MSC-04061-III

FINAL REPORT

SCHEDULING TECHNIQUE IMPROVEMENT STUDY

for

ADVANCED PROGRAMS

VOLUME III

STAGE I
ADVANCED SPACE TRANSPORT PROGRAM

25 July 1971

LTV Report No. 00.1444

VOUGHT MISSILES AND SPACE COMPANY

DALLAS, TEXAS

FOREWORD

The Scheduling Technique Improvement Study for Advanced Programs was conducted by the Vought Missiles & Space Company, LTV Aerospace Corporation, Dallas, Texas, under Contract No. NAS9-11659. This study was conducted for the Operations Analysis Branch of the Manned Spaceflight Center, National Aeronautics and Space Administration, Houston, Texas. The period of this contract covered twenty (20) weeks, including a two-week final reporting period. Contract dates were from 7 March 1971 through 25 July 1971.

This document is submitted in compliance with NAS9-11659, Paragraph V (Deliverable Items) of Exhibit A to the Statement of Work.

D P Crain
Prepared By

G. B. Schumbert
Approval

7/29/71
Date

ACKNOWLEDGMENTS

The following personnel provided significantly in the accomplishment of study objectives.

VMSC

D. P. Crain - Study Leader
H. H. Edwards
J. D. Harding
V. T. Harston
J. B. Roach
E. C. Schatz
K. H. Strickler

MSC

N. Jevas - Technical Monitor
W. Draper
H. Mandell

ABSTRACT

This report, in four volumes, is the final report of a twenty-week study conducted by Vought Missiles & Space Company for the Operations Analysis Branch, Manned Spacecraft Center (MSC), NASA, to generate improved techniques for scheduling major advanced programs. Study results directly support on-going and future programs within the National Aeronautics and Space Administration (NASA) as well as having application to any program, new or existing, under cognizance of the U. S. Government and its agencies where the techniques described herein may be utilized to estimate program milestone schedules. The basic technique is termed Time Estimating Relationships (TERs), where relationships are derived from statistical data to relate time to those technical parameters judged to be drivers in subsystem, system or total program scheduled development and delivery.

In addition to TER development, this study also addressed, and has reported herein, a comparative baseline for the scheduling improvement effort. Included are: (1) a master schedule for developing an Advanced Space Transport Program, (2) the Work Breakdown Structure and Dictionary (work statement) for the Program, (3) the detail schedules developed by standard techniques for estimating design and development, and (4) the logic diagrams which identify principle tasks and their sequence. All efforts reported herein are keyed to the Work Breakdown Structure (WBS) developed for an Advanced Space Transport Program in accordance with NASA level designations. This Program is used as the baseline for the study effort and is representative of programs being considered by NASA for operations in earth-to-near earth space environments.

The four volumes which contain the Final Report, under title of "Final Report, Scheduling Technique Improvement Study for Advanced Programs", are subtitled as follows:

Vol. I - Summary

Contains the final oral report presented to MSC covering the results of the entire study, including the TERs developed during the study. Contains, in addition, the objectives, approach and ground rules for generating the TERs, WBS Dictionary, Logic Charts, and Master and Detailed Schedules. The Work Breakdown Structure and Dictionary for the Total Program, for the Air Vehicle, for Integration and Assembly of Air Vehicle Stages and Payload, and for the Payload conclude this volume. A glossary of abbreviations, symbols and terms are included in the preamble to the text.

Vol. II - Stage II, Advanced Space Transport Program

Contains Stage II Work Breakdown Structure Dictionary, Detail Schedules and Logic Diagrams. Stage II (a manned, reusable orbiting transport vehicle) is defined consistently to the 6th (Assembly) Level and to the 7th (Component) Level for certain subsystems.

Vol. III - Stage I, Advanced Space Transport Program

Contains Stage I Work Breakdown Structure Dictionary, Detail Schedules and Logic Diagrams. Stage I (a manned, reusable boost vehicle) is defined consistently to the 5th (Subsystem) Level and to the 6th (Assembly) and 7th (Component) Levels for certain subsystems.

Vol. IV - Ground Support, Test, Training, Investment, Operations; Advanced Space Transport Program

Contains the Work Breakdown Structure Dictionary, Detail Schedules and Logic Diagrams for the major program elements for the life-cycle program other than Air Vehicle. These elements are consistently defined at the 3rd (Project) Level and partially defined at the 4th (System), 5th (Subsystem) and 6th (Assembly) Levels.

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SECTION 1

INTRODUCTION TO VOLUME III

This Volume contains the Work Breakdown Structure (WBS) Dictionary, Detail Schedules and Logic Diagrams for Block 1.4 (Stage I) of the Advanced Space Transport Program, introduced in Section 8 of Volume I to the Final Report.

The Master Schedule for this Program, also introduced in Section 8 of Volume I, is included here (Figure 0.0-W-1) for both reference purposes and for correlation with Detail Schedules shown on Page 1 of each WBS Dictionary writeup, or to callout to the Master Schedule where Detail Schedules are not provided.

The 'Top' WBS for the Advanced Space Transport Program, introduced in Section 8 of Volume I is included here (Figure 0.0-W-2) for reference purposes to show how Stage I (WBS ID 1.4), the subject of this volume, interfaces with the remainder of the Program.

For introductory data on the Work Breakdown Structure used for this study, for the top WBS Dictionary (WBS ID 0.0), for Master and Detail Schedules, and for Logic Diagrams, the reader is referred to Volume I.

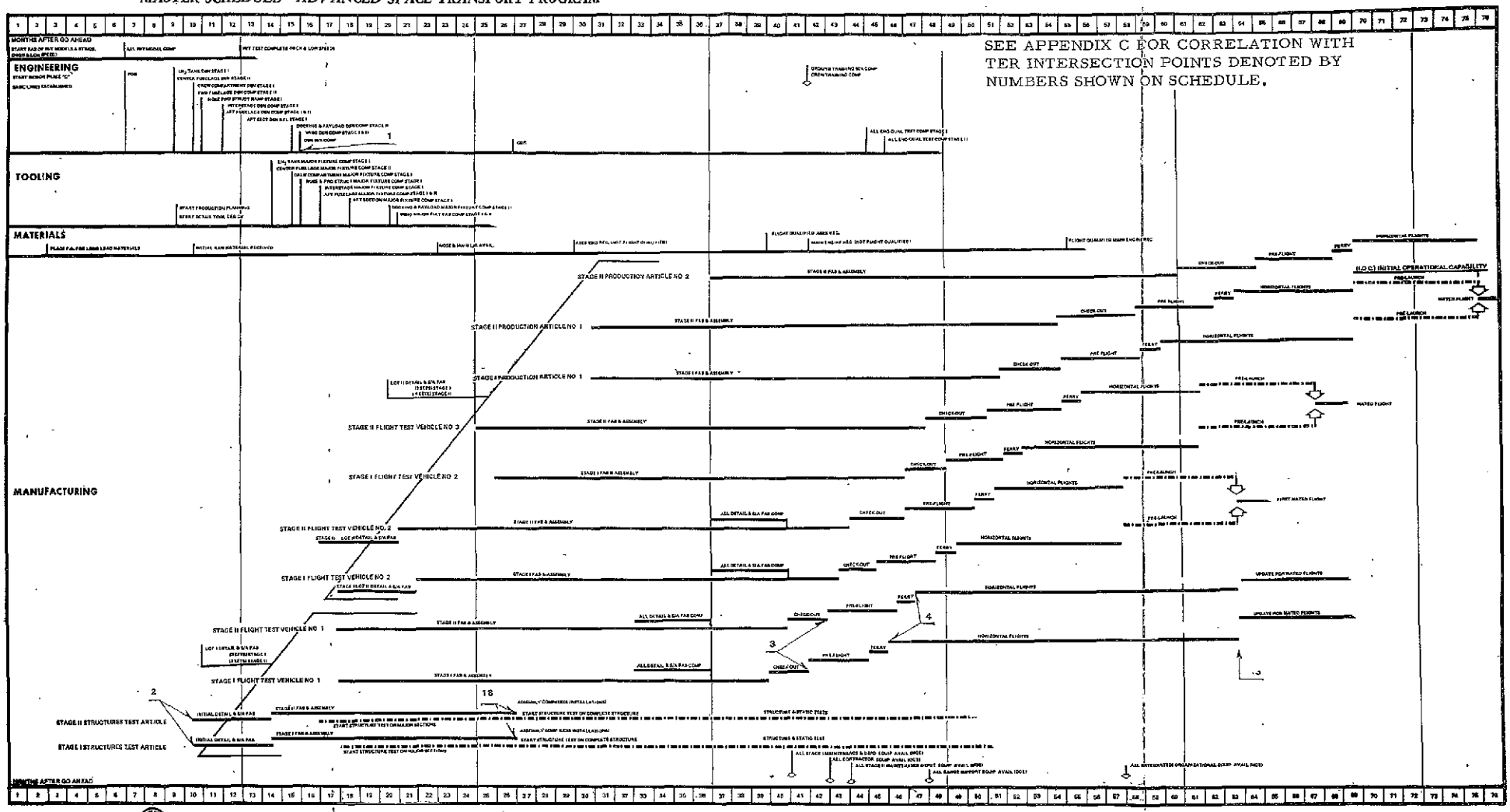
Stage II data of a similar nature to that reported herein is contained in Volume II. Remaining Program data (WBS ID 2.0 through 12.0) is contained in Volume IV.

