts, and first tool usage requirements.

The manufacturing flow schedule shown in Figure 4-2 begins with Engineering design effort at ATP, and defines the sequence of activities by Procurement, Planning, Tooling and Manufacturing through detail fabrication, subassembly and assembly, integration and installation, through final checkout and preparation for shipment. Major inspection points such as proof and leak check are also shown in this chart.

The Peak Rate Tree Chart presented in Figure 4-3 shows both detailed manufacturing steps and the units in flow at peak production rate. This chart is the key document that establishes individual unit timing and line position during peak manufacturing rate, and was established by analyzing both tooling and machinery capabilities and the elapsed hours required to maintain a full line at peak rate. When these data are organized into a logical work flow plan, the resulting chart establishes the baseline for manufacturing buildup and factory output to support NASA delivery milestones.

Additional detailed manufacturing sequence flow charts are contained in the Manufacturing Plan which follows in Section 4.1.3. Purchased components and fabricated details are shown in sequence of manufacture from raw material through various stages of processing and assembly to the final checkout position.

4.1.3 Manufacturing Plan

The manufacturing plan outlined in this section is structured as follows:

- Fabrication and Subassembly (structures) plan and Flow Plans.
- Tank Bonding and Insulation plan and Flow Plans
- Final Assembly and Final Joining Plan and Flow Plans
- Propulsion Fabrication and Subassembly Plan and Flow Plans
- Avionics Fabrication and Subassembly Plan and Flow Plans.
- Production Acceptance Test Plan

A descriptive narrative of the manufacturing approach for each of the above noted manufacturing tasks and the manufacturing flow plans are delineated in the following sections and in the same numerical order above.

4.1.3.1 Fabrication and Subassembly Plan (Structures)

The fabrication and subassembly requirements for the manufacture of the structural components comprising the space tug are state-of-the-art and will not require the development of unique manufacturing processes. Low cost "soft" tooling i.e., layout templates, router/blocks, drop hammer dies, etc., will be used extensively where practical. The LH_2 and the LO_2 domes will be subcontracted to a vendor that currently has the capability to manufacture a one piece dome. In order to accomplish this task in house the program costs would be higher, ergo the low cost requirement would not be met. The forward frame and the intertank frames will also be subcontract items to a vendor that specializes in this type of manufacture and is low cost oriented.

The fusion joining of the LH_2 tanks and the LO_2 tanks will be accomplished using the latest Tig welding techniques. Note: The welding process employed in the manufacture of the space tug LH_2 and LO_2 tanks is fully discussed in Section 4.5 Summary Analysis/Philosophy.

The manufacturing requirements for each of the space tug components are outlined in the space tug fabrication flow plans, see Figure 4-4 thru 4-8.

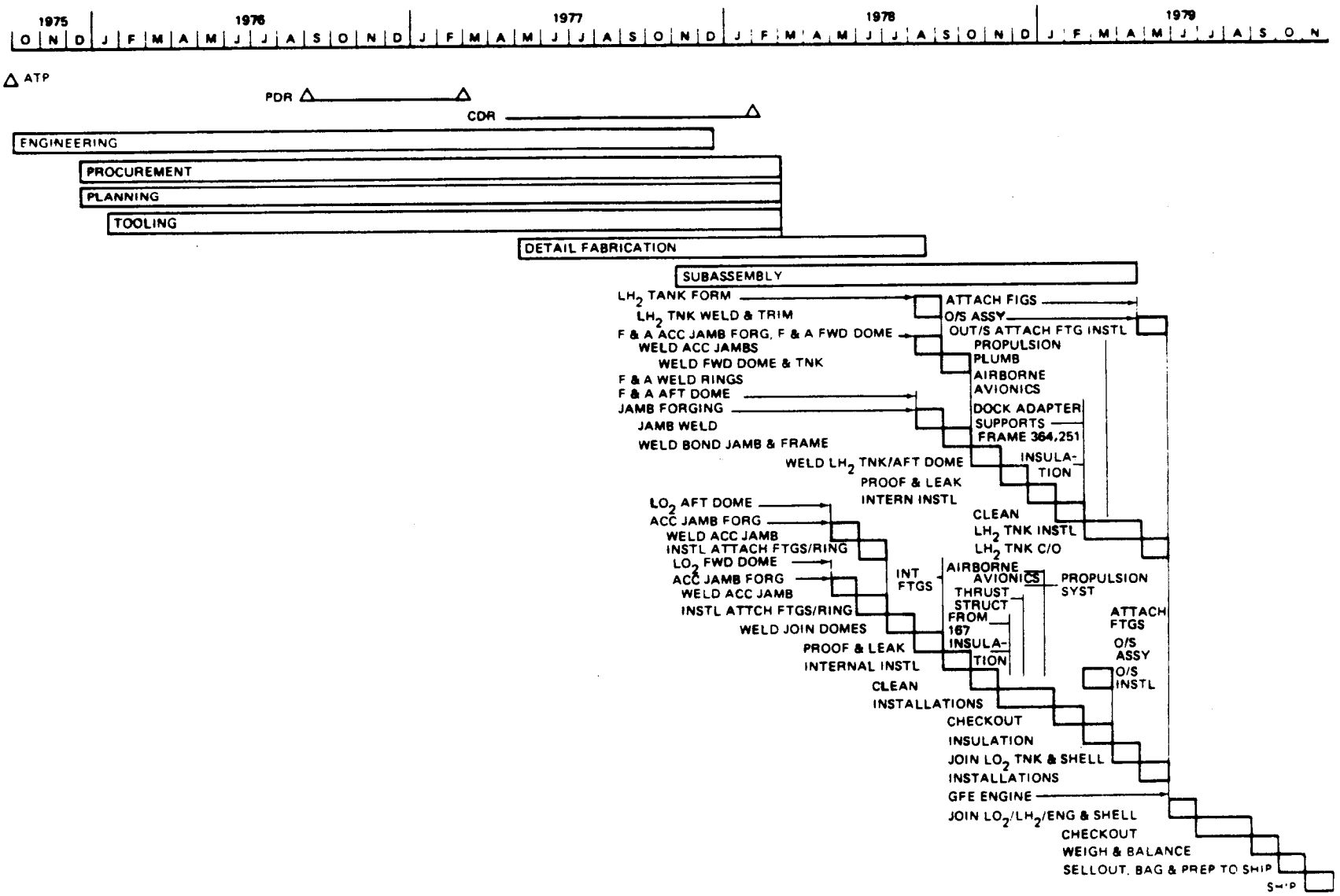


Figure 4-2. Space Tug Manufacturing Flow Schedule – Option 1

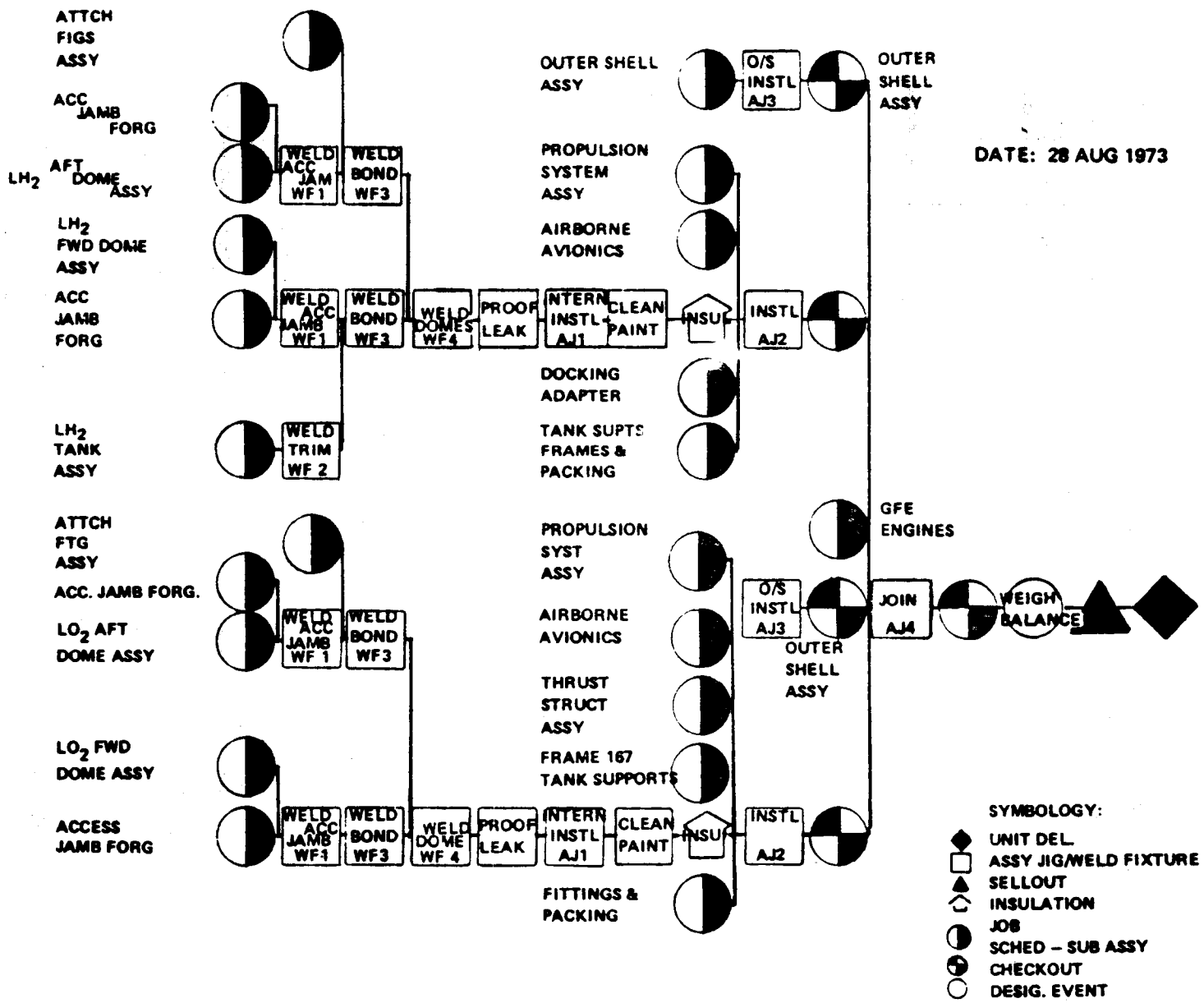


Figure 4-3. Space Tug System Study (Cryogenic) – Peak Rate Tree Chart (Max Rate 4 Per Year) – Option 1

4-7

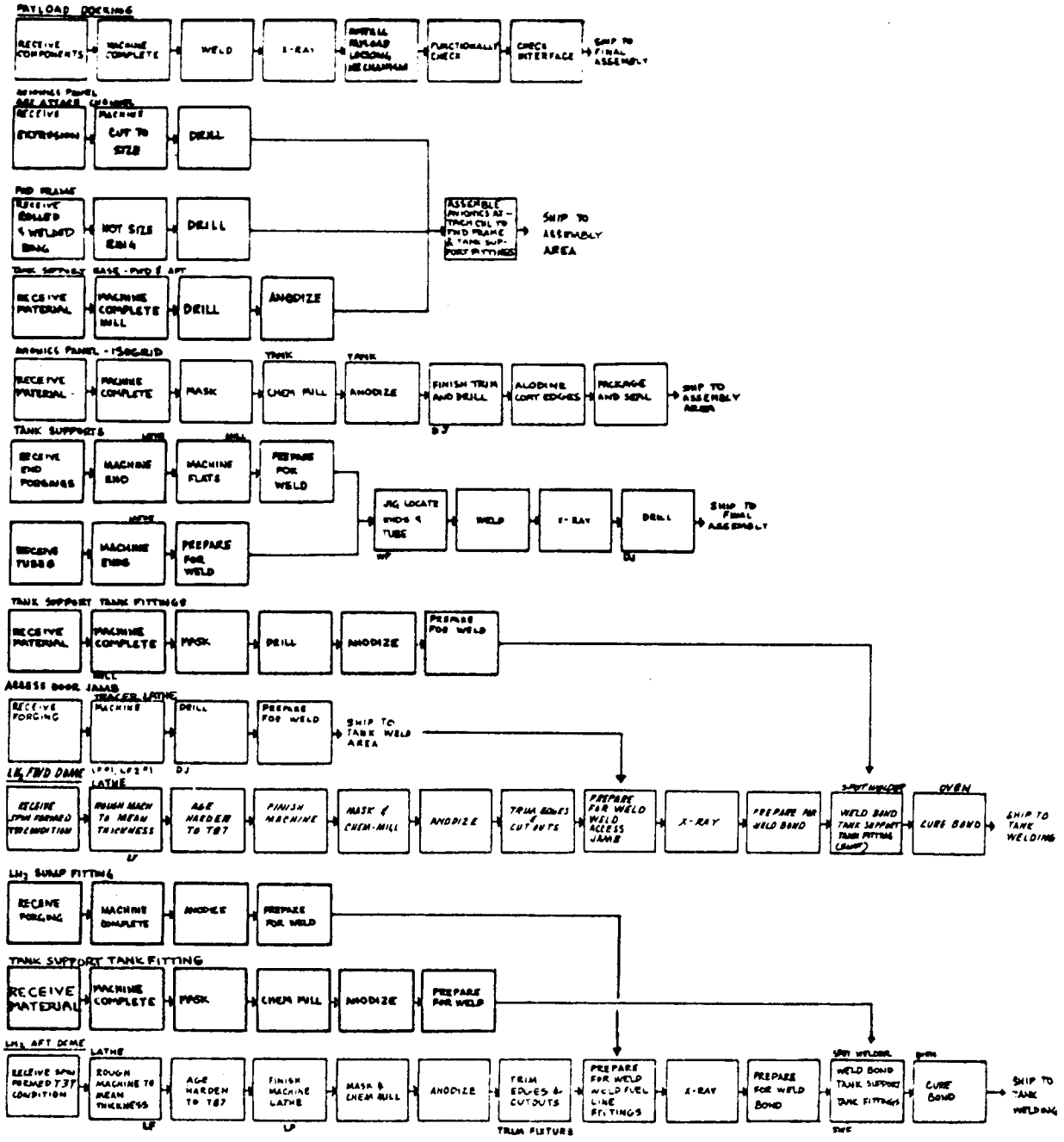


Figure 4-4 Space Tug Fabrication Flow Plan – Option 1 (Page I of 7)

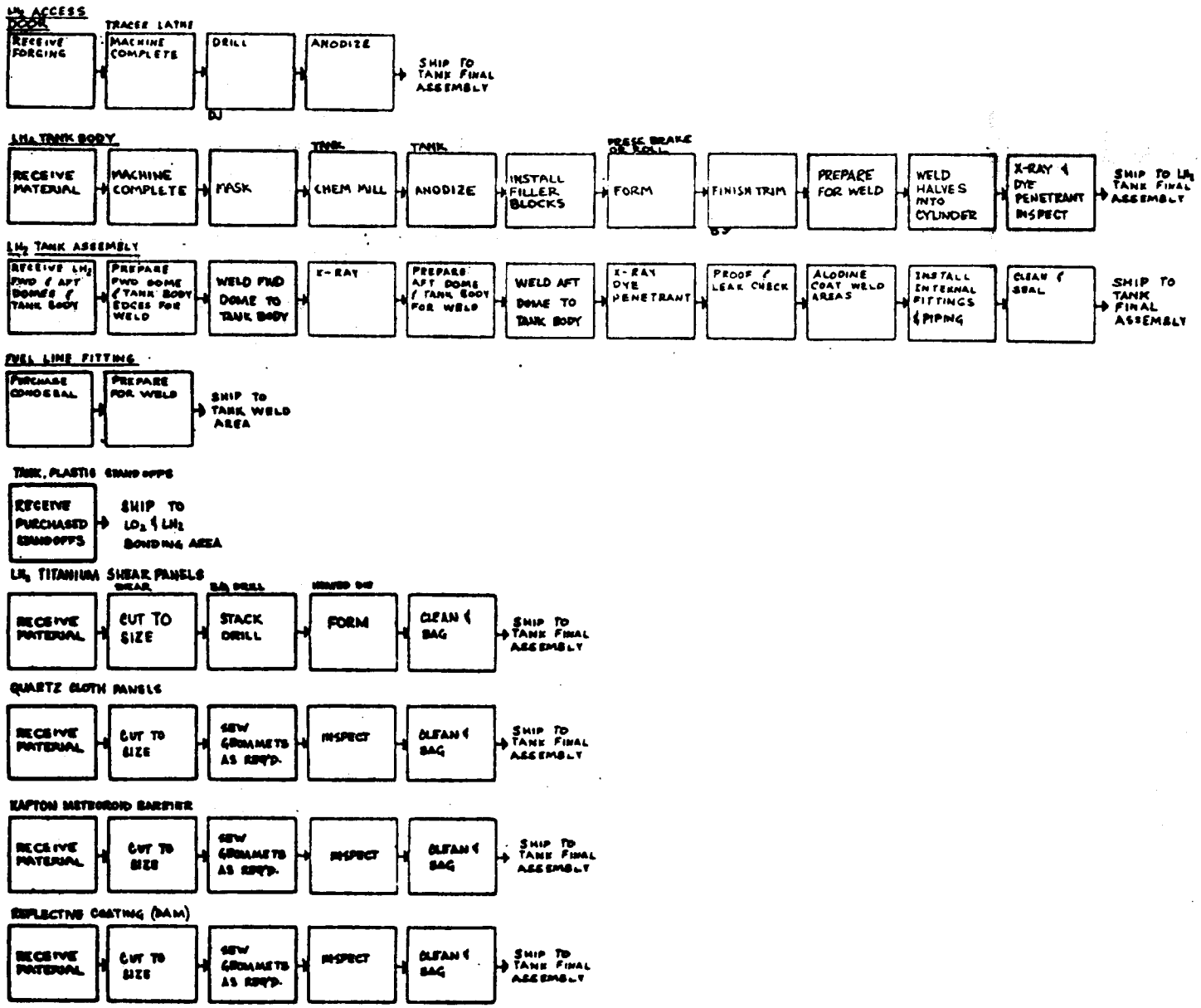


Figure 4-5 Space Tug Fabrication Flow Plan – Option 1 (Page 2 of 7)

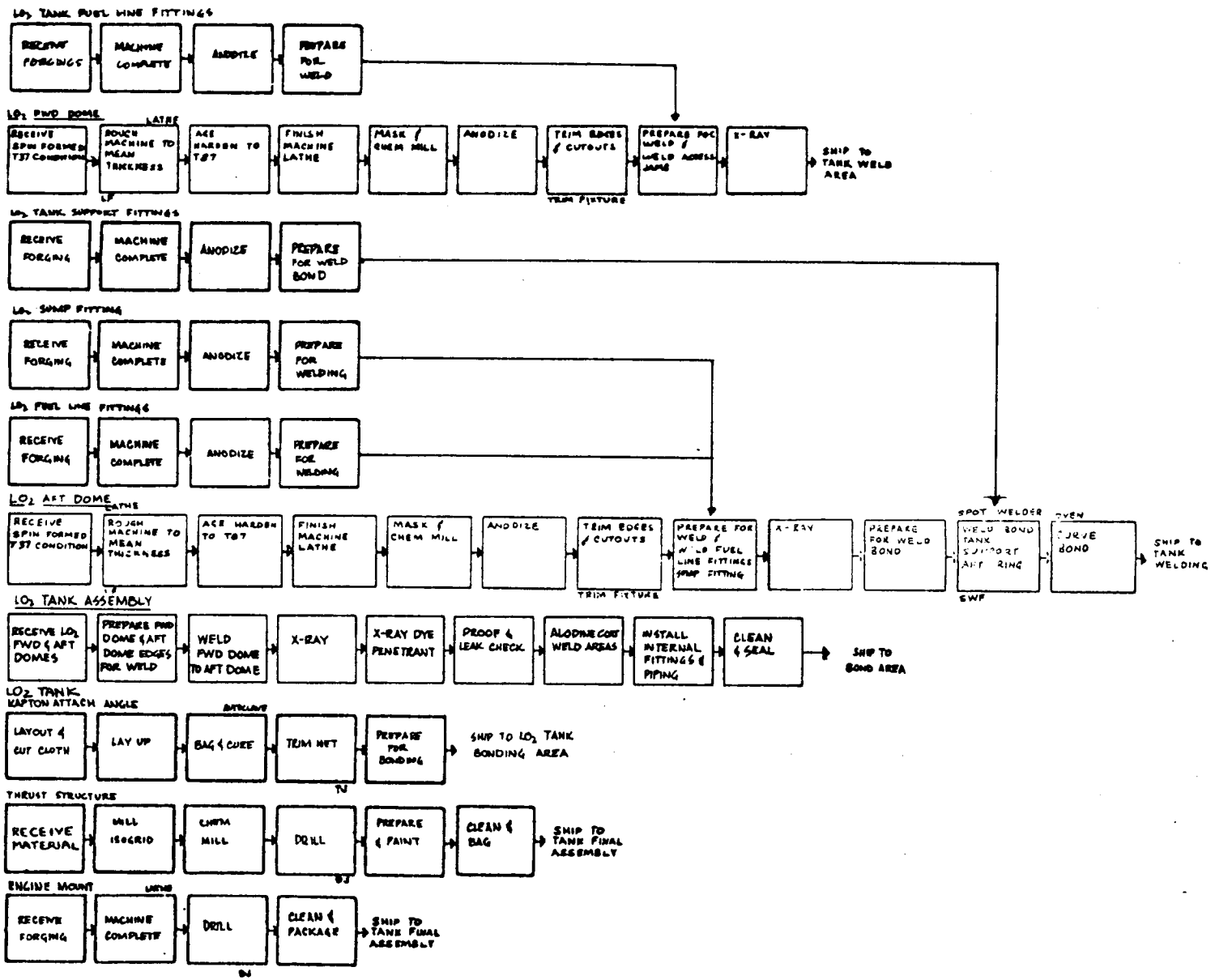


Figure 4-6 Space Tug Fabrication Flow Plan – Option 1 (Page 3 of 7)

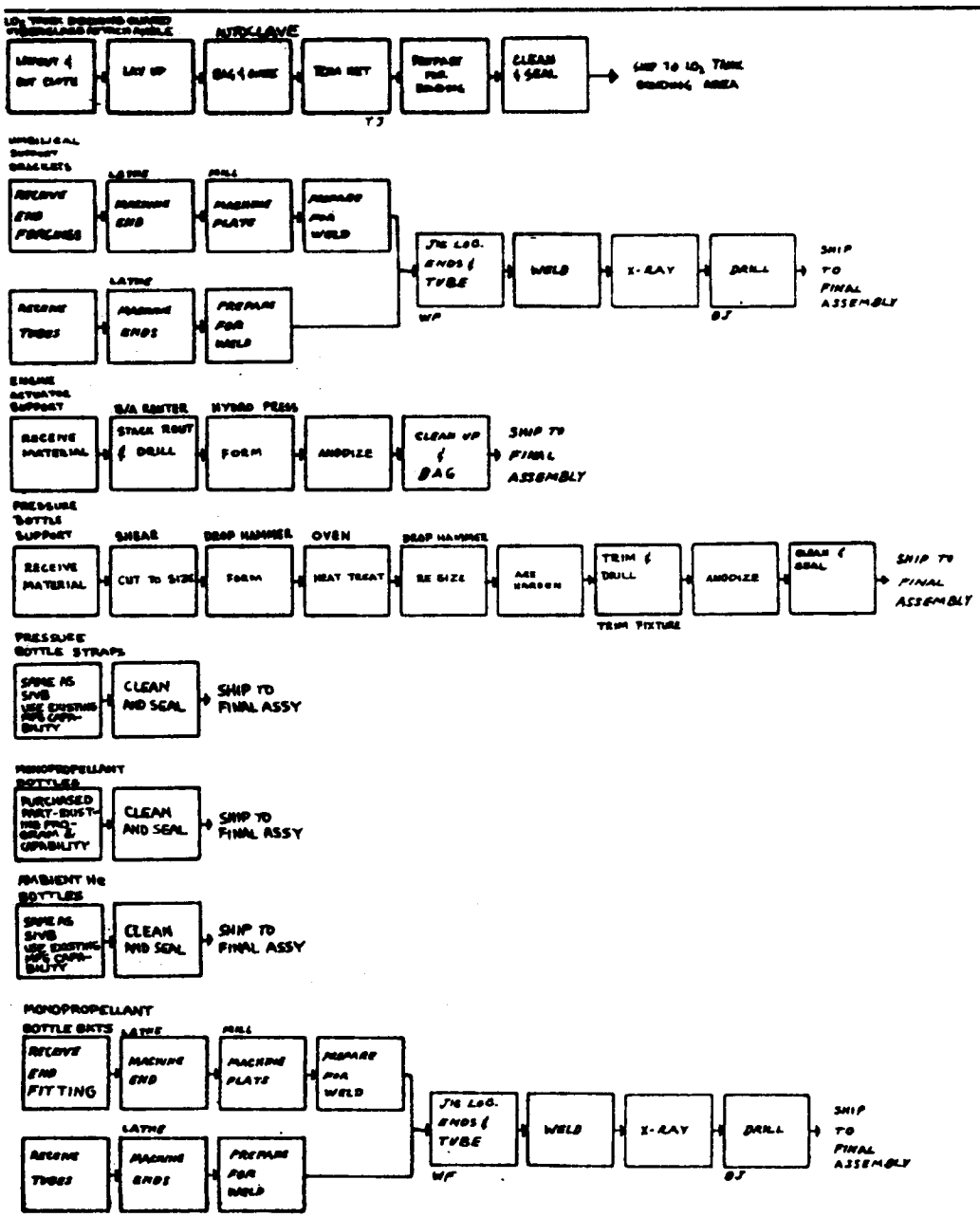


Figure 4-7 Space Tug Fabrication Flow Plan – Option 1 (Page 4 of 7)

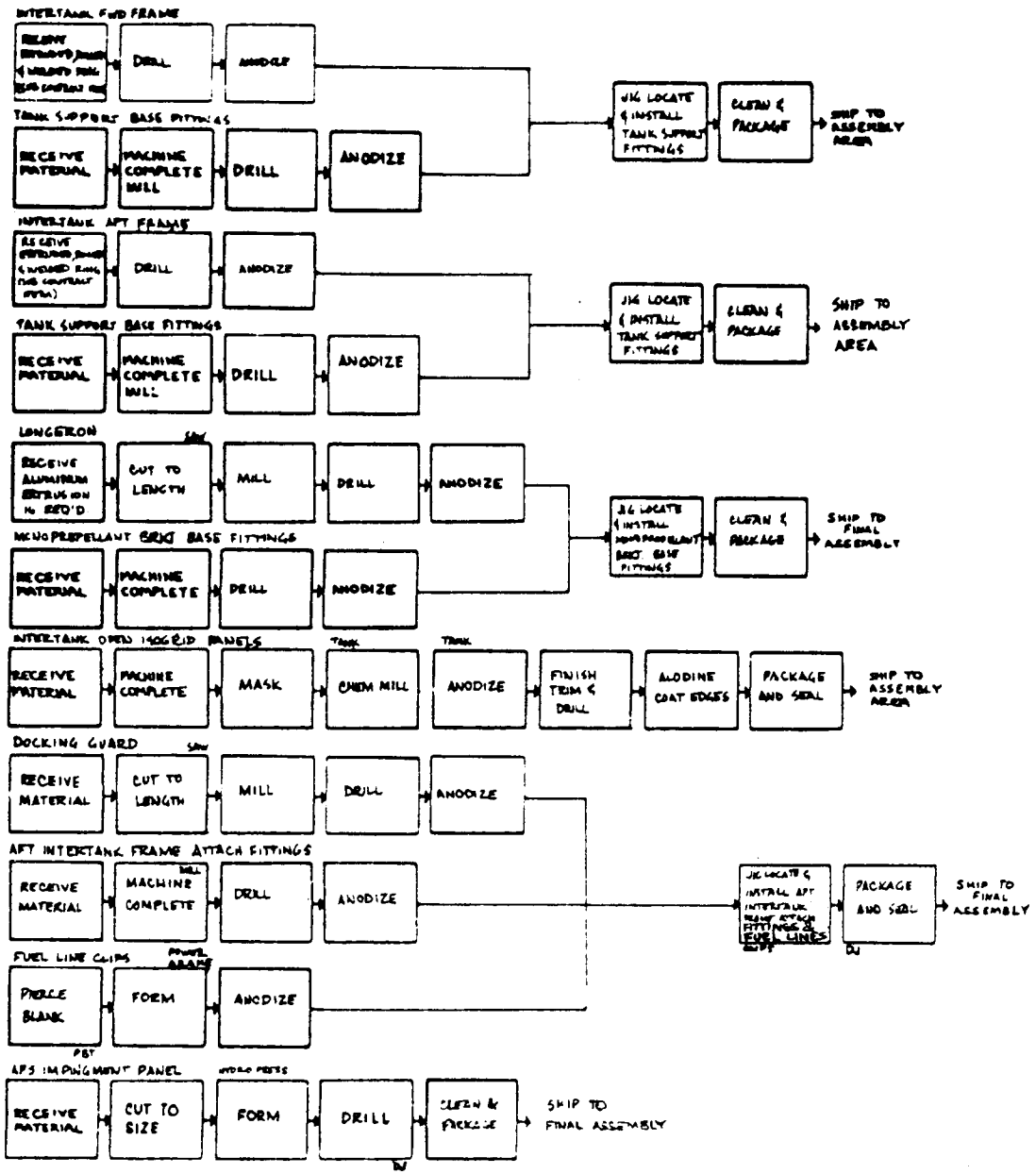


Figure 4-8 Space Tug Fabrication Flow Plan – Option 1 (Page 5 of 7)

4.1.3.2 Tank Bonding Plan

The tank bonding and insulation plan for the bonding of the insulation and the Kapton purge bag stand-offs is delineated in the space tug fabrication flow plan see Figure 4-9. SIVB technology and new bonding processes currently being developed in-house will be implemented into the tank bonding and insulation plan. The plastic stand-off's will be bonded to the tank wall and domes, the double aluminized mylar (DAM) will be fitted to the tank and will be pierced by the plastic standoff's and bonded to the tank.

4.1.3.3 Final Assembly and Final Joining Plan

The final assembly and final joining line sequence flow are outlined in the Final-Assembly/Joining flow plan see Figure 4-10. The LO_2 and the LH_2 tanks are built-up as modular assemblies in the horizontal mode. The LO_2 and the LH_2 subassembly jigs are then mated per leader pins and index points and the final joining, installations, and checkout are accomplished. After joining, checkout, integration etc., the space tug is emplaced into a handling fixture for installation of final closeouts. The interface requirements are verified per a master fixture, the center of gravity of the vehicle is established and the completed vehicle is bagged and prepared for shipping.

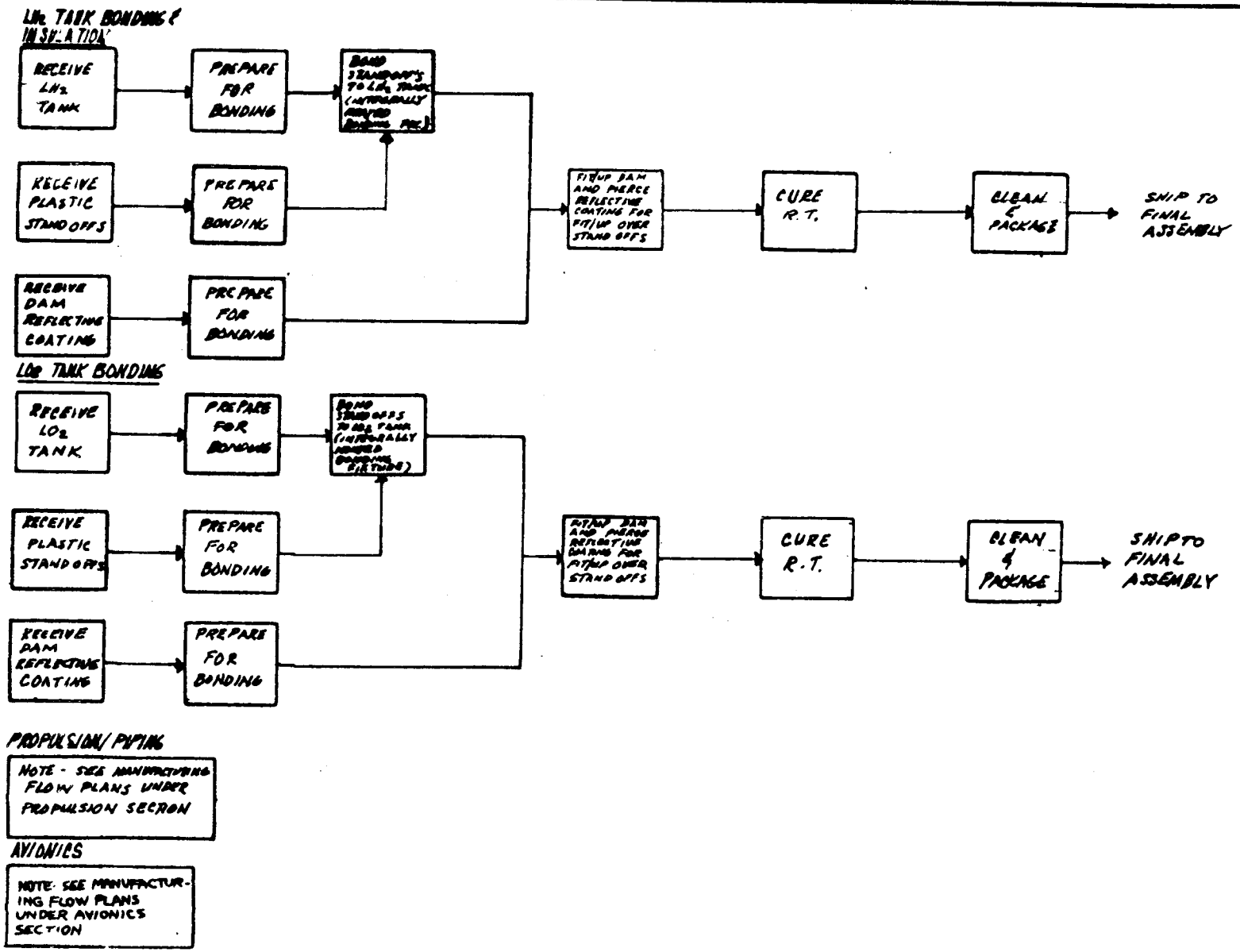


Figure 4-9 Space Tug Bonding and Insulation Flow Plan – Option 1 (Page 6 of 7)

4.1.3.4 Propulsion System

The major components which comprise the LO_2 and LH_2 propulsion ducts systems are as follows:

1. LO_2 Feed Duct and Sump Assembly
2. LO_2 Fill and Drain Duct
3. LO_2 Emergency Dump Duct
4. GO_2 Vent Duct
5. LH_2 Engine Feed Duct
6. LH_2 Fill and Drain Duct
7. GH_2 Vent Ducts

The external portions of all the ducts are 304L corrosive resistant steel (CRES) tubing with approximately 0.030 inch wall thickness. That portion of the duct which passes into the tanks will be 2219 aluminum. Master tooling parts (MTP's) will be developed for each duct to furnish the required manufacturing data for fabrication and weld assembly.

Each duct will be manufactured and tested as an integral unit. Upon installation, each duct system will be subjected to simple leak tests prior to system checkout. Manufacturing requirements are currently state-of-the-art.

The pneumatic system for the Space Tug is presented in Section 4.1.3.4.8.

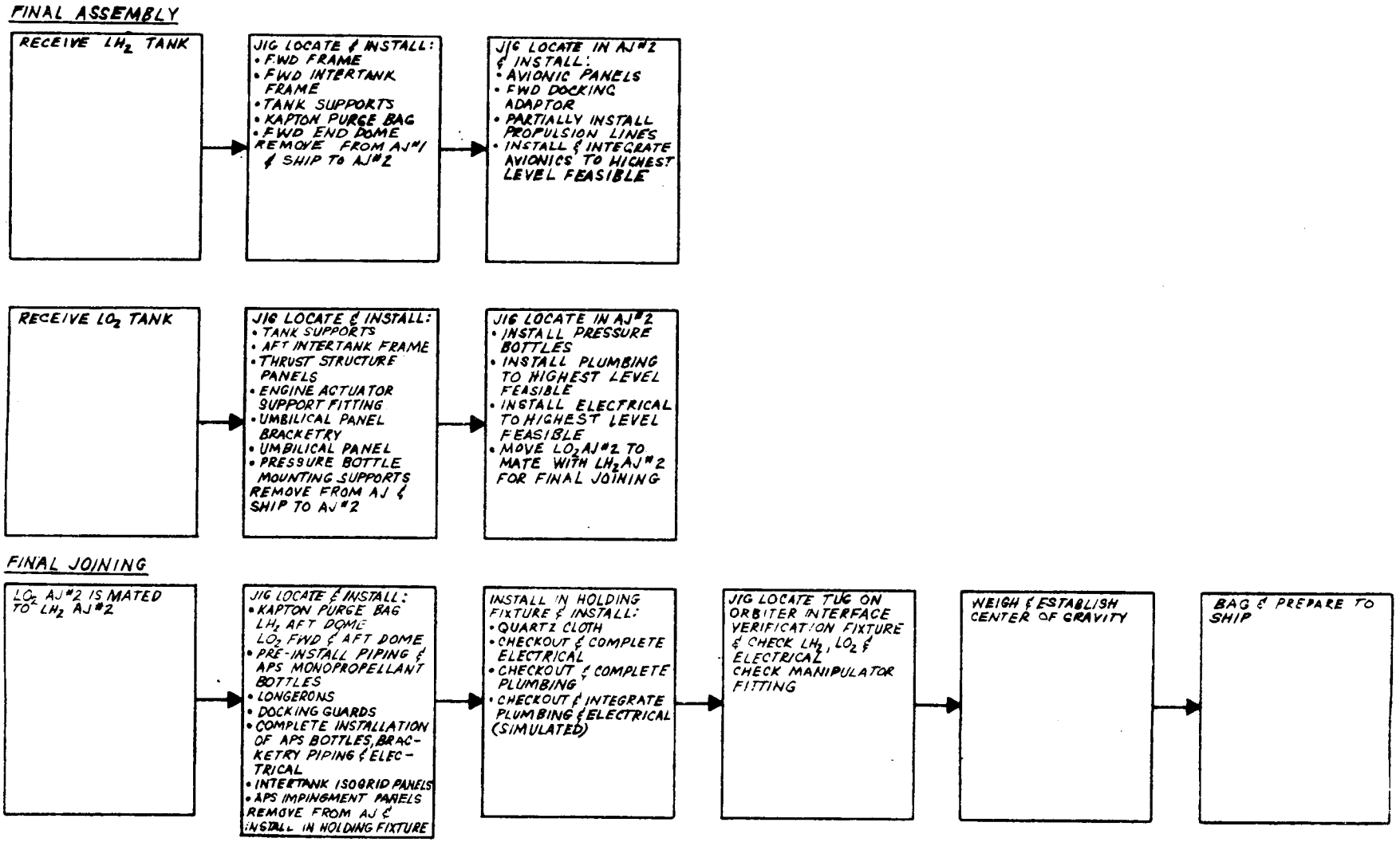


Figure 4-10 Space Tug Final – Assembly/Joining Flow Plan – Option 1 (Page 7 of 7)

4.1.3.4.1 LO_2 Feed Duct and Sump Assembly

The LO_2 feed duct is approximately 4 feet long, formed to connect the LO_2 tank with the engine. The duct assembly is made from four different segments of 2 inch diameter tubing with 3 flex gimbals and 2 flanges. The material is 304L corrosive resistant steel. (see Figures 4-11 to 4-13)

The sump assembly is approximately 15 inches in diameter at the tank attach flange and has a 2-inch nominal diameter flange on the duct end and is about 15 inches overall. The sump will be made from a "closed die" forging, which will only need minimal cleanup and attach hole drilling prior to assembly with the flange. The material is 2219 aluminum.

The welding operations will be present state-of-the-art. TIG welding processes will be used for the duct, with automatic TIG tube welding equipment, when applicable, typical for both steel and aluminum.

Handling fixtures will be furnished for protective moving, insulation application and storage. The size of the assemblies will allow hand pickup and no slings are anticipated. The flex gimbals will be purchased.

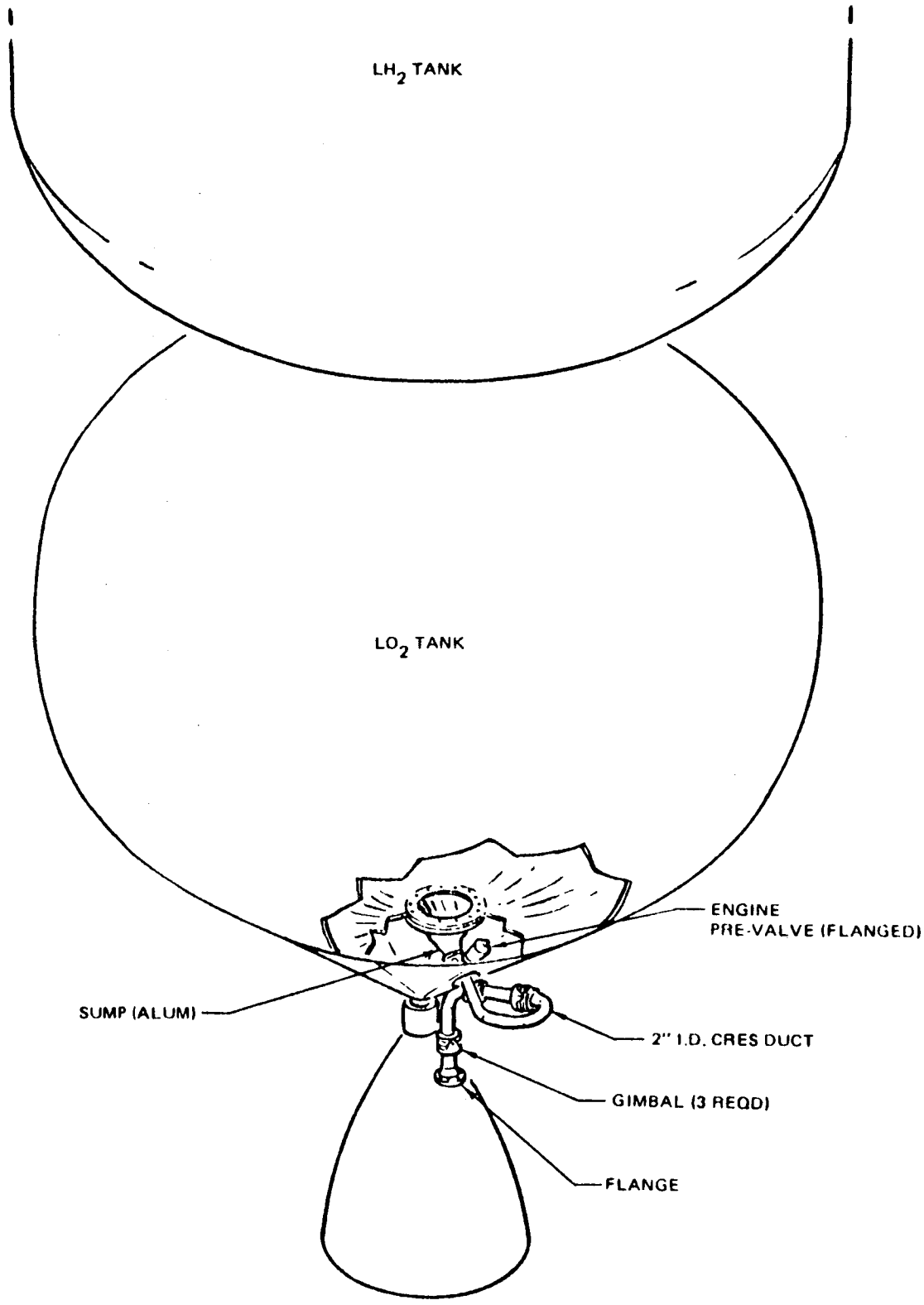


Figure 4-11 LO_2 Engine Feed Duct

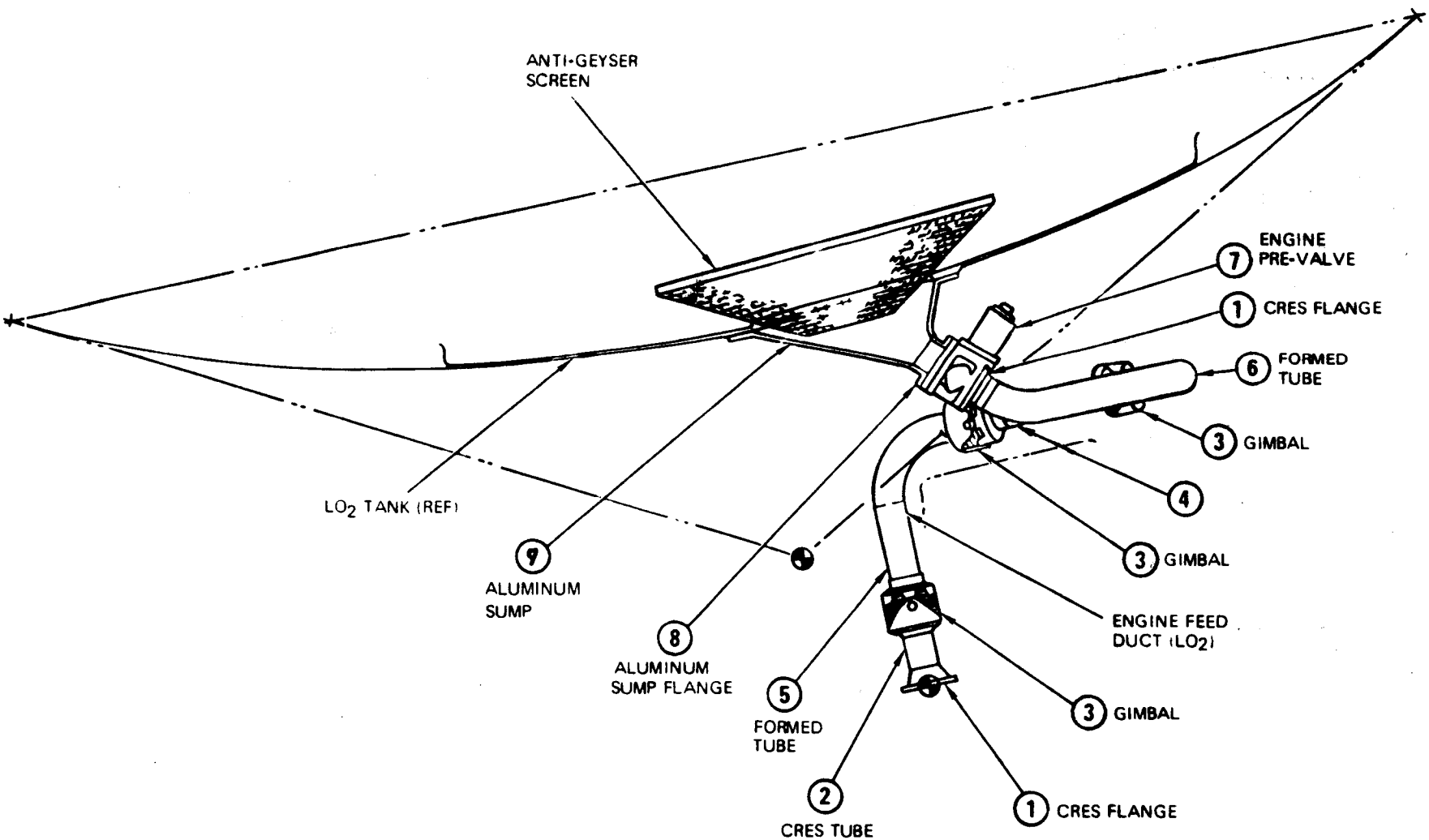


Figure 4-12 LO_2 Feed Duct and Sump Assembly

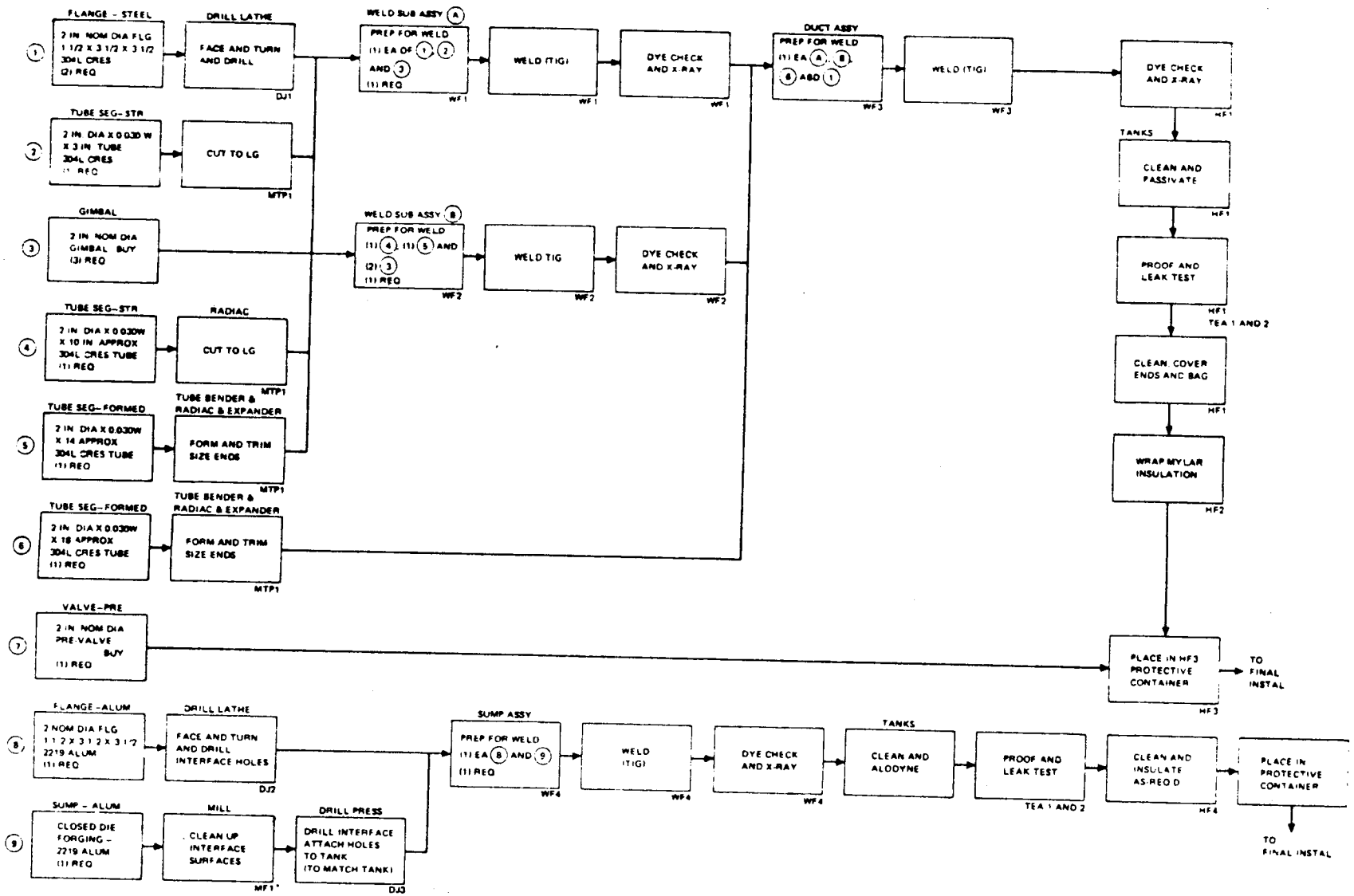


Figure 4-13. Space Tug LO_2 Feed Duct & Sump Assembly Manufacturing Sequence

4.1.3.4.2 LO_2 Fill and Drain Duct

The LO_2 fill and drain duct consists of a short corrosive resistant steel (304L) flex section, and an aluminum (2219) line that interfaces with the CRES flex section and is welded to LO_2 tank aft dome and extends into the LO_2 tank to approximately the aft centerline. (See Figures 4-14 to 4-16)

The flex section is made from 2-inch diameter tubing with two flex bellows, two flanges and a fill/drain valve. The CRES flex section is about 16 inches long. The aluminum section is made from 2-inch diameter formed tubing with a single flange which interfaces with the flex section. The aluminum section will be welded to the aft LO_2 tank dome during tank assembly.

The welding operations will be present state-of-the-art. Automatic TIG tube welding equipment will be used, when applicable.

Handling fixtures will be furnished for protective storage. No slings (HFH) will be required, as hand pickup is adequate. The flex bellows and control valve will be purchased.

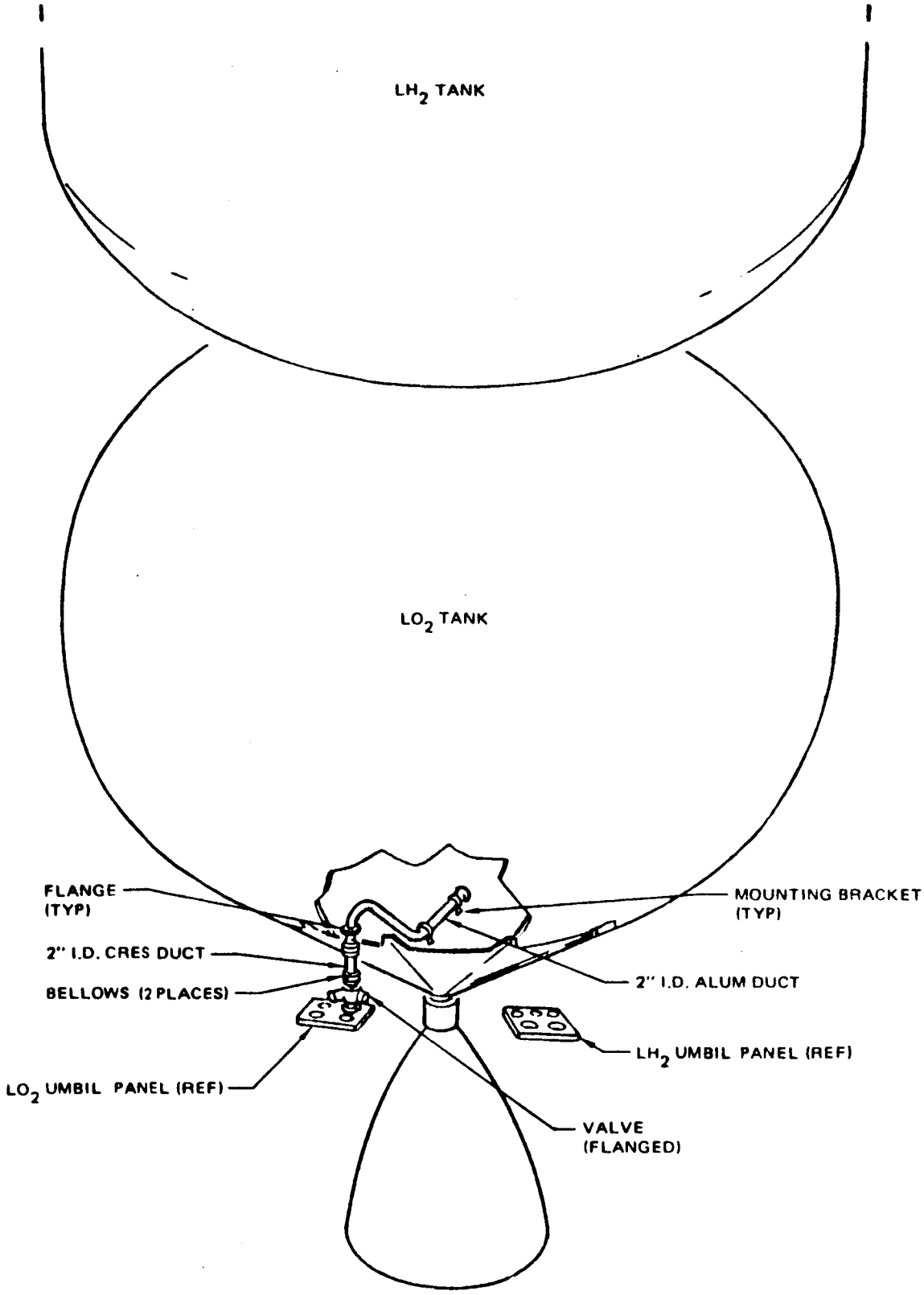


Figure 4-14 LO_2 Fill/Drain Duct

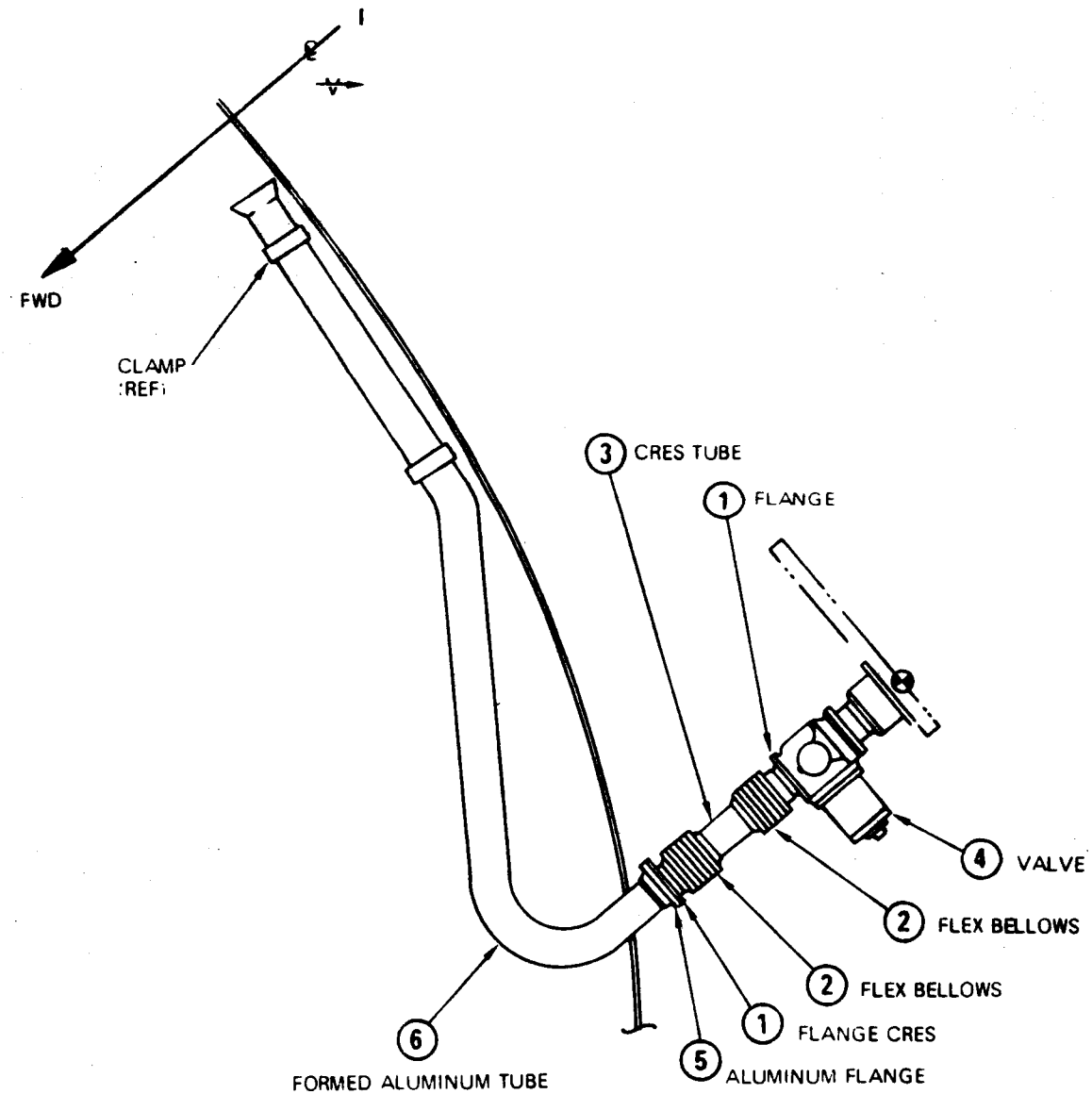


Figure 4-15 LO_2 Fill/Drain

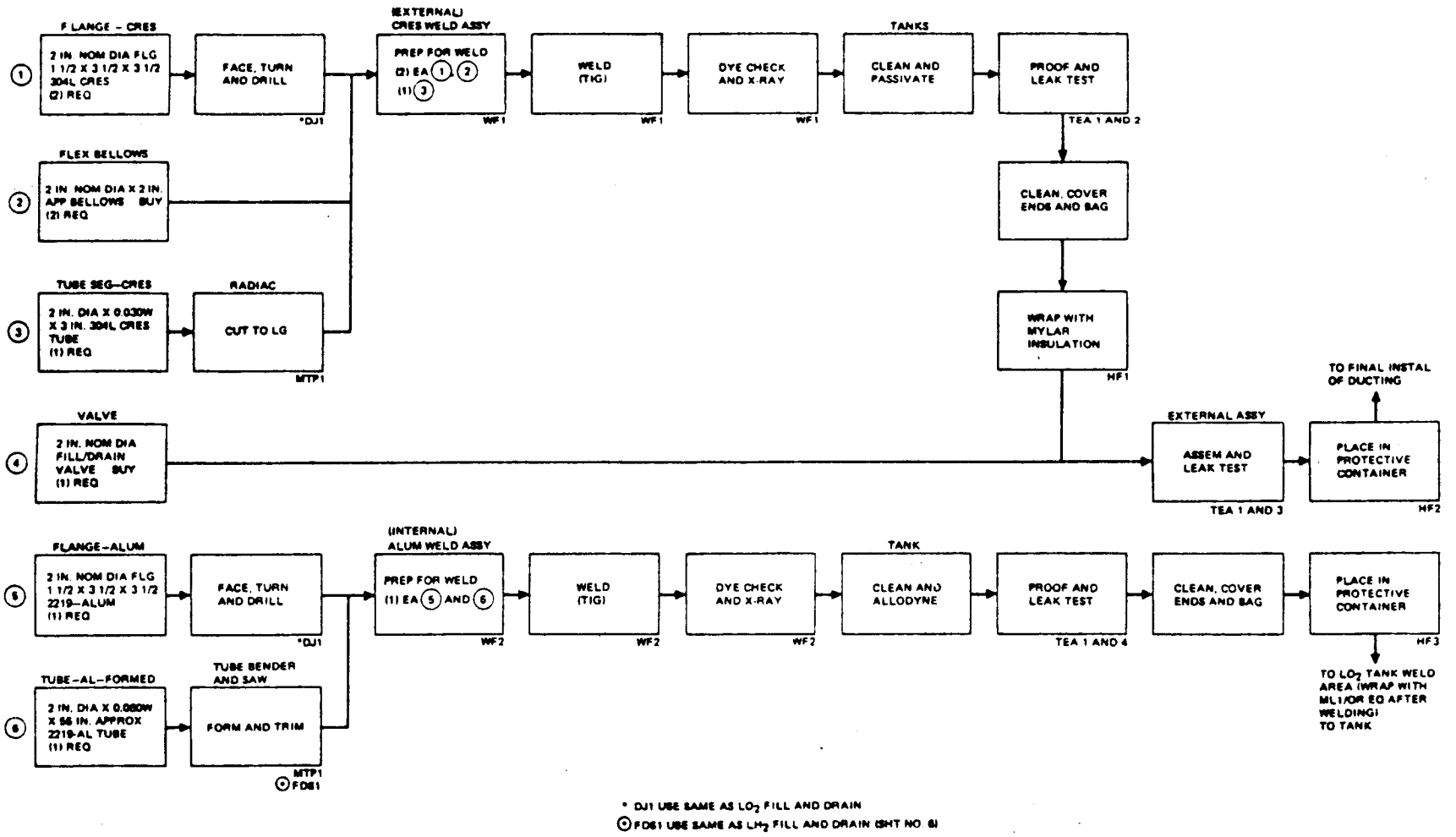


Figure 4-16. Space Tug LO_2 Fill & Drain Duct – Manufacturing Sequence

4.1.3.4.3 LO_2 Emergency Dump Duct

The LO_2 emergency dump duct is approximately 8-feet overall. The duct consists of a corrosive resistant steel flex section and a short aluminum section that will be welded to the LO_2 tank. The flex section is made from 3-inch diameter tubing with six flanges, two flex bellows and two control valves. (See Figures 4-17 to 4-21).

The welding operations will be present state-of-the-art. Automatic TIG tube welding equipment will be used, where applicable.

Handling fixtures (HF) will be furnished for protective moving, wrapping insulation and storage. The flex sections will be picked up by hand and only one sling (HFH) will be furnished to hoist the complete flex section. The flex bellows and the dump valves will be purchased.

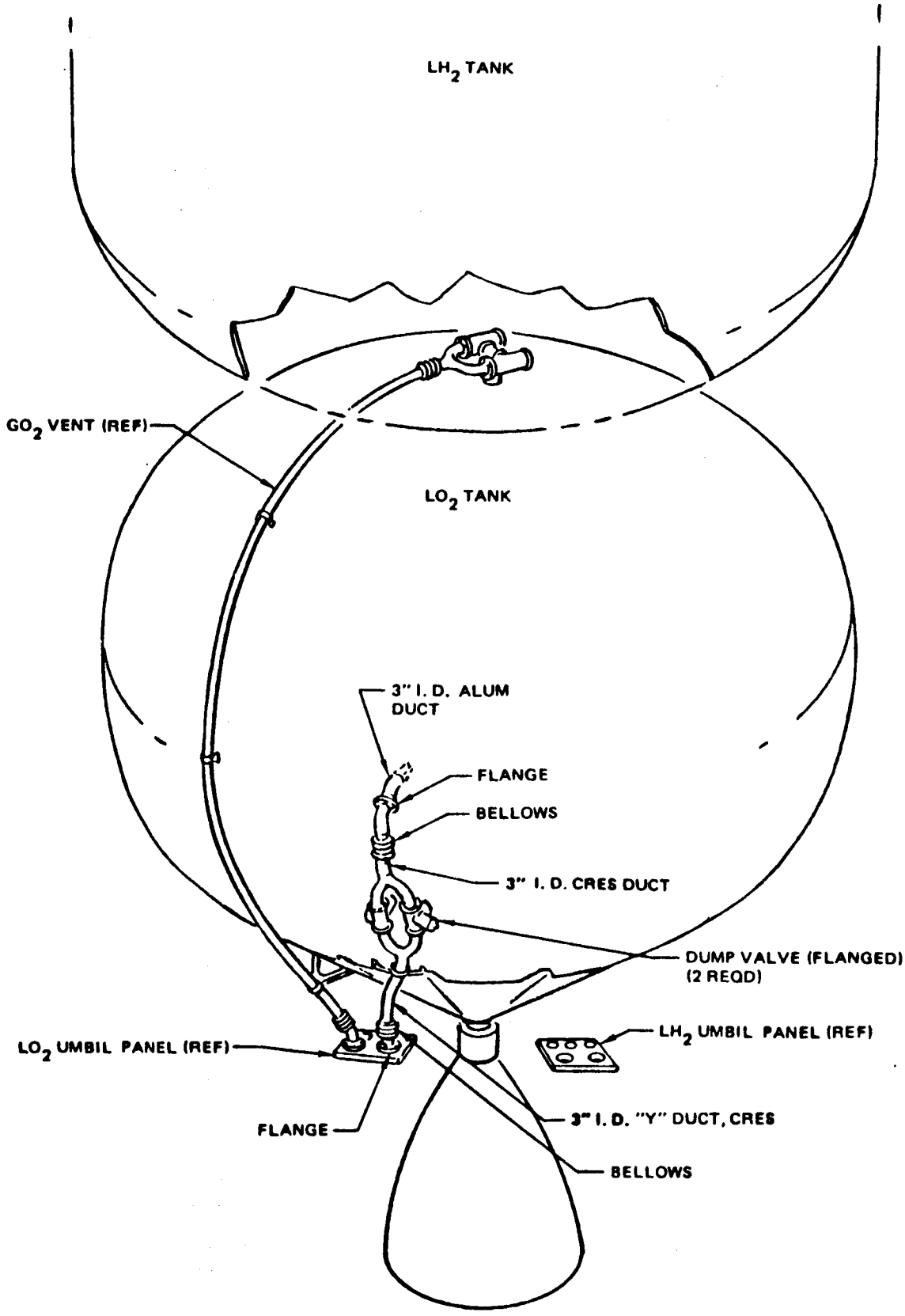


Figure 4-17 Emergency Dump Duct

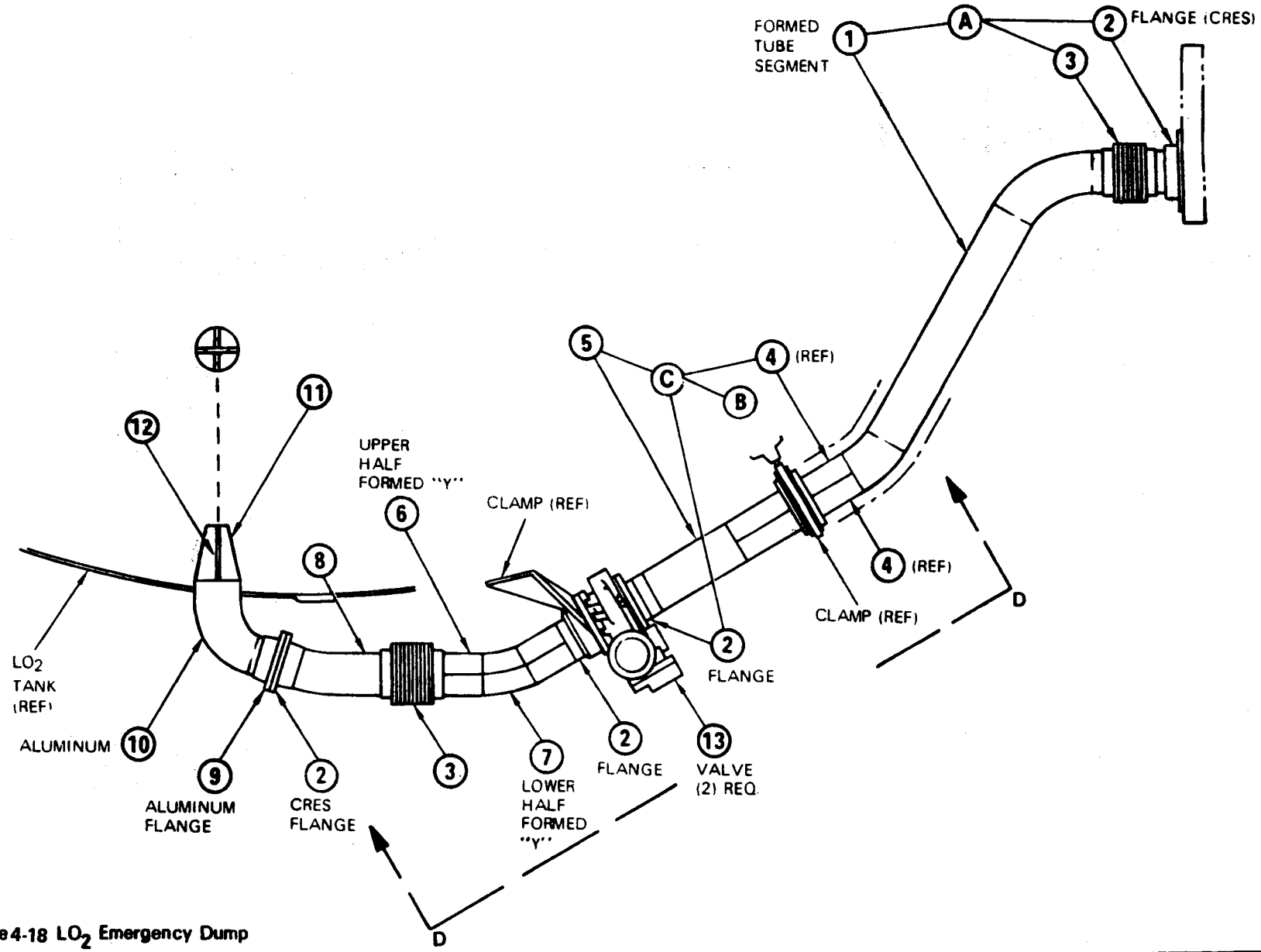


Figure 4-18 LO_2 Emergency Dump

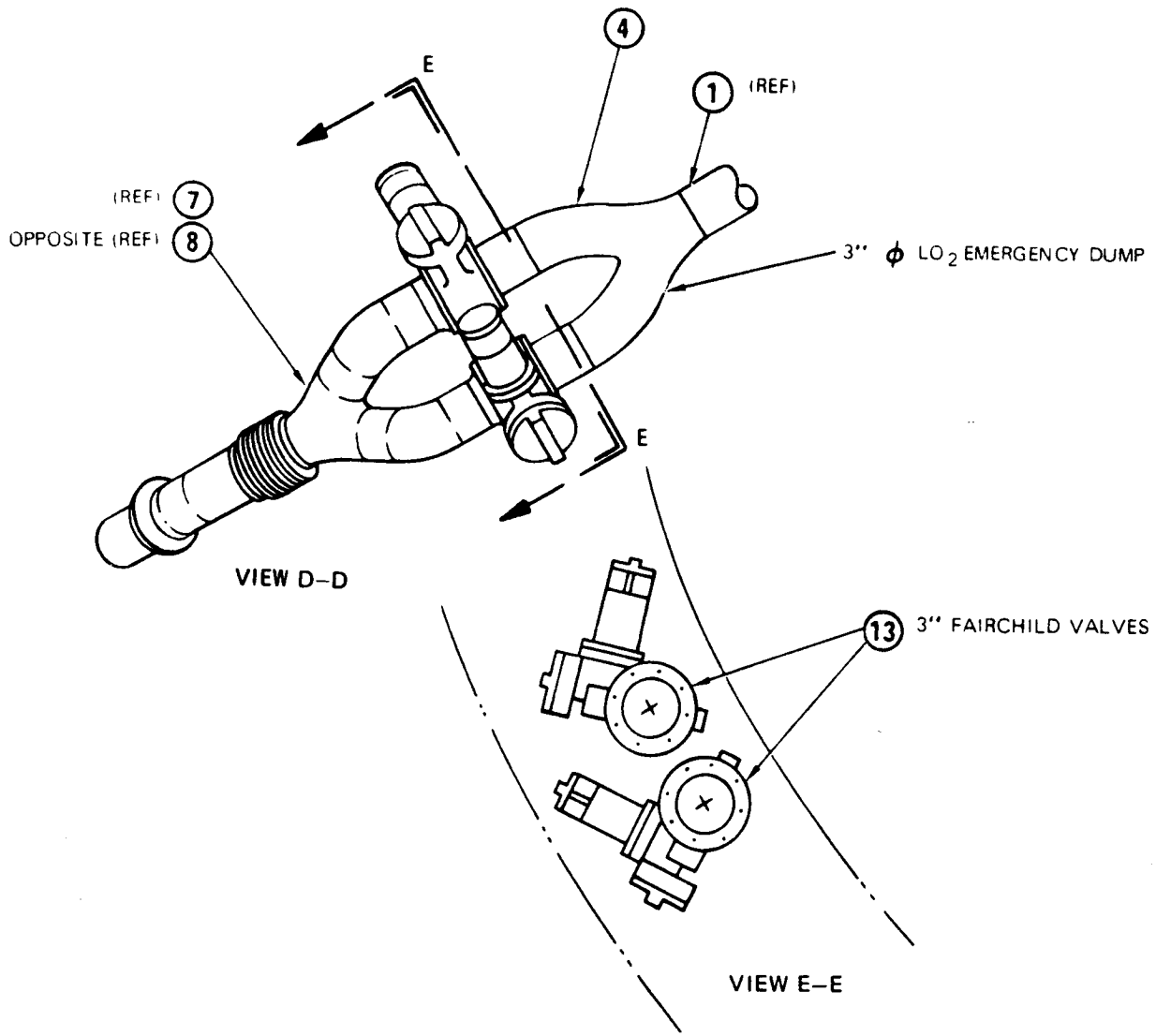


Figure 4-19 LO_2 Emergency Dump

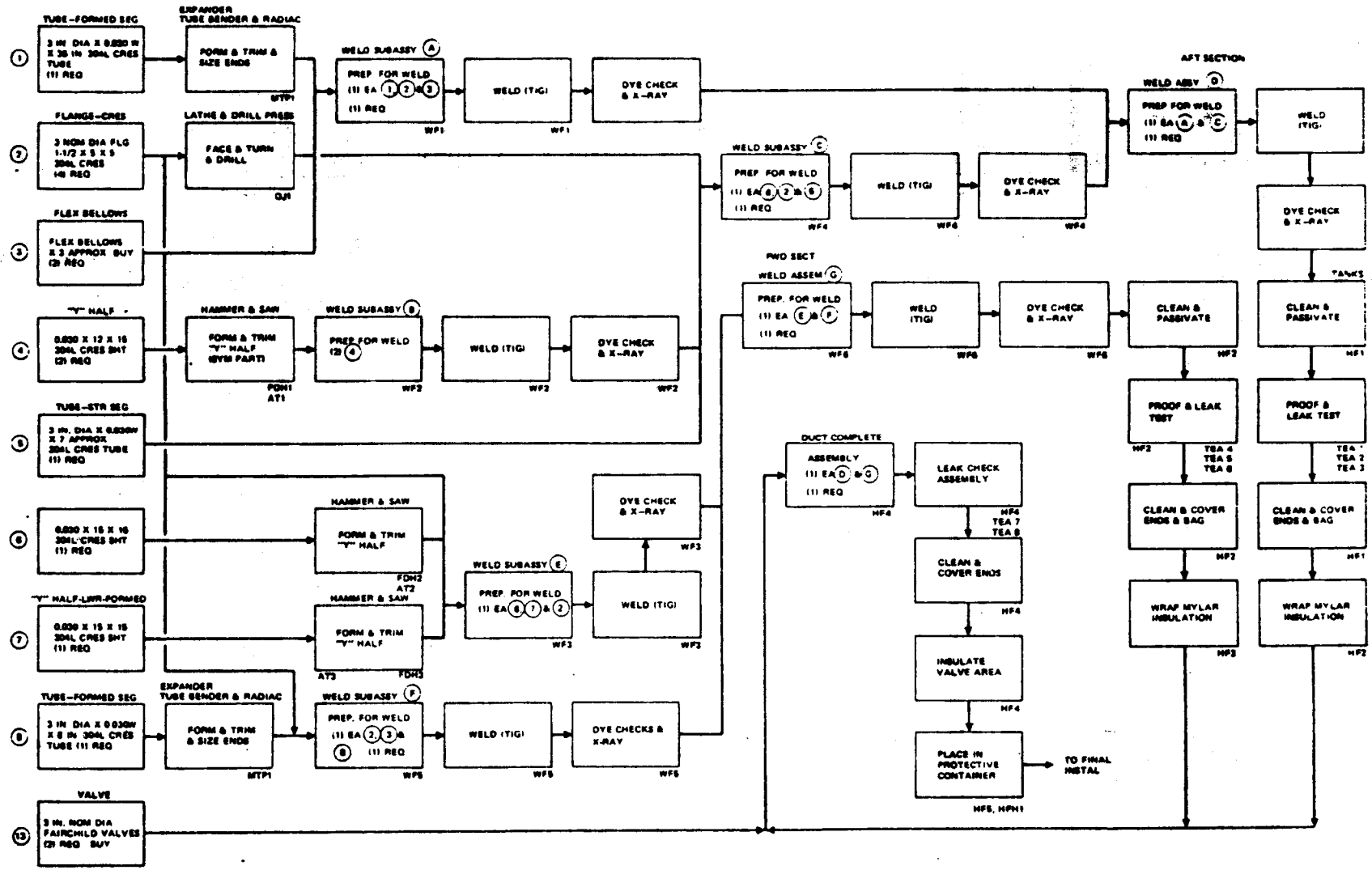


Figure 4-20. Space Tug LO_2 Emergency Dump Duct Manufacturing Sequence (Sheet 1 of 2)

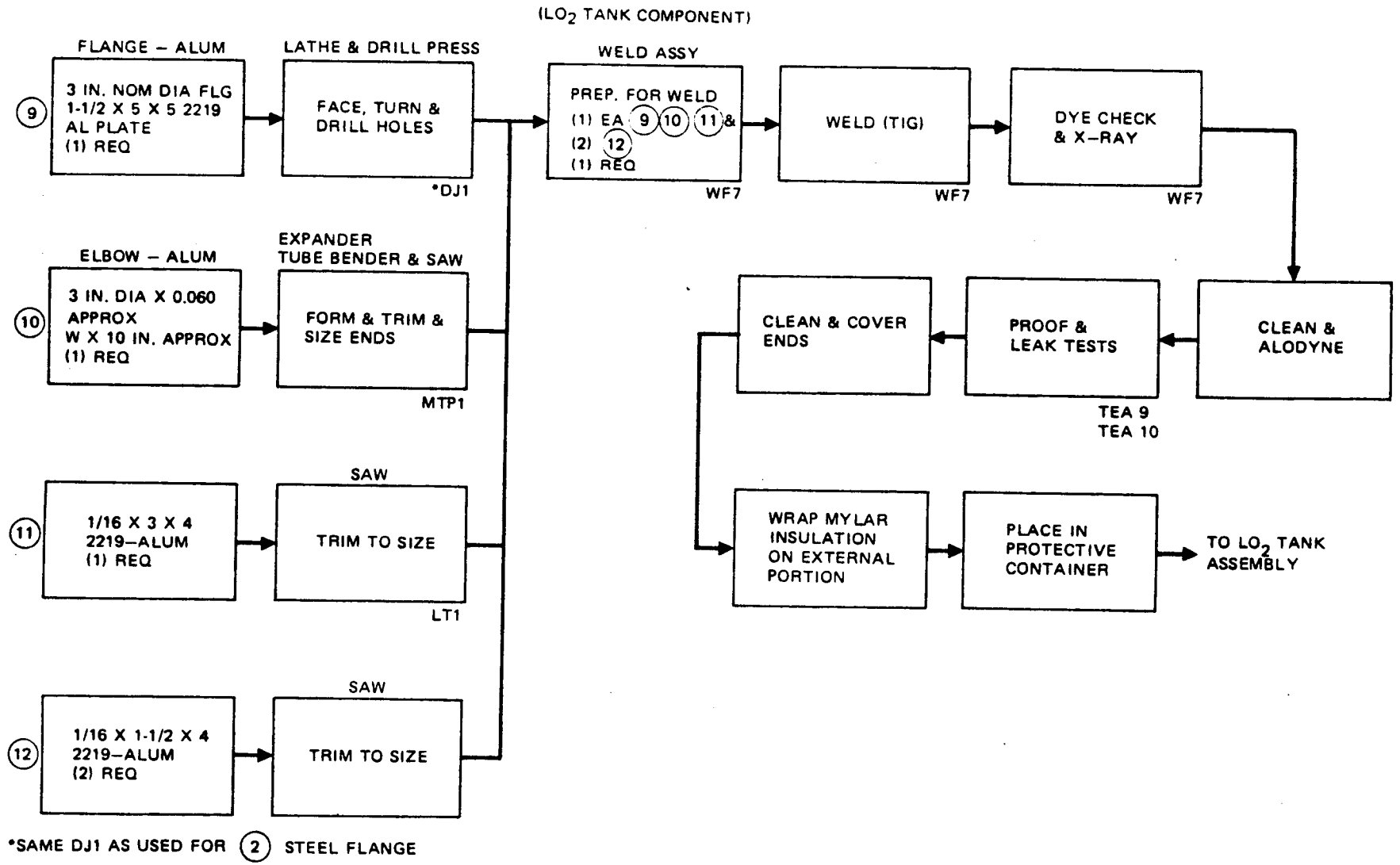


Figure 4-21. Space Tug LO_2 Emergency Dump Duct Manufacturing Sequence (Sheet 2 of 2)

4.1.3.4.4 GO_2 Vent Duct

The gaseous oxygen vent is approximately 15 feet long, formed to connect the LO_2 umbilical to the forward centerline of the LO_2 tank. The forward end of the duct is divided into a "Y" shape with two flanges to attach to the two vent valves. The duct assembly is made from 2 inch diameter tubing with two flex bellows, 3 flanges and two vent valves. The material is 304L corrosive resistant steel. (See Figures 4-22 to 4-24)

The welding operations will be present state-of-the-art. Automatic TIG tube welding equipment will be used, except where not applicable.