Appendix A is included in Volume III to enable the reader to review one contractor's version of Stage I, herein termed 'Baseline Concept - Stage I'. Appendix B provides an Index to Logic Diagram 'connectors'. Appendix C compares the Time Estimating Relationships (TERs) results contained in Volume I with certain Detail Schedule and Logic Diagram results contained in this Volume. The Glossary (List of Abbreviations, Symbols and Terms), introduced in Volume I, is repeated in this Volume as Appendix D.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

MASTER SCHEDULE - ADVANCED SPACE TRANSPORT PROGRAM



VOUGHT MISSILES AND SPACE COMPANY

FIGURE 0.0-W-1 MASTER SCHEDULE

FOLDOUT FRAME 1

FOLDOUT FRAME 2

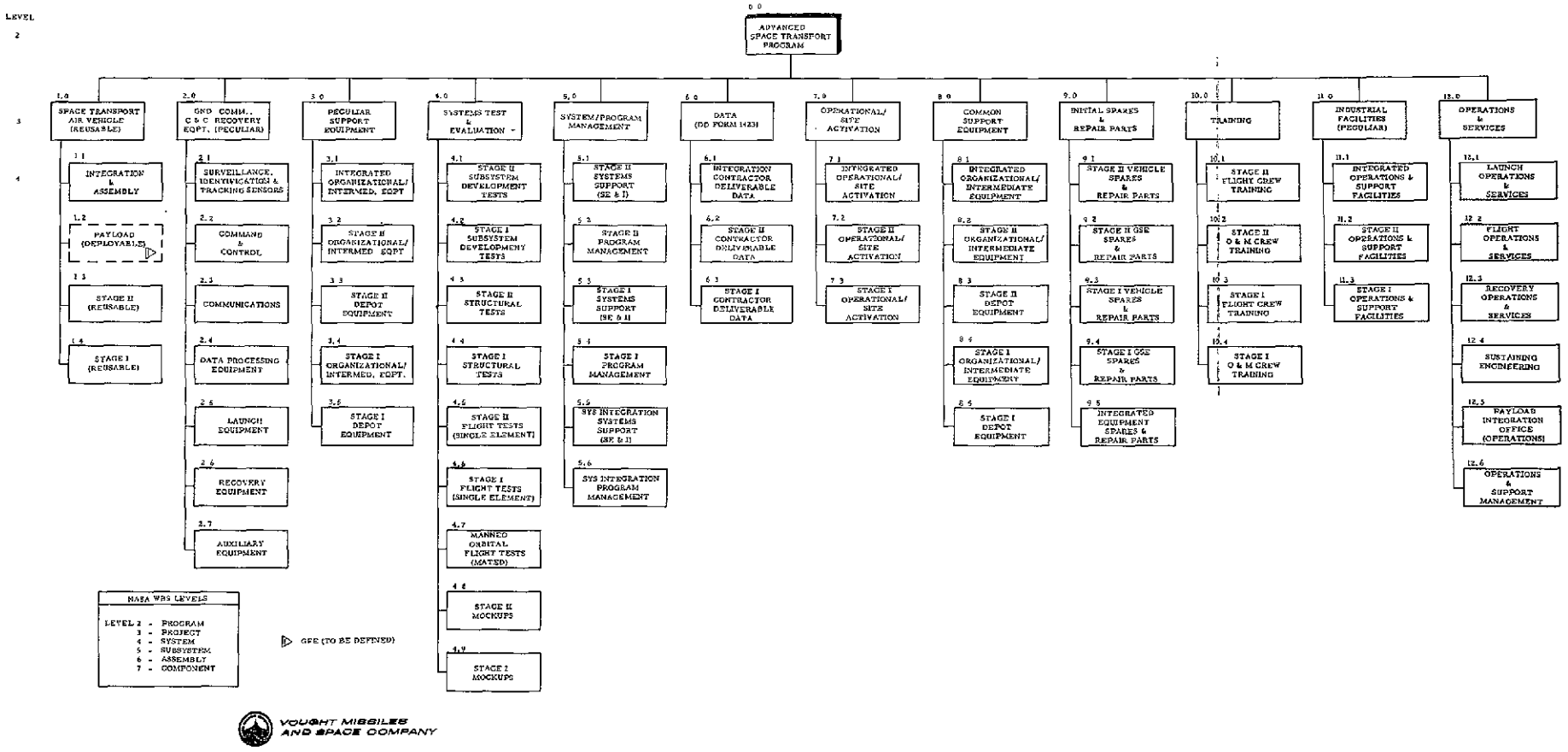


FIGURE 0.0-W-2

WORK BREAKDOWN STRUCTURE,
ADVANCED SPACE TRANSPORT PROGRAM
(WBS ID 0.0)

SECTION 2

WBS DICTIONARY, SCHEDULES & LOGIC DIAGRAMS (WBS ID 1.4, STAGE I)

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4

TASK TITLE STAGE I (REUSABLE)

LEVEL 4, System Level

WBS DICTIONARY

I. REQUIREMENTS

A means is required to accelerate Stage II and its GFE payloads to a point in the trajectory where Stage II can ignite its main engine to continue its orbital mission and subsequent return to earth for turnaround to next launch. The means to accomplish this function is designated as Stage I of an Advanced Space Transport Air Vehicle. Stage I is to be reusable, i.e., winged, to take advantage of aerodynamic lift to reenter following its boost phase and return to a designated, conventional runway landing site. Both Stage I and Stage II are to be manned. Following its landing, Stage I will also enter the turnaround function to prepare for its next flight.

TASK SCHEDULE MILESTONES

PERIOD ENDING

SEE LOWER LEVELS FOR DETAIL SCHEDULES

II. SUBSYSTEM DEFINITION

Twelve subsystems are required to configure a complete Stage I. To integrate and assemble these into either a mated flight test or operational vehicle, a thirteenth element is required. Figure 1.4-W-3 is the WBS of Stage I. The elements which comprise this system are as follows:

1.4.1	Integration and Assembly
1.4.2	Airframe and Structure
1.4.3	Primary Cryogenic Storage
1.4.4	Propulsion and Power Plant
1.4.5	Flight Control
1.4.6	Secondary Power
1.4.7	Environmental Control and Life Support
1.4.8	Guidance and Navigation
1.4.9	Communications and Navaids
1.4.10	Data Management
1.4.11	Displays and Controls
1.4.12	Crew Subsystems
1.4.13	Safety Subsystem

III. FUNCTIONAL DESCRIPTION

At Phase C go-ahead, systems engineering will complete the trade studies and System Requirements Analysis (SRA) begun in Phase B and will, at an appropriate point, conduct either a System Design Review or a Preliminary Design Review to establish Part I specifications of Contract End Items mutually agreed upon between the Stage I contractor, Systems Integrator, and NASA. If the review is held at the system or higher level, Stage II contractor data may also be presented to ensure the vehicle interfaces are properly defined. Upon approval of CEI Part I's, final design of Stage I will proceed. Component, assembly, and subsystem designs, generated through drawings, test specifications, and development part procurement or manufacture will be tested in WBS Block 1.4 as single subsystem tests and in WBS Block 4.2 as combined subsystem tests, the exception being engine tests which are performed through PFRT and cluster tests

FOLDOUT FRAME 1

FOLDOUT FRAME 2

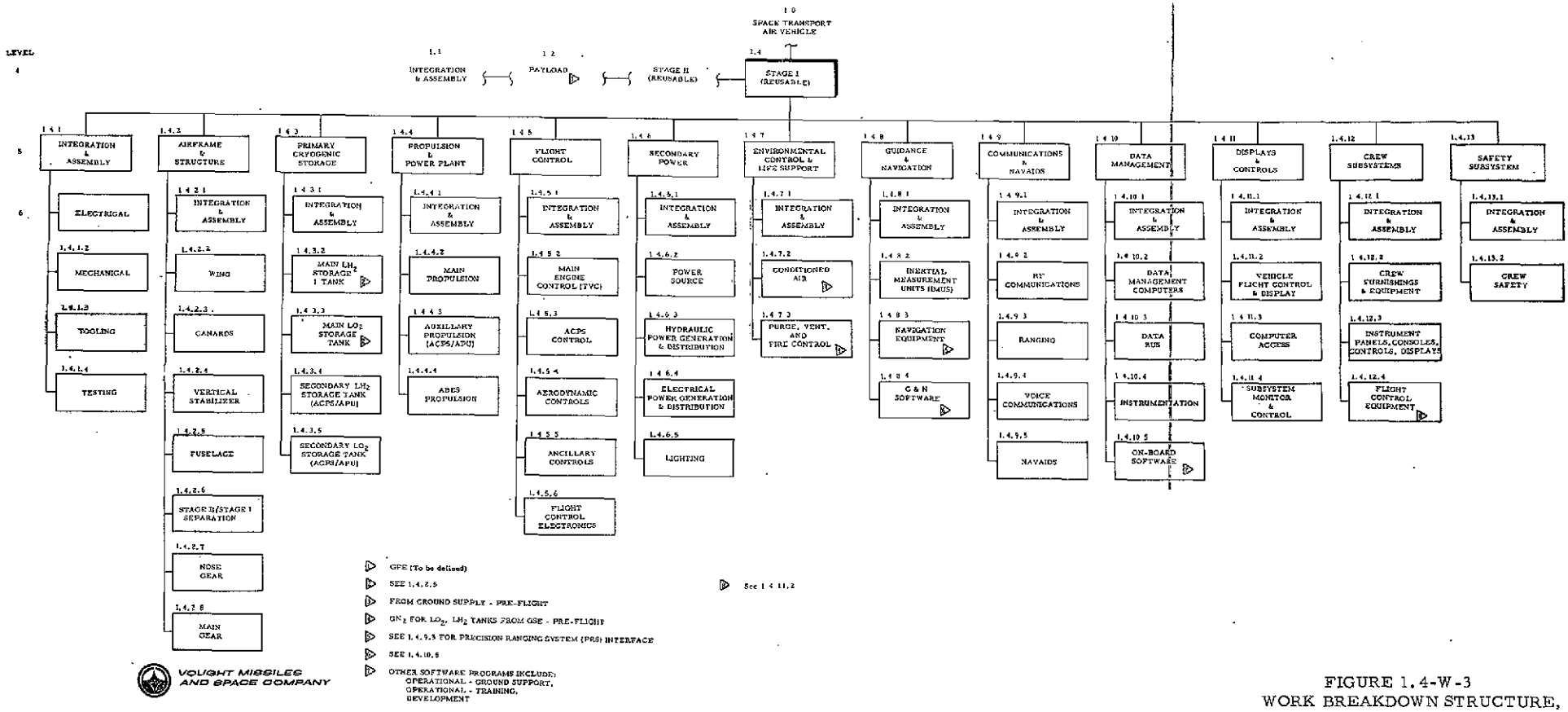


FIGURE 1.4-W-3
WORK BREAKDOWN STRUCTURE,
STAGE I (REUSABLE)
(WBS ID 1.4)

as part of System Test and Evaluation (WBS ID 4.2.8). Completion of Wind Tunnel testing will also be performed under WBS ID 4.2. To assist the designer, Stage I mockups (full scale, subsystem, laboratory) will be built or updated under WBS ID 4.9. To check the interfaces with Stage II, similar mockups will be available at the Stage II contractor facility. Mockups of main engines will be available at the GFE-supplied engine facility. At an appropriate point, Critical Design Reviews on portions of Stage I will be held to enable design to proceed on tooling needed to fabricate the Structural Test Vehicle, other test articles (wings, thermal protection, static and dynamic test articles), and finally Flight Test Vehicle No. 1 and on. Qualification acceptance of parts, components, assemblies, subsystems and system will proceed in accordance with System Effectiveness criteria (WBS ID 5.0). Instrumentation development necessary to measure and evaluate test articles is included in WBS ID 1.4 as well as software needed for onboard purposes. Details on specific subsystem design and development are covered under the appropriate subsystem. To support Flight Test (WBS ID 4.6 and 4.7), design engineering, tool engineering, manufacturing, materiel, and quality engineering associated with Stage I must support test planners and field personnel through the flight phases, data reduction and analysis, change coordination, etc., to ensure performance meets specification and that design deficiencies are identified and corrected as quickly as possible. This effort includes KUTD of drawings, specifications, and other configuration management aids as specified by contract and program management. Upon completion and acceptance of flight test hardware/software, WBS ID 1.4 must support the fabrication of production vehicles, including the interfaces with Stage II.

IV. DESIGN REQUIREMENTS

Level I and Level II requirements affecting Stage I are defined in WBS Dictionary Element 0.0, Advanced Space Transport Program, and will not be repeated here. Level III requirements pertaining to Stage II are defined in WBS Dictionary Element 1.3.

V. INTERFACES

Stage I interfaces with the Payload (WBS ID 1.2) through Stage II (WBS ID 1.3) as a design constraint during RDT&E and as a live constraint (cargo) in Operations (WBS ID 12.1). To form the Air Vehicle for mated flight test, Stage I interfaces with Stage II (WBS ID 1.3) through Integration and Assembly (WBS ID 1.1). To accomplish both flight test, flight and recovery, Stage I interfaces with operational ground support elements (WBS ID 2.0). Peculiar and common GSE interfaces with Stage I are defined under WBS ID 3.0 and 8.0. Stage I Cat. I and II tests and mockups are defined under WBS ID 4.0. System/Program Management interfaces with Stage I are covered in WBS ID 5.0. Deliverable data (drawings, specifications, tech orders, manuals) developed for Stage I are defined under WBS ID 6.0. Initial spares and repair parts for Stage I to achieve Program IOC are covered by WBS ID 9.0. Training of flight and ground crews for Stage I are defined under WBS ID 10.0. Operations involving Stage I are defined under WBS ID 12.0. Industrial facilities required to fabricate, inventory and logistically support Stage I are discussed under WBS ID 11.0.

VI. TEST REQUIREMENTS

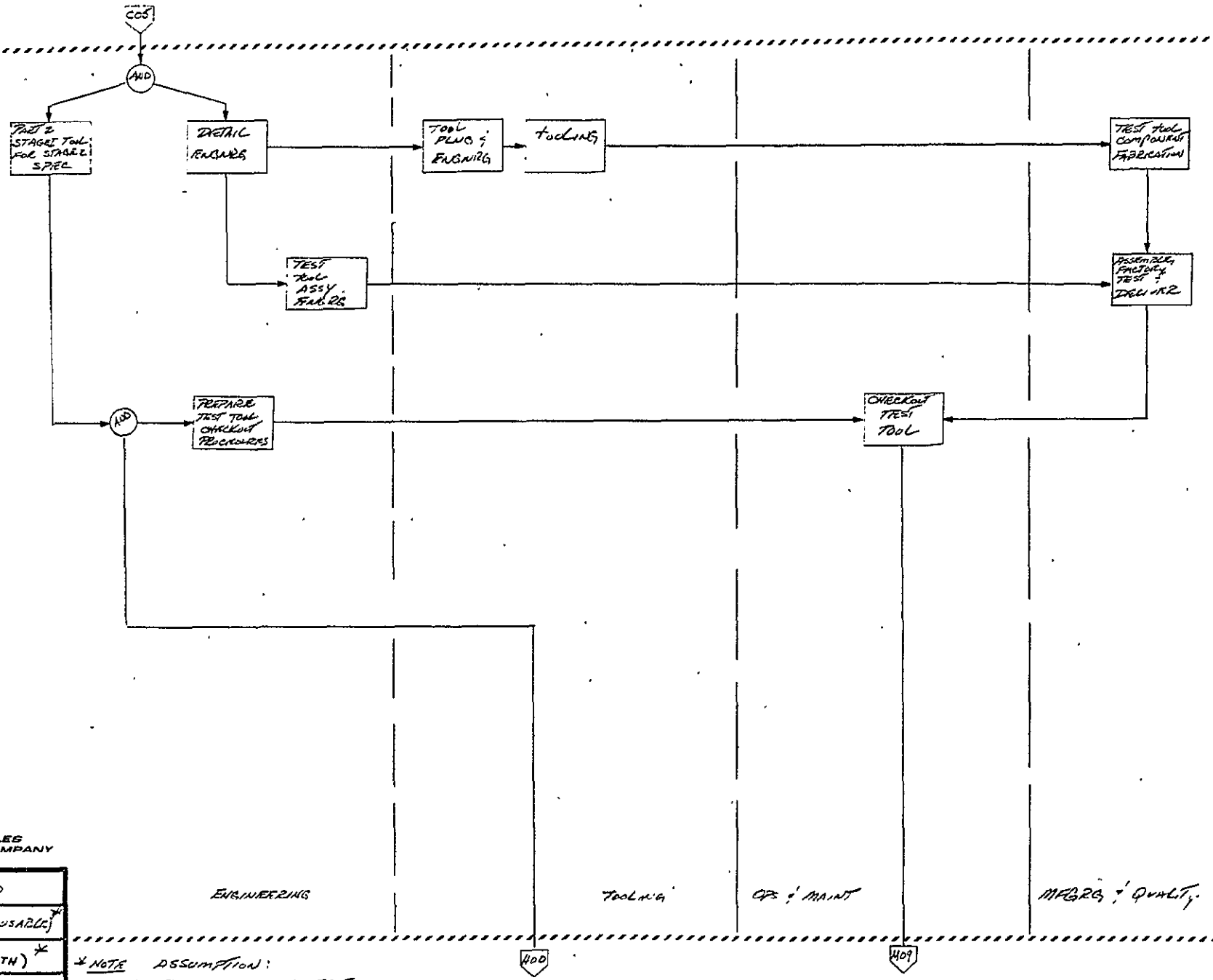
Single subsystem component, assembly, and subsystem tests (including software development) for Stage I are performed under the appropriate subsystem (1.4.2,...). Combined subsystem tests, engine tests, wind tunnel tests, and thermal tests (e.g., TPS-to-primary structure) are conducted under WBS ID 4.2. Structural testing of the Stage I airframe is conducted under WBS ID 4.4. Single element taxi, ferry flight, horizontal and vertical flight tests are performed under WBS ID 4.6.[1] Mated flight tests are defined under WBS ID 4.7.

VII. REFERENCES

(To be added)

[1] Current NASA planning calls for single element Vertical Flight Test to consist of tie-down Static Firings, only (no lift-off). This is subject to review during Phase C/D.

INPUTS



VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS, NO.	1.4.000
TITLE	STAGE 1 (REUSABLE)*
WBS LEVEL.	FOURTH (4TH) *
PAGE	1 OF 1
DATE	4 JUN 71

* NOTE ASSUMPTION:
AN ELECTRO-MECHANICAL TEST TOOL SIMULATING STAGE 1 WILL BE USED TO SYSTEMS TEST STAGE 2.

OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.1

TASK TITLE INTEGRATION AND ASSEMBLY (STAGE I)

LEVEL 5. Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

Means are required to integrate and assemble the various subsystems of Stage I, Space Transport Air Vehicle, in order to provide prototypes, structural test vehicles, flight test vehicles, and production vehicles for the Advanced Space Transport development, investment and operations phases. The means shall consist of Factory Test and/or Ground Support Equipment (FSE/GSE), tooling, and assembly and test procedures based on the configuration required.

II. ASSEMBLIES DEFINITION

Four major elements define Integration and Assembly (Stage I). These elements are shown on Figure 1.4-W-3, and cover the analysis, design, development and procurement or manufacture of the mechanical and

TASK SCHEDULE MILESTONES

PERIOD ENDING

SCHEDULE NOT GENERATED FOR THIS ELEMENT. SEE MASTER SCHEDULE.

electrical equipments, tooling, and test documentation required to combine components, assemblies and/or subsystems into prototypes, test articles or production vehicles as required. The WBS identification of Integration and Assembly (Stage I) is as follows:

1.3.1.1	Electrical
1.3.1.2	Mechanical
1.3.1.3	Tooling
1.3.1.4	Testing

III. FUNCTIONAL DESCRIPTION

Following Phase C Go-Ahead, Stage I Contract End Items will be defined by agreement between the Stage I contractor, Systems Integrator and NASA, and Part I CEI specifications will be prepared, presented and reviewed at either a System Design Review or Preliminary Design Review or reviews. Approval of these reviews by NASA will enable final design to proceed, together with completion of component, assembly, and subsystem tests through qualification testing. In parallel with the design, and with release of drawings on qualified hardware, the Stage Integration and Assembly effort can be completed. Analysis of how and where assembly should take place in order to build components, assemblies and subsystems will be conducted by manufacturing and facility engineering. The type, location, and provisioning of the fabrication facility(ies) will impact on this analysis. Tooling needed to assemble structure, tankage, plumbing, wiring, modules, etc., must be designed per tooling drawings. Location of parts storage, identification and design/procurement of mechanical and electrical servicing and test equipment, generation of test specifications by design engineers, and similar efforts are included in this element. Inasmuch as many of the assemblies will be subcontractor-supplied (engines, APUs, avionics), contract administration, materiel, manufacturing and engineering must work as a team to ensure parts and assemblies are manufactured per drawing, properly crated for shipping, properly delivered, received and inspected, and stored until required. The need for prototype equipment to support single and combined subsystem test and evaluation, for a structural test vehicle to test the airframe primary and secondary structure, ard then for flight test vehicles configured for horizontal and/or horizontal and vertical flight test will require careful planning to ensure deliverable items are correctly configured, that necessary subsystems and

test instrumentation are installed and checked and that procedures are complied with on part marking, configuration identification, etc. Handling equipment, servicing equipment, test equipment, test procedures, and final assembly are the major elements of WBS ID 1.4.1. Subassemblies of individual subsystems are covered under the individual subsystem WBS ID's.