Handling fixtures (HF) will be furnished for transportation, insulation wrapping and storage. The assembly will be picked up by a handling fixture sling (HFH), to simplify handling. The flex bellows and vent valves will be purchased.

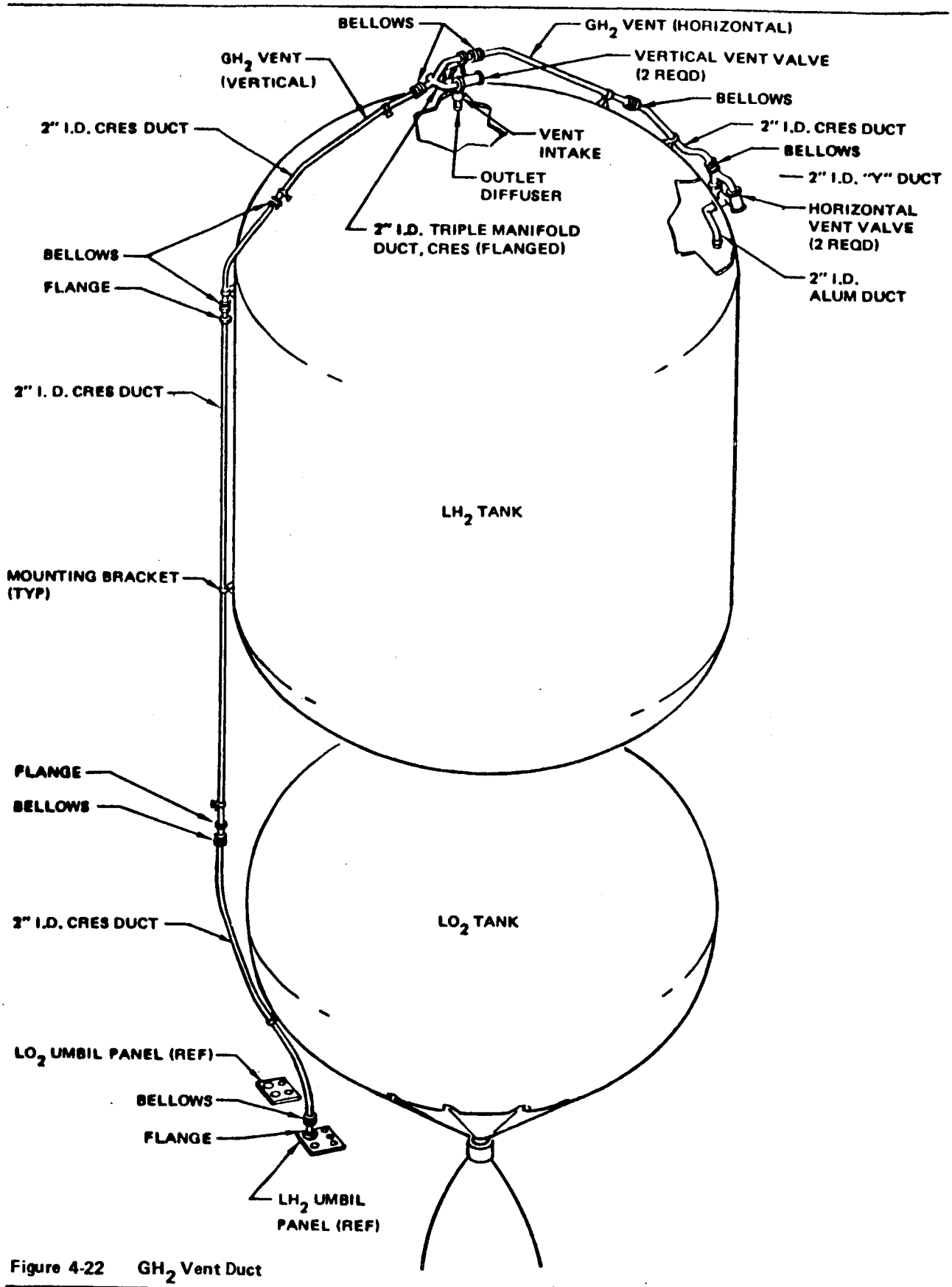


Figure 4-22 GH_2 Vent Duct

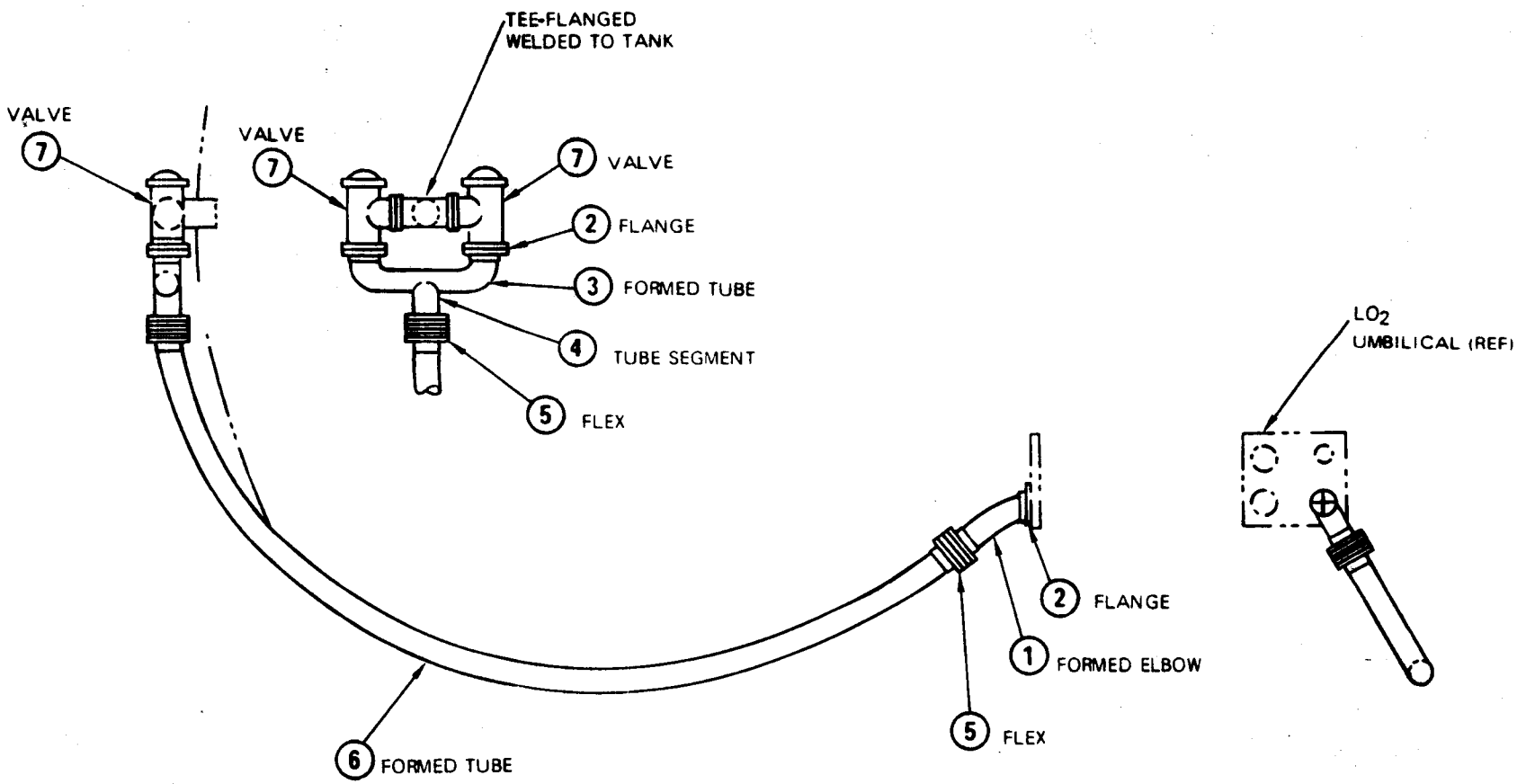


Figure 4-23 GO_2 Vent Duct

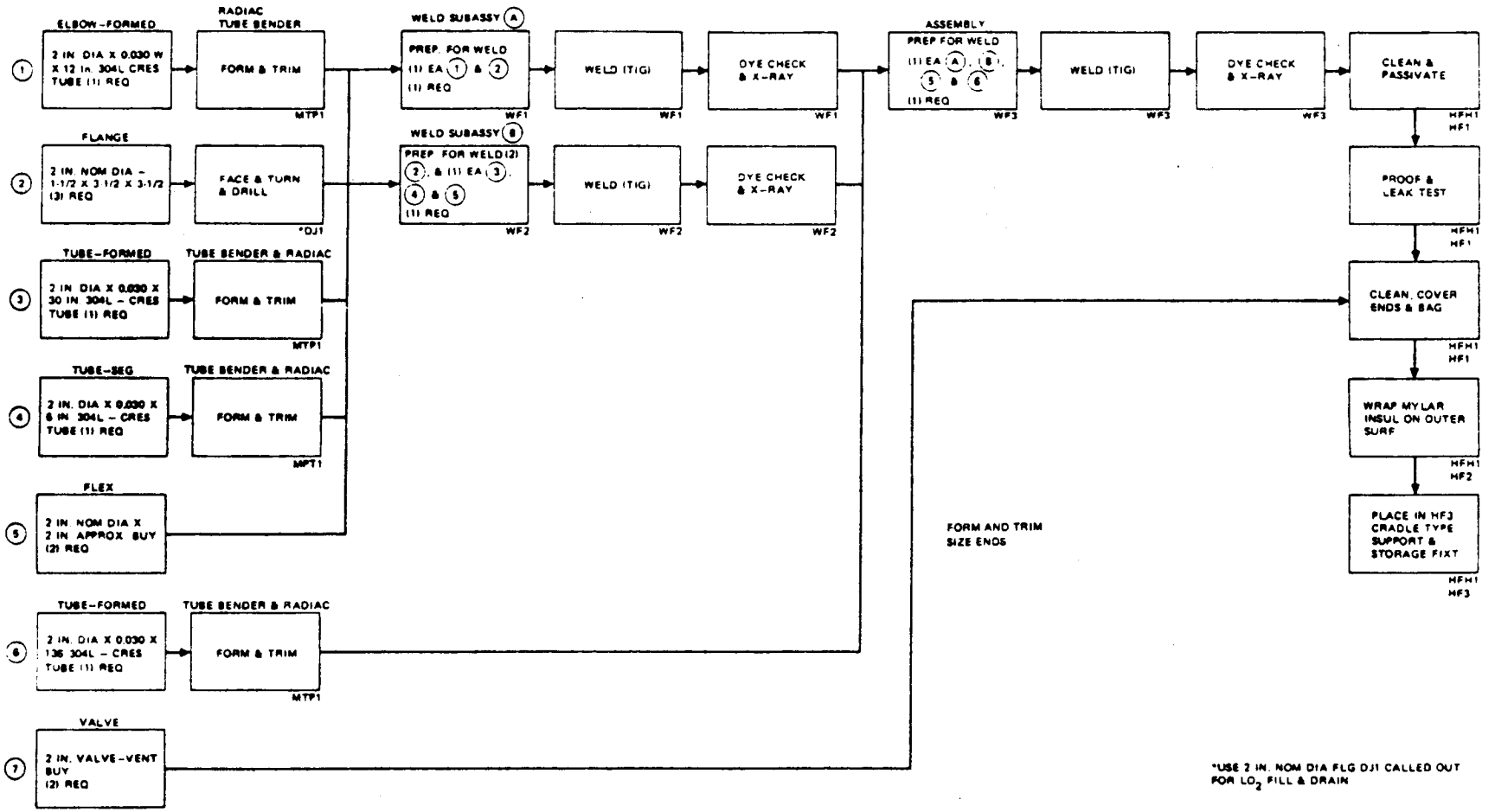


Figure 4-24. Space Tug GO_2 Vent Duct Manufacturing Sequence

4.1.3.4.5 LH_2 Engine Feed Duct

The LH_2 engine feed duct, with the exception of a small single-walled duct aft of the pre-valve, is vacuum jacketed. Vacuum jacketed ducting is within our manufacturing capability, however a cost tradeoff will be necessary to determine if we should make or buy the vacuum jacketed ducting. (See Figure 4-25 thru 4-27).

The LH_2 engine feed duct consists of three sections, refer to illustration: Section A includes the pre-valve and extends to the engine connection. This section is of single-wall construction, insulated with wrapped mylar or equivalent materials. Section B extends from the LH_2 tank sump to the approximate half breadth of the LO_2 tank. This section is double-walled, vacuum jacketed construction. Section C extends from approximately the LO_2 tank half breadth to the pre-valve. This duct section is also double-walled, vacuum jacketed construction. All three sections will use 304L corrosive resistant steel tubing. The flex bellows, pre-valve, burst disks and vacuum fittings will be purchased.

The vacuum jacketed duct sections will require more complex weld fixtures than the single walled ducts, and a precise sequence of assembly must be followed.

Each duct section will be proof and leak tested individually and after they are assembled, a simple leak test is required to assure the interface sealing reliability.

The welding operations will be present state-of-the-art. Automatic TIG tube welding equipment will be used, except where not applicable.

Handling fixtures (HF) will be furnished for transportation and storage. The large assemblies will be picked up by handling fixture--hoist (HFH) to prevent damage to the assemblies.

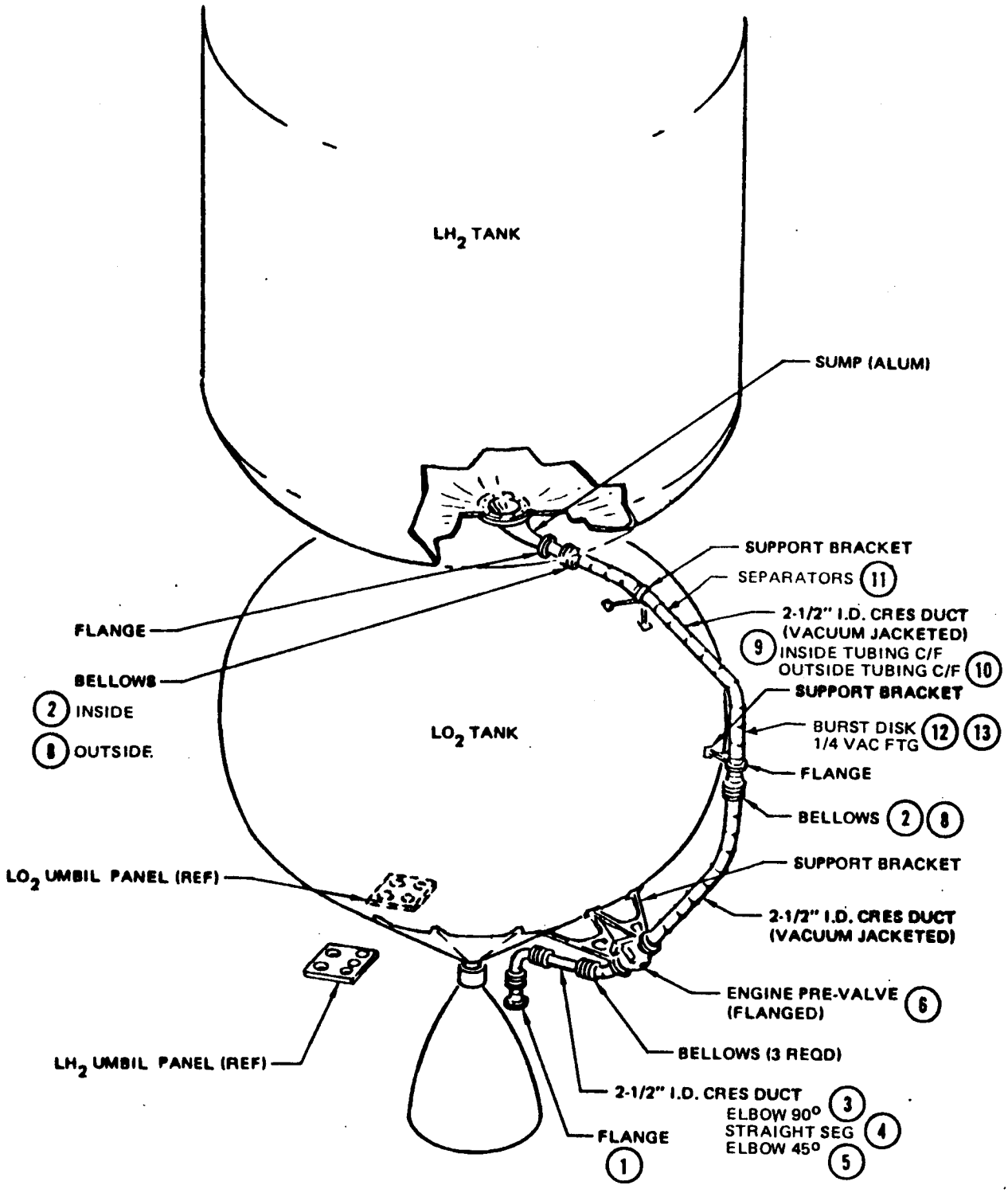


Figure 4-25 LH_2 Engine Feed Duct

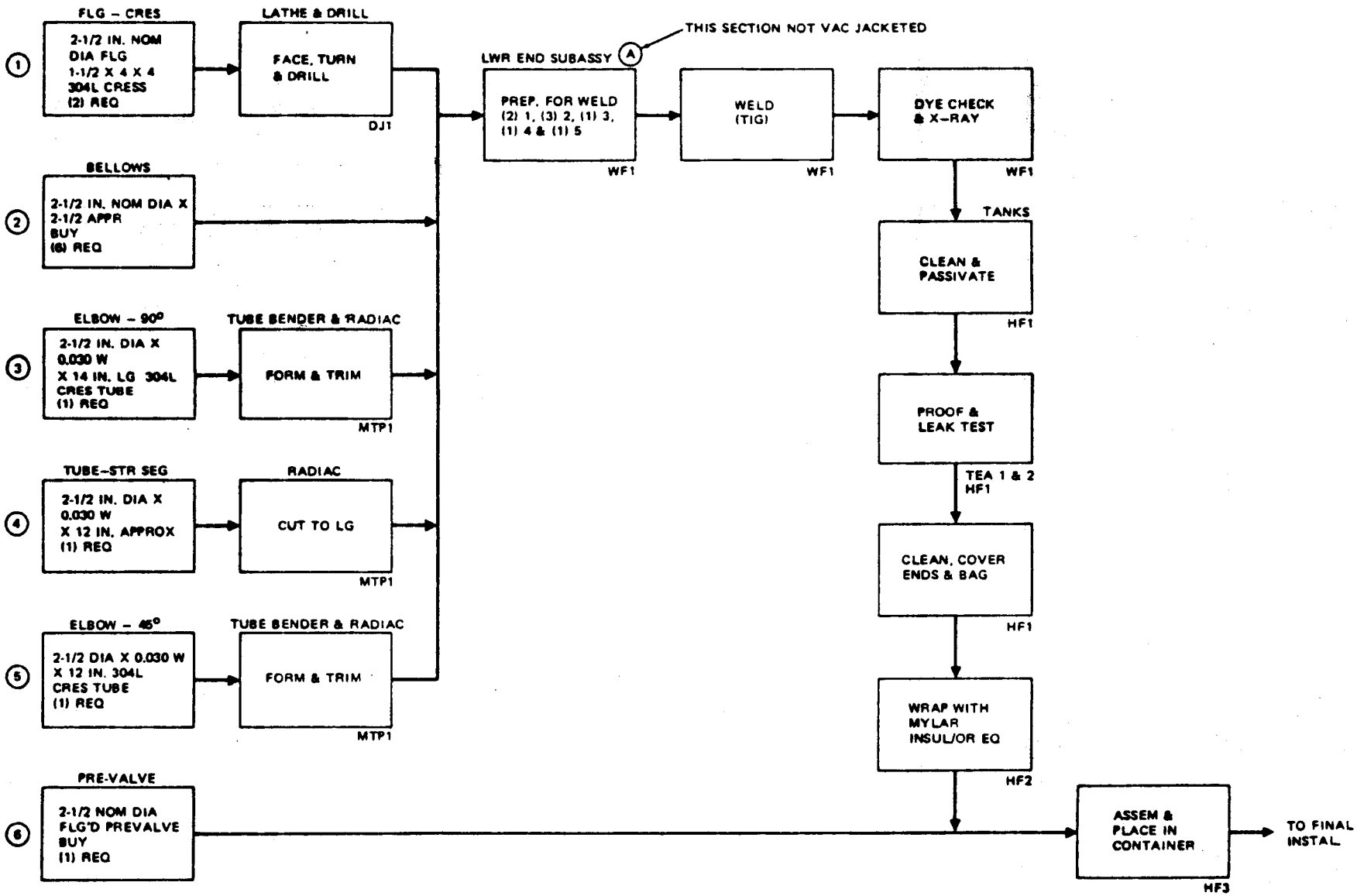


Figure 4-26 Space Tug LH_2 Feed Duct – Lwr Section Manufacturing Sequence (Sheet 1 of 2)

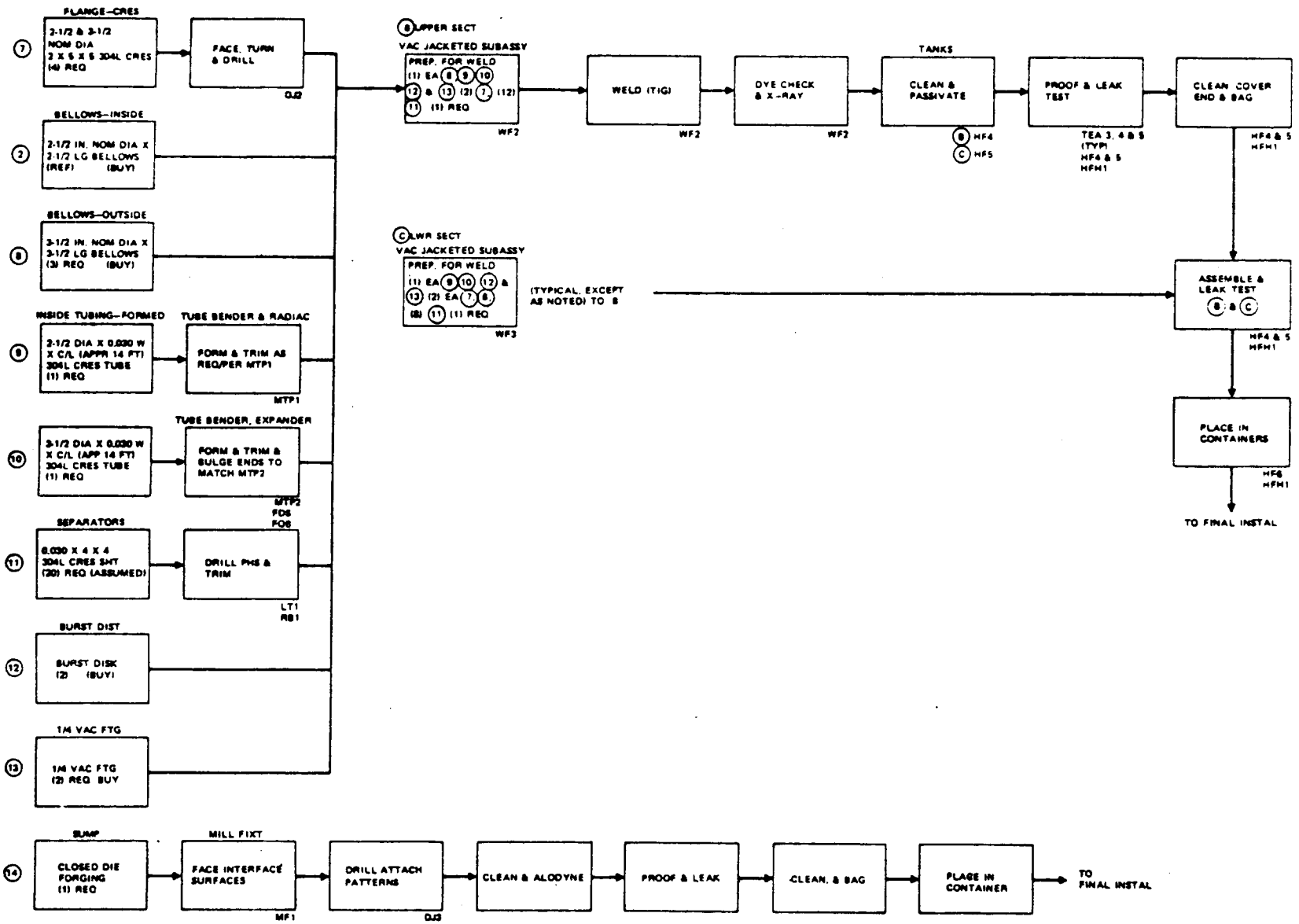


Figure 4-27 Space Tug LH_2 Feed Duct – Vac Jacked Section Manufacturing Sequence (Sheet 2 of 2)

4.1.3.4.6 LH_2 Fill/Drain Duct

The LH_2 fill/drain extends from the LH_2 umbilical panel up to and into the LH_2 tank. The duct is composed of many subassemblies which will make up ten (10) complete sections, as follows:

Aft "Y" section (D)
Forward "Y" section (F)
Inboard flex section (G)
Outboard flex section (H)
Forward vacuum jacketed section
Aft vacuum jacketed section
Inboard tank penetration (L) (aluminum)
Inboard tank penetration (N) (aluminum)
Outboard-inside flange extension into LH_2 tank (O) (aluminum)
(See Figure No. 4-28 thru 4-36)

The ducts will be made from 3046 corrosive resistant steel tubing, except that any duct which penetrates and/or extends into the LH_2 tank will be 2219 aluminum tubing. The flex bellows, valves, burst disks and vacuum fittings will be purchased. The vacuum jacketed duct sections will require more complex weld fixtures than the single walled ducts, and a precise sequence of assembly must be followed.

Each duct section will be proof and leak tested individually after assembly, while a simple leak test is required to leak test the interface sealing.

The welding operations will be present state-of-the-art. Automatic TIG tube welding equipment will be used, except where not applicable.

Handling fixtures (HF) will be furnished for transportation and storage. The large assemblies will be picked up by handling fixture-hoist (HFH) to prevent damage to the assemblies.

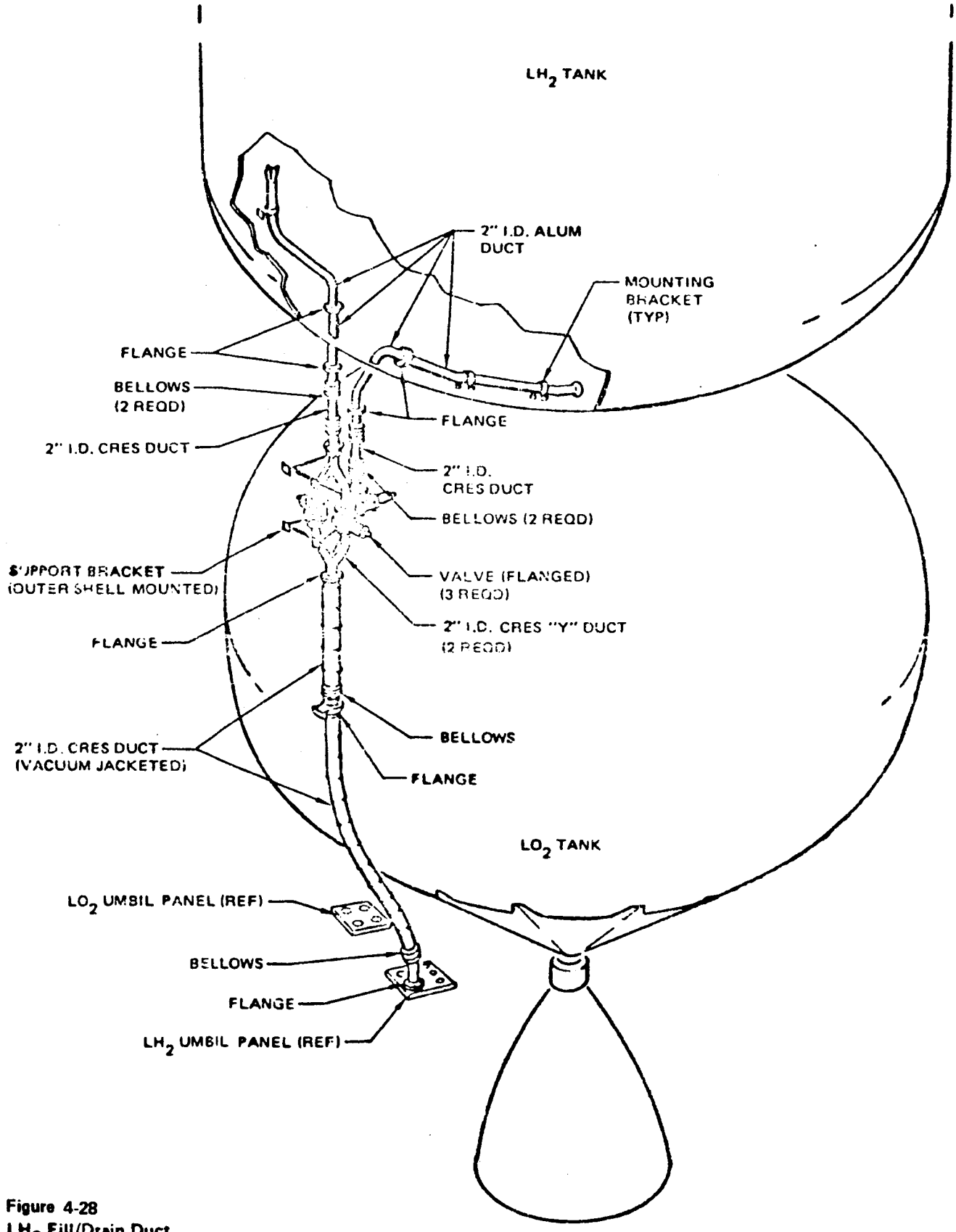


Figure 4-28
LH_2 Fill/Drain Duct

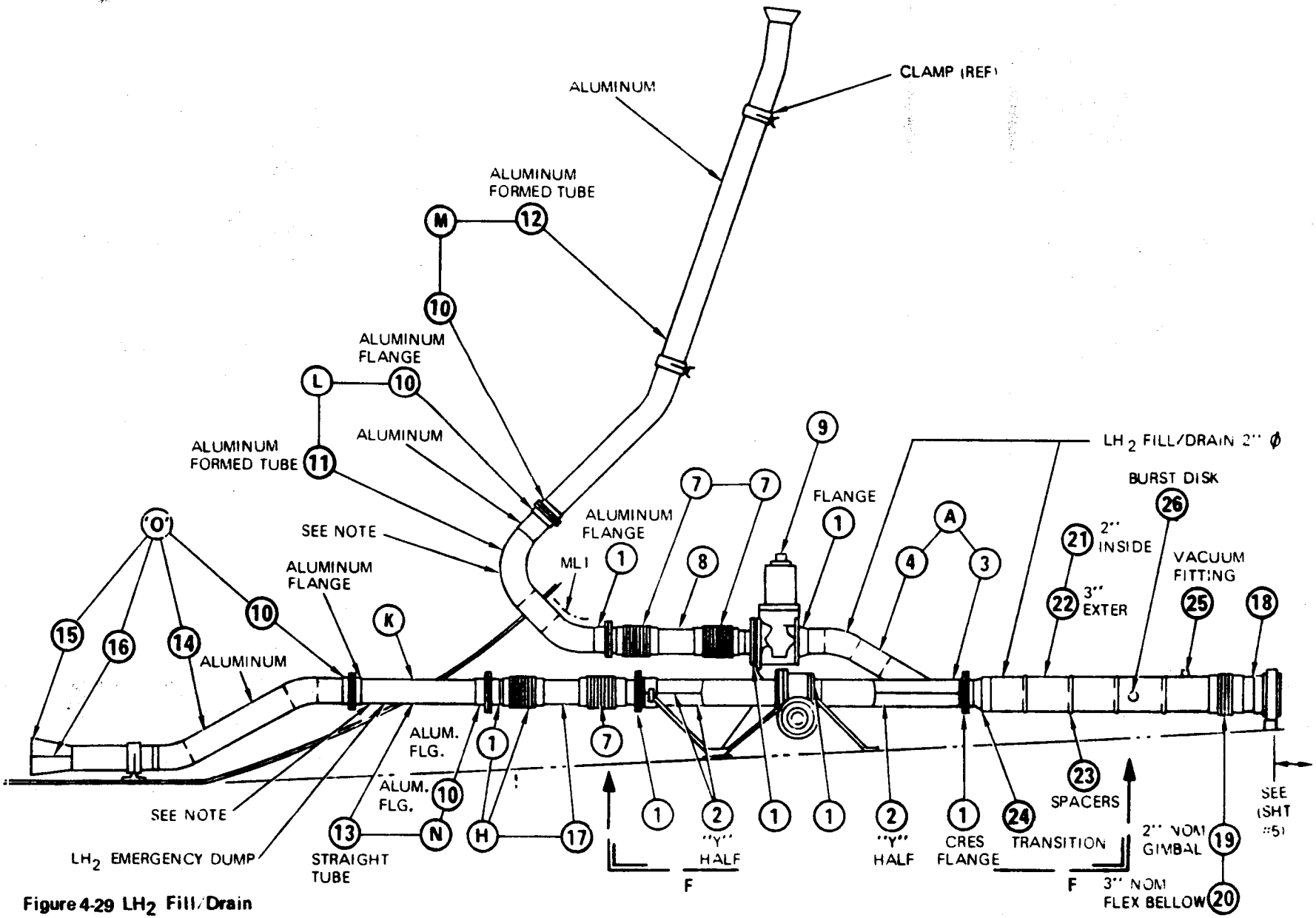


Figure 4-29 LH_2 Fill/Drain

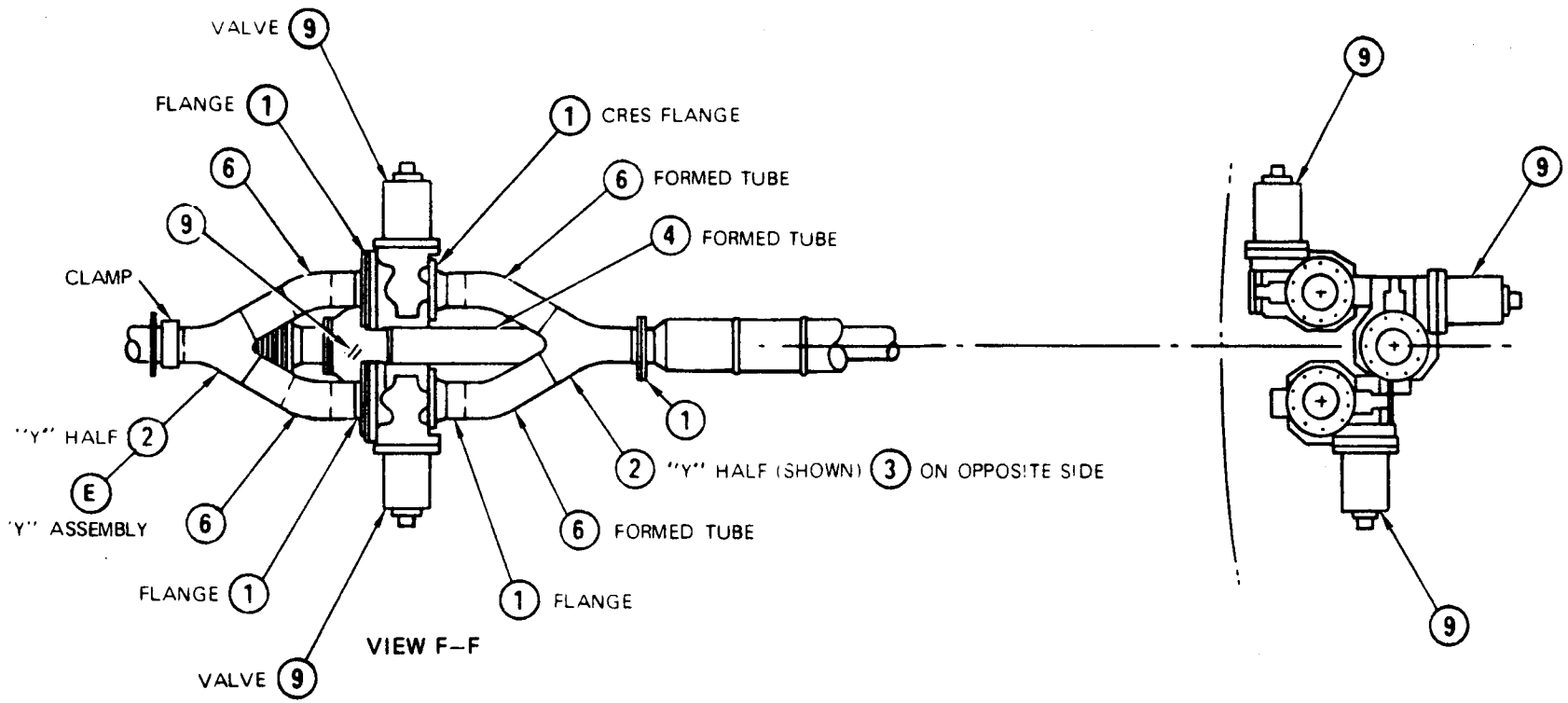


Figure 4-30 LH_2 Fill/Drain

4.4.4

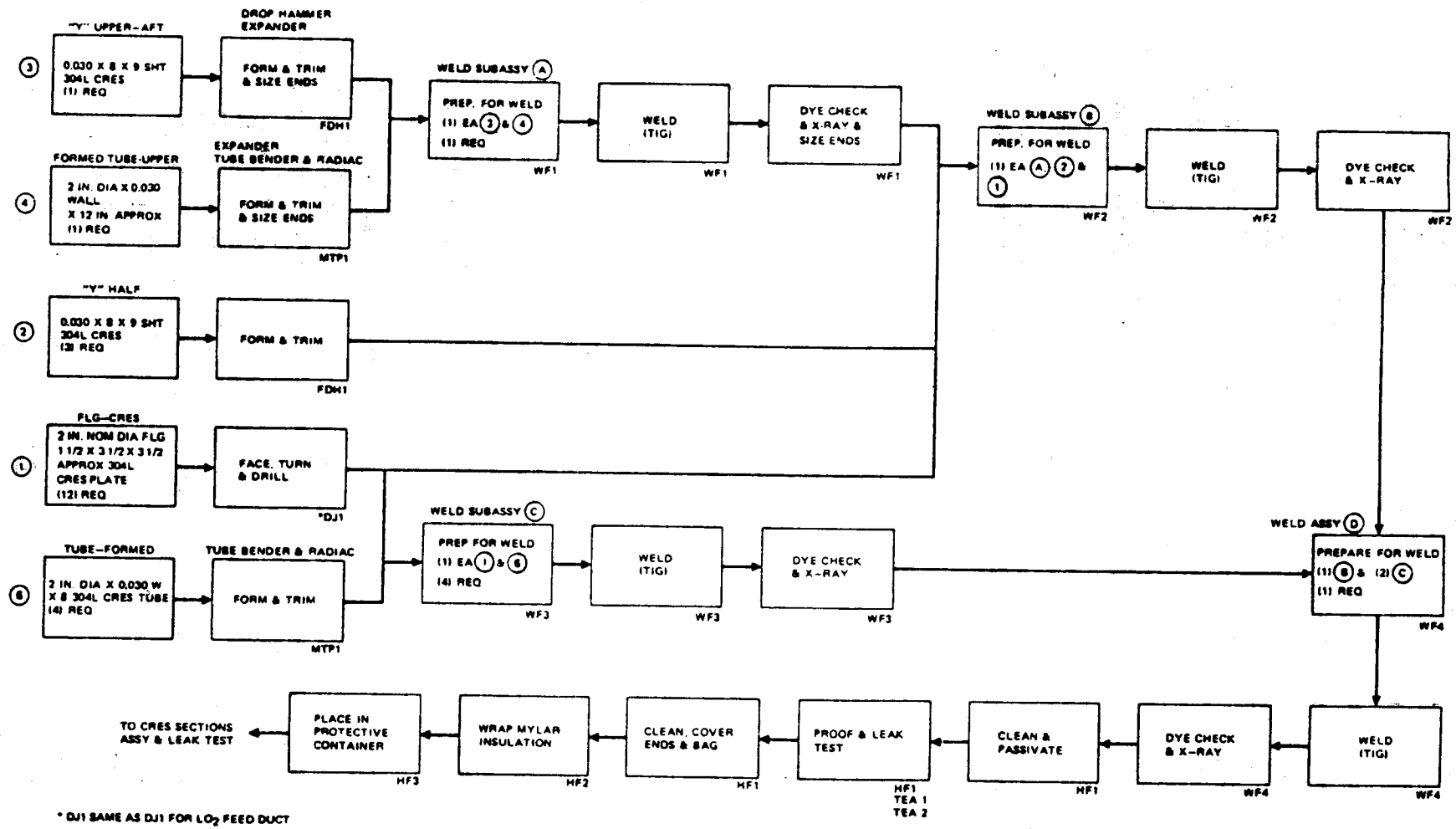


Figure 4-31 . Space Tug LH_2 Fill & Drain Duct Manufacturing Sequence (Sheet 1 of 6)

4-45

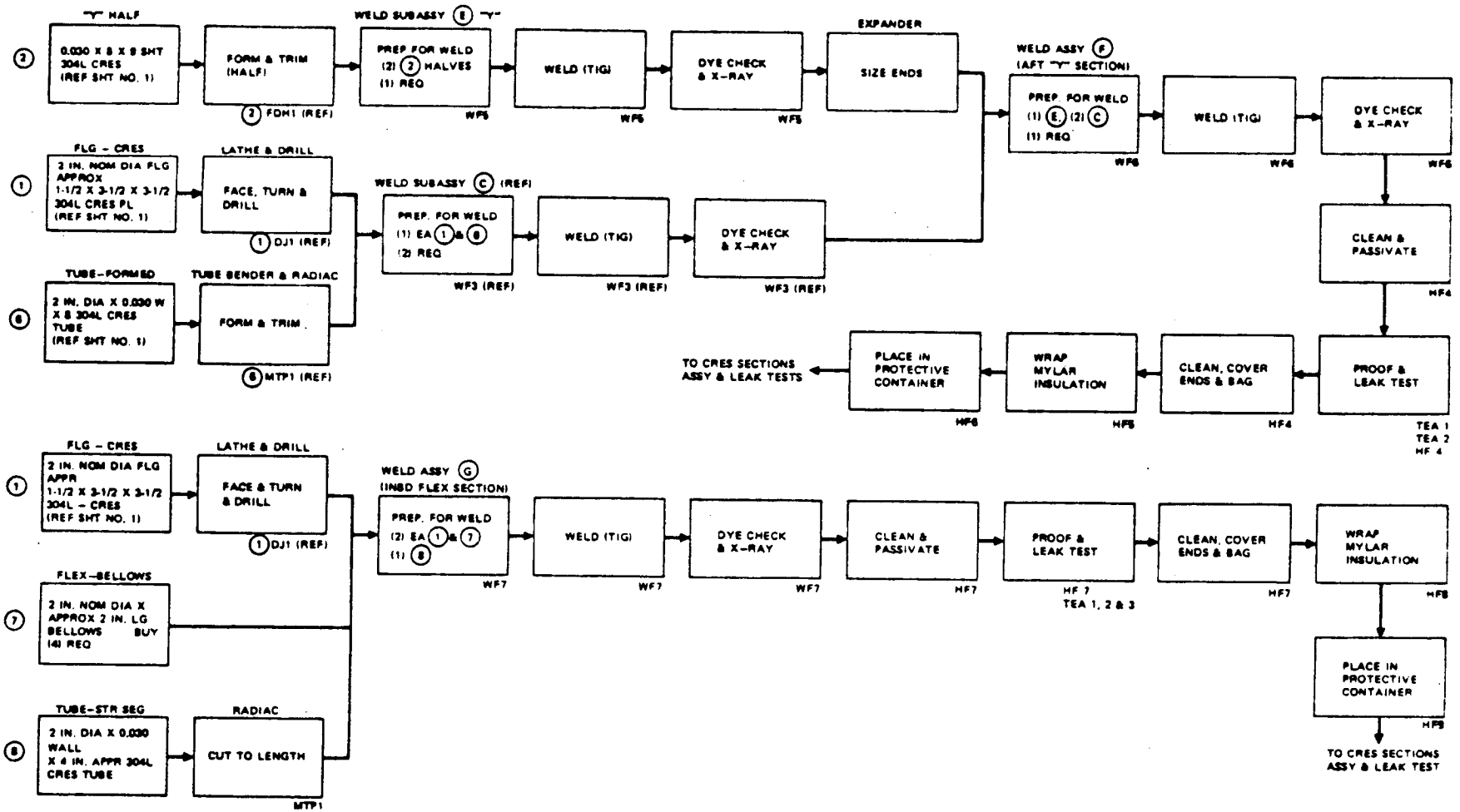


Figure 4-32. Space Tug LH_2 Fill & Drain Duct Manufacturing Sequence (Sheet 2 of 6)

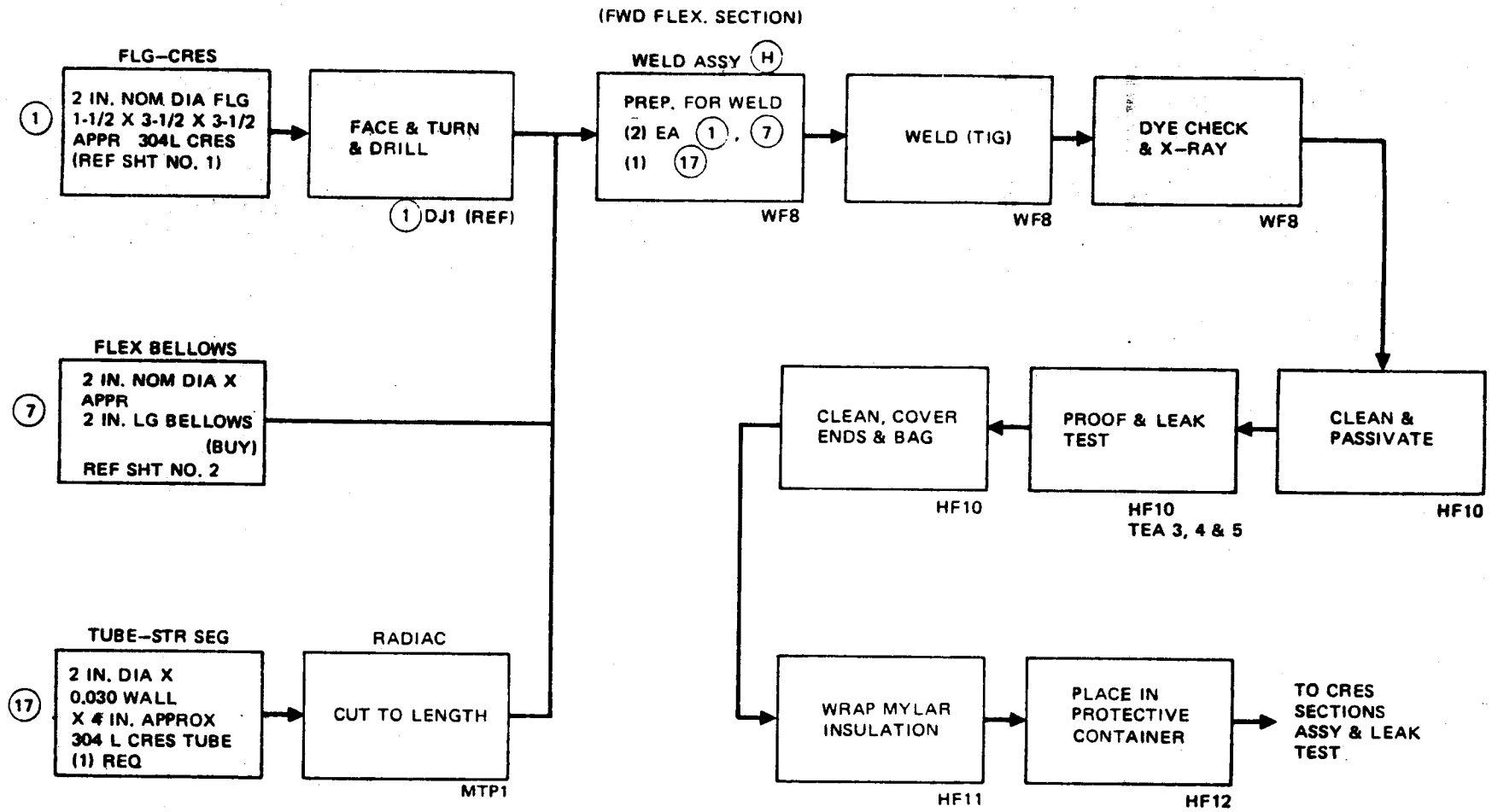


Figure 4-33. Space Tug LH_2 Fill & Drain Duct Manufacturing Sequence (Sheet 3 of 6)

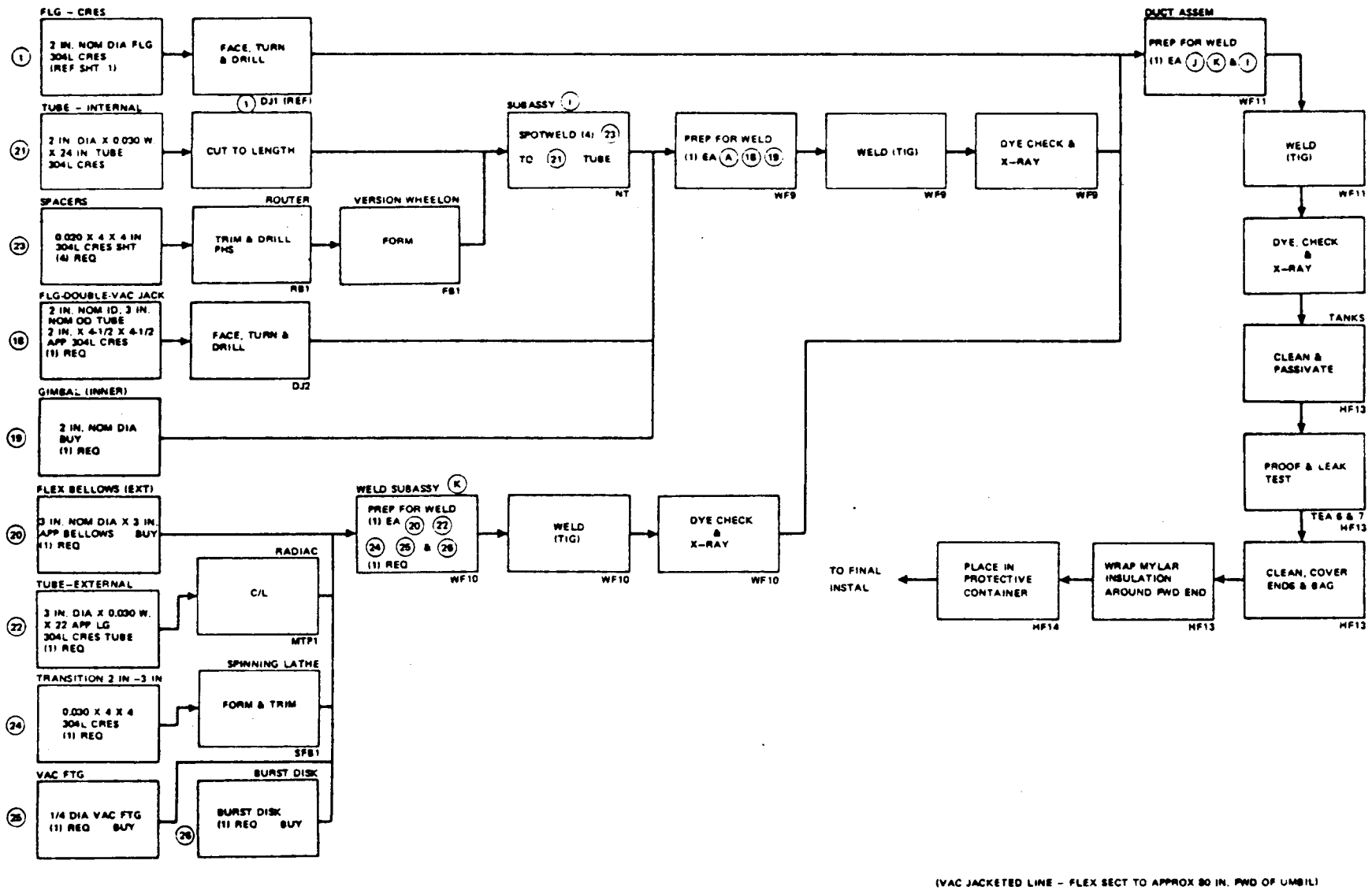


Figure 4-34. Space Tug LH_2 Fill & Drain Duct Manufacturing Sequence (Sheet 4 of 6)

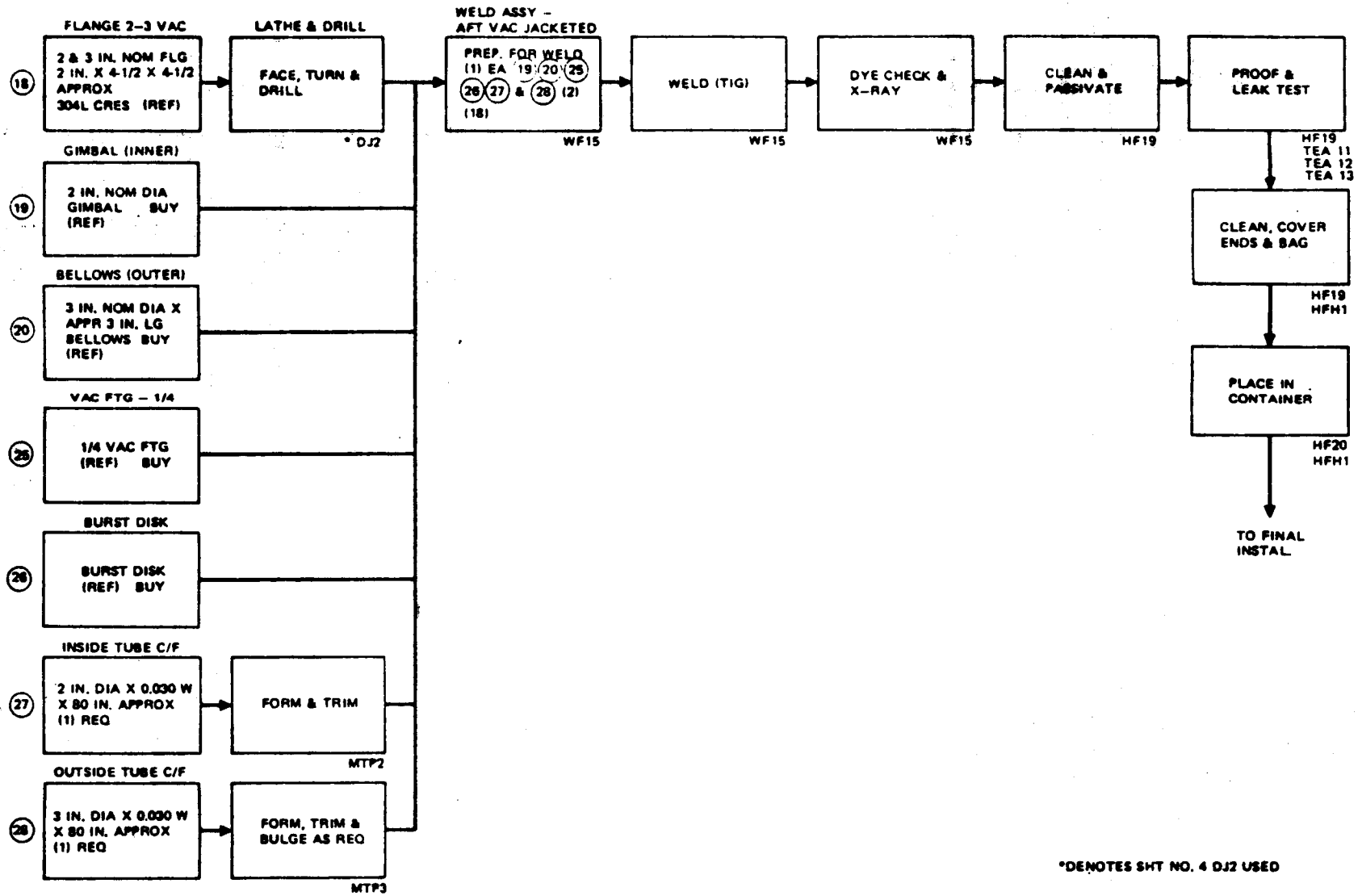


Figure 4-35. Space Tug LH_2 Fill & Drain Duct Manufacturing Sequence (Sheet 5 of 6)

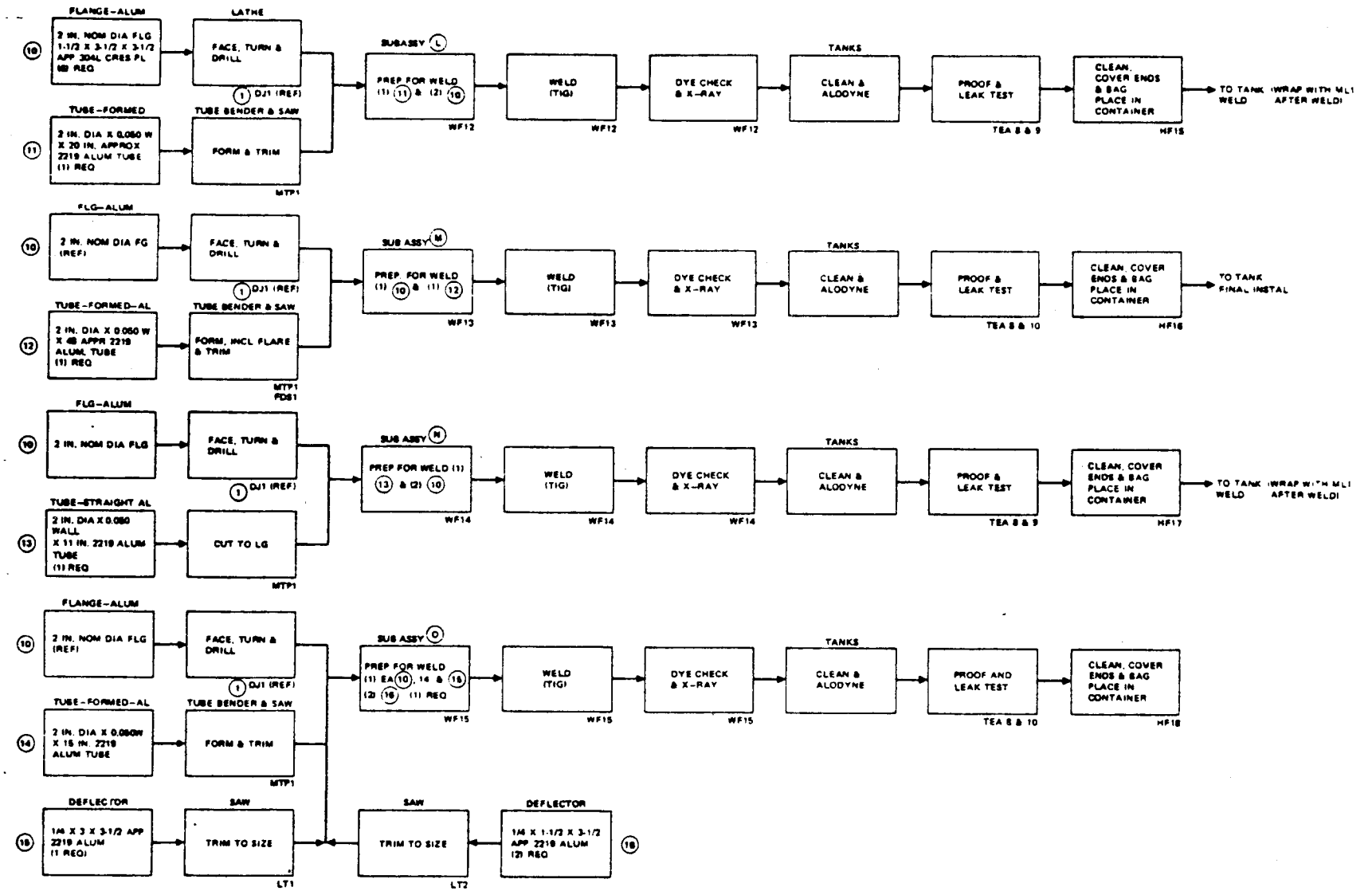


Figure 4-36. Space Tug LH_2 Fill & Drain Duct – Alum Sections Manufacturing Sequence (Sheet 6 of 6)

4.1.3.4.7 GH_2 Vent Ducts

The GH_2 vent system consists of 2 separate sections, namely the vertical and horizontal sections. The vertical section extends from the hydrogen umbilical to the forward centerline of the hydrogen tank. The horizontal section connects to the forward end of the vertical section and extends along the hydrogen dome to the upper side while in a horizontal position. The vertical section is approximately 30-feet long, while the horizontal section is approximately 9-feet long. Both sections consist of flanges, flex bellows, and 2-inch diameter tubing. The forward end of the vertical section has three flanges, with two flanges attaching to vent valves and the other to the horizontal section. (See Figure 4-37 thru 4-40).

The welding operations will be present state-of-the-art. Automatic TIG tube welding equipment will be used, except where not applicable.

Handling fixtures (HF) will be furnished for protectively moving, insulation wrapping and storage. A handling fixture hoist (HFH) will be furnished for the vertical section, however the horizontal section will be picked up by hand. The flex bellows and valves will be purchased.

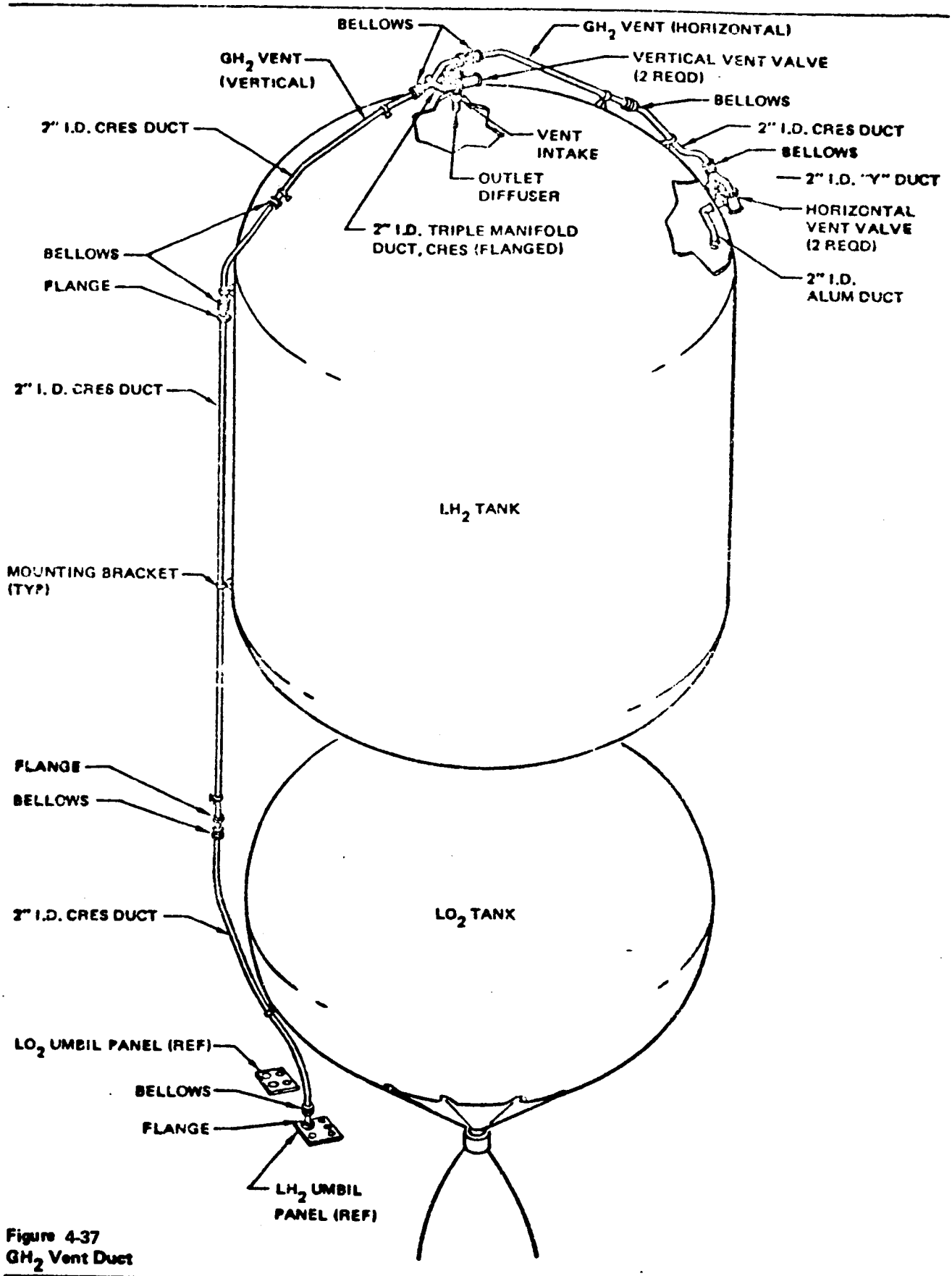


Figure 4-37
GH_2 Vent Duct

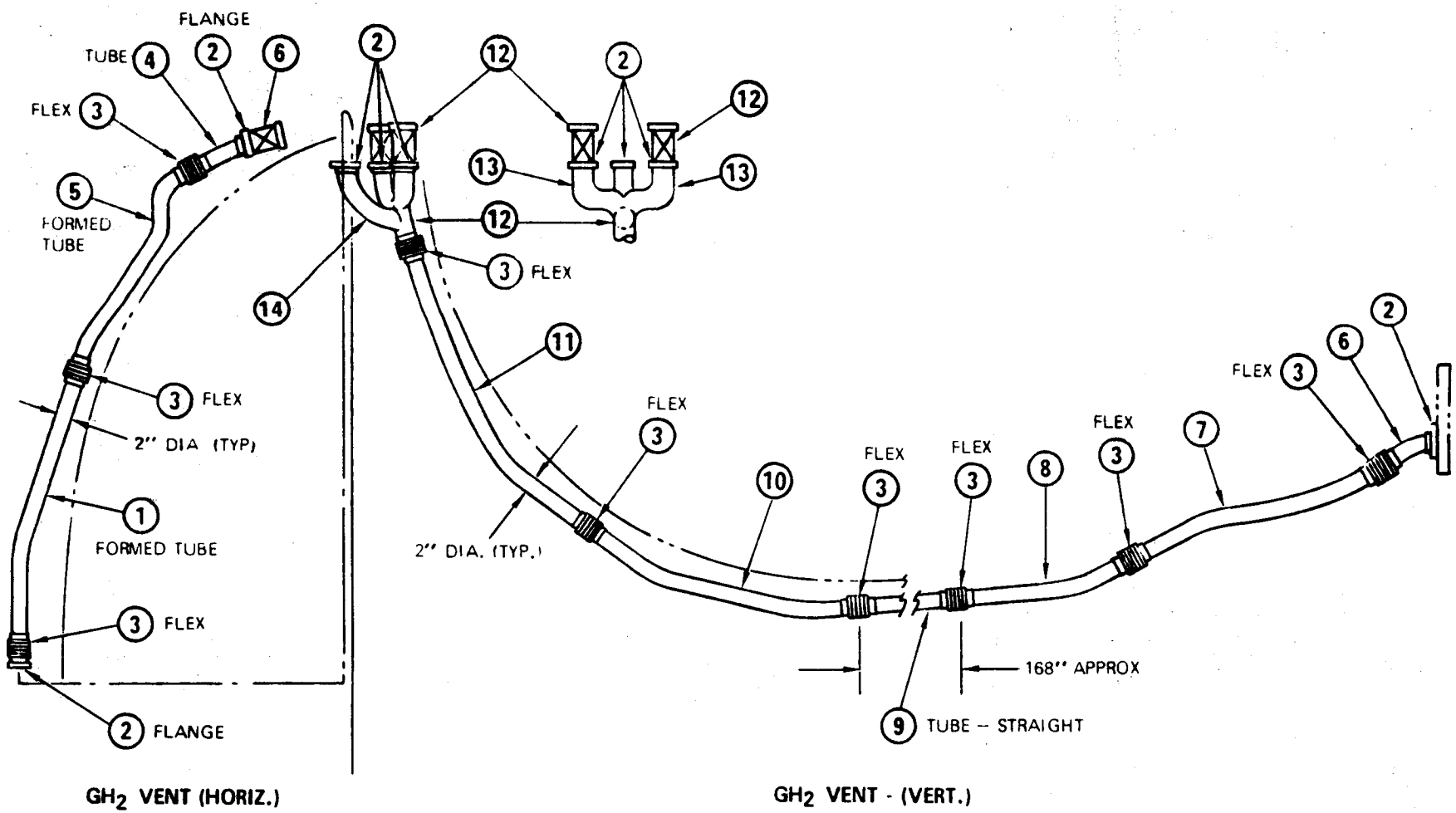


Figure 4-38 GH_2 Vent Duct

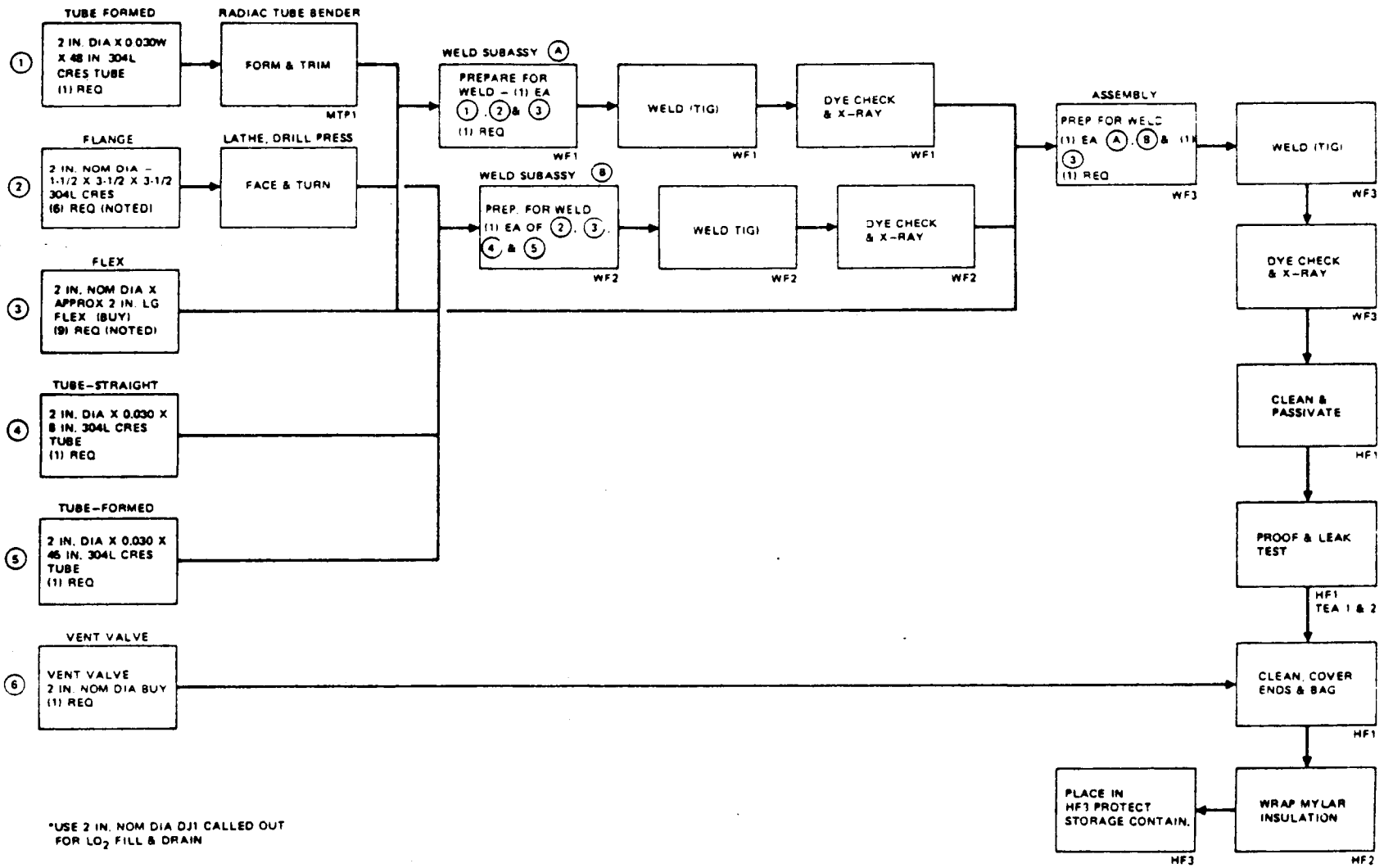


Figure 4-39. Space Tug GH_2 Vent – Horiz Section Manufacturing Sequence (Sheet 1 of 2)

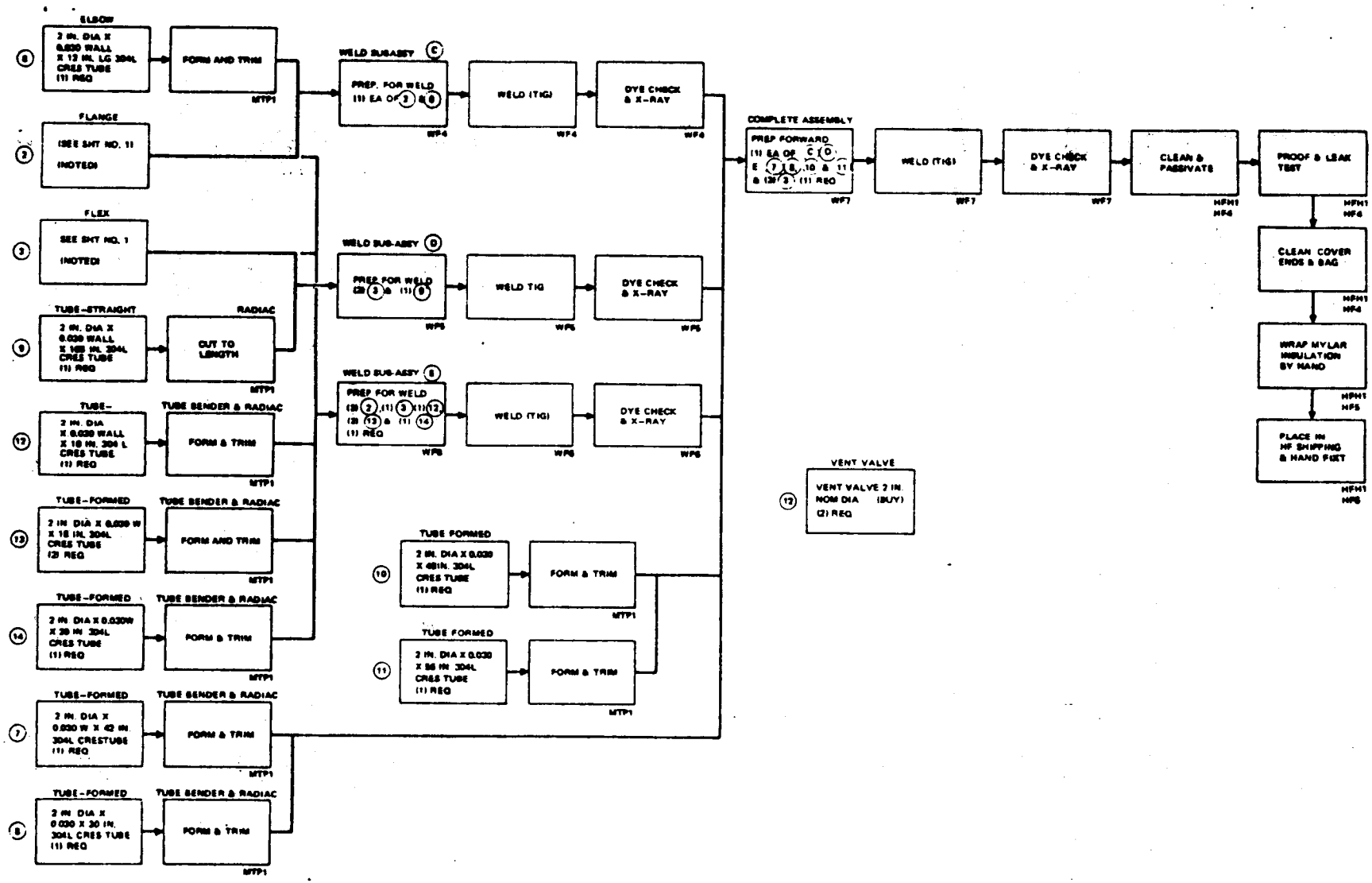


Figure 4-40. Space Tug GH_2 Vent – Vert. Section Manufacturing Sequence (Sheet 2 of 2)

4.1.3.4.8 Pneumatic (Helium) System

The pneumatic system consists of titanium storage bottles filled with helium and with 1/4 inch and 1/2 inch diameter tubing connecting the bottles to control valves for the following systems:

- LH_2 Feed
- LH_2 Fill and Drain
- GH_2 Vent
- LO_2 Feed
- LO_2 Fill and Drain
- LO_2 Emergency Dump
- GO_2 Vent

The tubing will be thin-walled corrosive resistant steel (304L) and will be brazed (or welded) in place, upon installation. The lengths and bend radii will be controlled by bend radius templets (BRT).

The pneumatic systems for the various configurations will be very similar except for the location of the pressure bottles, and resulting plumbing requirements. The ambient configuration bottles are located on the thrust structure, while the "cold" configuration bottles are located in the LO_2 tank. The cold configuration requires a helium heater at the umbilical, with additional plumbing.

4.1.3.5 Avionics Fabrication, Assembly, and Installation

The avionics fabrication, assembly and installation manufacturing concept is based on the use of modular electrical/electronic units. Typically, a module consists of a housing with 5-layer thick film hybrid assemblies, state-of-the art at MDAC, connected by a 4-layer flexible printed wiring harness. The modules are mounted on baseplates with an interconnecting wire harness to comprise a complete tested unit ready for installation on the vehicle support structure. Purchased assemblies will be adapted to the support structure by fabricated mounts. Instrumentation transducers that are integral to the vehicle structure or other subsystems will be installed during the relevant assembly operations. All other transducers, electrical/electronic units and interconnecting cable assemblies will be installed during and after final assembly of the vehicle. Items comprising the avionics subsystem are tabulated below.

Quantity	Unit	Quantity	Unit
50	Interconnecting Cables	1	RF MUX
10	MIU's	1	SGLS/USB Transponder
1	Data Control Unit	1	CMD Decoder
1	PCM Formatter	1	COMSEC. Equipment
1	GSE/ORB 1/F Unit	2	Tape Recorders
1	Spectrum Converter	1	High Gain Antenna
1	Computer	1	AGZU Primary Battery
6	Instrumentation Power Supply	1	NICAD Backup Battery
2	Startracker - Strapdown	1	NICAD Backup Battery
2	IMU - Tuned Rotor	1	Power Dist. Assembly-Hybrid
1	Mod/Demod Processor	1	Power Amplifier
1	OMNI - Directional Antenna	200	Transducers
1	Microwave Circuitry Installation		

The manufacturing and assembly concept will require minimum tooling. The manufacturing flow plans for the avionic components are depicted in Figures 4-41 and 4-42.