IV. DESIGN REQUIREMENTS

Major design requirements for WBS ID 1.4.1 include design of mechanical and electrical handling, servicing and electrical equipment required for Stage I Integration and Assembly and the design of tooling required for assembly of subsystems into the required test or production article. Close coordination between maintainability engineering and manufacturing needs to be maintained to ensure that equipment designs are reviewed for applicability to factory only or have potential multiple use in the field operations (horizontal and vertical test) and/or turnaround operations. Reviews also should continuously be conducted for identification of equipments as peculiar or common.

V. INTERFACES

WBS ID 1.4.1 directly interfaces with each of the twelve subsystems comprising Stage I, noted in Section II of WBS Dictionary Element 1.4. In addition, the following non-vehicle elements affect WBS ID 1.4.1.

WBS ID	Interface	Type of Interface
4.2	Subsystem Development Tests	When more than one subsystem, or assembly thereof, requires prototype equipment, WBS ID 1.4.1 will integrate and assemble as called out by drawing and test specification.
4.4	Structural Tests	Provide assembled structural test article, instrumentation, mass simulations as required.

WBS ID	Interface	Type of Interfaces
4.6	Single Element Flight Test Vehicles	Final assembly and test of FTVs, including retrofit to production vehicle following dedicated Horizontal FTV test program. Install main engines in vertical FTV following cluster engine firings. Provide field kits as needed. Provide spares as required.
4.7	Mated Flight Test Vehicles	Support as required (assume final assembly of these vehicles has been performed in above steps; otherwise, assemble and test per drawing and specification). Retrofit to production vehicle following vertical flight test program.
4.9	Mockups	Build or modify existing mockups as required.
12.1.3.1	Production Vehicles	Assemble and test per drawing and specification when required for operational program.
3.0/8.0	Ground Support Equipment	Any Factory Support Equipment (FSE) identified for field and/or operational use as GSE will be nameplated per MIL-STD for field procurement.

WBS ID	Interface	Type of Interfaces
5.0	System Engineering	Provide support to SE&I as required to provide CEI Part I/ Part II callouts for FSE/GSE, test procedures, etc. Comply with drawings and specifications affecting factory operations.
6.0	Data	Provide drawings and documentation on factory equipments as called out by contract as deliverable data.
9.0	Initial Spares and Repair Parts	Fabricate and deliver to site as required.
10.0	Training	Provide factory support for simulators and training aids as required.
11.0	Industrial Facilities	Production to Facility interfaces as required: planning, installations, utilization.
12.0	Operations	Production vehicle assembly and support through turnover to NASA.

VI. TEST REQUIREMENTS

The tests to be conducted in the WBS ID 1.4.1 element will be established by test engineering, design engineering, and manufacturing engineering. From the received component, assembly, module, and subsystem through final assembly, tests will be conducted to ensure electrical continuity, systems EMI compatibility, leak-proof connections, proper torquing on threaded connectors, structural integrity, etc. Many of these tests will be conducted at the subsystem level, with final assembly testing being minimized until system integration (end-to-end) testing prior to roll-out. These latter tests are more fully defined in WBS ID 4.2.9.

VII. REFERENCES

(To be added)

INPUTS

M02

K22

N06

K02

K05

K07

OR

ASSEMBLE CREW SECTION FOR HORIZON VEHICLE

CREW SECTION INTEGRATED CHECKOUT

AND

TRANSPORT TO FINAL ASSEMBLY PLANT

SECURE/ SEAL CREW SECTION

MODIFY SOFTWARE

MODIFY PROCEDURES

MODIFY GSE, CABLES, OR FIXTURES

AND

FINAL ASSY + BLACK BOX TESTS OF HORIZONTAL VEHICLE

NOTE

INCLUDES: AFT SECTION, MID SECTION, NOSE SECTION, CREW SECTION, WING, LANDING GEAR, THERMAL PANELS, ADES, MAIN GROUND TEST ENGINES, RCS GROUND TEST ENGINES, ANTENNAE AND FOLLOWING BLACK BOXES NOT WITHIN CREW SECTION – DATA MGMT, SECONDARY POWER, FLIGHT CONTROLS, COMMUNICATIONS AND GUIDANCE & NAVIGATION.

ASSEMBLE CREW SEC FOR VERTICAL VEHICLE

AND

CREW SECTION INTEGRATED CHECKOUT

SECURE/ SEAL CREW SECTION

TRANSPORT TO FINAL ASSEMBLY PLANT

AND

NOTE -

INCLUDES - AFT SECTION, MID-SECTION, NOSE SECTION CREW SECTION WING, LANDING GEAR, THERMAL PANELS, ADES, MAIN, AND RCS ENGINES, ANTENNAE AND FOLLOWING BLACK BOXES NOT WITHIN CREW SECTION: DATA MGMT, SECONDARY POWER, FLIGHT CONTROLS, COMMUNICATIONS, AND GUIDANCE & NAVIGATION.

FINAL ASSY + BLACK BOX TESTS OF VERTICAL VEHICLE

MFGRS

QUALITY

ENGINEERING

N10

N04

OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.4.1.0.0
TITLE	STAGE 1 INTEGRATION AND ASSEMBLY
WBS LEVEL	FIFTH (5TH)
PAGE	1 OF 1
DATE	26 MAY 71

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2

TASK TITLE AIRFRAME & STRUCTURE (STAGE I)

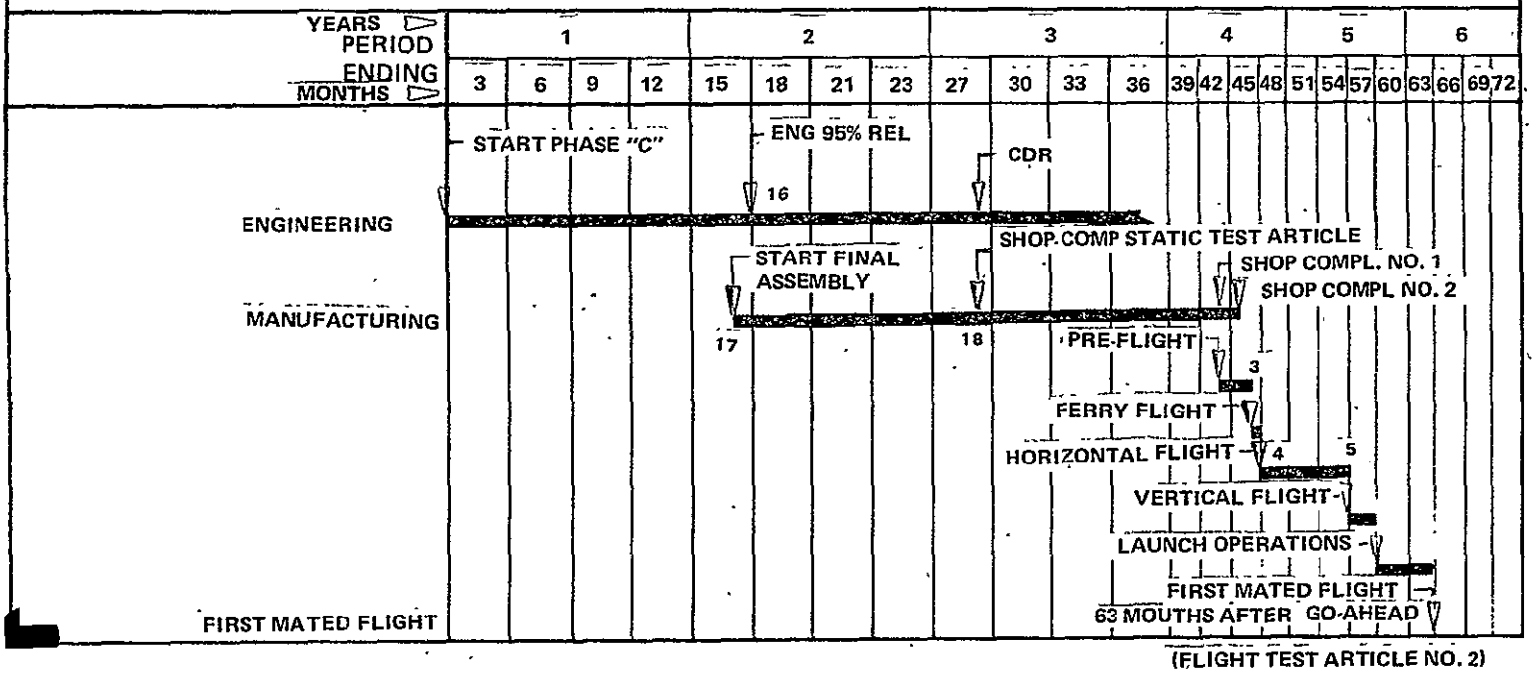
LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned, reusable, i.e., winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landing by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to maximum capability, depending

TASK SCHEDULE MILESTONES



on mission requirements.

To meet the above requirements, the airframe and structure of Stage I must provide properties and characteristics compatible with the total Stage I flight spectrum (pre-flight activities, launch activities, ascent in the Air Vehicle configuration, separation of Stage II, exoatmospheric maneuvers to achieve position for entry to desired landing site, reentry into the sensible atmosphere, transition to and through the transonic regime, subsonic cruise, deploy onboard air-breathing engines if required for approach or go-around, conduct final approach flare, touchdown, runout, and parking on the airport ramp for post-flight servicing). On-board air-breathing propulsion will be required for ferry flight.

In addition to Stage II plus full payload carrying capability in both the horizontal (pre-launch) and vertical (launch) mode, Stage I airframe and structure must provide: (1) volume and weight-carrying capability for Stage I crew; (2) for environmental control (active and passive) of the vehicle and its crew; (3) volume and weight-carrying capability for required on-board subsystems (propulsion, secondary power, avionics, safety); and (4) controls (exo and endoatmospheric) required to maintain flight attitudes and provide maneuvering capability during power-on, power-off flight phases. Finally, the airframe and structure must provide flotation for landing and taxiing and speed reduction capability to bring the vehicle to a safe end-of-runway halt in compliance with landing regulations appropriate to the airport.