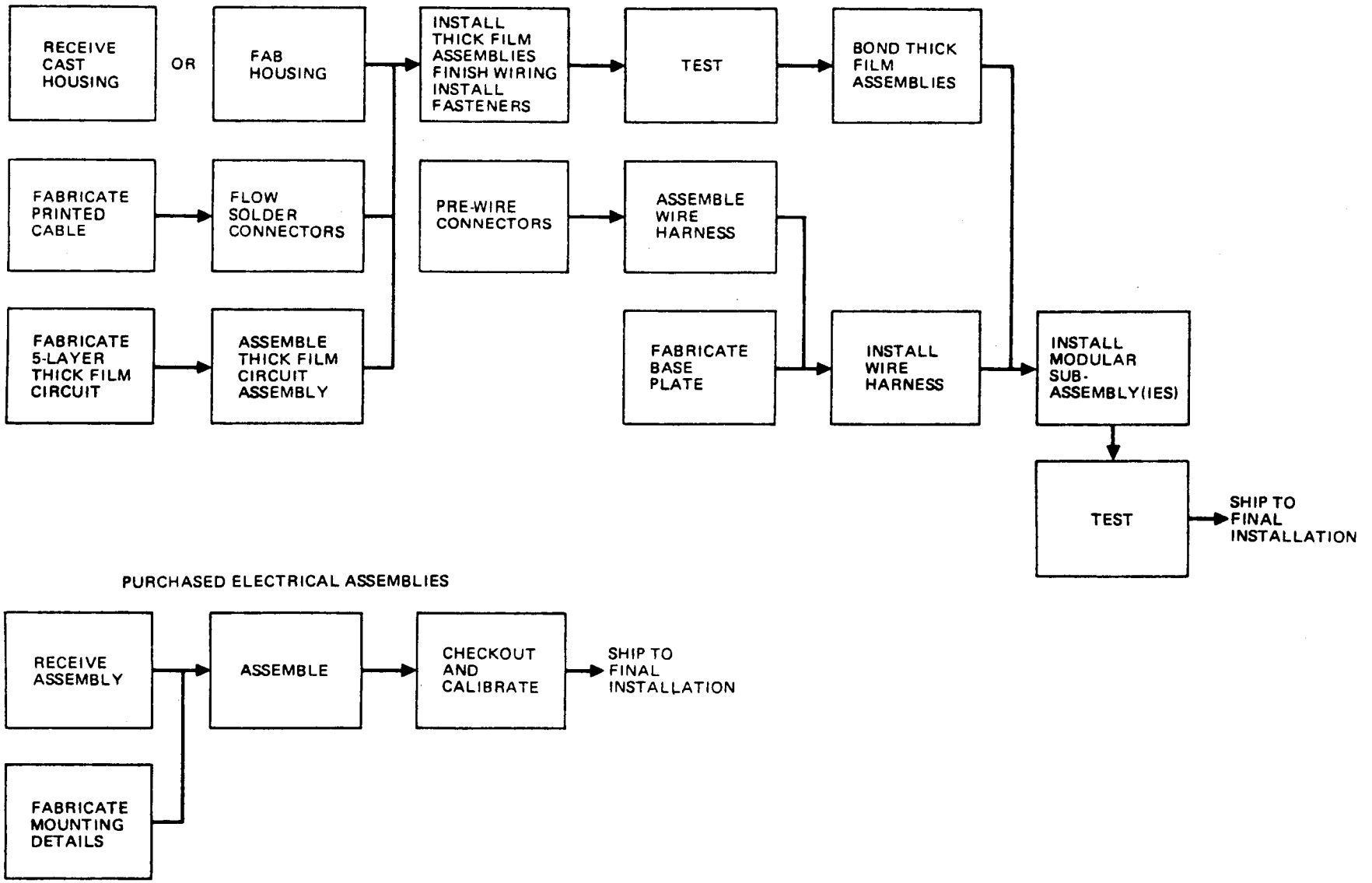


Figure 4-41. Electrical Assemblies

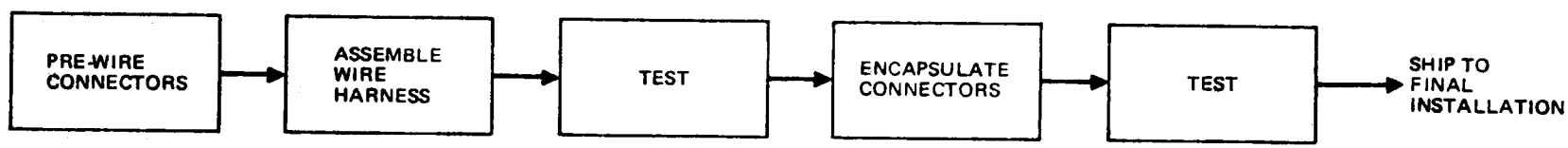


Figure 4-42. Interconnecting Cables

4.1.3.6 Production Acceptance Test Plan

MANUFACTURING IN-PROCESS TESTS - STRUCTURAL/MECHANICAL

Tank Structures

Propellant tanks will be proof and leak tested after basic assembly, but prior to further buildup. Each individual tank assembly will be connected to a hydrostatic test facility where it will undergo a proof pressure test.

The LH_2 tank will be filled with water while simultaneously submerged with water in an outer tank to prevent over-stressing of the aft dome due to static head pressure of the internal water. All LH_2 tanks will be tested with a uniform differential pressure in this manner.

The LO_2 tanks will be tested in the same facility, but will not be submerged during the test.

Structural integrity historical data formation will start at the time of tank proof tests by the real time monitoring and recording of acoustical emissions emanating from minute plastic deformation and fractures occurring upon initial pressurization. Emission quantity and rate recorded during the pressurization cycle will serve to uncover trends in structural weaknesses, and provide a real-time analysis of potential failures. Automated data handling will permit ongoing interpretation and warning during the proof test cycle should crack growth rates exceed a pre-determined level. Permanent test records will then provide a data base to be used in subsequent test result correlation.

During tug mid-life refurbishment operations, additional static pressure tests will be performed with further examination of acoustical emission data. This data will be correlated with the initial proof test data, enabling a more thorough structural integrity evaluation and life forecast per stage.

Initial leak tests will be performed on each tank assembly after proof tests. All leak tests will be done pneumatically using ambient gaseous helium as a trace gas with the test pressure not to exceed a 4:1 design burst ratio. All weld seams and each through fastener will be checked for leakage. Leak detection will be by the use of portable helium sniffers with clearly defined go, no-go acceptance requirements.

Tank leak checks will not be done during mid-life refurbishment unless the tanks are stripped of all insulation and sufficient reason exists.

Pneumatic Installations

Each pneumatic duct, line, and component joint will be leak tested after assembly with gaseous helium, pressurized to expected operating pressures except where some segments may exceed a 4:1 design burst ratio. No pneumatic testing will be performed at less than 4:1 unless sufficient shelter and shrapnel screening is provided.

Electronic Assemblies

Electronic black box subassemblies (PCB's, thick film substrates, etc.) will be tested on existing government owned automatic testers. Boards will be tested prior to and after conformal coating. Specialized test programs will be developed to thoroughly exercise each circuit and interrelated components prior to next assembly.

Final black box assemblies will be tested after all assembly operations are completed to ensure operability within go, no-go acceptance limits.

Major Subcontractor Hardware

Flight articles produced by a major subcontractor will be acceptance tested at the supplier prior to delivery. In-plant checkout capability will be necessary, however, to fault isolate subsystems to the black box level in parallel with vehicle checkout. Supplier system test sets may be required if practical.

Refurbishment

Intermediate and final checkout will be performed on all factory refurbished or modified vehicles in a similar manner as the initial factory checkout. Additional testing may involve specialized modification/rework tests not normally done in the initial checkout. Such tests are evident where structural modification or repairs are necessary. Remote site acoustic emission evaluation of tank quality is also anticipated. A very minimum of acceptance tests on refurbished vehicles would be a repeat of the original factory final checkout.

Data accumulated will be statistically compared with original and mission performance data to assist in the quality evaluation for future refurbishment duty cycle rework requirements.

Batteries

Batteries will not be received at the factory, but will be delivered directly to the launch site. Either battery simulators, or special batteries installed for the purpose of Tug checkout will be used for in-plant tests.

Factory Checkout - Tug Vehicle

Final system checkout will be as thorough as practical prior to shipment of each Tug vehicle from the factory. Launch, mission profile, and recovery operations will be simulated as close as practical in a factory ambient environment to exercise all on-board functional systems without actual propellant loading.

Checkout will be performed to go, no-go limit criteria controlled from manufacturing GSE. This checkout will in part simulate the launch checkout performed prior to launch.

All test operations will be performed by automated computer controlled GSE with go, no-go analysis displayed and printed on reproducible hard copy. This factory checkout GSE will be of the same design as the launch site GSE. Primary differences in factory checkout and launch checkout will include additional data recording at the factory to establish certain instrumentation calibration bases for mission purposes, payload simulation, more thorough leak rate evaluation, and the obvious absence of flight propellants.

Initial test program software will be developed and proven in the Integrated Avionics Test Unit (IATU) prior to first vehicle application. Subsequent software configurations will likewise be routinely verified in the final checkout position or offline prior to use.

4.2 TOOLING REQUIREMENTS

Tooling requirements generated by the fabrication and assembly flow plans previously outlined in Section 4.1.3 are presented in the following list, as are the tools needed to produce and/or modify items of Ground Support Equipment used for factory checkout. Tooling abbreviations are defined in the glossary of definitions.

TOOL DESIGNATIONS	TOOL NOMENCLATURE	TOOL DESIGNATIONS	TOOL NOMENCLATURE
AJ	Assembly Jig	MF	Mill Fixture
AT	Apply Templet	MMT	Master Masking Templet
ATP	Auxiliary Tool Production	MT	Masking Templet
BJ	Bonding Jig	MTP	Master Tooling Part
BRT	Bend Radius Templet	NMT	Negative Masking Templet
CT	Contour Templet	PLM	Plastic Laminating Mold
DD	Draw Die	PMT	Positive Masking Templet
DJ	Drill Jig	PT	Profile Templet
FB	Form Block	PTE	Production Test Equipment
FDH	Form Die-Hammer	RB	Router Block
FDS	Form Die-Swage	SFB	Spin Form Block
HF	Handling Fixture	SWF	Spotweld Fixture
HFH	Handling Fixture-Hoist	TEA	Test Equipment Accessory
LF	Lathe Fixture	TJ	Trim Jig
LT	Layout Templet	WF	Weld Fixture
MCM	Machine Control Medium	WJB	Wire Jig Board

TOOL LIST

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
1	Payload Docking	1	WF
		1	AJ
		1	ATP
		3	TEA
2	Avionics Panel	1	AJ
		1	DJ
		1	SFD (HOT)
		1	MF
		1	LT
		2	AT
3	Avionics Panel - Isogrid	1	MF
		1	MCM
		1	MT
4	Tank Supports	2	MF
		1	LF
		1	WF
		1	DJ
5	Tank Support Tank Fittings	1	MF
		1	MT
		1	DJ
6	LH_2 Forward Dome	4	LF
		1	SWF
		1	DJ
		1	MT
		2	HF
		1	HFH
		1	AT
		1	WF

TOOL LIST

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
7	LH_2 Aft Dome	1	MF
		1	DJ
		2	MT
		2	LF
		2	HF
		1	TJ
		1	WF
		1	SWF
8	LH_2 Access Door	1	LF
		1	PT
		1	DJ
9	LH_2 Tank Body	1	MF
		1	MT
		1	CT
		1	WF
		1	HF
		1	HFH
10	LH_2 Tank Assembly	1	WF
		2	HF
		1	HFH
		8	TEA
		2	PTE
11	LH_2 Titanium Shear Panels	1	LT
		1	AT
		1	FB
12	Quartz Cloth Panels	1	LT
13	Kapton Meteoroid Barrier	1	LT

TOOL LIST

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
14	Reflective Coating (DAM)	1	LT
15	LO_2 Tank Duct Attach Fittings	1	LF
		1	PT
16	LO_2 Forward Dome	2	LF
		1	MT
		2	HF
		1	HFH
		1	TJ
		1	WF
17	LO_2 Aft Dome	2	MF
		1	PT
		3	LF
		2	DJ
		1	DD
		1	MT
		1	WF
		1	SWF
		3	HF
		1	HFH
18	LO_2 Tank Assembly	1	WF
		2	HF
		1	HFH
		8	TEA
		2	PTE
19	LO_2 Tank Kapton Attach Angle	1	LT
20	Thrust Structure	1	MF
		1	MCM
		1	DJ
		1	HF

TOOL LIST

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
21	Engine Mount	1	LF
		1	DJ
		1	HF
22	LO_2 Tank Docking Guard Attach Angle (Fibreglass)	1	PLM
		1	TJ
		1	HF
23	Umbilical Support Brackets	1	LF
		1	MF
		1	WF
		1	DJ
24	Engine Actuator Support	1	LT
		1	RB
		1	FB
25	Pressure Bottle Support	1	LT
		1	FDH
		1	TJ
		1	HF
26	Pressure Bottle Straps	-	Use SIVB Mfg Capability
27	Monopropellant Bottles	-	Use SIVB Mfg Capability
28	Ambient Helium Bottles	-	Use SIVB Mfg Capability
29	Monopropellant Bottle Brackets	2	LF
		1	WF
		1	DJ

TOOL LIST

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
30	Intertank Forward Frame	1	AT
		1	MF
		1	DJ
		1	AJ
31	Intertank Aft Frame	1	AT
		1	MF
		1	DJ
		1	AJ
32	Longeron and Monopropellant Bracket Fittings	1	LT
		1	AT
		1	MF
		1	DJ
		1	AJ
33	Intertank Open Isogrid Panels	1	MF
		1	MCM
		1	MT
		1	DJ
34	Docking Guard Aft Intertank Frame Attach Fittings and Fuel Line Clips	2	LT
		1	AT
		1	MF
		1	DJ
		1	AJ
35	APS Impingement Panel	1	LT
		1	FB
		1	AT
36	LH_2 Tank Bonding and Insulation	1	BJ
		1	HF
		1	HFH

TOOL LIST

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
37	LO_2 Tank Bonding	1	BJ
		1	HF
		1	HFH

TOOL LIST

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
38	PROPULSION:		
	LO_2 FEED DUCT (2 IN. DIA.)		
	Flanges	2	Drill Jig
	Tubing	1	Master Tooling Part
	Sump (Alum. Forging)	1	Mill Fixture
		1	Drill Jig
	Weld Assemblies	4	Weld Fixtures
		4	Handling Fixtures
		2	Test Equipment Adapters
	LO_2 FILL/DRAIN (2 IN. DIA.)		
	Flanges	*	Drill Jig
	Tubing	1	Master Tooling Part
		1	Form Die Swage
	Weld Assemblies	2	Weld Fixtures
		3	Handling Fixtures
		4	Test Equipment Adapters
	LO_2 EMERGENCY DUMP (3 IN. DIA.)		
	Flanges	1	Drill Jig
	Tubing	1	Master Tooling Part

*Denotes same drill jig as item No. 1

TOOL LIST

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
38 (Cont)	LO_2 EMERGENCY DUMP (Cont)		
	"Y" Halves	3	Form Die-Hammer
		3	Apply Templet
	Flow Deflector	2	Layout Templets
	Weld Assemblies	7	Weld Fixture
		4	Handling Fixture
		10	Test Equipment Adapter
	GO_2 Vent Duct (2 IN. DIA.)		
	Flanges	*	Drill Jig
	Tubing	1	Master Tooling Part
	Weld Assemblies	3	Weld Fixture
		3	Handling Fixture
		1	Handling Fixture-Hoist
		2	Test Equip. Adapter
	LH_2 ENGINE FEED DUCT (2-1/2 in. ID/ 3-1/2 in. O.D.) VAC. JACKETED		
	Flanges	2	Drill Jig
	Tubing	2	Master Tooling Part
		1	Form Die Bulge
		1	Form Dia Swage
	Separators	1	Layout Templet
		1	Router Block
		1	Form Block

*Denotes same drill jig as item No. 1

TOOL LIST

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
38 (Cont)	LH_2 ENGINE FEED DUCT (Cont)		
	Weld Assemblies	3	Weld Fixture
		6	Handling Fixture
		1	Handling Fixture-Hoist
		5	Test Equipment Adapter
	Sump	1	Mill Fixture
	LH_2 FILL/DRAIN (2 in. DIA)		
	Flanges	1	Drill Jig (Vac. Jacket Ftg.)
		*	Drill Jig (2 in. Nom. Dia.)
	Tubing	7	Master Tooling Parts (inside duct and outer vacuum cover)
	"Y"	1	Form Die Hammer
	Spacers	1	Router Block
		1	Form Block
	Deflectors	2	Layout Templets
	Transition	1	Spin Form Block
	Weld Assemblies	16	Weld Fixtures
		18	Handling Fixtures
		13	Test Equip. Adapters
		1	Handling Fixt.-Hoist

*Denotes same drill jig as item No. 1

TOOL LIST

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
38 (Cont)	GH_2 VENT (2 in. DIA)		
	Flanges	*	Drill Jig
	Tubing	1	Master Tooling Part
	Weld Assemblies	7	Weld Fixtures
		6	Handling Fixtures
		1	Handling Fixture-Hoist
		2	Test Equipment Adapters
	PNEUMATIC (HELIUM) (1/2 in. and 1/4 in. DIA.)		
	Tubing	20 (Estimated)	Bend Radius Templates

*Denotes same drill jig as item No. 1

TOOL LIST - AVIONICS

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
39	AVIONICS:		
	Interconnecting Cables - Avionics	1	Wire Jig Board
	Base Plate - MIU	1	Drill Jig
	Wire Harness Assy - MIU	1	Wire Jig Board
	Module Assy - MIU	1	Assembly Jig
		1	Bonding Jig
	Printed Cable Assy - 49 Pin	1	Assembly Jig
	Printed Cable - Module Printed Cable	2	Master Masking Templet
		3	Positive Masking Templet
		3	Negative Masking Templet
		1	Masking Templet
		1	Trim Jig
	5-Layer Thick Film Assy	10	Master Masking Templet
		10	Positive Masking Templet
	Base Plate - System Control Unit	1	Drill Jig
	Wire Harness Assy - System Control	1	Wire Jig Board
	Module - System Control	1	Assembly Jig
		1	Bonding Jig
	Printed Cable Assy - System Control	1	Assembly Jig

TOOL LIST - AVIONICS

ITEM	PART NOMENCLATURE	QUANTITY	TOOL NOMENCLATURE
39 (Cont)	Printed Cable - Module Printed Cable	2	Master Masking Templet
		3	Positive Masking Templet
		3	Negative Masking Templet
		1	Masking Templet
		1	Trim Jig
	5-Layer - Thick Film Circuit - Thick Film Assy	10	Master Masking Templet
		10	Positive Masking Templet
	Base Plate - GSE/ORB I/F Unit	1	Drill Jig
	Base Plate - Mod/Demod Processor	1	Drill Jig
	Wire Harness - Mod/Demod Processor	1	Wire Jig Board
	Base Plate - Power Distribution-Hybrid	1	Drill Jig
	Base Plate - Power Distrib.-Solid State	1	Drill Jig
	5-Layer Thick Film Circuit	10	Master Masking Templet
		10	Positive Masking Templet

TOOL LIST - GSE

ITEM	PART NOMENCLATURE	TOTAL QUANTITY	TOOL NOMENCLATURE
40	GROUND SUPPORT EQUIPMENT		
	OPTION NO. 1 - GSE TEST SET		
	Estimated: 1241 Circuit Boards -	*	
	20 Config. (5 in. X 7 in. Boards)	6	Assembly Jig
		20	Negative Masking Templet
		20	Positive Masking Templet
		4	Trim Jig
	OPTION NO. 2 - GSE TEST SET	*	
	Estimated: 1442 Circuit Boards -	6	Assembly Jig
	20 Config. (5 in. X 7 in. Boards)	20	Negative Masking Templet
	(= 201 Boards)	20	Positive Masking Templet
		4	Trim Jig
	OPTION NO. 3 INITIAL - GSE TEST SET	*	
	Same as Option No. 1	6	Assembly Jig
		20	Negative Masking Templet
		20	Positive Masking Templet
		4	Trim Jig
	OPTION NO. 3 FINAL - GSE TEST SET	*	
	Same as Option No. 2	6	Assembly Jig
	(= 201 Boards)		
		20	Negative Masking Templet
		20	Positive Masking Templet
		4	Trim Jig

Notes:
1. All other GSE will be purchased or made on no-tool basis.
2. Assembly jigs are simple support tools.
*3. Denotes rate tooling has been included

4.3 FACILITIES

Detailed analysis and evaluation of program facility requirements to support a minimum cost DDT&E effort and low, early-year funding for Option 1 has determined that existing MDAC facilities can be utilized for most requirements. This evaluation was based on a "bottoms up" analysis of operation's requirements for manufacturing, test, integration, and checkout, and program needs were then matched against lists of existing modified, and new facilities. The basis for final determination was the availability and compatibility of identified items, and the predicted cost of supplemental equipment and modifications for adaptability.

Production facilities were evaluated using the horizontal mating method as the preferred approach. Facilities identified are not configuration sensitive, and cost alone was not the sole determinant in the selection of support equipment.

4.3.1 Manufacturing Facilities

Manufacture, assembly and checkout of the Space Tug will be accomplished at the McDonnell Douglas Astronautics Company (MDAC) facility in Huntington Beach, California. This facility was so planned and designed from its inception as to provide fully integrated capabilities for the production of space vehicles. Buildings include provisions for engineering and administrative offices, a Systems Integration Laboratory, Structural Test Laboratory, Space Simulation Laboratory, Production Test Laboratory, a manufacturing and assembly building, insulation building, a final assembly and checkout building, and other service and support facilities.

During development and production of the Space Tug, maximum utilization will be made of existing MDAC and government-owned facilities used on the Saturn S-IVB program and the Orbital Workshop. Full program support will be provided by existing machine shops, sheet metal shops, processing equipment, electrical/electronic fabrication and assembly facilities, and supporting inspection and test laboratories.

A preliminary list of additional facility requirements identified at this time for each of the configurations is shown in the table in Section 3.1. Also included are tentative costs and estimates of procurement lead times. A

100,000 class clean room for final assembly is listed in these requirements to satisfy contract requirements.

4.3.2 Test Facilities

Existing laboratories and facilities at MDAC in Huntington Beach will be utilized for production testing and checkout operations. Little or no modification of these laboratories will be required for Space Tug program use, as these facilities were designed for use on space vehicle hardware and assemblies.

Propulsion Test Vehicle (PTV) tests will be conducted in test cell J4 at the AEDC facility in Tullahoma. This test cell will provide the altitude simulation capability lacking in the test facilities at Huntsville. Thermal tests of the vehicle will be accomplished in the NASA high-vacuum facility, utilizing an existing scaled-down and instrumented tank that will fit the 15 foot diameter chamber. These government facilities are available for program use at no cost or at a nominal fee, depending on the using agency.

4.4 Special Requirements

The special requirements of the Space Tug manufacturing plan is the fabrication of the single piece LH_2 and LO_2 domes tooling and the procurement of the test sets of domes for testing. All other manufacturing requirements are state-of-the-art.

4.5 Summary - Analysis/Philosophy

This section contains the analysis and philosophy engendered into the Space Tug manufacturing plan.

4.5.1 Analysis

The analysis of the Space Tug manufacturing plan illustrates the following requirements were achieved:

- Minimum DDT&E
- Manufacturing methods and processes employed are state-of-the-art.
- Low tooling costs - standard tools and "soft" tooling utilized to the maximum.
- Low early year funding required to accomplish the manufacturing requirements.
- Cost effective production with high reliability.
- Manufacturing rate is compatible with the scheduled delivery requirements.

4.5.2 Philosophy

The philosophy engendered into the Space Tug manufacturing plan is motivated by the following requirements:

- 0.97 reliability factor
- Minimum DDT&E
- Reuseable vehicle
- Recycle capability
- Low program cost
- Low early year funding

In order to meet these requirements the following manufacturing philosophies have been instilled into the manufacturing plan of the Space Tug.

1. Automate where economically feasible to reduce manufacturing manpower requirements. Areas of automation are as follows:
   a) Numerically controlled machining of all machined components. Programmed dwell cycles for change and design revisions.
2. Fusion joining of the LO_2 and the LH_2 tanks will be accomplished automatically using the latest TIG welding techniques, i.e., electronics sensing devices, closed circuit television and other monitoring devices.
3. The fabrication of the LH_2 and LO_2 aluminum 2219 Cassinian tapered domes are purchased as single piece spin-formed domes in a T37 condition, machined in-house to a nominal thickness and taper chem-milled.
4. Reduction of components will be the concept for this manufacturing plan. Extruded and welded stub frames, and large sheet stock will be used.
5. Commonality and multi-use parts will be the manufacturing and engineering objectives of this plan, i.e., tank supports, tank support fittings.
6. A tool master program will be used on all field joints and verification matching interfaces.
7. "Soft" tooling will be used where practical and economical.

4.6 IMPACT OF OPTION SENSITIVITIES

The impact of the option sensitivities for the following options are delineated in this section:

1. Programmatic sensitivity for a 2 year delay IOC (December 31, 1981).
2. DDT&E effects for >36-hour mission duration.
3. Impact to provide 300 watts to payload.

The impact of the above noted options is delineated in the following sections and in the same numerical order.

4.6.1 IOC Delay of Two Years

The IOC delay of two years impacts manufacturing as follows:

1. DDT&E will be accomplished on a single shift basis.

2. Long lead procurement will be extended.

3. The manufacturing rate of 2.8 vehicles per year produces peaks and valleys in the manufacturing flow. The reduced rate of manufacture is not as good a manufacturing flow as four per year requirement of the original schedule.
4. Facility activation will not be impacted by this option.

4.6.2 Extended Duration Mission

The extended duration mission does not impact the manufacturing plan.

4.6.3 Impact to Provide 300 Watts to Payload

The impact of providing 300 watts to payload does not impact the manufacturing plan.

4.7 GSE Requirements

This section defines the Ground Support Equipment (GSE) required for factory checkout only. The items listed below will be used in-plant to support checkout operations during acceptance testing, but do not represent the total complement of GSE required for the Space Tug program.

A schematic depicting GSE interconnection and Tug hookup for final system checkout is shown in Figure 4-43 .

		Figure
1.	APS Breakout Control Box	4-44
2.	Space Tug Simulator	4-45
3.	Spacecraft Simulator	4-46
4.	Propellant or Pneumatic Control Console	4-47
5.	Propulsion Pneumatic Console	4-48
6.	Propellant Utilization Component Test Set	4-49
7.	Printed Circuit Card Component Test Set	4-50
8.	Power System Test Set	4-51
9.	Orbiter Simulator	4-52
10.	Signal Conditioning Unit	4-53
11.	Guidance and Navigation Test Set	4-54
12.	Guidance and Navigation System Checkout Kit	4-55
13.	Digital Events Recorder	4-56
14.	Data Management Test Set	4-57
15.	Communication System Test Set	4-58
16.	Checkout Cable Kit	4-59

The following pages identify the unique applications of the listed items, and show quantity requirements, the functional requirements, and a brief description of the equipment. Where applicable, the similarity to existing items of other MDAC-designed GSE is noted for comparison.

Included in the Tool List in Section 4.2 are the tools required to produce (or to modify existing) items of GSE for factory checkout use. Refer to Section 6.11.6 for a description of all operational GSE required to support the Space Tug program. The percentage of reworked and new GSE is also noted, as is a description of refurbishment requirements.

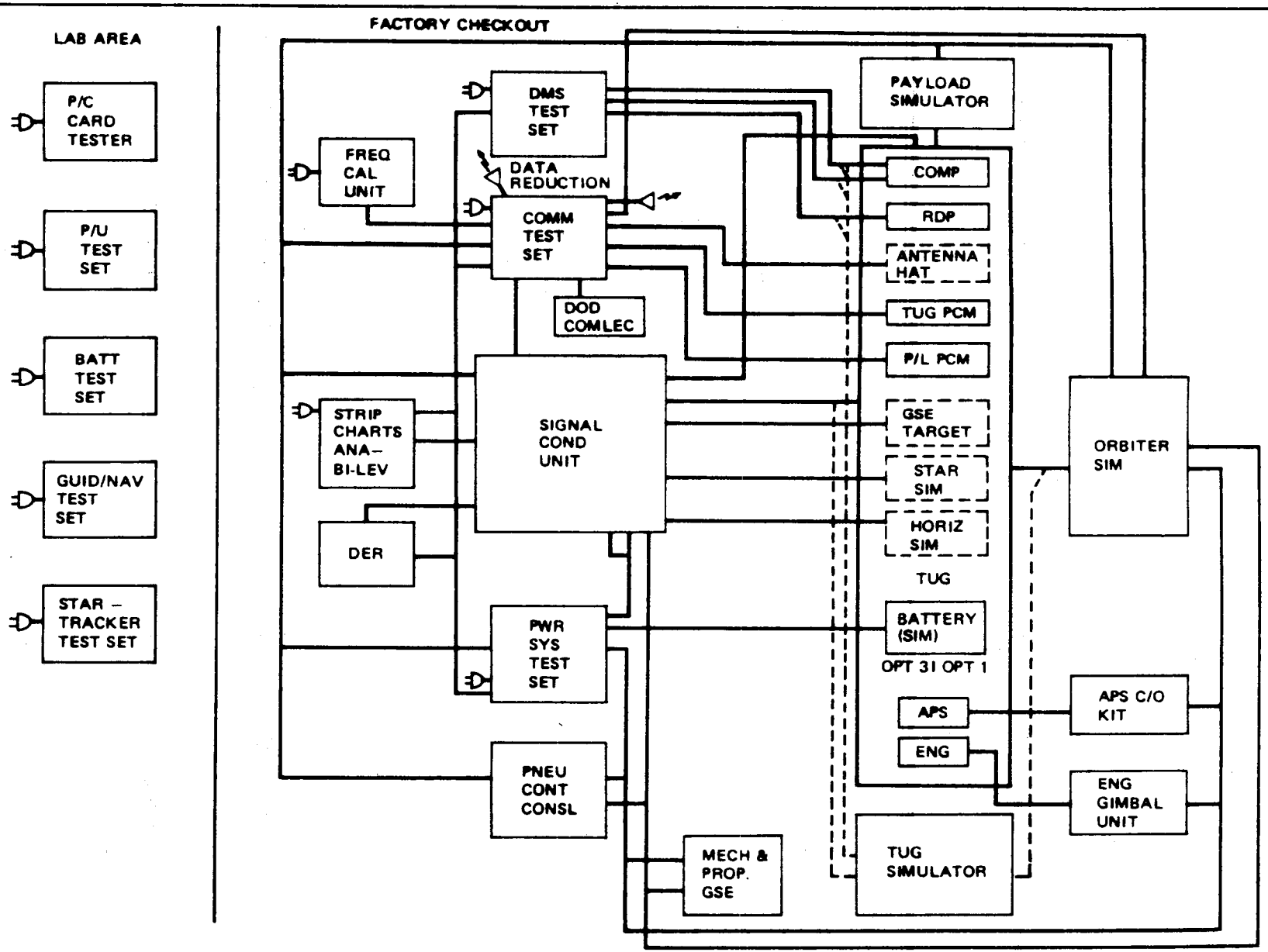
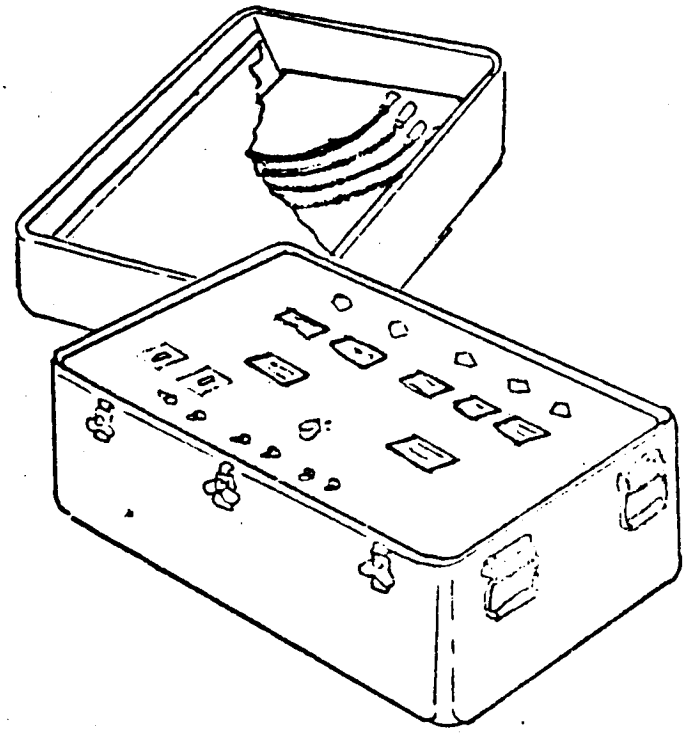


Figure 4-43 GSE Interconnection/Tug Hookup



APS BREAKOUT CONTROL BOX

FUNCTIONAL REQUIREMENTS:

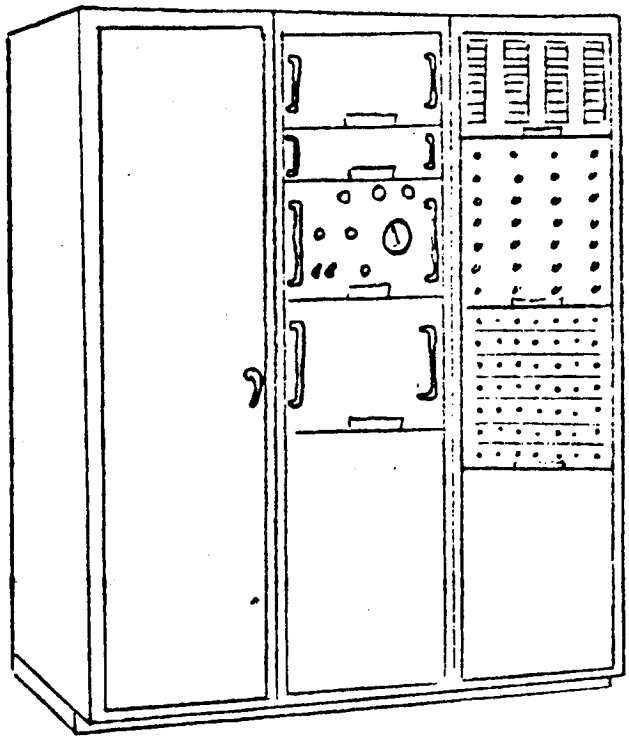
Provides individual electrical control of the APS thruster valves and isolation valves for checkout.

EQUIPMENT DESCRIPTION:

Twelve cable assemblies, suitcase assembly which contains one momentary sw., five push button indicator sw., one toggle sw., six indicator lamps, two circuit breakers, one six-bank wafer sw., five fuses, twelve connectors, and associated wiring. (Similar to DSV-7-106).

FACTORY REQUIREMENTS: 1

Figure 4-44



SPACE TUG SIMULATOR

FUNCTIONAL REQUIREMENTS:

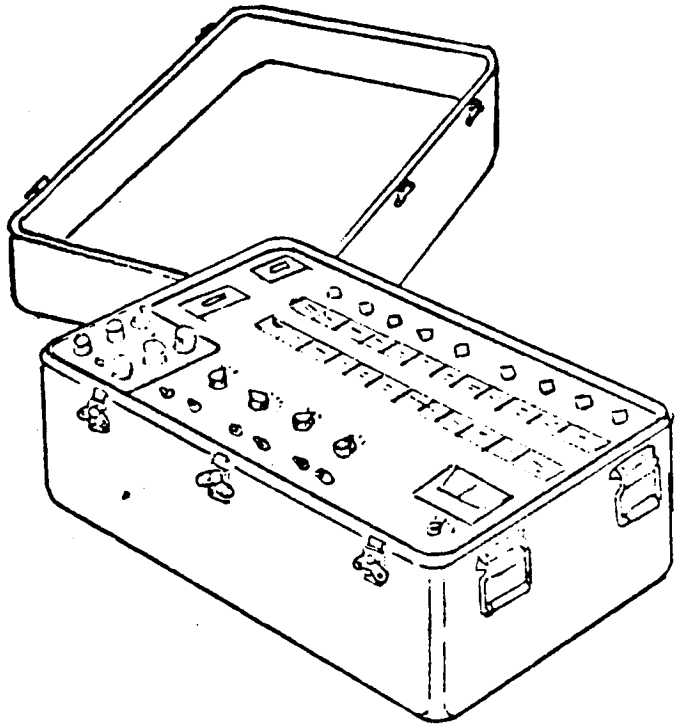
Functionally simulates Tug electrical parameters for verification of GSE, payloads and Shuttle interfaces.

EQUIPMENT DESCRIPTION:

3 Bay console interfacing with computer complex containing logic cards, encoder, decoder, and load test, test point assembly, indicator panels, logic power supply, path panel (similar to DSV-4B-132).

FACTORY REQUIREMENTS: 1

Figure 4-45



SPACECRAFT SIMULATOR

FUNCTIONAL REQUIREMENT:

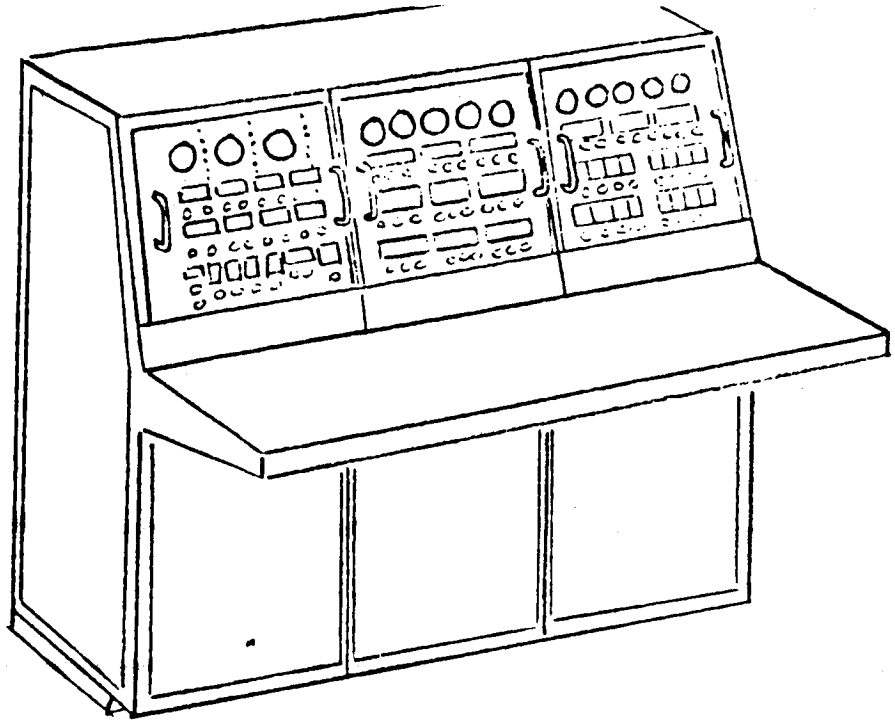
Functionally simulates Tug/Spacecraft interface for verification of electrical parameters.

EQUIPMENT DESCRIPTION:

Portable tester containing encoder, decoder and load test circuits.

FACTORY REQUIREMENTS: 1

Figure 4-46



PROPELLANT OR PNEUMATIC CONTROL CONSOLE

FUNCTIONAL REQUIREMENTS:

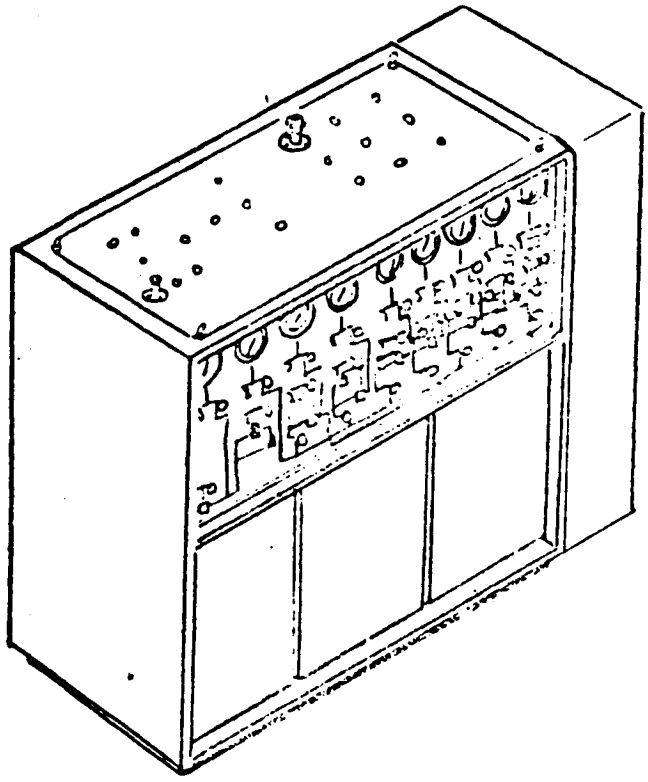
Controls and pneumatic regulated gas supplies for vehicle pressurization of pneumatics and propellant systems. Used for checkout, purge, and pressure checks and loading of pneumatics into Tug vehicle. Monitors propellant loading and unloading. Capable of semi-automatic or manual loading of propellants.

EQUIPMENT DESCRIPTION:

Three bay console with intercom, light and indicators, switches, and alpha numerical display, and associated circuitry. (Similar to DSV-4B-233.)

FACTORY REQUIREMENTS: 1

Figure 4-47



PROPULSION PNEUMATIC CONSOLE
(CHECKOUT)

FUNCTIONAL REQUIREMENTS:

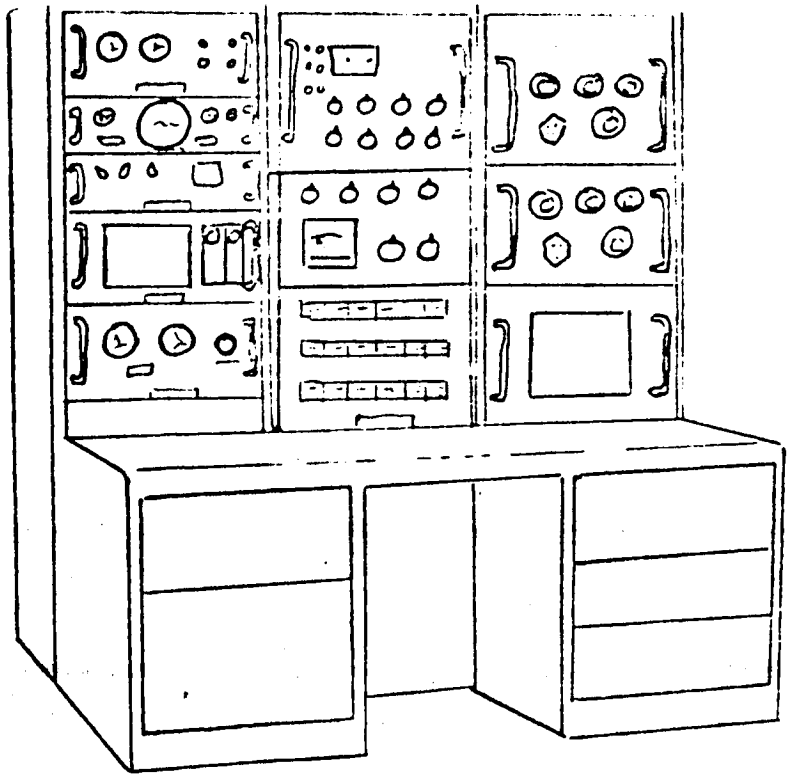
Provide regulated gas supplies to vehicle for pressurization of pneumatic and propellant systems. Used for leak and functional checks, purging, pressure draining, and application of blanket pressures.

EQUIPMENT DESCRIPTION:

Pneumatic console such as DSV-4B-321 modified as required for special Tug requirements.

FACTORY REQUIREMENTS: 1

Figure 4-48



PROPELLANT UTILIZATION COMPONENT TEST SET

FUNCTIONAL REQUIREMENTS:

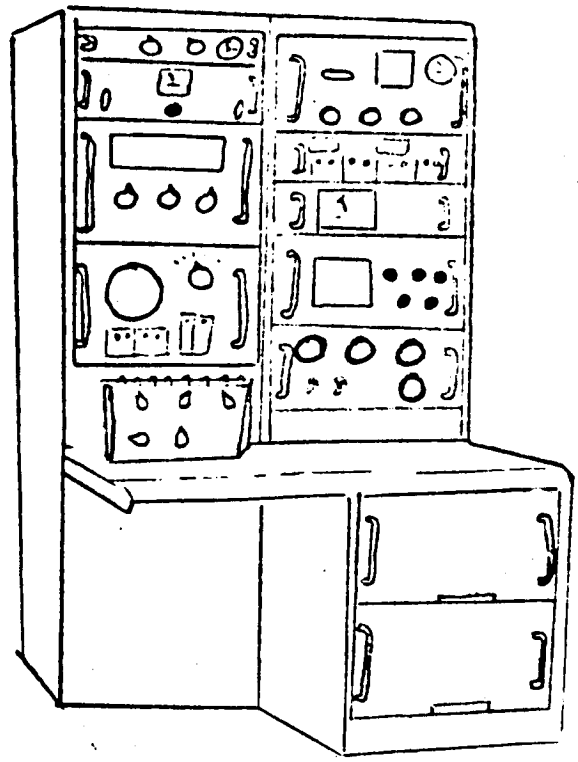
Tests and calibrates P.U. electronics assembly adjustments.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-112

FACTORY REQUIREMENTS: 1

Figure 4-49



PRINTED CIRCUIT CARD COMPONENT TEST SET

FUNCTIONAL REQUIREMENTS:

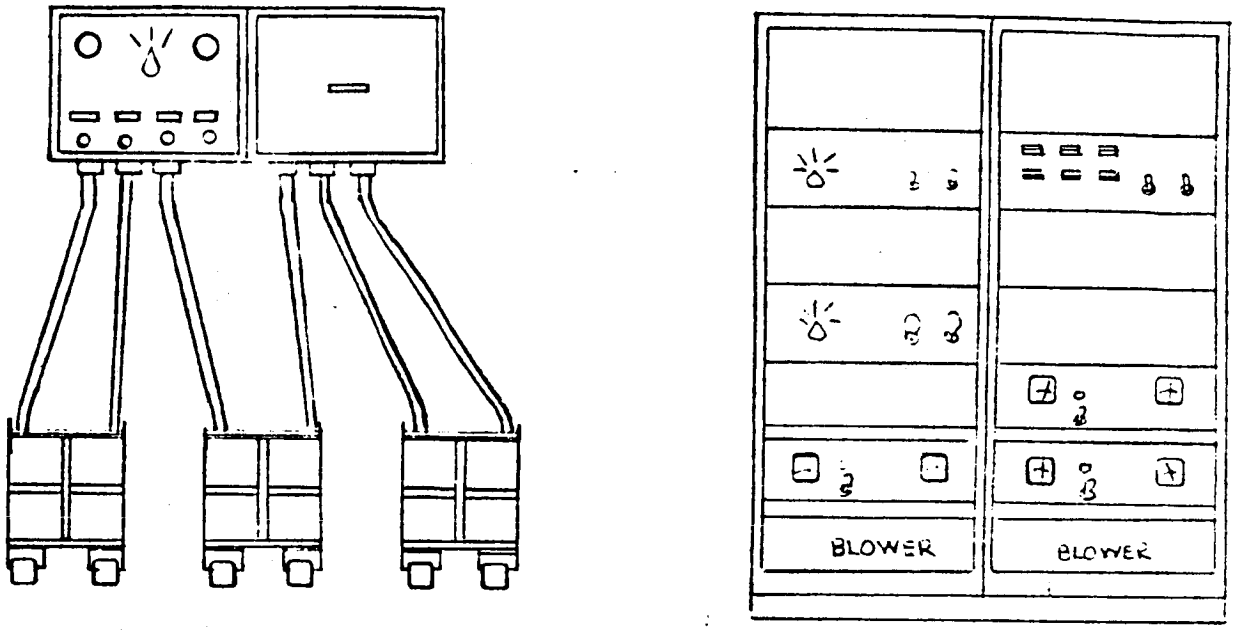
Tests printed circuit cards and isolates difficulties to component level. Provides voltages, input stimuli, and loads. Monitors outputs of cards being tested.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-104

FACTORY REQUIREMENTS: 1

Figure 4-50



POWER SYSTEM TEST SET

FUNCTIONAL REQUIREMENTS:

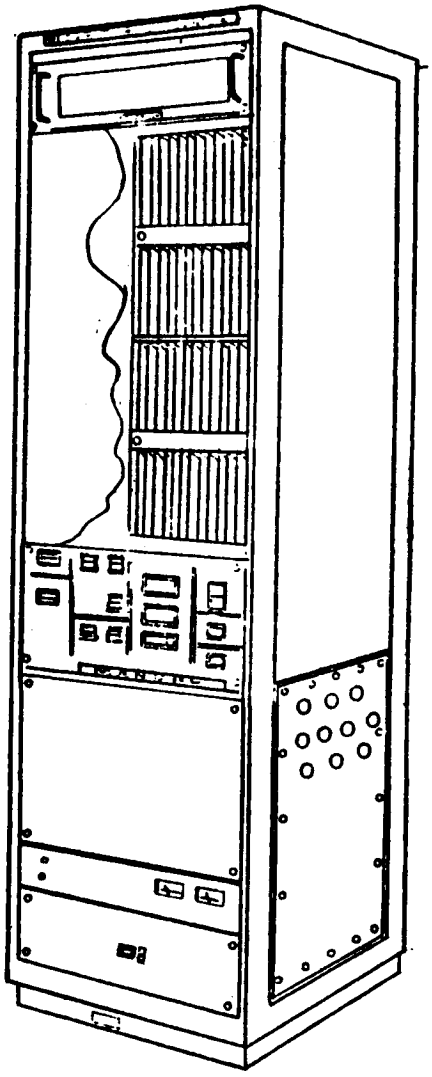
Provide means to load fuel cells and vehicle power distribution system. Provide ground power sources for vehicle and GSE. Provide emergency power in event facility power malfunction.

EQUIPMENT DESCRIPTION:

Two bay rack of electrical equipment containing two independent programmable power supplies for vehicle power, one programmable power supply for GSE power, and programmable loads for vehicle power system C/O, a backup battery unit is provided for emergency power.

FACTORY REQUIREMENTS: I

Figure 4-51



ORBITER SIMULATOR

Figure 4-52

NAME: ORBITER SIMULATOR

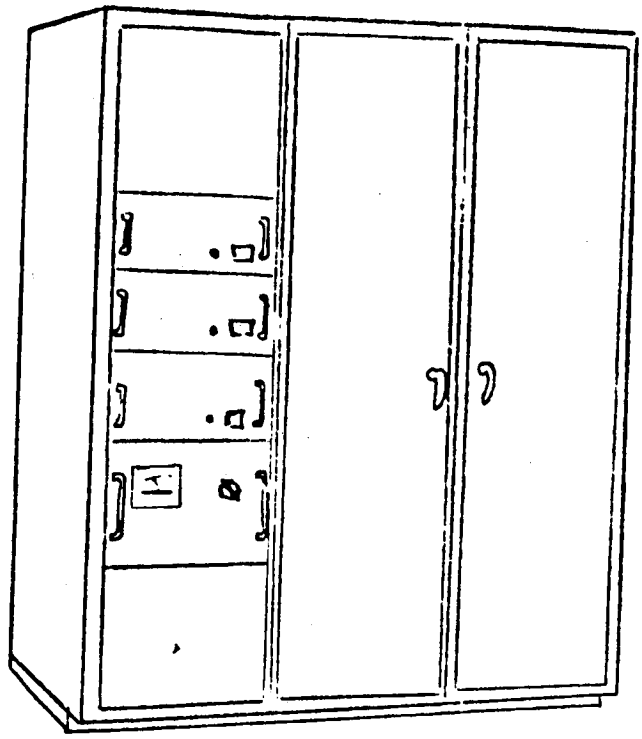
FUNCTIONAL REQUIREMENTS:

Functionally simulates orbiter/Tug interfaces for verification of electrical parameters.

EQUIPMENT DESCRIPTION:

Portable test set containing encoder, decoder and load test circuits. Contains switches and indicator lights.

FACTORY REQUIREMENTS: 1



SIGNAL CONDITIONING UNIT

FUNCTIONAL REQUIREMENTS:

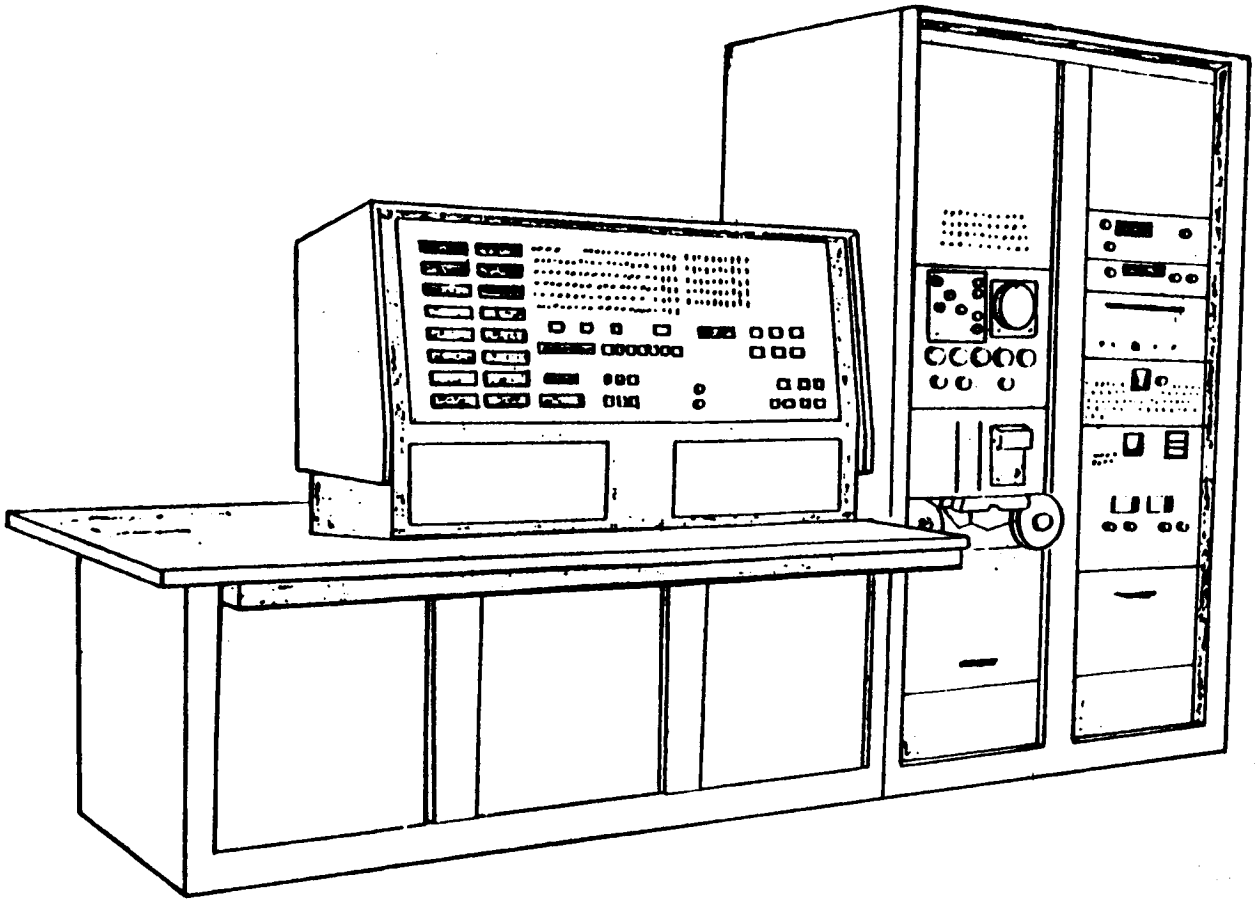
Interfaces between Tug vehicle and GSE for signal and power conditioning, and distribution.

EQUIPMENT DESCRIPTION:

Consists of a 3 bay console which contains junction box, (1) 1032 point patch panel assembly, (10) isolation amplifiers, (1) 4 row relay-plane, (10) buffer amplifiers, (1) logic power supply, and (20) connectors and associated wiring. (Similar to DSV-3B-133).

FACTORY REQUIREMENTS: 1

Figure 4-53



GUIDANCE AND NAVIGATION TEST SET

Figure 4-54

NAME: GUIDANCE AND NAVIGATION TEST SET

FUNCTIONAL REQUIREMENTS:

Monitors and verifies checkout of IMU and GC. It provides calibration, alignment and simulation of navigation programs. Capable of simulations of all flight programs.

EQUIPMENT DESCRIPTION:

Rate table and associated electronic bays which include display panel, control panel, oscilloscope, universal counter, digital voltmeter, interface (DIU) assembly, power supplies, digital printer paper tape punch, test point control panel, downlink display panel, etc. (Available from Delta Program.)

FACTORY REQUIREMENTS: 1

NAME: GUIDANCE AND NAVIGATION SYSTEM CHECKOUT KIT (PICTORIAL VIEW OMITTED)

FUNCTIONAL REQUIREMENTS:

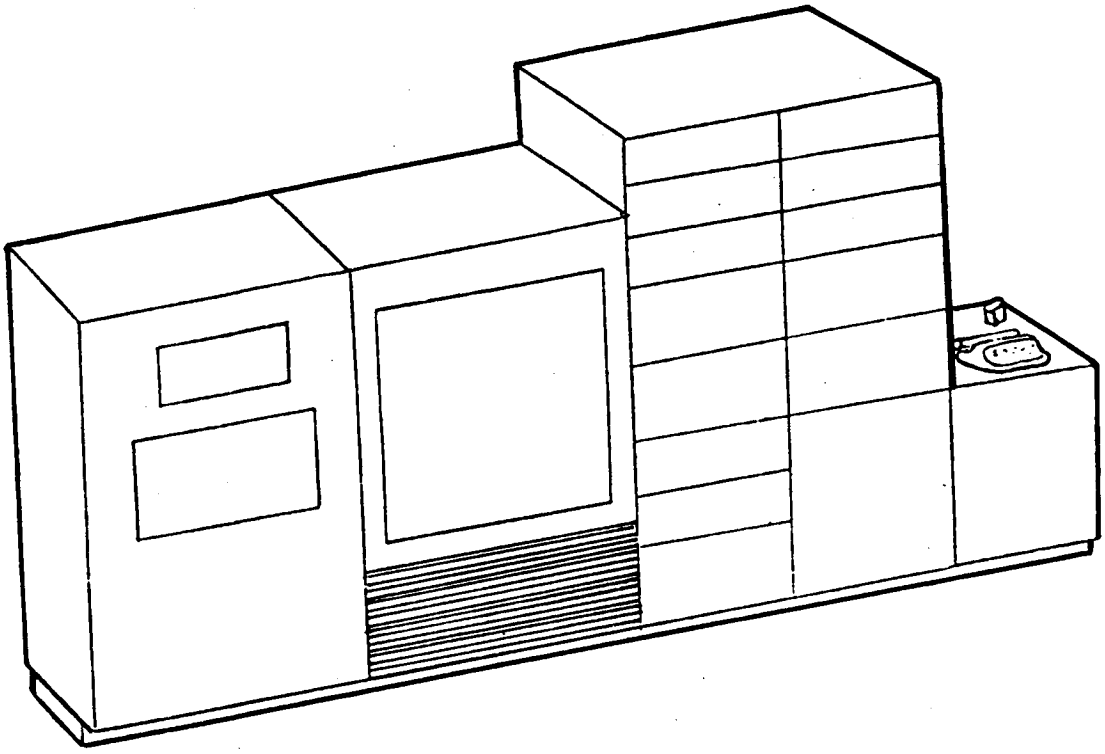
Interfaces between Tug IMU and GC and the laboratory test equipment. Also provides mounting of IMU to rate table.

EQUIPMENT DESCRIPTION:

Consists of IMU holding fixture and cables. (Available from Delta Program.)

FACTORY REQUIREMENTS: 1

Figure 4-55



DIGITAL EVENTS RECORDER (DER)

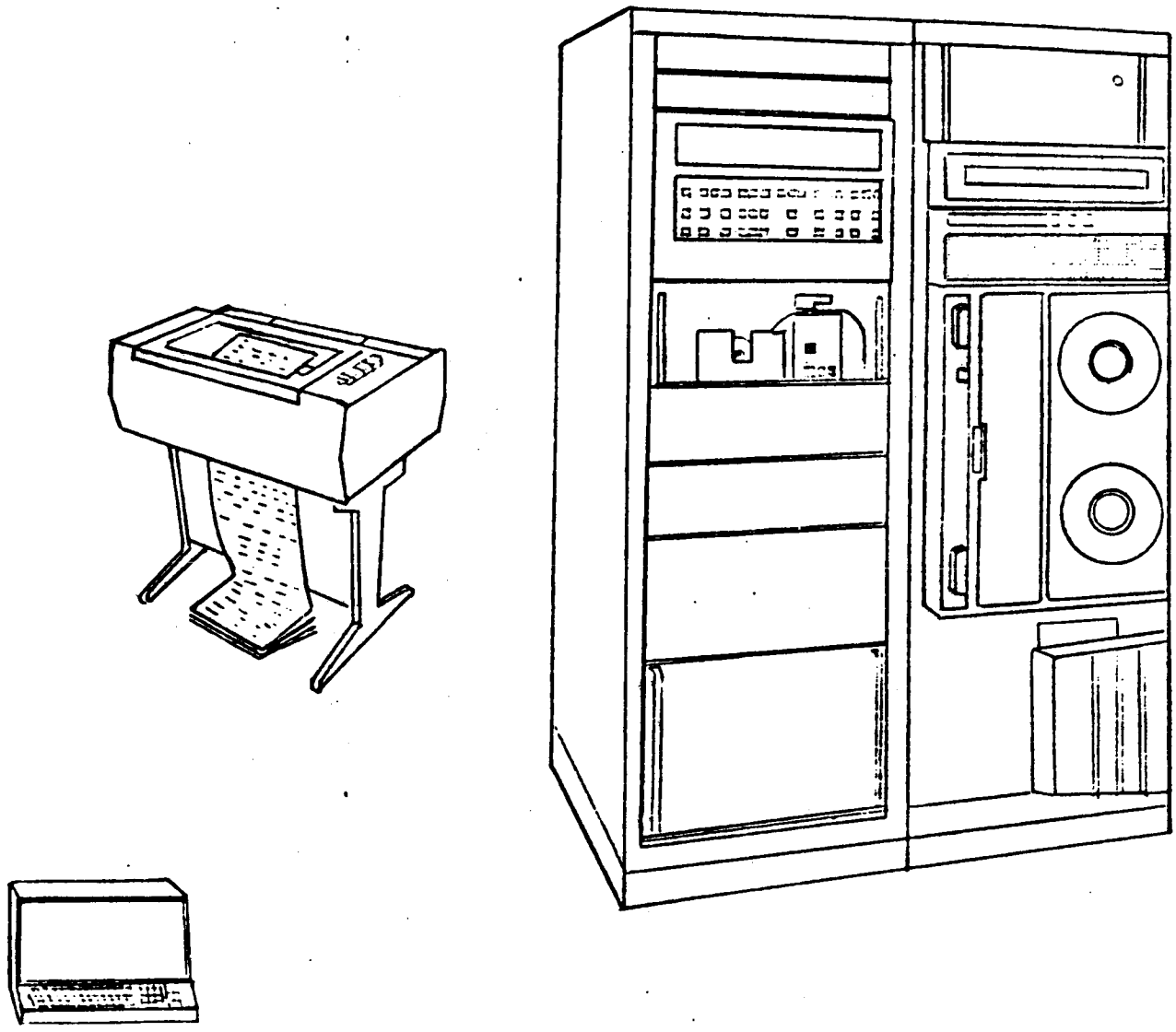
FUNCTIONAL REQUIREMENTS:

Collects discrete status (on/off) data and compares data against previously recorded information. Prints or tape punches output results for permanent record.

EQUIPMENT DESCRIPTION: Similar to DSV-4B-289

FACTORY REQUIREMENTS: 1 GFE

Figure 4-56



DATA MANAGEMENT TEST SET

FUNCTIONAL REQUIREMENTS:

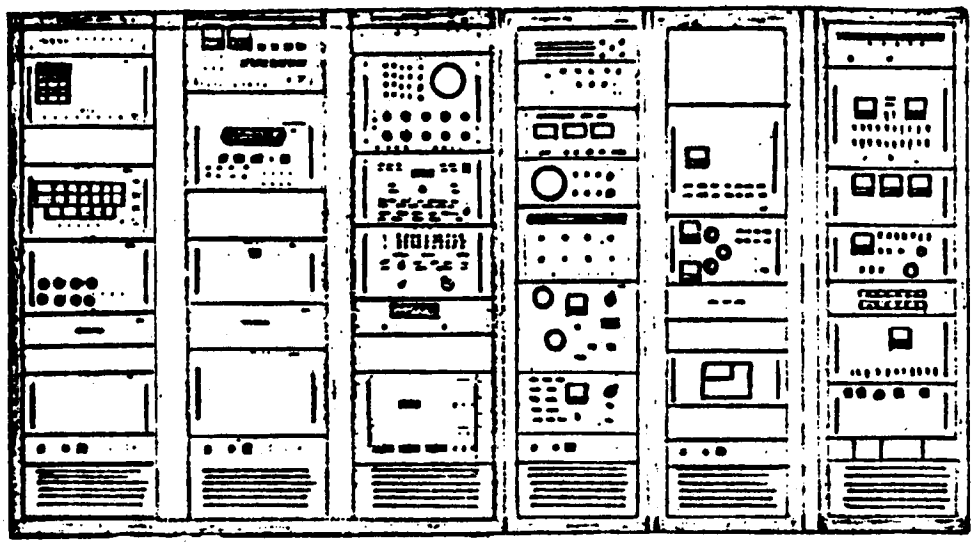
Controls operation of DMS computer and monitors computer status, initials program loading and verification, performs functional verification of DMS command and control functions, interface with other T/S for dedicated displays, verify selected subsystem parameters as program.

EQUIPMENT DESCRIPTION:

Portable console interfacing with computer for program verification and DMS memory dump C/O, paper tape memory loader, tape reader, DMS computer control and status panel, dedicated display panel for DMS function and programmable display for other subsystem functions (GNC, Comm, Power, and Prop.) - CRT

FACTORY REQUIREMENTS: 1

Figure 4-57



COMMUNICATION SYSTEM TEST SET

Functional Requirements

Receives, demodulates PCM data from spacecraft, provides for output to computer storage, contains display for visual data monitoring of incoming signals and routing of data to external areas for further processing. Can be controlled locally or through computer.

Equipment Description

NOMENCLATURE	QTY	FACTORY LAUNCH	DE-ORBIT	REMARKS
X-Y Recorder	1	X	*	*Equipment to be
Sweep Oscillator	1	X	*	made available
Signal Generator	1	X	*	at launch complex
VSWR Meter	1	X	*	in the event of
RF Power Meter	1	X	*	transmission
RF Misc. Equipment	TBD	X	*	failures.
Frequency Counter	1	X	X	Similar to DSV-
Frequency Converter	1			4B-123 and DSV-
S-Band Test Transmitter	2			4B-125
S-Band Test Receiver	2			
S-Band FM Receiver	1			
Payload PCM Demodulator	1			

Figure 4-58

Equipment Description (Cont'd)

NOMENCLATURE	QTY	FACTORY	LAUNCH	DE-ORBIT	REMARKS
SGLS/NASA PCM Demodulator	1				
PCM Decommutator	2				
PRN Ranging Assembly (SGLS/NASA)	2				
Error Rate Measuring Unit	1				
Command Signal Conditioner (SGLS/NASA)	2				
Regulated Power Supply	2				
Logic Power Supply	2				
PCM Simulator	1				
Oscilloscope	1				
Calibration Test Panel	1				
Manual Control Panel	1				
RF Switch Panel	1				
Source Selector Panel	1				
RF Attenuator Panel	1				
Quick Loop Panel	2				
Voice Communication Panel	3				
RMS Voltmeter	1				
Circuit Breaker Panel	2				
Patch Panel	1				
Analog Strip Chart	3				Similar to
Bilevel Strip Chart	3				DSV-4B-240,
FM Oscillograph	2				DSV-4B-238,
Digital to Analog Converters	80				DSV-4B-239
Galvanometer Drive Amplifiers	6				

FACTORY REQUIREMENTS: 1

NAME: CHECKOUT CABLE KIT (PICTORIAL VIEW OMITTED)

FUNCTIONAL REQUIREMENTS:

Provides interconnects between test sets, vehicle, power, etc.

EQUIPMENT DESCRIPTION:

Consists of all cable, (power, RF, signal) required to support Tug Unique checkout in all areas. Cable network - 70 cable assemblies (80 fet) long - (35) 60 pin cables; (18) 4 pin cables; (5) 39 pin cables; 7 coax cables; (5) 24 pin cables; breakout cables and general breakout box. Similar to DSV-4B-726A.

FACTORY REQUIREMENTS: 1

Figure 4-59

Section 5

SPECIAL PROGRAMMATICS

The three subsections to Section 5 address innovations in program implementation, management innovations, and potential government task sharing capabilities.

5.1 PROGRAM IMPLEMENTATION INNOVATIONS

Program Option 1 is heavily constrained by: a minimum DDT&E cost; a low peak year funding; and a fixed IOC date. In reviewing the areas available to us to exercise our creativity, we have reached the conclusion that there is very little opportunity to innovate. In trying to minimize DDT&E costs and keep annual funding low our approach on Option 1 is to reduce to the absolute minimum: the design, the manufacturing, and the operational unknowns by maximizing the use of proven systems and off-the-shelf hardware.

In the design area standard well-proven techniques are used to design and fabricate the 2219 aluminum tankage.

In the test area off-the-shelf propulsion subsystems enable us to eliminate, with low risk, the ground hot firing of the RL-10 engine. To further reduce costs we are recommending the elimination of a dedicated Shuttle flight test to prove operational integrity of the Tug-Shuttle interfaces, instead we suggest use of a ground interface verification unit.

In the use of of-the-shelf hardware much of the Avionics has been proven on other programs as the ACPS system has. In addition, maximum use is made of existing GSE (e.g., from S-IVB and Delta programs) and existing Facilities (Factory, Test, ETR, and WTR).

In the program management area there are opportunities to adopt a low-cost effective management approach using available tools and techniques developed for use on DoD, NASA, as well as commercial programs from throughout the MDC corporate family. The program management approach is discussed in subsection 5.2.

5.2 PROGRAM MANAGEMENT FOR THE SPACE TUG PROJECT

MDAC's management approach to the Space Tug project is to apply the tools and techniques most appropriate to ensure project control at an acceptable cost level. Our approach includes reaffirming the Government's management requirements so that we can be appropriately responsive to their needs. MDAC's available management tools and techniques have evolved during extensive development and use with both NASA and DoD programs as well as on Douglas' commercial aircraft programs.

As demonstrated during the Space Tug Phase A Systems Study, the MDAC management philosophy emphasizes "cost planning." This cost planning, which will continue throughout all phases of program definition and beyond, will result in cost-awareness/cost-avoidance attitudes that are essential to effective project cost control. Cost planning is not limited to the prime contractor's role, but will extend through the working relationships to the Government and to the suppliers to establish clear-cut cost objectives and the management plans appropriate for achieving these objectives.

MDAC's cost-awareness/cost-avoidance philosophy on Space Tug emphasizes the identification of and the avoidance of all unnecessary costs. This will call for close contractor/Government working relationships and teamwork to define and manage to only those effective project requirements. The net effect of the application of this philosophy is to develop the Space Tug with only the necessary equipment, material, and labor, and hence at lower costs.

Actions that highlight the MDAC low-cost management approach on Space Tug include:

- Develop (in concert with the customer) well-defined mission performance parameters and cost objectives early in DDT&E.
- Assign highly capable personnel with applicable experience.
- Develop well-defined program plans based upon essential technical and management requirements to accomplish the mission. These program plans will be brief and concise and directive in nature to provide clear management direction and assessment without excess detail.
- Provide closely coupled contractor/Government working relationships including collocation of counterparts and task-sharing where effective.

- Develop specific contractual clauses that provide motivation to both contractor and Government to achieve the lowest cost consistent with excellence of performance and tight schedule requirements.
- Operate critical change control under strict criteria (is it functionally necessary — it is cost-effective) for accept/reject decision.
- Apply management systems responsible to the needs of contractor/Government and provide timely visibility into potential problem areas to avoid vulnerability to unplanned cost or schedule delays.
- Procure "Buy" items, particularly off-the-shelf material and subsystems components, from lowest-cost, technically capable suppliers.

Features of several of the more crucial management systems are presented below:

- Performance Measurement System (PMS)
  The MDAC PMS is an on-line approved system currently in use on the Air Force ACE program, the Army SAFEGUARD/Spartan and Site Defense programs, and the Navy Harpoon program. Our experiences show that a low-cost and effective PMS requires a realistic WBS structure, ability to selectively apply BCWS/BCWP and variance analyses, ability to adjust the levels of reporting and control to the magnitude of the cost risk represented by the WBS elements, and to provide management reports at meaningful time intervals.
- Cost-Per-Flight (CPF) Management Controls
  CPF controls have been developed that are closely integrated with the PMS and the change control system. Based upon MDAC's life-cycle-cost-modeling technology, CPF provides cost goals (targets) throughout the WBS. CPF provides continuing predictive capability for total cost, and impact assessment, and variance projections against lower-level WBS element cost targets as well as total project cost. Multi-discipline specialists work closely together to develop the cost estimates leading to the CPF targets. The task and functional managers are accountable for successful attainment of CPF goals, including development of the options and trade analyses necessary to

recover should unfavorable variances appear. One of the keys to achieving low-cost objectives is to understand the impact of decisions on program costs — a primary purpose of CPF.

- Configuration and Change Management (CM)

  The goal of CM is to effectively define contract item configuration and to manage change. On Space Tug, once a configuration is defined, it is imperative that strict criteria, by which a proposed change can be evaluated and accepted/rejected rapidly and effectively, be established. The configuration control board chaired by the program manager will use the CPF analysis to know the impact of changes against the CPF targets and the cost budgets. There is a corollary to the use of strict change criteria which implies that to avoid unnecessary costs, the mission requirements are well defined and the design team can design it right the first time to minimize change.

- Information Management (IM)

  The most effective as well as lowest-cost IM system makes maximum use of informal direct communication between designated contractor/Government counterparts for daily decision-making. This informal interchange is backed up by the formal contractual reporting system, which provides documentation of the key data and decision/action items for historical reference. The contracted data procurement document (DRD) and data requirements list (DRL) will make maximum use of internal data whever possible. In addition, MDAC's accessioning and deferred delivery methods will offer the customer up-to-date information on available internal documentation while minimizing the need for routine submission of data.

- Procurement Management

  MDAC's approach to make-or-buy, source selection, and procurement is to make use of existing proven industry capabilities while maintaining focus on the CPF targets. CPF targets are passed on to subcontractors and suppliers with appropriate contract incentives. Supplier reports are integrated into our PMS and CPF project reviews with a minimum of reprocessing. In accord with our internal information management system, the customer will have direct access to subcontractor/supplier data.

- Engineering Management

  MDAC's design team has extensive and successful cryogenic launch vehicle experience. A single organization will perform analyses, integration, and design tasks supported by functional specialists, as required (tooling, manufacturing, quality, test, logistics, etc) who are involved from project inception. Supporting this multi-discipline team approach is the recommendation for collocating contractor/customer/supplier representatives to encourage face-to-face daily dialogue. Cost-per-flight targets are assigned down to the lowest practical level of the WBS, and the design team will have specific Design-to-Cost (DTC) training. As the design concept evolves, senior engineers will be part of the team that will review the mission requirements, the design requirements, the detailed specifications, and the design drawings to ensure a thorough evaluation of alternatives to emphasize low-life-cycle costs, standard parts, and off-the-shelf hardware. Critical technical performance parameters, e.g., CPF, are selected for status reporting to provide most-meaningful technical progress assessment. Parameters are tracked by time-dependent trend data or single-point events and are measured by analysis or test with variances reported in time for corrective action with minimum cost/schedule impact. In addition to the above, the Engineering and the Manufacturing releases are closely coordinated (jointly signed off) before release to ensure full understanding and communication of each others' requirements and intentions.

In summary, application of MDAC's cost-awareness/cost-avoidance philosophy will enable Space Tug to avoid unnecessary material and labor costs. We will:

A. Understand the essential mission and program requirements, specifically:
   1. Technical
   2. Management
   3. Cost

B. Design and manage to meet the essential life-cycle requirements and the CPF targets

C. Test to verify design but minimize test hardware requirements and testing activities.

5.3 TASK SHARING

A library of both NASA and Air Force facilities and capabilities has been established by MDAC at MSFC and documentation indexes are available. Our review of these reference materials has identified potential areas for government task sharing on Space Tug. These areas are summarized on Table 5.3-1. Tables 5.3-2 through 5.3-8 contain the NASA and the Air Force Documentation Indexes. Table 5.3-9 summarizes the investigation into the MSFC S-IVB Battleship Test Stand conversion. Tables 5.3-10 and 5.3-11 summarizes the investigation into the AEDC Test Chamber capabilities. Table 5.3-12 presents a summary of the items reviewed for potential task sharing at AEDC.

Table 5.3-1 GOVERNMENT TASK SHARING CAPABILITY AREAS

ORGANIZATION / [illegible] ELEMENT	NASA				DOD			
	MSFC	JSC	KSC(ETR)	LeRC	WPAFB	AEDC	WTR	SAMSO
[illegible] TYPE								
320.03.03 AVIONICS	X	X			X			
320.03.04 PROPULSION	X	X		X				
[illegible]								
320.03.04 PROPULSION	X	X		X		X		
320.03.03 AVIONICS	X	X			X			
FACILITIES EVALUATION/MODIFICATION								
320.06 FACILITIES			X				X	
MISSION PLANNING								
320.11.01	X	X						SPECIFIC PLANNING
MISSION SUPPORT								
320.11.02	X	X	X				X	X

Table 5.3-2

FACILITIES & CAPABILITIES RESOURCES DOCUMENTS ACQUISITION

DOCUMENTATION INDEXES
MULTIPLE LISTINGS

ALL NASA, AIRFORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES

- NASA TECHNICAL FACILITIES CATALOG - NHB 8800.5, MARCH 1967, VOLUMES I AND II
- MDAC HYFAX REPORT
  - NASA N72-12182 - WIND TUNNELS - CR 1874
  - NASA N72-13233 - PROPULSION - CR 1875
  - NASA N72-12183 - STRUCTURES - CR 1876
  - NASA N72-14274 - FLT SIMULATORS - CR 1877
- AFSC-M-DH-1-3 PERSONNEL SUBSYSTEM (MUST BE UTILIZED WITHIN THE CONFINES OF THE REDSTONE SCIENTIFIC INFORMATION CENTER)

Table 5.3-3

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

DOCUMENTATION INDEXES

NASA

AMES

- RESEARCH FACILITIES SUMMARY
- SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING

FLIGHT RESEARCH CENTER

- CONTACT DISCUSSED THEIR HIGH TEMPERATURE LOADS LABORATORY AND HANGAR TYPE FACILITIES
- SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING

GIFSS

- LACK OF INTEREST DEMONSTRATED
- ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING

GSFC

- CONTACT INDICATED NOTHING WAS AVAILABLE AT EITHER OF THE GODDARD FACILITIES
- SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

Table 5.3-4

DOCUMENTATION INDEXES

NASA

JPL

- (SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING)

JSC

- THE BLUE BOOK OF ORGANIZATION FUNCTIONS KEY PERSONNEL
- MAJOR TEST FACILITIES OF THE ENGINEERING & DEVELOPMENT DIRECTORATE
- (SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING)

KSC

- ORGANIZATION FUNCTIONS KEY PERSONNEL - GP-768 - JANUARY 1, 1973 (REV. 1/73)
- KSC ORGANIZATION MANAGEMENT NOTICES - KN 1142.1 - 1 - 25
- FACILITIES DESCRIPTIONS, KSC/ETR, MAY 15, 1971, TR-1080, REV 1
- SUPPORT SERVICES HANDBOOK, AUGUST 11, 1971, KHB 8610-1A/AD
- (SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING)

Table 5.3-5

DOCUMENTATION INDEXES

NASA

LeRC

- HAVE NEVER PUT TOGETHER A FACILITY HANDBOOK
- WORLD'S LARGEST SPACE CHAMBER - 100 FT. DIAMETER BY 120 FT. HIGH, BUILT FOR NUCLEAR - PLUM BROOK STATION
- SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES DOCUMENT

LRC

- SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES DOCUMENT

MSFC

- MSFC ORGANIZATION HANDBOOK
  - S&E LAB ORGANIZATION CHARTS
- TECHNICAL FACILITIES AND EQUIPMENT DIGEST
- ASTRIONICS LABORATORY FACILITIES AND CAPABILITIES
- MACHINE TOOL MANUFACTURING MASTER INDEX, VOLUME I
- MACHINE TOOL MANUFACTURING MASTER INDEX, VOLUME II
- MSFC EQUIPMENT AVAILABILITY LISTING, JANUARY, 1973

Table 5.3-6

DOCUMENTATION INDEXES

NASA

MSFC (CONTINUED)

- SATURN/SKYLAB/ENGINES CONFIGURATION MANAGEMENT MANUAL - NO. MM8040. 10A DATED FEBRUARY 17, 1970
- NASA MISSISSIPPI TEST FACILITY
- MICHOUD ASSEMBLY FACILITY
- SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING

WHITE SANDS

- SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING
- WHITE SANDS TEST FACILITY

Table 5.3-7

DOCUMENTATION INDEXES

AIR FORCE

AEDC

- TECHNICAL FACILITIES HANDBOOK. 9TH EDITION
- DOD FUNDING POLICY & REQUIRED BUDGET ACTION FOR FY 75
- TEST HIGHLIGHTS, ALL ISSUES
- ASSORTED LETTERS ON NEW TESTING CAPABILITIES AT AEDC
- S-IVB BATTLESHIP TEST FACILITY, COMPLETE INFORMATION

AFSCP

- ACQUISITION MANAGEMENT, A GUIDE FOR PROGRAM MANAGEMENT - AFSCP-800-3

WPAFB

- DESCRIPTIONS OF AFAPL/PO IN-HOUSE FACILITIES
- AIR FORCE AVIONICS LABORATORY, TECHNICAL PROGRAMS & CONTACTS. THE DYNAMIC ANALYZER COMPLEX MISSION & CAPABILITY
- MISSION ORGANIZATION ACCOMPLISHMENTS
- AIR FORCE MATERIALS LABORATORY, MISSION ORGANIZATION AND ACCOMPLISHMENTS
- AEROSPACE POWER FACILITIES
- TECHNICAL PROGRAM AND CONTACTS
- SEE ALL NASA, AIR FORCE OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING

Table 5.3-8

DOCUMENTATION INDEXES (CONTINUED)

AIR FORCE

EAFB

- AIR FORCE ROCKET PROPULSION LABORATORY FACILITY BROCHURE
- SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING

GRIFFISS AIR FORCE BASE

- ROME AIR DEVELOPMENT CENTER
- SEE ALL NASA, AIR FORCE, OTHER GOVERNMENT & INDUSTRY FACILITIES LISTING

Table 5.3-9

GOVERNMENT FACILITY INVESTIGATION

FACILITY:

- MSFC S-IVB BATTLESHIP TEST STAND/CONVERSION TO SPACE TUG FACILITY

DISCUSSION:

- SUFFICIENT PROPELLANT, GAS, INSTRUMENTATION AND ETC. FOR COLD FLOW AND STATIC FIRING
- MODIFICATION REQUIRED
  - REMOVE EXISTING TANKAGE
  - MODIFY EXISTING THRUST SUPPORT RING AND WORK PLATFORMS
  - MODIFY FACILITY PROPELLANT, GAS & INSTRUMENTATION INTERFACE TO VEHICLE
  - ADDITION OF ALTITUDE SIMULATION SYSTEM
  - ROM QUOTE TO BE MADE

Table 5.3-10

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

GOVERNMENT FACILITIES INVESTIGATION

FACILITY:

AEDC MARK I CHAMBER

LOCATION:

TULLAHOMA, TENN.