Constraints on Stage I airframe and structure, in addition to mission environment capability through a specified lifetime, include the following: (1) maintainability, (2) reliability, (3) safety compliance, (4) operability, (5) aerodynamic stability, (6) human factors acceptability, (7) quality assurance, (8) commonality and/or exchangability between vehicle tail numbers and (9) cost minimization through use of proven technology, good design practice, good production practice, and thorough flight qualification prior to achieving operational status.

II. ASSEMBLIES DEFINITION

The choice of airframe and structure assemblies for Stage I is, in a sense, dependent on stage configuration. The assemblies listed below and shown on Figure 1.4-W-3 are based upon the baseline concept and are thus subject to any modifications resulting from selected concept definition.

1.4.2.1	Integration and Assembly
1.4.2.2	Wing
1.4.2.3	Canard
1.4.2.4	Vertical Stabilizer
1.4.2.5	Fuselage
1.4.2.6	Stage II/Stage I Separation
1.4.2.7	Nose Gear
1.4.2.8	Main Gear

III. FUNCTIONAL DESCRIPTION

The airframe and structure provide the aerodynamic shape, volume and load carrying capability to meet the mission requirements. This includes providing the required interface with Stage II and its payload in the pre-launch, launch, and Stage I acceleration-to-staging point ascent phases of the Space Transport mission, then returning intact to earth and turnaround for maintenance and preparation for next mission launch. Ground handling capability in either a horizontal or vertical attitude must be provided. For the heat loads associated with engine firing (base heating), for ascent, for possible Stage II plume impingement, and for reentry, primary and secondary structure must be thermally protected, as well as providing a heat barrier to crew and other Stage I subsystems. Aerodynamic and aero thermodynamic stability and control capability must be provided throughout all flight phases. GFE provided main engine thrust [engines are common between Stage I and Stage II in baseline concept] must be dissipated throughout the primary structure to reduce dynamic and acoustic energies associated with a throttleable thrust level. Mating with Stage II must be positive during Stage I-Stage II handling, countdown, launch and ascent. At separation (Stage I-controlled in normal mode, Stage II-controlled in backup mode), loads induced by

Stage II engine thrust and separation must be properly handled by structure.

The cryogenic propellant tanks (LH_2, LO_2) for main engine thrust are integral with structure in the baseline concept and must assist in carrying all flight loads, whether tanks are full, partially full, or empty. These tanks will account for much of Stage I volume and weight and must be optimized for both producibility, integrity, pressure variation tolerance and load carrying capability. Secondary propellant tanks to carry additional cryogens for other propulsion needs, if required, must be incorporated into interstices so as not to significantly disturb the c. g. and mass property shifts with subsequent effect on vehicle airworthiness. To prevent weight buildup from frost forming on sides of main propulsion tanks, insulation, if required, should be added to tank structures in accordance with mission duration, heat transfer, and temperature differentials anticipated. Purge of potentially hazardous liquids and gases which collect inboard must be available throughout the mission. Venting shall not impose hazards nor provide impulse to the mission.

For an aerodynamically stable vehicle operating in the atmosphere, aerodynamic surfaces and controls must be provided. For main lift, a wing must be provided. Its size, shape, sweepback and weight will be a function of the aerodynamic properties imposed on it. For high crossrange capability, its L/D must be optimized to reduce drag, resist aeroelastic couplings with other aerodynamic surfaces which tend to induce instability, tolerate heat loads without undesired deformation of shape, while enabling control of angle-of-attack, sideslip and/or bank angle to be introduced to achieve desired downrange and crossrange capability. In addition to desired L/D properties for reentry, the wing must provide adequate lift to enter the transition phase without inducing undesired aeroelastic dynamics and instabilities, then to provide stable power-off cruise capability in the transonic and high subsonic regions to either a power-on (nominal mode) or power-off approach, flare and landing region. Adequate lift for climbout and cruise for ferry flights must also be provided in wing design.

For vertical stability and horizontal stability to augment wing action, a vertical stabilizer and canard (or horizontal stabilizer) will be required. The vertical stabilizer, with conventional rudder attached, will provide lateral control needed for crossrange control. The trimmable canard used in the baseline concept will enable angle-of-attack control to assist in balancing c.g. shifts due to rear main engine weight in the propellant-depleted state following ascent through reentry.

For landing on conventional concrete runways, a steerable nose gear and brakable main gear will be required. They should be retractable and operated through conventional servomechanisms. Crab control under high side gust conditions is a tradeoff to be evaluated.

For crew station needs, a pressure vessel cabin and equipment compartment will be required. This vessel is part of the airframe and should be located for crew visibility, including windows, egress/ingress, escape, etc.

Air-breathing engines, required for ferry flights and go-around landings, should be internally stowed in the fuselage and wing during flight phases when they are not required, then deployed at endoatmospheric altitudes when they are required. Thrust from these engines, when firing, as well as their inert weight, must be accounted for, including tankage for fuel needed for mission return and for ferry flights.

A separation mechanism which both holds and constrains Stage II (with full payloads) is required. This mechanism must release and translate Stage II on command such that there is sufficient clearance for unhindered Stage II acceleration away from Stage I without damage to either stage. The mechanism must be retractable following staging.

For access to critical components or structure during scheduled or unscheduled maintenance cycles, access doors, panels and openings should be provided. Sealing these against critical environments must be provided.

External thermal protection by means of replaceable leading edges, nose cap and aero surface/body panels should be incorporated into the design if materials are chosen which ablate or otherwise corrode or degrade due to handling and to repeated mission cycling. Inspection panels must be provided to verify internal fastening of such thermal protection has not been degraded. Internal structural insulation, if subject to degradation over the required Program life, should be inspectable and replaceable without major overhaul.

To achieve operational status, the airframe and structure will be verified in the RDT&E phase by following the steps briefed below:

A. Phase C Go-Ahead Through PDR - Depending on end item (CEI) breakdown of Stage I, completion of preliminary design will result in a Part I specification affecting airframe and structure. Detailed definitions will specify performance, interfaces, and effectiveness required of this subsystem. Upon approval of CEI Part I, final design can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II can be prepared. (See Para. VI for tests affecting this phase).

C. CDR to Qualification Testing - Release of drawings to manufacturing will allow final integration and Assembly to be performed to build the Structural Test Vehicle and Flight Test Vehicles to be used for Pre-flight, Ferry Test, Horizontal Flight Test, Single Element Vertical Flight Test, and mated Flight Test programs. Qualification will finally be granted through DD 250 (or equivalent) buyoff when airframe and structure, as well as all other Stage I subsystems, prove they meet specification to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Level I and Level II requirements affecting airframe and structure are stated in WBS Dictionary Element 0.0 and will not be repeated here. In addition to those cited, standard aircraft and spacecraft design practice will apply to aircraft and structure through choice of strong, light weight materials which can be fabricated within the state-of-the-art (aluminum and titanium for example). Materials which, in addition to strength and light weight, must posses thermal capability should be selected only if they have proven technology development behind them or can prove such capability in a normal test program. Insulation materials should be lightweight, have low heat conductivity, possess needed strength, be easily fabricated, and resist corrosion or be properly coated for this purpose. Crew windshields, if subjected to direct or indirect thermal energies, must resist undue expansion, must remain transparent, should reduce glare, prevent fogging, etc. Landing gear must be properly designed to handle repeated landing loads, provide adequate flotation, be retractable and extendable in a positive manner, and be compatible with intended environment. Additional design requirements will be specified as applicable based upon CEI Part 1's when generated.

V. INTERFACES

The airframe and structure for Stage I interfaces with all other subsystems of the Stage as noted on Figure 1.4-W-3 and specified in WBS Dictionary Element 1.4. The payload constraint is stated in WBS Dictionary Element 1.2. In addition, interfaces exist with Stage II (WBS ID 1.3) through the separation mechanism (WBS ID 1.4.2.6), and through a need for stage-to-stage communications (WBS IDs 1.4.9.4 - to - 1.3.9.4). For ground handling and operations, interfaces exist with Peculiar and Common Support Equipment (WBS ID 3.0/8.0), with operational Launch and Recovery Equipments (WBS ID 2.0), with Test and Evaluation (WBS ID 4.0), with System/Program Management (WBS ID 5.0), with Data (WBS 6.0), with initial Spares and Repair Parts (WBS ID 9.0), with Training (WBS ID 10.0), with Industrial Facilities (WBS ID 11.0), and with Operations (WBS ID 12.0). These interfaces are spelled out on the referenced WBS Dictionary element descriptions as applicable.