DISCUSSION:

- ADEQUATE DYNAMIC TEST CAPABILITY EXCEPT FOR ACOUSTICS
- LIMITED TO LN_2 AND SMALL QUANITY OF LH_2
- GOOD SOLAR HEAT SIMULATION CAPABILITY
- GOOD SPACE ENVIRONMENT SIMULATION CAPABILITY, BUT SLOW PUMP DOWN RATE
- GOOD INSTRUMENTATION CAPABILITY
- ROM QUOTE MADE

5.1/5

Table 5.3-11

GOVERNMENT FACILITIES INVESTIGATION

FACILITY:

AEDC J-3 AND J-4 TEST CHAMBER

LOCATION:

TULLAHOMA, TENN.

DISCUSSION:

- GOOD ALTITUDE ENGINE FIRING TEST FACILITIES AT 75,000 FT.
- GOOD PROPELLANT, GAS, INSTRUMENTATION AND ETC. CAPABILITY
- NO DYNAMIC AND SPACE HEAT SIMULATION CAPABILITY
- REACTIVATION REQUIRED
- J-3 TOO SMALL FOR TUG VEHICLE TESTING
- ROM QUOTE MADE

Table 5.3-12

TASK SHARING INVESTIGATIONS

ITEMS REVIEWED

- o STAGE TESTS
  - o FLT VIBR SIMULATIONS
    - o LIFTOFF TO ORBITAL INSERTION
    - o TUG OPERATION (DEPLOY AND/OR RETRIEVE)
    - o RE-ENTRY AND LANDING
  - o FLT THERMAL SIMULATION
    - o INSULATION EVALUATION
      - o PROPELLANT DEPLETION (SIMULATE)
      - o SOLAR ENVIRONMENT (SIMULATE)
    - o LH_2 BOILOFF
- o ENGINE/STAGE TESTS
  - o COLD FLOW
  - o ENGINE FIRING

SECTION 6

COST DATA

This section contains cost estimates for each program phase (DDT&E), production and operations) by WBS element and subdivisions of work. Also included are: funding estimates for each program phase by WBS element; total program funding distribution; cost per flight data; and technical characteristics data.

Since subsection 6.2 contains first unit production costs through Level 7 for WBS 320-03 Vehicle Main Stage on Cost Data Form A(2) recurring (production), the Level 7 information is not repeated by itself in Subsection 6.8. Instead Subsection 6.8 is being used as the most convenient location for the LEADER II cost model printout for costs of each program phase and the total program, as well as: costs for first production unit costs through Level 7; and initial spares and operational spares costs through Level 6.

6.1 DDT&E PER WBS ELEMENTS

This subsection contains cost estimates for each WBS element through Level 7, as appropriate, displayed on Cost Data Form A(1), nonrecurring (DDT&E). The definitions of each column are as follows:

Identification Number: The appropriate WBS code corresponding to the item of cost.

WBS Identification: The alphanumeric nomenclature of the item from the WBS.

WBS Level: The level at which the cost is accumulated:

Level 3	-	Project
Level 4	-	System/Module
Level 5	-	Subsystem
Level 6	-	Assembly
Level 7	-	Component

Expected Cost: The cost estimate for the WBS item. For production and operations items, the WBS item cost is the total cumulative cost for the number of units quantified in the "number of units" column.

Confidence Rating: The value of (1), lowest, through (4), highest, representing the estimator's confidence in the estimate shown in the WBS item cost column. The value is obtained by reviewing the Government criteria contained

in Table 6.1-1 and subjectively selecting the code considered to be most applicable. At summary levels the confidence rating values are weighted averages of the confidence ratings of constitutent WBS elements at subordinate levels.

Td: The time in months required to perform an activity. For nonrecurring (DDT&E) activity, the Td is the time required from Authorization to Proceed (ATP) with Phase C (nonrecurring/DDT&E) through completion of designs, development, test and evaluation, which usually is at FACI-First Article Configuration Inspection. Td for production generally is the time from the start of ground system installation and test procedures verification through completion of flight evaluation and preparation of ground system and flight vehicles for long term storage.

Ts: The lead time in months measured from the start of Td to the Initial Operational Capability (IOC), the launch milestone date.

Spread Function: An index number representing a cost distribution curve which the estimator recommends for the time phasing of costs over the Td time span. The index number represents the percentage of total cost (of the WBS item for the program phase) expected to be expended in 50 percent of the Td time span. At summary levels the spread functions are weighted averages of the

Table 6.1-1
CONFIDENCE LEVEL GROUPS FOR COST ESTIMATES

	CONFIDENCE LEVEL 1 LOW	CONFIDENCE LEVEL 2 MEDIUM LOW	CONFIDENCE LEVEL 3 MEDIUM HIGH	CONFIDENCE LEVEL 4 HIGH
ESTIMATING CONDITIONS	Estimating Time and Information Access Completely inadequate amount of time provided to make the estimate or there is a complete lack of access to useful data sources. Ground Rules and Assumptions No guidance was provided on ground rules and all assumptions made by the estimator were arbitrary.	Estimating Time and Information Access A very short due date or major problems of access to available data tend to make this estimate highly uncertain. Ground Rules and Assumptions Very little guidance was provided relative to ground rules. Most of the assumptions made by the estimator were considered quite arbitrary.	Estimating Time and Information Access A more accurate estimate could have been made if freer access or more time had been available to research known data sources. Ground Rules and Assumptions Ground rules were generally adequate. Many of the assumptions were authenticated but a substantial number are considered questionable.	Estimating Time and Information Access There were minor problems of access to available data and there was generally sufficient time to define and cost the item. Ground Rules and Assumptions Major ground rules were provided and most of the assumptions were authenticated.
NATURE OF THE ITEM	State-of-the-Art The item is substantially beyond the current state-of-the-art. Major development work is required. Production Experience No production of any kind has been started.	State-of-the-Art The item is slightly beyond the state-of-the-art and some development work will be required. Production Experience Experimental laboratory fabrication of a similar item is in process.	State-of-the-Art The item is within the state-of-the-art but no commercial counterpart exists. Production Experience A prototype of the item has been produced.	State-of-the-Art The item will involve a minor modification of commercial or standard aerospace issue items. Production Experience the item has been produced in limited quantity.
ITEM DESCRIPTION	Specification Status No work on a specification has started. Operating Program Characteristics None of the OPC for using the item have been formulated.	Specification Status Work on a specification is in an early stage and only general requirements are identified. Operating Program Characteristics The general outline of the OPC under which the item will be used has been only tentatively defined and many specific details are lacking.	Specification Status A specification for the item has not been completed but a specification on a similar item is available. Operating Program Characteristics The general outline of the OPC has been formulated but many specific details are lacking.	Specification Status A specification for the item has been prepared but is under review or revision. Operating Program Characteristics The OPC have been substantially defined but are under review or revision.
COST METHODS AND DATA	Methods The estimate is almost a poor guess and little or no confidence can be placed in it. Data An almost total lack of current and reliable relevant data make the cost estimate completely uncertain.	Methods A highly arbitrary rule-of-thumb has been used. Data The data used to make the estimate highly suspect, very sparse in quantity, and characterized by major inconsistencies.	Methods A commonly used rule-of-thumb cost factor but with no supporting backup has been used. Data The data used have been obtained from official or standard sources. Notable inconsistencies, lack of currency, gaps in data reduce the confidence in the estimate.	Methods The basic method used to derive the cost is well documented but no double-check or authentication has been possible Data The data used are generally relevant and from a reputable source. They are incomplete, preliminary, or not completely current however.

spread functions of constituent WBS elements at subordinate levels.

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T D	T S	SPREAD FUNCT.
32001	PROJECT MGMT.	4	7.08	3.0	60	54	0
32002	SYS. ENGR. & INT.	4	14.23	3.0	60	54	40
32003	VEH MAIN STAGE	4	102.17	3.8	55	54	59
32004	VEH AUX. STAGE	4	1.63	3.0	35	44	50
32005	LOGISTICS	4	3.02	3.0	39	45	0
32006	FACILITIES	4	5.17	3.0	76	55	50
32007	GRND. SUPT. EQUIP	4	32.09	4.0	66	51	40
32008	VEHICLE TEST	4	21.32	3.0	54	48	40
32009	LAUNCH OPNS. WTR	4	.00	3.0	39	45	0
32010	LAUNCH OPNS ETR	4	.00	3.0	39	45	0
32011	FLIGHT OPNS NASA	4	5.33	3.0	41	35	60
32012	FLIGHT OPNS DOD	4	4.79	3.0	41	35	60
32013	REFURB &INTEG WTR	4	.11	3.0	39	45	0
32014	REFURB &INTEG ETR	4	.11	3.0	39	45	0
320	TOTAL	3	197.05	3.6	77	54	50

6-9

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T 0	T 3	SPREAD FUNCT.
32001	PROJECT MGMT.	4	7.08	3.0	60	54	0
3200101	COST/PERF. MGMT.	5	4.86	3.0	60	54	0
3200102	PROJ. DIRECTION	5	2.08	3.0	60	54	0
3200103	INFORM. MGMT.	5	.14	3.0	60	54	0

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T D	T S	SPREAD FUNCT.
32002	SYS. ENGR. & INT.	4	14.23	3.0	60	54	40
3200201	TUG SYS. ENGR.	5	11.38	3.0	60	54	40
3200202	SHUTTLE I/F	5	.71	3.0	60	54	40
3200203	PAYLOAD I/F	5	2.13	3.0	60	54	40

8-7

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T D	T S	SPREAD FUNCT.
32003	VEH MAIN STAGE	4	102.17	3.8	55	54	59
3200301	STRUCTURES	5	16.38	4.0	45	54	60
3200302	THERMAL CONTROL	5	.93	3.0	43	54	60
3200303	AVIONICS	5	28.01	4.0	48	54	57
3200304	PROPULSION	5	32.70	4.0	45	54	59
3200305	ORBITER I/F	5	12.89	3.0	55	54	68
3200306	DROP TANKS	5	.00	3.0	0	0	0
3200307	FINAL ASSY & C/O	5	11.25	3.0	51	54	59
320030101	FUEL TK & SUPT	6	3.96	4.0	45	54	60
320030102	OXID. TK & SUPT	6	2.01	4.0	45	54	60
320030103	BODY STRUCTURE	6	4.09	4.0	45	54	60
320030104	THRUST STRUCTURE	6	1.58	4.0	45	54	60
320030105	METEOROID SHIELD	6	.98	4.0	45	54	60
320030106	PAYLOAD I/F	6	2.74	4.0	45	54	59
320030107	INSTL, ASSY & C/O	6	1.21	4.0	45	54	60
320030201	FUEL TANK INSL	6	.16	3.0	43	54	60
320030202	OXID. TANK INSL.	6	.08	3.0	43	54	60
320030203	INSL. PURGE SYS.	6	.65	3.0	43	54	60
320030204	THERM CONT. SYS.	6	.00	3.0	0	0	0
320030205	INSTL ASSY & C/O	6	.04	3.0	43	54	60
320030301	DATA MGMT. 3	6	10.69	4.0	48	54	53
320030302	G N & C	6	1.47	4.0	48	54	60
320030303	COMMUNICATIONS	6	7.16	4.0	48	54	56
320030304	INSTRUMENTATION	6	2.08	4.0	48	54	60
320030305	ELECT. POWER	6	.14	4.0	48	54	56
320030306	PWR. DIST. & CONT	6	.91	4.0	48	54	59
320030307	INSTL, ASSY & C/O	6	5.56	4.0	48	54	59
320030401	MAIN ENGINE 3	6	13.00	4.0	45	54	60
320030402	MAIN ENG. SUPT	6	12.11	4.0	45	54	57
320030403	ACPS ENGINE	6	.41	4.0	45	54	57
320030404	ACPS ENG. SUPT	6	5.62	4.0	45	54	59
320030405	INSTL, ASSY & C/O	6	1.56	4.0	45	54	59
320030501	STRUCTURES	6	4.01	3.0	55	54	69
320030502	I/F PANELS	6	6.47	3.0	55	54	68
320030503	PURGE PROV.	6	.00	3.0	0	0	0
320030504	ABORT PROV.	6	1.45	3.0	55	54	68
320030505	INSTL, ASSY & C/O	6	.95	3.0	55	54	68
320030701	FINAL ASSY	6	8.53	3.0	51	54	59
320030702	C/O	6	2.73	3.0	51	54	59
32003010101	LH2 DOMES	7	1.74	4.0	45	54	60
32003010102	LH2 CYLINDER	7	1.92	4.0	45	54	60
32003010103	LH2 SUPPORTS	7	.30	4.0	45	54	60
32003010201	LO2 DOMES	7	1.67	4.0	45	54	60
32003010202	LO2 SUPPORTS	7	.35	4.0	45	54	60
32003010301	FWD AFT SKIRT	7	.00	4.0	0	0	0
32003010302	INTERTANK	7	1.94	4.0	45	54	60

STUDY TITLE: SPACE TUG SYS STY (CRT)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T O	T S	SPREAD FUNCT.
32003010303	SDWL SHELL	7	2.15	4.0	45	54	60
32003030101	COMPUTER	7	6.22	4.0	48	54	57
32003030102	DATA DISTR.	7	.00	4.0	0	0	0
32003030103	EQ. THERM CONT.	7	.75	4.0	48	54	54
32003030104	CIRCUITRY 3	7	.59	4.0	48	54	59
32003030105	SOFTWARE	7	2.33	4.0	48	54	60
32003030106	SOFTWARE	7	.00	4.0	0	0	0
32003030107	SOFTWARE	7	.00	4.0	0	0	0
32003030108	INSTL. ASSY & C/O	7	.79	4.0	48	54	58
32003030201	I M U	7	.72	4.0	48	54	60
32003030202	TRACKING/ELECT 3	7	.65	4.0	48	54	60
32003030203	REN DEZ&DOCKING 3	7	.00	4.0	0	0	0
32003030204	INSTL. ASSY & C/O	7	.11	4.0	48	54	60
32003030301	M/W CIRC +RF MUX	7	2.20	4.0	48	54	56
32003030302	TRANSPONDERS 3	7	1.72	4.0	48	54	55
32003030303	POWER AMP.	7	.56	4.0	48	54	57
32003030304	ANTENNA	7	.36	4.0	48	54	55
32003030305	DEC/ENC+MOD/DEM	7	1.12	4.0	48	54	57
32003030306	TAPE RECORDER	7	.42	4.0	48	54	53
32003030307	P/L INTER EQUIP	7	.24	4.0	48	54	60
32003030308	INSTL. ASSY & C/O	7	.53	4.0	48	54	56
32003030401	DATA SENSORS	7	.06	4.0	48	54	60
32003030402	SIGNAL COND.	7	.14	4.0	48	54	57
32003030403	CIRCUITRY	7	1.73	4.0	48	54	60
32003030404	INSTL. ASSY & C/O	7	.15	4.0	48	54	60
32003030501	BATTERY	7	.13	4.0	48	54	56
32003030502	FUEL CELL 3	7	.00	4.0	0	0	0
32003030503	INSTL. ASSY & C/O	7	.01	4.0	48	54	56
32003030601	DISTR.	7	.85	4.0	48	54	59
32003030602	TANKS SYSTEM 3	7	.00	4.0	0	0	0
32003030603	INSTL. ASSY & C/O	7	.07	4.0	48	54	59

STUDY TITLE: SPACE TUG SYS STY (CRT)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T D	T S	SPREAD PUNCT.
32004	VEH AUX. STAGE	4	1.63	3.0	35	44	50
3200401	VEH AUX. STAGE	5	1.62	3.0	35	44	50

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T 0	T 5	SPREAD FUNCT.
32005	LOGISTICS	4	3.02	3.0	39	45	0
3200501	TRANSP. & HDLG.	5	.00	3.0	0	0	0
3200502	TRAINING	5	1.70	3.0	39	45	0
3200503	INV CONT. & WHSNG	5	1.32	3.0	39	45	0
320050201	SIM. & EQUIP.	6	.00	3.0	39	45	0
320050202	GROUND CREW	6	1.70	3.0	39	45	0

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T D	T S	SPREAD PUNCT.
32006	FACILITIES	4	5.17	3.0	76	53	50
3200601	MANUFACTURING	5	1.12	3.0	76	53	50
3200602	TEST	5	1.50	3.0	76	53	50
3200603	ETR MAINT. & REF.	5	1.02	3.0	76	53	50
3200604	ETR LAUNCH	5	.39	3.0	76	53	50
3200605	WTR MAINT. & REF.	5	.77	3.0	76	53	50
3200606	WTR LAUNCH	5	.38	3.0	76	53	50
320060101	DES./CONST.	6	1.09	3.0	76	53	50
320060102	ACTIV./MAINT.	6	.02	3.0	76	53	50
320060201	DES./CONST.	6	1.50	3.0	76	53	50
320060202	ACTIV./MAINT.	6	.00	3.0	0	0	0
320060301	DES./CONST.	6	1.00	3.0	76	53	50
320060302	ACTIV./MAINT.	6	.02	3.0	76	53	50
320060401	DES./CONST.	6	.38	3.0	76	53	50
320060402	ACTIV./MAINT.	6	.01	3.0	76	53	50
320060501	DES./CONST.	6	.75	3.0	76	53	50
320060502	ACTIV./MAINT.	6	.01	3.0	76	53	50
320060601	DES./CONST. 3	6	.37	3.0	76	53	50
320060602	ACTIV./MAINT. 3	6	.01	3.0	76	53	50

STUDY TITLE: SPACE TUG SYS STY (CRYT)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T O	T S	SPREAD FUNCT.
32007	GRND. SUPT. EQUIP	4	32.09	4.0	66	51	40
3200701	MFG. GSE	5	7.42	4.0	66	51	40
3200702	ETR GSE	5	11.90	4.0	66	51	40
3200703	WTR GSE	5	11.82	4.0	66	51	40
3200704	FLT OPS GSE(NASA)	5	.48	4.0	66	51	40
3200705	FLT OPS GSE(DOD)	5	.48	4.0	66	51	40
320070101	HARDWARE	6	4.40	4.0	66	51	40
320070102	SITE ACTIV.	6	.09	4.0	66	51	40
320070103	MAINT.	6	.00	4.0	0	0	0
320070104	SOFTWARE	6	2.94	4.0	66	51	40
320070201	HARDWARE	6	7.51	4.0	66	51	40
320070202	SITE ACTIV.	6	2.48	4.0	66	51	40
320070203	MAINT.	6	.00	4.0	0	0	0
320070204	SOFTWARE	6	1.91	4.0	66	51	40
320070301	HARDWARE	6	7.40	4.0	66	51	40
320070302	SITE ACTIV.	6	2.44	4.0	66	51	40
320070303	MAINT.	6	.00	4.0	0	0	0
320070304	SOFTWARE	6	1.98	4.0	66	51	40
320070401	HARDWARE 3	6	.00	4.0	0	0	0
320070402	SITE ACTIV. 3	6	.00	4.0	0	0	0
320070404	SOFTWARE 3	6	.47	4.0	66	51	40
320070501	HARDWARE 3	6	.00	4.0	0	0	0
320070502	SITE ACTIV. 3	6	.00	4.0	0	0	0
320070504	SOFTWARE 3	6	.47	4.0	66	51	40

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T D	T S	SPREAD PUNCT.
32008	VEHICLE TEST	4	21.32	3.0	54	48	40
3200801	GND TEST HDWE.	5	13.73	3.0	33	48	40
3200802	GND TEST OPNS.	5	6.84	3.0	33	40	40
3200804	FLT. TEST OPNS	5	.75	3.0	12	6	50
320080101	PTV TEST	6	3.66	3.0	33	48	40
320080102	MAJOR TEST ART.	6	9.60	3.0	33	48	40
320080103	MOCKUPS	6	.47	3.0	33	48	40

STUDY TITLE: SPACE TUG SYS STY (CRYT)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T O	T S	SPREAD FUNCT.
32009	LAUNCH OPNS. WTR	4	.00	3.0	0	0	0
3200901	LNCH SITE SVCES	5	.00	3.0	0	0	0
3200902	TUG/SHTL MATING	5	.00	3.0	0	0	0
3200903	PRELAUNCH C/O	5	.00	3.0	0	0	0
3200904	COUNTDOWN	5	.00	3.0	0	0	0
3200905	PRLNTS. & GASES	5	.00	3.0	0	0	0
3200906	POST FLT. SAFING	5	.00	3.0	0	0	0

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T D	T S	SPREAD FUNCT.
32010	LAUNCH OPNS ETR	4	.00	3.0	0	0	0
3201001	LNCH SITE SVCES	5	.00	3.0	0	0	0
3201002	TUG/SHTL MATING	5	.00	3.0	0	0	0
3201003	PRELAUNCH C/O	5	.00	3.0	0	0	0
3201004	COUNTDOWN	5	.00	3.0	0	0	0
3201005	PRLNTS & GASES	5	.00	3.0	0	0	0
3201006	POST FLT. SAFING	5	.00	3.0	0	0	0

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE 1 OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T D	T S	SPREAD FUNCT.
32011	FLIGHT OPNS NASA	4	5.33	3.0	41	35	60
3201101	MISSION PLG.	5	2.44	3.0	41	35	60
3201102	FLT. CONTROL	5	.37	3.0	41	35	60
3201103	FLT. EVAL.	5	.00	3.0	0	0	0
3201104	FLT. SUPT. SFTWRE	5	2.53	3.0	41	35	60

81-9

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T O	T S	SPREAD FUNCT.
32012	FLIGHT OPNS DOD	4	4.79	3.0	41	35	60
3201201	MISSION PLG	5	2.19	3.0	41	35	60
3201202	FLT. CONTROL	5	.55	3.0	41	35	60
3201203	FLT. EVAL.	5	.00	3.0	0	0	0
3201204	FLT. SUPT. SFTWRE	5	2.27	3.0	41	35	60

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T O	T S	SPREAD FUNCT.
32013	REFURB &INTEG WTR	4	.11	3.0	39	45	0
3201301	SCH MAINT & REF	5	.00	3.0	0	0	0
3201302	UNSCH MAINT & REF	5	.00	3.0	0	0	0
3201303	POST MAINT C/O	5	.00	3.0	0	0	0
3201304	TUG/PL MAING &/CO	5	.00	3.0	0	0	0
3201305	REFURB RQMTS PLB	5	.11	3.0	39	45	0
3201306	DEPOT MAINT	5	.00	3.0	0	0	0

6-20

STUB TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(1)
NON-RECURRING (DDT&E)

DATE: AUGUST 29,1973
PAGE 12 OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T O	T S	SPREAD FUNCT.
32014	REFURB &INTEG ETR	4	.11	3.0	39	45	0
3201401	SCH MAINT & REF	5	.00	3.0	0	0	0
3201402	UNSCH MAINT & REF	5	.00	3.0	0	0	0
3201403	POST MAINT C/O	5	.00	3.0	0	0	0
3201404	TUG/PL MATING,C/O	5	.00	3.0	0	0	0
3201405	REFURB RQMTS PLO	5	.11	3.0	39	45	0
3201406	DEPOT MAINT	5	.00	3.0	0	0	0

6.2 PRODUCTION PER WBS ELEMENTS

This subsection contains cost estimates for each WBS element through Level 7, as appropriate, displayed on Cost Data Form A(2), recurring (production). The definitions of each colum are as follows:

Identification Number: The appropriate WBS code corresponding to the item of cost.

WBS Identification: The alphanumeric nomenclature of the item from the WBS.

WBS Level: The level at which the cost is accumulated:

Level 3	-	Project
Level 4	-	System/Module
Level 5	-	Subsystem
Level 6	-	Assembly
Level 7	-	Component

First Unit (T1) Cost: The production cost of the theoretical first hardware unit. It is considered to be the y-axis intercept of the learning curve on a log-log plot. The LEADER II cost model prints out this cost under the title of "Memo T1" for WBS 320-03 Vehicle Main Stage and subordinate elements thereof.

Number of Units: The quantity of units for each WBS item used in the production and operations phases of the program.

Expected Cost: The cost estimate for the WBS item. For

production and operations items, the WBS item cost is the total cumulative cost for the number of units quantified in the "number of units" column.

Reference Unit: The production sequence number of the first unit that is used in the recurring phase of the program.

Confidence Rating: A value of (1), lowest, through (4), highest, representing the estimators confidence in the estimate shown in the WBS item cost column. The value is obtained by reviewing the Government criteria contained in Table 6.2-1 and subjectively selecting the code considered to be most applicable. At summary levels the confidence rating values are weighted averages of the confidence ratings of constituent WBS elements at subordinate levels.

Reference Unit Cost: The cost of the reference unit. At subordinate levels the cost is the specific cost of the reference unit. At summary levels the cost is the weighted average of the constituent subordinate reference units.

Td: The time in months required to perform an activity. For nonrecurring (DDT&E) activity, the Td is the time required from Authorization to Proceed (ATP) with Phase C (nonrecurring/DDT&E) through completion of designs, development, test and evaluation, which usually is at FACI-First

Table 6.2-1
CONFIDENCE LEVEL GROUPS FOR COST ESTIMATES

	CONFIDENCE LEVEL 1 LOW	CONFIDENCE LEVEL 2 MEDIUM LOW	CONFIDENCE LEVEL 3 MEDIUM HIGH	CONFIDENCE LEVEL 4 HIGH
ESTIMATING CONDITIONS	Estimating Time and Information Access Completely inadequate amount of time provided to make the estimate or there is a complete lack of access to useful data sources. Ground Rules and Assumptions No guidance was provided on ground rules and all assumptions made by the estimator were arbitrary.	Estimating Time and Information Access A very short due date or major problems of access to available data tend to make this estimate highly uncertain. Ground Rules and Assumptions Very little guidance was provided relative to ground rules. Most of the assumptions made by the estimator were considered quite arbitrary.	Estimating Time and Information Access A more accurate estimate could have been made if freer access or more time had been available to research known data sources. Ground Rules and Assumptions Ground rules were generally adequate. Many of the assumptions were authenticated but a substantial number are considered questionable.	Estimating Time and Information Access There were minor problems of access to available data and there was generally sufficient time to define and cost the item. Ground Rules and Assumptions Major ground rules were provided and most of the assumptions were authenticated.
NATURE OF THE ITEM	State-of-the-Art The item is substantially beyond the current state-of-the-art. Major development work is required. Production Experience No production of any kind has been started.	State-of-the-Art The item is slightly beyond the state-of-the-art and some development work will be required. Production Experience Experimental laboratory fabrication of a similar item is in process.	State-of-the-Art The item is within the state-of-the-art but no commercial counterpart exists. Production Experience A prototype of the item has been produced.	State-of-the-Art The item will involve a minor modification of commercial or standard aerospace issue items. Production Experience the item has been produced in limited quantity.
ITEM DESCRIPTION	Specification Status No work on a specification has started. Operating Program Characteristics None of the OPC for using the item have been formulated.	Specification Status Work on a specification is in an early stage and only general requirements are identified. Operating Program Characteristics The general outline of the OPC under which the item will be used has been only tentatively defined and many specific details are lacking.	Specification Status A specification for the item has not been completed but a specification on a similar item is available. Operating Program Characteristics The general outline of the OPC has been formulated but many specific details are lacking.	Specification Status A specification for the item has been prepared but is under review or revision. Operating Program Characteristics The OPC have been substantially defined but are under review or revision.
COST METHODS AND DATA	Methods The estimate is almost a poor guess and little or no confidence can be placed in it. Data An almost total lack of current and reliable relevant data make the cost estimate completely uncertain.	Methods A highly arbitrary rule-of-thumb has been used. Data The data used to make the estimate highly suspect, very sparse in quantity, and characterized by major inconsistencies.	Methods A commonly used rule-of-thumb cost factor but with no supporting backup has been used. Data The data used have been obtained from official or standard sources. Notable inconsistencies, lack of currency, gaps in data reduce the confidence in the estimate.	Methods The basic method used to derive the cost is well-documented but no double-check or authentication has been possible Data The data used are generally relevant and from a reputable source. They are incomplete, preliminary, or not completely current however.

Article Configuration Inspection. Td for production generally is the time from PDR-Preliminary Design Release through flight article(s) assembly and acceptance. Td for operations generally is the time from the start of ground system installation and test procedures verification through completion of flight evaluation and preparation of ground system and flight vehicles for long term storage.

Ts: The lead time in months is measured from the start of Td to the Initial Operational Capability (IOC). The launch milestone date.

Spread Function: An index number representing a cost distribution curve which the estimator recommends for the time phasing of costs over the Td time span. The index number represents the percentage of total cost (of the WBS item for the program phase) expected to be expended in 50 percent of the Td time span. At summary levels the spread functions are weighted averages of the spread functions of constituent WBS elements at subordinate levels.

Learning Index: A numerical index of a learning rate related to the recurring cost. A straight line cumulative average index is used in these calculations. At summary levels the learning indices of constituent WBS elements at subordinate levels.

Launch Milestone Date: The date used in conjunction with Ts.

STUDY TITLE: SPACE TUG SYS. STUDY
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

DATE: AUGUST 29, 1973
PAGE / OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1ST UNIT COST T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32001	PROJECT MGMT.	4	1.0	.00	5.08	1	.00	3.0	56	6	0	100
32002	SYS. ENGR. & INT.	4	1.0	.00	42.70	1	.00	3.0	56	6	50	100
32003	VEH MAIN STAGE	4	13.3	14.44	113.80	1	14.44	3.7	95	44	41	90
32004	VEH AUX. STAGE	4	1.0	.00	16.35	1	.00	3.0	90	0	60	100
32005	LOGISTICS	4	1.0	.00	.30	1	.00	3.0	48	4	0	100
32006	FACILITIES	4	1.0	.00	.33	1	.00	3.0	73	23	0	100
32007	GRND. SUPT. EQUIP	4	1.0	.00	1.02	1	.00	4.0	73	23	0	100
32008	VEHICLE TEST	4	1.0	.00	.00	1	.00	3.0	12	-3	50	100
320	TOTAL	3	.5	14.44	179.57	2	14.44	3.5	134	44	44	95

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

DATE: AUGUST 29,1973
PAGE 2 OF 12

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	1ST UNIT COST T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32001	PROJECT MGMT.	4	1.0	.00	5.08	1	.00	3.0	56	6	0	100
3200101	COST/PERF. MGMT.	5	1.0	.00	3.46	1	.00	3.0	56	6	0	100
3200102	PROJ. DIRECTION	5	1.0	.00	1.51	1	.00	3.0	56	6	0	100
3200103	INFORM. MGMT.	5	1.0	.00	.11	1	.00	3.0	56	6	0	100

6-27

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	1ST UNIT COST T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T U	T S	SPREAD FUNCT.	LEARN INDEX
32002	SYS. ENGR. & INT.	4	1.0	.00	42.70	1	.00	3.0	56	6	50	100
3200201	TUG SYS. ENGR.	5	1.0	.00	6.23	1	.00	3.0	56	6	50	100
3200202	SHUTTLE I/F	5	1.0	.00	1.56	1	.00	3.0	56	6	50	100
3200203	PAYLOAD I/F	5	1.0	.00	3.12	1	.00	3.0	56	6	50	100
3200204	SUST. ENGR.	5	1.0	.00	31.79	1	.00	3.0	56	6	50	100

1A 1B

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

DATE: AUGUST 29,1973
PAGE - OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1ST UNIT COST T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T U	T S	SPREAD FUNCT.	LEARN INDEX
32003	VEH MAIN STAGE	4	13.3	14.44	113.80	1	14.44	3.7	95	44	41	90
3200301	STRUCTURES	5	13.0	1.51	13.12	1	1.51	4.0	74	44	40	90
3200302	THERMAL CONTROL	5	13.0	.48	4.22	1	.48	3.0	79	44	40	90
3200303	AVIONICS	5	13.3	4.58	40.70	1	4.58	4.0	74	38	40	90
3200304	PROPULSION	5	13.7	3.38	30.50	1	3.38	4.0	77	44	40	90
3200305	ORBITER I/F	5	5.2	2.30	8.78	1	2.30	3.0	48	32	50	90
3200306	DROP TANKS	5	13.0	.00	.00	1	.00	3.0	0	0	0	100
3200307	FINAL ASSY & C/O	5	13.0	2.20	16.47	1	2.20	3.0	76	25	40	90
320030101	FUEL TK & SUPT	6	13.0	.29	2.55	1	.29	4.0	74	44	40	90
320030102	OXID. TK & SUPT	6	13.0	.24	2.10	1	.24	4.0	74	44	40	90
320030103	BODY STRUCTURE	6	13.0	.09	.82	1	.09	4.0	74	44	40	90
320030104	THRUST STRUCTURE	6	13.0	.06	.56	1	.06	4.0	74	44	40	90
320030105	METEOROID SHIELD	6	13.0	.43	3.83	1	.43	4.0	74	44	40	90
320030106	PAYLOAD I/F	6	13.0	.28	2.45	1	.28	4.0	74	44	40	90
320030107	INSTL. ASSY & C/O	6	13.0	.11	.82	1	.11	4.0	74	44	40	90
320030201	FUEL TANK INSL	6	13.0	.11	.93	1	.11	3.0	79	44	40	90
320030202	OXID. TANK INSL.	6	13.0	.05	.48	1	.05	3.0	79	44	40	90
320030203	INSL. PURGE SYS.	6	13.0	.30	2.66	1	.30	3.0	79	44	40	90
320030204	THERM CONT. SYS.	6	13.0	.00	.00	1	.00	3.0	0	0	0	90
320030205	INSTL ASSY & C/O	6	13.0	.02	.17	1	.02	3.0	79	44	40	90
320030301	DATA MGMT. 3	6	13.3	1.02	9.18	1	1.02	4.0	74	38	40	90
320030302	G N & C	6	13.0	1.12	9.89	1	1.12	4.0	74	38	40	90
320030303	COMMUNICATIONS	6	13.2	1.83	16.38	1	1.83	4.0	74	38	40	90
320030304	INSTRUMENTATION	6	13.0	.18	1.57	1	.18	4.0	74	38	40	90
320030305	ELECT. POWER	6	19.0	.05	.80	1	.05	4.0	74	38	40	95
320030306	PWR. DIST. & CONT	6	13.0	.03	.37	1	.03	4.0	74	38	40	95
320030307	INSTL. ASSY & C/O	6	13.0	.34	2.51	1	.34	4.0	74	38	40	90
320030401	MAIN ENGINE	6	15.8	.70	7.26	1	.70	4.0	77	44	40	90
320030402	MAIN ENG. SUPT	6	13.0	1.64	14.45	1	1.64	4.0	77	44	40	90
320030403	ACPS ENGINE	6	13.4	.12	1.10	1	.12	4.0	77	44	40	90
320030404	ACPS ENG. SUPT	6	13.0	.74	6.51	1	.74	4.0	77	44	40	90
320030405	INSTL. ASSY & C/O	6	13.0	.16	1.18	1	.16	4.0	77	44	40	90
320030501	STRUCTURES	6	5.1	.36	1.38	1	.36	3.0	48	32	50	90
320030502	I/F PANELS	6	5.2	1.49	5.79	1	1.49	3.0	48	32	50	90
320030503	PURGE PROV.	6	6.0	.00	.00	1	.00	3.0	0	0	0	90
320030504	ABORT PROV.	6	5.0	.28	1.07	1	.28	3.0	48	32	50	90
320030505	INSTL. ASSY & C/O	6	5.0	.17	.55	1	.17	3.0	48	32	50	90
320030701	FINAL ASSY	6	13.0	1.84	13.72	1	1.84	3.0	76	25	40	90
320030702	C/O	6	13.0	.37	2.74	1	.37	3.0	76	25	40	90
32003010101	LH2 DOMES	7	1.0	.08	.00	1	.08	4.0	0	0	0	90
32003010102	LH2 CYLINDER	7	1.0	.07	.00	1	.07	4.0	0	0	0	90
32003010103	LH2 SUPPORTS	7	24.0	.14	.00	1	.14	4.0	0	0	0	90
32003010201	LO2 DOMES	7	1.0	.11	.00	1	.11	4.0	0	0	0	90
32003010202	LO2 SUPPORTS	7	16.0	.13	.00	1	.13	4.0	0	0	0	90
32003010301	FWD AFT SKIRT	7	1.0	.00	.00	1	.00	4.0	0	0	0	90
32003010302	INTERTANK	7	1.0	.04	.00	1	.04	4.0	0	0	0	90

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-2507

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

DATE: AUGUST 29,1973
PAGE 5 OF 7

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1ST UNIT COST T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32003010303	SDWL SHELL	7	1.0	.05	.00	1	.05	4.0	0	0	0	90
32003030101	COMPUTER	7	1.0	.82	.00	1	.82	4.0	0	0	0	100
32003030102	DATA DISTR.	7	1.0	.00	.00	1	.00	4.0	0	0	0	100
32003030103	EQ. THERM CONT.	7	1.0	.11	.00	1	.11	4.0	0	0	0	90
32003030104	CIRCUITRY 3	7	1.0	.03	.00	1	.03	4.0	0	0	0	90
32003030108	INSTL, ASSY & C/O	7	1.0	.08	.00	1	.08	4.0	0	0	0	100
32003030201	I M U	7	2.0	.71	.00	1	.71	4.0	0	0	0	90
32003030202	TRACKING/ELECT	7	2.0	.32	.00	1	.32	4.0	0	0	0	90
32003030203	REN DEZ& DOCKING	7	1.0	.00	.00	1	.00	4.0	0	0	0	90
32003030204	INSTL, ASSY & C/O	7	1.0	.08	.00	1	.08	4.0	0	0	0	100
32003030301	M/W CIRC +RF MUX	7	1.0	.40	.00	1	.40	4.0	0	0	0	90
32003030302	TRANSPONDERS 3	7	1.0	.43	.00	1	.43	4.0	0	0	0	90
32003030303	POWER AMP.	7	2.0	.18	.00	1	.18	4.0	0	0	0	90
32003030304	ANTENNA	7	1.0	.09	.00	1	.09	4.0	0	0	0	90
32003030305	DEC/ENC+MOD/DEM	7	1.0	.37	.00	1	.37	4.0	0	0	0	90
32003030306	TAPE RECORDER 3	7	2.0	.15	.00	1	.15	4.0	0	0	0	90
32003030307	P/L INTER EQUIP	7	1.0	.08	.00	1	.08	4.0	0	0	0	90
32003030308	INSTL, ASSY & C/O	7	1.0	.14	.00	1	.14	4.0	0	0	0	100
32003030401	DATA SENSORS	7	34.0	.04	.00	1	.04	4.0	0	0	0	90
32003030402	SIGNAL COND.	7	5.0	.04	.00	1	.04	4.0	0	0	0	90
32003030403	CIRCUITRY	7	1.0	.09	.00	1	.09	4.0	0	0	0	90
32003030404	INSTL, ASSY & C/O	7	1.0	.01	.00	1	.01	4.0	0	0	0	100
32003030501	BATTERY	7	1.0	.05	.00	1	.05	4.0	0	0	0	95
32003030502	FUEL CELL	7	1.0	.00	.00	1	.00	4.0	0	0	0	95
32003030503	INSTL, ASSY & C/O	7	1.0	.00	.00	1	.00	4.0	0	0	0	100
32003030601	DISTR.	7	1.0	.03	.00	1	.03	4.0	0	0	0	95
32003030602	TANKS SYSTEM	7	1.0	.00	.00	1	.00	4.0	0	0	0	95
32003030603	INSTL, ASSY & C/O	7	1.0	.00	.00	1	.00	4.0	0	0	0	100

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

DATE: AUGUST 29,1973
PAGE 1 OF 1

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	1ST UNIT COST	T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFIG RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32004	VEH AUX. STAGE	4	1.0		.00	16.35	1	.00	3.0	90	0	60	100
3200401	VEH AUX. STAGE	5	1.0		.00	16.35	1	.00	3.0	90	0	60	100

STUDY TITLE: SPACE TUG [illegible]
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

DATE: AUGUST 29,1973
PAGE 7 OF 5

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	1ST UNIT COST T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32005	LOGISTICS	4	1.0	.00	.30	1	.00	3.0	48	4	0	100
3200501	TRANSP. & HDLG.	5	1.0	.00	.30	1	.00	3.0	48	4	0	100
3200502	TRAINING	5	1.0	.00	.00	1	.00	3.0	0	0	0	100
3200503	INV CONT. & WHSNG	5	1.0	.00	.00	1	.00	3.0	0	0	0	100
320050201	SIM. & EQUIP.	6	1.0	.00	.00	1	.00	3.0	0	0	0	100

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

DATE: AUGUST 29,1973
PAGE 5 OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	1ST UNIT COST	T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32006	FACILITIES	4	1.0		.00	.33	1	.00	3.0	73	23	0	100
3200601	MANUFACTURING	5	1.0		.00	.33	1	.00	3.0	73	23	0	100
3200602	TEST	5	1.0		.00	.00	1	.00	3.0	0	0	0	100
320060101	DES./CONST.	6	1.0		.00	.00	1	.00	3.0	0	0	0	100
320060102	ACTIV./MAINT.	6	1.0		.00	.33	1	.00	3.0	73	23	0	100
320060201	DES./CONST.	6	1.0		.00	.00	1	.00	3.0	0	0	0	100
320060202	ACTIV./MAINT.	6	1.0		.00	.00	1	.00	3.0	0	0	0	100

STUDY TITLE: SPACE TUG STS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

DATE: AUGUST 29,1973
PAGE 9 OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	1ST UNIT COST T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32007	GRND. SUPT. EQUIP	4	1.0	.00	1.02	1	.00	4.0	73	23	0	100
3200701	MFG. GSE	5	1.0	.00	1.02	1	.00	4.0	73	23	0	100
320070101	HARDWARE	6	1.0	.00	.00	1	.00	4.0	0	0	0	100
320070102	SITE ACTIV.	6	1.0	.00	.00	1	.00	4.0	0	0	0	100
320070103	MAINT.	6	1.0	.00	1.02	1	.00	4.0	73	23	0	100

STUDY TITLE: SPACE TUG SYS STY (CRT)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	1ST UNIT COST	T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32008	VEHICLE TEST	4	1.0		.00	.00	1	.00	3.0	0	0	0	100

6.3 OPERATIONS PER WBS ELEMENTS

This subsection contains cost estimates for each WBS element through Level 6, as appropriate, displayed on Cost Data Form A(3), recurring (operations). The definitions of each column is as follows:

Identification Number: The appropriate WBS code corresponding to the item of cost.

WBS Identification: The alphanumeric nomenclature of the item from the WBS.

WBS Level: The level at which the cost is accumulated:

Level 3	-	Project
Level 4	-	System/Module
Level 5	-	Subsystem
Level 6	-	Assembly
Level 7	-	Component

Number of Units: The quantity of units for each WBS item used in the production and operations phases of the program.

Expected Cost: The cost estimate for the WBS item. For production and operations items, the WBS item cost is the total cumulative cost for the number of units quantified in the "number of units" column.

Reference Unit: The production sequence number of the

first unit that is used in the recurring phase of the program.

Confidence Rating: A value of (1), lowest, through (4), highest, representing the estimator's confidence in the estimate shown in the WBS item cost colum. The value is obtained by reviewing the Government criteria contained in Table 6.3-1 and subjectively selecting the code considered to be most applicable. At summary levels the confidence rating values are weighted averages of the confidence ratings of constituent WBS elements at subordinate levels.

Reference Unit Cost: The cost of the reference unit. At subordinate levels the cost is the specific cost of the reference unit. At summary levels the cost is the weighted average of the constituent subordinate reference units.

Td: The time in months required to perform an activity. For nonrecurring (DDT&E activity, the Td is the time required from Authorization to Proceed (ATP) with Phase C (nonrecurring/ DDT&E) through completion of designs, development, test and evaluation, which usually is at FACI-First Article Configuration Inspection. Td for production generally is the time from PDR-Preliminary Design Release through flight article(s) assembly and acceptance. Td for operations generally is the time from the start of ground system installation and test procedures verification through completion of flight evaluation and preparation of ground system and flight

Table 6.3-1
CONFIDENCE LEVEL GROUPS FOR COST ESTIMATES

	CONFIDENCE LEVEL 1 LOW	CONFIDENCE LEVEL 2 MEDIUM LOW	CONFIDENCE LEVEL 3 MEDIUM HIGH	CONFIDENCE LEVEL 4 HIGH
ESTIMATING CONDITIONS	Estimating Time and Information Access Completely inadequate amount of time provided to make the estimate or there is a complete lack of access to useful data sources. Ground Rules and Assumptions No guidance was provided on ground rules and all assumptions made by the estimator were arbitrary.	Estimating Time and Information Access A very short due date or major problems of access to available data tend to make this estimate highly uncertain. Ground Rules and Assumptions Very little guidance was provided relative to ground rules. Most of the assumptions made by the estimator were considered quite arbitrary.	Estimating Time and Information Access A more accurate estimate could have been made if freer access or more time had been available to research known data sources. Ground Rules and Assumptions Ground rules were generally adequate. Many of the assumptions were authenticated but a substantial number are considered questionable.	Estimating Time and Information Access There were minor problems of access to available data and there was generally sufficient time to define and cost the item. Ground Rules and Assumptions Major ground rules were provided and most of the assumptions were authenticated.
NATURE OF THE ITEM	State-of-the-Art The item is substantially beyond the current state-of-the-art. Major development work is required. Production Experience No production of any kind has been started.	State-of-the-Art The item is slightly beyond the state-of-the-art and some development work will be required. Production Experience Experimental laboratory fabrication of a similar item is in process.	State-of-the-Art The item is within the state-of-the-art but no commercial counterpart exists. Production Experience A prototype of the item has been produced.	State-of-the-Art The item will involve a minor modification of commercial or standard aerospace issue items. Production Experience The item has been produced in limited quantity.
ITEM DESCRIPTION	Specification Status No work on a specification has started. Operating Program Characteristics None of the OPC for using the item have been formulated.	Specification Status Work on a specification is in an early stage and only general requirements are identified. Operating Program Characteristics The general outline of the OPC under which the item will be used has been only tentatively defined and many specific details are lacking.	Specification Status A specification for the item has not been completed but a specification on a similar item is available. Operating Program Characteristics The general outline of the OPC has been formulated but many specific details are lacking.	Specification Status A specification for the item has been prepared but is under review or revision. Operating Program Characteristics The OPC have been substantially defined but are under review or revision.
COST METHODS AND DATA	Methods The estimate is almost a poor guess and little or no confidence can be placed in it. Data An almost total lack of current and reliable relevant data make the cost estimate completely uncertain.	Methods A highly arbitrary rule-of-thumb has been used. Data The data used to make the estimate highly suspect, very sparse in quantity, and characterized by major inconsistencies.	Methods A commonly used rule-of-thumb cost factor but with no supporting backup has been used. Data The data used have been obtained from official or standard sources. Notable inconsistencies, lack of currency, gaps in data reduce the confidence in the estimate.	Methods The basic method used to derive the cost is well documented but no double-check or authentication has been possible Data The data used are generally relevant and from a reputable source. They are incomplete, preliminary, or not completely current however.

vehicles for long term storage.

Ts: The lead time in months measured from the start of Td to the Initial Operational Capability (IOC), the launch milestone date.

Spread Function: An index number representing a cost distribution curve which the estimator recommends for the time phasing of costs over the Td time span. The index number represents the percentage of total cost (of the WBS item for the program phase) expected to be expended in 50 percent of the Td time span. At summary levels the spread functions are weighted averages of the spread functions of constituent WBS elements at subordinate levels.

Learning Index: A numerical index of a learning rate related to the recurring cost. A straight line cumulative average index is used in these calculations. At summary levels the learning index is the weighted average of the learning indices of constituent WBS elements at subordinate levels.

Launch Milestone Date: The date used in conjunction with Ts.

First Unit (T1) Cost: The production cost of the theoretical First Hardware Unit. It is considered to be the y-axis intercept of the learning curve on a Log-Log plot. The LEADER II Cost Model prints out this cost under the title of "Memo T1" for WBS 320-03-Vehicle Main Stage and subordinate elements thereof.

STUDY TITLE: SPACE TUG SYS STY (CRT)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29, 1973
PAGE - OF -

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32001	PROJECT MGMT.	4	1.0	7.32	1	.00	3.0	135	6	0	100
32002	SYS. ENGR. & INT.	4	1.0	11.21	1	.00	3.0	135	6	0	100
32003	VEH MAIN STAGE 3	4	.0	13.89	14	.00	4.0	129	0	0	94
32004	VEH AUX. STAGE	4	1.0	.00	1	.00	3.0	129	0	0	100
32005	LOGISTICS	4	1.0	6.71	1	.00	3.0	129	0	0	100
32006	FACILITIES	4	1.0	1.21	1	.00	3.0	129	0	0	100
32007	GRND. SUPT. EQUIP	4	1.0	7.70	1	.00	4.0	129	0	0	100
32009	LAUNCH OPNS. WTR	4	1.0	21.35	1	.00	3.0	102	-27	0	100
32010	LAUNCH OPNS ETR	4	1.0	54.06	1	.00	3.0	135	6	0	100
32011	FLIGHT OPNS NASA	4	1.0	36.39	1	.00	3.0	135	6	0	100
32012	FLIGHT OPNS DOD	4	1.0	32.87	1	.00	3.0	123	-6	0	100
32013	REFURB &INTEG WTR	4	1.0	14.70	4	.00	3.0	102	-27	0	100
32014	REFURB &INTEG ETR	4	1.0	49.80	6	.00	3.0	135	6	0	100
320	TOTAL	3	.0	257.20	6	.00	3.1	135	6	0	100

6-40

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE 2 OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32001	PROJECT MGMT.	4	1.0	7.32	1	.00	3.0	135	5	0	100
3200101	COST/PERF. MGMT.	5	1.0	4.81	1	.00	3.0	135	6	0	100
3200102	PROJ. DIRECTION	5	1.0	2.30	1	.00	3.0	135	6	0	100
3200103	INFORM. MGMT. 3	5	1.0	.21	1	.00	3.0	135	6	0	100

STUDY TITLE: SPACE TUG SYS STY (PART)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE 2 OF 2

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32002	SYS. ENGR. & INT.	4	1.0	11.21	1	.00	3.0	135	6	0	100
3200204	SUST. ENGR. 3	5	1.0	11.21	1	.00	3.0	135	6	0	100

24-9

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE 4 OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32003	VEH MAIN STAGE 3	4	.0	13.89	14	.00	4.0	129	0	0	94
3200301	STRUCTURES	5	.2	.18	14	.00	4.0	117	0	0	90
3200302	THERMAL CONTROL	5	.0	.06	14	.00	3.0	117	0	0	90
3200303	AVIONICS 3	5	.1	10.68	14	.00	4.0	129	0	0	95
3200304	PROPULSION	5	.0	2.45	14	.00	4.0	117	0	0	89
3200305	ORBITER I/F	5	.0	.54	6	.00	3.0	117	0	0	90
3200306	DROP TANKS	5	.0	.00	14	.00	3.0	0	0	0	100
3200307	FINAL ASSY & C/O	5	.0	.00	14	.00	3.0	0	0	0	100
320030101	FUEL TK & SUPT	6	.0	.00	14	.00	4.0	0	0	0	90
320030102	OXID. TK & SUPT	6	.0	.00	14	.00	4.0	0	0	0	90
320030103	BODY STRUCTURE	6	.0	.00	14	.00	4.0	0	0	0	90
320030104	THRUST STRUC	6	.0	.00	14	.00	4.0	0	0	0	90
320030105	METEOROID SH	6	.0	.00	14	.00	4.0	0	0	0	90
320030106	PAYLOAD I/F	6	.0	.00	14	.00	4.0	0	0	0	90
320030107	INSTL. ASSY & C/O	6	.0	.00	14	.00	4.0	0	0	0	100
320030201	FUEL TANK INSL	6	.2	.01	14	.00	3.0	117	0	0	90
320030202	OXID. TANK INSL.	6	.4	.01	14	.00	3.0	117	0	0	90
320030203	INSL. PURGE SYS.	6	.2	.03	14	.00	3.0	117	0	0	90
320030204	THERM CONT. SYS.	6	.0	.00	14	.00	3.0	0	0	0	90
320030205	INSTL. ASSY & C/O	6	.0	.00	14	.00	3.0	0	0	0	100
320030301	DATA MGMT. 3	6	1.0	2.53	14	.00	4.0	129	0	0	98
320030302	G N & C	6	.1	.04	14	.00	4.0	117	0	0	90
320030303	COMMUNICATIONS	6	.5	.34	14	.00	4.0	117	0	0	90
320030304	INSTRUMENTATION	6	1.8	.18	14	.00	4.0	117	0	0	90
320030305	ELECT. POWER	6	219.0	7.38	14	.00	4.0	117	0	0	95
320030306	PWR. DIST. & CONT	6	.2	.01	14	.00	4.0	117	0	0	95
320030307	INSTL. ASSY & C/O	6	.0	.00	14	.00	4.0	0	0	0	100
320030401	MAIN ENGINE	6	3.6	1.41	14	.00	4.0	117	0	0	90
320030402	MAIN ENG. SUPT	6	.4	.41	14	.00	4.0	117	0	0	90
320030403	ACPS ENGINE	6	8.2	.55	14	.00	4.0	117	0	0	90
320030404	ACPS ENG. SUPT	6	.2	.09	14	.00	4.0	117	0	0	90
320030405	INSTL. ASSY & C/O	6	.0	.00	14	.00	4.0	0	0	0	100
320030501	STRUCTURES	6	.1	.03	6	.00	3.0	117	0	0	90
320030502	I/F PANELS	6	.5	.49	6	.00	3.0	117	0	0	90
320030503	PURGE PROV.	6	1.0	.00	6	.00	3.0	0	0	0	90
320030504	ABORT PROV.	6	.1	.02	6	.00	3.0	117	0	0	90
320030505	INSTL. ASSY & C/O	6	.0	.00	6	.00	3.0	0	0	0	100
320030701	FINAL ASSY	6	.0	.00	14	.00	3.0	0	0	0	100
320030702	C/O	6	.0	.00	14	.00	3.0	0	0	0	100
32003030105	SOFTWARE 3	7	1.0	2.22	14	.00	4.0	129	0	0	100

STUDY TITLE: SPACE TUG [illegible]
CONTRACT NO.: NAS 8-2967

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32004	VEH AUX. STAGE	4	1.0	.00	1	.00	3.0	0	0	0	100

6-44

IA 20

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32005	LOGISTICS	4	1.0	6.71	1	.00	3.0	129	0	0	100
3200501	TRANSP. & HDLG.	5	1.0	.33	1	.00	3.0	129	0	0	100
3200502	TRAINING	5	1.0	1.70	1	.00	3.0	129	0	0	100
3200503	INV CONT. & WHSNG	5	1.0	4.67	1	.00	3.0	129	0	0	100
320050201	SIMS. & EQUIP.	6	1.0	.00	1	.00	3.0	0	0	0	100
320050202	GROUND CREW	6	1.0	1.70	1	.00	3.0	129	0	0	100

SH-9

STUDY TITLE: SPACE TUG SYS STY (CRT)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE - OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32006	FACILITIES	4	1.0	1.21	1	.00	3.0	129	0	0	100
3200603	ETR MAINT. & REF.	5	1.0	.55	1	.00	3.0	129	0	0	100
3200604	ETR LAUNCH	5	1.0	.21	1	.00	3.0	129	0	0	100
3200605	WTR MAINT. & REF.	5	1.0	.30	1	.00	3.0	129	0	0	100
3200606	WTR LAUNCH	5	1.0	.15	1	.00	3.0	129	0	0	100
320060301	DES./CONST.	6	1.0	.00	1	.00	3.0	0	0	0	100
320060302	ACTIV./MAINT.	6	1.0	.55	1	.00	3.0	129	0	0	100
320060401	DES./CONST.	6	1.0	.00	1	.00	3.0	0	0	0	100
320060402	ACTIV./MAINT.	6	1.0	.21	1	.00	3.0	129	0	0	100
320060501	DES./CONST.	6	1.0	.00	1	.00	3.0	0	0	0	100
320060502	ACTIV./MAINT.	6	1.0	.30	1	.00	3.0	129	0	0	100
320060601	DES./CONST. 3	6	1.0	.00	1	.00	3.0	0	0	0	100
320060602	ACTIV./MAINT. 3	6	1.0	.15	1	.00	3.0	129	0	0	100

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE - OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32007	GRND. SUPT. EQUIP	4	1.0	7.70	1	.00	4.0	129	0	0	100
3200701	MFG. GSE 3	5	1.0	.00	1	.00	4.0	0	0	0	100
3200702	ETR GSE	5	1.0	3.36	1	.00	4.0	129	0	0	100
3200703	WTR GSE	5	1.0	2.16	1	.00	4.0	129	0	0	100
3200704	FLT OPS GSE(NASA)	5	1.0	1.09	1	.00	4.0	129	0	0	100
3200705	FLT OPS GSE(DOD)	5	1.0	1.09	1	.00	4.0	129	0	0	100
320070104	SOFTWARE 3	6	1.0	.00	1	.00	4.0	0	0	0	100
320070201	HARDWARE	6	1.0	.00	1	.00	4.0	0	0	0	100
320070202	SITE ACTIV.	6	1.0	.00	1	.00	4.0	0	0	0	100
320070203	MAINT.	6	1.0	2.41	1	.00	4.0	129	0	0	100
320070204	SOFTWARE	6	1.0	.95	1	.00	4.0	129	0	0	100
320070301	HARDWARE	6	1.0	.00	1	.00	4.0	0	0	0	100
320070302	SITE ACTIV.	6	1.0	.00	1	.00	4.0	0	0	0	100
320070303	MAINT.	6	1.0	2.00	1	.00	4.0	129	0	0	100
320070304	SOFTWARE 3	6	1.0	.16	1	.00	4.0	129	0	0	100
320070403	MAINT. 3	6	1.0	.00	1	.00	4.0	0	0	0	100
320070404	SOFTWARE 3	6	1.0	1.09	1	.00	4.0	129	0	0	100
320070503	MAINT. 3	6	1.0	.00	1	.00	4.0	0	0	0	100
320070504	SOFTWARE 3	6	1.0	1.09	1	.00	4.0	129	0	0	100

STUDY TITLE: SPACE TUG S[illegible]
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE [illegible] OF [illegible]

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32009	LAUNCH OPNS. WTR	4	1.0	21.35	1	.00	3.0	102	-27	0	100
3200901	LNCH SITE SVCES	5	1.0	8.18	1	.00	3.0	102	-27	0	100
3200902	TUG/SHTL MATING	5	1.0	2.39	1	.00	3.0	102	-27	0	100
3200903	PRELAUNCH C/O	5	1.0	3.07	1	.00	3.0	102	-27	0	100
3200904	COUNTDOWN	5	1.0	3.75	1	.00	3.0	102	-27	0	100
3200905	PRLNTS. & GASES	5	1.0	.20	1	.00	3.0	102	-27	0	100
3200906	POST FLT. SAFING	5	1.0	3.75	1	.00	3.0	102	-27	0	100

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE 11 OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32010	LAUNCH OPNS ETR	4	1.0	54.06	1	.00	3.0	135	6	0	100
3201001	LNCH SITE SVCES	5	1.0	20.46	1	.00	3.0	135	6	0	100
3201002	TUG/SHTL MATING	5	1.0	5.97	1	.00	3.0	135	6	0	100
3201003	PRELAUNCH C/O	5	1.0	9.38	1	.00	3.0	135	6	0	100
3201004	COUNTDOWN	5	1.0	7.67	1	.00	3.0	135	6	0	100
3201005	PRLNTS & GASES	5	1.0	1.21	1	.00	3.0	135	6	0	100
3201006	POST FLT. SAFING	5	1.0	9.38	1	.00	3.0	135	6	0	100

STUDY TITLE: SPACE TUG SYS STY (CRT)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE 1 OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32011	FLIGHT OPNS NASA	4	1.0	36.39	1	.00	3.0	135	6	0	100
3201101	MISSION PLG.	5	1.0	5.38	1	.00	3.0	135	6	0	100
3201102	FLT. CONTROL	5	1.0	23.62	1	.00	3.0	135	6	0	100
3201103	FLT. EVAL.	5	1.0	5.03	1	.00	3.0	135	6	0	100
3201104	FLT. SUPT. SFTWRE	5	1.0	2.46	1	.00	3.0	135	6	0	100

6-50

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE 1 OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32012	FLIGHT OPNS DOD	4	1.0	32.87	1	.00	3.0	123	-6	0	100
3201201	MISSION PLG 3	5	1.0	4.83	1	.00	3.0	123	-6	0	100
3201202	FLT. CONTROL	5	1.0	21.42	1	.00	3.0	123	-6	0	100
3201203	FLT. EVAL.	5	1.0	4.41	1	.00	3.0	123	-6	0	100
3201204	FLT. SUPT. SFTWRE	5	1.0	2.20	1	.00	3.0	123	-6	0	100

15-9

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE 1 OF 1

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32013	REFURB &INTEG #TK	4	1.0	14.70	4	.00	3.0	102	-27	0	100
3201301	SCH MAINT & REF	5	1.0	4.43	1	.00	3.0	102	-27	0	100
3201302	UNSCH MAINT & REF	5	1.0	1.36	1	.00	3.0	102	-27	0	100
3201303	POST MAINT C/O	5	1.0	.34	1	.00	3.0	102	-27	0	100
3201304	TUG/PL MAING &/CO	5	1.0	3.41	1	.00	3.0	102	-27	0	100
3201305	REFURB RQMTS PLG	5	1.0	1.36	1	.00	3.0	102	-27	0	100
3201306	DEPOT MAINT	5	32.0	3.79	14	.00	3.0	102	-27	0	100

6-52

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO.: NAS 8-29677

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

DATE: AUGUST 29,1973
PAGE OF

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	COMPLX RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
32014	REFURB &INTEG ETR	4	1.0	49.80	7	.00	3.0	135	6	0	100
3201401	SCH MAINT & REF	5	1.0	11.08	1	.00	3.0	135	6	0	100
3201402	UNSCH MAINT & REF	5	1.0	3.41	1	.00	3.0	135	6	0	100
3201403	POST MAINT C/O	5	1.0	.85	1	.00	3.0	135	6	0	100
3201404	TUG/PL MATING/C/O	5	1.0	8.52	1	.00	3.0	135	6	0	100
3201405	REFURB RQMTS PLG	5	1.0	3.41	1	.00	3.0	135	6	0	100
3201406	DEPOT MAINT	5	190.0	22.52	14	.00	3.0	135	6	0	100

6.4 DDT&E Funding Distribution

This subsection contains the time-phaseed cost estimates required to accomplish the DDT&E phase of the program for each WBS element. Funding by Government Fiscal Year is displayed on Cost Data Form-C through WBS Level 7.

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29,1973
PAGE: 1 OF

X NON RECURRING(DDT&E) | RECURRING(PRODUCTION) | RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
320	TOTAL PROJ PHASE	12.9	53.1	68.5	40.6	17.1	4.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
32001	PROJECT MGMT.	1.1	1.4	1.4	1.4	1.4	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200101	COST/PERF. MGMT.	.7	1.0	1.0	1.0	1.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200102	PROJ. DIRECTION	.3	.4	.4	.4	.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200103	INFORM. MGMT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32002	SYS. ENGR. & INT.	.3	2.2	4.4	4.6	2.6	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200201	TUG SYS. ENGR.	.2	1.8	3.5	3.7	2.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200202	SHUTTLE I/F	.0	.1	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200203	PAYLOAD I/F	.0	.3	.6	.7	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003	VEH MAIN STAGE	11.4	39.9	37.7	12.5	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200301	STRUCTURES	2.0	6.8	6.0	1.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200302	THERMAL CONTROL	.1	.4	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200303	AVIONICS	2.8	10.5	10.7	3.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200304	PROPULSION	3.8	13.6	12.2	3.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200305	ORBITER I/F	1.6	4.7	4.3	2.1	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200306	DROP TANKS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200307	FINAL ASSY & C/O	1.0	3.9	4.2	2.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32004	VEH AUX. STAGE	.0	.3	.9	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200401	VEH AUX. STAGE	.0	.3	.9	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32005	LOGISTICS	.0	.9	.9	.9	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200501	TRANSP. & HDLG.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200502	TRAINING	.0	.5	.5	.5	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200503	INV CONT. & WHSNG	.0	.4	.4	.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32006	FACILITIES	.1	.6	1.2	1.5	1.2	.6	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200601	MANUFACTURING	.0	.1	.3	.3	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200602	TEST	.0	.2	.4	.4	.4	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200603	ETR MAINT. & REF.	.0	.1	.2	.3	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200604	ETR LAUNCH	.0	.0	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200605	WTR MAINT. & REF.	.0	.1	.2	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200606	WTR LAUNCH	.0	.0	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32007	GRND. SUPT. EQUIP	.1	2.9	7.4	9.9	8.4	3.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200701	MFG. GSE	.0	.7	1.7	2.3	1.9	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200702	ETR GSE	.1	1.1	2.8	3.7	3.1	1.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200703	WTR GSE	.1	1.1	2.7	3.6	3.1	1.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200704	FLT OPS GSE(NASA)	.0	.0	.1	.2	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200705	FLT OPS GSE(DOD)	.0	.0	.1	.2	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008	VEHICLE TEST	.1	4.8	11.2	4.5	.8	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200801	GND TEST HDWE.	.1	4.4	7.9	1.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200802	GND TEST OPNS.	.0	.3	3.3	3.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200804	FLT. TEST OPNS	.0	.0	.0	.0	.7	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32009	LAUNCH OPNS. WTR	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200901	LNCH SITE SVCES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200902	TUG/SHTL MATING	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200903	PRELAUNCH C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200904	COUNTDOWN	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200905	PRLNTS. & GASES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200906	POST FLT. SAFING	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

SS-9

STUDY TITLE: SPACE TUG S/S S' CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29,1973
PAGE: 2 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
32010	LAUNCH OPNS ETR	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201001	LNCH SITE SVCES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201002	TUG/SHTL MATING	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201003	PRELAUNCH C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201004	COUNTDOWN	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201005	PRLNTS & GASES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201006	POST FLT. SAFING	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32011	FLIGHT OPNS NASA	.0	.0	1.7	2.5	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201101	MISSION PLG.	.0	.0	.8	1.1	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201102	FLT. CONTROL	.0	.0	.1	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201103	FLT. EVAL.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201104	FLT. SUPT. SFTWRE	.0	.0	.8	1.2	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32012	FLIGHT OPNS DOD	.0	.0	1.5	2.3	.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201201	MISSION PLG	.0	.0	.7	1.0	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201202	FLT. CONTROL	.0	.0	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201203	FLT. EVAL.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201204	FLT. SUPT. SFTWRE	.0	.0	.7	1.1	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32013	REFURB &INTEG WTR	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201301	SCH MAINT & REF	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201302	UNSCH MAINT & REF	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201303	POST MAINT C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201304	TUG/PL MAING &/CO	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201305	REFURB RQMTS PLG	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201306	DEPOT MAINT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32014	REFURB &INTEG ETR	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201401	SCH MAINT & REF	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201402	UNSCH MAINT & REF	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201403	POST MAINT C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201404	TUG/PL MATING,C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201405	REFURB RQMTS PLG	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201406	DEPOT MAINT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030101	FUEL TK & SUPT	.5	1.6	1.4	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030102	OXID. TK & SUPT	.2	.8	.7	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030103	BODY STRUCTURE	.5	1.7	1.5	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030104	THRUST STRUCTURE	.2	.6	.5	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030105	METEOROID SHIELD	.1	.4	.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030106	PAYLOAD I/F	.3	1.1	1.0	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030107	INSTL. ASSY & C/O	.1	.5	.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030201	FUEL TANK INSL	.0	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030202	OXID. TANK INSL.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030203	INSL. PURGE SYS.	.1	.3	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030204	THERM CONT. SYS.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030205	INSTL ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030301	DATA MGMT. 3	1.1	4.0	4.1	1.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030302	G N & C	.2	.5	.5	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030303	COMMUNICATIONS	.7	2.6	2.8	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29,1973
PAGE: 3 OF

X NON RECURRING(DDT&E) | RECURRING(PRODUCTION) | RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
320030304	INSTRUMENTATION	.2	.8	.8	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030305	ELECT. POWER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030306	PWR. DIST. & CONT	.1	.3	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030307	INSTL. ASSY & C/O	.6	2.1	2.1	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030401	MAIN ENGINE 3	1.6	5.5	4.8	1.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030402	MAIN ENG. SUPT	1.3	5.0	4.6	1.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030403	ACPS ENGINE	.0	.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030404	ACPS ENG. SUPT	.7	2.3	2.1	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030405	INSTL. ASSY & C/O	.2	.7	.6	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030501	STRUCTURES	.5	1.5	1.3	.8	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030502	I/F PANELS	.8	2.3	2.1	1.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030503	PURGE PROV.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030504	ABORT PROV.	.2	.5	.5	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030505	INSTL. ASSY & C/O	.1	.4	.3	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030701	FINAL ASSY	.8	2.9	3.2	1.5	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030702	C/O	.2	.9	1.0	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320050201	SIM. & EQUIP.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320050202	GROUND CREW	.0	.5	.5	.5	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060101	DES./CONST.	.0	.1	.3	.3	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060102	ACTIV./MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060201	DES./CONST.	.0	.2	.4	.4	.4	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060202	ACTIV./MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060301	DES./CONST.	.0	.1	.2	.3	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060302	ACTIV./MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060401	DES./CONST.	.0	.0	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060402	ACTIV./MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060501	DES./CONST.	.0	.1	.2	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060502	ACTIV./MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060601	DES./CONST. 3	.0	.0	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060602	ACTIV./MAINT. 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070101	HARDWARE	.0	.4	1.0	1.4	1.2	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070102	SITE ACTIV.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070103	MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070104	SOFTWARE	.0	.3	.7	.9	.8	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070201	HARDWARE	.0	.7	1.7	2.3	2.0	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070202	SITE ACTIV.	.0	.2	.6	.8	.7	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070203	MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070204	SOFTWARE	.0	.2	.4	.6	.5	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070301	HARDWARE	.0	.7	1.7	2.3	1.9	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070302	SITE ACTIV.	.0	.2	.6	.7	.6	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070303	MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070304	SOFTWARE	.0	.2	.5	.6	.5	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070401	HARDWARE 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070402	SITE ACTIV. 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070404	SOFTWARE 3	.0	.0	.1	.2	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070501	HARDWARE 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

STUDY TITLE: SPACE TUG S E T (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29,1973
PAGE: 4 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
320070502	SITE ACTIV. 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070504	SOFTWARE 3	.0	.0	.1	.2	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320080101	PTV TEST	.0	1.2	2.1	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320080102	MAJOR TEST ART.	.0	3.1	3.3	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320080103	MOCKUPS	.0	.2	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003010101	LH2 DOMES	.2	.7	.6	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003010102	LH2 CYLINDER	.2	.8	.7	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003010103	LH2 SUPPORTS	.0	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003010201	LO2 DOMES	.2	.7	.6	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003010202	LO2 SUPPORTS	.0	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003010301	FWD AFT SKIRT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003010302	INTERTANK	.2	.8	.7	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003010303	SOWL SHELL	.3	.9	.8	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030101	COMPUTER	.6	2.3	2.4	.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030102	DATA DISTR.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030103	EQ. THERM CONT.	.1	.3	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030104	CIRCUITRY 3	.1	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030105	SOFTWARE	.3	.9	.9	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030106	SOFTWARE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030107	SOFTWARE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030108	INSTL, ASSY & C/O	.1	.3	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030201	I M U	.1	.3	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030202	TRACKING/ELECT 3	.1	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030203	REN DEZ&DOCKING 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030204	INSTL, ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030301	M/W CIRC +RF MUX	.2	.8	.9	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030302	TRANSPONDERS 3	.2	.6	.7	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030303	POWER AMP.	.1	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030304	ANTENNA	.0	.1	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030305	DEC/ENC+MOD/DEM	.1	.4	.4	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030306	TAPE RECORDER	.0	.1	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030307	P/L INTER EQUIP	.0	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030308	INSTL, ASSY & C/O	.0	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030401	DATA SENSORS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030402	SIGNAL COND.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030403	CIRCUITRY	.2	.7	.6	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030404	INSTL, ASSY & C/O	.0	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030501	BATTERY	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030502	FUEL CELL 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030503	INSTL, ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030601	DISTR.	.1	.3	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030602	TANKS SYSTEM 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003030603	INSTL, ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29,1973
PAGE: 5 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
32001	PROJECT MGMT.	1.1	1.4	1.4	1.4	1.4	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32002	SYS. ENGR. & INT.	.3	2.2	4.4	4.6	2.6	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32003	VEH MAIN STAGE	11.4	39.9	37.7	12.5	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32004	VEH AUX. STAGE	.0	.3	.9	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32005	LOGISTICS	.0	.9	.9	.9	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32006	FACILITIES	.1	.6	1.2	1.8	1.2	.6	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
32007	GRND. SUPT. EQUIP	.1	2.9	7.4	9.9	8.4	3.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008	VEHICLE TEST	.1	4.8	11.2	4.5	.8	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32009	LAUNCH OPNS. WTR	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32010	LAUNCH OPNS ETR	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32011	FLIGHT OPNS NASA	.0	.0	1.7	2.5	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32012	FLIGHT OPNS DOD	.0	.0	1.5	2.3	.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32013	REFURB &INTEG WTR	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32014	REFURB &INTEG ETR	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320	TOTAL PROJ PHASE	12.9	53.1	68.5	40.6	17.1	4.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0

6.5 Production Funding Distribution

This subsection contains the time-phased cost estimates to accomplish the Production phase of the program for each WBS element. Funding by Government Fiscal Year is displayed on Cost Data Form-C through WBS Level 7.

STUDY TITLE: SPACE TUG SYS STY (GRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29,1973
PAGE: 1 OF

NON RECURRING(DDT&E) X RECURRING(PRODUCTION) RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
320	TOTAL PROJ PHASE	.0	.9	8.2	21.4	32.1	41.0	39.8	23.2	8.5	2.8	1.6	.4	.0	.0	.0	.0
32001	PROJECT MGMT.	.0	.0	.0	.0	.8	1.1	1.1	1.1	1.0	.0	.0	.0	.0	.0	.0	.0
3200101	COST/PERF. MGMT.	.0	.0	.0	.0	.6	.7	.7	.7	.7	.0	.0	.0	.0	.0	.0	.0
3200102	PROJ. DIRECTION	.0	.0	.0	.0	.2	.3	.3	.3	.3	.0	.0	.0	.0	.0	.0	.0
3200103	INFORM. MGMT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32002	SYS. ENGR. & INT.	.0	.0	.0	.0	1.4	10.4	16.6	12.0	2.4	.0	.0	.0	.0	.0	.0	.0
3200201	TUG SYS. ENGR.	.0	.0	.0	.0	.2	1.5	2.4	1.7	.3	.0	.0	.0	.0	.0	.0	.0
3200202	SHUTTLE I/F	.0	.0	.0	.0	.1	.4	.6	.4	.1	.0	.0	.0	.0	.0	.0	.0
3200203	PAYLOAD I/F	.0	.0	.0	.0	.1	.8	1.2	.9	.2	.0	.0	.0	.0	.0	.0	.0
32003	VEH MAIN STAGE	.0	.9	8.2	21.2	29.6	27.9	18.9	8.1	1.3	.0	.0	.0	.0	.0	.0	.0
3200301	STRUCTURES	.0	.2	1.5	2.9	3.7	3.2	1.6	.1	.0	.0	.0	.0	.0	.0	.0	.0
3200302	THERMAL CONTROL	.0	.1	.4	.8	1.1	1.1	.7	.1	.0	.0	.0	.0	.0	.0	.0	.0
3200303	AVIONICS	.0	.1	2.4	7.0	10.6	11.0	7.8	1.9	.0	.0	.0	.0	.0	.0	.0	.0
3200304	PROPULSION	.0	.5	3.2	6.3	8.1	7.5	4.5	.6	.0	.0	.0	.0	.0	.0	.0	.0
3200305	ORBITER I/F	.0	.0	.7	3.3	3.6	1.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200306	DROP TANKS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200307	FINAL ASSY & C/O	.0	.0	.0	.8	2.5	4.0	4.4	3.4	1.3	.0	.0	.0	.0	.0	.0	.0
32004	VEH AUX. STAGE	.0	.0	.0	.0	.1	1.4	2.9	3.7	3.6	2.8	1.6	.4	.0	.0	.0	.0
3200401	VEH AUX. STAGE	.0	.0	.0	.0	.1	1.4	2.9	3.7	3.6	2.8	1.6	.4	.0	.0	.0	.0
32005	LOGISTICS	.0	.0	.0	.0	.0	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0
3200501	TRANSP. & HDLG.	.0	.0	.0	.0	.0	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0
3200502	TRAINING	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200503	INV CONT. & WHSNG	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32006	FACILITIES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200601	MANUFACTURING	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200602	TEST	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32007	GRND. SUPT. EQUIP	.0	.0	.0	.2	.2	.2	.2	.2	.2	.0	.0	.0	.0	.0	.0	.0
3200701	MFG. GSE	.0	.0	.0	.2	.2	.2	.2	.2	.2	.0	.0	.0	.0	.0	.0	.0
32008	VEHICLE TEST	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030101	FUEL TK & SUPT	.0	.0	.3	.6	.7	.6	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030102	OXID. TK & SUPT	.0	.0	.2	.5	.6	.5	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030103	BODY STRUCTURE	.0	.0	.1	.2	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030104	THRUST STRUCTURE	.0	.0	.1	.1	.2	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030105	METEOROID SHIELD	.0	.1	.4	.8	1.1	.9	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030106	PAYLOAD I/F	.0	.0	.3	.6	.7	.6	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030107	INSTL. ASSY & C/O	.0	.0	.1	.2	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030201	FUEL TANK INSL	.0	.0	.1	.2	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030202	OXID. TANK INSL.	.0	.0	.0	.1	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030203	INSL. PURGE SYS.	.0	.0	.3	.5	.7	.7	.4	.1	.0	.0	.0	.0	.0	.0	.0	.0
320030204	THERM CONT. SYS.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030205	INSTL ASSY & C/O	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030301	DATA MGMT. 3	.0	.0	.5	1.6	2.4	2.5	1.7	.4	.0	.0	.0	.0	.0	.0	.0	.0
320030302	G N & C	.0	.0	.6	1.7	2.6	2.7	1.9	.5	.0	.0	.0	.0	.0	.0	.0	.0
320030303	COMMUNICATIONS	.0	.0	1.0	2.8	4.3	4.4	3.1	.8	.0	.0	.0	.0	.0	.0	.0	.0
320030304	INSTRUMENTATION	.0	.0	.1	.3	.4	.4	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0
320030305	ELECT. POWER	.0	.0	.0	.1	.2	.2	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030306	PWR. DIST. & CONT	.0	.0	.0	.1	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0

179

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29,1973
PAGE: / OF

NON RECURRING(DDT&E) X RECURRING(PRODUCTION) RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
320030307	INSTL, ASSY & C/O	.0	.0	.1	.4	.7	.7	.5	.1	.0	.0	.0	.0	.0	.0	.0	.0
320030401	MAIN ENGINE 3	.0	.1	.8	1.8	1.9	1.8	1.1	.1	.0	.0	.0	.0	.0	.0	.0	.0
320030402	MAIN ENG. SUPT	.0	.2	1.5	3.0	3.8	3.5	2.1	.3	.0	.0	.0	.0	.0	.0	.0	.0
320030403	ACPS ENGINE	.0	.0	.1	.2	.3	.3	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030404	ACPS ENG. SUPT	.0	.1	.7	1.3	1.7	1.6	1.0	.1	.0	.0	.0	.0	.0	.0	.0	.0
320030405	INSTL, ASSY & C/O	.0	.0	.1	.2	.3	.3	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030501	STRUCTURES	.0	.0	.1	.5	.6	.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030502	I/F PANELS	.0	.0	.5	2.2	2.4	.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030503	PURGE PROV.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030504	ABORT PROV.	.0	.0	.1	.4	.5	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030505	INSTL, ASSY & C/O	.0	.0	.0	.2	.2	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030701	FINAL ASSY	.0	.0	.0	.6	2.1	3.3	3.7	2.9	1.1	.0	.0	.0	.0	.0	.0	.0
320030702	C/O	.0	.0	.0	.1	.4	.7	.7	.6	.2	.0	.0	.0	.0	.0	.0	.0
320050201	SIM. & EQUIP.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060101	DES./CONST.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060102	ACTIV./MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060201	DES./CONST.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060202	ACTIV./MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070101	HARDWARE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070102	SITE ACTIV.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070103	MAINT.	.0	.0	.0	.2	.2	.2	.2	.2	.2	.0	.0	.0	.0	.0	.0	.0
3200204	SUST. ENGR.	.0	.0	.0	.0	1.0	7.7	12.4	8.9	1.8	.0	.0	.0	.0	.0	.0	.0
3200803	FLT. TEST HDWE.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320080301	STRUCTURES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320080302	THERMAL CONTROL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320080303	AVIONICS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320080304	PROPULSION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320080305	ORBITER I/F	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320080306	DROP TANKS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320080307	FINAL ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030101	FUEL TK & SUPT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030102	OXID. TK & SUPT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030103	BODY STRUCTURE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030104	THRUST STRUCTURE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030105	METEOROID SHIELD	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030106	PAYLOAD I/F	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030107	INSTL, ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030201	FUEL TANK INSL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030202	OXID TANK INSL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030203	INSL PURGE SYS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030204	THERM CONT SYS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030205	INSTL, ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030301	DATA MGMT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030302	G N & C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030303	COMMUNICATIONS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030304	INSTRUMENTATION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

229

/C-7

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29,1973
PAGE: OF

NON RECURRING(DDT&E) X RECURRING(PRODUCTION) RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
32008030305	ELECT. POWER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030306	PWR DIST. & CONT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030307	INSTL, ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030401	MAIN ENGINE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030402	MAIN ENG SUPT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030403	ACPS ENGINE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030404	ACPS ENG SUPT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030405	INSTL, ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030501	STRUCTURES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030502	I/F PANELS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030503	PURGE PROV.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030504	ABORT PROV.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030505	INSTL, ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030701	FINAL ASSY	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32008030702	C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29,1973
PAGE: OF

NON RECURRING(DDT&E) X RECURRING(PRODUCTION) RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
32001	PROJECT MGMT.	.0	.0	.0	.0	.8	1.1	1.1	1.1	1.0	.0	.0	.0	.0	.0	.0	.0
32002	SYS. ENGR. & INT.	.0	.0	.0	.0	1.4	10.4	16.6	12.0	2.4	.0	.0	.0	.0	.0	.0	.0
32003	VEH MAIN STAGE	.0	.9	8.2	21.2	29.6	27.9	18.9	6.1	1.3	.0	.0	.0	.0	.0	.0	.0
32004	VEH AUX. STAGE	.0	.0	.0	.0	.1	1.4	2.9	3.7	3.6	2.8	1.6	.4	.0	.0	.0	.0
32005	LOGISTICS	.0	.0	.0	.0	.0	.1	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0
32006	FACILITIES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32007	GRND. SUPT. EQUIP	.0	.0	.0	.2	.2	.2	.2	.2	.2	.0	.0	.0	.0	.0	.0	.0
32008	VEHICLE TEST	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320	TOTAL PROJ PHASE	.0	.9	8.2	21.4	32.1	41.0	39.8	23.2	8.5	2.8	1.6	.4	.0	.0	.0	.0

649

6.6 Operations Funding Distribution

This subsection contains the time-phased cost estimates required to accomplish the Operations phase of the program for each WBS element. Funding by Government Fiscal Year is displayed on Cost Data Form C through WBS Level 6, except for recurring software for the Data Management Assembly (WBS 320-03-03-01-05) which is reported and funded at Level 7.

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29, 1973
PAGE: OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
320	TOTAL PROJ PHASE	.0	.0	.0	.0	11.3	19.3	20.1	24.4	24.4	24.4	24.4	24.4	24.4	24.4	23.8	11.6
32001	PROJECT MGMT.	.0	.0	.0	.0	.5	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.3
3200101	COST/PERF. MGMT.	.0	.0	.0	.0	.3	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	.2
3200102	PROJ. DIRECTION	.0	.0	.0	.0	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1
3200103	INFORM. MGMT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32002	SYS. ENGR. & INT.	.0	.0	.0	.0	.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.5
32003	VEH MAIN STAGE	.0	.0	.0	.0	.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	.8	.1
3200301	STRUCTURES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200302	THERMAL CONTROL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200303	AVIONICS	.0	.0	.0	.0	.3	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	.6	.1
3200304	PROPULSION	.0	.0	.0	.0	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1	.0
3200305	ORBITER I/F	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.0	.0
3200306	DROP TANKS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200307	FINAL ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32004	VEH AUX. STAGE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32005	LOGISTICS	.0	.0	.0	.0	.2	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.3
3200501	TRANSP. & HDLG.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200502	TRAINING	.0	.0	.0	.0	.0	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1
3200503	INV CONT. & WHSNG	.0	.0	.0	.0	.1	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	.2
32006	FACILITIES	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
3200603	ETR MAINT. & REF.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200604	ETR LAUNCH	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200605	WTR MAINT. & REF.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200606	WTR LAUNCH	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32007	GRND. SUPT. EQUIP	.0	.0	.0	.0	.2	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.4
3200701	MFG. GSE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200702	ETR GSE	.0	.0	.0	.0	.1	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.2
3200703	WTR GSE	.0	.0	.0	.0	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1
3200704	FLT OPS GSE(NASA)	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
3200705	FLT OPS GSE(DOD)	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
32009	LAUNCH OPNS. WTR	.0	.0	.0	.0	.0	.0	.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1.3
3200901	LNCH SITE SVCES	.0	.0	.0	.0	.0	.0	.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.5
3200902	TUG/SHTL MATING	.0	.0	.0	.0	.0	.0	.0	.3	.3	.3	.3	.3	.3	.3	.3	.1
3200903	PRELAUNCH C/O	.0	.0	.0	.0	.0	.0	.0	.4	.4	.4	.4	.4	.4	.4	.4	.2
3200904	COUNTDOWN	.0	.0	.0	.0	.0	.0	.0	.4	.4	.4	.4	.4	.4	.4	.4	.2
3200905	PRLNTS. & GASES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3200906	POST FLT. SAFING	.0	.0	.0	.0	.0	.0	.0	.4	.4	.4	.4	.4	.4	.4	.4	.2
32010	LAUNCH OPNS ETR	.0	.0	.0	.0	3.6	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	2.4
3201001	LNCH SITE SVCES	.0	.0	.0	.0	1.4	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	.9
3201002	TUG/SHTL MATING	.0	.0	.0	.0	.4	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.3
3201003	PRELAUNCH C/O	.0	.0	.0	.0	.6	.8	.8	.8	.8	.8	.8	.8	.8	.8	.8	.4
3201004	COUNTDOWN	.0	.0	.0	.0	.5	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.3
3201005	PRLNTS & GASES	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
3201006	POST FLT. SAFING	.0	.0	.0	.0	.6	.8	.8	.8	.8	.8	.8	.8	.8	.8	.8	.4
32011	FLIGHT OPNS NASA	.0	.0	.0	.0	2.4	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.6
3201101	MISSION PLG.	.0	.0	.0	.0	.4	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.2
3201102	FLT. CONTROL	.0	.0	.0	.0	1.6	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	1.0

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29, 1973
PAGE: 1 OF -

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
3201103	FLT. EVAL.	.0	.0	.0	.0	.3	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	.2
3201104	FLT. SUPT. SFTWRE	.0	.0	.0	.0	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1
32012	FLIGHT OPNS DOD	.0	.0	.0	.0	.0	2.4	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.6
3201201	MISSION PLG	.0	.0	.0	.0	.0	.4	.5	.5	.5	.5	.5	.5	.5	.5	.5	.2
3201202	FLT. CONTROL	.0	.0	.0	.0	.0	1.6	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	1.0
3201203	FLT. EVAL.	.0	.0	.0	.0	.0	.3	.4	.4	.4	.4	.4	.4	.4	.4	.4	.2
3201204	FLT. SUPT. SFTWRE	.0	.0	.0	.0	.0	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1
32013	REFURB &INTEG WTR	.0	.0	.0	.0	.0	.0	.0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	.9
3201301	SCH MAINT & REF	.0	.0	.0	.0	.0	.0	.0	.5	.5	.5	.5	.5	.5	.5	.5	.3
3201302	UNSCH MAINT & REF	.0	.0	.0	.0	.0	.0	.0	.2	.2	.2	.2	.2	.2	.2	.2	.1
3201303	POST MAINT C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3201304	TUG/PL MAING &/CO	.0	.0	.0	.0	.0	.0	.0	.4	.4	.4	.4	.4	.4	.4	.4	.2
3201305	REFURB RQMTS PLG	.0	.0	.0	.0	.0	.0	.0	.2	.2	.2	.2	.2	.2	.2	.2	.1
3201306	DEPOT MAINT	.0	.0	.0	.0	.0	.0	.0	.4	.4	.4	.4	.4	.4	.4	.4	.2
32014	REFURB &INTEG ETR	.0	.0	.0	.0	3.3	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	2.2
3201401	SCH MAINT & REF	.0	.0	.0	.0	.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.5
3201402	UNSCH MAINT & REF	.0	.0	.0	.0	.2	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.2
3201403	POST MAINT C/O	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.0
3201404	TUG/PL MATING,C/O	.0	.0	.0	.0	.6	.8	.8	.8	.8	.8	.8	.8	.8	.8	.8	.4
3201405	REFURB RQMTS PLG	.0	.0	.0	.0	.2	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.2
3201406	DEPOT MAINT	.0	.0	.0	.0	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
320030101	FUEL TK & SUPT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030102	OXID. TK & SUPT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030103	BODY STRUCTURE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030104	THRUST STRUCTURE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030105	METEOROID SHIELD	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030106	PAYLOAD I/F	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030107	INSTL. ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030201	FUEL TANK INSL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030202	OXID. TANK INSL.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030203	INSL. PURGE SYS.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030204	THERM CONT. SYS.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030205	INSTL ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030301	DATA MGMT. 3	.0	.0	.0	.0	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1
320030302	G N & C	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030303	COMMUNICATIONS	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.0	.0
320030304	INSTRUMENTAIION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030305	ELECT. POWER	.0	.0	.0	.0	.2	.8	.8	.8	.8	.8	.8	.8	.8	.8	.4	.0
320030306	PWR. DIST. & CONT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030307	INSTL. ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030401	MAIN ENGINE 3	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.0
320030402	MAIN ENG. SUPT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030403	ACPS ENGINE	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.0	.0
320030404	ACPS ENG. SUPT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030405	INSTL. ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030501	STRUCTURES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29, 1973
PAGE: OF

NON RECURRING(DDT&E)

RECURRING(PRODUCTION)

X RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
320030502	I/F PANELS	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.0	.0
320030503	PURGE PROV.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030504	ABORT PROV.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030505	INSTL. ASSY & C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030701	FINAL ASSY	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320030702	C/O	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320050201	SIM. & EQUIP.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320050202	GROUND CREW	.0	.0	.0	.0	.0	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1
320060301	DES./CONST.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060302	ACTIV./MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060401	DES./CONST.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060402	ACTIV./MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060501	DES./CONST.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060502	ACTIV./MAINT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060601	DES./CONST. 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320060602	ACTIV./MAINT. 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070104	SOFTWARE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070201	HARDWARE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070202	SITE ACTIV.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070203	MAINT.	.0	.0	.0	.0	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1
320070204	SOFTWARE	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.0
320070301	HARDWARE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070302	SITE ACTIV.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070303	MAINT.	.0	.0	.0	.0	.0	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1
320070304	SOFTWARE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070404	SOFTWARE 3	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
320070504	SOFTWARE 3	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
32003030105	SOFTWARE	.0	.0	.0	.0	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1
3200204	SUST. ENGR.	.0	.0	.0	.0	.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.5
320070403	MAINT. 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
320070503	MAINT. 3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

FUNDING SCHEDULE
DATA FORM C

DATE: AUGUST 29, 1973
PAGE: OF

NON RECURRING(DDTAE) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91
32001	PROJECT MGMT.	.0	.0	.0	.0	.5	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.3
32002	SYS. ENGR. & INT.	.0	.0	.0	.0	.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.5
32003	VEH MAIN STAGE	.0	.0	.0	.0	.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	.8	.1
32004	VEH AUX. STAGE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32005	LOGISTICS	.0	.0	.0	.0	.2	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.3
32006	FACILITIES	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
32007	GRND. SUPT. EQUIP	.0	.0	.0	.0	.2	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.4
32009	LAUNCH OPNS. WTR	.0	.0	.0	.0	.0	.0	.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1.3
32010	LAUNCH OPNS ETR	.0	.0	.0	.0	3.6	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	2.4
32011	FLIGHT OPNS NASA	.0	.0	.0	.0	2.4	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.6
32012	FLIGHT OPNS DOD	.0	.0	.0	.0	.0	2.4	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.6
32013	REFURB &INTEG WTR	.0	.0	.0	.0	.0	.0	.0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	.9
32014	REFURB &INTEG ETR	.0	.0	.0	.0	3.3	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	2.2
320	TOTAL PROJ PHASE	.0	.0	.0	.0	11.3	19.3	20.1	24.4	24.4	24.4	24.4	24.4	24.4	24.4	23.8	11.6

STOP

COMPUTE TIME 18.734
READY

*

6.7 Total Program Funding Distribution

This subsection presents summary charts for the following WBS elements:

WBS No.	Level	Identification
320	3	Total Space Tug Project
320-03	4	Vehicle Main Stage
320-04	4	Vehicle Auxiliary Stage
320-07	4	Ground Support Equipment
320-08	4	Vehicle Test
320-03-01	5	Structures
320-03-02	5	Thermal Control
320-03-03	5	Avionics
320-03-04	5	Propulsion
320-03-05	5	Orbiter Interface
320-03-07	5	Final Assembly and Checkout

Each summary chart highlights the relationship of cost estimates to technical characteristics and schedules. It also presents an overview of the funding annually and cumulatively by Government Fiscal Year.

No summary chart is presented for WBS 320-03-06 - Drop Tanks, since no drop tanks are required or costed for this program option.

PROGRAM OPTION NO. 1
WBS 320 LEVEL-3 TOTAL SPACE TUG PROJECT COST SUMMARY

TECHNICAL CHARACTERISTICS - OPTION NO. 1
WBS 320 TOTAL SPACE TUG PROJECT

MAJOR HARDWARE

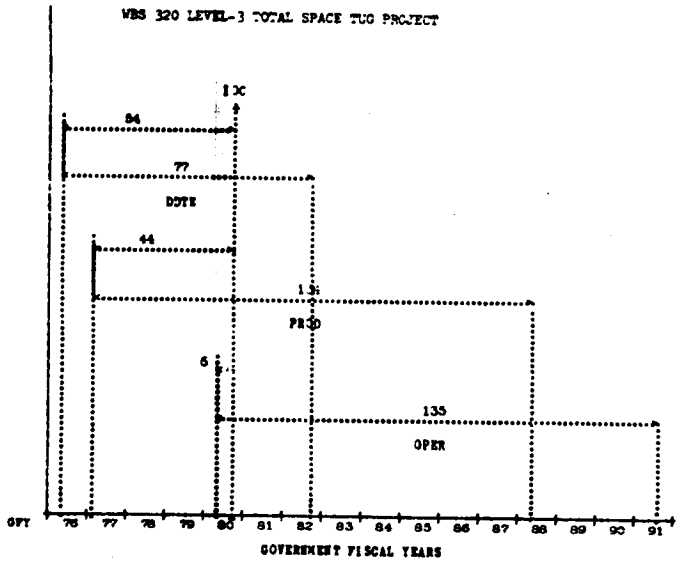
SPACE TUG VEHICLE MAIN STAGE	- 13 VEHICLES
SPACE TUG VEHICLE AUXILIARY STAGE	- 3 STAGES

OTHER SYSTEM ELEMENTS

PROJECT MANAGEMENT	
SYSTEMS ENGINEERING AND INTEGRATION	
LOGISTICS	- TRANSPORTATION, TRAINING, SIMULATION
FACILITIES	- FACTORY, TEST, ETR, WTR
GROUND SUPPORT EQUIPMENT	- FACTORY, ETR, WTR
VEHICLE TEST	- FTV, MAJOR TEST ARTICLES
LAUNCH OPERATIONS - WTR	- 32 LAUNCHES
LAUNCH OPERATIONS - ETR	- 190 LAUNCHES
FLIGHT OPERATIONS - NASA	- 117 FLIGHTS
FLIGHT OPERATIONS - DOD	- 105 FLIGHTS
REFURBISHMENT AND MAINTENANCE - WTR	- 32 REFURBISHMENTS
REFURBISHMENT AND MAINTENANCE - ETR	- 190 REFURBISHMENTS

PROGRAM OPTION NO. 1

WBS 320 LEVEL-3 TOTAL SPACE TUG PROJECT

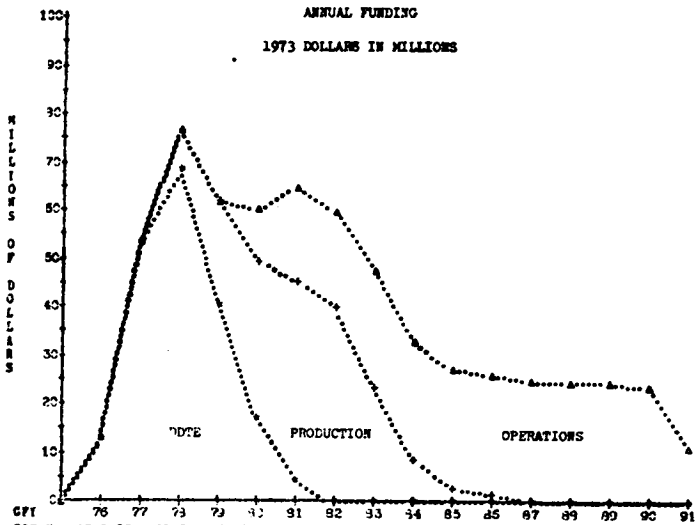


PROGRAM OPTION NO. 1

WBS 320 LEVEL-3 TOTAL SPACE TUG PROJECT

ANNUAL FUNDING

1973 DOLLARS IN MILLIONS



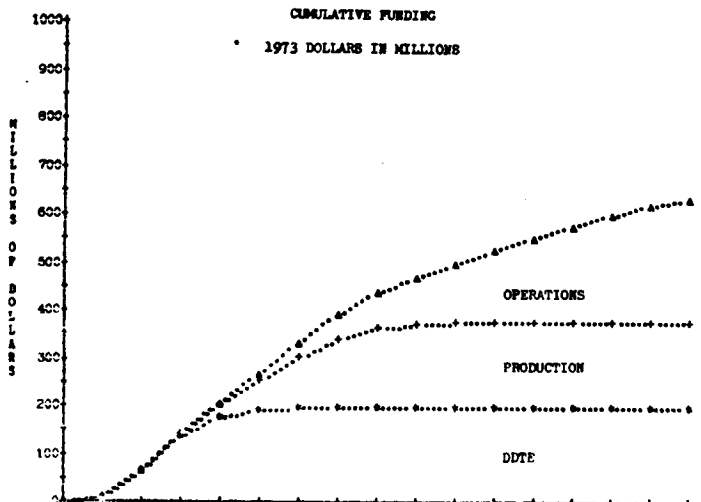
GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDTE	12.9	53.1	68.5	40.6	17.1	4.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.9	8.2	21.4	32.1	41.0	39.8	23.2	8.5	2.9	1.3	.4	.0	.0	.0	.0
OPER	.0	.0	.0	.0	11.3	19.3	20.1	24.4	24.4	24.4	24.4	24.4	24.4	24.4	23.8	11.6
TOTAL	12.9	54.0	76.7	62.0	60.5	64.7	60.0	47.6	32.9	27.2	26.0	24.8	24.4	24.4	23.8	11.6

PROGRAM OPTION NO. 1

WBS 320 LEVEL-3 TOTAL SPACE TUG PROJECT

CUMULATIVE FUNDING

1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDTE	13	66	135	175	192	197	197	197	197	197	197	197	197	197	197	197
PROD	0	1	9	30	63	104	143	167	175	178	179	180	180	180	180	180
OPER	0	0	0	0	11	31	51	75	99	124	148	173	197	221	245	257
TOTAL	12	66	143	205	266	330	390	439	471	498	524	549	573	598	621	633

PROGRAM OPTION NO. 1
WBS 320-03 LEVEL-4 VEHICLE MAIN STAGE COST SUMMARY

TECHNICAL CHARACTERISTICS - OPTION NO. 1

WBS 320-03 SPACE TUG VEHICLE MAIN STAGE

TECHNICAL DESCRIPTION

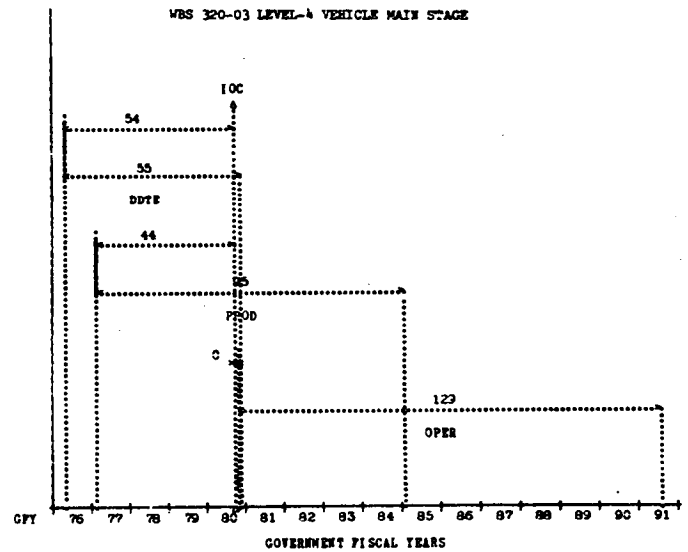
TOTAL LENGTH	398.8 IN. (32.5 FT.)
MAXIMUM DIAMETER	176.0 IN. (14.7 FT.)
TOTAL WEIGHT (WITH 10% CONTINGENCY)	6602 LBS.
MAXIMUM PAYLOAD CAPABILITY	2200 LBS (SYNCHRONOUS ORBIT)
RETRIEVAL CAPABILITY	NONE
CONFIGURATION	LOAD CARRYING TANK (LCT)

STAGE CHARACTERISTICS

SUBSYSTEMS/ELEMENTS	
STRUCTURES	2219 ALUM.; BODY - OPEN ISOGRID; TANKS - TAPERED DOMES
THERMAL CONTROL	DAM COATING/KAPTON PURGE BAG
AVIONICS	DMS, GN&C, COMM., INSTR., ELECT. POWER, POWER DISTR.
PROPULSION	CAT. I - RL10; AMB. He PRESS.; TRANSTAGE MONOPROP. ACPS
ORBITER INTERFACE	TILT TABLE; TRUNNION; INTERFACE PANELS; ABORT PROVISIONS
FINAL ASSEMBLY AND CHECKOUT	
SIZING MISSION	PAYLOAD DEPLOYMENT
LAUNCH SITES/FLIGHTS	ETR/190 AND WTR/32
NO. PRODUCTION UNITS	13
FOR OPERATIONS	10
FOR RELIABILITY	3

PROGRAM OPTION NO. 1

WBS 320-03 LEVEL-4 VEHICLE MAIN STAGE

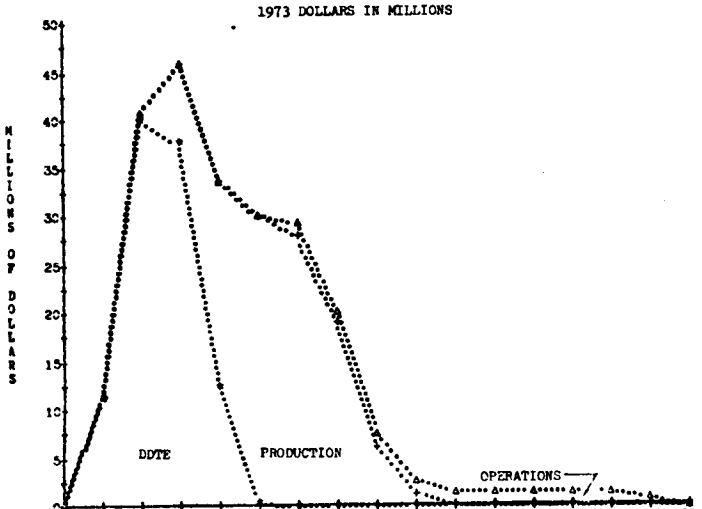


PROGRAM OPTION NO. 1

WBS 320-03 LEVEL-4 VEHICLE MAIN STAGE

ANNUAL FUNDING

1973 DOLLARS IN MILLIONS



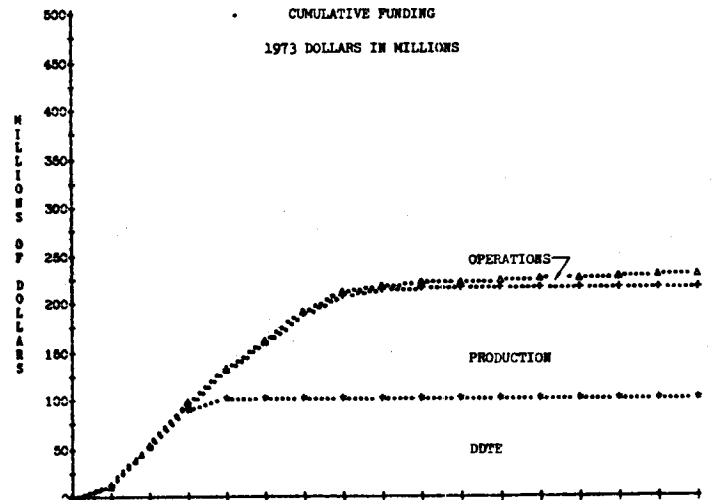
GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	11.4	39.9	37.7	12.5	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.9	8.2	21.2	29.6	27.9	18.9	6.1	1.3	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	.8	.1
TOTAL	11.4	40.8	45.9	33.7	30.3	29.3	20.3	7.5	2.7	1.4	1.4	1.4	1.4	1.4	.8	.1

PROGRAM OPTION NO. 1

WBS 320-03 LEVEL-4 VEHICLE MAIN STAGE

CUMULATIVE FUNDING

1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	11	51	89	101	102	102	102	102	102	102	102	102	102	102	102	102
PROD	0	1	9	30	60	88	107	113	114	114	114	114	114	114	114	114
OPER	0	0	0	0	0	2	3	4	6	7	9	10	11	13	14	14
TOTAL	11	52	98	131	162	191	211	219	221	223	224	226	227	228	229	

PROGRAM OPTION NO. 1
WBS 320-04 LEVEL-4 VEHICLE AUXILIARY STAGE COST SUMMARY

TECHNICAL CHARACTERISTICS - OPTION NO. 1

WBS 320-04 SPACE TUG VEHICLE AUXILIARY STAGE

TECHNICAL DESCRIPTION

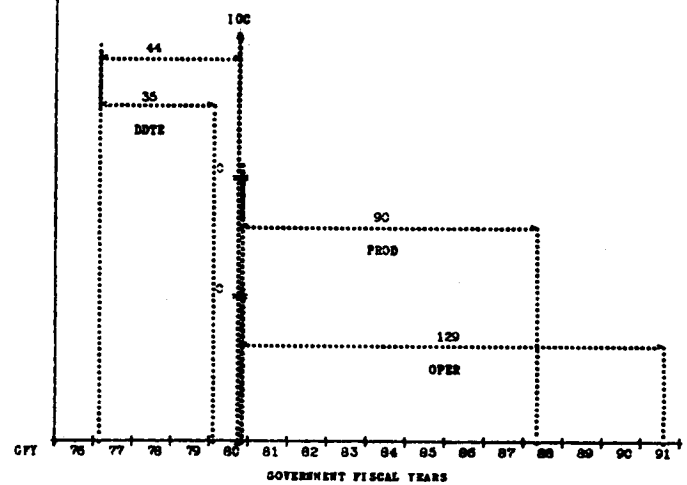
KICK STAGE TO PAYLOAD OPEN TRUSS WEIGHT	80 LB

STAGE CHARACTERISTICS

SOLID ROCKET MOTOR (SRM)	POLARIS A-3 (2ND STAGE) WITH GUIDANCE
SRM TECHNOLOGY	MINIMUM MODIFICATION
NO. KICKSTAGE MISSIONS	9
NO. TRUSS ASSEMBLIES REQUIRED	9 (EXPENDABLE)
NO. SRM'S REQUIRED	9 (EXPENDABLE)

PROGRAM OPTION NO. 1

WBS 320-04 LEVEL-4 VEHICLE AUXILIARY STAGE

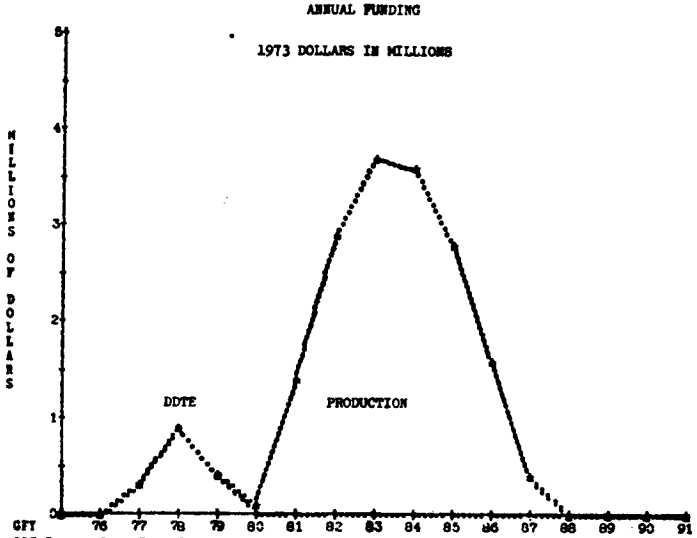


PROGRAM OPTION NO. 1

WBS 320-04 LEVEL-4 VEHICLE AUXILIARY STAGE

ANNUAL FUNDING

1973 DOLLARS IN MILLIONS



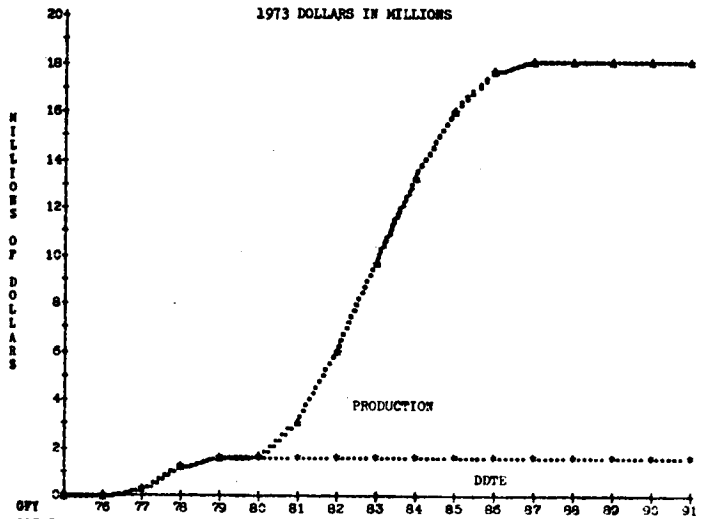
GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	.0	.3	.9	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	.0	.0	.1	1.4	2.9	3.7	3.6	2.8	1.6	.4	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	.0	.3	.9	.4	.1	1.4	2.9	3.7	3.6	2.8	1.6	.4	.0	.0	.0	.0

PROGRAM OPTION NO. 1

WBS 320-04 LEVEL 4 VEHICLE AUXILIARY STAGE

CUMULATIVE FUNDING

1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	.0	.3	1.2	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
PROD	.0	.0	.0	.0	.1	1.5	4.4	8.1	11.7	14.5	16.1	16.5	16.5	16.5	16.5	16.5
OPER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	.0	.3	1.2	1.6	1.7	3.1	6.0	9.7	13.3	16.1	17.7	18.1	18.1	18.1	18.1	18.1

PROGRAM OPTION NO. 1
WBS 320-07 LEVEL-4 GROUND SUPPORT EQUIPMENT COST SUMMARY

TECHNICAL CHARACTERISTICS - OPTION NO. 1
WBS 320-07 GROUND SUPPORT EQUIPMENT

GSE METHODOLOGY

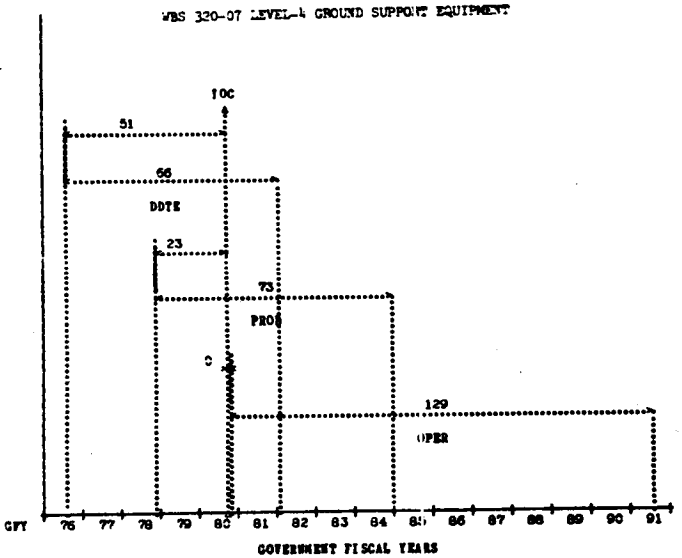
GROUND RULE

MAXIMIZING USE OF EXISTING S-IVB/SKYLAB GSE IS ASSUMED. COSTS OF GSE NOT SIMILAR TO S-IVB/SKYLAB GSE ARE BASED ON AN "AVERAGE UNIT COST OF S-IVB GSE," DERIVED BY DIVIDING THE TOTAL COST OF S-IVB GSE BY THE NUMBER OF GSE UNITS INCLUDED IN THAT COST. THE COST OF AN AVERAGE UNIT OF S-IVB GSE HAS BEEN ALLOCATED TO "NON-RECURRING" AND "RECURRING" PORTIONS BASED ON RATIO OF THESE ELEMENTS FOR THE TOTAL S-IVB GSE. COSTS FOR SPACE TUG GSE UNITS HAS BEEN ESTIMATED AS A PERCENTAGE OF THE BASE.

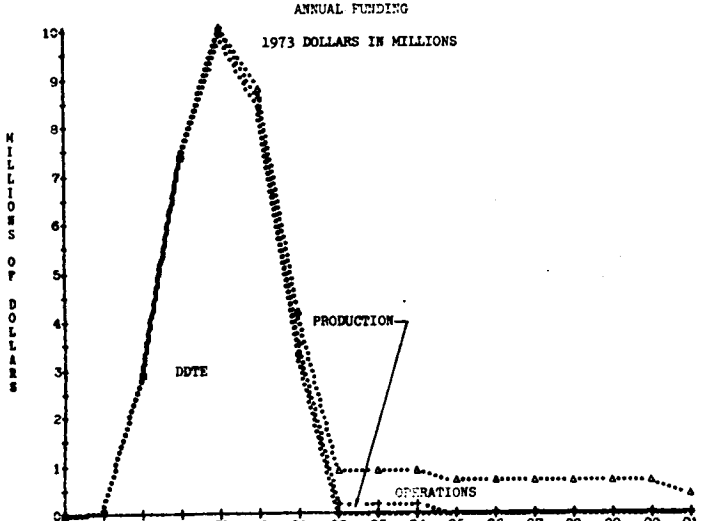
GSE CHARACTERISTICS

GSE LOCATIONS	MANUFACTURING FACILITY ETR WTR NASA FLIGHT OPERATIONS DOD FLIGHT OPERATIONS CENTER
TYPES	BOTH HARDWARE AND SOFTWARE
REQUIREMENT	SUPPORT OF DEVELOPMENT QUALIFICATION AND ACCEPTANCE TESTING, SPACE TUG FABRICATION, SPACE TUG TRANSPORTATION AND HANDLING, INTEGRATION OF TUG AND PAYLOAD, AND INTEGRATION OF TUG AND ORBITER.

PROGRAM OPTION NO. 1
WBS 320-07 LEVEL-4 GROUND SUPPORT EQUIPMENT

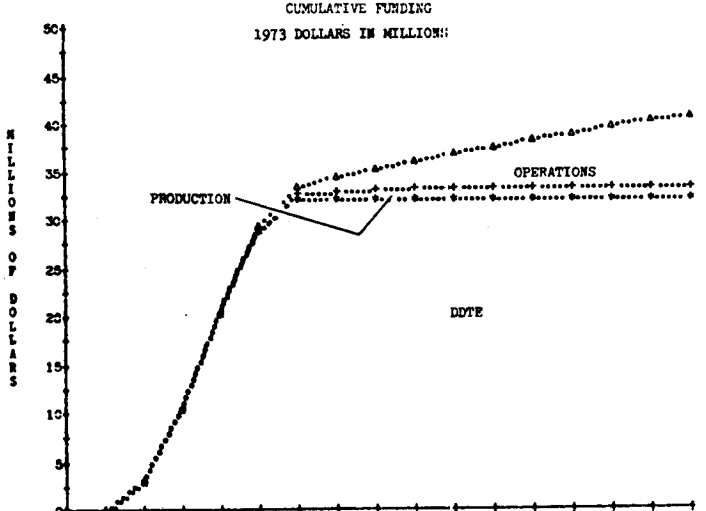


PROGRAM OPTION NO. 1
WBS 320-07 LEVEL 4 GROUND SUPPORT EQUIPMENT
ANNUAL FUNDING
1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	.1	2.9	7.4	9.9	8.4	3.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	.0	.2	.2	.2	.2	.2	.2	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.2	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.4
TOTAL	.1	2.9	7.4	10.1	8.8	4.2	.9	.9	.9	.7	.7	.7	.7	.7	.7	.4

PROGRAM OPTION NO. 1
WBS 320-07 LEVEL-4 GROUND SUPPORT EQUIPMENT
CUMULATIVE FUNDING
1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	.1	3.0	10.4	20.3	28.7	32.0	32.0	32.0	32.0	32.0	32.0	32.0	32.0	32.0	32.0	32.0
PROD	.0	.0	.0	.2	.4	.6	.8	1.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
OPER	.0	.0	.0	.0	.2	.9	1.6	2.3	3.0	3.7	4.4	5.1	5.9	6.5	7.2	7.6
TOTAL	.1	3.0	10.4	20.5	29.3	33.5	34.4	35.3	36.2	36.9	37.6	38.3	39.0	39.7	40.4	40.8

PROGRAM OPTION NO. 1
WBS 320-08 LEVEL-4 VEHICLE TEST COST SUMMARY

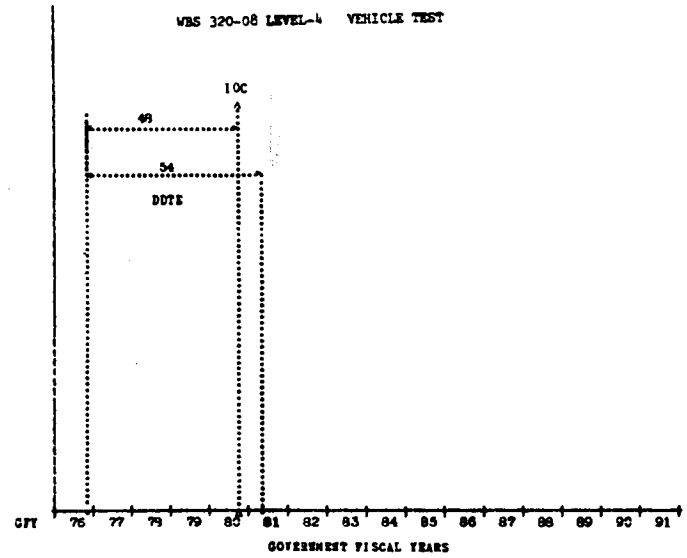
TECHNICAL CHARACTERISTICS - OPTION NO. 1

WBS 320-08 VEHICLE TEST

DESCRIPTORS	CHARACTERISTICS
TYPES OF TESTING	PROPULSION TEST VEHICLE
	MAJOR TEST ARTICLE
	MOCKUPS
TEST CATAGORIES	GROUND TEST HARDWARE
	FLIGHT TEST INSTRUMENTATION
	GROUND TEST OPERATIONS
	FLIGHT TEST OPERATIONS

PROGRAM OPTION NO. 1

WBS 320-08 LEVEL-4 VEHICLE TEST

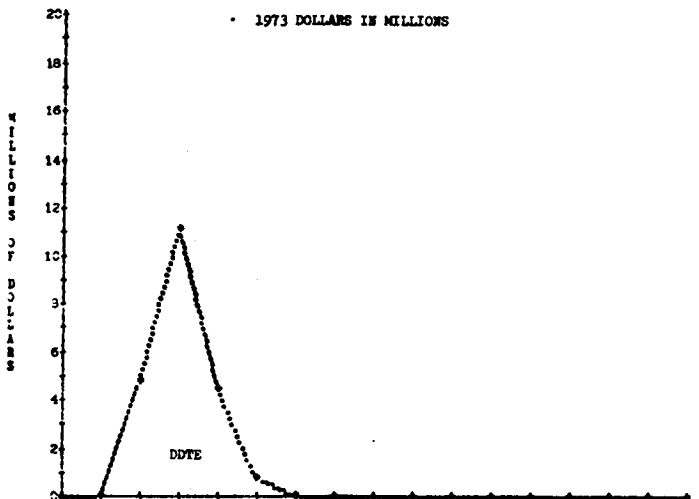


PROGRAM OPTION NO. 1

WBS 320-08 LEVEL-4 VEHICLE TEST

ANNUAL FUNDING

1973 DOLLARS IN MILLIONS



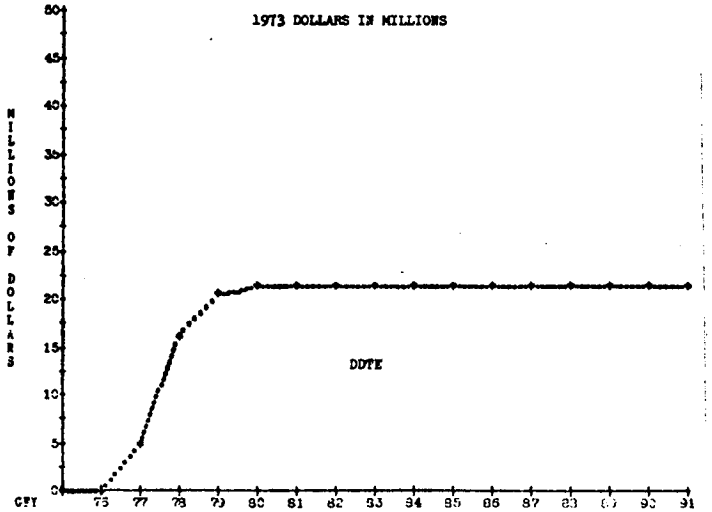
GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDTE	.1	4.8	11.2	4.5	.8	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	.1	4.8	11.2	4.5	.8	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

PROGRAM OPTION NO. 1

WBS-320-08 LEVEL-4 VEHICLE TEST

CUMULATIVE FUNDING

1973 DOLLARS IN MILLIONS



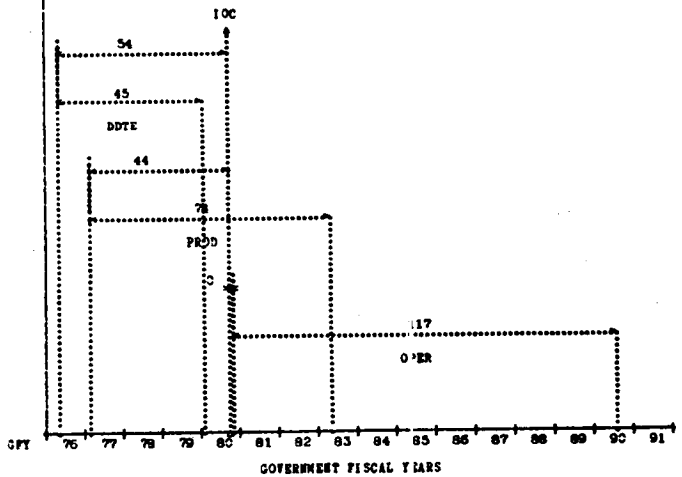
GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDTE	.1	4.9	16.1	20.6	21.4	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5
PROD	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	.1	4.9	16.1	20.6	21.4	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5

PROGRAM OPTION NO. 1
WBS 320-03-01 LEVEL-5 VEHICLE MAIN STAGE
STRUCTURES SUBSYSTEM COST SUMMARY

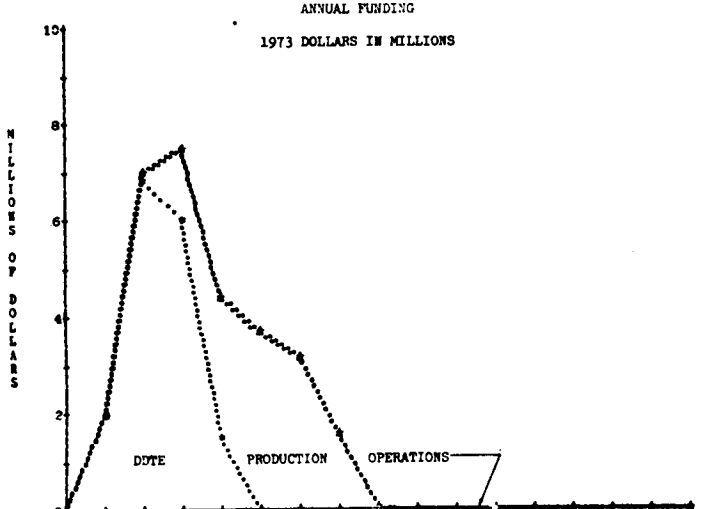
TECHNICAL CHARACTERISTICS - OPTION NO. 1
WBS 320-03-01 STRUCTURES

DESCRIPTORS	COST WEIGHTS	CHARACTERISTICS
STRUCTURE SUBSYSTEM	2494 LBS	
SUBSYSTEM ASSEMBLIES		
LH_2 FUEL TANK	742 LBS	DOMES - 2219 ALUM., TAPERED; SIDEWALL - 2219 ALUM., CLOSED ISOGRID; SUPPORTS - TITANIUM TUBES
LOX TANK	314 LBS	DOMES - 2219 ALUM., TAPERED; SUPPORTS - TITANIUM TUBES
BODY STRUCTURE	1027 LBS	LONGERONS - 2219 ALUM.; SHEAR PANELS - 2219 ALUM., OPEN ISOGRID; SUPPORTS - TITANIUM TUBULAR TRUSS
THRUST STRUCTURE	106 LBS	TITANIUM OPEN ICOGRID
METEOROID SHIELD	77 LBS	6 MIL DACRON BARRIER/BAG
PAYLOAD INTERFACE	128 LBS	
TUG TO PAYLOAD SQUARE FRAME TRUSS	100 LBS	ALUM. TUBE TRUSSES, 3 REQ. (REUSABLE FOR 9 KICKSTAGE MISSIONS

PROGRAM OPTION NO. 1
WBS 320-03-01 LEVEL-5 VEHICLE MAIN STAGE
STRUCTURES SUBSYSTEM

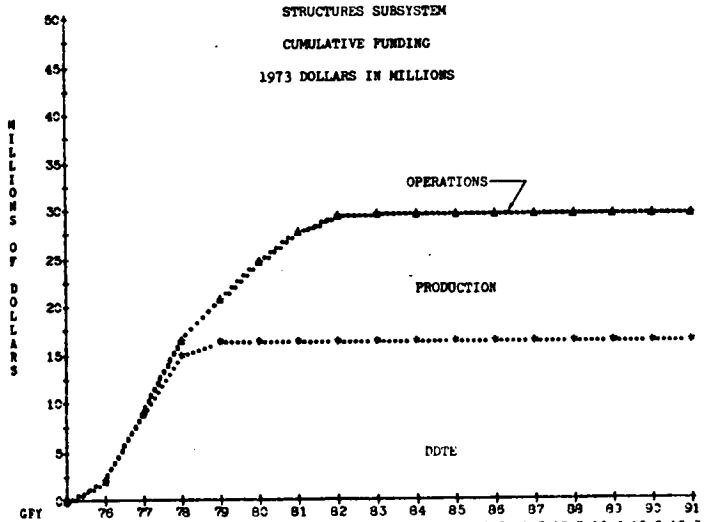


PROGRAM OPTION NO. 1
WBS 320-03-01 LEVEL-5 VEHICLE MAIN STAGE
STRUCTURES SUBSYSTEM
ANNUAL FUNDING
1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	2.0	6.9	6.0	1.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.2	1.5	2.9	3.7	3.2	1.6	.1	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	2.0	7.0	7.5	4.4	3.7	3.2	1.6	.1	.0	.0	.0	.0	.0	.0	.0	.0

PROGRAM OPTION NO. 1
WBS 320-03-01 LEVEL-5 VEHICLE MAIN STAGE -
STRUCTURES SUBSYSTEM
CUMULATIVE FUNDING
1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	2.0	8.9	14.9	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3
PROD	.0	.2	1.7	4.6	8.3	11.5	13.1	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
OPER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	2.0	9.0	16.5	20.9	24.6	27.8	29.4	29.5	29.5	29.5	29.5	29.8	29.8	29.5	29.5	29.5

PROGRAM OPTION NO. 1
WBS 320-03-02 LEVEL-5 VEHICLE MAIN STAGE
THERMAL CONTROL SUBSYSTEM COST SUMMARY

TECHNICAL CHARACTERISTICS - OPTION NO. 1

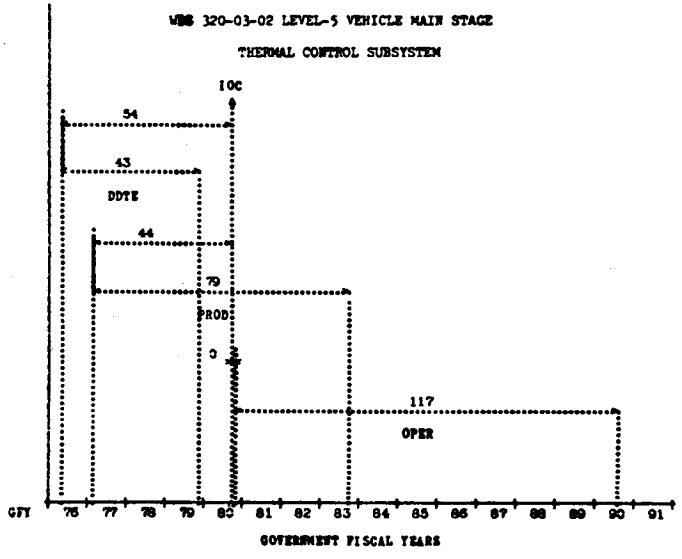
WBS 320-03-02 THERMAL CONTROL

DESCRIPTORS	CORE WEIGHT	CHARACTERISTICS
THERMAL CONTROL SUBSYSTEM	90 LBS	DAM COATING/KAPTON PURGE BAG/0.25 DACRON NET; STANDOFFS - FIBERGLASS; PURGE BAG/BARRIER

PROGRAM OPTION NO. 1

WBS 320-03-02 LEVEL-5 VEHICLE MAIN STAGE

THERMAL CONTROL SUBSYSTEM



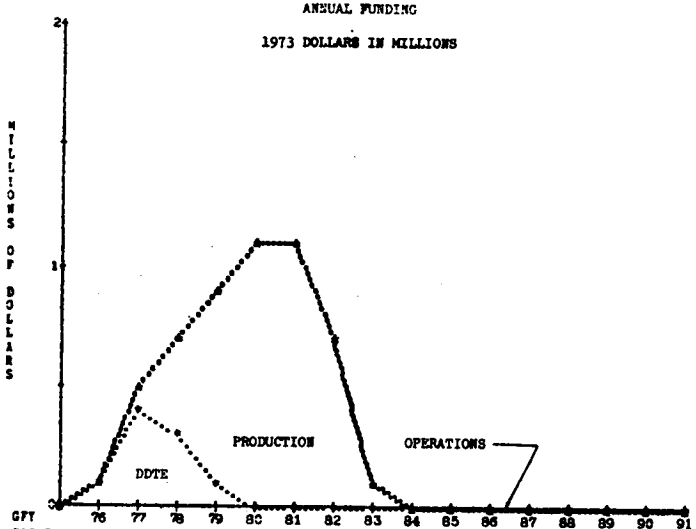
PROGRAM OPTION NO. 1

WBS 320-03-02 LEVEL-5 VEHICLE MAIN STAGE -

THERMAL CONTROL SUBSYSTEM

ANNUAL FUNDING

1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT-E	.1	.4	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.1	.4	.8	1.1	1.1	.7	.1	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	.1	.5	.7	.9	1.1	1.1	.7	.1	.0	.0	.0	.0	.0	.0	.0	.0

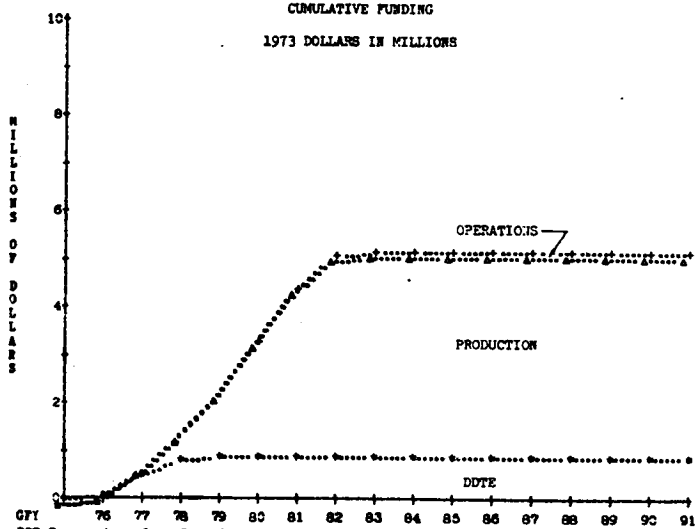
PROGRAM OPTION NO. 1

WBS 320-03-02 LEVEL-5 VEHICLE MAIN STAGE -

THERMAL CONTROL SUBSYSTEM

CUMULATIVE FUNDING

1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT-E	.1	.5	.8	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
PROD	.0	.1	.5	1.3	2.4	3.5	4.2	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
OPER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	.1	.6	1.3	2.2	3.3	4.4	5.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2

6-77

PROGRAM OPTION NO. 1
WBS 320-03-03 LEVEL-5 VEHICLE MAIN STAGE
AVIONICS SUBSYSTEM COST SUMMARY

TECHNICAL CHARACTERISTICS - OPTION NO. 1

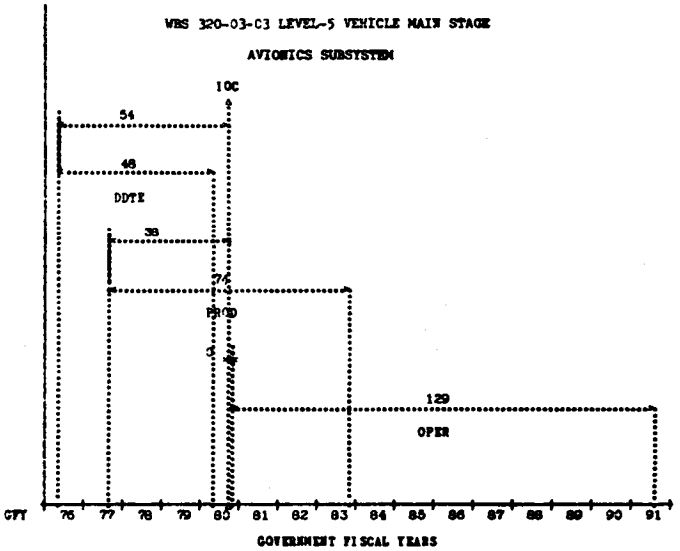
WBS 320-03-03 AVIONICS

DESCRIPTORS	CHARACTERISTICS
AVIONICS SUBSYSTEM	
DATA MANAGEMENT	COMPUTER (16 BIT - 24K), THERMAL CONTROL, CIRCUITRY, SOFTWARE
GUIDANCE, NAVIGATION, AND CONTROL	IMU, TRACKING/ELECT.
COMMUNICATIONS	MICROWAVE CIRCUITRY + RF MULTIPLEXER, TRANSPONDERS, POWER AMP, ANTENNA, DEC/ENC + MOD/DEM, TAPE RECORDER, P/L INTERFACE EQUIP.
INSTRUMENTATION	DATA SENSORS, SIGNAL COND, CIRCUITRY
ELECTRICAL POWER	BATTERY
POWER DISTRIBUTION AND CONTROL	DISTRIBUTION, TANKS SYSTEM

PROGRAM OPTION NO. 1

WBS 320-03-03 LEVEL-5 VEHICLE MAIN STAGE

AVIONICS SUBSYSTEM



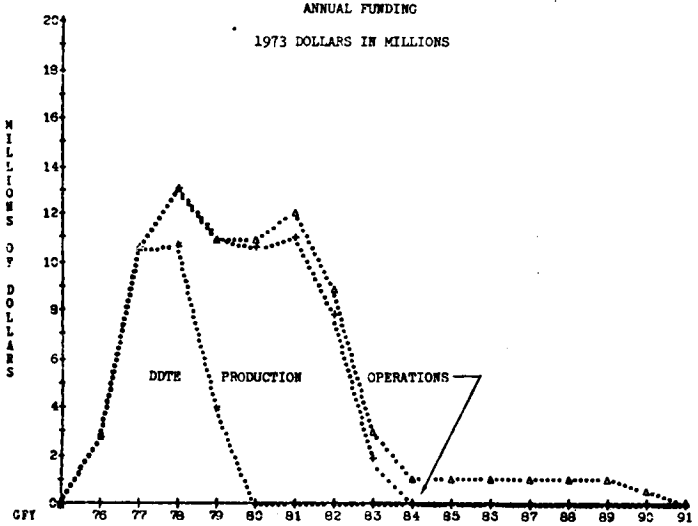
PROGRAM OPTION NO. 1

WBS 320-03-03 LEVEL-5 VEHICLE MAIN STAGE -

AVIONICS SUBSYSTEM

ANNUAL FUNDING

1973 DOLLARS IN MILLIONS



FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	2.8	10.5	10.7	3.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.1	2.4	7.0	10.6	11.0	7.8	1.9	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.3	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	.6	.1
TOTAL	2.8	10.6	13.1	10.9	10.9	12.1	8.9	3.0	1.1	1.1	1.1	1.1	1.1	1.1	.6	.1

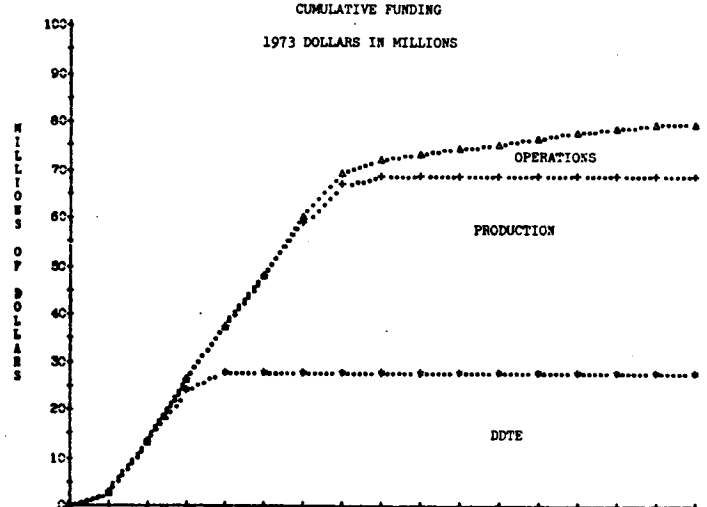
PROGRAM OPTION NO. 1

WBS 320-03-03 LEVEL-5 VEHICLE MAIN STAGE -

AVIONICS SUBSYSTEM

CUMULATIVE FUNDING

1973 DOLLARS IN MILLIONS



FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	2.8	13.3	24.0	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9
PROD	.0	.1	2.5	9.5	20.1	31.1	38.9	40.8	40.8	40.8	40.9	40.9	40.9	40.9	40.8	40.3
OPER	.0	.0	.0	.0	.3	1.4	2.5	3.6	4.7	5.8	6.9	8.0	9.1	10.2	10.9	10.9
TOTAL	2.8	13.4	26.5	37.4	48.3	60.4	69.3	72.3	73.4	74.5	75.6	76.7	77.9	79.0	79.5	79.6

PROGRAM OPTION NO. 1
WBS 320-03-04 LEVEL-5 VEHICLE MAIN STAGE
PROPULSION SUBSYSTEM COST SUMMARY

TECHNICAL CHARACTERISTICS - OPTION NO. 1

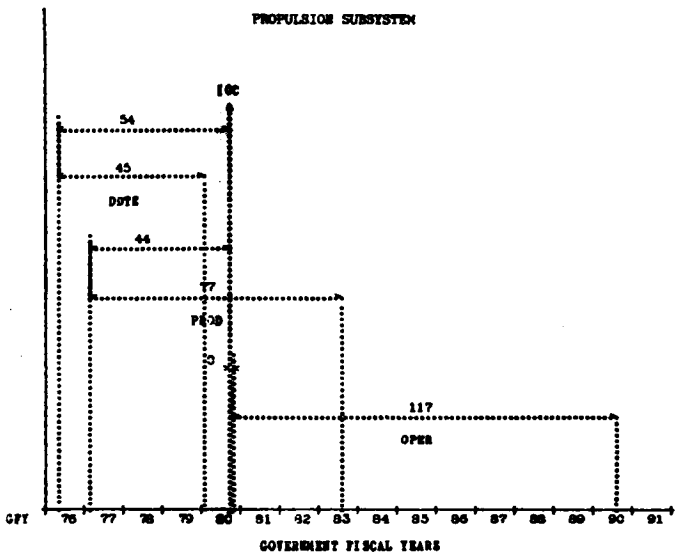
WBS 320-03-04 PROPULSION

DESCRIPTORS	COST WEIGHT	CHARACTERISTICS
PROPULSION SUBSYSTEM	1729 LBS	
SUBSYSTEM ASSEMBLIES		
MAIN ENGINE	347 LBS	CAT I - RL10, GFE
TVC	52 LBS	APOLLO SPS
PRESSURIZATION	680 LBS	S-IVB DERIVATIVE AMBIENT HELIUM + ENGINE GH_2 BLEED (INCLUDES LVM AND 5-4.5 FT^3 BOTTLES)
FEED	62 LBS	DEVELOPED COMPONENTS
FILL AND DRAIN	50 LBS	DEVELOPED COMPONENTS
VENT	180 LBS	DEVELOPED COMPONENTS
PROPELLANT UTILIZATION	36 LBS	CLOSED LOOP CAPACITANCE PROBE
PNEUMATICS		SUPPLIED BY AMB. He PRESS. ASSEMBLY
PROPELLANT ORIENTATION		PROPELLANTS SETTLED BY FIRING TWO AFT POINTING 27/16 THRUSTORS
LO_2 ABORT DUMP	78 LBS	VALVES AND 3 INCH DISCONNECT AND UNJACKETED DUCTING
ENGINE AND FEEDLINE CHILLDOWN		BLEED PROPELLANTS TRICKLED THROUGH FEEDLINE AND ENGINE WHILE FIRING ACPS THRUSTORS FOR PROPELLANT SETTLING.
ACPS (INCLUDING THRUSTORS)	264 LBS	BLOWDOWN MONOPROPELLANT (N_2H_4) - DEVELOPED, 70,000 LB-SEC.
THRUSTORS		16-25 LBF MR-3C TANGENTIAL THRUSTORS REQ.
MAIN ENGINE EMR		5.5 TO 1.0

PROGRAM OPTION NO. 1

WBS 320-03-04 LEVEL-5 VEHICLE MAIN STAGE

PROPULSION SUBSYSTEM



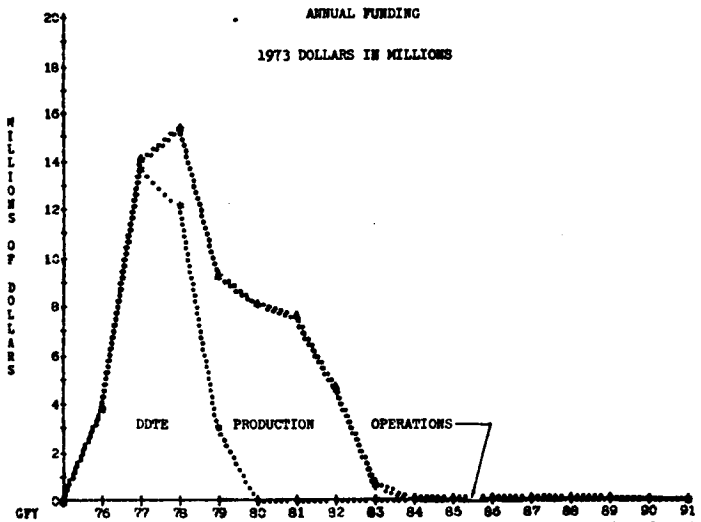
PROGRAM OPTION NO. 1

WBS 320-03-04 LEVEL-5 VEHICLE MAIN STAGE -

PROPULSION SUBSYSTEM

ANNUAL FUNDING

1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	3.8	13.6	12.2	3.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.5	3.2	6.3	8.1	7.5	4.5	.6	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	.1	.0
TOTAL	3.8	14.1	15.4	9.3	8.2	7.7	4.7	.8	.2	.2	.2	.2	.2	.2	.1	.0

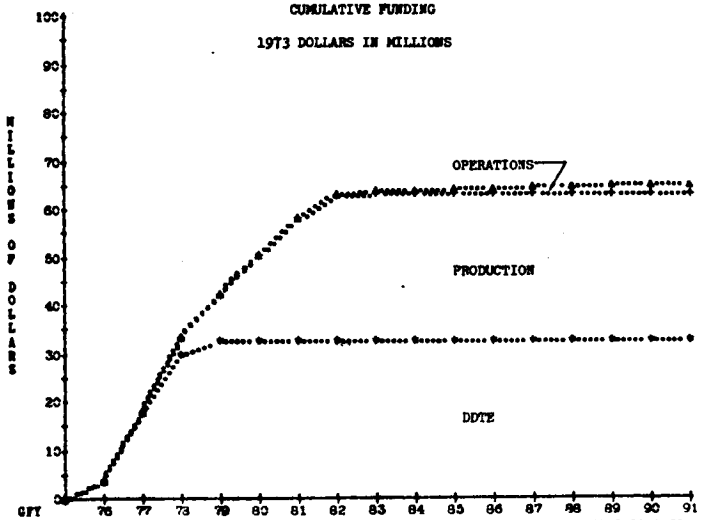
PROGRAM OPTION NO. 1

WBS 320-03-05 LEVEL-5 VEHICLE MAIN STAGE -

PROPULSION SUBSYSTEM

CUMULATIVE FUNDING

1973 DOLLARS IN MILLIONS



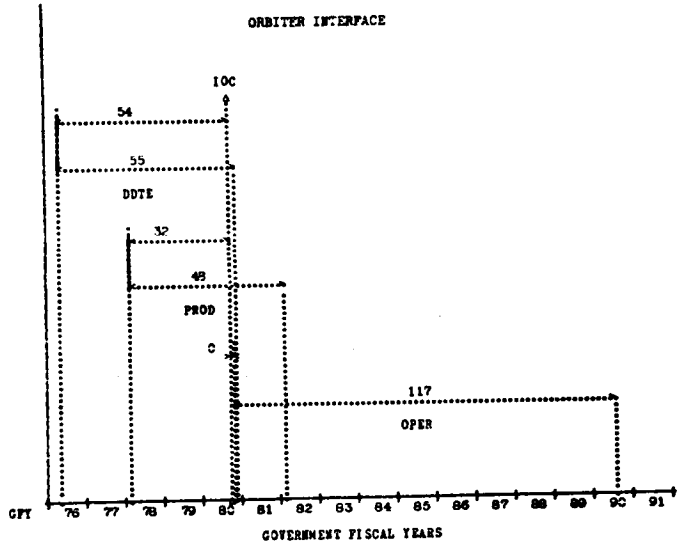
GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	3.8	17.4	29.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6
PROD	.0	.5	3.7	10.0	18.1	25.6	30.1	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7
OPER	.0	.0	.0	.0	.1	.3	.5	.7	.9	1.1	1.3	1.5	1.7	1.9	2.0	2.0
TOTAL	3.8	17.9	33.3	42.6	50.8	58.5	63.2	64.0	64.2	64.4	64.6	64.8	65.0	65.2	65.3	65.3

PROGRAM OPTION NO. 1
WBS 320-03-05 LEVEL-5 VEHICLE MAIN STAGE
ORBITER INTERFACE COST SUMMARY

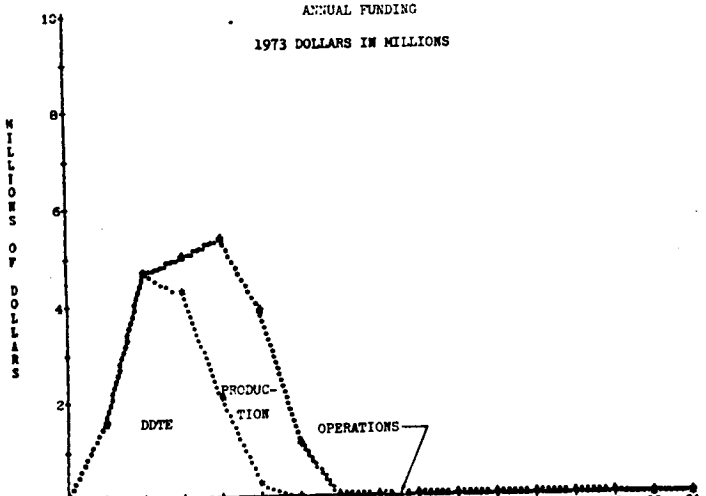
TECHNICAL CHARACTERISTICS - OPTION NO. 1
WBS 320-03-05 ORBITER INTERFACE

DESCRIPTORS	COST WEIGHT	CHARACTERISTICS
TUG ANCILLARY EQUIPMENT	2402 LBS	
STRUCTURES	1112 LBS	TILT TABLE AND TRUNNION
INTERFACE PANELS	1195 LBS	ELECTRICAL UMBILICAL PANEL
		FLUID UMBILICAL PANEL
		TUG CONTROL AND DISPLAY PANEL
		C&W COMPARATOR AND DISPLAY PANEL
		A/D CONVERTER AND MUX
		DIGITAL RECORDER
		END EFFECTORS AND T/V LIGHTING
		CABLES
		DISTRIBUTORS
ABORT PROVISIONS	95 LBS	

PROGRAM OPTION NO. 1
WBS 320-03-05 LEVEL-5 VEHICLE MAIN STAGE
ORBITER INTERFACE

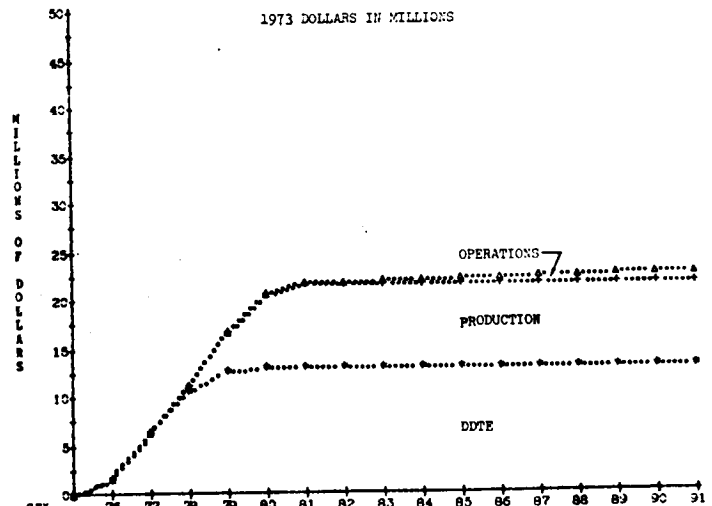


PROGRAM OPTION NO. 1
WBS 320-03-05 LEVEL-5 VEHICLE MAIN STAGE -
ORBITER INTERFACE
ANNUAL FUNDING
1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	1.6	4.7	4.3	2.1	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	.7	3.3	3.6	1.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	.0	.0
TOTAL	1.6	4.7	5.0	5.4	3.9	1.2	.1	.1	.1	.1	.1	.1	.1	.1	.0	.0

PROGRAM OPTION NO. 1
WBS 320-03-05 LEVEL-5 VEHICLE MAIN STAGE -
ORBITER INTERFACE
CUMULATIVE FUNDING
1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	1.6	6.3	10.6	12.7	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
PROD	.0	.0	.7	4.0	7.6	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
OPER	.0	.0	.0	.0	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	.9	.9
TOTAL	1.6	6.3	11.3	16.7	20.6	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.6	22.6

PROGRAM OPTION NO. 1
WBS 320-03-07 LEVEL-5 VEHICLE MAIN STAGE
FINAL ASSEMBLY AND CHECKOUT COST SUMMARY

TECHNICAL CHARACTERISTICS - OPTION NO. 1

WBS 320-03-07 FINAL ASSEMBLY AND CHECKOUT

TECHNICAL DESCRIPTION

MANUFACTURING RESPONSIBILITY

PROVIDE ALL MATERIAL FOR 13 MAIN STAGES

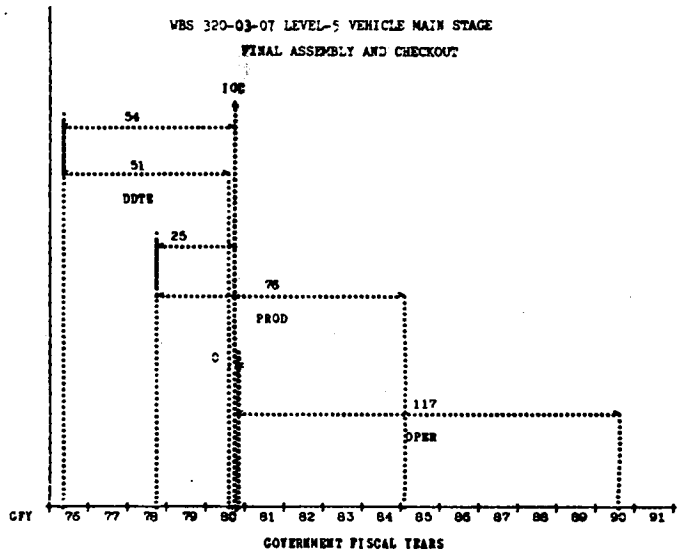
FABRICATE, ASSEMBLE, AND ACCEPTANCE TEST 13 MAIN STAGES, INCLUDING SUBSYSTEMS, ASSEMBLIES, AND COMPONENTS

PROVIDE QUALITY ASSURANCE, PRODUCTION CONTROL CALIBRATION AND OTHER SUPPORT FOR PRODUCTION OPERATIONS

PROGRAM OPTION NO. 1

WBS 320-03-07 LEVEL-5 VEHICLE MAIN STAGE

FINAL ASSEMBLY AND CHECKOUT



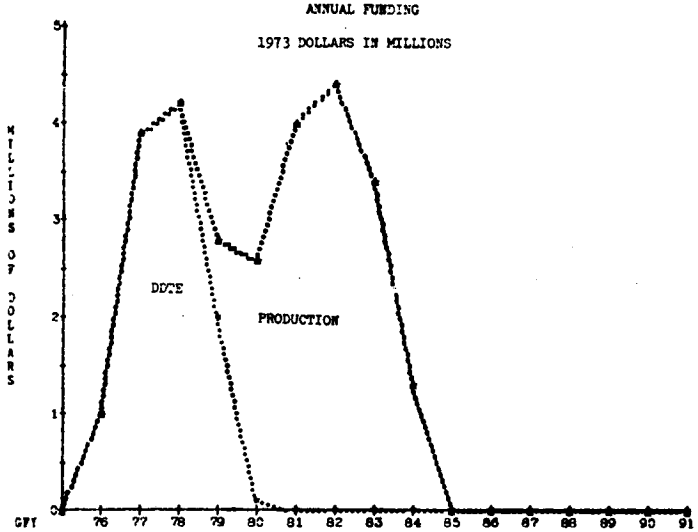
PROGRAM OPTION NO. 1

WBS 320-03-07 LEVEL-5 VEHICLE MAIN STAGE -

FINAL ASSEMBLY AND CHECKOUT

ANNUAL FUNDING

1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	1.0	3.9	4.2	2.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.0	.0	.8	2.5	4.0	4.4	3.4	1.3	.0	.0	.0	.0	.0	.0	.0
OPER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	1.0	3.9	4.2	2.8	2.6	4.0	4.4	3.4	1.3	.0	.0	.0	.0	.0	.0	.0

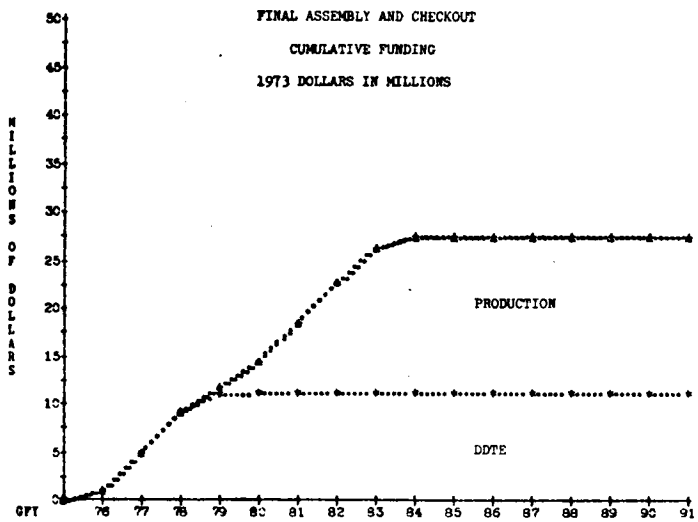
PROGRAM OPTION NO. 1

WBS 320-03-07 LEVEL-5 VEHICLE MAIN STAGE -

FINAL ASSEMBLY AND CHECKOUT

CUMULATIVE FUNDING

1973 DOLLARS IN MILLIONS



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDT+E	1.0	4.9	9.1	11.1	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
PROD	.0	.0	.0	.8	3.3	7.3	11.7	15.1	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4
OPER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	1.0	4.9	9.1	11.9	14.5	18.5	22.9	26.3	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6

6.8 First Unit Production Cost per WBS

It is understood that the intent of this subsection is a presentation of first unit production costs through WBS Level 7. Since these costs are presented as part of Cost Data Form-A (2) recurring (Production) in subsection 6.2 above, reference is made to that subsection rather than merely duplicate the Level-7 data in this subsection.

Instead, this subsection is being used as the most convenient location for the LEADER II cost model printout for costs of each program phase and the total program, as well as costs for first production unit costs through Level 7, and initial spares and operational spares costs through Level 6.