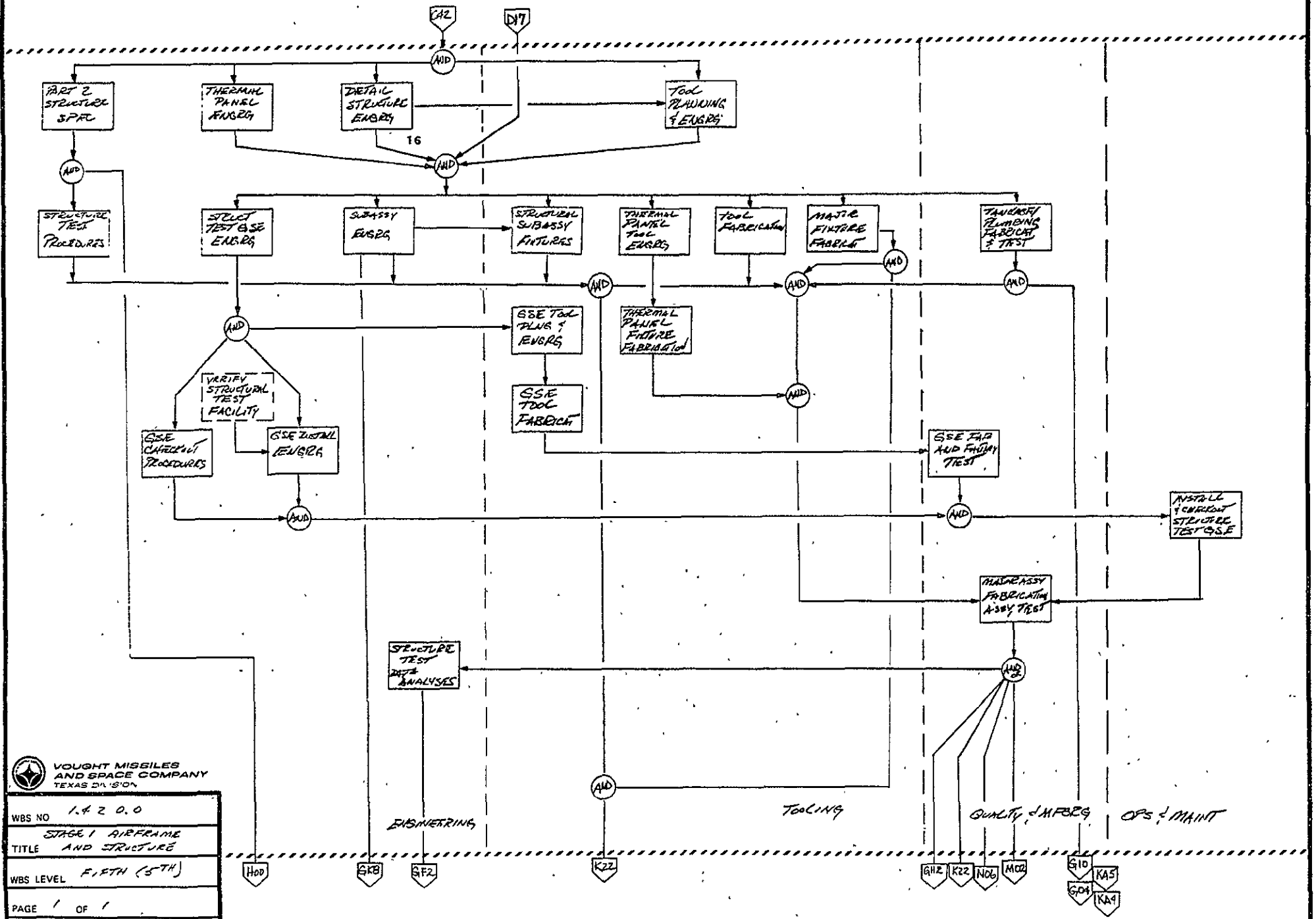
VI. TEST REQUIREMENTS

Airframe and structure component and assembly testing will be conducted as required under subject WBS element. Static, dynamic and thermal tests will be conducted under WBS ID 4.2, as will completion of wind tunnel testing. Structural Test Vehicle testing in either a static jig or hydrodynamic test fixture will be conducted under WBS ID 4.4. Flight testing will be conducted under WBS ID 4.6 and 4.7.

VII. REFERENCES

(To be added)

INPUTS



OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.4.2.0.0
TITLE	STAGE I AIRFRAME AND STRUCTURE
WBS LEVEL	FIFTH (5TH)
PAGE	1 OF 1
DATE	27 MAY 71

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.2

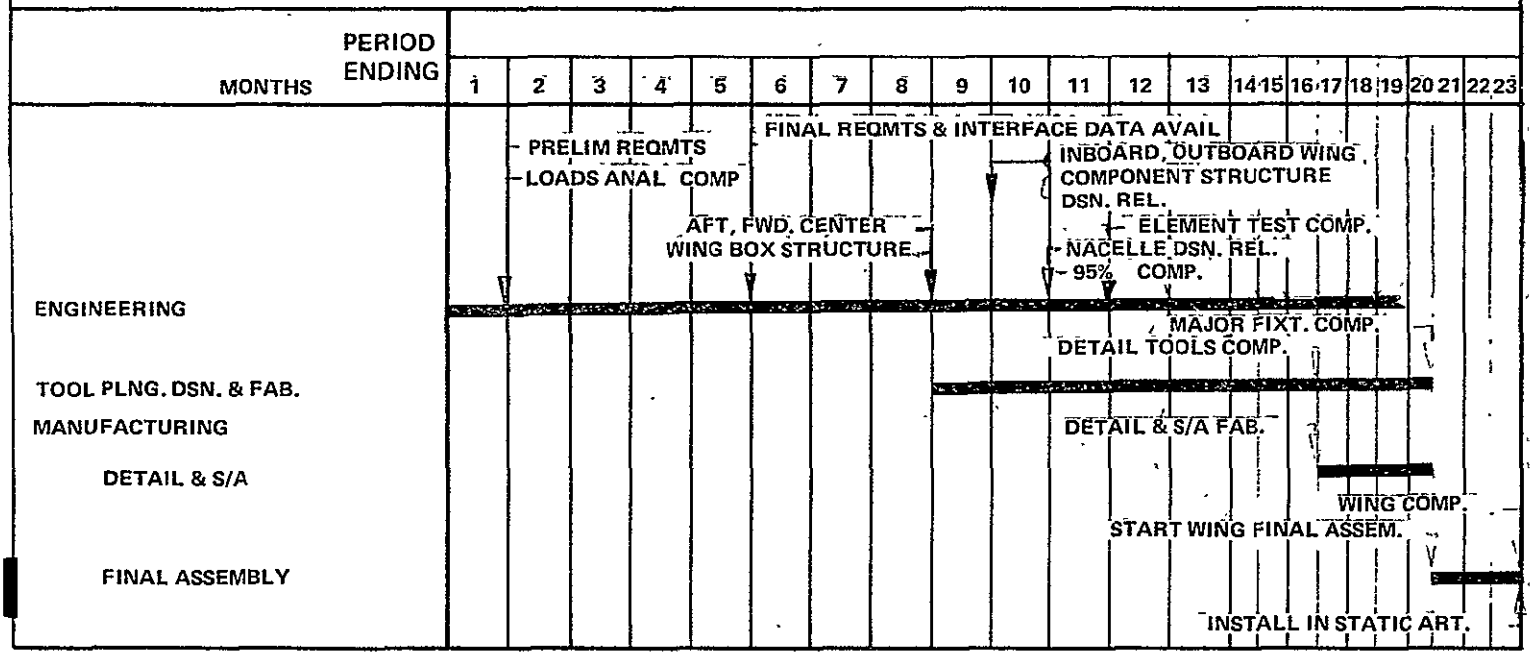
TASK TITLE WING (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.2)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.2.8

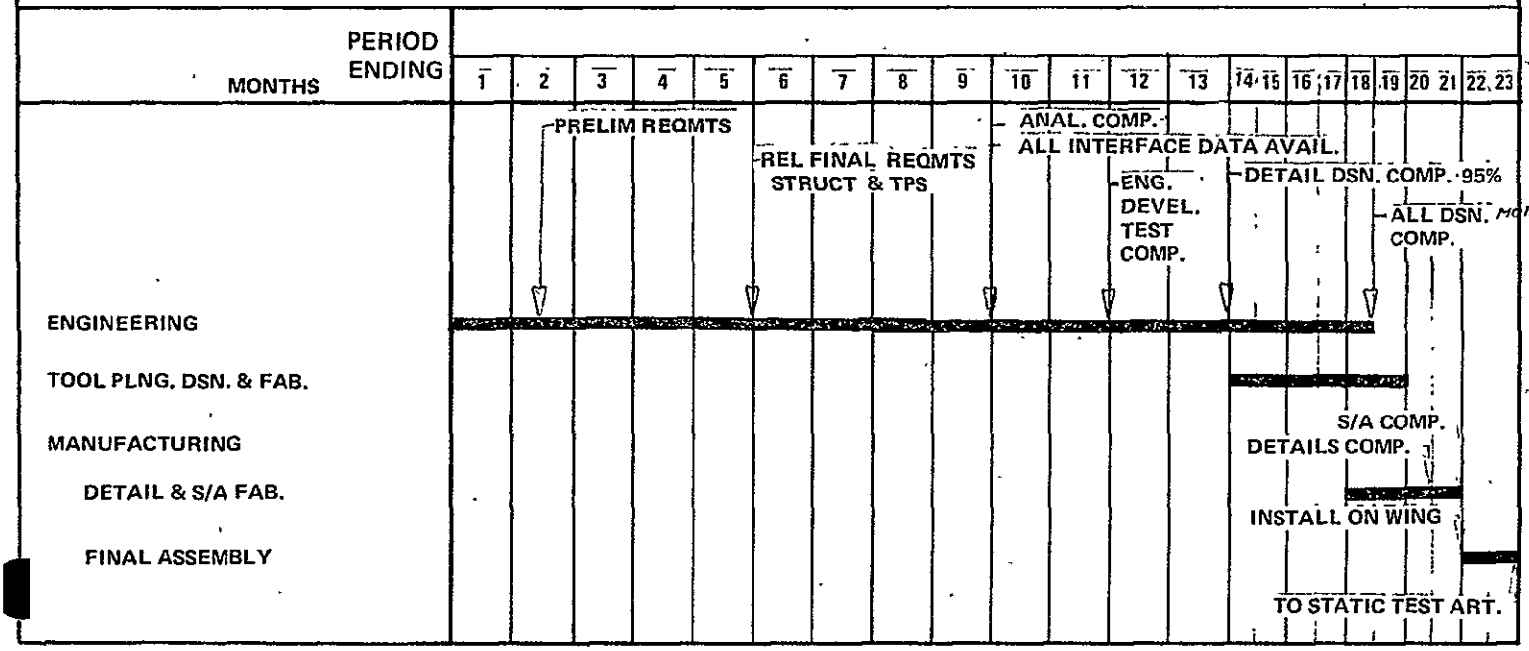
TASK TITLE ELEVONS STRUCTURE (STAGE I)

LEVEL 7, Component Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.2)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.2.11