OPTION 1 13 VEHICLES TUG101R 8/28/73 10:00 PM

ABS	COST ELEMENT C	EDMD (MIL)	6TH + 7TH (MIL)	8TH (MIL)	TOTAL DDT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
10	TOTAL PROJECT MGMT	7.08	.00	.00	7.08	.00	5.08	.00	5.08	7.32	.00	7.32	19.47
20	TOTAL SYS. ENGR. &	14.23	.00	.00	14.23	.00	42.70	.00	42.70	11.21	.00	11.21	68.14
30	TOTAL VEH MAIN STA	88.11	14.06	.00	102.17	14.44	111.78	2.01	113.80	2.22	11.67	13.89	229.86
40	TOTAL VEH AUX. STA	1.62	.00	.00	1.62	.00	16.35	.00	16.35	.00	.00	.00	17.97
50	TOTAL LOGISTICS	3.02	.00	.00	3.02	.00	.30	.00	.30	6.71	.00	6.71	10.03
60	TOTAL FACILITIES	5.17	.00	.00	5.17	.00	.33	.00	.33	1.21	.00	1.21	6.70
70	TOTAL GRND. SUPT.	32.09	.00	.00	32.09	.00	1.02	.00	1.02	7.70	.00	7.70	40.81
80	TOTAL VEHICLE TEST	.00	20.57	.75	21.32	.00	.00	.00	.00	.00	.00	.00	21.32
90	TOTAL LAUNCH OPNS.	.00	.00	.00	.00	.00	.00	.00	.00	21.35	.00	21.35	21.35
100	TOTAL LAUNCH OPNS	.00	.00	.00	.00	.00	.00	.00	.00	54.06	.00	54.06	54.06
110	TOTAL FLIGHT OPNS	5.33	.00	.00	5.33	.00	.00	.00	.00	36.39	.00	36.39	41.72
120	TOTAL FLIGHT OPNS	4.79	.00	.00	4.79	.00	.00	.00	.00	32.86	.00	32.86	37.65
130	TOTAL REFURB &INTE	.11	.00	.00	.11	.00	.00	.00	.00	14.70	.00	14.70	14.81
140	TOTAL REFURB &INTE	.11	.00	.00	.11	.00	.00	.00	.00	49.80	.00	49.80	49.91
	TOTAL	161.66	34.63	.75	197.05	14.44	177.56	2.01	179.57	245.53	11.67	257.20	633.82

OPTION 1 13 VEHICLES TUG101R 8/ 9/73 10:00 PM

WBS	COST ELEMENT	C	EDMD (MIL)	OTH (MIL)	FTH (MIL)	TOTAL ODTAE (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
10	PROJECT MGMT.	3												
11	COST/PERF. MGMT.	3	4.86	.00	.00	4.86	.00	3.46	.00	3.46	4.81	.00	4.81	13.12
12	PROJ. DIRECTION	3	2.08	.00	.00	2.08	.00	1.51	.00	1.51	2.30	.00	2.30	5.89
13	INFORM. MGMT.	3	.14	.00	.00	.14	.00	.11	.00	.11	.21	.00	.21	.46
	TOTAL PROJECT MGMT		7.08	.00	.00	7.08	.00	5.08	.00	5.08	7.32	.00	7.32	19.47
	TOTAL		7.08	.00	.00	7.08	.00	5.08	.00	5.08	7.32	.00	7.32	19.47

A8-9

OPTION 1 13 VEHICLES TUG101R 8/28/73 10:00 PM

WBS	COST ELEMENT	C	EDAD (MIL)	OTH (MIL)	PTH (MIL)	TOTAL DDT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
20	SYS. ENGR. & INT.	3												
21	TUG SYS. ENGR.	3	11.38	.00	.00	11.38	.00	6.23	.00	6.23	.00	.00	.00	17.62
22	SHUTTLE I/F	3	.71	.00	.00	.71	.00	1.56	.00	1.56	.00	.00	.00	2.28
23	PAYLOAD I/F	3	2.13	.00	.00	2.13	.00	3.12	.00	3.12	.00	.00	.00	5.25
24	SUST. ENGR.	3	.00	.00	.00	.00	.00	31.79	.00	31.79	11.21	.00	11.21	43.00
	TOTAL SYS. ENGR. &		14.23	.00	.00	14.23	.00	42.70	.00	42.70	11.21	.00	11.21	68.14
	TOTAL		14.23	.00	.00	14.23	.00	42.70	.00	42.70	11.21	.00	11.21	68.14

OPTION 1 13 VEHICLES TUG101R 8/28/73 10:00 PM

WBS	COST ELEMENT	C	EDGD (MIL)	GTH (MIL)	FTH (MIL)	TOTAL DDTAE (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
30	VEH MAIN STAGE	3												
31	STRUCTURES	3	16.08	.30	.00	16.38	1.51	13.12	.00	13.12	.00	.16	.16	29.67
32	THERMAL CONTROL	3	.93	.00	.00	.93	.48	4.22	.00	4.22	.00	.06	.06	5.21
33	AVIONICS	3	22.25	5.76	.00	28.01	4.58	40.06	.64	40.70	2.22	8.46	10.68	79.39
34	PROPULSION	3	28.35	4.35	.00	32.70	3.36	29.37	1.13	30.50	.00	2.45	2.45	65.65
35	ORBITER I/F	3	10.29	2.60	.00	12.89	2.30	8.54	.24	8.78	.00	.54	.54	22.21
36	DROP TANKS	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
37	FINAL ASSY & C/O	3	10.21	1.04	.00	11.25	2.20	16.47	.00	16.47	.00	.00	.00	27.72
	TOTAL VEH MAIN STA		88.11	14.06	.00	102.17	14.44	111.78	2.01	113.80	2.22	11.67	13.89	229.86
	TOTAL		88.11	14.06	.00	102.17	14.44	111.78	2.01	113.80	2.22	11.67	13.89	229.86

289

LEVEL 6

WBS	COST ELEMENT	C	EDBD (MIL)	GTH (MIL)	FTH (MIL)	TOTAL ODT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
3101	FUEL TK & SUPT	3	3.96	.00	.00	3.96	.29	2.55	.00	2.55	.00	.00	.00	6.51
3102	OXID. TK & SUPT	3	2.01	.00	.00	2.01	.24	2.10	.00	2.10	.00	.00	.00	4.11
3103	BODY STRUCTURE	3	4.09	.00	.00	4.09	.09	.82	.00	.82	.00	.00	.00	4.90
3104	THRUST STRUCTURE	3	1.38	.00	.00	1.38	.06	.56	.00	.56	.00	.00	.00	1.95
3105	METEOROID SHIELD	3	.98	.00	.00	.98	.43	3.83	.00	3.83	.00	.00	.00	4.81
3106	PAYLOAD I/F	3	2.47	.28	.00	2.74	.28	2.45	.00	2.45	.00	.00	.00	5.19
3107	INSTL. ASSY & C/O	3	1.19	.02	.00	1.21	.11	.82	.00	.82	.00	.00	.00	2.03
31	STRUCTURE		16.08	.30	.00	16.38	1.51	13.12	.00	13.12	.00	.00	.00	29.51
3201	FUEL TANK INSL	3	.16	.00	.00	.16	.11	.93	.00	.93	.00	.01	.01	1.11
3202	OXID. TANK INSL.	3	.08	.00	.00	.08	.05	.46	.00	.46	.00	.01	.01	.55
3203	INSL. PURGE SYS.	3	.64	.00	.00	.65	.30	2.66	.00	2.66	.00	.03	.03	3.33
3204	THERM CONT. SYS.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
3205	INSTL ASSY & C/O	3	.04	.00	.00	.04	.02	.17	.00	.17	.00	.00	.00	.21
32	THERMAL CONTROL		.93	.00	.00	.93	.48	4.22	.00	4.22	.00	.06	.06	5.21
3301	DATA MGMT.	3	8.41	2.28	.00	10.69	1.02	9.02	.17	9.18	2.22	.31	2.53	22.40
3302	G N & C	3	1.47	.00	.00	1.47	1.12	9.88	.01	9.89	.00	.04	.04	11.40
3303	COMMUNICATIONS	3	4.26	2.90	.00	7.16	1.83	16.15	.23	16.38	.00	.54	.54	24.08
3304	INSTRUMENTATION	3	2.04	.04	.00	2.08	.18	1.57	.00	1.57	.00	.18	.18	3.83
3305	ELECT. POWER	3	.09	.05	.00	.14	.05	.57	.23	.80	.00	7.38	7.38	8.31
3306	PWR. DIST. & CONTS		.85	.07	.00	.91	.03	.37	.00	.37	.00	.01	.01	1.29
3307	INSTL. ASSY & C/O	3	5.13	.43	.00	5.56	.34	2.51	.00	2.51	.00	.00	.00	8.07
33	AVIONICS		22.25	5.76	.00	28.01	4.68	40.06	.64	40.70	2.22	8.46	10.68	79.39
3401	MAIN ENGINE	3	13.08	.00	.00	13.00	.70	6.16	1.10	7.26	.00	1.41	1.41	21.67
3402	MAIN ENG. SUPT	3	8.83	3.28	.00	12.11	1.64	14.45	.00	14.45	.00	.41	.41	26.97
3403	ACPS ENGINE	3	.28	.12	.00	.41	.12	1.07	.03	1.10	.00	.55	.55	2.05
3404	ACPS ENG. SUPT	3	4.88	.74	.00	5.62	.74	6.51	.00	6.51	.00	.09	.09	12.22
3405	INSTL. ASSY & C/O	3	1.35	.21	.00	1.56	.16	1.18	.00	1.18	.00	.00	.00	2.73
34	PROPULSION		28.35	4.35	.00	32.70	3.36	29.37	1.13	30.50	.00	2.45	2.45	65.05
3501	STRUCTURES	3	3.69	.36	.00	4.01	.36	1.36	.02	1.38	.00	.03	.03	5.42
3502	I/F PANELS	3	4.99	1.49	.00	6.47	1.49	5.58	.21	5.79	.00	.49	.49	12.76
3503	PURGE PROV.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
3504	ABORT PROV.	3	.89	.56	.00	1.45	.28	1.06	.01	1.07	.00	.02	.02	2.53
3505	INSTL. ASSY & C/O	3	.76	.19	.00	.95	.17	.55	.00	.55	.00	.00	.00	1.50
35	ORBITER I/F		10.29	2.60	.00	12.89	2.30	8.54	.24	8.78	.00	.54	.54	22.21

LEVEL 6

WBS	COST ELEMENT	C	EDAD (MIL)	GTH (MIL)	FTH (MIL)	TOTAL DDT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
3701	FINAL ASSY	3	7.88	.65	.00	8.53	1.84	13.72	.00	13.72	.00	.00	.00	22.25
3702	C/O	3	2.34	.39	.00	2.73	.37	2.74	.00	2.74	.00	.00	.00	5.47
37	FINAL ASSY & C/O		10.21	1.04	.00	11.25	2.20	16.47	.00	16.47	.00	.00	.00	27.72

LEVEL 7

WBS	COST ELEMENT	C	EO&D (MIL)	GTH (MIL)	FTH (MIL)	TOTAL DUT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
310101	LH2 DOMES	3	1.74	.00	.00	1.74	.08	.00	.00	.00	.00	.00	.00	1.74
310102	LH2 CYLINDER	3	1.92	.00	.00	1.92	.07	.00	.00	.00	.00	.00	.00	1.92
310103	LH2 SUPPORTS	3	.30	.00	.00	.30	.14	.00	.00	.00	.00	.00	.00	.30
3101	FUEL TK & SUPT		3.96	.00	.00	3.96	.29	.00	.00	.00	.00	.00	.00	3.96
310201	LO2 DOMES	3	1.67	.00	.00	1.67	.11	.00	.00	.00	.00	.00	.00	1.67
310202	LO2 SUPPORTS	3	.35	.00	.00	.35	.13	.00	.00	.00	.00	.00	.00	.35
3102	OXID. TK & SUPT		2.01	.00	.00	2.01	.24	.00	.00	.00	.00	.00	.00	2.01
310301	FWD AFT SKIRT	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
310302	INTERTANK	3	1.94	.00	.00	1.94	.04	.00	.00	.00	.00	.00	.00	1.94
310303	SDWL SHELL	3	2.15	.00	.00	2.15	.05	.00	.00	.00	.00	.00	.00	2.15
3103	BODY STRUCTURE		4.09	.00	.00	4.09	.09	.00	.00	.00	.00	.00	.00	4.09
330101	COMPUTER	3	4.59	1.63	.00	6.22	.82	.00	.00	.00	.00	.00	.00	6.22
330102	DATA DISTR.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
330103	EQ. THERM CONT.	3	.33	.42	.00	.75	.11	.00	.00	.00	.00	.00	.00	.75
330104	CIRCUITRY	3	.53	.05	.00	.59	.03	.00	.00	.00	.00	.00	.00	.59
330105	SOFTWARE	3	2.33	.00	.00	2.33	.00	.00	.00	.00	2.22	.00	2.22	4.55
330106	SOFTWARE	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
330107	SOFTWARE	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
330108	INSTL. ASSY & C/O3		.62	.17	.00	.79	.08	.00	.00	.00	.00	.00	.00	.79
3301	DATA MGMT.		8.41	2.28	.00	10.69	1.02	.00	.00	.00	2.22	.00	2.22	12.91
330201	I M U	3	.71	.00	.00	.72	.71	.00	.00	.00	.00	.00	.00	.72
330202	TRACKING/ELECT	3	.65	.00	.00	.65	.32	.00	.00	.00	.00	.00	.00	.65
330203	REN DEZ&DOCKING	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
330204	INSTL. ASSY & C/O3		.11	.00	.00	.11	.08	.00	.00	.00	.00	.00	.00	.11
3302	G N & C		1.47	.00	.00	1.47	1.12	.00	.00	.00	.00	.00	.00	1.47
330301	M/W CIRC +RF MUX	3	1.40	.80	.00	2.20	.40	.00	.00	.00	.00	.00	.00	2.20
330302	TRANSPONDERS	3	.87	.85	.00	1.72	.43	.00	.00	.00	.00	.00	.00	1.72
330303	POWER AMP.	3	.38	.18	.00	.56	.18	.00	.00	.00	.00	.00	.00	.56
330304	ANTENNA	3	.18	.18	.00	.36	.09	.00	.00	.00	.00	.00	.00	.36
330305	DEC/ENC+MOD/DEM	3	.75	.37	.00	1.12	.37	.00	.00	.00	.00	.00	.00	1.12
330306	TAPE RECORDER	3	.12	.30	.00	.42	.15	.00	.00	.00	.00	.00	.00	.42
330307	P/L INTER EQUIP	3	.24	.00	.00	.24	.08	.00	.00	.00	.00	.00	.00	.24
330308	INSTL. ASSY & C/O3		.32	.21	.00	.53	.14	.00	.00	.00	.00	.00	.00	.53
3303	COMMUNICATIONS		4.26	2.90	.00	7.16	1.43	.00	.00	.00	.00	.00	.00	7.16

WBS	COST ELEMENT	C	EDAD (MIL)	GTH (MIL)	FTH (MIL)	TOTAL DDT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
330401	DATA SENSORS	3	.06	.00	.00	.06	.04	.00	.00	.00	.00	.00	.00	.06
330402	SIGNAL COND.	3	.10	.04	.00	.14	.04	.00	.00	.00	.00	.00	.00	.14
330403	CIRCUITRY	3	1.73	.00	.00	1.73	.09	.00	.00	.00	.00	.00	.00	1.73
330404	INSTL, ASSY & C/O3		.15	.00	.00	.15	.01	.00	.00	.00	.00	.00	.00	.15
3304	INSTRUMENTATION		2.04	.04	.00	2.08	.18	.00	.00	.00	.00	.00	.00	2.08
330501	BATTERY	3	.08	.05	.00	.13	.05	.00	.00	.00	.00	.00	.00	.13
330502	FUEL CELL	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
330503	INSTL, ASSY & C/O3		.01	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	.01
3305	ELECT. POWER		.09	.05	.00	.14	.05	.00	.00	.00	.00	.00	.00	.14
330601	DISTR.	3	.78	.06	.00	.85	.03	.00	.00	.00	.00	.00	.00	.85
330602	TANKS SYSTEM	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
330603	INSTL, ASSY & C/O		.06	.00	.00	.07	.00	.00	.00	.00	.00	.00	.00	.07
3306	PWR, DIST, & CONT		.85	.07	.00	.91	.03	.00	.00	.00	.00	.00	.00	.91

OPTION 1 13 VEHICLES TU6101H 8/28/73 10:00 PM

WBS	COST ELEMENT	C	EDBD (MIL)	GTH (MIL)	FTH (MIL)	TOTAL OUTSE (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
40	VEH AUX, STAGE	3												
41	VEH AUX, STAGE	3	1.62	.00	.00	1.62	.00	16.35	.00	16.35	.00	.00	.00	17.97
	TOTAL VEH AUX, STA		1.62	.00	.00	1.62	.00	16.35	.00	16.35	.00	.00	.00	17.97
	TOTAL		1.62	.00	.00	1.62	.00	16.35	.00	16.35	.00	.00	.00	17.97

OPTION 1 13 VEHICLES TUG101R 8/28/73 10:00 PM

NWS	COST ELEMENT	C	SDRI (MIL)	GTM (MIL)	FTM (MIL)	TOTAL DOT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
50	LOGISTICS	3												
51	TRANSP. & HDLG.	3	.00	.00	.00	.00	.00	.30	.00	.30	.33	.00	.33	.63
52	TRAINING	3	1.70	.00	.00	1.70	.00	.00	.00	.00	1.70	.00	1.70	3.40
53	INV CONT. & WHSNG	3	1.32	.00	.00	1.32	.00	.00	.00	.00	4.67	.00	4.67	5.99
	TOTAL LOGISTICS		3.02	.00	.00	3.02	.00	.30	.00	.30	6.71	.00	6.71	10.03
	TOTAL		3.02	.00	.00	3.02	.00	.30	.00	.30	6.71	.00	6.71	10.03

692

LEVEL 6

WBS	COST ELEMENT	C	EDBD (MIL)	GTH (MIL)	FTH (MIL)	TOTAL DDT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
5201	SIM. & EQUIP.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
5202	GROUND CREW	3	1.70	.00	.00	1.70	.00	.00	.00	.00	1.70	.00	1.70	3.40
52	TRAINING		1.70	.00	.00	1.70	.00	.00	.00	.00	1.70	.00	1.70	3.40

OPTION 1 13 VEHICLES TU .01R 8/28/73 10:00 PM

WBS	COST ELEMENT	C	EUHO (MIL)	GTM (MIL)	FTM (MIL)	TOTAL UDTBL (MIL)	MEMO TI (MIL)	VEH PHOD (MIL)	IN SPRS (MIL)	TOT PHOD (MIL)	OPER ACTIV (MIL)	OHS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
60	FACILITIES	3												
61	MANUFACTURING	3	1.12	.00	.00	1.12	.00	.33	.00	.33	.00	.00	.00	1.45
62	TEST	3	1.50	.00	.00	1.50	.00	.00	.00	.00	.00	.00	.00	1.50
63	ETR MAINT. & REF.	3	1.02	.00	.00	1.02	.00	.00	.00	.00	.55	.00	.55	1.57
64	ETR LAUNCH	3	.39	.00	.00	.39	.00	.00	.00	.00	.21	.00	.21	.60
65	WTR MAINT. & REF.	3	.76	.00	.00	.76	.00	.00	.00	.00	.30	.00	.30	1.06
66	WTR LAUNCH	3	.38	.00	.00	.38	.00	.00	.00	.00	.15	.00	.15	.53
	TOTAL FACILITIES		5.17	.00	.00	5.17	.00	.33	.00	.33	1.21	.00	1.21	6.70
	TOTAL		5.17	.00	.00	5.17	.00	.33	.00	.33	1.21	.00	1.21	6.70

6-94

LEVEL 6

WBS	COST ELEMENT	C	EDCD (MIL)	GTH (MIL)	FTH (MIL)	TOTAL OUT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
6101	DES./CONST.	3	1.09	.00	.00	1.09	.00	.00	.00	.00	.00	.00	.00	1.09
6102	ACTIV./MAINT.	3	.02	.00	.00	.02	.00	.33	.00	.33	.00	.00	.00	.35
61	MANUFACTURING		1.12	.00	.00	1.12	.00	.33	.00	.33	.00	.00	.00	1.45
6201	DES./CONST.	3	1.50	.00	.00	1.50	.00	.00	.00	.00	.00	.00	.00	1.50
6202	ACTIV./MAINT.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
62	TEST		1.50	.00	.00	1.50	.00	.00	.00	.00	.00	.00	.00	1.50
6301	DES./CONST.	3	1.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	1.00
6302	ACTIV./MAINT.	3	.02	.00	.00	.02	.00	.00	.00	.00	.55	.00	.55	.57
63	ETR MAINT. & REF.		1.02	.00	.00	1.02	.00	.00	.00	.00	.55	.00	.55	1.57
6401	DES./CONST.	3	.38	.00	.00	.38	.00	.00	.00	.00	.00	.00	.00	.38
6402	ACTIV./MAINT.	3	.01	.00	.00	.01	.00	.00	.00	.00	.21	.00	.21	.22
64	ETR LAUNCH		.39	.00	.00	.39	.00	.00	.00	.00	.21	.00	.21	.60
6501	DES./CONST.	3	.75	.00	.00	.75	.00	.00	.00	.00	.00	.00	.00	.75
6502	ACTIV./MAINT.	3	.01	.00	.00	.01	.00	.00	.00	.00	.30	.00	.30	.31
65	WTR MAINT. & REF.		.76	.00	.00	.76	.00	.00	.00	.00	.30	.00	.30	1.06
6601	DES./CONST.	3	.37	.00	.00	.37	.00	.00	.00	.00	.00	.00	.00	.37
6602	ACTIV./MAINT.	3	.01	.00	.00	.01	.00	.00	.00	.00	.15	.00	.15	.16
66	WTR LAUNCH		.38	.00	.00	.38	.00	.00	.00	.00	.15	.00	.15	.53

OPTION 1 13 VEHICLES TUG101R 8/28/73 10:00 PM

ANS	COST ELEMENT	C	EDRD (MIL)	GTM (MIL)	+ FTM (MIL)	TOTAL DDTAE (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
70	GRND. SUPT. EQUIPS													
71	MFG. GSE	3	7.42	.00	.00	7.42	.00	1.02	.00	1.02	.00	.00	.00	8.44
72	ETH GSE	3	11.90	.00	.00	11.90	.00	.00	.00	.00	3.36	.00	3.36	15.26
73	WTR GSE	3	11.82	.00	.00	11.82	.00	.00	.00	.00	2.16	.00	2.16	13.98
74	FLT OPS GSE(NASA)		.47	.00	.00	.47	.00	.00	.00	.00	1.09	.00	1.09	1.56
75	FLT OPS GSE(DOD)		.47	.00	.00	.47	.00	.00	.00	.00	1.09	.00	1.09	1.56
	TOTAL GRND. SUPT.		32.09	.00	.00	32.09	.00	1.02	.00	1.02	7.70	.00	7.70	40.81
	TOTAL		32.09	.00	.00	32.09	.00	1.02	.00	1.02	7.70	.00	7.70	40.81

LEVEL 6

WBS	COST ELEMENT	C	EDAD (MIL)	GTH (MIL)	FTH (MIL)	TOTAL DUT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
7101	HARDWARE	3	4.40	.00	.00	4.40	.00	.00	.00	.00	.00	.00	.00	4.40
7102	SITE ACTIV.	3	.09	.00	.00	.09	.00	.00	.00	.00	.00	.00	.00	.09
7103	MAINT.	3	.00	.00	.00	.00	.00	1.02	.00	1.02	.00	.00	.00	1.02
7104	SOFTWARE	3	2.94	.00	.00	2.94	.00	.00	.00	.00	.00	.00	.00	2.94
71	MFG. GSE		7.42	.00	.00	7.42	.00	1.02	.00	1.02	.00	.00	.00	8.44
7201	HARDWARE	3	7.51	.00	.00	7.51	.00	.00	.00	.00	.00	.00	.00	7.51
7202	SITE ACTIV.	3	2.48	.00	.00	2.48	.00	.00	.00	.00	.00	.00	.00	2.48
7203	MAINT.	3	.00	.00	.00	.00	.00	.00	.00	.00	2.41	.00	2.41	2.41
7204	SOFTWARE	3	1.91	.00	.00	1.91	.00	.00	.00	.00	.95	.00	.95	2.86
72	ETR GSE		11.90	.00	.00	11.90	.00	.00	.00	.00	3.36	.00	3.36	15.26
7301	HARDWARE	3	7.40	.00	.00	7.40	.00	.00	.00	.00	.00	.00	.00	7.40
7302	SITE ACTIV.	3	2.44	.00	.00	2.44	.00	.00	.00	.00	.00	.00	.00	2.44
7303	MAINT.	3	.00	.00	.00	.00	.00	.00	.00	.00	2.00	.00	2.00	2.00
7304	SOFTWARE	3	1.98	.00	.00	1.98	.00	.00	.00	.00	.16	.00	.16	2.14
73	WTR GSE		11.82	.00	.00	11.82	.00	.00	.00	.00	2.16	.00	2.16	13.98
7401	HARDWARE	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7402	SITE ACTIV.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7403	MAINT.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7404	SOFTWARE	3	.47	.00	.00	.47	.00	.00	.00	.00	1.09	.00	1.09	1.56
74	HARDWA(S) SUBTOTAL		.47	.00	.00	.47	.00	.00	.00	.00	1.09	.00	1.09	1.56
7501	HARDWARE	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7502	SITE ACTIV.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7503	MAINT.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7504	SOFTWARE	3	.47	.00	.00	.47	.00	.00	.00	.00	1.09	.00	1.09	1.56
75	HARDWA(S) SUBTOTAL		.47	.00	.00	.47	.00	.00	.00	.00	1.09	.00	1.09	1.56

OPTION 1 13 VEHICLES TUG101R 8/28/73 10:00 PM

WBS	COST ELEMENT	C	EO&D (MIL)	GTM + FTM (MIL)	FTM (MIL)	TOTAL OUT&S (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
80	VEHICLE TEST	3												
81	GND TEST HDWE.	3	.00	13.73	.00	13.73	.00	.00	.00	.00	.00	.00	.00	13.73
82	GND TEST OPNS.	3	.00	6.84	.00	6.84	.00	.00	.00	.00	.00	.00	.00	6.84
83	FLT. TEST HDWE.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
84	FLT. TEST OPNS	3	.00	.00	.75	.75	.00	.00	.00	.00	.00	.00	.00	.75
	TOTAL VEHICLE TEST		.00	20.57	.75	21.32	.00	.00	.00	.00	.00	.00	.00	21.32
	TOTAL		.00	20.57	.75	21.32	.00	.00	.00	.00	.00	.00	.00	21.32

B-9

LEVEL 6

WBS	COST ELEMENT	C	EDBD (MIL)	GTH (MIL)	FTH (MIL)	TOTAL DDT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
8101	PTV TEST	3	.00	3.66	.00	3.66	.00	.00	.00	.00	.00	.00	.00	3.66
8102	MAJOR TEST ART.	3	.00	9.00	.00	9.00	.00	.00	.00	.00	.00	.00	.00	9.00
8103	MOCKUPS	3	.00	.47	.00	.47	.00	.00	.00	.00	.00	.00	.00	.47
81	GND TEST HDWE.		.00	13.73	.00	13.73	.00	.00	.00	.00	.00	.00	.00	13.73
8301	STRUCTURES	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8302	THERMAL CONTROL	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8303	AVIONICS	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8304	PROPULSION	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8305	ORBITER I/F	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8306	DROP TANKS	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8307	FINAL ASSY & C/O	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
83	FLT. TEST HDWE.		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

LEVEL 7

#85	COST ELEMENT	C	EUND (MIL)	6TH (MIL)	FTH (MIL)	TOTAL DDT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
830102	OXID. TK & SUPT.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830103	BODY STRUCTURE	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830104	THRUST STRUCTURE		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830105	METEOROID SHIELD	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830106	PAYLOAD I/F	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830107	INSTL. ASSY & C/O	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8301	STRUCTURES		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830201	FUEL TANK INSL	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830202	OXID TANK INSL	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830203	INSL PURGE SYS	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830204	THERM CONT SYS	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830205	INSTL. ASSY & C/O	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8302	THERMAL CONTROL		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830301	DATA MGMT.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830302	G N & C	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830303	COMMUNICATIONS	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830304	INSTRUMENTATION	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830305	ELECT. POWER	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830306	PWR DIST. & CONT	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830307	INSTL. ASSY & C/O	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8303	AVIONICS		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830401	MAIN ENGINE	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830402	MAIN ENG SUPT.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830403	ACPS ENGINE	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830404	ACPS ENG SUPT	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830405	INSTL. ASSY & C/O	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8304	PROPULSION		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830501	STRUCTURES	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830502	I/F PANELS	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830503	PURGE PROV.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830504	ABORT PROV.	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
830505	INSTL. ASSY & C/O	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8305	ORBITER I/F		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

6-100

LEVEL 7

WBS	COST ELEMENT	C	ED&D (MIL)	GTH (MIL)	FTH (MIL)	TOTAL DDT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
830701	FINAL ASSY	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
~~830702~~	~~C/O~~	~~3~~	~~.00~~	~~.00~~	~~.00~~	~~.00~~	~~.00~~	~~.00~~	~~.00~~	~~.00~~	~~.00~~	~~.00~~	~~.00~~	~~.00~~
8307	FINAL ASSY & C/O		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

OPTION 1 13 VEHICLES TUG101R 8/26/73 10:00 PM

WBS	COST ELEMENT	C	ED&D (MIL)	GTH + FTH (MIL)	TOTAL UDTAE (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
90	LAUNCH OPNS. WTR	3											
91	LNCH SITE SVCES	3	.00	.00	.00	.00	.00	.00	.00	.00	8.18	.00	8.18	8.18
92	TUG/SHTL MATING	3	.00	.00	.00	.00	.00	.00	.00	.00	2.39	.00	2.39	2.39
93	PRELAUNCH C/O	3	.00	.00	.00	.00	.00	.00	.00	.00	3.07	.00	3.07	3.07
94	COUNTDOWN	3	.00	.00	.00	.00	.00	.00	.00	.00	3.75	.00	3.75	3.75
95	PRLNTS. & GASES	3	.00	.00	.00	.00	.00	.00	.00	.00	.20	.00	.20	.20
96	POST FLT. SAFING	3	.00	.00	.00	.00	.00	.00	.00	.00	3.75	.00	3.75	3.75
	TOTAL LAUNCH OPNS.		.00	.00	.00	.00	.00	.00	.00	.00	21.35	.00	21.35	21.35
	TOTAL		.00	.00	.00	.00	.00	.00	.00	.00	21.35	.00	21.35	21.35

6-102

OPTION 1. 13 VEHICLES TUG101R 8/28/73 10:00 PM

NMS	COST ELEMENT	C	EDBU (MIL)	GTM + FTM (MIL)	TOTAL DDTAE (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPNS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPNS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
100	LAUNCH OPNS ETH	3											
101	LNCH SITE SVCES	3	.00	.00	.00	.00	.00	.00	.00	.00	20.46	.00	20.46	20.46
102	TUG/SHTL MATING	3	.00	.00	.00	.00	.00	.00	.00	.00	5.97	.00	5.97	5.97
103	PRELAUNCH C/O	3	.00	.00	.00	.00	.00	.00	.00	.00	9.38	.00	9.38	9.38
104	COUNTDOWN	3	.00	.00	.00	.00	.00	.00	.00	.00	7.67	.00	7.67	7.67
105	PRLNTS & GASES	3	.00	.00	.00	.00	.00	.00	.00	.00	1.21	.00	1.21	1.21
106	POST FLT. SAFING	3	.00	.00	.00	.00	.00	.00	.00	.00	9.38	.00	9.38	9.38
	TOTAL LAUNCH OPNS		.00	.00	.00	.00	.00	.00	.00	.00	54.06	.00	54.06	54.06
	TOTAL		.00	.00	.00	.00	.00	.00	.00	.00	54.06	.00	54.06	54.06

OPTION 1 13 VEHICLES TUG101R 8/28/73 10100 PM

WBS	COST ELEMENT	C	EDCD (MIL)	GTH (MIL)	FTH (MIL)	TOTAL DDT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OHS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
110	FLIGHT OPNS NASA	3												
111	MISSION PLG.	3	2.44	.00	.00	2.44	.00	.00	.00	.00	5.38	.00	5.38	7.82
112	FLT. CONTROL	3	.37	.00	.00	.37	.00	.00	.00	.00	23.52	.00	23.52	23.89
113	FLT. EVAL.	3	.00	.00	.00	.00	.00	.00	.00	.00	5.03	.00	5.03	5.03
114	FLT. SUPT. SFTWRE	3	2.53	.00	.00	2.53	.00	.00	.00	.00	2.46	.00	2.46	4.99
	TOTAL FLIGHT OPNS		5.33	.00	.00	5.33	.00	.00	.00	.00	36.39	.00	36.39	41.72
	TOTAL		5.33	.00	.00	5.33	.00	.00	.00	.00	36.39	.00	36.39	41.72

6-104

OPTION 1 13 VEHICLES TUG101R 8/26/73 10:00 PM

WBS	COST ELEMENT	C	EO&D (MIL)	GTH (MIL)	FTH (MIL)	TOTAL OD&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
120	FLIGHT OPNS	DOD	3											
121	MISSION PLG		3	2.19	.00	.00	2.19	.00	.00	.00	.00	4.83	.00	4.83	7.02
122	FLT. CONTROL		3	.33	.00	.00	.33	.00	.00	.00	.00	21.42	.00	21.42	21.75
123	FLT. EVAL.		3	.00	.00	.00	.00	.00	.00	.00	.00	4.41	.00	4.41	4.41
124	FLT. SUPT. SFTWRE		3	2.27	.00	.00	2.27	.00	.00	.00	.00	2.20	.00	2.20	4.47
	TOTAL FLIGHT OPNS			4.79	.00	.00	4.79	.00	.00	.00	.00	32.86	.00	32.86	37.65
	TOTAL			4.79	.00	.00	4.79	.00	.00	.00	.00	32.86	.00	32.86	37.65

6-105

OPTION 1 13 VEHICLES TUG101R 8/28/73 10:00 PM

WBS	COST ELEMENT	C	ED&D (MIL)	GTH (MIL)	FTH (MIL)	TOTAL OUTAS (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SERVS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SERVS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
130	REFURB &INTEG WTH3													
131	SCH MAINT & REF	3	.00	.00	.00	.00	.00	.00	.00	.00	4.43	.00	4.43	4.43
132	UNSCH MAINT & REF3		.00	.00	.00	.00	.00	.00	.00	.00	1.36	.00	1.36	1.36
133	POST MAINT C/O	3	.00	.00	.00	.00	.00	.00	.00	.00	.34	.00	.34	.34
134	TUG/PL MAING &/CO3		.00	.00	.00	.00	.00	.00	.00	.00	3.41	.00	3.41	3.41
135	REFURB RQMTS PLG	3	.11	.00	.00	.11	.00	.00	.00	.00	1.36	.00	1.36	1.47
136	DEPOT MAINT	3	.00	.00	.00	.00	.00	.00	.00	.00	3.79	.00	3.79	3.79
	TOTAL REFURB &INTE		.11	.00	.00	.11	.00	.00	.00	.00	14.70	.00	14.70	14.81
	TOTAL		.11	.00	.00	.11	.00	.00	.00	.00	14.70	.00	14.70	14.81

OPTION 1. 13 VEHICLES TUG101R 8/28/73 10:00 PM

#US	COST ELEMENT G	EUOU (MIL)	GTH (MIL)	FTH (MIL)	TOTAL DOT&E (MIL)	MEMO T1 (MIL)	VEH PROD (MIL)	IN SPRS (MIL)	TOT PROD (MIL)	OPER ACTIV (MIL)	OPS SPRS (MIL)	TOT OPER (MIL)	TOTAL (MIL)
140	REFURB & INTEG ETH3												
141	SCH MAINT & REF 3	.00	.00	.00	.00	.00	.00	.00	.00	11.08	.00	11.08	11.08
142	UNSCH MAINT & REF3	.00	.00	.00	.00	.00	.00	.00	.00	3.41	.00	3.41	3.41
143	POST MAINT C/O 3	.00	.00	.00	.00	.00	.00	.00	.00	.85	.00	.85	.85
144	TUG/PL MATING,C/O3	.00	.00	.00	.00	.00	.00	.00	.00	8.52	.00	8.52	8.52
145	REFURB RQMTS PL0 3	.11	.00	.00	.11	.00	.00	.00	.00	3.41	.00	3.41	3.52
146	DEPOT MAINT 3	.00	.00	.00	.00	.00	.00	.00	.00	22.52	.00	22.52	22.52
	TOTAL REFURB &INTE	.11	.00	.00	.11	.00	.00	.00	.00	49.80	.00	49.80	49.91
	TOTAL	.11	.00	.00	.11	.00	.00	.00	.00	49.80	.00	49.80	49.91

6.9 Cost Per Flight

Cost per flight values have been calculated and are reported in accordance with letter No. PD-TUG-P(015-74), dated 3 August 1973, from the Chairman, Programmatics/Cost Panel to the COR's. The costs per flight are presented by Agency (NASA/DOD) and by Flight Mode. Since no DOD flights require either an expended Tug or an expended auxiliary stage, no DOD cost per flight sheets have been included for Mode-2 and Mod-3. Tables 6.9-1 through 6.9-4 provide the required average cost per flight displays.

Table 6.9-1 AVERAGE COST PER FLIGHT

AGENCY NASA

MODE 1 - REUSABLE BASIC STAGE

PROGRAM OPTION 1

LAUNCH OPERATIONS		$ 390,189
Tug/Shuttle mating and checkout	$ 37,312	
Tug/Payload mating and checkout	53,302	
Prelaunch checkout	55,719	
Countdown	50,887	
Propellant and gases	6,410	
Post flight safing	58,633	
Site services and support	127,926	
MAINTENANCE AND REFURBISHMENT		$ 288,829
Scheduled maintenance and refurbishment	$ 69,294	
Unscheduled maintenance and refurbishment	21,321	
Tug engine maintenance and refurbishment	11,538	
Tug vehicle spares	45,966	
Tug engine spares	6,410	
Post maintenance checkout	5,287	
Refurbishment requirements planning	21,321	
Depot maintenance	107,692	
TOTAL GROUND OPERATIONS (Launch and Maintenance and Refurbishment)		$ 679,018
FLIGHT OPERATIONS		$ 311,000
Mission planning	$ 46,000	
Flight control	201,000	
Flight evaluation	43,000	
Flight software	21,000	
OPERATIONS SUPPORT		$ 156,154
Airborne software update	$ 10,085	
GSE maintenance	20,000	
Sustaining engineering	50,513	
Program management	33,162	
Transportation and handling	1,453	
Inventory control and warehousing	21,197	
Facilities maintenance	5,470	
GSE software update	14,274	
EXPENDABLE VEHICLE MAIN STAGE		$ -0-
EXPENDABLE VEHICLE AUXILIARY STAGE		$ -0-
TOTAL AVERAGE PER FLIGHT COST		$ 1,146,170

Table 6.9-2 AVERAGE COST PER FLIGHT

AGENCY NASA

MODE 2 - EXPENDED TUG

PROGRAM OPTION 1

LAUNCH OPERATIONS		$ 390,189
Tug/Shuttle mating and checkout	$ 37,312	
Tug/Payload mating and checkout	53,302	
Prelaunch checkout	55,719	
Countdown	50,887	
Propellant and gases	6,410	
Post flight safing	58,633	
Site services and support	127,926	
MAINTENANCE AND REFURBISHMENT		$ -0-
Scheduled maintenance and refurbishment	$ -0-	
Unscheduled maintenance and refurbishment	-0-	
Tug engine maintenance and refurbishment	-0-	
Tug vehicle spares	-0-	
Tug engine spares	-0-	
Post maintenance checkout	-0-	
Refurbishment requirements planning	-0-	
Depot maintenance	-0-	
TOTAL GROUND OPERATIONS (Launch and Maintenance and Refurbishment)		$ 390,189
FLIGHT OPERATIONS		$ 311,000
Mission planning	$ 46,000	
Flight control	201,000	
Flight evaluation	43,000	
Flight software	21,000	
OPERATIONS SUPPORT		$ 156,154
Airborne software update	$ 10,085	
GSE maintenance	20,000	
Sustaining engineering	50,513	
Program management	33,162	
Transportation and handling	1,453	
Inventory control and warehousing	21,197	
Facilities maintenance	5,470	
GSE software update	14,274	
EXPENDABLE VEHICLE MAIN STAGE		$ 12,220,000
EXPENDABLE VEHICLE AUXILIARY STAGE		$ -0-
TOTAL AVERAGE PER FLIGHT COST		$ 13,077,343

Table 6.9-3 AVERAGE COST PER FLIGHT

AGENCY NASA

MODE 3 - EXPENDED KICK STAGE

PROGRAM OPTION 3

LAUNCH OPERATIONS		$ 390,189
Tug/Shuttle mating and checkout	$ 37,312	
Tug/Payload mating and checkout	53,302	
Prelaunch checkout	55,719	
Countdown	50,887	
Propellant and gases	6,410	
Post flight safing	58,633	
Site services and support	127,926	
MAINTENANCE AND REFURBISHMENT		$ 288,829
Scheduled maintenance and refurbishment	$ 69,294	
Unscheduled maintenance and refurbishment	21,321	
Tug engine maintenance and refurbishment	11,538	
Tug vehicle spares	45,966	
Tug engine spares	6,410	
Post maintenance checkout	5,287	
Refurbishment requirements planning	21,321	
Depot maintenance	107,692	
TOTAL GROUND OPERATIONS (Launch and Maintenance and Refurbishment)		$ 679,018
FLIGHT OPERATIONS		$ 311,000
Mission planning	$ 46,000	
Flight control	201,000	
Flight evaluation	43,000	
Flight software	21,000	
OPERATIONS SUPPORT		$ 156,154
Airborne software update	$ 10,085	
GSE maintenance	20,000	
Sustaining engineering	50,513	
Program management	33,162	
Transportation and handling	1,453	
Inventory control and warehousing	21,197	
Facilities maintenance	5,470	
GSE software update	14,274	
EXPENDABLE VEHICLE MAIN STAGE		$ -0-
EXPENDABLE VEHICLE AUXILIARY STAGE		$ 2,300,000
TOTAL AVERAGE PER FLIGHT COST		$ 3,446,170

Table 6.9-4 AVERAGE COST PER FLIGHT

AGENCY DOD

MODE 1 - REUSABLE BASIC STAGE

PROGRAM OPTION 1

LAUNCH OPERATIONS		$ 397,003
Tug/Shuttle mating and checkout	$ 37,987	
Tug/Payload mating and checkout	54,267	
Prelaunch checkout	56,446	
Countdown	52,088	
Propellant and gases	6,286	
Post flight safing	59,694	
Site services and support	130,240	
MAINTENANCE AND REFURBISHMENT		$ 289,839
Scheduled maintenance and refurbishment	$ 70,547	
Unscheduled maintenance and refurbishment	21,706	
Tug engine maintenance and refurbishment	11,238	
Tug vehicle spares	46,495	
Tug engine spares	6,286	
Post maintenance checkout	5,385	
Refurbishment requirements planning	21,706	
Depot maintenance	106,476	
TOTAL GROUND OPERATIONS (Launch and Maintenance and Refurbishment)		$ 686,847
FLIGHT OPERATIONS		$ 313,000
Mission planning	$ 46,000	
Flight control	204,000	
Flight evaluation	42,000	
Flight software	21,000	
OPERATIONS SUPPORT		$ 155,620
Airborne software update	$ 9,905	
GSE maintenance	19,238	
Sustaining engineering	50,476	
Program management	32,762	
Transportation and handling	1,524	
Inventory control and warehousing	20,857	
Facilities maintenance	5,429	
GSE software update	15,429	
EXPENDABLE VEHICLE MAIN STAGE		$ -0-
EXPENDABLE VEHICLE AUXILIARY STAGE		$ -0-
TOTAL AVERAGE PER FLIGHT COST		$ 1,155,467

6.10 Subdivisions of Work (Form T)

Provided in this subsection on Data Form T are the subdivisions of work as defined in the following Government-furnished documents:

Data Package - Space Tug System Studies, dated April 1973.

Space Tug Systems Studies - Work Breakdown Structure and Dictionary, prepared by PD-TUG-P and dated 7 May 1973.

Estimated costs and hours are reported on Data Form-T for WBS elements through Level 6, although the calculations are performed through Level 7. The estimated costs and hours on Data Form-T are consistent with the definitions in the Work Breakdown Structure and Dictionary, as follows:

1. Engineering is the design, development, analysis, evaluation, and redesign of TUG hardware, GSE, and associated planning and analysis activities. It includes such activities as configuration management, the preparation of specifications, drawings, parts lists, wiring diagrams, technical coordination between engineering and other activities, facilities engineering, vendor coordination, test planning and scheduling, analysis of test results, safety analysis, data reduction and engineering report preparation. It also includes the engineering activities required to support Production and the Operational phases. Materials and subcontracts associated with the above activities are included.

2. Manufacturing includes product and materials receiving, ware-

housing, fabrication, processing, assembly installation, reworking, modifications, experimental production, shop support to engineering checkout, preparation of hardware for shipping and preparation of necessary manufacturing associated paper work. Includes quality control and inspection activities. This Subdivision of Work (SOW) also includes technicians who support various test operations as as launch operations and refurbishment activities. Materials and subcontracts associated with the above activities are included.

3. Tooling and STE includes planning, design, fabrication, quality control and inspection, modification, maintenance, and rework of all tools, dies, jigs, fixtures, gauges, handling equipment, work platforms, and test equipment and Special Test Equipment (STE) in support of the manufacturing process. It also includes writing and planning tool orders, certification of welding operations, maintaining tool and STE records, preparation of templates, scheduling and controlling all tool and STE orders, programming and preparation of tapes for all numerically controlled machine parts, and calibration and periodic maintenance of production and test tooling. It also includes the necessary tooling maintenance for the Production and Operational phases. Materials and subcontracts associated with the above activities are included.

4. Quality and Reliability Assurance (Q&RA) includes the establishment of Q&RA policies, procedures and requirements; Q&RA review of procurement requests and plans; test plans from a Q&RA standpoint and Q&RA report preparation. Develops Q&RA training plans and certification of quality control personnel. Also includes failure review, analysis and reporting. Materials and subcontracts associ-

ated with the above activities are included.

5. Testing involves the investigations on all components, assemblies, subsystems, and systems to determine operational characteristics, verify the suitability in meeting the required criteria, and assure compatiability with the overall system and its intended operational/nonoperational environment. Such tests include design feasibility test, qualification test, design verification tests, reliability tests, and bench functional and environmental tests. Monitoring tests, data reduction, and report preparation are also included. Materials and subcontracts associated with the above activities are included.

6. Management/Other includes all management and administrative effort for planning, organizing, coordinating, directing, controlling, and approving that is required to accomplish the program objectives. Other items not included in the preceding subdivisions should be included in this item where possible. Materials and subcontracts associated with the above activities are included.

The "total costs" shown on Data Form-T are the same as the "expected costs" presented on Cost Data Form-A, which in turn are time-phased on Cost Data Form-C.

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 16 OF

x NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32001	PROJECT MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	241	7.08	241	7.08
32002	SYS. ENGR. & INT.	472	13.38	0	.00	0	.00	0	.00	27	.64	0	.21	499	14.23
32003	VEH MAIN STAGE	1459	42.40	409	10.54	550	13.52	121	2.70	1174	33.02	0	.00	3713	102.17
32004	VEH AUX. STAGE	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.62	0	1.62
32005	LOGISTICS	12	.27	0	.00	0	.00	0	.00	0	.00	150	2.75	162	3.02
32006	FACILITIES	0	.00	0	.00	0	.00	0	.00	0	.00	0	5.17	0	5.17
32007	GRND. SUPT. EQUIP	357	10.11	562	15.95	65	1.44	104	2.31	97	2.28	0	.00	1184	32.09
32008	VEHICLE TEST	178	4.15	521	13.01	0	.00	159	3.39	33	.77	0	.00	891	21.32
32009	LAUNCH OPNS. WTR	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32010	LAUNCH OPNS ETR	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32011	FLIGHT OPNS NASA	110	2.57	102	1.83	0	.00	39	.75	0	.00	10	.19	262	5.33
32012	FLIGHT OPNS DOD	99	2.31	92	1.64	0	.00	35	.67	0	.00	9	.17	235	4.79
32013	REFURB &INTEG WTR	0	.00	3	.08	0	.00	1	.02	0	.01	0	.00	4	.11
32014	REFURB &INTEG ETR	0	.00	3	.08	0	.00	1	.02	0	.01	0	.00	4	.11
	TOTAL	2687	75.19	1692	43.14	615	14.96	460	9.85	1331	36.72	410	17.19	7195	197.05

6-116

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 1 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32001	PROJECT MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	241	7.08	241	7.08
3200101	COST/PERF. MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	165	4.86	165	4.86
3200102	PROJ. DIRECTION	0	.00	0	.00	0	.00	0	.00	0	.00	71	2.08	71	2.08
3200103	INFORM. MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	5	.14	5	.14

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 2 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32002	SYS. ENGR. & INT.	472	13.38	0	.00	0	.00	0	.00	27	.64	0	.21	499	14.23
3200201	TUG SYS. ENGR.	377	10.70	0	.00	0	.00	0	.00	22	.51	0	.17	399	11.38
3200202	SHUTTLE I/F	24	.67	0	.00	0	.00	0	.00	1	.03	0	.01	25	.71
3200203	PAYLOAD I/F	71	2.00	0	.00	0	.00	0	.00	4	.10	0	.03	75	2.13

811-9

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 3 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32003	VEH MAIN STAGE	1459	42.40	409	10.54	550	13.52	121	2.70	1174	33.02	0	.00	3713	102.17
3200301	STRUCTURES	176	5.05	10	.21	218	5.37	3	.07	211	5.68	0	.00	619	16.38
3200302	THERMAL CONTROL	10	.29	0	.00	13	.31	0	.00	12	.33	0	.00	35	.93
3200303	AVIONICS	432	12.62	159	4.39	20	.49	47	1.05	366	9.47	0	.00	1024	28.01
3200304	PROPULSION	469	13.86	120	3.32	45	1.05	36	.79	440	13.60	0	.00	1109	32.70
3200305	ORBITER I/F	113	3.23	89	1.84	139	3.44	26	.59	142	3.80	0	.00	510	12.89
3200306	DROP TANKS	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200307	FINAL ASSY & C/O	259	7.35	30	.78	115	2.86	9	.20	3	.06	0	.00	417	11.25
320030101	FUEL TK & SUPT	43	1.24	0	.00	54	1.32	0	.00	52	1.39	0	.00	149	3.96
320030102	OXID. TK & SUPT	22	.63	0	.00	27	.67	0	.00	26	.71	0	.00	76	2.01
320030103	BODY STRUCTURE	45	1.28	0	.00	55	1.37	0	.00	53	1.44	0	.00	154	4.09
320030104	THRUST STRUCTURE	15	.43	0	.00	19	.46	0	.00	18	.49	0	.00	52	1.38
320030105	METEOROID SHIELD	11	.31	0	.00	13	.33	0	.00	13	.35	0	.00	37	.98
320030106	PAYLOAD I/F	27	.77	10	.20	33	.82	3	.06	33	.89	0	.00	106	2.74
320030107	INSTL, ASSY & C/O	13	.37	1	.02	16	.40	0	.01	16	.42	0	.00	46	1.21
320030201	FUEL TANK INSL	2	.05	0	.00	2	.05	0	.00	2	.06	0	.00	6	.16
320030202	OXID. TANK INSL.	1	.03	0	.00	1	.03	0	.00	1	.03	0	.00	3	.08
320030203	INSL. PURGE SYS.	7	.20	0	.00	9	.22	0	.00	8	.23	0	.00	24	.65
320030204	THERM CONT. SYS.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030205	INSTL ASSY & C/O	0	.01	0	.00	1	.01	0	.00	1	.02	0	.00	2	.04
320030301	DATA MGMT. 3	163	4.77	63	1.74	8	.18	19	.41	139	3.58	0	.00	391	10.69
320030302	G N & C	29	.83	0	.00	1	.03	0	.00	23	.61	0	.00	53	1.47
320030303	COMMUNICATIONS	83	2.42	80	2.21	4	.09	24	.53	74	1.91	0	.00	265	7.16
320030304	INSTRUMENTATION	40	1.16	1	.03	2	.04	0	.01	32	.84	0	.00	75	2.08
320030305	ELECT. POWER	2	.05	1	.04	0	.00	0	.01	1	.04	0	.00	5	.14
320030306	PWR. DIST. & CONT	16	.48	2	.05	1	.02	1	.01	14	.35	0	.00	35	.91
320030307	INSTL, ASSY & C/O	100	2.91	12	.33	5	.11	3	.08	82	2.13	0	.00	202	5.55
320030401	MAIN ENGINE 3	215	6.36	0	.00	21	.48	0	.00	197	6.16	0	.00	433	13.00
320030402	MAIN ENG. SUPT	146	4.32	91	2.50	14	.33	27	.60	142	4.37	0	.00	419	12.11
320030403	ACPS ENGINE	5	.14	3	.09	0	.01	1	.02	5	.14	0	.00	14	.41
320030404	ACPS ENG. SUPT	81	2.39	20	.56	8	.18	6	.13	76	2.36	0	.00	191	5.62
320030405	INSTL, ASSY & C/O	22	.66	6	.16	2	.05	2	.04	21	.65	0	.00	53	1.56
320030501	STRUCTURES	40	1.15	12	.25	49	1.22	4	.08	49	1.31	0	.00	154	4.01
320030502	I/F PANELS	55	1.57	51	1.05	67	1.67	15	.34	70	1.86	0	.00	258	6.47
320030503	PURGE PROV.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030504	ABORT PROV.	10	.28	19	.40	12	.30	6	.13	13	.35	0	.00	60	1.45
320030505	INSTL, ASSY & C/O	8	.24	7	.14	10	.25	2	.04	11	.28	0	.00	38	.95
320030701	FINAL ASSY	200	5.67	19	.49	89	2.21	6	.12	2	.04	0	.00	315	8.53
320030702	C/O	59	1.68	11	.29	26	.65	3	.07	1	.02	0	.00	101	2.73
32003010101	LH2 DOMES	19	.55	0	.00	24	.58	0	.00	23	.61	0	.00	65	1.74
32003010102	LH2 CYLINDER	21	.60	0	.00	26	.64	0	.00	25	.68	0	.00	72	1.92
32003010103	LH2 SUPPORTS	3	.09	0	.00	4	.10	0	.00	4	.11	0	.00	11	.30
32003010201	LO2 DOMES	18	.52	0	.00	23	.56	0	.00	22	.59	0	.00	63	1.67
32003010202	LO2 SUPPORTS	4	.11	0	.00	5	.12	0	.00	5	.12	0	.00	13	.35
32003010301	FWD AFT SKIRT	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32003010302	INTERTANK	21	.61	0	.00	26	.65	0	.00	25	.68	0	.00	73	1.94

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 4 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32003010303	SOWL SHELL	24	.67	0	.00	29	.72	0	.00	28	.76	0	.00	81	2.15
32003030101	COMPUTER	89	2.60	45	1.24	4	.10	13	.30	77	1.98	0	.00	228	6.22
32003030102	DATA DISTR.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32003030103	EQ. THERM CONT.	6	.19	12	.32	0	.01	5	.08	6	.16	0	.00	28	.75
32003030104	CIRCUITRY 3	10	.30	1	.04	0	.01	0	.01	9	.22	0	.00	21	.59
32003030105	SOFTWARE	45	1.32	0	.00	2	.05	0	.00	37	.96	0	.00	84	2.33
32003030106	SOFTWARE	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32003030107	SOFTWARE	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32003030108	INSTL, ASSY & C/O	12	.35	5	.13	1	.01	1	.03	10	.27	0	.00	29	.79
32003030201	I M U	14	.41	0	.00	1	.02	0	.00	11	.29	0	.00	26	.72
32003030202	TRACKING/ELECT 3	13	.37	0	.00	1	.01	0	.00	10	.27	0	.00	23	.65
32003030203	REN DEZ&DOCKING 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32003030204	INSTL, ASSY & C/O	2	.06	0	.00	0	.00	0	.00	2	.04	0	.00	4	.11
32003030301	M/W CIRC +RF MUX	27	.79	22	.61	1	.03	7	.15	24	.62	0	.00	81	2.20
32003030302	TRANSPONDERS 3	17	.49	24	.65	1	.02	7	.16	16	.41	0	.00	64	1.72
32003030303	POWER AMP.	7	.22	5	.14	0	.01	1	.03	7	.17	0	.00	21	.56
32003030304	ANTENNA	3	.10	5	.14	0	.00	1	.03	5	.08	0	.00	13	.36
32003030305	DEC/ENC+MOD/DEM	15	.43	10	.29	1	.02	3	.07	13	.33	0	.00	41	1.12
32003030306	TAPE RECORDER	2	.07	8	.22	0	.00	2	.05	3	.07	0	.00	16	.42
32003030307	P/L INTER EQUIP	5	.14	0	.00	0	.01	0	.00	4	.10	0	.00	9	.24
32003030308	INSTL, ASSY & C/O	6	.18	6	.16	0	.01	2	.04	6	.14	0	.00	20	.53
32003030401	DATA SENSORS	1	.03	0	.00	0	.00	0	.00	1	.02	0	.00	2	.06
32003030402	SIGNAL COND.	2	.06	1	.03	0	.00	0	.01	2	.04	0	.00	5	.14
32003030403	CIRCUITRY	34	.98	0	.00	2	.04	0	.00	27	.71	0	.00	62	1.73
32003030404	INSTL, ASSY & C/O	3	.09	0	.00	0	.00	0	.00	2	.06	0	.00	6	.15
32003030501	BATTERY	2	.05	1	.04	0	.00	0	.01	1	.04	0	.00	5	.13
32003030502	FUEL CELL 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32003030503	INSTL, ASSY & C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.01
32003030601	DISTR.	15	.44	2	.05	1	.02	1	.01	13	.33	0	.00	31	.85
32003030602	TANKS SYSTEM 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32003030603	INSTL, ASSY & C/O	1	.04	0	.00	0	.00	0	.00	1	.03	0	.00	2	.07

6120

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 5 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32004	VEH AUX. STAGE	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.62	0	1.62
3200401	VEH AUX. STAGE	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.62	0	1.62

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 6 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32005	LOGISTICS	12	.27	0	.00	0	.00	0	.00	0	.00	150	2.75	162	3.02
3200501	TRANSP. & HDLG.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200502	TRAINING	6	.15	0	.00	0	.00	0	.00	0	.00	85	1.55	91	1.70
3200503	INV CONT. & WHSNG	5	.12	0	.00	0	.00	0	.00	0	.00	65	1.20	70	1.32
320050201	SIM. & EQUIP.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320050202	GROUND CREW	6	.15	0	.00	0	.00	0	.00	0	.00	85	1.55	91	1.70

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-24677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 7 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32006	FACILITIES	0	.00	0	.00	0	.00	0	.00	0	.00	0	5.17	0	5.17
3200601	MANUFACTURING	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.12	0	1.12
3200602	TEST	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.50	0	1.50
3200603	ETR MAINT. & REF.	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.02	0	1.02
3200604	ETR LAUNCH	0	.00	0	.00	0	.00	0	.00	0	.00	0	.39	0	.39
320060[illegible]	WTR MAINT. & REF.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.76	0	.76
320060[illegible]	WTR LAUNCH	0	.00	0	.00	0	.00	0	.00	0	.00	0	.38	0	.38
320060101	DES./CONST.	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.09	0	1.09
320060102	ACTIV./MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.02	0	.02
320060201	DES./CONST.	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.50	0	1.50
320060202	ACTIV./MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320060301	DES./CONST.	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.00	0	1.00
320060302	ACTIV./MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.02	0	.02
320060401	DES./CONST.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.38	0	.38
320060402	ACTIV./MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.01	0	.01
320060501	DES./CONST.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.75	0	.75
320060502	ACTIV./MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.01	0	.01
320060601	DES./CONST. 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.37	0	.37
320060602	ACTIV./MAINT. 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.01	0	.01

6-123

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 8 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32007	GRND. SUPT. EQUIP	357	10.11	562	15.95	65	1.44	104	2.31	97	2.28	0	.00	1184	32.09
3200701	MFG. GSE	82	2.34	130	3.69	15	.33	24	.53	22	.53	0	.00	274	7.42
3200702	ETR GSE	132	3.75	208	5.91	24	.54	38	.86	36	.84	0	.00	437	11.90
3200703	WTR GSE	131	3.72	207	5.87	24	.53	38	.85	36	.84	0	.00	436	11.82
3200704	FLT OPS GSE(NASA)	5	.15	8	.24	1	.02	2	.03	1	.03	0	.00	18	.47
3200705	FLT OPS GSE(DOD)	5	.15	8	.24	1	.02	2	.03	1	.03	0	.00	18	.47
320070101	HARDWARE	49	1.38	77	2.19	9	.20	14	.32	13	.31	0	.00	162	4.40
320070102	SITE ACTIV.	1	.03	2	.04	0	.00	0	.01	0	.01	0	.00	3	.09
320070103	MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070104	SOFTWARE	33	.92	51	1.46	6	.13	9	.21	9	.21	0	.00	108	2.94
320070201	HARDWARE	83	2.37	131	3.73	15	.34	24	.54	23	.53	0	.00	277	7.51
320070202	SITE ACTIV.	28	.78	43	1.23	5	.11	8	.18	7	.18	0	.00	91	2.48
320070203	MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070204	SOFTWARE	21	.60	33	.95	4	.09	6	.14	6	.14	0	.00	71	1.91
320070301	HARDWARE	82	2.33	129	3.68	15	.33	24	.53	22	.53	0	.00	273	7.40
320070302	SITE ACTIV.	27	.77	43	1.21	5	.11	8	.18	7	.17	0	.00	90	2.44
320070303	MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070304	SOFTWARE	22	.62	35	.98	4	.09	6	.14	6	.14	0	.00	73	1.98
320070401	HARDWARE 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070402	SITE ACTIV. 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070404	SOFTWARE 3	5	.15	8	.24	1	.02	2	.03	1	.03	0	.00	18	.47
320070501	HARDWARE 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070502	SITE ACTIV. 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070504	SOFTWARE 3	5	.15	8	.24	1	.02	2	.03	1	.03	0	.00	18	.47

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 9 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
3200B	VEHICLE TEST	178	4.15	521	15.01	0	.00	159	3.39	33	.77	0	.00	891	21.32
3200B01	GND TEST HDWE.	0	.00	379	10.46	0	.00	112	2.50	33	.77	0	.00	524	13.73
3200B02	GND TEST OPNS.	149	3.49	133	2.46	0	.00	47	.89	0	.00	0	.00	334	6.84
3200B04	FLT. TEST OPNS	28	.66	5	.09	0	.00	0	.00	0	.00	0	.00	33	.75
320080101	PTV TEST	0	.00	101	2.79	0	.00	30	.67	9	.21	0	.00	140	3.66
320080102	MAJOR TEST ART.	0	.00	265	7.31	0	.00	78	1.75	23	.54	0	.00	366	9.60
320080103	MOCKUPS	0	.00	13	.36	0	.00	4	.09	1	.03	0	.00	18	.47

6-125

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 10 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32009	LAUNCH OPNS. WTR	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200901	LNCH SITE SVCES	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200902	TUG/SHTL MATING	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200903	PRELAUNCH C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200904	COUNTDOWN	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200905	PRLNTS. & GASES	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200906	POST FLT. SAFING	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 11 OF

X NON RECURRING(DDT&E) | RECURRING(PRODUCTION) | RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32010	LAUNCH OPNS ETR	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201001	LNCH SITE SVCES	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201002	TUG/SHTL MATING	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201003	PRELAUNCH C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201004	COUNTDOWN	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201005	PRLNTS & GASES	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201006	POST FLT. SAFING	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 12 OF

X NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32011	FLIGHT OPNS NASA	110	2.57	102	1.83	0	.00	39	.75	0	.00	10	.19	262	5.33
3201101	MISSION PLG.	50	1.17	47	.84	0	.00	18	.34	0	.00	5	.09	120	2.44
3201102	FLT. CONTROL	8	.18	7	.13	0	.00	3	.05	0	.00	1	.01	18	.37
3201103	FLT. EVAL.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201104	FLT. SUPT. SFTWRE	52	1.22	48	.87	0	.00	19	.35	0	.00	5	.09	124	2.53

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 13 OF

X NON RECURRING(DDTAE) | RECURRING(PRODUCTION) | RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32012	FLIGHT OPNS DOD	99	2.31	92	1.64	0	.00	35	.67	0	.00	9	.17	235	4.79
3201201	MISSION PLG	45	1.05	42	.75	0	.00	16	.31	0	.00	4	.08	108	2.19
3201202	FLT. CONTROL	7	.16	6	.11	0	.00	2	.05	0	.00	1	.01	16	.33
3201203	FLT. EVAL.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201204	FLT. SUPT. SFTWRE	47	1.09	43	.78	0	.00	17	.32	0	.00	4	.08	112	2.27

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 14 OF

X NON RECURRING(DDTAE) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32013	REFURB &INTEG WTR	0	.00	3	.08	0	.00	1	.02	0	.01	0	.00	4	.11
3201301	SCH MAINT & REF	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201302	UNSCH MAINT & REF	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201303	POST MAINT C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201304	TUG/PL MAING &/CO	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201305	REFURB RQMTS PLG	0	.00	3	.08	0	.00	1	.02	0	.01	0	.00	4	.11
3201306	DEPOT MAINT	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 15 OF

x NON RECURRING(DDT&E) RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32014	REFURB &INTEG ETR	0	.00	3	.08	0	.00	1	.02	0	.01	0	.00	4	.11
3201401	SCH MAINT & REF	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201402	UNSCH MAINT & REP	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201403	POST MAINT C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201404	TUG/PL MATING,C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3201405	REFURB RQMTS PLG	0	.00	3	.08	0	.00	1	.02	0	.01	0	.00	4	.11
3201406	DEPOT MAINT	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00

STUDY TITLE: SPACE TUG SYS STY (CRY) | COST ESTIMATE | DATE: AUGUST 29,1973
CONTRACT NO: NAS 8-29677 | DATA FORM T | PAGE: 25 OF

NON RECURRING(DDT&E) | X RECURRING(PRODUCTION) | RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32001	PROJECT MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	173	5.08	173	5.08
32002	SYS. ENGR. & INT.	998	28.28	204	3.88	0	.00	215	4.80	237	5.58	0	.16	1654	42.70
32003	VEH MAIN STAGE	0	.00	3537	85.01	0	.00	989	22.03	287	6.70	0	.00	4812	113.80
32004	VEH AUX. STAGE	0	.00	0	.00	0	.00	0	.00	0	.00	0	16.35	0	16.35
32005	LOGISTICS	1	.03	0	.00	0	.00	0	.00	0	.00	15	.27	16	.30
32006	FACILITIES	0	.00	0	.00	0	.00	0	.00	0	.00	0	.33	0	.33
32007	GRND. SUPT. EQUIP	0	.00	28	.78	0	.00	8	.19	2	.06	0	.00	39	1.02
32008	VEHICLE TEST	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
	TOTAL	999	28.31	3569	89.67	0	.00	1212	27.01	526	12.40	188	22.19	6694	179.57

6-132

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 17 OF

NON RECURRING(DDT&E) X RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32001	PROJECT MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	173	5.08	173	5.08
3200101	COST/PERF. MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	118	3.46	118	3.46
3200102	PROJ. DIRECTION	0	.00	0	.00	0	.00	0	.00	0	.00	52	1.51	52	1.51
3200103	INFORM. MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	4	.11	4	.11

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 18 OF

NON RECURRING(DDT&E) X RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32002	SYS. ENGR. & INT.	998	28.28	204	3.88	0	.00	215	4.80	237	5.58	0	.16	1654	42.70
3200201	TUG SYS. ENGR.	207	5.86	0	.00	0	.00	0	.00	12	.28	0	.09	219	6.23
3200202	SHUTTLE I/F	52	1.47	0	.00	0	.00	0	.00	3	.07	0	.02	55	1.56
3200203	PAYLOAD I/F	103	2.93	0	.00	0	.00	0	.00	6	.14	0	.05	109	3.12
3200204	SUST. ENGR.	636	18.02	204	3.88	0	.00	215	4.80	216	5.09	0	.00	1271	31.79

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 19 OF

NON RECURRING(DDT&E) X RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32005	VEH MAIN STAGE	0	.00	3337	85.01	0	.00	989	22.03	287	6.76	0	.00	4612	113.80
3200301	STRUCTURES	0	.00	449	9.25	0	.00	133	2.97	38	.91	0	.00	620	13.12
3200302	THERMAL CONTROL	0	.00	144	2.98	0	.00	43	.95	12	.29	0	.00	200	4.22
3200303	AVIONICS	0	.00	1123	31.01	0	.00	332	7.41	97	2.28	0	.00	1552	40.70
3200304	PROPULSION	0	.00	841	23.24	0	.00	249	5.55	73	1.71	0	.00	1163	30.50
3200305	ORBITER I/F	0	.00	300	6.19	0	.00	89	1.99	26	.61	0	.00	415	8.78
3200306	DROP TANKS	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200307	FINAL ASSY & C/O	0	.00	478	12.33	0	.00	142	3.16	41	.97	0	.00	662	16.47
320030101	FUEL TK & SUPT	0	.00	87	1.80	0	.00	26	.58	7	.18	0	.00	121	2.55
320030102	OXID. TK & SUPT	0	.00	72	1.48	0	.00	21	.47	6	.14	0	.00	99	2.10
320030103	BODY STRUCTURE	0	.00	28	.58	0	.00	8	.18	2	.06	0	.00	39	.82
320030104	THRUST STRUC	0	.00	19	.40	0	.00	6	.13	2	.04	0	.00	27	.56
320030105	METEOROID SH	0	.00	131	2.70	0	.00	39	.87	11	.26	0	.00	181	3.83
320030106	PAYLOAD I/F	0	.00	84	1.73	0	.00	25	.55	7	.17	0	.00	116	2.45
320030107	INSTL, ASSY & C/O	0	.00	25	.53	0	.00	8	.19	2	.06	0	.00	39	.82
320030201	FUEL TANK IN	0	.00	32	.66	0	.00	9	.21	3	.06	0	.00	44	.93
320030202	OXID. TANK I	0	.00	16	.32	0	.00	5	.10	1	.03	0	.00	22	.46
320030203	INSL. PURGE SYS.	0	.00	91	1.87	0	.00	27	.60	8	.18	0	.00	126	2.66
320030204	THERM CONT. SYS.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030205	INSTL ASSY & C/O	0	.00	6	.12	0	.00	2	.04	0	.01	0	.00	8	.17
320030301	DATA MGMT. 3	0	.00	233	7.00	0	.00	73	1.67	22	.51	0	.00	330	9.18
320030302	G N & C	0	.00	273	7.54	0	.00	81	1.80	24	.55	0	.00	377	9.89
320030303	COMMUNICATIONS	0	.00	452	12.48	0	.00	134	2.98	39	.92	0	.00	625	16.38
320030304	INSTRUMENTATION	0	.00	43	1.19	0	.00	13	.29	4	.09	0	.00	60	1.57
320030305	ELECT. POWER	0	.00	22	.61	0	.00	7	.14	2	.04	0	.00	30	.80
320030306	PWR. DIST. & CONT	0	.00	10	.28	0	.00	3	.07	1	.02	0	.00	14	.37
320030307	INSTL, ASSY & C/O	0	.00	69	1.91	0	.00	21	.46	6	.14	0	.00	96	2.51
320030401	MAIN ENGINE	0	.00	200	5.53	0	.00	59	1.32	17	.41	0	.00	277	7.26
320030402	MAIN ENG. SUPT	0	.00	399	11.01	0	.00	118	2.63	34	.81	0	.00	551	14.45
320030403	ACPS ENGINE	0	.00	30	.84	0	.00	9	.20	3	.06	0	.00	42	1.10
320030404	ACPS ENG. SUPT	0	.00	179	4.96	0	.00	53	1.18	15	.36	0	.00	248	6.51
320030405	INSTL, ASSY & C/O	0	.00	32	.90	0	.00	10	.21	3	.07	0	.00	45	1.18
320030501	STRUCTURES	0	.00	47	.97	0	.00	14	.31	4	.10	0	.00	65	1.38
320030502	I/F PANELS	0	.00	198	4.08	0	.00	59	1.31	17	.40	0	.00	274	5.79
320030503	PURGE PROV.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030504	ABORT PROV.	0	.00	36	.75	0	.00	11	.24	3	.07	0	.00	50	1.07
320030505	INSTL, ASSY & C/O	0	.00	19	.39	0	.00	6	.12	2	.04	0	.00	26	.55
320030701	FINAL ASSY	0	.00	399	10.28	0	.00	118	2.63	34	.81	0	.00	551	13.72
320030702	C/O	0	.00	80	2.06	0	.00	24	.53	7	.16	0	.00	110	2.74

6-135

STUDY TITLE: SPACE TUG SYS S' (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 20 OF

NON RECURRING(DDT&E) | RECURRING(PRODUCTION) | RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32004	VEH AUX. STAGE	0	.00	0	.00	0	.00	0	.00	0	.00	0	16.35	0	16.35
3200401	VEH AUX. STAGE	0	.00	0	.00	0	.00	0	.00	0	.00	0	16.35	0	16.35

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 21 OF

NON RECURRING(DDT&E) X RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32005	LOGISTICS	1	.03	0	.00	0	.00	0	.00	0	.00	15	.27	16	.30
3200501	TRANSP. & MDLG.	1	.03	0	.00	0	.00	0	.00	0	.00	15	.27	16	.30
3200502	TRAINING	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200503	INV CONT. & WHSNG	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320050201	SIM. & EQUIP.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00

STUDY TITLE: SPACE TUG SYS STD (CRY) | COST ESTIMATE | DATE: AUGUST 29,1973
CONTRACT NO: NAS 8-29677 | DATA FORM T | PAGE: 22 OF

NON RECURRING(DDT&E) | X RECURRING(PRODUCTION) | RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32006	FACILITIES	0	.00	0	.00	0	.00	0	.00	0	.00	0	.33	0	.33
3200601	MANUFACTURING	0	.00	0	.00	0	.00	0	.00	0	.00	0	.33	0	.33
3200602	TEST	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320060101	DES./CONST.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320060102	ACTIV./MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.33	0	.33
320060201	DES./CONST.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320060202	ACTIV./MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00

6-138

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 23 OF

NON RECURRING(DDT&E) X RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32007	GRND. SUPT. EQUIP	0	.00	28	.78	0	.00	8	.19	2	.06	0	.00	39	1.02
3200701	MFG. GSE	0	.00	28	.78	0	.00	8	.19	2	.06	0	.00	39	1.02
320070101	HARDWARE	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070102	SITE ACTIV.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070103	MAINT.	0	.00	28	.78	0	.00	8	.19	2	.06	0	.00	39	1.02

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 24 OF

NON RECURRING(DDT&E) X RECURRING(PRODUCTION) RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32008	VEHICLE TEST	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00

6-140

STUDY TITLE: SPACE TUG SYS STY (CHY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM 1

DATE: AUGUST 29,1975
PAGE: 39 OF

NON RECURRING(DDTAE) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32001	PROJECT MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	249	7.32	249	7.32
32002	SYS. ENGR. & INT.	224	6.36	72	1.37	0	.00	76	1.69	76	1.79	0	.00	448	11.21
32003	VEH MAIN STAGE 3	0	.00	388	10.54	0	.00	115	2.56	33	.79	0	.00	537	13.89
32004	VEH AUX. STAGE	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32005	LOGISTICS	26	.60	0	.00	0	.00	0	.00	0	.00	333	6.11	359	6.71
32006	FACILITIES	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.21	0	1.21
32007	GRND. SUPT. EQUIP	0	.00	212	5.87	0	.00	63	1.40	18	.43	0	.00	294	7.70
32009	LAUNCH OPNS. WTR	257	6.00	435	7.79	0	.00	86	1.62	48	1.09	272	4.85	1098	21.35
32010	LAUNCH OPNS ETR	651	15.19	1102	19.73	0	.00	217	4.11	121	2.76	689	12.27	2780	54.06
32011	FLIGHT OPNS NASA	752	17.54	697	12.48	0	.00	269	5.09	0	.00	71	1.27	1789	36.39
32012	FLIGHT OPNS DOD	679	15.84	630	11.27	0	.00	243	4.60	0	.00	65	1.15	1616	32.86
32013	REFURB &INTEG WTR	0	.00	406	11.20	0	.00	120	2.68	35	.82	0	.00	561	14.70
32014	REFURB &INTEG ETR	0	.00	1374	37.95	0	.00	407	9.06	118	2.79	0	.00	1899	49.80
	TOTAL	2589	61.52	5318	118.20	0	.00	1596	32.82	449	10.47	1679	34.18	11630	257.20

STOP

COMPUTE TIME 25.548
READY

6-141

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 26 OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32001	PROJECT MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	249	7.32	249	7.32
3200101	COST/PERF. MGMT.	0	.00	0	.00	0	.00	0	.00	0	.00	164	4.81	164	4.81
3200102	PROJ. DIRECTION	0	.00	0	.00	0	.00	0	.00	0	.00	78	2.30	78	2.30
3200103	INFORM. MGMT. 3	0	.00	0	.00	0	.00	0	.00	0	.00	7	.21	7	.21

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-24677

COST ESTIMATE
DATA FORM 7

DATE: AUGUST 29,1975
PAGE: 27 OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32002	SYS. ENGR. & INT.	224	6.36	72	1.37	0	.00	76	1.69	76	1.79	0	.00	448	11.21
3200204	SUST. ENGR. 3	224	6.36	72	1.37	0	.00	76	1.69	76	1.79	0	.00	448	11.21

NON RECURRING(DDT&E) RECURRING(PRODUCTION) & RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32003	VEH MAIN STAGE 3	0	.00	388	10.54	0	.00	115	2.56	33	.79	0	.00	537	13.89
3200301	STRUCTURES	0	.00	6	.11	0	.00	2	.04	0	.01	0	.00	8	.16
3200302	THERMAL CONTROL	0	.00	2	.04	0	.00	1	.01	0	.00	0	.00	3	.06
3200303	AVIONICS 3	0	.00	295	8.14	0	.00	87	1.94	25	.60	0	.00	407	10.68
3200304	PROPULSION	0	.00	68	1.87	0	.00	20	.45	6	.14	0	.00	93	2.45
3200305	ORBITER I/F	0	.00	18	.38	0	.00	5	.12	2	.04	0	.00	25	.54
3200306	DROP TANKS	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200307	FINAL ASSY & C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030101	FUEL TK & SUPT	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030102	OXID. TK & SUPT	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030103	BODY STRUCTURE	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030104	THRUST STRUC	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030105	METEOROID SH	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030106	PAYLOAD I/F	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030107	INSTL. ASSY & C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030201	FUEL TANK INSL	0	.00	1	.01	0	.00	0	.00	0	.00	0	.00	1	.01
320030202	OXID. TANK INSL.	0	.00	0	.01	0	.00	0	.00	0	.00	0	.00	1	.01
320030203	INSL. PURGE SYS.	0	.00	1	.02	0	.00	0	.01	0	.00	0	.00	1	.03
320030204	THERM CONT. SYS.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030205	INSTL. ASSY & C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030301	DATA MGMT. 3	0	.00	70	1.93	0	.00	21	.46	6	.14	0	.00	97	2.53
320030302	G N & C	0	.00	1	.03	0	.00	0	.01	0	.00	0	.00	2	.04
320030303	COMMUNICATIONS	0	.00	15	.41	0	.00	4	.10	1	.03	0	.00	21	.54
320030304	INSTRUMENTATION	0	.00	5	.14	0	.00	1	.03	0	.01	0	.00	7	.18
320030305	ELECT. POWER	0	.00	204	5.62	0	.00	60	1.34	18	.41	0	.00	281	7.38
320030306	PWR. DIST. & CONT	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.01
320030307	INSTL. ASSY & C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030401	MAIN ENGINE	0	.00	39	1.07	0	.00	12	.26	3	.08	0	.00	54	1.41
320030402	MAIN ENG. SUPT	0	.00	11	.31	0	.00	3	.07	1	.02	0	.00	15	.41
320030403	ACPS ENGINE	0	.00	15	.42	0	.00	4	.10	1	.03	0	.00	21	.55
320030404	ACPS ENG. SUPT	0	.00	2	.07	0	.00	1	.02	0	.01	0	.00	3	.09
320030405	INSTL. ASSY & C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030501	STRUCTURES	0	.00	1	.02	0	.00	0	.01	0	.00	0	.00	1	.03
320030502	I/F PANELS	0	.00	17	.35	0	.00	5	.11	1	.03	0	.00	23	.49
320030503	PURGE PROV.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030504	ABORT PROV.	0	.00	1	.01	0	.00	0	.00	0	.00	0	.00	1	.02
320030505	INSTL. ASSY & C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030701	FINAL ASSY	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320030702	C/O	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
32003030105	SOFTWARE 3	0	.00	61	1.69	0	.00	18	.40	5	.12	0	.00	85	2.22

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 24 OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32004	VEH AUX. STAGE	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00

6-145

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 30 OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32005	LOGISTICS	26	.60	0	.00	0	.00	0	.00	0	.00	333	6.11	359	6.71
3200501	TRANSP. & HDLG.	1	.03	0	.00	0	.00	0	.00	0	.00	17	.31	18	.33
3200502	TRAINING	6	.15	0	.00	0	.00	0	.00	0	.00	85	1.55	91	1.70
3200503	INV CONT. & WHSNG	18	.42	0	.00	0	.00	0	.00	0	.00	232	4.26	250	4.67
320050201	SIM. & EQUIP.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320050202	GROUND CREW	6	.15	0	.00	0	.00	0	.00	0	.00	85	1.55	91	1.70

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 31 OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32006	FACILITIES	0	.00	0	.00	0	.00	0	.00	0	.00	0	1.21	0	1.21
3200603	ETR MAINT. & REF.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.55	0	.55
3200604	ETR LAUNCH	0	.00	0	.00	0	.00	0	.00	0	.00	0	.21	0	.21
3200605	WTR MAINT. & REF.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.30	0	.30
3200606	WTR LAUNCH	0	.00	0	.00	0	.00	0	.00	0	.00	0	.15	0	.15
320060301	DES./CONST.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320060302	ACTIV./MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.55	0	.55
320060401	DES./CONST.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320060402	ACTIV./MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.21	0	.21
320060501	DES./CONST.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320060502	ACTIV./MAINT.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.30	0	.30
320060601	DES./CONST. 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320060602	ACTIV./MAINT. 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.15	0	.15

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 32 OF

NON RECURRING(DDTAE) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32007	GRND. SUPT. EQUIP	0	.00	212	5.87	0	.00	63	1.40	18	.43	0	.00	294	7.70
3200701	MFG. GSE 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
3200702	ETR GSE	0	.00	93	2.56	0	.00	27	.61	8	.19	0	.00	128	3.36
3200703	WTR GSE	0	.00	60	1.65	0	.00	18	.39	5	.12	0	.00	83	2.16
3200704	FLT OPS GSE(NASA)	0	.00	30	.83	0	.00	9	.20	3	.06	0	.00	41	1.09
3200705	FLT OPS GSE(DOD)	0	.00	30	.83	0	.00	9	.20	3	.06	0	.00	41	1.09
320070104	SOFTWARE 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070201	HARDWARE	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070202	SITE ACTIV.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070203	MAINT.	0	.00	66	1.84	0	.00	20	.44	6	.13	0	.00	92	2.41
320070204	SOFTWARE	0	.00	26	.72	0	.00	8	.17	2	.05	0	.00	36	.95
320070301	HARDWARE	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070302	SITE ACTIV.	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070303	MAINT.	0	.00	55	1.53	0	.00	16	.36	5	.11	0	.00	76	2.00
320070304	SOFTWARE 3	0	.00	4	.12	0	.00	1	.03	0	.01	0	.00	6	.16
320070403	MAINT. 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070404	SOFTWARE 3	0	.00	30	.83	0	.00	9	.20	3	.06	0	.00	41	1.09
320070503	MAINT. 3	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
320070504	SOFTWARE 3	0	.00	30	.83	0	.00	9	.20	3	.06	0	.00	41	1.09

STUDY TITLE: SPACE TUG SYS STY (CHY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 33 OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32009	LAUNCH OPNS. WTR	257	6.00	435	7.79	0	.00	86	1.62	48	1.09	272	4.85	1098	21.35
3200901	LNCH SITE SVCES	99	2.30	167	2.99	0	.00	33	.62	18	.42	104	1.86	421	8.18
3200902	TUG/SHTL MATING	29	.67	49	.87	0	.00	10	.18	5	.12	30	.54	123	2.39
3200903	PRELAUNCH C/O	37	.86	63	1.12	0	.00	12	.23	7	.16	39	.70	158	3.07
3200904	COUNTDOWN	45	1.05	76	1.37	0	.00	15	.29	8	.19	48	.85	193	3.75
3200905	PHLNTS. & GASES	2	.06	4	.07	0	.00	1	.02	0	.01	3	.05	10	.20
3200906	POST FLT. SAFING	45	1.05	76	1.37	0	.00	15	.29	8	.19	48	.85	193	3.75

6-149

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 34 OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32010	LAUNCH OPNS ETR	651	15.19	1102	19.73	0	.00	217	4.11	121	2.76	689	12.27	2780	54.06
3201001	LNCH SITE SVCES	246	5.75	417	7.47	0	.00	82	1.55	46	1.04	261	4.64	1052	20.46
3201002	TUG/SHTL MATING	72	1.68	122	2.18	0	.00	24	.45	13	.30	76	1.35	307	5.97
3201003	PRELAUNCH C/O	113	2.63	191	3.42	0	.00	38	.71	21	.48	119	2.13	482	9.38
3201004	COUNTDOWN	92	2.16	156	2.80	0	.00	31	.58	17	.39	98	1.74	395	7.67
3201005	PRLNTS & GASES	15	.34	25	.44	0	.00	5	.09	3	.06	15	.27	62	1.21
3201006	POST FLT, SAFING	113	2.63	191	3.42	0	.00	38	.71	21	.48	119	2.13	482	9.38

6-150

STUDY TITLE: SPACE TUG SYS STY (CHY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 35 OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32011	FLIGHT OPNS NASA	752	17.54	697	12.48	0	.00	269	5.09	0	.00	71	1.27	1789	36.39
3201101	MISSION PLG.	111	2.59	103	1.85	0	.00	40	.75	0	.00	11	.19	265	5.38
3201102	FLT. CONTROL	488	11.34	451	8.07	0	.00	174	3.29	0	.00	46	.82	1157	23.52
3201103	FLT. EVAL.	104	2.42	96	1.73	0	.00	37	.70	0	.00	10	.18	247	5.03
3201104	FLT. SUPT. SFTWRE	51	1.18	47	.84	0	.00	18	.34	0	.00	5	.09	121	2.46

151-9

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 36 OF

NON RECURRING(DDTRE) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32012	FLIGHT OPNS DOD	679	15.84	630	11.27	0	.00	243	4.60	0	.00	65	1.15	1616	32.86
3201201	MISSION PLG 3	100	2.33	93	1.66	0	.00	36	.68	0	.00	9	.17	238	4.83
3201202	FLT. CONTROL	443	10.32	410	7.35	0	.00	158	3.00	0	.00	42	.75	1053	21.42
3201203	FLT. EVAL.	91	2.13	85	1.51	0	.00	33	.62	0	.00	9	.15	217	4.41
3201204	FLT. SUPT. SFTWRE	46	1.06	42	.76	0	.00	16	.31	0	.00	4	.08	108	2.20

6-152

STUDY TITLE: SPACE TUG SYS STY (CHY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 37 OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32013	REFURB &INTEG WTR	0	.00	406	11.20	0	.00	120	2.68	35	.82	0	.00	561	14.70
3201301	SCH MAINT & REF	0	.00	122	3.38	0	.00	36	.81	11	.25	0	.00	169	4.43
3201302	UNSCH MAINT & REP	0	.00	38	1.04	0	.00	11	.25	3	.08	0	.00	52	1.36
3201303	POST MAINT C/O	0	.00	9	.26	0	.00	3	.06	1	.02	0	.00	13	.34
3201304	TUG/PL MAING &/CO	0	.00	94	2.60	0	.00	28	.62	8	.19	0	.00	130	3.41
3201305	REFURB RQMTS PLG	0	.00	38	1.04	0	.00	11	.25	3	.08	0	.00	52	1.36
3201306	DEPOT MAINT	0	.00	105	2.89	0	.00	31	.69	9	.21	0	.00	145	3.79

6-158

STUDY TITLE: SPACE TUG SYS STY (CRY)
CONTRACT NO: NAS 8-29677

COST ESTIMATE
DATA FORM T

DATE: AUGUST 29,1973
PAGE: 38 OF

NON RECURRING(DDT&E) RECURRING(PRODUCTION) X RECURRING(OPERATIONS)

SUBDIVISIONS OF WORK (DOLLARS IN MILLIONS, HOURS IN THOUSANDS)

WBS IDENTIFIER NUMBER	WBS NAME	ENGINEERING HOURS	ENGINEERING DOLLARS	MANUFACTURING HOURS	MANUFACTURING DOLLARS	TOOLING & STE HOURS	TOOLING & STE DOLLARS	QUAL & REL A HOURS	QUAL & REL A DOLLARS	TESTING HOURS	TESTING DOLLARS	MGMT & OTHER HOURS	MGMT & OTHER DOLLARS	TOTAL HOURS	TOTAL DOLLARS
32014	REFURB &INTEG ETR	0	.00	1374	37.95	0	.00	407	9.06	118	2.79	0	.00	1899	49.80
3201401	SCH MAINT & REF	0	.00	306	8.44	0	.00	91	2.02	26	.62	0	.00	423	11.08
3201402	UNSCH MAINT & REF	0	.00	94	2.60	0	.00	28	.62	8	.19	0	.00	130	3.41
3201403	POST MAINT C/O	0	.00	24	.65	0	.00	7	.16	2	.05	0	.00	33	.85
3201404	TUG/PL MATING,C/O	0	.00	235	6.50	0	.00	70	1.55	20	.48	0	.00	325	8.52
3201405	REFURB RQMTS PLG	0	.00	94	2.60	0	.00	28	.62	8	.19	0	.00	130	3.41
3201406	DEPOT MAINT	0	.00	621	17.16	0	.00	184	4.10	54	1.26	0	.00	859	22.52

A51-9

6.11 Technical Characteristics Data (Form-B)

This subsection presents on Data Form-B the technical, physical and mission characteristics which have a significant effect on the cost of an item. As required, Data Form-B contains parameters that have been utilized in generating the cost estimates.