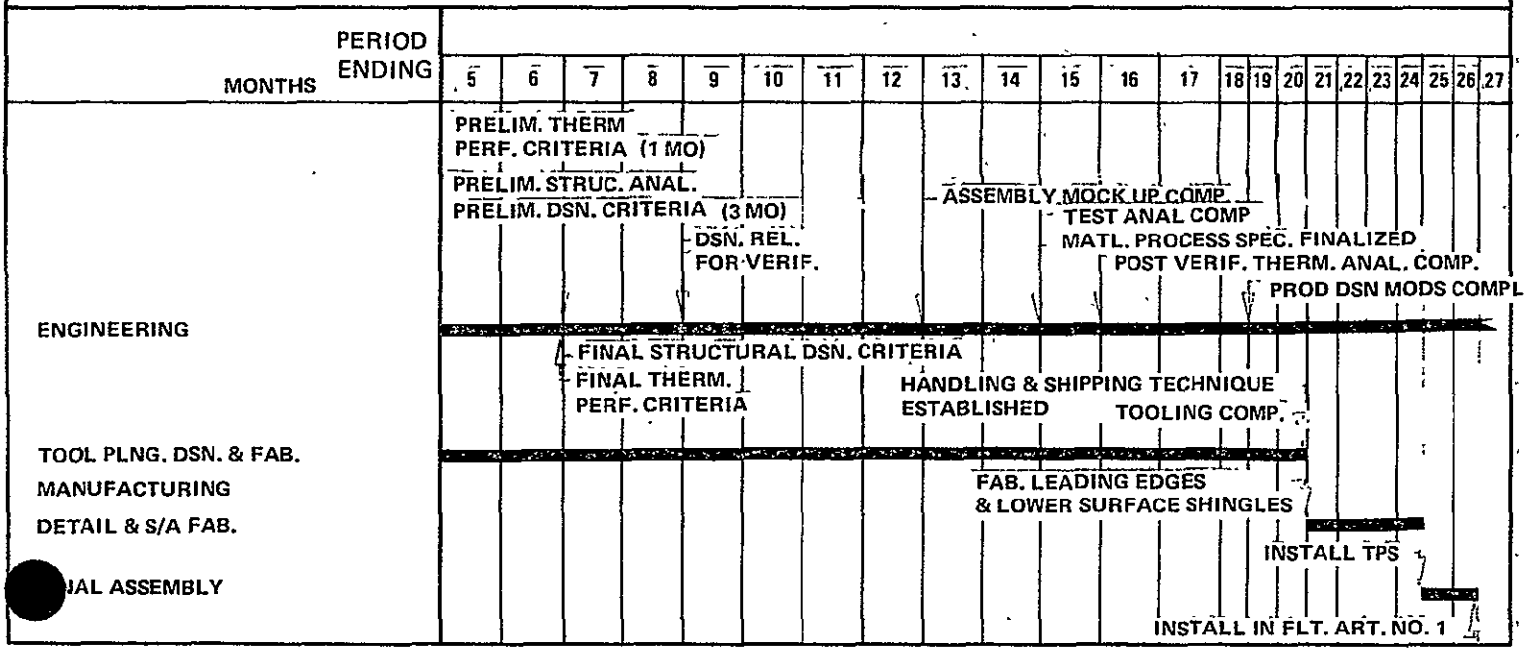
TASK TITLE WING TPS (STAGE I)

LEVEL 7, Component Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.2)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.3

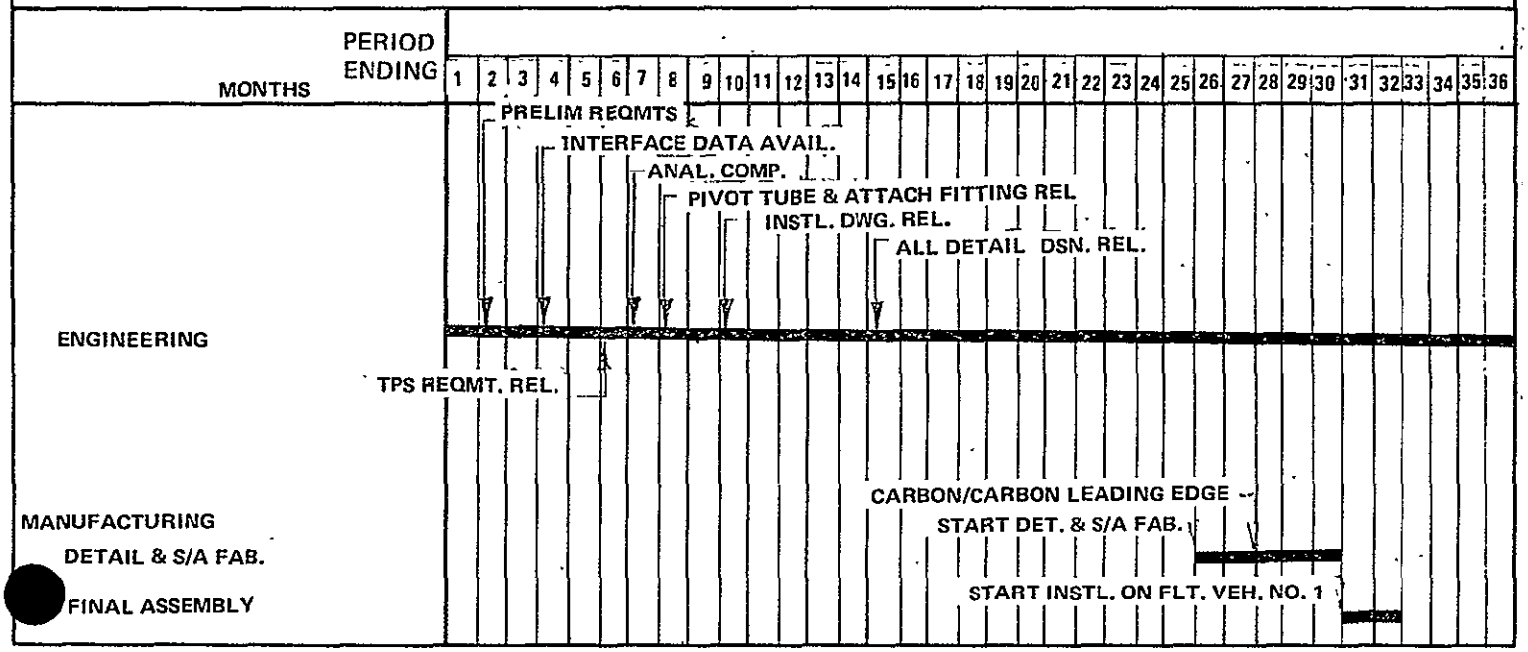
TASK TITLE CANARD (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.2)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.4

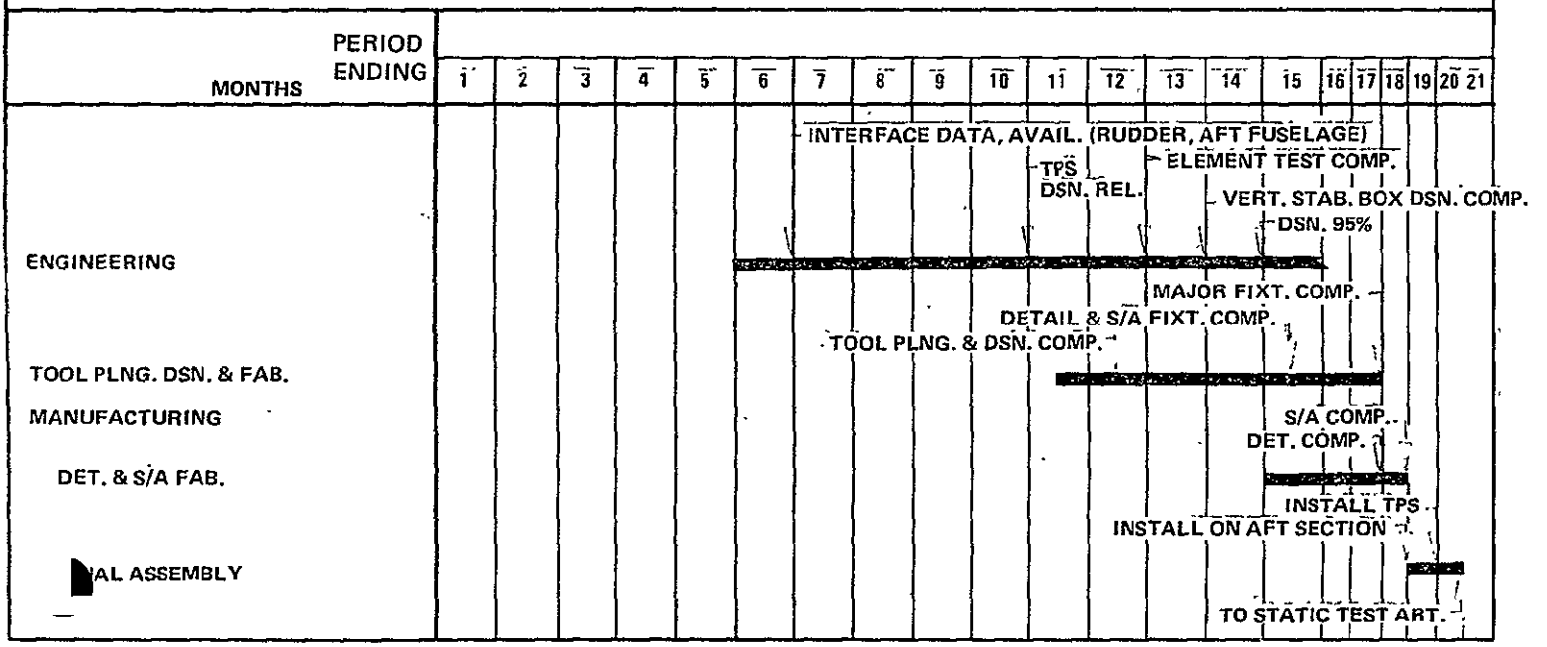
TASK TITLE VERTICAL STABILIZER (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.2)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.5

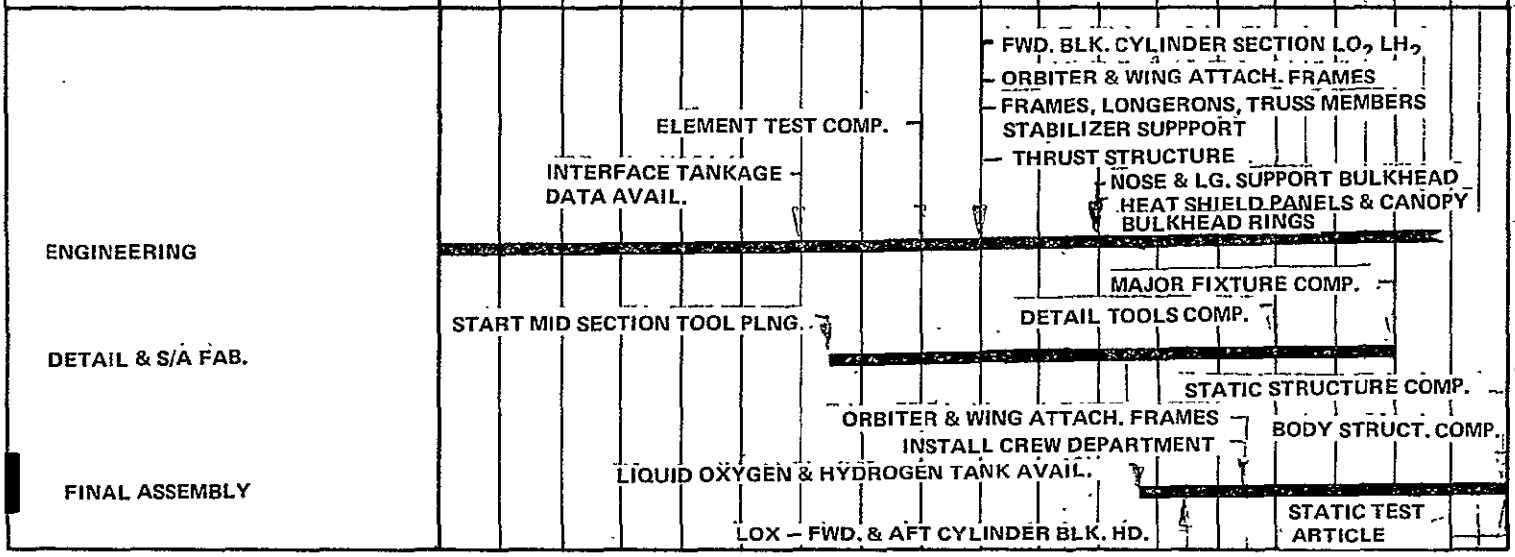
TASK TITLE FUSELAGE (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.2)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.5.2