The data in Form-B complies with the following stipulation in Data Requirement Document MF-003M dated 7 May 1971: "Since the TCD is used for cost parameter purposes, it is not necessary that the sums of the lower level individual characteristics, such as weight or volume, equal the total weight or volume of the higher level WBS item."

In addition to, and/or in conjunction with, the parameters stated on Data Form-B, the following factors are reflected in the estimated costs:

Technology

Size/Shape/Materials/Weight

Fabrication/Assembly Methods

Tooling Requirements

Quantities - Subsystems/Flight Articles

Commonality

Maintainability

Test Philosophy

Complexity/Workability

TECHNICAL CHARACTERISTICS DATA FORM B

STUDY TITLE SPACE TUG SYSTEMS STUDY (CRYOGENIC) OPTION NO. 1 DATE 3 September 1973

CONTRACT NO. NAS 8-29677 PAGE 1 OF 6

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	QUANTITY OR VALUE	UNITS OF MEASURE	CHARACTERISTICS	NOTES
320	Total Tug Project	-	-	Summation	
320-01	Project Management	5	Percent	Σ 320-(320-01 + 320-02)	
320-02	Systems Engrg. & Integr.	Note	-	DDT&E-%; Prod.-Factor;	Ops. - Level of Effort
320-03	Vehicle Main Stage	-	-	Σ Subsystems	
320-03-01	Structures Subsystem	-	-	Σ Assembly Costs	
320-03-01-01	Fuel Tank and Support	742	Pounds	ΣComponents	
320-03-01-02	Oxidizer Tank and Support	314	Pounds	ΣComponents	
320-03-01-03	Body Structure	1,027	Pounds	Σ Components	
320-03-01-04	Thrust Structure	106	Pounds		
320-03-01-05	Meteoroid Shield	77	-	Direct Estimate	
320-03-01-06	Payload Interface	128	Pounds		
320-03-01-07	Installation, Assembly & C/O	8	Percent		
320-03-02	Thermal Control Subsystem	-	-	ΣAssembly Costs	
320-03-02-01	Fuel Tank Insulation	-	-	Direct Estimate	
320-03-02-02	Oxidizer Tank Insulation	-	-	" "	
320-03-02-03	Insulation Purge System	-	-	" "	
320-03-02-04	Control System	-	-	" "	
320-03-02-05	Installation, Assembly & C/O	8	Percent		
320-03-03	Avionics Subsystem	-	-	Σ Assembly Costs	
320-03-03-01	Data Management	-	-	Σ Component Costs	
320-03-01-01-01	Computer	-	-	Direct Estimate	
320-03-03-01-02	Data Distribution	-	-	-	
320-03-03 -03	Bus Controller	-	-	-	

251-2

TECHNICAL CHARACTERISTICS DATA FORM B

STUDY TITLE SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO. NAS 8-29677

OPTION NO. 1

DATE 3 September 1973

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	QUANTITY OR VALUE	UNITS OF MEASURE	CHARACTERISTICS	NOTES
320-03-03-01-04	Circuitry	79.5	Pounds		
320-03-03-01-05	Software - A	-	-	Direct Estimate	
320-03-03-01-06	Software - B	-	-	-	
320-03-03-01-07	Software - C	-	-	-	
320-03-03-01-08	Installation, Assembly & C/O	8	Percent		
320-03-03-02	GN&C	-	-	Σ Assembly Costs	
320-03-03-02-01	IMU	-	-	Direct Estimate	
320-03-03-02-02	Star Tracker	-	-	" "	
320-03-03-02-03	Laser Radar	-	-	-	
320-03-03-02-04	Installation, Assembly & C/O	8	Percent		
320-03-03-03	Communications	-	-	Σ Assembly Costs	
320-03-03-03-01	Microwave Circuitry/RF-Mplxr.	24	Pounds	Direct Estimate for RF Mtplxr.	
320-03-03-03-02	Transponders	32/36	Watts		
320-03-03-03-03	Power Amplifier			Direct Estimate	
320-03-03-03-04	Antenna			" "	
320-03-03-03-05	Decoder/Encoder - Mod./Demod.			" "	
320-03-03-03-06	Tape Recorder			" "	
320-03-03-03-07	P/L Interface Equip. - Com Sec.	14	Watts		
320-03-03-03-08	Installation, Assembly & C/O	8	Percent		
320-03-03-04	Instrumentation	-	-	Σ Assembly Costs	
320-03-03-04-01	Data Sensors	-	-	Direct Estimate	
320-03-03-04-02	Signal Conditioning	7	Pounds		
320-03-03-04-03	Circuitry	79.5	Pounds		

TECHNICAL CHARACTERISTICS DATA FORM B

STUDY TITLE SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO. NAS 8-29677

OPTION NO. 1

DATE 3 September 1973

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	QUANTITY OR VALUE	UNITS OF MEASURE	CHARACTERISTICS	NOTES
320-03-03-04-04	Installation, Assembly & C/O	8	Percent		
320-03-03-05	Electrical Power	-	-	ΣAssembly Costs	
320-03-03-05-01	Battery	-	-	Direct Estimate	
320-03-03-05-02	Fuel Cell	-	-	-	
320-03-03-05-03	Installation, Assembly & C/O	8	Percent		
320-03-03-06	Power Distribution & Control	-	-	ΣAssembly Costs	
320-03-03-06-01	Distribution	90	Pounds		
320-03-03-06-02	Tanks - Fuel/Cell	-	-	-	
320-03-03-06-03	Installation, Assembly & C/O	8	Percent		
320-03-04	Propulsion	-	-	ΣAssembly Costs	
320-03-04-01	Main Engine (GFE)	D&D = $13.0M T_1 - $0.7M	Per Unit	Government Furnished	
320-03-04-02	Main Engine Support	-	-	ΣComponent Level Estimates	
320-03-04-03	ACPS Engine	25	LBf		
320-03-04-04	ACPS Engine Support	264	Pounds	Less Thrustors	
320-03-04-05	Installation, Assembly & C/O	8	Percent		
320-03-05	Orbiter Interface			ΣAssembly Costs	
320-03-05-01	Structures	498/614	Tact Table/ Trunnion		
320-03-05-02	Interface Panels			ΣIndividual Panel Costs	
320-03-05-03	Purge Provisions	-	-	-	
320-03-05-04	Abort Provisions	95	Pounds		
320-03-05-05	Installation, Assembly & C/O	8	Percent		
320-03-06	Drop Tanks	-	-	-	
320-03-07	Final Assembly & C/O	-	Percent	Individual Factors DDT&E/Prod./Ops.	

851-9

TECHNICAL CHARACTERISTICS DATA FORM B

STUDY TITLE SPACE TUG SYSTEMS STUDY (CRYOGENIC) DATE 3 September 1973

CONTRACT NO. NAS 8-29677 OPTION NO. 1 PAGE 4 OF 6

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	QUANTITY OR VALUE	UNITS OF MEASURE	CHARACTERISTICS	NOTES
320-04	Space Tug Auxiliary Stage	-	-	Direct Estimate-Stage Costs provided by Government	
320-05	Logistics	-	-	Summation	
320-05-01	Transportation & Handling			Direct Estimate - Operations	
320-05-02	Training	-	-	Direct Estimate	
320-05-03	Inventory Control & Warehsng.	-	-	" "	
320-06	Facilities	-	-	Summation	
320-06-01	Manufacturing	-	-	Direct EStimate	
320-06-02	Test	-	-	" "	
320-06-03	Maint. & Refurb. - ETR	-	-	" "	
320-06-04	ETR Launch	-	-	" "	
320-06-05	Maint. & Refurb. - WTR	-	-	" "	
320-06-06	WTR Launch	-	-	" "	
320-07	Ground Support Equipment	-	-	Summation	
320-07-01	Manufacturing GSE	-	-	Direct Estimate	
320-07-02	ETR GSE	-	-	" "	
320-07-03	WTR GSE	-	-	" "	
320-07-04	Flight Ops. GSE - NASA	-	-	" "	
320-07-05	Flight Ops. GSE - DOD	-	-	" "	
320-08	Vehicle Test	-	-	Summation	
320-08-01	Ground Test Hardware	-	-	No. Equivalent Units by Subsystem and Assembly	
320-08-02	Ground Test Operations	-	-	Direct Estimate	
320-08-03	Flight Test Hardware	-	-	-	
320-08-04	Flight Test Operations	-	-	Direct Estimate	

TECHNICAL CHARACTERISTICS DATA FORM B

STUDY TITLE SPACE TUG SYSTEMS STUDY (CRYOGENIC)

DATE 3 September 1973

CONTRACT NO. NAS 8-29677

OPTION NO. 1

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	QUANTITY OR VALUE	UNITS OF MEASURE	CHARACTERISTICS	NOTES
320-09	Launch Operations - WTR	-	-	Direct Estimate	
320-09-01	Launch Site Services & Support	-	-	" "	
320-09-02	Tug/Shuttle Mating & C/O	-	-	" "	
320-09-03	Prelaunch Checkout	-	-	" "	
320-09-04	Countdown			" "	
320-09-05	Propellants & Gases			" "	
320-09-06	Post Flight Safing			" "	
320-10	Launch Operations - ETR			" "	
320-10-01	Launch Site Services & Support			" "	
320-10-02	Tug/Shuttle Mating & C/O			" "	
320-10-03	Prelaunch Checkout			" "	
320-10-04	Countdown			" "	
320-10-05	Propellants & Gases			" "	
320-10-06	Post Flight Safing			" "	
320-11	Flight Operations - NASA			Summation	
320-11-01	Mission Planning			Direct Estimate	
320-11-02	Flight Control			" "	
320-11-03	Flight Evaluation			" "	
320-11-04	Flight Support Software			" "	
320-12	Flight Operations - DOD			Summation	
320-12-01	Mission Planning			Direct Estimate	
320-12-02	Flight Control			" "	
320-12-03	Flight Evaluation			" "	

6-160

TECHNICAL CHARACTERISTICS DATA FORM B

STUDY TITLE SPACE TUG SYSTEMS STUDY (CRYOGENIC) DATE 3 September 1973

CONTRACT NO. NAS 8-29677 OPTION NO. 1 PAGE 6 OF 6

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	QUANTITY OR VALUE	UNITS OF MEASURE	CHARACTERISTICS	NOTES
320-12-04	Flight Support Software			Direct Estimate	
320-13	Refurbishment & Integr. - WTR			Summation	
320-13-01	Scheduled Maint. & Refurb.			Direct Estimate	
320-13-02	Unsched. Maint. & Refurb.			" "	
320-13-03	Post Maintenance Checkout			" "	
320-13-04	Tug/Payload Mating & C/O			" "	
320-13-05	Refurb. Requirements Planning			" "	
320-13-06	Depot Maintenance			" "	
320-14	Refurbishment & Integr. - FTR			Summation	
320-14-01	Scheduled Maint. & Refurb.			Direct Estimate	
320-14-02	Unsched. Maint. & Refurb.			" "	
320-14-03	Post Maintenance Checkout			" "	
320-14-04	Tug/Payload Mating & C/O			" "	
320-14-05	Refurb. Requirements Planning			" "	
320-14-06	Depot Maintenance			" "	

6.12 COST DATA ADJUSTMENTS

Subsequent to the cost model run, a discrepancy was discovered in the ground operations manloading inputs which had a significant impact on ground operations costs. Time limitations precluded re-running the LEADER II Cost Model and the associated Cost Data Forms. However, the affected cost data have been adjusted and are presented in this section. An adjusted cost summary is provided. Table 6.12-1 presents an adjusted cost tabulation. Adjusted cost per flight displays are included and reflect adjusted ground operations manloading, Tables 6.12-2 through 6.12-5, which show the adjusted values identified by as asterisk. Original calculations were presented in Section 6.9.

Since no DOD flights require either an expended Tug or an expended auxiliary stage, no DOD cost per flight sheets have been included for Mode 2 and Mod 3.

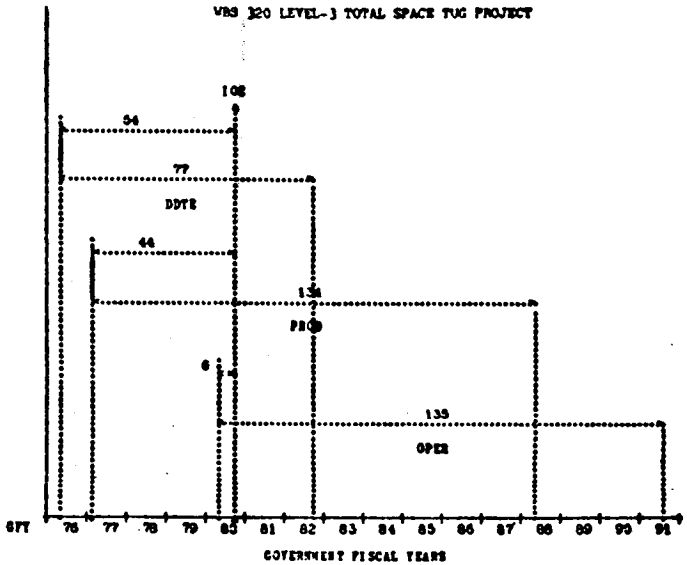
COST SUMMARY – PROGRAM OPTION NO. 1

TECHNICAL CHARACTERISTICS - OPTION NO. 1
WBS 320 TOTAL SPACE TUG PROJECT

MAJOR HARDWARE	
SPACE TUG VEHICLE MAIN STAGE	- 13 VEHICLES
SPACE TUG VEHICLE AUXILIARY STAGE	- 9 STAGES
OTHER OPTION ELEMENTS	
PROJECT MANAGEMENT	
SYSTEMS ENGINEERING AND INTEGRATION	
LOGISTICS	- TRANSPORTATION, TRAINING, SIMULATION
FACILITIES	- FACTORY, TEST, ETR, WTR
GROUND SUPPORT EQUIPMENT	- FACTORY, ETR, WTR
VEHICLE TEST	- PTV, MAJOR TEST ARTICLES
LAUNCH OPERATIONS - WTR	- 32 LAUNCHES
LAUNCH OPERATIONS - ETR	- 190 LAUNCHES
FLIGHT OPERATIONS - NASA	- 117 FLIGHTS
FLIGHT OPERATIONS - DOD	- 105 FLIGHTS
REFURBISHMENT AND MAINTENANCE - WTR	- 32 REFURBISHMENTS
REFURBISHMENT AND MAINTENANCE - ETR	- 190 REFURBISHMENTS

PROGRAM OPTION NO. 1

WBS 320 LEVEL-3 TOTAL SPACE TUG PROJECT

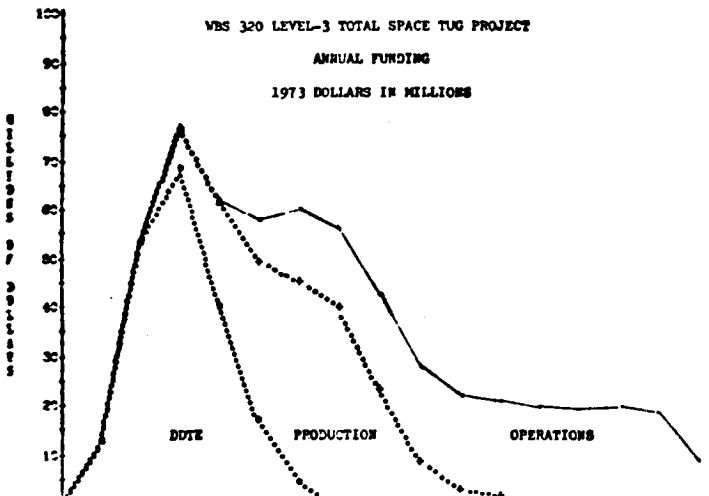


PROGRAM OPTION NO. 1

WBS 320 LEVEL-3 TOTAL SPACE TUG PROJECT

ANNUAL FUNDING

1973 DOLLARS IN MILLIONS



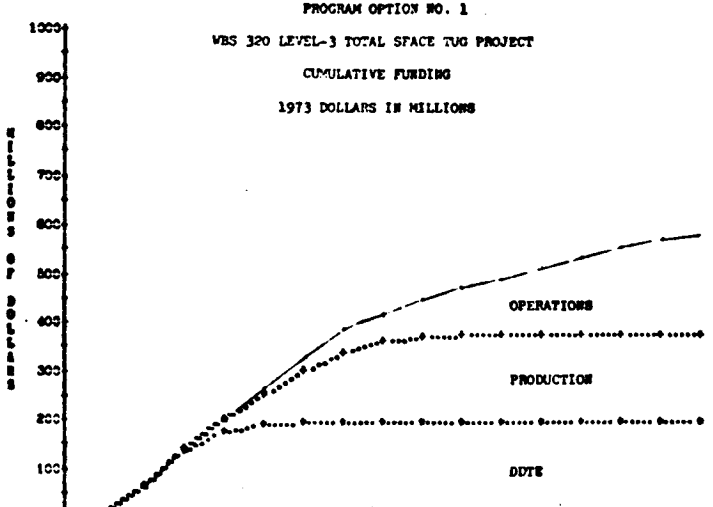
FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDTE	12.9	53.1	60.5	40.6	17.1	4.4	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
PROD	.0	.9	8.2	21.4	32.1	41.0	33.9	23.2	8.5	2.8	1.6	.4	.0	.0	.0	.0
OPER	.0	.0	.0	.0	8.8	15.2	15.9	19.0	19.0	19.0	19.0	19.0	19.0	19.0	18.8	9.1
TOTAL	12.9	54.0	76.7	62.0	58.0	60.6	55.8	42.2	27.5	21.8	20.6	19.4	19.0	19.0	18.8	9.1

PROGRAM OPTION NO. 1

WBS 320 LEVEL-3 TOTAL SPACE TUG PROJECT

CUMULATIVE FUNDING

1973 DOLLARS IN MILLIONS



FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
DDTE	13	66	135	175	192	197	197	197	197	197	197	197	197	197	197	197
PROD	0	1	9	33	65	106	143	167	175	178	179	180	180	180	180	180
OPER	0	0	0	0	9	24	40	59	78	97	116	135	154	173	192	201
TOTAL	12	66	143	208	264	325	380	423	450	472	492	512	531	550	569	578

6-163

Table 6.12-1

PROGRAM OPTION NO. 1

SUMMARY COST TABULATION

1973 DOLLARS IN MILLIONS

Total Program Costs		Unit Costs	
DDT&E	$197.05	Vehicle Main Stage	
Production	179.57	First Prod. Unit - Hardware	$14.44
		Average Unit (including Support)	12.22
Operations	* 200.81		
		Vehicle Auxiliary Stage	
Total	* $577.43	Average Unit (including Startup)	2.30
		Average Cost per Flight	
		Mode 1 - NASA	* 0.90
		Mode 1 - DOD	* 0.90
		Mode 2 - NASA	* 12.89
		Mode 2 - DOD	Not required
		Mode 3 - NASA	* 3.20
		Mode 3 - DOD	Not required

* Adjusted Values

Table 6.12-2 AVERAGE COST PER FLIGHT Adjusted-*

MODE 1 - REUSABLE BASIC TUG

AGENCY NASA

PROGRAM OPTION 1

LAUNCH OPERATIONS			* $ 198,301
Tug/Shuttle mating and checkout	* $	18,656	
Tug/Payload mating and checkout	*	26,651	
Prelaunch checkout	*	27,860	
Countdown	*	25,444	
Propellant and gases		6,410	
Post flight safing	*	29,317	
Site services and support	*	63,963	
MAINTENANCE AND REFURBISHMENT			* $ 230,219
Scheduled maintenance and refurbishment	* $	34,647	
Unscheduled maintenance and refurbishment	*	10,661	
Tug engine maintenance and refurbishment		11,538	
Tug vehicle spares		45,966	
Tug engine spares		6,410	
Post maintenance checkout	*	2,644	
Refurbishment requirements planning	*	10,661	
Depot maintenance		107,692	
TOTAL GROUND OPERATIONS (Launch and Maintenance and Refurbishment)			* $ 428,520
FLIGHT OPERATIONS			$ 311,000
Mission planning	$	46,000	
Flight control		201,000	
Flight evaluation		43,000	
Flight software		21,000	
OPERATIONS SUPPORT			$ 156,154
Airborne software update	$	10,085	
GSE maintenance		20,000	
Sustaining engineering		50,513	
Program management		33,162	
Transportation and handling		1,453	
Inventory control and warehousing		21,197	
Facilities maintenance		5,470	
GSE software update		14,274	
EXPENDABLE VEHICLE MAIN STAGE			$ - 0 -
EXPENDABLE VEHICLE AUXILIARY STAGE			$ - 0 -
TOTAL AVERAGE PER FLIGHT COST			* $ 895,674

Table 6.12-3

MODE 2 - EXPENDED TUG

AVERAGE COST PER FLIGHT
Adjusted - *

AGENCY NASA

PROGRAM OPTION 1

LAUNCH OPERATIONS			* $ 198,301
Tug/Shuttle mating and checkout	*	$ 18,656	
Tug/Payload mating and checkout	*	26,651	
Prelaunch checkout	*	27,860	
Countdown	*	25,444	
Propellant and gases		6,410	
Post flight safing	*	29,317	
Site services and support	*	63,963	
MAINTENANCE AND REFURBISHMENT			$ - 0 -
Scheduled maintenance and refurbishment		$	
Unscheduled maintenance and refurbishment			
Tug engine maintenance and refurbishment			
Tug vehicle spares			
Tug engine spares			
Post maintenance checkout			
Refurbishment requirements planning			
Depot maintenance			
TOTAL GROUND OPERATIONS (Launch and Maintenance and Refurbishment)			* $ 198,301
FLIGHT OPERATIONS			$ 311,000
Mission planning		$ 46,000	
Flight control		201,000	
Flight evaluation		43,000	
Flight software		21,000	
OPERATIONS SUPPORT			$ 156,154
Airborne software update		$ 10,085	
GSE maintenance		20,000	
Sustaining engineering		50,513	
Program management		33,162	
Transportation and handling		1,453	
Inventory control and warehousing		21,197	
Facilities maintenance		5,470	
GSE software update		14,274	
EXPENDABLE VEHICLE MAIN STAGE			$ 12,220,000
EXPENDABLE VEHICLE AUXILIARY STAGE			$ - 0 -
TOTAL AVERAGE PER FLIGHT COST			* $ 12,885,455

Table 6.12-4 AVERAGE COST PER FLIGHT Adjusted - * AGENCY NASA

MODE 3 - EXPENDED KICK STAGE PROGRAM OPTION 1

LAUNCH OPERATIONS		* $ 198,301
Tug/Shuttle mating and checkout	* $ 18,656	
Tug/Payload mating and checkout	* 26,651	
Prelaunch checkout	* 27,860	
Countdown	* 25,444	
Propellant and gases	6,410	
Post flight safing	* 29,317	
Site services and support	* 63,963	
MAINTENANCE AND REFURBISHMENT		$ 230,219
Scheduled maintenance and refurbishment	* $ 34,647	
Unscheduled maintenance and refurbishment	* 10,661	
Tug engine maintenance and refurbishment	11,538	
Tug vehicle spares	45,966	
Tug engine spares	6,410	
Post maintenance checkout	* 2,644	
Refurbishment requirements planning	* 10,661	
Depot maintenance	107,692	
TOTAL GROUND OPERATIONS (Launch and Maintenance and Refurbishment)		* $ 428,520
FLIGHT OPERATIONS		$ 311,000
Mission planning	$ 46,000	
Flight control	201,000	
Flight evaluation	41,000	
Flight software	21,000	
OPERATIONS SUPPORT		$ 156,154
Airborne software update	$ 10,085	
GSE maintenance	20,000	
Sustaining engineering	50,513	
Program management	34,162	
Transportation and handling	1,453	
Inventory control and warehousing	21,197	
Facilities maintenance	5,470	
GSE software update	14,274	
EXPENDABLE VEHICLE MAIN STAGE		$ - 0 -
EXPENDABLE VEHICLE AUXILIARY STAGE		$ 2,300,000
TOTAL AVERAGE PER FLIGHT COST		* $ 3,195,674

Table 6.12-5 AVERAGE COST PER FLIGHT Adjusted - *

AGENCY DOD

MODE 1 - REUSABLE BASIC STAGE

PROGRAM OPTION 1

LAUNCH OPERATIONS			* $ 201,648
Tug/Shuttle mating and checkout	*	$ 18,994	
Tug/Payload mating and checkout	*	27,134	
Prelaunch checkout	*	28,223	
Countdown	*	26,044	
Propellant and gases		6,286	
Post flight safing	*	29,847	
Site services and support	*	65,120	
MAINTENANCE AND REFURBISHMENT			* $ 230,168
Scheduled maintenance and refurbishment	*	$ 35,274	
Unscheduled maintenance and refurbishment	*	10,853	
Tug engine maintenance and refurbishment		11,238	
Tug vehicle spares		46,495	
Tug engine spares		6,286	
Post maintenance checkout	*	2,693	
Refurbishment requirements planning	*	10,853	
Depot maintenance		106,476	
TOTAL GROUND OPERATIONS (Launch and Maintenance and Refurbishment)			* $ 431,816
FLIGHT OPERATIONS			$ 313,000
Mission planning		$ 46,000	
Flight control		204,000	
Flight evaluation		42,000	
Flight software		21,000	
OPERATIONS SUPPORT			$ 155,620
Airborne software update		$ 9,905	
GSE maintenance		19,238	
Sustaining engineering		50,476	
Program management		32,762	
Transportation and handling		1,524	
Inventory control and warehousing		20,857	
Facilities maintenance		5,429	
GSE software update		15,429	
EXPENDABLE VEHICLE MAIN STAGE			$ - 0 -
EXPENDABLE VEHICLE AUXILIARY STAGE			$ - 0 -
TOTAL AVERAGE PER FLIGHT COST (1973 $ IN MILLIONS)			* $ 900,436

Section 7
FLIGHT SCHEDULES

This section presents programmatics input data in the form of flight schedules for Option 1 (Tables 7-1 through 7-5), a flight requirement summary (Table 7-6) depicting the annual flight composition, and a Tug fleet utilization schedule (Table 7-7). The flight schedules are provided in accordance with the formatting instructions contained in NASA letter PD-TUG-P (028-74).

These data were generated by mission accomplishment analysis in conjunction with ground launch/refurbishment and mission operations timeline and turnaround analyses. Supporting details of these analyses are reported in Volume 4, Mission Accomplishment.

The major influence on fleet sizing is the number of expendable Tug missions required. A contributing factor is the number of vehicles to be provided for contingency (expected reliability losses based on one loss per 100 vehicle flights). For Option 1 these considerations result in a total fleet buy of 13 vehicles.

Table 7-1

FLIGHT SCHEDULE

TUG CONCEPT OPTION 1

LAUNCH SITE ETR/WTR AGENCY NASA/DOD

COMPANY MDAC

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TUG (BASIC)**		3	14	16	30	(2) 26	22	(1) 21	(1) 28	20	(3) 28	(1) 20	(8) 228
AUXILIARY STAGE				(2)		(2)		(3)	(2)				(9)
DROP TANKS													0
(OTHER)	1*												1
SHUTTLE **	1*	3	14	16	30	26	22	21	28	20	28	20	229

() DENOTES NUMBER EXPENDED.

REMARKS: 20 payloads not accommodated due to Shuttle limit of 3 Tug flights in 1980

* IVU Test Flight

** Includes reflights due to Tug reliability losses

Table 7-2

F L I G H T S C H E D U L E

TUG CONCEPT OPTION 1

LAUNCH SITE ETR AGENCY NASA

COMPANY MDAC

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TUG (BASIC)		3	8	8	11	(2) 13	9	(1) 9	(1) 14	8	(3) 13	(1) 8	(8) 104
AUXILIARY STAGE				(2)		(2)		(3)	(2)				(9)
DROP TANKS													0
(OTHER)	1*												1
SHUTTLE	1*	3	8	8	11	13	9	9	14	8	13	8	105

() DENOTES NUMBER EXPENDED.

REMARKS: 9 NASA payloads not accommodated due to Shuttle limit of 3 Tug flights in 1980

* IVU Test Flight

Table 7-3

FLIGHT SCHEDULE

TUG CONCEPT OPTION 1

LAUNCH SITE ETR AGENCY DOD

COMPANY MDAC

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TUG (BASIC)			6	8	11	11	8	8	10	10	7	10	89
AUXILIARY STAGE													0
DROP TANKS													0
(OTHER)													0
SHUTTLE			6	8	11	11	8	8	10	10	7	10	89

() DENOTES NUMBER EXPENDED.

REMARKS: 11 DOD payloads not accommodated due to Shuttle limit of 3 Tug flights in 1980

Table 7-4

F L I G H T S C H E D U L E

TUG CONCEPT OPTION 1

LAUNCH SITE WTR AGENCY NASA

COMPANY MDAC

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TUG (BASIC)					3	1	3	1	2	1	4	1	16
AUXILIARY STAGE													
DROP TANKS													
(OTHER)													
SHUTTLE					3	1	3	1	2	1	4	1	16

() DENOTES NUMBER EXPENDED.

REMARKS:

Table 7-5

FLIGHT SCHEDULE

TUG CONCEPT OPTION 1

LAUNCH SITE WTR AGENCY DOD

COMPANY MDAC

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TUG (BASIC)					4	1	2	2	2	1	3	1	16
AUXILIARY STAGE													
DROP TANKS													
(OTHER)													
SHUTTLE					4	1	2	2	2	1	3	1	16

() DENOTES NUMBER EXPENDED.

REMARKS:

Table 7-6

FLIGHT REQUIREMENTS

OPTION 1

	80	81	82	83	84	85	86	87	88	89	90	TOTAL
ETR												
NASA	3	8	6	11	9	9	5	11	8	10	7	87
DOD	-	6	8	11	11	8	8	10	10	7	10	89
NASA EXPENDABLE	-	-	-	-	2	-	1	1	-	3	1	8
NASA KICK STAGE	-	-	2	-	2	-	3	2	-	-	-	9
DOD KICK STAGE	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	3	14	16	22	24	17	17	24	18	20	18	193
WTR												
NASA	-	-	-	3	1	3	1	2	1	4	1	16
DOD	-	-	-	4	1	2	2	2	1	3	1	16
TOTAL	0	0	0	7	2	5	3	4	2	7	2	32
REFLIGHTS / LOSSES				1			1			1		3

Table 7-7

EQUAL USAGE SCHEDULE

OPTION 1

	80	81	82	83	84	85	86	87	88	89	90	TOTAL
NUMBER OF FLIGHTS	3	14	16	29	26	22	20	28	20	27	20	225
NUMBER OF EXPENDED TUGS					2		1	1		3	1	8
TUG ID 1	2	4	2	3	3							14
2	1	6	2	6	6							21
3		4	4	6	5	3	2					24
4			4	6	4	3	3	3				23
5			2	4	4	4	4	2	2	2		24
6			2	4	4	4	4	2	2	2		24
7						8	7	4	3	2		24
8								10	10	2	2	24
9								7	3	8	6	24
10										11	12	23
REFLIGHTS / LOSSES				1			1			1		3

SECTION 8

COST SENSITIVITIES FOR THE PROGRAM OPTION

This section presents the results of cost sensitivities analyses for the following primary program options defined for the Tug Program Option No. 1:

- Two-Year IOC Delay
- Greater Than 36-Hour Mission Duration
- 300-Watt Power to Payload

- Two-Year IOC Delay

The objectives of this analysis involved an examination of techniques to lower peak annual funding while maintaining reasonably low DDT&E costs, and an attempt to optimize the required program ATP date. Reference is made to Subsection 11.6 which presents the methodology and cost and funding impacts which result from varying the IOC dates. The data in the following paragraphs have been extracted from Subsection 11.6.

8.1 Impact on DDT&E

A two-year delay in IOC would result in a 17.5 precent increase in DDT&E costs, from $197.0 million to $231.5 million - an increase of $34.5 million. This assumes that the October 1975 ATP date is held fixed while the IOC date is delayed two years. If however, the ATP date is delayed to October 1976 while the IOC date is delayed two years, analysis has determined that DDT&E cost is increased by 3.5 percent, or $7 million, to $204 million. Since this latter case also involved the lowest maximum cost risked to meet schedules, it would be recommended

from a DDT&E cost standpoint.

8.2 Impact on Production

A two-year delay in IOC would result in an 18 percent increase in the project level value for total production costs - a $32 million increase from $179.6 million to $211.9 million. It was determined, however, that either a one-year or two-year extension of the production schedule would permit planning production of the Vehicle Main Stage on a single-shift basis. This tended to hold the two-year delay impact down to the 18 percent - $32 million deltas, which would have been higher, if a two-shift production had been assumed. The analysis futher determined that a one-year extension of the production schedule would be more efficient and would actually achieve a 4 percent or $7 million reduction in total production costs.

8.3 Impact on Operations

Schedule impacts on operations costs were quantified on the basis of the variations in numbers of flights at the average cost per flight value. The two-year IOC delay would reduce the number of flights by 26 from the baseline - 89 versus 63. This would result in a $23.4 million reduction in operations costs - $80.1 million versus $56.7 millions.

8.4 Impact on Funding

DDT&E

Figure 8.4-1 presents the comparative DDT&E funding impacts of the two-year IOC delay. The case-1 funding curve reflects holding

	Number of Flights				
CY	'80	'81	'82	'83	'84
Baseline	3	14	16	29	27
Two-Year IOC Delay	0	0	16	20	27
Difference	-3	-14	0	-9	0

These differences are reflected in the funding curves. The minor funding difference for GFY 1991 results from calendar year versus fiscal year account for the flights.

Total Project

Figure 8.4-4 and Table 8.4-1 present the total project comparison of the two-year IOC delay, case-1, with the baseline. This case would move the funding peak year from FGY 1978 to GFY 1982 and would reduce peak year funding by 10 percent or $7.3 million, from $76.7 million to $69.4 million.

For case-2, the funding peak year also would be moved from GFY 1978 to GFY 1982 and peak year funding at $68.6 million would represent an $8.1 million, or 11 percent, reduction from the baseline. A cost comparison of the three programmatic alternates is listed below.

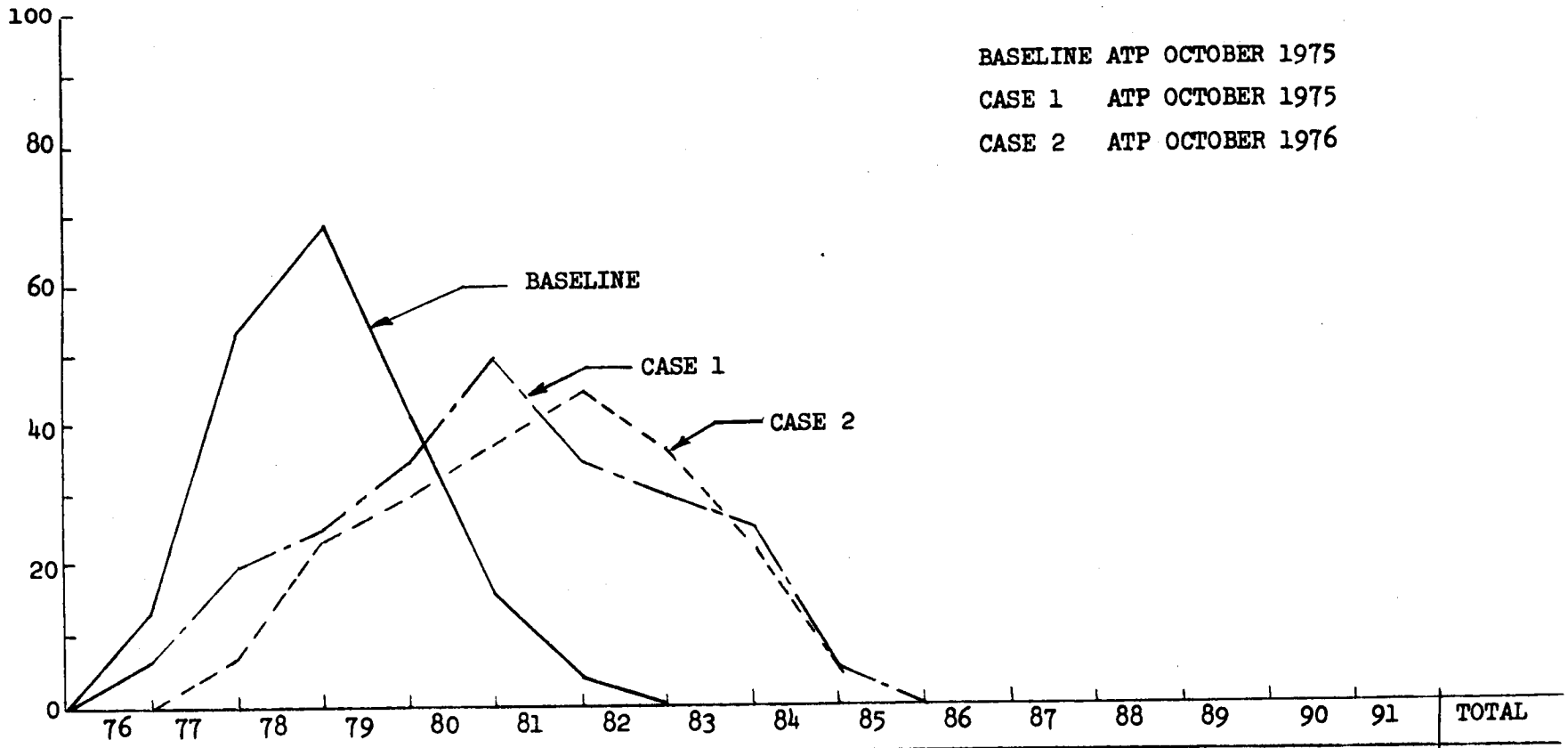
1973 DOLLARS IN MILLIONS

	Baseline	Two-year Delay in IOC			
		CASE 1		CASE 2	
		Cost	Δ	Cost	Δ
DDT&E	$197.1	$231.5	+$34.4	$204.0	+$ 6.9
Production	179.6	211.9	+ 32.3	172.5	- 7.1
Operations	200.8	177.4	- 23.4	177.4	- 23.4
Total	$577.5	$620.8	+$43.3	$553.9	-$23.6

Figure 8.4-1 OPTION NO. 1

2 YEAR IOC DELAY -- IMPACT ON DDT&E FUNDING

ANNUAL FUNDING



GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
BASELINE	12.9	53.1	68.5	40.6	17.1	4.4	0.1										197.1
CASE 1	6.5	20.0	25.0	35.0	50.0	35.0	30.0	25.0	5.0								231.5
CASE 2		6.0	23.0	30.0	37.0	45.0	36.0	22.0	5.0								204.0

the same ATP as the baseline, but delaying the IOC date by two years. This approach would move the peak funding year from GFY 1978 to GFY 1980, and would reduce peak year funding from $68.5 million to $50 million - a 27 percent reduction. The impacts of adopting the programmatics of case 2 are: (1) peak year funding would be delayed to GFY 1981; (2) peak year funding would be reduced to $45 million, while incurring a minimal cost penalty from the baseline.

Production

Figure 8.4-2 illustrates the comparative production funding impacts of the two-year IOC delay. The case-1 funding curve is the result of holding the October 1975 ATP date and delaying the IOC date by two years. The peak funding year would remain at GFY 1981, but the peak funding would be reduced by 27 percent, from $41 million to $30 million. For case-2, the ATP date is assumed to be October 1976, while retaining the two-year delay in the IOC date. The funding peak year for case-2 would be GFY 1983 - a two-year delay from the baseline - and peak year funding would amount to $25.4 million - a 38 percent reduction from the baseline.

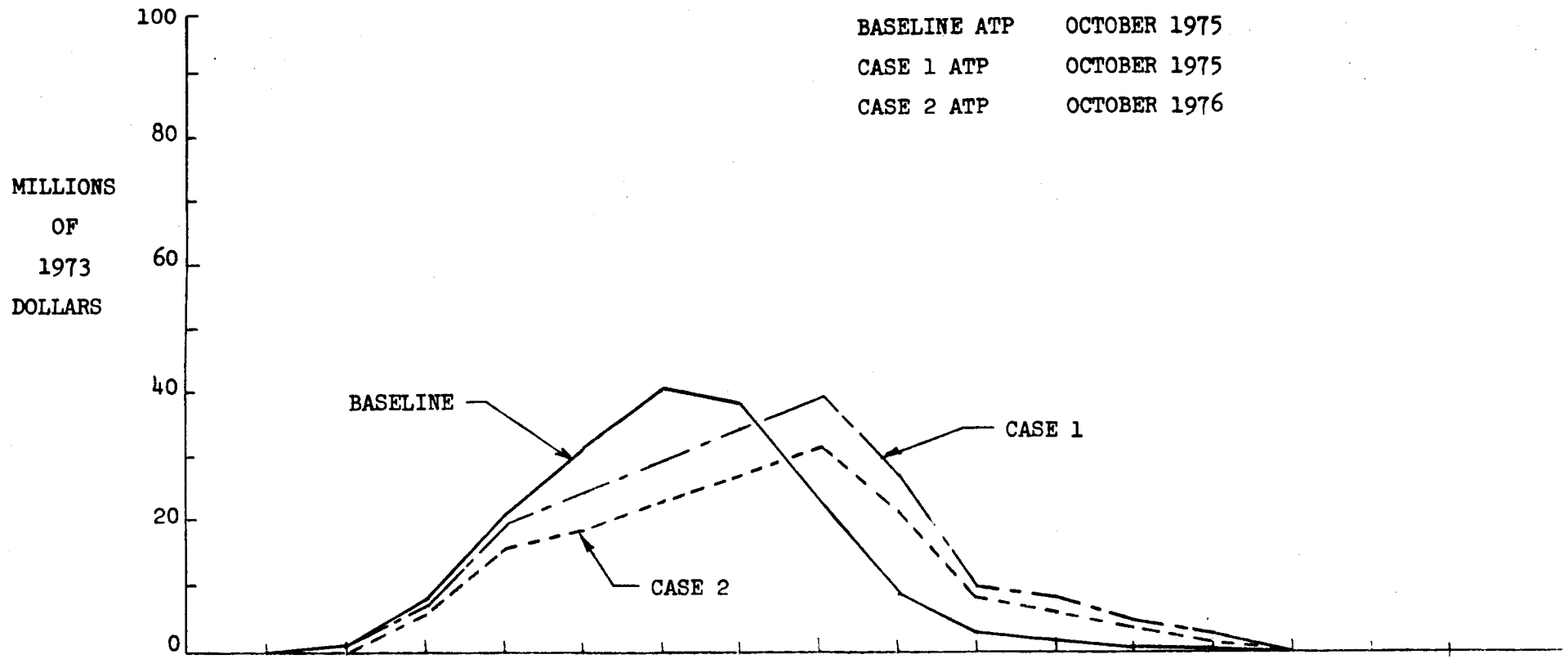
Operations

Figure 8.4-3 compares the relative funding for the two-year IOC delay and the baseline. The two-year delay in IOC reduces the number of flights in the early years of operations - as follows:

FIGURE 8.4-2 OPTION NO. 1

2 YEAR IOC DELAY-IMPACT ON PRODUCTION FUNDING

ANNUAL FUNDING

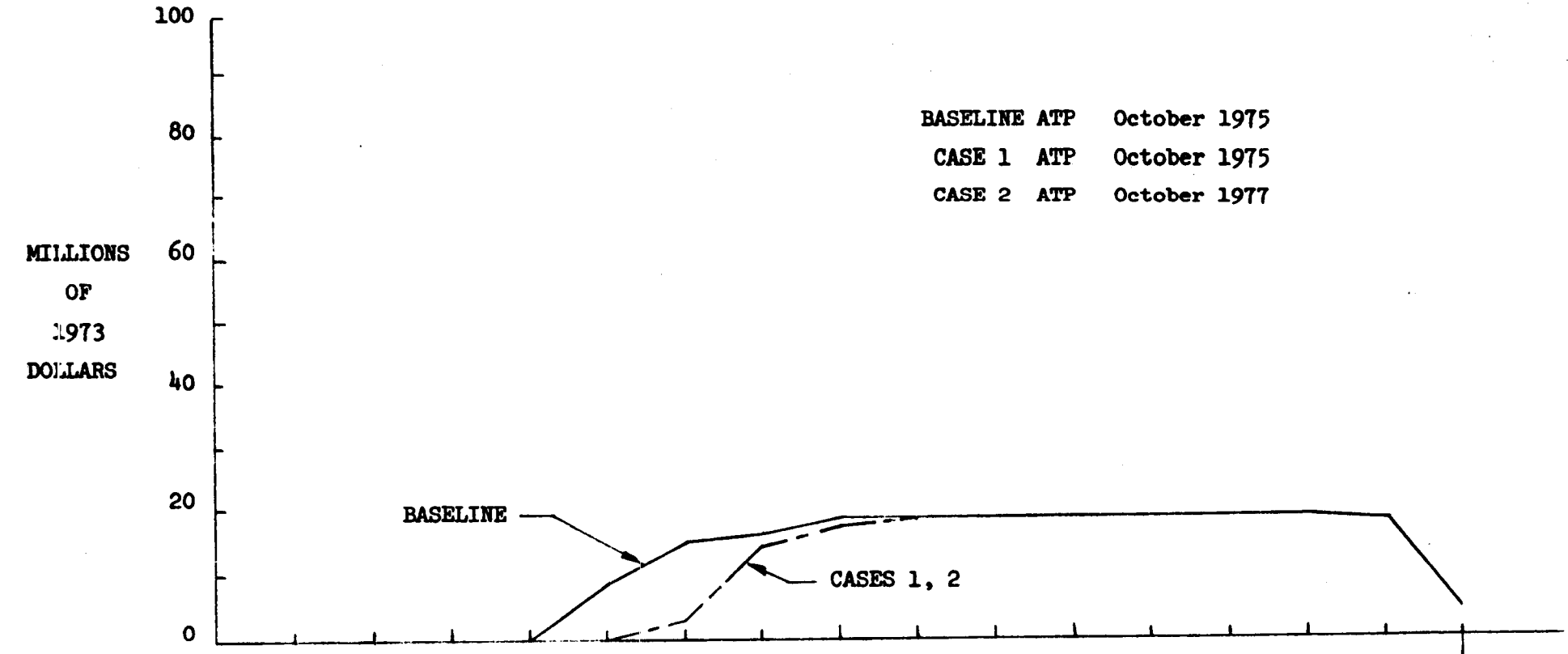


GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
BASELINE	-	0.9	8.2	21.4	32.1	41.0	39.8	23.2	8.5	2.8	1.6	0.4					179.6
CASE 1		1.0	8.0	20.0	25.0	30.0	35.0	40.0	27.0	10.0	8.0	5.0	3.0				211.9
CASE 2			6.6	16.4	20.0	24.5	28.6	32.7	22.1	8.2	6.6	4.3	2.5				172.5

FIGURE 8.4-3 OPTION No. 1

2 YEAR IOC DELAY - IMPACT ON OPERATIONS FUNDING

ANNUAL FUNDING



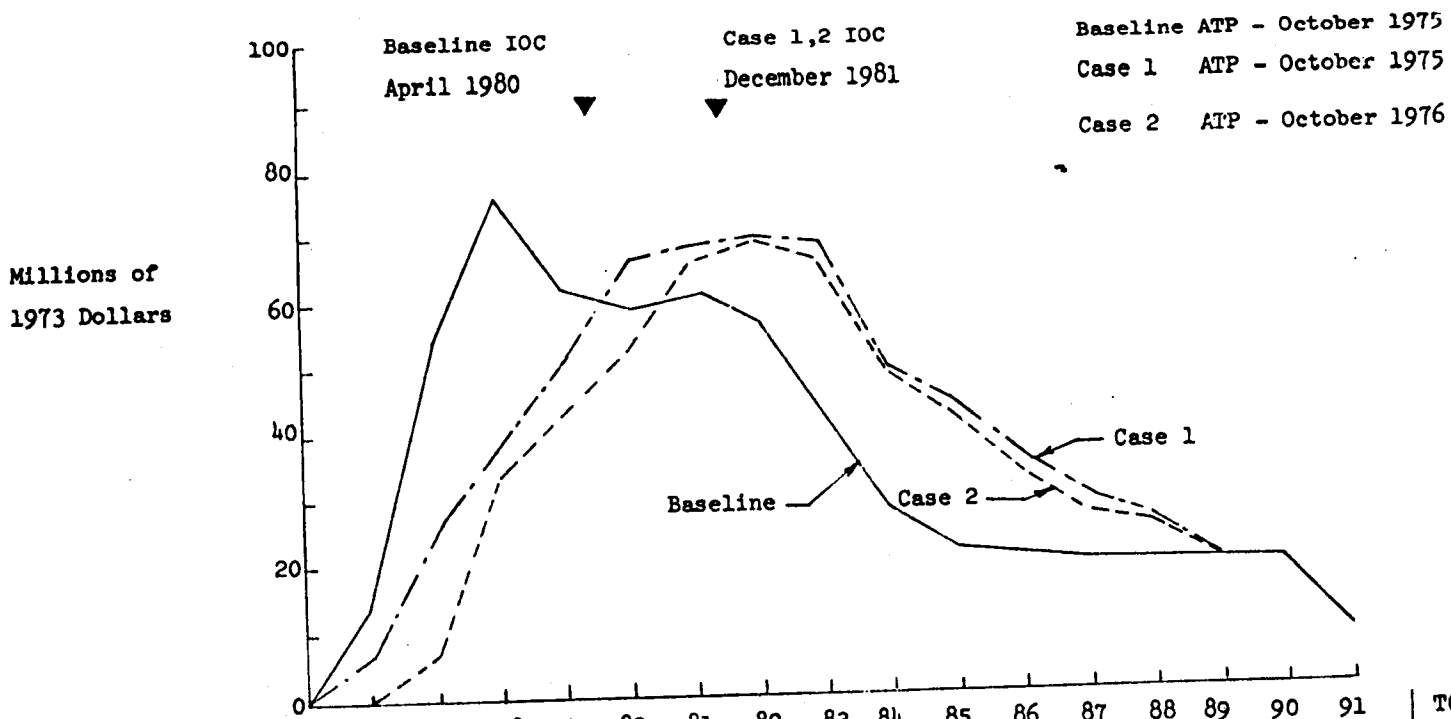
GFY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
BASELINE					8.8	15.2	15.9	19.0	19.0	19.0	19.0	19.0	19.0	19.0	18.8	9.1	200.8
CASE 1						2.7	14.4	18.0	19.0	19.0	19.0	19.0	19.0	19.0	18.8	9.5	177.4
CASE 2						2.7	14.4	18.0	19.0	19.0	19.0	19.0	19.0	19.0	18.8	9.5	177.4

OPTION 1

2 YEAR IOC DELAY - IMPACT ON TOTAL PROJECT FUNDING

WBS 320 LEVEL 3 - TOTAL SPACE TUG PROJECT

ANNUAL FUNDING



GVT. FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
BASELINE	12.9	54.0	76.7	62.0	58.0	60.6	55.8	42.2	27.5	21.8	20.6	19.4	19.0	19.0	18.8	9.1	577.5
CASE 1	6.5	25.0	37.5	50.0	66.0	67.7	69.4	68.0	49.0	44.0	36.0	29.0	25.4	19.0	18.8	9.5	620.8
CASE 2		6.0	33.4	42.0	51.4	65.2	68.6	65.4	48.0	42.3	33.7	25.6	25.0	19.0	18.8	9.5	553.9

FIGURE 8.4-4

8-8

OPTION 1

2 YEAR IOC DELAY - IMPACT ON TOTAL PROJECT FUNDING AND COST

WBS 320 LEVEL 3 - TOTAL SPACE TUG PROJECT

ANNUAL FUNDING - TABULAR

GOVT. FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
BASELINE																	
DDT&E	12.9	53.1	68.5	40.6	17.1	4.4	0.1										197.1
PRODUCTION		0.9	8.2	21.4	32.1	41.0	39.8	23.2	8.5	2.8	1.6	0.4					179.6
OPERATIONS					8.8	15.2	15.9	19.0	19.0	19.0	19.0	19.0	19.0	19.0	18.8	9.1	200.8
TOTAL	12.9	54.0	76.7	62.0	58.0	60.6	55.8	42.2	27.5	21.8	20.6	19.4	19.0	19.0	18.8	9.1	577.5
CASE 1																	
DDT&E	6.5	20.0	25.0	35.0	50.0	35.0	30.0	25.0	5.0								231.5
PRODUCTION		5.0	12.5	15.0	16.0	30.0	25.0	25.0	25.0	25.0	17.0	10.0	6.4				211.9
OPERATIONS						2.7	14.4	18.0	19.0	19.0	19.0	19.0	19.0	19.0	18.8	9.5	177.4
TOTAL	6.5	25.0	37.5	50.0	66.0	67.7	69.4	68.0	49.0	44.0	36.0	29.0	25.4	19.0	18.8	9.5	620.8
CASE 2																	
DDT&E		6.0	23.0	30.0	37.0	45.0	36.0	22.0	5.0								204.0
PRODUCTION			10.4	12.0	14.4	17.8	18.2	25.4	24.0	23.3	14.7	6.6	6.0				172.5
OPERATIONS						2.7	14.4	18.0	19.0	19.0	19.0	19.0	19.0	19.0	18.8	9.5	177.4
TOTAL		6.0	33.4	42.0	51.4	65.2	68.6	65.4	48.0	42.3	33.7	25.6	25.0	19.0	18.8	9.5	553.9

TABLE 8.4-1

- Greater Than 36-Hour Mission Duration

A sensitivity study was performed to determine the impact on the Option 1 vehicle of extending its mission duration capability from 1-1/2 days to 6 days. The impact was assessed for the following two cases:

Case-1 - The degradation in geosynchronous deployment capability with extended mission duration was determined for no substitutions in the Option 1 subsystems. The only changes made were to increase the batteries and ACPS propellant capacity commensurate with the increasing power and attitude stabilization requirements.

Case-2 - For this case, subsystems were selectively changed as a function of extended duration wherever the geosynchronous deployment capability fell below the initial 36-hour value.

Reference is made to Section 9 of Volume 5 for detail of this analysis.

8.1 Impact on DDT&E

Case-1 - No additional DDT&E costs were identified for this case.

Case-2 - Project level costs were quantified for the subsystem variations and are displayed in Table 8.1-1. LEADER II Cost Model methodology was used to estimate the costs.

TABLE 8.1-1

SUBSYSTEM DDT&E COSTS(1) FOR INCREASED MISSION DURATION

(1) Project level values in 1973 $ Millions

OPTION 1 SUBSYSTEM	UPDATED SUBSYSTEM	Δ DDT&E
Ambient He Repressurization DDT&E = 3.321 $M	Heated He Repressurization DDT&E = 4.377 $M	+1.056 $M
AGENA Technology AG-Zn Batteries DDT&E = 0.197 $M	G. E. Fuel Cells DDT&E = 9.285 $M	+9.088 $M
Radiation-Barrier DDT&E = 1.210 $M	Multilayer Insulation DDT&E = 2.950 $M	+1.740 $M
Blowdown N2 H4 DDT&E = 9.734 $M	N2 O4/MMH DDT&E = 16.329 $M	+6.595 $M

8.2 Impact on Production

Production costs for the subsystem elements were estimated, using LEADER II Cost Model methodology, for the 13 vehicles required by this program option. The costs were calculated at the project level and are presented in Table 8.2-1.

TABLE 8.2-1

SUBSYSTEM PRODUCTION COSTS (1) FOR INCREASED MISSION DURATION

(1) Project level values (13 vehicles) in 1973 $ millions

OPTION 1 SUBSYSTEM	UPDATED SUBSYSTEM	Δ PRODUCTION
Ambient He Repressurization Production = 4.459 $M	Heated He Repressurization Production = 6.006 $M	+ 1.547 $M
AGENA Technology AG-Zn Batteries Production = .715 $M	G. E. Fuel Cells Production = 12.311 $M	+11.596 $M
Radiation-Barrier Production = 6.760 $M	Multilayer Insulation Production = 5.733 $M	- 1.027 $M
Blowdown Ne H4 Production = 12.227 $M	N2 H4/MMH Production = 17.615 $M	+ 5.278 $M
TOTAL Production = 24.271 $M	TOTAL Production = 41.665 $M	TOTAL +17.394 $M

8.3 Impact on Operations

Table 8.3-1 presents the flight operations cost sensitivity to increase a mission duration. These are DDT&E flight operations

costs for software development and crew training. There would be no impact on recurring operations costs, since the flight operations costs for the baseline already requires continuous 24-hour coverage.

TABLE 8.3-1

FLIGHT OPERATION COSTS SENSITIVITY TO INCREASED MISSION DURATION

Mission Time (hours)	36	72	144
DDT&E ($M)	9.98	10.58	11.72
Costs ($M)	0	0.60	1.74
Percent Increase in DDT&E Costs/Hr	0	0.166	0.162

8.4 Impact on Funding

No funding impacts were determined, since this was not identified as a requirement.

- 300-Watts Power to Payload

The purpose of this sensitivity study was to determine the impact of adding the capability to provide the payload with 300 watts of continuous power.

The Option 1 primary power system utilizes batteries. Because of this it was felt the minimum impact would be obtained by the addition of more battery power, rather than changing to a different power source such as a fuel cell.

The current Option 1 power system contains two 775-amp-hr batteries, based on AGENA design. It was determined that substituting three 650-amp-hr AGENA-based design batteries provided ample additional power to supply the payload 300 watts continuous, not only for the 11.9-hour deployment time, but throughout a full mission, should a sortie mission be required.

Refer to Section 9.1 of Volume 5 for details of this analysis.

8.1 Impact on DDT&E

Because the batteries differ only in unit size and are based on the same state-of-the-art design, no additional DDT&E cost could be identified.

8.2 Impact on Production

The first unit production cost for three 650-amp-hr batteries was estimated to be some $11,500 per vehicle higher than the cost of two 775-amp-hr batteries used in the current Option 1 design. The total production impact for the fleet of 13 units of vehicle main stage is tabulated below:

TOTAL PRODUCTION COST

1973 DOLLARS IN MILLIONS

	BASELINE	300-W to Payload	Δ
(2) 775 AH Batteries	$.317	-	+$.101
(3) 650 AH Batteries	-	$.418	

8.3 Impact on Operations

Operations cost impacts were calculated as the comparative cost of 224 shipsets following the 13 shipsets used in production. The 224 shipsets were comprised of 212 replacements and 12 spares (at 5 percent). The respective costs are tabulated below.

TOTAL OPERATIONS COSTS

(224 SHIPSETS)

1973 DOLLARS IN MILLIONS

BASELINE (2 - 775 AH)	300-W to Payload (3 - 650 AH)	Δ
$3.400	$4.486	+$1.086

8.4 Impact on Funding

No funding impacts were quantified, since this was not identified as a specific requirement. However, the following tabulation is presented to summarize the above project phase impacts.

300-WATTS POWER TO PAYLOAD SUMMARY

1973 DOLLARS IN MILLIONS

	DDT&E	PRODUCTION	OPERATIONS	TOTAL
BASELINE				
(2) 775 AH Batteries	$ .080	$ .317	$ 3.400	$ 3.797
300-W to Payload				
(3) 650 AH Batteries	$ .080	$ .418	$ 4.486	$ 4.984
Δ	-0-	+$ .101	+$ 1.086	+$ 1.187

SECTION 9

RISK ASSESSMENT

The following paragraph is quoted directly from the Statement of Work:

5.4.1.1 Project Assessment

> "The contractor shall conduct a study to identify all development risk (technical and cost) uncertainties involved with each concept and option studied. An assessment of the operations and capabilities risks of developing various Tug configurations for various levels of development costs will be made. Technical and programmatic uncertainties that could significantly affect the schedules, costs, or that could result in failure to achieve any vital capability requirements will be identified and discussed. Special consideration should be given critical technology areas, critical design factors (e.g., mass fraction), off-the-shelf vs. new hardware development, design sensitivities, etc. This activity will be conducted throughout the study and will be coordinated closely with all other tasks at appropriate times."

To quantify the technical, cost, and schedule uncertainties, requested above, MDAC-W used a Risk Assessment Scoring Guide (see the accompanying Tables). This guide provides a range of values from 0 to 10, i.e., "no risk" to "high risk" for different defined levels of the following four criteria: estimating conditions; nature of the item; item description; and method of analysis and data. Using the Risk Assessment Scoring Guide, multi-discipline teams (representing the engineering technologies, manufacturing, test, logistics, safety, reliability, ground and flight operations, cost, schedule, and program management experts, as appropriate) assigned risk values to each of the WBS elements at the lowest WBS level considered meaningful. Separate data sheets were developed for each program option for the DDT&E, the production, and the operational phases.

The risk values assigned at the lower WBS levels were summarized to the subsystems level, the systems level, and then the project level. Any WBS element receiving a risk value of 5 or higher is discussed, and the reasons for the moderate to high risk value documented. NOTE: The highest risk value assigned at the lower WBS level is the risk value carried forward at the summary WBS level.

Table 9-1

RISK ASSESSMENT SCORING GUIDE

RANGE	ESTIMATING CONDITIONS
8, 9, 10	Estimating Time and Information Access Completely inadequate amount of time provided to make the estimate or there is a complete lack of access to useful data sources. Ground Rules and Assumptions No guidance was provided on ground rules and all assumptions made by the analyst were arbitrary.
5, 6, 7	Estimating Time and Information Access A very short due date or major problems of access to available data tend to make this estimate highly uncertain. Ground Rules and Assumptions Very little guidance was provided relative to ground rules. Most of the assumptions made by the analyst were considered quite arbitrary.
2, 3, 4	Estimating Time and Information Access A more accurate estimate could have been made if freer access or more time had been available to research known data sources. Ground Rules and Assumptions Ground rules were generally inadequate. Many of the assumptions were authenticated but a substantial number are considered questionable.
0, 1	Estimating Time and Information Access There were minor problems of access to available data and there was generally sufficient time to define the item. Ground Rules and Assumptions Major ground rules were provided and most of the assumptions were authenticated.

MCDONNELL DOUGLAS CORPORATION

Table 9-2

RISK ASSESSMENT SCORING GUIDE

RANGE	NATURE OF THE ITEM
8, 9, 10	State-of-the-Art The item is substantially beyond the current state-of-the-art. Major development work is required. Production Experience No production of any kind has been started.
5, 6, 7	State-of-the-Art The item is slightly beyond the state-of-the-art and some development work will be required. Production Experience Experimental laboratory fabrication of a similar item is in process.
2, 3, 4	State-of-the-Art The item is within the state-of-the-art but no commercial counterpart exists. Production Experience A prototype of the item has been produced.
0, 1	State-of-the-Art The item will involve a minor modification of commercial or standard aerospace issue items. Production Experience The item has been produced in limited quantity.

MCDONNELL DOUGLAS CORPORATION

Table 9-3

RISK ASSESSMENT SCORING GUIDE

RANGE	ITEM DESCRIPTION
8, 9, 10	Specification Status No work on a specification has started. Operating Program Characteristics None of the OPC for using the item have been formulated.
5, 6, 7	Specification Status Work on a specification is in an early stage and only general requirements are identified. Operating Program Characteristics The general outline of the OPC under which the item will be used has been only tentatively defined and many specific details are lacking.
2, 3, 4	Specification Status A specification for the item has not been completed but a specification on a similar item is available. Operating Program Characteristics The general outline of the OPC has been formulated, but many specific details are lacking.
0, 1	Specification Status A specification for the item has been prepared but is under review or revision. Operating Program Characteristics The OPC have been substantially defined, but are under review or revision.

MCDONNELL DOUGLAS CORPORATION

Table 9-4

RISK ASSESSMENT SCORING GUIDE

RANGE	METHODS OF ANALYSIS AND DATA
8, 9, 10	**Methods** The estimate is almost a poor guess and little or no confidence can be placed in it. **Data** An almost total lack of current and reliable relevant data make the estimate completely uncertain.
5, 6, 7	**Methods** A highly arbitrary rule-of-thumb has been used. **Data** The data used to make the estimate are highly suspect, very sparse in quantity, and characterized by major inconsistencies.
2, 3, 4	**Methods** A commonly used rule-of-thumb, but with no supporting backup, has been used. **Data** The data have been obtained from official or standard sources. Notable inconsistencies, lack of currency, or gaps in data reduce the confidence in the estimate.
0, 1	**Methods** The basic method used to derive the data is well documented, but no double-check or authentication has been possible. **Data** The data used are generally relevant and from a reputable source. They are incomplete, preliminary, or not completely current, however.

MCDONNELL DOUGLAS CORPORATION

RISK ASSESSMENT SUMMARY PROGRAM OPTION 1

The Space Tug project is in the early stages of program definition (Phase A). We are confident that as definition of the hardware, software, and programmatics evolve, that the risk values identified will dimish significantly. Therefore, we assess Program Option 1 as a moderately low risk program.

On a scale of 0 to 10 (i.e., low risk to high risk respectively) the average life-cycle risk values for Option 1 are: 2.4 for Cost; 1.9 for Schedule; and 2.4 for Technical performance. (Refer to RISK ASSESSMENT SUMMARY on the following page). These relatively low risk values mean that the multi-discipline team of experts, who have assessed the uncertainties in accomplishing the cost, schedule, and technical objectives and assigned the risk values, have a moderately high degree of confidence that all objectives will be met for every WBS element in every phase of the project. Their collective judgments are based on the following:

1) Specifications on similar hardware and software items are available;
2) The hardware and software subsystems/components are well within the state-of-the-art and (as a minimum) prototype items have been produced (in many cases off-the-shelf hardware is selected);
3) The estimating ground rules and assumptions were generally adequate although subject to some question; and
4) The data have generally been obtained from reliable sources.

In the Risk Assessment Data Sheets accompanying this Summary, a narrative risk assessment is provided for all cost, schedule, and technical risk values of 5 or greater. It is significant that most of the moderate to high risk values shown are due to the preliminary or incomplete nature of the information available and are

not due to technical or capability uncertainties, Therefore, as further definition of the program evolves, we can expect a corresponding decrease in all risk values.

Table 9-5

RISK ASSESSMENT SUMMARY PROGRAM OPTION 1

Risk Values (0 = Low; 10 = High Risk)

	Risk Area		
Project Phase	Cost	Schedule	Technical
DDT&E	2.9	1.8	2.7
PROD	2.2	1.6	2.4
OPNS	2.1	2.2	2.1
Average Life Cycle Risk Values	2.4	1.9	2.4

Table 9-6 (Page 1 of 9)

RISK ASSESSMENT DATA SHEET

Program Option 1, DDT&E Phase
Page 1 of 5

WBS Element	Risk Values 0 = Low; 10 = High			Risk Assessment (Risk Values of 5 or Greater)
	Cost	Sched	Tech	
320-01 Project Management	3	1	1	
320-02 Systems Engr & Integration	3	1	1	
320-03 Vehicle Main Stage				
-01 Structures	2	2	2	
-02 Thermal Control	2	2	4	
-03 Avionics	2	1	3	
-04 Propulsion	2	1	3	
-05 Orbiter Interface	5	1	6	Prelim. Spec. Definition (Cost); Prelim. Abort Data & Analysis (Tech)
-06 Drop Tanks	N/A	N/A	N/A	
-07 Final Ass'y & c/o	2	2	5	Pressure/Chemical/Heat Hazards (Tech)
320-04 Vehicle Auxiliary Stage	5	GFE	1	Mfg. Start-up on Poseidon Questionable (Cost)

Table 9-7 (Page 2 of 9)

RISK ASSESSMENT DATA SHEET

WBS Element	Risk Values 0 = Low; 10 = High			Risk Assessment (Risk Values of 5 or Greater)
	Cost	Sched	Tech	
320-05 Logistics	3	3	1	
320-06 Facilities	5	3	1	Prelim. Info Only (Cost)
320-07 Ground Support Equipment	3	2	5	Prelim. Info for GSE Software (Tech)
320-08 Vehicle Test	3	2	4	
320-09 Launch Opns - WTR	-	-	-	
320-10 Launch Opns - ETR	-	-	-	
320-11 Flight Opns - WTR	2	3	2	
320-12 Flight Opns - ETR	2	3	2	
320-13 Refurb & Integration - WTR	-	-	-	
320-14 Refurb & Integration - ETR	-	-	-	
TOTAL SCORE	44	27	41	
MAXIMUM SCORE POSSIBLE	150	150	150	
RISK VALUE (0-10 SCALE)	2.9	1.8	2.7	

Table 9-8 (Page 3 of 9)

RISK ASSESSMENT DATA SHEET

WBS Element	Risk Values 0 = Low; 10 = High Cost	Sched	Tech	Risk Assessment (Risk Values of 5 or Greater)
320-03 Space Tug Vehicle Main Stage				
-01 Structures	2	2	2	
Fuel Tank & Support			2	
Oxidizer Tank & Support			2	
Body Structure			2	
Thrust Structure			2	
Meteoroid Shield			2	
Payload Interface			1	
Installation, Assembly & Check.				
-02 Thermal Control	2	2	5	Prelim. info (tech)
Fuel Tank Insulation			4	
Oxidizer Tank Insulation			3	
Insulation Purge System			4	
Control System			3	
Installation, Assembly & Check.			5	Bonding definition required

Table 9-9 (Page 4 of 9)

RISK ASSESSMENT DATA SHEET

Program Option 1, DDT&E Phase
Page 4 of 5

WBS Element	Risk Values 0 = Low; 10 = High Cost	Sched	Tech	Risk Assessment (Risk Values of 5 or Greater)
320-03 Space Tug Vehicle Main Stage				
-03 Avionics	2	1	3	
Data Management	1		3	
GN&C	1		3	
Communications	2		2	
Instrumentation	1		1	
Electrical Power	1		1	
Power Distribution & Control	1		2	
Installation, Assembly & Check.	1		3	
-04 Propulsion	2	1	4	
Main Engine (GFE)			4	
Main Engine Support			3	
ACPS Engine			0	
ACPS Engine Support			2	
Installation, Assembly & Check.			2	

Table 9-10 (Page 5 of 9)

RISK ASSESSMENT DATA SHEET

WBS Element	Risk Values 0 = Low; 10 = High Cost	Sched	Tech	Risk Assessment (Risk Values of 5 or Greater)
320-03 Space Tug Vehicle Main Stage				
-05 Orbiter Interface	5	1	6	Prelim. info (cost); prelim. spec. definition (tech)
Structures			2	
Interface Panels			3	
Purge Provisions			4	
Abort Provisions			6	Abort techniques & operational interfaces have been derived by analysis
Installation, Assembly & Check.			4	
-06 Drop Tanks	N/A	N/A	N/A	
Structures				
Thermal Insulation				
Propellant Support System				
Installation, Assembly & Check.				
-07 Final Assembly & Checkout	2	2	5	
Final Assembly			3	
Checkout			5	Pressure/chemical/heat hazards (tech)
-04 Space Tug Vehicle, Aux. Stage	5	GFE	1	Manufacturing start-up on Poseidon questionable (cost)

Table 9-11 (Page 6 of 9)

RISK ASSESSMENT DATA SHEET

Program Option 1, PROD Phase
Page 1 of 2

WBS Element	Risk Values 0 = Low; 10 = High			Risk Assessment (Values of 5 or Greater)
	Cost	Sched	Tech	
320-01 Project Management	2	1	1	
320-02 Systems Engr & Integration	2	1	1	
320-03 Vehicle Main Stage				
-01 Structures	2	2	4	
-02 Thermal Control	2	2	1	
-03 Avionics	2	1	3	
-04 Propulsion	2	1	3	
-05 Orbiter Interface	3	1	5	Prelim. Spec. Definition (Tech)
-06 Drop Tanks	N/A	N/A	N/A	
-07 Final Ass'y & c/o	2	2	5	Pressure/Chemical/Heat Hazards (Tech)
320-04 Vehicle Auxiliary Stage	5	GFE	GFE	Mfg. Start-up on Poseidon Questionable (Cost)

Table 9-12 (Page 7 of 9)

RISK ASSESSMENT DATA SHEET

Program Option 1, PROD Phase
Page 2 of 2

WBS Element	Risk Values 0 = Low; 10 = High			Risk Assessment (Values of 5 or Greater)
	Cost	Sched	Tech	
320-05 Logistics	2	3	1	
320-06 Facilities	1	3	1	
320-07 Ground Support Equipment	1	2	4	
320-08 Vehicle Test	-	-	-	
320-09 Launch Opns - WTR	-	-	-	
320-10 Launch Opns - ETR	-	-	-	
320-11 Flight Opns - WTR	-	-	-	
320-12 Flight Opns - ETR	-	-	-	
320-13 Refurb & Integration - WTR	-	-	-	
320-14 Refurb & Integration - ETR	-	-	-	
TOTAL SCORE	26	19	29	
MAXIMUM SCORE POSSIBLE	120	120	120	
RISK VALUE (0-10 SCALE)	2.2	1.6	2.4	

Table 9-13 (Page 8 of 9)

RISK ASSESSMENT DATA SHEET

Program Option 1, OPNS Phase
Page 1 of 2

WBS Element	Risk Values 0 = Low; 10 = High			Risk Assessment (Values of 5 or Greater)
	Cost	Sched	Tech	
320-01 Project Management	-	-	-	
320-02 Systems Engr & Integration	-	-	-	
320-03 Vehicle Main Stage				
-01 Structures	1	2	1	
-02 Thermal Control	1	2	1	
-03 Avionics	1	1	2	
-04 Propulsion	1	1	3	
-05 Orbiter Interface	1	1	1	
-06 Drop Tanks	N/A	N/A	N/A	
-07 Final Ass'y & c/o	N/A	N/A	N/A	
320-04 Vehicle Auxiliary Stage	1	GFE	1	

Table 9-14 (Page 9 of 9)

RISK ASSESSMENT DATA SHEET

Program Option 1, OPNS Phase
Page 2 of 2

WBS Element	Risk Values 0 = Low; 10 = High			Risk Assessment (Values of 5 or Greater)
	Cost	Sched	Tech	
320-05 Logistics	2	3	1	
320-06 Facilities	3	3	1	
320-07 Ground Support Equipment	2	2	1	
320-08 Vehicle Test	-	-	-	
320-09 Launch Opns - WTR	3	3	4	
320-10 Launch Opns - ETR	3	3	4	
320-11 Flight Opns - WTR	3	3	4	
320-12 Flight Opns - ETR	3	3	4	
320-13 Refurb & Integration - WTR	3	3	2	
320-14 Refurb & Integration - ETR	3	3	2	
TOTAL SCORE	31	33	32	
MAXIMUM SCORE POSSIBLE	150	150	150	
RISK VALUE (0-10 SCALE)	2.1	2.2	2.1	

9-16

Section 10

SUPPORTING RESEARCH AND TECHNOLOGY (SR&T)

The SR&T requirements for Option 1 are shown in Table 10-1. Because of the high emphasis on low DDT&E associated with this option very little SR&T has been identified.

The first item, development of potential hazard/failure detection techniques, relates to safety and is applicable to any tug program, regardless of funding constraints. The second item relates to establishing basic data required to develop an effective thermal control system.

The SR&T for this option is equal to approximately 0.4% of total DDT&E.

The following paragraphs give a more detailed explanation of each SR&T item identified in the table.

10.1 STRUCTURES

10.1.1 Develop Potential Hazard/Failure Detection Techniques

Technology Deficiencies

Shuttle and Shuttle payloads present new challenges in reliability and safety requirements because of the necessity of reusable space transportation elements. In current space missions such as Skylab, for example, only limited attention was given to failure detection techniques for overboard or on-board leaks which might present a toxic, fire, or explosion hazard. A comprehensive study program on a damage control system for leaks was carried out by MDAC in 1970-72 for the 10 year Space Station. (NAS 1-10184 and NAS 1-10840.) The results of this program provides the basis for identifying failure detection techniques for future space systems.

The Space Tug in terms of hazards and failure modes presents a major safety threat as regards tank explosions and leaks leading to toxic/fire effects and gas explosions damaging the Orbiter. In addition to the major LOX/LH_2 tankage, similar considerations apply to ancillary propellants, fuel cells, and general plumbing. For the Tug system, conventional ground based NDE techniques are

Table 10-1

S R & T S U M M A R Y - - O P T I O N 1

WBS ELEMENT/OPTION	TECHNOLOGY REQUIREMENT	COST ($M)	TIME(YEARS)	REQUIRED START TIME
320-03-01 STRUCTURES	DEVELOP POTENTIAL HAZARD/FAILURE DETECTION TECHNIQUES	0.75	1.5	CY 2/75
320-03-02 THERMAL CONTROL RADIATION BARRIER AND PURGE BAG	ESTABLISH THERMAL PERFORMANCE, MATERIAL PROPERTIES AND PURGE BAG MATERIAL AND FAB. TECHNIQUES	0.09	1.0	9/75
	TOTAL	0.84		

inadequate. What is required is a permanently installed monitoring system which will give early warning of leaks or precursor damage notes so as to allow effective remedial action to be taken.

A continuous monitoring system should perform a dual function: (1) Monitor potential modes in space and (2) Function as part of the ground checkout system prior to launch.

Recommended Solution(s)

A primary failure detection technique which shows great promise as applied to Space Tug is the acoustic method. In-house MDAC research has demonstrated the power of this method in detecting leaks and precursor damage modes from a variety of fluids (gas and liquid) including cryogens. Piezoelectric acoustic transducers permanently mounted on tanks and related plumbing can perform in both a passive and active mode. In the passive monitoring mode, a transducer array can detect and locate by triangulation techniques: (1) dynamic flaws that can lead to leaks or catastrophic failures. Acoustic emission bursts are emitted by dynamic flaws which can be detected. (2) Physical leaks. The fluid leaking through the container will generate a unique ultrasonic signal which propagates in the container wall and is detected by transducers bonded to the wall. Active mode operation is envisioned as being employed during ground checkout as part of NDE operations. In this mode, Lamb waves would be propagated in the tank wall to detect flaws.

To complement the acoustic detection technique, a tape detection technique is judged promising for plumbing, valves, etc., where acoustic signals may not be present. An example would be a leak from a flange or heavily insulated pipe. For tape methods, electrical resistance, color change, or blistering phenomena are all potentially useful.

Schedule

The proposed schedule for this effort is shown on Table **10.1.1-1.**

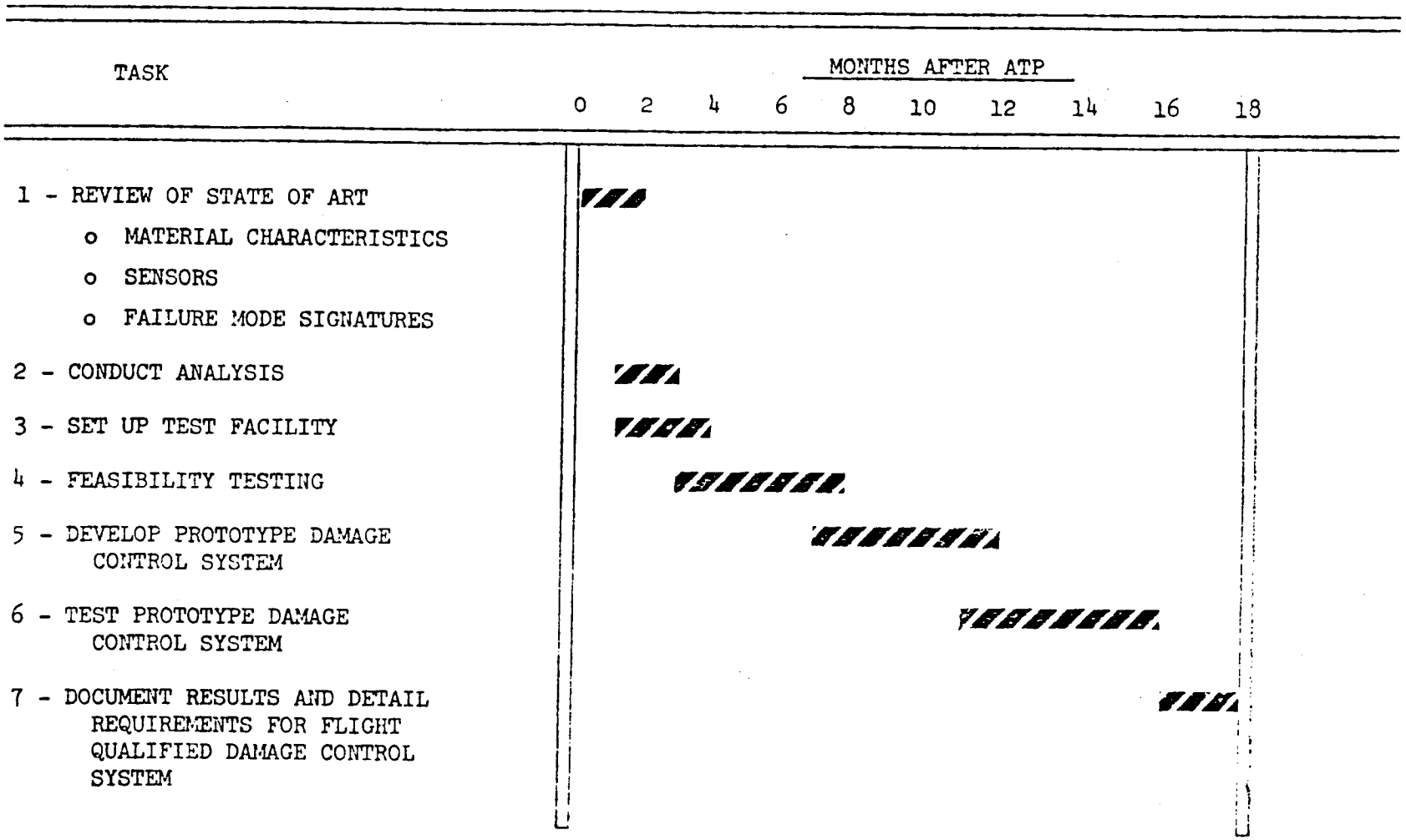
Level of Effort

The projected level of effort is based upon past experience on damage control systems. For an 18 month program resulting in the development and test of a prototype damage control system, funding requirements are estimated at $750,000.

Table 10.1.1-1

SR&T SCHEDULE

DAMAGE CONTROL SYSTEM



	18 Month Time Period
Manpower (6 man years/year)	9 man years
Funding	
Engrg + Technician	$500,000
Equipment + Materials	200,000
Miscellaneous (Travel Reports, etc.)	50,000
	$750,000

10.2 THERMAL CONTROL

A survey of the supporting research and technology (SR&T) requirements related to the insulation systems on the fuel and oxidizer tanks was accomplished. This effort identified three areas in which further information is required. These are shown in Table 10.2-1. An estimated one year is needed for this effort.

The effects of configuration variables on the thermal performance could be accomplished with small samples on a calorimeter. The MDAC heat flux gage calorimeter would be well-suited for this testing. This calorimeter is discussed in References 1 and 4. The insulation referred to in Table 10.2-1 is that between the LH_2 tank and the radiation barrier on this tank. Several data points for each configuration variable would be obtained to allow a more optimum design in future systems of this type.

The material property at LH_2 temperature of primary interest is brittleness. Testing of the candidate materials to ensure selecting materials which will maintain their structural integrity at LH_2 temperatures is needed. Subjecting the candidate materials to the thermal cycling anticipated in a reusable system is also needed to ensure proper material selection for applications of this type.

The effort needed for the purge bag includes both the evaluation of candidate bag materials and the bag fabrication techniques. The testing involved would include environmental testing of the bag material and strength and leakage testing of the potential techniques for joining the gore segments of the bag. The selection and attachment of closures would also be considered.

Table 10.2-1

SR&T REQUIREMENTS

REQUIREMENT	$ (THOUSAND)
THERMAL PERFORMANCE - EFFECT OF CONFIGURATION VARIABLES	50
(A) INSULATION THICKNESS (GROUND HOLD PERIOD HEATING)	
(B) INSULATION MATERIAL	
(C) STANDOFFS	
MATERIAL PROPERTIES	10
(A) AT LH_2 TEMPERATURES	
(B) EFFECT OF THERMAL CYCLING	
PURGE BAG	30
(A) MATERIAL	
(B) FABRICATION TECHNIQUES	
TOTAL	90

Section 11
SPECIAL COST SENSITIVITIES

This section discusses a series of special cost sensitivity analyses conducted for Option 1 as called for by the Government-furnished outline and as required by action item 54 from the First Review Meeting. The majority of these trades can be examined in the light of their effects upon production and operations costs since most of the variables in question affect the number of flights and the increase or decrease in flight hardware (Tug vehicles or kick stages) required to support the change in traffic. The sensitivity of program cost to changes in schedule is a different and more complex analysis. Section 11.6 describes this analysis for Option 1.

11.1 COST VS PAYLOAD WEIGHT

Variations in payload weight of ± 20% were examined for impact on number of flights and for changes in flight hardware required. The resulting program cost sensitivity is shown in the following table.

PAYLOAD WEIGHT CHANGE	SENSITIVITIES				
	NUMBER OF FLIGHTS		HARDWARE CHANGE		DOLLARS
	ΔFLIGHTS	Δ$	ΔHARDWARE	Δ$	TOTAL IN M
+20%	+8	+7.2	+32 Ks	+17.8	+25.0
-20%	-3	-2.7	0	0	- 2.7

11.2 COST VS TRAFFIC RATE

Variations in traffic rate of ± 10% were examined for impact on number of flights and for changes in flight hardware required. The resulting program cost sensitivity is shown in the following table:

OPTION 1 TRAFFIC RATE CHANGE	SENSITIVITIES				
	NUMBER OF FLIGHTS		HARDWARE CHANGE		DOLLARS
	ΔFLIGHTS	Δ$	ΔHARDWARE	Δ$	TOTAL IN M
+10%	+22	+19.8	0	0	+19.8
-10%	-22	-19.8	0	0	-19.8

11.3 COST VS DRY WEIGHT

Variations in vehicle dry weight of ± 10% were examined for impact on number of flights and for changes in flight hardware required. The resulting program cost sensitivity is shown in the following table:

OPTION 1 DRY WEIGHT CHANGE	SENSITIVITIES				
	NUMBER OF FLIGHTS		HARDWARE CHANGE		DOLLARS
	ΔFLIGHTS	Δ$	ΔHARDWARE	Δ$	TOTAL IN M
+10%	+46	+44.4	+2 TUG +60 Ks	+24.44 +36.60	+102.4
-10%	-9	-8.1	0	0	-8.1

11.4 COST VS DELETION OF EXPENDABLES

Deletion of expendables was examined for impact on number of flights and for changes in flight hardware required. The resulting program cost sensitivity is shown in the following table:

	SENSITIVITIES				
	NUMBER OF FLIGHTS		HARDWARE CHANGE		DOLLARS
OPTION 1	ΔFLIGHTS	Δ$	ΔHARDWARE	Δ$	TOTAL IN M
DELETE EXPENDABLES	-8	-7.2	-7 TUG	-85.5	-92.7

11.5 COST VS. CHANGE IN ISP (10 SEC.)

	SENSITIVITIES				
	NUMBER OF FLIGHTS		HARDWARE CHANGE		DOLLARS
OPTION 1 CHANGE IN ISP	ΔFLIGHTS	Δ$	ΔHARDWARE	Δ$	TOTAL IN M
+10 SEC	-9	-8.1	0	0	-8.1
-10 SEC	+13	+11.7	+42 Ks	+25.6	+37.3

11.6 Cost versus Schedule

Cost and funding impacts were quantified for variations from the baseline schedule. The variations used were ± one and ± two years. Costs and funding were estimated for these schedule variations in terms of DDT&E, and production. Schedule impacts on operations and funding were quantified based on the variation in number of flights at an average cost per flight (reference adjusted average cost per flight values presented in Subsection 6.12).

DDT&E IMPACT

Methodology

DDT&E cost impacts were quantified in relation to the baseline schedule as shown in simplified form in Figure 11.6-1. The baseline schedule of 54 months, from 1 October 1975 ATP to 1 April 1980 IOC, was considered to be a reasonable schedule for a reasonable cost. The CDR point, 26 months after ATP, was considered to be the point at which dollars could not buy time. These assumptions are shown as basics on the graph in Figure 11.6-2. It also was assumed that the baseline DDT&E cost, identified as C1 on the graph, was equivalent to an index of 100 percent, since it is an expected or reasonable cost for a reasonable schedule. C1 is composed of two elements F1, or costs that are fixed with time, and V1, or costs that are variable with time. At the baseline IOC point, both F1 and V1 were considered to be 50 percent of C1. The fixed costs which vary directly with time include such ele-

PROGRAM OPTION I
BASELINE SCHEDULE

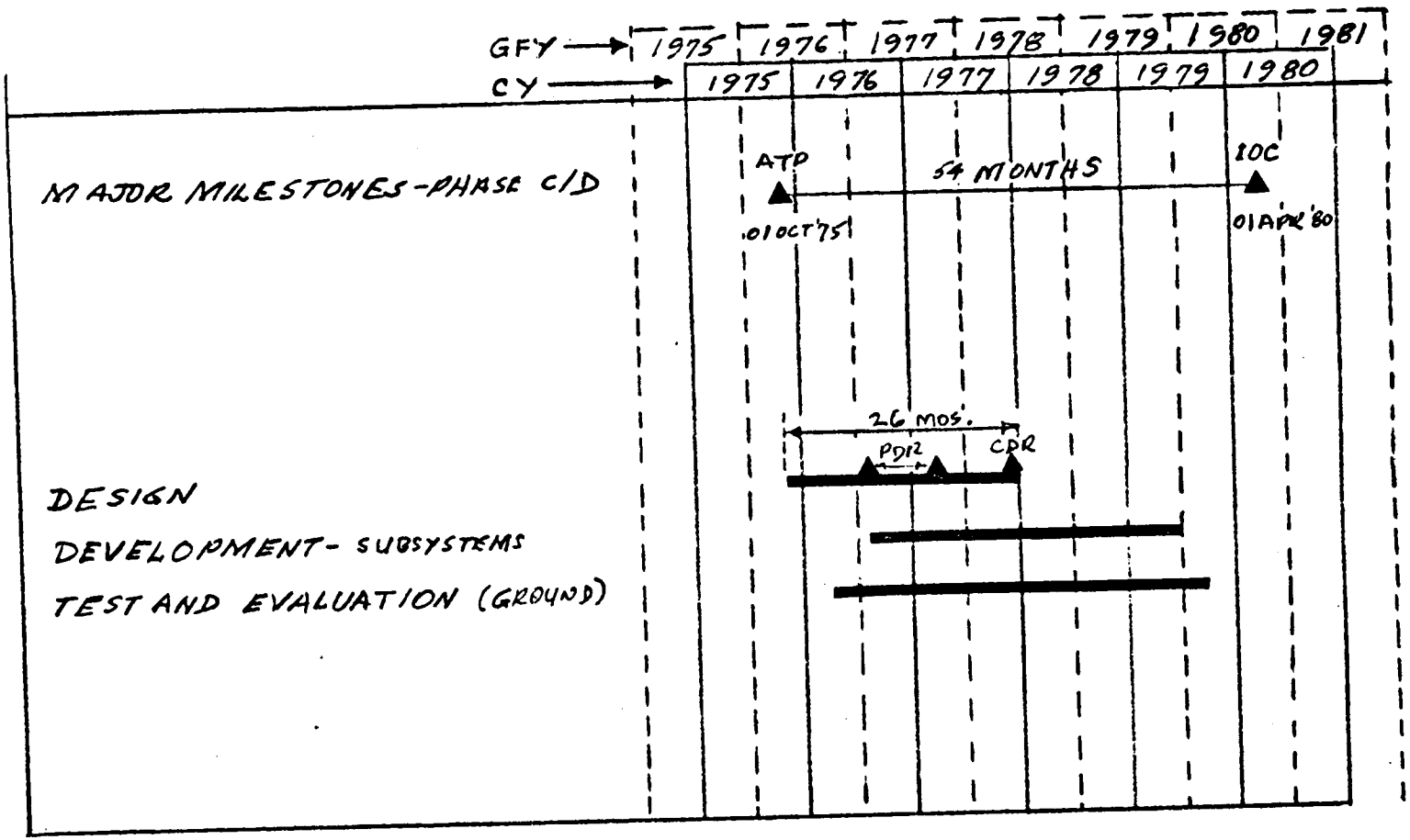
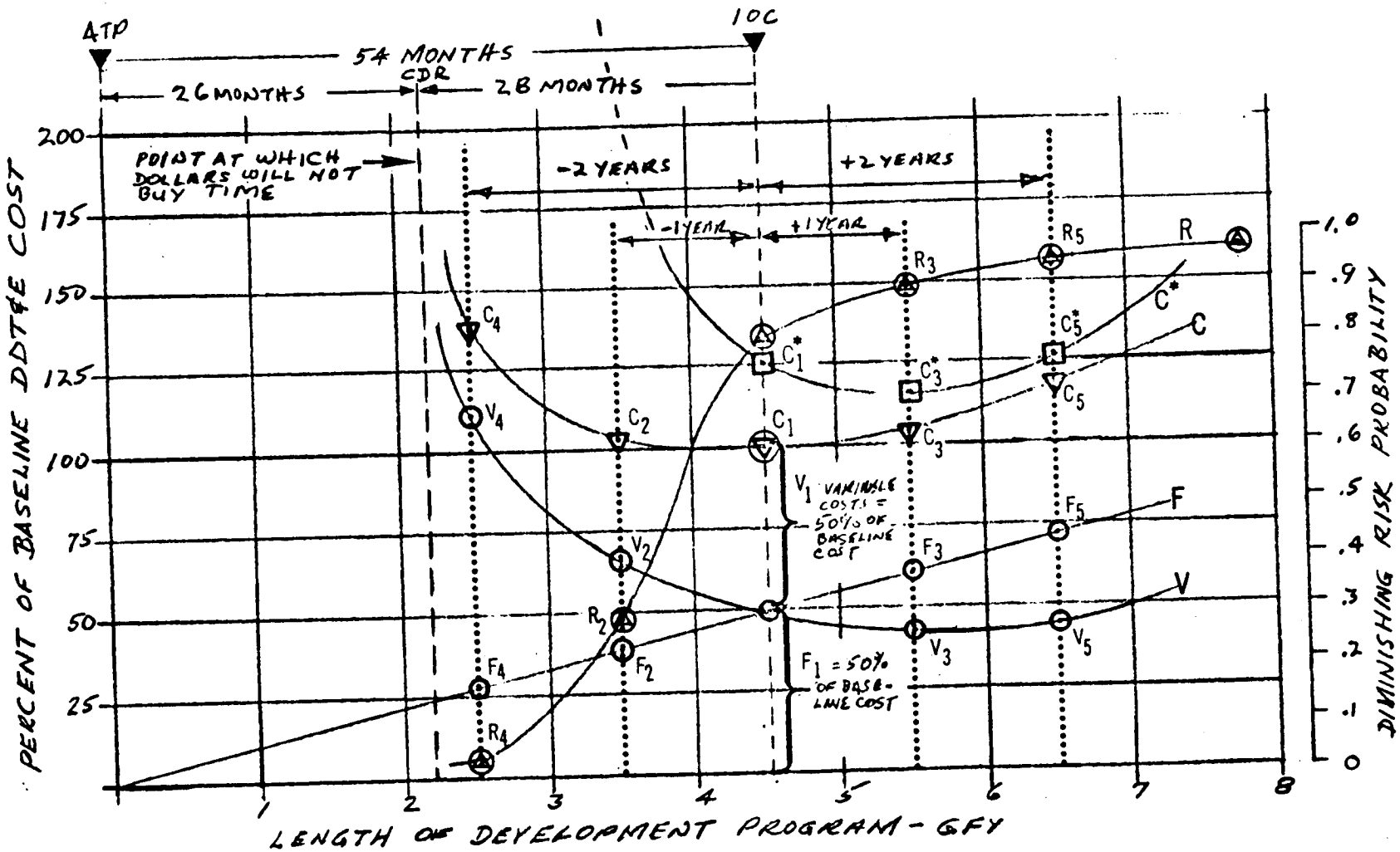


Figure 11.6-1

ments as depreciation, interest, overhead dollars and labor corps. The variable costs which vary inversely with time (excluding risk) includes such elements as overtime premium, shift differential rates, and worker inefficiency. The values for F are those along the straight line "F" at the intercepts with the schedule variation points. The values for "V" at these intercepts are those for a parabolic line, derived from historical experience, which passes through the 50 percent value at IOC. The values along line "C" are the summations of respective "F" and "V" values, which are tabulated in Figure 11.6-3 for the equation Cn = Fn + Vn. The "R" curve is a diminishing risk probability curve and related to the scale at the right of Figure 11.6-2. Along this curve, R4 at a value of .03, represents the point at which it would be impractical to try to reduce the diminishing risk probability below the .03 value. At the other end of the curve, R5 at .97 represents the point at which it would be impractical to try to achieve the 1.0 diminishing risk probability. R1 at IOC was considered to have a diminishing risk probability of .8. The remaining values along this curve were based on experienced judgement. All values along the curve reflect the probability of not meeting program objectives in terms of cost and schedule - - it having been assumed that performance objectives could be achieved equally well for any of the posulated cost/schedule combinations. The Rn values are tabulated in Figure 11.6-3. The C* curve in Figure 11.6-2, and the corresponding table in Figure 11.6-3, show the index of maximum cost risked to meet development objectives. The C* values were derived using the equation:

$$C^*n = Cn \div Rn$$

PROGRAM OPTION 1
DEVELOPMENT SCHEDULE-RISK-COST SENSITIVITY ANALYSIS



MCDONNELL DOUGLAS CORPORATION

Figure 11.6-2

PROGRAM OPTION No. 1

DEVELOPMENT SCHEDULE/RISK COST ESTIMATES

$C_n = F_n + V_n$

n	F	V	C
4	.275	1.000	1.375
2	.375	.650	1.025
1(Base)	.500	.500	1.000
3	.610	.425	1.035
5	.725	.450	1.175

R_n

n	R
4	.30
2	.27
1	.80
3	.90
5	.94

$C^*_n = C_n + R_n$

n	C	R	C*
4	1.375	.30	4.583
2	1.025	.27	3.796
1	1.000	.80	1.250
3	1.035	.90	1.150
5	1.175	.94	1.250

APPLYING FACTORS TO OPTION NO. 1

DDT&E COST AT $197.05 MILLION

n	SCHEDULE ADJUSTMENT IN YEARS	EXPECTED COST		MAXIMUM COST RISKED TO MEET SCHEDULE	
		C	1973 $ MIL	C	1973 $ MIL
4	-2	1.375	270.94	4.583	903.08
2	-1	1.025	201.98	3.796	748.00
1	0	1.000	197.05	1.250	246.31
3	+1	1.035	203.95	1.150	226.61
5	+2	1.175	231.53	1.250	246.31

FIGURE 11.6-3

Applying the factors to the baseline DDT&E cost for Program Option No. 1 resulted in the two sets of cost impacts shown in Figure 11.6-3. The initial table shows the expected cost impacts. The second table presents the dollar values for C*.

Cost Sensitivities

The expected cost table in Figure 11.6-3 indicates that the following conclusions might be drawn:

- o The development schedule could be varied by ± one year with only minimal impact on DDT&E cost (2.5 - 3.5%).
- o A two-year extension of the development schedule would increase DDT&E cost by 17.5%.
- o A two-year compression of the DDT&E schedule would increase DDT&E costs by 37.5%.

The table of maximum cost risked to meet schedule provides the basis for another significant conclusion:

- o That by extending the baseline schedule by one year, the C* value can be reduced from the baseline index of 1.25 to an index of 1.15. The corresponding cost could be reduced from $246 million to $227 million.

Combining these conclusions lead to further conclusions:

- o That, from a DDT&E cost/risk standpoint, it would be preferable to:

- Delay ATP one year, from October 1975 to October 1976.

- Extend by one year the months between ATP and IOC, thus achieving a two-year delay of IOC from the baseline.

o That, the results of these actions would be:

- Only a 3.5% increase in DDT&E cost (from $197 to $204 million).

- A reduction in the maximum cost risked to meet schedule from $246 to $227 million, or -8%.

PRODUCTION IMPACT

Methodology

The methodology followed in determining production rate cost sensitivity due to schedule adjustment was similar to that followed for DDT&E. The impacts were quantified for variations of ± one year and ± two years from the baseline schedule. Figure 11.6-4 summarizes the cost methodology and the resultant cost sensitivities. The equation shown assumes that the baseline cost for the baseline schedule has an index of 1.0 and that the index is composed of two equal factors (.5 each). One factor is that which results from elements variable with time, while the second factor represents the elements that are fixed with time. Measurement of the schedule variation impact on the variable factor was accomplished using the equation element by which the new number of production months was divided by a parabolic equation form. The fixed element cost impact

PROGRAM OPTION NO. 1

PRODUCTION RATE COST SENSITIVITY

1973 DOLLARS IN MILLIONS

	SCHEDULE ADJUSTMENT IN YEARS	PRODUCTION RATE PER YEAR	PRODUCTION RATE FACTOR (1)	VEHICLE MAIN STAGE COSTS TOTAL	VEHICLE MAIN STAGE COSTS AVG. UNIT	TOTAL PROJECT PRODUCTION COSTS $ (3)	TOTAL PROJECT PRODUCTION COSTS TOTAL $
	-2	6.20	1.5428	167.96	12.92	+77.29	256.86
	-1	3.72	1.1691	127.28	9.79	+19.24	198.81
Baseline	0	2.89	1.0453	113.80	8.75	-	179.57
	-1	2.36	1.0000	108.87	8.37	- 7.04	172.53
	+2	2.00	1.2531	136.42	10.49	+32.28	211.85

Note: (1) Factor derived from following equation:

$$\text{New Expected Cost Factor (NECF)} = \left\{ \left[\underbrace{\frac{\text{New No. Months}}{\left[-66.52 + (3.2 * \text{New No. Mos.})\right]}}_{\text{Variable Elements Cost Impact}} \right. \right. \underbrace{\times .5 \left(\begin{array}{c}\text{Baseline}\\ \text{Expected}\\ \text{Cost Factor}\\ \text{(BECF)}\end{array}\right)}_{\text{Assume Baseline Includes .5 Variable Elements}} \left. \right] + \left[\underbrace{\left(\frac{\text{New No. Mos.}}{\text{Base No. Mos}}\right)}_{\text{Fixed Element Cost Impact}} \underbrace{\times .5 \left(\begin{array}{c}\text{Baseline}\\ \text{Expected}\\ \text{Cost Factor}\\ \text{(BECF)}\end{array}\right)}_{\text{Assume Baseline Includes .5 Fixed Elements}} \right] \left. \right\} \underbrace{+ F'}_{\text{Assume Planning Prior to Prod. Start has F' Effect}}$$

(NNM) (2) (4)

(2) Parabolic equation derived from least squares regression analysis

(3) Project level costs; include system level and + S.E. and I at .382 and Project Management at .045

(4) F' = Normalized index derived from equation: $F' = \frac{42.99\ (\text{New No. Months})^{-1.06}}{F \text{ of Case No. Months}}$

FIGURE 11.6-4

was determined by the simple equation form which divided the new number of months by the base number of months. In addition to the values produced by substituting the appropriate variables, it was felt that the index should be adjusted to reflect the influence of planning the production approach for a given rate. This planning would start prior to production initiation, of course. The F' equation was derived to fulfill this function.

Cost Sensitivities

Figure 11.6-4 presents the tabulated results of applying the production rate factor to schedule and companionate production rate variations from the baseline. The baseline rate was established as that needed to have two vehicles available at IOC. The production rate factor for the baseline case was computed at 1.045 versus 1.00 for a schedule adding one year to the production time, which meant that the rate of 2.36 per year would yield an index of 1.0, or the lowest vehicle main stage production cost (system level). Analysis also revealed that the 2.36 rate could be achieved with a single shift (versus two-shift for the baseline) production force. It is this more efficient approach which is reflected in the equation variables used to generate the index. The table also presents average unit costs for the production of thirteen units of the vehicle main stage.

A separate table within Figure 11.6-4 presents the total project level production cost impacts in terms of Delta (change) from the baseline, as well as total cost. These values were calculated by adding the costs for Systems Engineering and Integration (SE&I) and Project Management. At the total project level a reduction

of seven million dollars could be achieved by lengthening the production schedule by one year. The other schedule/rate variations result in significant increases in total production cost.

OPERATIONS IMPACT

Methodology

Schedule impacts on operations costs were quantified based on variation in the number of flights at an average cost per flight. (Reference Section 6.12 of this book and volume.) The relative numbers of flights used for the two-year IOC delay program were as follows:

NUMBER OF FLIGHTS

Cy	'80	'81	'82	'83	'84	TOTALS	
Baseline	3	14	16	29	27	89	Same Number of Flights After 1984
Cost at $.9M/Flight	$ 2.7	$12.6	$14.4	$26.1	$24.3	$80.1	
Two-year IOC Delay	0	0	16	20	27	63	
Cost at $.9M/Flight	0	0	$14.4	$18.0	$24.3	$56.7	

Cost Sensitivity

From the calculations above, the two-year IOC delay would have the following impact on operations costs:

For Two-Year IOC Delay

Number of Flights = (89-63) = 26

Operations Cost = ($80.1 - $56.7) = $23.4M

Section 12

DOD ACQUISITION APPROACH (AFSCP 800-3)

By agreement with the NASA/SAMSO COR's submittal of this section for Option 1 has been deferred until after the Data Dump.

SECTION 13

13 COST ESTIMATING METHODOLOGY

13.1 Overall Cost Methodology

13.1.1 Summary

Existing, proven analytical tools in the hands of experienced analysts have been utilized to achieve the study objective of reliable, consistent, well-defined and documented "should cost" estimates and funding projections within the constraints of budget and schedule. The ability to effectively and realistically estimate costs and funding is dependent upon three major factors: (1) completeness and comprehensiveness of definitions; (2) the validity of an applicable data base; and (3) the ability to relate these two factors utilizing highly qualified estimators.

The LEADER II cost model has been used to relate the technical and programmatic definitions, provided by other members of the study team, to the Cost Data Base stored in the cost model and to generate cost estimates and funding analyses in accordance with the NASA-approved WBS. The estimates effectively correlate technical performance, schedules and costs. As a rapid, multi-faceted, techno-economic tool for estimating costs, funding and manpower, LEADER II has been used to measure higher-level cost and funding impacts of lower level alternatives. Its use contributes to the credibility, consistency and traceability of the cost estimates. It has been used to generate the cost and funding of Space Tug Project's total life cycle and elements thereof based on CER's (Cost Estimating Relationships), cost factors, or direct inputs values.

The CER's and cost factors, which constitute the LEADER II data base, have been developed over a seven-year period from data quotes, and study values of function, physical, performance, schedule and cost on a number of major programs. The basic data used in the LEADER II data base were derived principally from Thor/Delta, SIV/SIVB, Sky Lab, SOAR II, Gemini, MOL, Sortie/Lab, Saturn/Apollo, and Titan. In addition, data specifically for the Space Tug has been received from prospective suppliers in response to formal Requests for Information. The cost model, as modified to conform to the Space Tug WBS, encompasses 865 lines of data (each for the basic equations and the variable file) and a cross reference matrix of 276 lines.

As depicted in Figure 13.1.1-1, development of the CER's began with collecting and validating applicable physical, performance and cost data and then normalizing the data to a common baseline. The data were then classified within homogeneous groupings. Multivariable regression analysis and other statistical techniques were used to identify these parameters which best predicted costs, and to derive the equations, or CER's, which expressed the costs as a function of technical/performance values. The CER's were tested and validated before being incorporated into the cost model. Each of the steps in CER development was documented to provide a traceable record from raw source data and rationale and methodology used in the analyses, through CER development and validation.

Having adequate and valid cost data is a primary requisite for the development of reliable CER's. As an organizational element of

CER DEVELOPMENT CYCLE

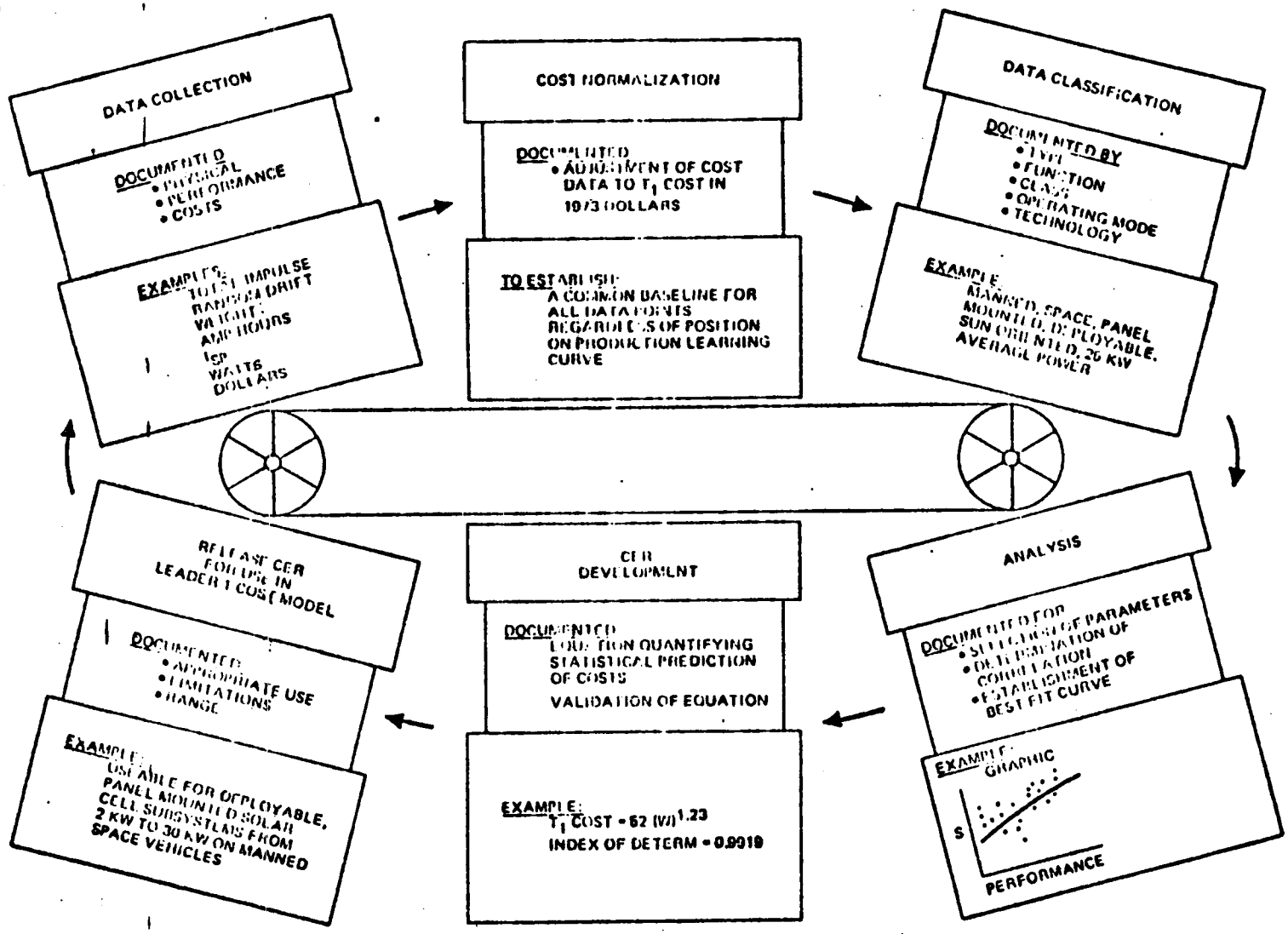


Figure 13.1.1-1

the Fiscal Management Subdivision, the Advance Systems Cost Analysis team uniquely has access to historical and proprietary data contained in its departmental data bank. The Data Bank for many years has actively collected, catalogued and stored pertinent techno-economic and cost information obtained from industry, government agencies and non-profit organizations. The Data Bank serves as a repository for departmental and technical or performance data.

A description of the cost estimating technique for each WBS element, as appropriate, is contained in Table 13.1.1-1

13.1.2 Assumptions, Ground Rules and Rationale

13.1.2.1 Cost estimates are in constant 1973 dollars.

13.1.2.2 Cost estimates have been developed in consonance with the Government provided Space Tug Systems Studies Work Breakdown Structure and Dictionary, PD-Tug-P, dated 7 May 1973, and with clarifications/amendments thereto appearing in the following documents: (1) Data Package, Spage Tug Systems Studies, April 1973; (2) Memorandum PD-Tug-P (020-74), dated 10 August 1973, from PD-Tug-P/Mr. Stucker to PD-Tug-C/Mr. Orillion, subject: Changes to the Work Breakdown Structure and Dictionary. Figure 13.1.2.2-1 displays the WBS as amended.

13.1.2.3 Candidate concept costs have been estimated and are reported at or below the WBS level shown in the Government provided WBS Diagram and Dictionary. The costs have been estimated at the same level of detail as the technical data, which generally has been

OVERALL COST METHODOLOGY

STUDY TITLE: SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO.: NAS 8-29677

DATE: 5 September 1973

WBS ELEMENT		ESTIMATING TECHNIQUE APPLIED
WBS NUMBER	WBS INDENTIFICATION	
320	Total Tug Project	Summation of lower level values
320-01	Project Management	Percentages of costs excluding Project Management and Systems Engineering and Integration
320-02	Systems Engrg. & Integration	DDT&E - Percentage of WBS 320-03 Vehicle Main Stage DDT&E cost Production - Level of effort computed as a function of vehicle complexity, production schedule, production rate, and Total Production Cost for WBS 320-03, Vehicle Main Stage. Operations - Time-related level of effort.
320-03	Vehicle Main Stage	Summation of lower level values.
320-03-01	Structures Subsystem	Summation of lower level CER's and direct estimates expressing costs as a function of designs, types of material, power, performance, methods of fabrication, quantities, and other considerations as summarized on Data Form-B. Main Engine costs were provided by the Government. CER's were cross-checked against vendor quotes for certain assemblies and components.
320-03-02	Thermal Control Subsystem	
320-03-03	Avionics Subsystem	
320-03-04	Propulsion Subsystem	
320-03-05	Orbiter Interface Subsystem	Initial Spares and Operational Spares calculated as decimal portions of First Unit Cost of Assembly Hardware (Level 6) following the Production Quantity x Quantity of Spares at Level 6 on the appropriate Learning Curve.
320-03-06	Drop Tanks Subsystem	None required
320-03-07	Final Assembly & Checkout	Percentage of subsystems costs excluding Final Assembly and Checkout.

Table 13.1.1-1

OVERALL COST METHODOLOGY

STUDY TITLE: SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO.: NAS 8-29677

DATE: 5 September 1973

PAGE 2 OF 4

WBS ELEMENT		ESTIMATING TECHNIQUE APPLIED
WBS NUMBER	WBS INDENTIFICATION	
320-04	Vehicle Auxiliary Stage	Stage costs supplied by the Government. Adaptation/Integration costs estimated using CER's at Subsystem/Assembly levels.
320-05	Logistics	Summation of lower level values
320-05-01	Transportation & Handling	Cost/Trip x Number of Trips
320-05-02	Training	Summation of Lower Level Values
320-05-02-01	Simulation and Equipment	Vehicle equivalent Units x Unit Cost
320-05-02-02	Training	Ground Crew / Flight Operations } Labor Man-Months x Cost/Man-Month
320-05-03	Inventory Control & Warehousing	Labor Man-Months x Cost/Man-Month
320-06	Facilities	Summation of lower level values Design and Construction - Quantities by Site x Current Unit Values Activation - Percentage of Design/Construction Cost Maintenance - Factor/Year x Number of Years
320-07	Ground Support	Summation of lower level values Hardware - Unit Cost x Number of Units at each Location - Factory, ETR and WTR Activation - Percentage of Hardware Cost Software - Number of Words x Average Cost/Word Maintenance: Hardware - Percentage/Year x Number of Years Software - Update Cost/Flight x Number of Flights

Table 13.1.1-1

WBS ELEMENT		ESTIMATING TECHNIQUE APPLIED
WBS NUMBER	WBS INDENTIFICATION	
320-08	Vehicle Test	Summation of Lower Level Values
320-08-01	Ground Test Hardware	Number of equivalent units by Subsystem and Assembly
320-08-02	Ground Test Operations	Number of Man-Months by Skill x Rates Per Man-Month by Skill
320-08-03	Flight Test Hardware	Number of equivalent complete units of Vehicle Main Stage x First Unit Cost of Vehicle Main Stage
320-08-04	Flight Test Operations	Number of Man-Months by Skill x Rates Per Man-Month by Skill
320-09	Launch Operations - WTR	Summation of Lower Level Values
320-09-01	Launch Site Services/Support	Summation of number of Man-Months by Skill, by Shift, by Task, by specific year x Rates Per Man-Month by Skill
320-09-02	Tug/Shuttle Mating and Checkout	
320-09-03	Prelaunch Checkout	
320-09-04	Countdown	
320-09-06	Post-Flight Safing	
320-09-05	Propellant and Gases	Number of pounds Per Flight x Costs Per Pound (Provided by the Government) x Number of Flights
320-10	Launch Operations - ETR	Same as 320-09
320-11	Flight Operations - NASA	Summation of Lower Level Values
320-11-01	Mission Planning	Summation of: [Number of Man-Months by Skill, by Task, by Specific Year, by Agency x Rates Per Man-Month by Skill] + [Number of Computer Hours Per Year x Cost Per Computer Hour]
320-11-02	Flight Control	
320-11-03	Flight Evaluation	
320-11-04	Flight Support Software	

Table 13.1.1-1

OVERALL COST METHODOLOGY

STUDY TITLE: SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO.: NAS 8-29677

DATE: 5 September 1973

WBS ELEMENT		ESTIMATING TECHNIQUE APPLIED
WBS NUMBER	WBS INDENTIFICATION	
320-12	Flight Operations - DOD	Same as 320-11
320-13	Refurbishment and Integration - WTR	Summation of Lower Level Values
320-13-01	Scheduled Maintenance and Refurbishment	Summation of the Number of Man-Months by Skill, by Shift, by Task, by Specific Year x Rates Per Man-Month by Skill
320-13-02	Unscheduled Maintenance and Refurbishment	
320-13-03	Post Maintenance Checkout	
320-13-04	Tug/Payload Mating and Checkout	
320-13-05	Refurbishment Requirements Plannint	
320-13-06	Depot Maintenance	Summation of Per Flight Values per Subsystem x Number of Flights. Per Flight Values Per Subsystem derived from analyses at Assembly and Component Levels - Levels 5 and 6
320-14	Refurbishment and Integration - ETR	Same as 320-13.

Table 13.1.1-1

LEVEL 3

320 SPACE TUG PROJECT

DDT&E

PRODUCTION

OPERATIONS

LEVEL 4

320-01 PROJECT MANAGEMENT

320-02 SYSTEMS ENGR AND INTEGRATION

320-03 SPACE TUG VEHICLE MAIN STAGE

320-04 SPACE TUG VEHICLE AUXILIARY STAGE

320-05 LOGISTICS

320-06 FACILITIES

320-07 GROUND SUPPORT EQUIPMENT

VEHICL TEST

LEVEL 5 & 6

320-01-01 COST/PERFORM MGMT
320-01-02 PROJECT DIRECTION
320-01-03 INFORMATION MGMT

320-02-01 TUG SYSTEMS ENGRG
320-02-02 SHUTTLE INTERFACE
320-02-03 PAYLOAD INTERFACE
320-02-04 SUSTAINING ENGRG

320-03-01 STRUCTURES
- 320-03-01-01 FUEL TK & SPT
- 320-03-01-02 OXID TK & SPT
- 320-03-01-03 BODY STRUCTURE
- 320-03-01-04 THRUST STRUC
- 320-03-01-05 METEOROID SH
- 320-03-01-06 PAYLOAD INTFAC
- 320-03-01-07 INST ASM & C/O

320-03-02 THERMAL CONTROL
- 320-03-02-01 FUEL TK INSUL
- 320-03-02-02 OXID TK INSUL
- 320-03-02-03 INSUL PURG SYS
- 320-03-02-04 CONTROL SYSTEM
- 320-03-02-05 INST ASM & C/O

320-03-03 AVIONICS
- 320-03-03-01 DATA MGMT
- 320-03-03-02 GN&C
- 320-03-03-03 COMMUNICATIONS
- 320-03-03-04 INSTRUMENTATION
- 320-03-03-05 ELEC POWER
- 320-03-03-06 PWR DIST & CNTL
- 320-03-03-07 INST ASM & C/O

320-03-04 PROPULSION
- 320-03-04-01 MAIN ENG (GFE)
- 320-03-04-02 MAIN ENG SUPT
- 320-03-04-03 ACPS ENGINE
- 320-03-04-04 ACPS ENG SUPT
- 320-03-04-05 INST ASM & C/O

320-03-05 ORBITER INTERFACE
- 320-03-05-01 STRUCTURES
- 320-03-05-02 INTRFAC PANELS
- 320-03-05-03 PURGE PROVISION
- 320-03-05-04 ABORT PROVISION
- 320-03-05-05 INST ASM & C/O

320-03-06 DROP TANKS
- 320-03-06-01 STRUCTURES
- 320-03-06-02 THERMAL INSUL
- 320-03-06-03 PROP SUPT SYS
- 320-03-06-04 INST ASM & C/O

320-03-07 FINAL ASSEMBLY & C/O
- 320-03-07-01 FINAL ASSEMBLY
- 320-03-07-02 CHECKOUT

320-05-01 TRANSPORT & HANDLING

320-05-02 TRAINING
- 320-05-02-01 SIM. & EQUIP.
- 320-05-02-02 GROUND CREW
- 320-05-02-03 FLT OPER CREW

320-05-03 INV CONTL & WAREH

320-06-01 MANUFACTURING
- 320-06-01-01 DESIGN/CONSTR
- 320-06-01-02 ACTIVA/MAINTE

320-06-02 TEST
- 320-06-02-01 DESIGN/CONSTR
- 320-06-02-02 ACTIVA/MAINTE

320-06-03 MAINT & REFURB. ETR
- 320-06-03-01 DESIGN/CONSTR
- 320-06-03-02 ACTIVA/MAINTE

320-06-04 ETR LAUNCH
- 320-06-04-01 DESIGN/CONSTR
- 320-06-04-02 ACTIVA/MAINTE

320-06-05 MAINT & REFURB. WTR
- 320-06-05-01 DESIGN/CONSTR
- 320-06-05-02 ACTIVA/MAINTE

320-06-06 WTR LAUNCH
- 320-06-06-01 DESIGN/CONSTR
- 320-06-06-02 ACTIVA/MAINTE

320-07-01 MFG GSE
- 320-07-01-01 HARDWARE
- 320-07-01-02 SITE ACT
- 320-07-01-03 MAINTENANCE
- 320-07-01-04 SOFTWARE

320-07-02 EAST TEST RNG GSE
- 320-07-02-01 HARDWARE
- 320-07-02-02 SITE ACT
- 320-07-02-03 MAINTENANCE
- 320-07-02-04 SOFTWARE

320-07-03 WEST TEST RNG GSE
- 320-07-03-01 HARDWARE
- 320-07-03-02 SITE ACT
- 320-07-03-03 MAINTENANCE
- 320-07-03-04 SOFTWARE

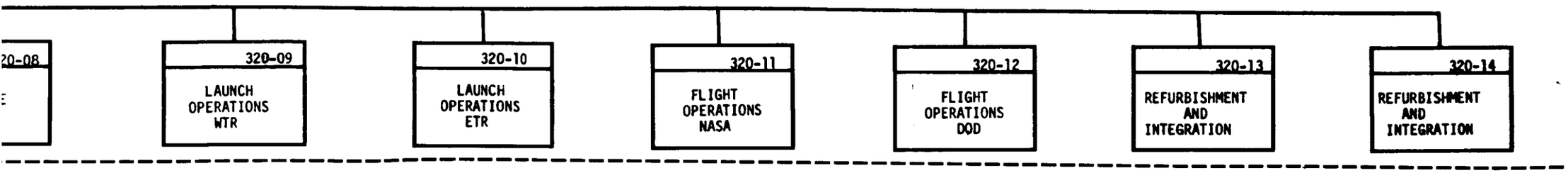
320-07-04 FLT OPER CONTROL GSE (NASA)
- 320-07-04-01 HARDWARE
- 320-07-04-02 SITE ACT
- 320-07-04-03 MAINTENANCE
- 320-07-04-04 SOFTWARE

320-07-05 FLT OPER CONTROL GSE (DOD)
- 320-07-05-01 HARDWARE
- 320-07-05-02 SITE ACT
- 320-07-05-03 MAINTENANCE
- 320-07-05-04 SOFTWARE

320-08-01 G
- 320-08-01-

320-08-01-

320-08-02 G
320-08-03 F
320-08-04 F



ND TEST HDWRE
01 PTV TEST/ BATTLESHIP
02 MAJOR TEST ARTICLES
03 MOCKUPS
ND TEST OPER
T TEST HDWRE
T TEST OPER

320-09-01	LAUNCH SITE SERVICES SUPT
320-09-02	TUG/SHUTTLE MATING & C/O
320-09-03	PRELAUNCH C/O
320-09-04	COUNTDOWN
320-09-05	PROPELLANTS & GSE
320-09-06	POST FLIGHT SAFING

320-10-01	LAUNCH SITE SERVICES/SUPT
320-10-02	TUG/SHUTTLE MATING & C/O
320-10-03	PRELAUNCH C/O
320-10-04	COUNTDOWN
320-10-05	PROPELLANTS & GASES
320-10-06	POST FLIGHT SAFING

320-11-01	MISSION PLNG
320-11-02	FLIGHT CONTROL
320-11-03	FLIGHT EVAL.
320-11-04	FLIGHT SUPT SOFTWARE

320-12-01	MISSION PLNG
320-12-02	FLIGHT CONTROL
320-12-03	FLIGHT EVAL.
320-12-04	FLIGHT SUPT. SOFTWARE

320-13-01	SCHED MAINT. & REFURBISHMENT
320-13-02	UNSCHED. MAINT. & REFURBISHMENT
320-13-03	POST MAINT C/O
320-13-04	TUG/PAYLOAD MATING & C/O
320-13-05	REFURBISHMENT REQMTS PLNG
320-13-06	DEPOT MAINT.

320-14-01	SCHED. MAINT & REFURBISH.
320-14-02	UNSCHED. MAINT. & REFURB.
320-14-03	POST MAINT C/O
320-14-04	TUG/PAYLOAD MATING & C/O
320-14-05	REFURBISH. REQMTS PLNG.
320-14-06	DEPOT MAINT.

2

Figure 13.1.2.2-1. Space Tug Work Breakdown Structure

one or more levels below that reported.

13.1.2.4 The cost estimates are commensurate with the program definitions available at this time, the relative level of study effort, and with the understanding that the estimates are only for preliminary planning and tradeoff study purposes.

13.1.2.5 Funding estimates are reported by Government Fiscal Year - 1 July through 30 June.

13.1.2.6 The cost estimates reflect recent employment levels (calendar 1968-1972) and a 6 percent (compounded annually) inflation factor to derive values in terms of 1973 dollars. The estimates also reflect reduced Project Management, Systems Engineering and Integration, and Manufacturing costs. (Reference: Results of MDAC Special Cost Reduction Task.) Thus, the cost estimates effectively assume that timely award of a Phase C/D Contract; (1) would cause contractor employment to approach the 1968-1972 levels; and (2) that the Phase C/D effort would achieve effective management at reduced cost.

13.1.2.7 The cost estimates assume that all required Supporting Research and Technology (SRT), identified separately in Sections 2.6 and 10, will be available when needed.

The cost estimates and reporting are consistent with the following Government Action Items:

Reference: PD-Tug-P, 4 April 1973

4. ACTION ITEM:

WHAT IS THE LOWEST LEVEL OF COST REPORTING REQUIRED?

RESPONSE:

COST AND TECHNICAL DATA FOR DATA FORMS A(1), A(2), A(3) AND B SHOULD BE REPORTED TO THE LOWEST LEVEL SHOWN ON THE APPROVED COMMON WBS.

COST AND MANPOWER DATA FOR DATA FORM C SHOULD BE REPORTED AT WBS LEVEL 4 EXCEPT FOR THE FOLLOWING CATEGORIES: VEHICLE MAIN STAGE, AUXILIARY STAGE, FACILITIES, GSE, VEHICLE TEST, LAUNCH OPERATIONS AND REFURBISHMENT AND INTEGRATION SHOULD BE REPORTED AT WBS LEVEL 5.

5. ACTION ITEM:

WHAT IS THE SHUTTLE COST PER FLIGHT?

RESPONSE:

THE SHUTTLE COST PER FLIGHT IS $10.5M FOR THE PURPOSES OF THESE STUDIES.

8. ACTION ITEM:

COST OF EXISTING KICK STAGES?

RESPONSE:

REQUESTS FOR THE COST OF EXISTING KICK STAGES SHOULD BE MADE TO DICK KLAN, MSFC, 205-453-0462. ANY MODIFICATIONS NECESSARY FOR TUG APPLICATION OR DEVELOPMENT OF NEW KICK STAGES SHOULD BE ESTIMATED AND REPORTED BY THE CONTRACTORS.

9. ACTION ITEM:

WHAT YEAR DOLLARS SHOULD COSTS BE REPORTED?

RESPONSE:

ALL COSTS SHOULD BE REPORTED IN CONSTANT 1973 DOLLARS.

10. ACTION ITEM:

HOW WILL COST BE HANDLED FOR LOSS OF MISSION/PAYLOAD RESULTING FROM TUG RELIABILITY?

RESPONSE:

THE COST OF A "LOST" TUG SHOULD BE CONSIDERED IN SIZING THE TUG FLEET. IN THE EVENT A MISSION IS ABORTED AND MUST BE REFLOWN, THE COST OF A SECOND FLIGHT SHOULD BE INCLUDED. COST OF THE PAYLOADS THEMSELVES SHOULD NOT BE CONSIDERED.

11. ACTION ITEM:

USE OF COST DATA FORMATS - NASA AND USAF PHASING.

RESPONSE:

THE DATA FORMS A(1), A(2), A(3), B AND T SHOULD BE COMMON TO BOTH NASA AND USAF. BECAUSE OF THE DIFFERENT PHASING, IT MAY BE NECESSARY TO COMPLETE TWO SETS OF DATA FORM C; ONE TO REFLECT NASA PHASING AND ONE FOR THE USAF PHASING.

12. ACTION ITEM:

WHAT LEARNING CURVE SHOULD BE USED?

RESPONSE:

A LEARNING CURVE MAY BE USED TO ESTIMATE HARDWARE QUANTITY COSTS. THE TYPE LEARNING CURVE USED (STRAIGHT-LINE PROJECTION OF CUMULATIVE AVERAGE COSTS OR STRAIGHT-LINE PROJECTED UNIT COSTS) SHOULD BE NOTED AND THE PERCENT OF LEARNING SPECIFIED.

13. ACTION ITEM:

HOW WILL THE POSSIBLE USE OF GOVERNMENT FACILITIES/PERSONNEL BE HANDLED?

RESPONSE:

IN KEEPING WITH THE LOW COST PHILOSOPHY, USE OF EXISTING GOVERNMENT FACILITIES SHOULD BE CONSIDERED WHERE PRACTICAL. ANY MODIFICATIONS AND/OR NEW FACILITIES SHOULD BE IDENTIFIED AND ESTIMATED.

IN THOSE INSTANCES WHERE THE USE OF GOVERNMENT PERSONNEL TO PERFORM SPECIFIC FUNCTIONS AND/OR PORTIONS OF THE TUG PROJECT IS CONSIDERED IN KEEPING WITH THE LOW COST PHILOSOPHY, THESE SHOULD BE CLEARLY IDENTIFIED. HOWEVER, THE CONTRACTORS SHOULD ESTIMATE THE COST OF THOSE FUNCTIONS AND/OR ACTIVITIES AND REPORT THAT COST AS IF A CONTRACTOR WERE TO ACCOMPLISH THEM. THE GOVERNMENT WILL ESTIMATE THE POSSIBLE SAVINGS IF ACCOMPLISHED BY GOVERNMENT PERSONNEL.

13.1.2.8 As directed by the Government, Operations cost estimates for ground tracking, i.e., MSFN/STADAN, include the cost of personnel required for tracking the Tug, even though these same people may track other space vehicles at other times. For example, if the Tug requires these people for only four hours, the Tug project is charged for a full eight hour day.

13.1.2.9 The cost estimates assume that DDT&E and Production essentially would be accomplished at MDAC's Huntington Beach, California, facilities.

13.1.2.10 As directed by the Government, the cost estimates assume that existing STE/GSE/PTE, etc., from previous programs (e.g., SIVB) will be available for Space Tug at no cost except for modification/upgrading costs which would be Tug peculiar and would then be chargeable. The storage and maintenance costs of existing facilities and GSE up to the time of Space Tug use are not chargeable to the Tug Program.

13.1.2.11 The following main engine costs have been provided by the Government and incorporated in the cost estimates:

Table 13.1.2.11-1

SPACE TUG MAIN ENGINE CANDIDATES

COSTS AND DEVELOPMENT TIMES

1973 DOLLARS IN MILLIONS

Main Engine	Total DDT&E Cost	First Unit Cost	Development Time to PFC (Mos.)	Development Time to FFC (Mos.)
Category I RL10(1)	$ 13.00	$0.70	-	24
Category IIA RL10(2)				
With Pumped Idle	57.00	0.80	36	48
Without Pumped Idle	50.00	0.80	36	48
Category IIB RL10(1)	52.00	0.80	27	35
Category IV RL10(1)	119.00	0.90	48	60
Aerospike (1)	140.00	1.10	43	60
Advanced Space (1)	154.00	1.20	54	66

Note: (1) Values provided by S. Saucier - NASA/MSFC to C. Bonner - MDAC-W, 5 June 1973 - Documented in Record of Discussion.

(2) Values provided by S. Saucier to C. Bonner, 25 August 1973 - Documented in Record of Discussion.

13.1.2.12 The following vehicle auxiliary stage costs have been provided by the Government and incorporated in the cost estimates:

Vehicle Auxiliary Stage	1973 Dollars in Millions Start-Up	Recurring Production Unit Cost	Recurring Operations Cost/Flight
Burner II	-	$ .530	$ .140
Polaris A3, Second Stage -	$ 8.00	.270	
Basic with Guidance	+2.00	+ .300	
Poseidon, Second Stage -	$10.0	$ .355	
Basic with Guidance	+2.70	+4.95	

13.1.2.13 The costs per pound of candidate propellants have been provided by the Government to assure consistency in the Tug contractor trade studies. These costs have been incorporated in the MDAC estimates.

PROPELLANT		COST $/POUND
Liquid Oxygen	LOX	.013
Liquid Hydrogen	LH2	.50
Nitrogen Tetroxide	N2O4	.12
High Density Acid	HDA	.30
Monomethyl Hydrazine	MMH	2.75
Unsymetrical Dimethyl Hydrazine	UDMH	.55
50% N2H4 and 50% UDMH	AEROZINE-50	1.00
Hydrazine	N2H4	1.85

13.1.2.14 Based on its own sources, MDAC has estimated the cost of gaseous helium at $7.86 per pound. The Government has concurred in this value.

13.1.2.15 Launch operations cost estimates have been calculated using the following general ground rules and assumptions:

1. That manloading per year, per shift, per site by skill level are for direct and indirect personnel.

2. That launch site support services are equivalent to 24% of personnel and are included in No. 1 above.

3. That launch site direct and indirect personnel will perform GSE maintenance within their regular shift activities.

4. That home plant support is equivalent to 15% of field location manhours (excluding Project Management and System Engineering).

5. That the cost of field site personnel is based on mid 1973 hourly rates.

6. That the weighted average cost of inplant support (for No. 4 above) is based on mid-1973 hourly rates.

7. That Government Program/Project Management of launch operations is part of the Government's institutional base and thus is excluded from Tug project costs.

13.1.2.16 Flight Operations cost estimates have been calculated using the following general ground rules and assumptions:

1. That the attached manhours per flight include field site direct and indirect personnel.

2. That home plant support is equivalent to 10% of field site manhours. (Excluding Project Management and System Engineering.)

3. That the field site manhours reflect a 97% learning curve.

4. That the weighted average cost of field site personnel is based on mid-1973 hourly rates.

5. That the weighted average cost of inplant support is based on mid-1973 hourly rates.

6. That "computer hours/flight" reflect sharing existing computers with others, i.e., Shuttle Orbiter, Payloads.

7. That the average cost of a computer hour/flight including both machine and labor costs has been based on recent quotations.

8. That flight support and software (WBS 32A-114, 124) is a one time activity and its cost thus is part of DDT&E.

13.1.2.17 The cost estimates have been calculated to be total cost to the Government excluding NASA Program Management and Systems Support and Prime Contractor Fee on costs at System Level 4 and above, in accordance with NASA direction.

13.2 Description of Estimating Philosophy

The general equation form for CER's expressing recurring costs is shown in Figure 13.2-1. In this equation form, Y=A*X**B(F) the "A" value is the driver which generates the specific first unit cost by moving from the Y-intercept along a line (straight-line on a log-log plot) whose slope is expressed by the exponent "B". If the cost so calculated fairly represents an item whose design, method of fabrication, technology and other attendant variables are virtually the same as the data base from which the equation was derived, then the cost could be accepted as calculated. However, this seldom is the case and some means must be provided to adjust the calculated cost to indeed reflect the characteristics of the item being estimated. The "F" factor is included in the equation to perform the adjustment function. Quantification of the "F" factor is performed by the systems cost analyst and is predicated upon: (1) his knowledge of the data base; (2) his understanding of the item being estimated, achieved through continuous communication with other members of the study team; and (3) his professional expertise. Fortuitously, the systems cost analysts on the Space Tug Study Team are among those

SPACE TUG COST METHODOLOGY

EXAMPLE -- STRUCTURE ASSEMBLY COMPLETE

LEADER II COST MODEL CER'S -- RECURRING COSTS

- GENERAL EQUATION FORM

  $$COST = A(X)^B \cdot F$$

  WHERE: A = A CONSTANT
  X = A VARIABLE (I.E., AREA, WEIGHT)
  B = AN EXPONENT
  F = A COMPLEXITY FACTOR, WHOSE FUNCTION IS TO MODIFY THE BASIC EQUATION TO REFLECT DEVIATION FROM THE BASE FOR VARIOUS MATERIALS AND TYPES OF CONSTRUCTION

  EACH EQUATION DERIVED BY ANALYSIS (I.E., REGRESSION ANALYSIS) FROM A KNOWN DATA BASE

- DATA BASE INCLUDES COST AND ENGINEERING DATA FROM:

SIVB	SPACE STATION (MODULAR)
SKYLAB	SORTIE LAB
SHUTTLE EXTERNAL TANK	SOAR II
NUCLEAR STAGE	ADVANCED COMPOSITES STUDIES

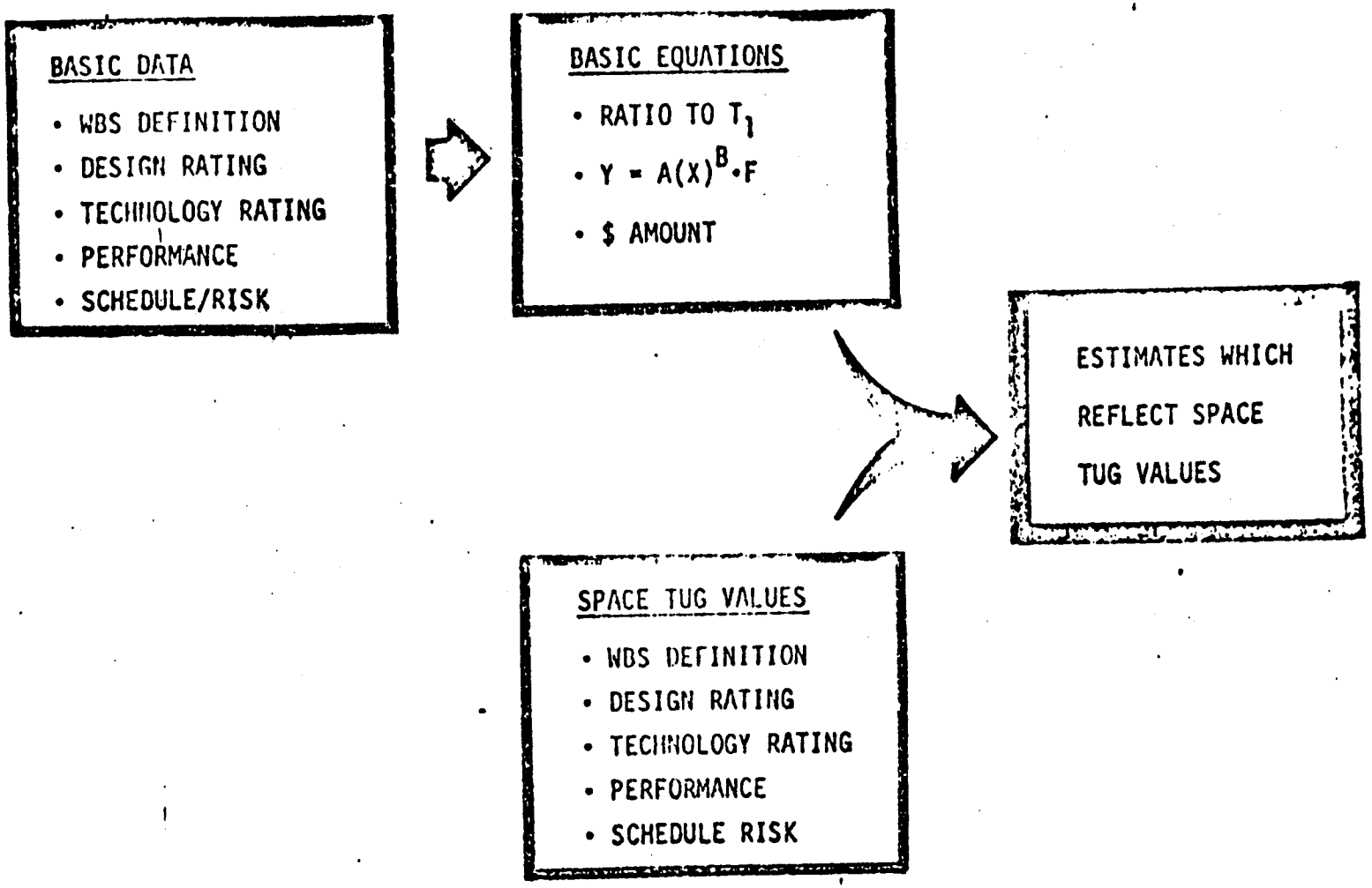
MCDONNELL DOUGLAS

Figure 13.2-1

who build the CER building blocks for the LEADER cost model. Thus, they have all three requisites for quantification of the "F" values.

The methodology used for calculating DDT&E costs is summarized in Figure 13.2-2. Three basic equation forms are used to relate basic data to Space Tug values and generate DDT&E cost estimates which realistically reflect the Space Tug values. The first equation form is a "ratio to T1". As used for the Space Tug WBS elements, this equation has meant that Engineering Design and Development cost is "N" times the first unit production cost. The second equation form, Y=A*X**B(F), is the same as that used for first unit production cost and discussed in the preceeding paragraph. The third equation form is a specific dollar value which usually has been derived from quotations submitted by prospective suppliers of assemblies and components. Similar to the practice for first unit production cost estimating, the "F" factor is quantified by the systems cost analyst to reflect Space Tug values for specific WBS elements in terms of design rating, technology rating and schedule risk, which are defined in Figure 13.2-3. Ground test hardware quantities and flight test hardware quantitites have been established at the component, assembly, subsystem and system levels as discussed in Section 2 of this book. The estimated costs for ground test hardware and flight test hardware are the result of applying equivalent quantity values to first unit production cost at the appropriate WBS levels.

SPACE TUG COST METHODOLOGY
DDT&E COST ESTIMATES



MCDONNELL DOUGLAS

Figure 13.2-2

SPACE TUG COST METHODOLOGY
DDT&E COST ESTIMATE FACTORS

- **DESIGN RATING**

5	COMPLETELY "OFF THE SHELF" OR PREVIOUSLY DESIGNED AND MANUFACTURED ON OTHER MONEY -- NO DDT&E
4	APPROXIMATELY 75 PERCENT OF SUBSYSTEM PREVIOUSLY DESIGNED AND MANUFACTURED ON OTHER MONEY. NEW OR REDESIGN EFFORT REQUIRED ON REMAINDER.
3	APPROXIMATELY 50 PERCENT OF SUBSYSTEM PREVIOUSLY DESIGNED AND MANUFACTURED ON OTHER MONEY. NEW OR REDESIGN EFFORT REQUIRED ON REMAINDER.
2	APPROXIMATELY 25 PERCENT OF SUBSYSTEM PREVIOUSLY DESIGNED AND MANUFACTURED ON OTHER MONEY. NEW OR REDESIGN EFFORT REQUIRED ON REMAINDER.
1	COMPLETELY NEW OR REDESIGN EFFORT ON ALL ITEMS IN THE SUBSYSTEM.

- **TECHNOLOGY RATING**

100	COMPLETELY NEW TECHNOLOGY, ASSUMING THE SRT WHICH WE HAVE PROGRAMMED IS COMPLETED BY PHASE C ATP.
1	COMPLETELY EXISTING TECHNOLOGY WITH SAME SRT ASSUMPTION.

- **SCHEDULE RISK**

EXPRESSED AS A PERCENT OF A BASELINE (100 PERCENT), WHICH IS THE EXPECTED COST FOR THE EXPECTED SCHEDULE; LEADS TO DERIVATION OF MAXIMUM COST RISKED TO MEET DEVELOPMENT OBJECTIVES FOR GIVEN PERFORMANCE GOALS.

Figure 13.2-3

Whether the estimate is for DDT&E cost or recurring production cost, quantification of the "F" value is the product of the cost analyst's judgement of a number of influencing elements in addition to those identified above. These additional elements include: reliability, maintainability, safety, commonality, workability/fabrication methods, DDT&E approach versus change traffic, and knowldge of prospective suppliers' pricing policies and cost performance - actuals versus estimates.

This latter knowledge has been paricularly useful in evaluating the ROM quotations from propective suppliers in response to Requests for Information on this study. Thus, the factors applied to the suppliers quotes have varied to reflect individual company performance, as well as the cost of sub-contract management.

In accordance with NASA direction, the cost estimates represent cost to the Government, except for NASA Program Management and and System Support and Prime Contractor Fee on costs at System Level 4 and above. Thus, the costs include those for the main engine, which has been identified as GFE. Reference also is made to Subsection 13.1.2, Assumptions, Ground Rules and Rationale.

13.3 Related Historical Programs

As noted above, the related historical programs, which constitute the data base for the LEADER II cost model, include: Saturn SIV/SIVB, Skylab, Space Station (modular), SOAR II, Sortie Lab, Thor/Delta, Gemini, MOL, Saturn/Apollo, and Titan.

The data base also incorporates the results of a number of Government-funded and industry-funded studies, and the quotations submitted by prospective suppliers of assemblies/ components.

Table 13.3-1 lists the WBS elements whose costs have been estimated using CER's, Cost Factors, and Direct Estimates/ Other, through Component Level 7.

TABLE 13.3-1

COST METHODOLOGY
APPLICATION OF CER'S, COST
FACTORS AND DIRECT ESTIMATES

STUDY TITLE: SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO.: NAS 8-29677

DATE: 3 September 1973

WBS IDENTIFICATION NUMBER	WBS INDENTIFICATION	DDT&E			PRODUCTION			OPERATIONS	
		CER'S	COST FACTORS	DIRECT EST/OTHER	CER'S	COST FACTORS	DIRECT EST/OTHER	COST FACTORS	DIRECT EST/OTHER
320	Total Tug Project			x			x		x
320-01	Project Management		x			x		x	
320-02	Systems Eng'g. & Integration		x			x			x
320-03	Vehicle Main Stage			x			x	x	
320-03-01	Structures Subsystem			x			x		x
320-03-01-01	Fuel Tank and Support	x			x			x	
320-03-01-02	Oxidizer Tank and Support	x			x			x	
320-03-01-03	Body Structure	x			x			x	
320-03-01-04	Thrust Structure	x			x			x	
320-03-01-05	Meteoroid Shield	x			x			x	
320-03-01-06	Payload Interface	x			x			x	
320-03-01-07	Installation, Assembly & C/O		x			x		x	
320-03-02	Thermal Control Subsystem			x			x		x
320-03-02-01	Fuel Tank Insulation			x			x	x	
320-03-02-02	Oxidizer Tank Insulation			x			x	x	
320-03-02-04	Insulation Purge System			x			x	x	
320-03-02-04	Control System			x			x	x	
320-03-02-05	Installation, Assembly & C/O		x			x		x	
320-03-03	Avionics Subsystem								
320-03-03-01	Data Management			x			x		x
320-03-03-01-01	Computer			x			x		x
320-03-03-01-02	Data Distribution	x			x			x	
320-03-01-03	Bus Controller	x			x			x	
320-03-03-01-04	Other	x			x			x	

TABLE 13.3-1

COST METHODOLOGY
APPLICATION OF CER'S, COST
FACTORS AND DIRECT ESTIMATES

STUDY TITLE: SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO.: NAS 8-29677

DATE: 3 September 1973

PAGE 2 OF 6

WBS IDENTIFICATION NUMBER	WBS INDENTIFICATION	DDT&E			PRODUCTION			OPERATIONS	
		CER'S	COST FACTORS	DIRECT EST/OTHER	CER'S	COST FACTORS	DIRECT EST/OTHER	COST FACTORS	DIRECT EST/OTHER
320-03-03-01-05	Software - A			x			--	x	
320-03-03-01-06	Software - B	--	--	--	--	--	--	--	--
320-03-03-01-07	Software - C	--	--	--	--	--	--	--	--
320-03-03-01-08	Installation, Assembly & C/O		x			x		x	
320-03-03-02	GN&C			x			x		x
320-03-03-02-01	IMU			x			x	x	
320-03-03-02-02	Star Tracker			x			x	x	
320-03-03-02-03	Laser Radar	--	--	--	--	--	--	--	--
320-03-03-02-04	Installation, Assembly & C/O		x			x		x	
320-03-03-03	Communications			x			x		x
320-03-03-03-01	Microwave Circuitry/RF-MPLXR	x			x			x	
320-03-03-03-02	Transponders	x			x			x	
320-03-03-03-03	Power Amplifier			x			x	x	
320-02-02-02-04	Antenna			x			x	x	
320-03-03-03-05	Decoder/Encoder-Mod./ Demod.			x			x	x	
320-03-03-03-06	Tape Recorder			x			x	x	
320-03-03-03-07	P/L Interface Equip.-Com Sec.	x			x			x	
320-03-03-03-08	Installation, Assembly & C/O		x			x		x	
320-03-03-04	Instrumentation			x			x		x
320-03-03-04-01	Data Sensors		x				x	x	
320-03-03-04-02	Signal Conditioning	x			x			x	
320-03-03-04-03	Circuitry	x			x			x	
320-03-03-04-04	Installation, Assembly & C/O		x			x		x	
320-03-03-05	Electrical Power			x			x		x

TABLE 13.3-1

COST METHODOLOGY
APPLICATION OF CER'S, COST
FACTORS AND DIRECT ESTIMATES

STUDY TITLE: SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO.: NAS 8-29677

DATE: 3 September 1973

PAGE 3 OF 6

WBS IDENTIFICATION NUMBER	WBS INDENTIFICATION	DDT&E			PRODUCTION			OPERATIONS	
		CER'S	COST FACTORS	DIRECT EST/OTHER	CER'S	COST FACTORS	DIRECT EST/OTHER	COST FACTORS	DIRECT EST/OTHER
320-03-03-05-01	Battery			x			x	x	
320-03-03-05-02	Fuel Cell	--	--	--	--	--	--	--	--
320-03-03-05-03	Installation, Assembly & C/O		x			x		x	
320-03-03-06	Power Distribution & Control			x			x		x
320-03-03-06-01	Distribution	x			x			x	
320-03-03-06-02	Tanks - Fuel Cell	--	--	--	--	--	--	--	--
320-03-03-06-03	Installation, Assembly & C/O		x			x		x	
320-03-04	Propulsion			x			x		x
320-03-04-01	Main Engine (GFE)			x			x	x	
320-03-04-02	Main Engine Support	x			x			x	
320-03-04-03	ACPS Engine			x			x	x	
320-03-04-04	ACPS Engine Support	x			x			x	
320-03-04-05	Installation, Assembly & C/O		x			x		x	
320-03-05	Orbiter Interface			x			x		x
320-03-05-01	Structures	x			x			x	
320-03-05-02	Interface Panels	x			x			x	
320-03-05-03	Purge Provisions	--	--	--	--	--	--	--	--
320-03-05-04	Abort Provisions	x			x			x	
320-03-05-05	Installation, Assembly & C/O		x			x		x	
320-03-06	Drop Tanks	--	--	--	--	--	--	--	--
320-03-07	Final Assembly & Checkout		x			x		x	
320-04	Space Tug Auxiliary Stage			x			x	--	--
320-05	Logistics			x	--	--	--		x
320-05-01	Transportation & Handling	--	--	--	--	--	--		x

TABLE 13.3-1

COST METHODOLOGY
APPLICATION OF CER'S, COST
FACTORS AND DIRECT ESTIMATES

STUDY TITLE: SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO.: NAS 8-29677

DATE: 3 September 1973

PAGE 4 OF 6

WBS IDENTIFICATION NUMBER	WBS INDENTIFICATION	DDT&E			PRODUCTION			OPERATIONS	
		CER'S	COST FACTORS	DIRECT EST/OTHER	CER'S	COST FACTORS	DIRECT EST/OTHER	COST FACTORS	DIRECT EST/OTHER
320-05-02	Training			x	--	--	--		x
320-05-03	Inventory Control & Warehsng.			x	--	--	--		x
320-06	Facilities			x			x		x
320-06-01	Manufacturing			x		x		--	--
320-06-02	Test			x	--	--	--	--	--
320-06-03	Maint. & Refurb. - ETR			x	--	--	--	x	
320-06-04	ETR Launch			x	--	--	--	x	
320-06-05	Maint. & Refurb. - WTR			x	--	--	--	x	
320-06-06	WTR Launch			x	--	--	--	x	
320-07	Ground Support Equipment			x		x		x	
320-07-01	Manufacturing GSE			x		x		--	--
320-07-02	ETR GSE			x	--	--	--	x	
320-07-03	WTR GSE			x	--	--	--	x	
320-07-04	Flight Ops. GSE-NASA			x	--	--	--	x	
320-07-05	Flight Ops. Gse-DOD			x	--	--	--	x	
320-08	Vehicle Test			x	--	--	--	--	--
320-08-01	Ground Test Hardware		x		--	--	--	--	--
320-08-02	Ground Test Operations			x	--	--	--	--	--
320-08-03	Flight Test Hardware	--	--	--	--	--	--	--	--
320-08-04	Flight Test Operations			x	--	--	--	--	--
320-09	Launch Operations - WTR	--	--	--	--	--	--		x
320-09-01	Launch Site Services & Support	--	--	--	--	--	--		x
320-09-02	Tug/Shuttle Mating & C/O	--	--	--	--	--	--		x
320-09-03	Prelaunch Checkout	--	--	--	--	--	--		x

TABLE 13.3-1

COST METHODOLOGY
APPLICATION OF CER'S, COST
FACTORS AND DIRECT ESTIMATES

STUDY TITLE: SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO.: NAS 8-29677

DATE: 3 September 1973

WBS IDENTIFICATION NUMBER	WBS INDENTIFICATION	DDT&E			PRODUCTION			OPERATIONS	
		CER'S	COST FACTORS	DIRECT EST/OTHER	CER'S	COST FACTORS	DIRECT EST/OTHER	COST FACTORS	DIRECT EST/OTHER
320-09-04	Countdown	--	--	--	--	--	--		x
320-09-05	Propellants & Gases	--	--	--	--	--	--		x
320-09-06	Post Flight Safing	--	--	--	--	--	--		x
320-10	Launch Operations - ETR	--	--	--	--	--	--		x
320-10-01	Launch Site Services & Support	--	--	--	--	--	--		x
320-10-02	Tug/Shuttle Mating & C/O	--	--	--	--	--	--		x
320-10-03	Prelaunch Checkout	--	--	--	--	--	--		x
320-10-04	Countdown	--	--	--	--	--	--		x
320-10-05	Propellant & Gases	--	--	--	--	--	--		x
320-10-06	Post Flight Safing	--	--	--	--	--	--		x
320-11	Flight Operations - NASA			x	--	--	--		x
320-11-01	Mission Planning			x	--	--	--		x
320-11-02	Flight Control			x	--	--	--		x
320-11-03	Flight Evaluation			x	--	--	--		x
320-11-04	Flight Support Software			x	--	--	--		x
320-12	Flight Operations - DOD			x	--	--	--		x
320-12-01	Mission Planning			x	--	--	--		x
320-12-02	Flight Control			x	--	--	--		x
320-12-03	Flight Evaluation			x	--	--	--		x
320-12-04	Flight Support Software			x	--	--	--		x
320-13	Refurbishment & Integr.-WTR			x	--	--	--		x
320-13-01	Scheduled Maint. & Refurb.	--	--	--	--	--	--		x
320-13-02	Unsched. Maint. & Refurb.	--	--	--	--	--	--		x
320-13-03	Post Maintenance Checkout	--	--	--	--	--	--		x

TABLE 13.3-1

COST METHODOLOGY
APPLICATION OF CER'S, COST
FACTORS AND DIRECT ESTIMATES

STUDY TITLE: SPACE TUG SYSTEMS STUDY (CRYOGENIC)

CONTRACT NO.: NAS 8-29677

DATE: 3 September 1973

PAGE 6 OF 6

WBS IDENTIFICATION NUMBER	WBS INDENTIFICATION	DITAE			PRODUCTION			OPERATIONS	
		CER'S	COST FACTORS	DIRECT EST/OTHER	CER'S	COST FACTORS	DIRECT EST/OTHER	COST FACTORS	DIRECT EST/OTHER
320-13-04	Tug/Payload Mating & C/O	--	--	--	--	--	--		x
320-13-05	Refurb. Requirements Planning			x	--	--	--		x
320-13-06	Depot Maintenance	--	--	--	--	--	--		x
320-14	Refurbishment & Integr.-ETR			x	--	--	--		x
320-14-01	Scheduled Maint. & Refurb.	--	--	--	--	--	--		x
320-14-02	Unsched. Maint. & Refurb.	--	--	--	--	--	--		x
320-14-03	Post Maintenance Checkout	--	--	--	--	--	--		x
320-14-04	Tug/Payload Mating & C/O	--	--	--	--	--	--		x
320-14-05	Refurb. Requirements Planning			x	--	--	--		x
320-14-06	Depot Maintenance	--	--	--	--	--	--		x

Section 14

OTHER SENSITIVITIES AS DEFINED

This section presents a summary of the results of several discrete sensitivity analyses defined as of interest for application to the baseline Option 1. Each of these sensitivities, basically performed by the system engineering disciplines, was supported by programmatics and cost analysis where applicable. Cost impacts were developed from previous subsystem/component cost analyses and the baseline Option 1 cost model output data presented in Section 6. Table 14-1 identifies the sensitivities analyzed and summarizes, in the requested government format, the results.

Detail discussions and supporting data and rationale for each of the sensitivities is provided in Volume 5, Book 1, Section 9.2.

Table 14-1 SENSITIVITY RESULTS SUMMARY - OPTION 1

Sensitivity Area	Reference	Impact Delta (Reference)							
		Cost ($ millions)				Veh. Design			
		TECH	DDT&E	First Unit	Total OPN	Inert Wt(lb)	P/L Del Wt.	Dev. Risk	Critical Tech. Areas
Autonomy	Level IV								
Level III			2.82	0.06	-19.03	2	- 5.4	None	None
Level II		5.0	18.06	1.37	-14.31	238	-643	Medium	Auto Mfn. & Mission Plan.
Level I		5.0	15.08	1.37	-19.52	238	-643	Low to med.	Auto. Nav.
0.97 Reliability	0.97/36								
0.97/72 hr.		0	0	0	-	0	0	None	None
0.97/142 hr.		0	3.4	0.46	-	26	- 70	None	None
6 Day Duration									
72 Hour	36 Hour	0	10.74	1.30	-	-700	+800	Low	None
144 Hour		1.0	11.88	1.41	-	-630	-200	Low	MLI
DOD Comm. Req.	NASA Req.	0	0.50	0.13	-	136	-367	Medium	High gain antenna
300$^{\omega}$ Power to Payload	0	0	0	0.01	0	154	-425	Low	None
Design Life (> 100)	20 Reuses	0	0	0	0	0	0	None	None
Rendezvous and Docking	None	5	6.59	0.61	-	188	-517	High	Sensor
Spin Stab. P/L Retrieval	W/O	0	0	0	0	0	0	None	None