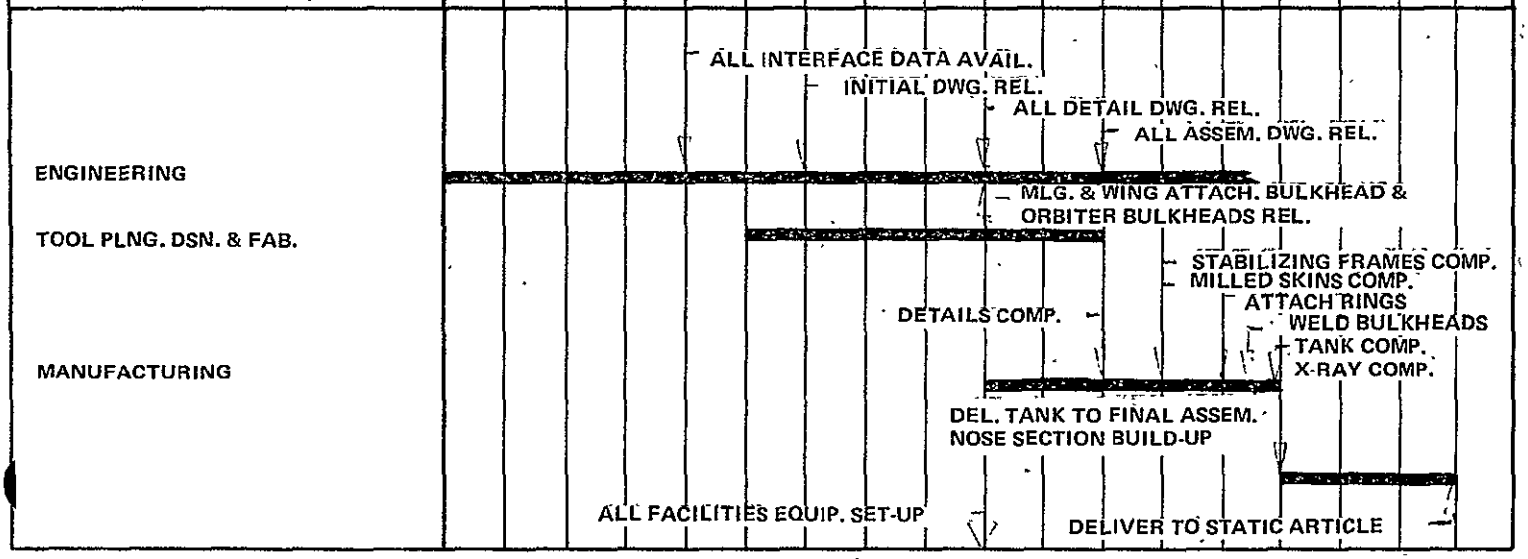
TASK TITLE MAIN LH_2 STORAGE TANK (STAGE I)

LEVEL 7, Component Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.2 and 1.4.3)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.5.3

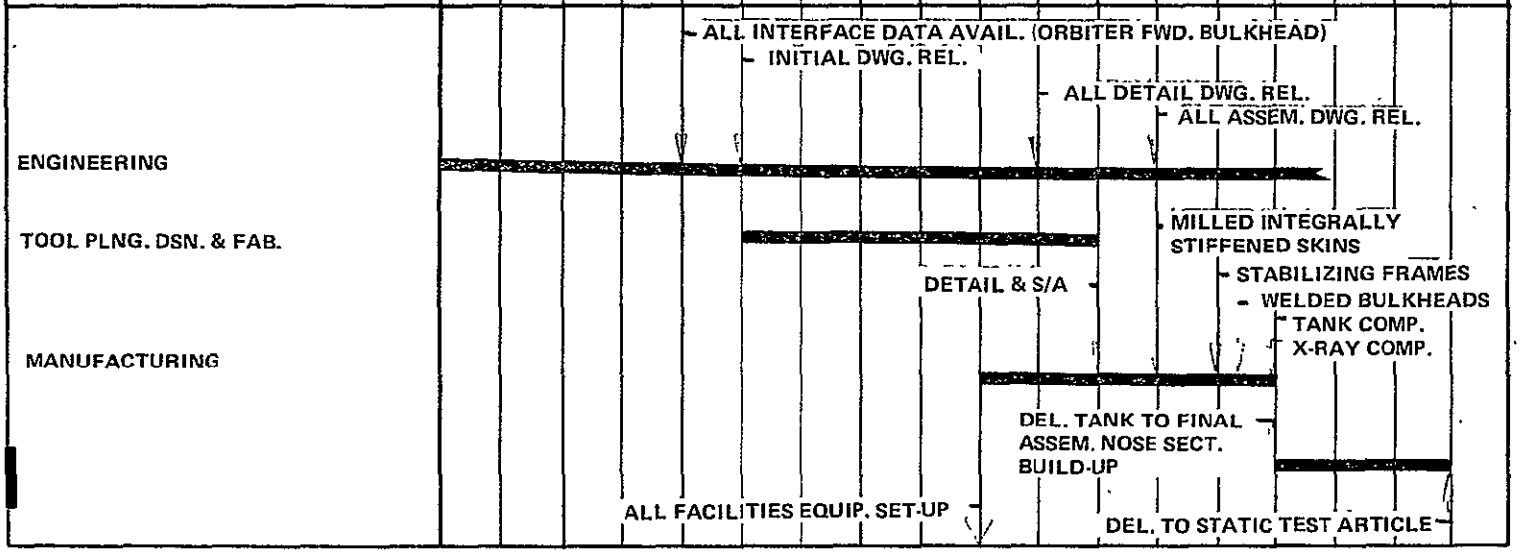
TASK TITLE MAIN LO_2 STORAGE TANK (STAGE I)

LEVEL 7, Component Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Elements 1.4.2 and 1.4.3)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.6

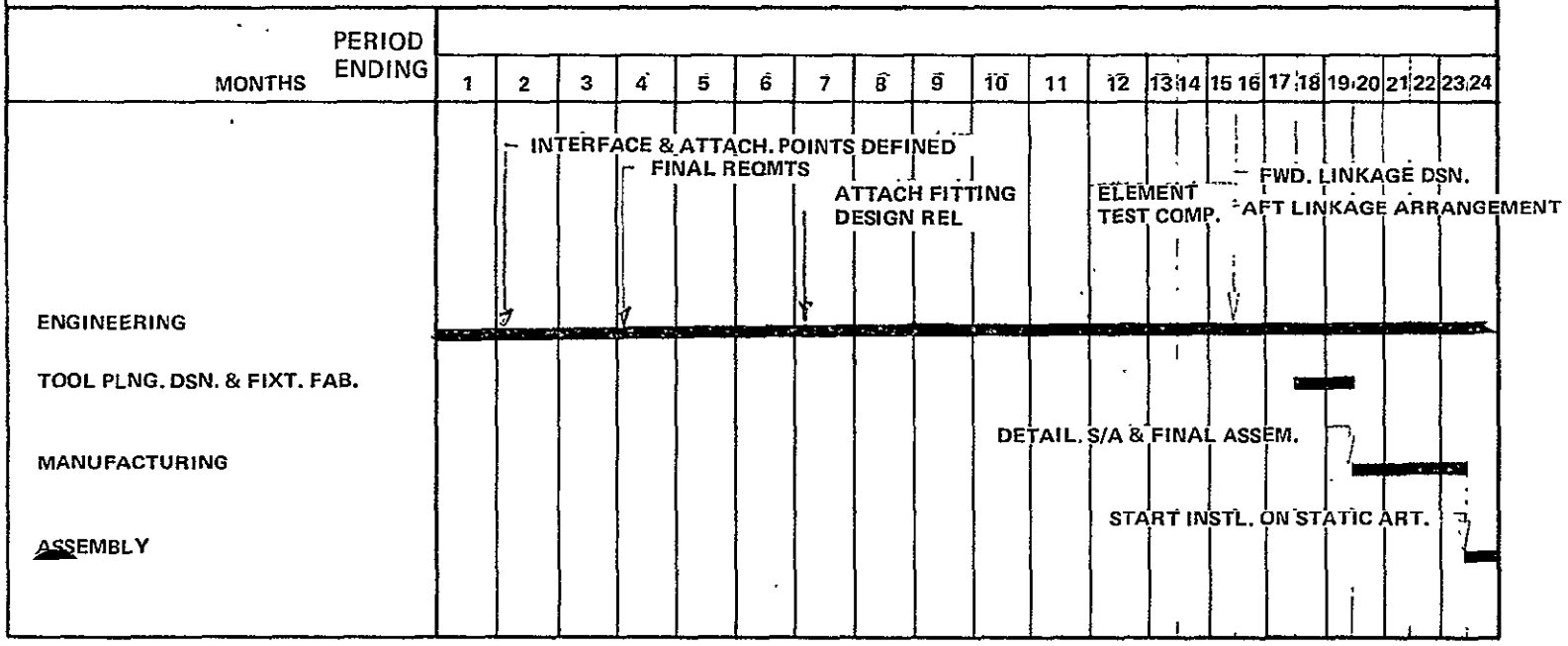
TASK TITLE STAGE II/STAGE I SEPARATION (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.2)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.7

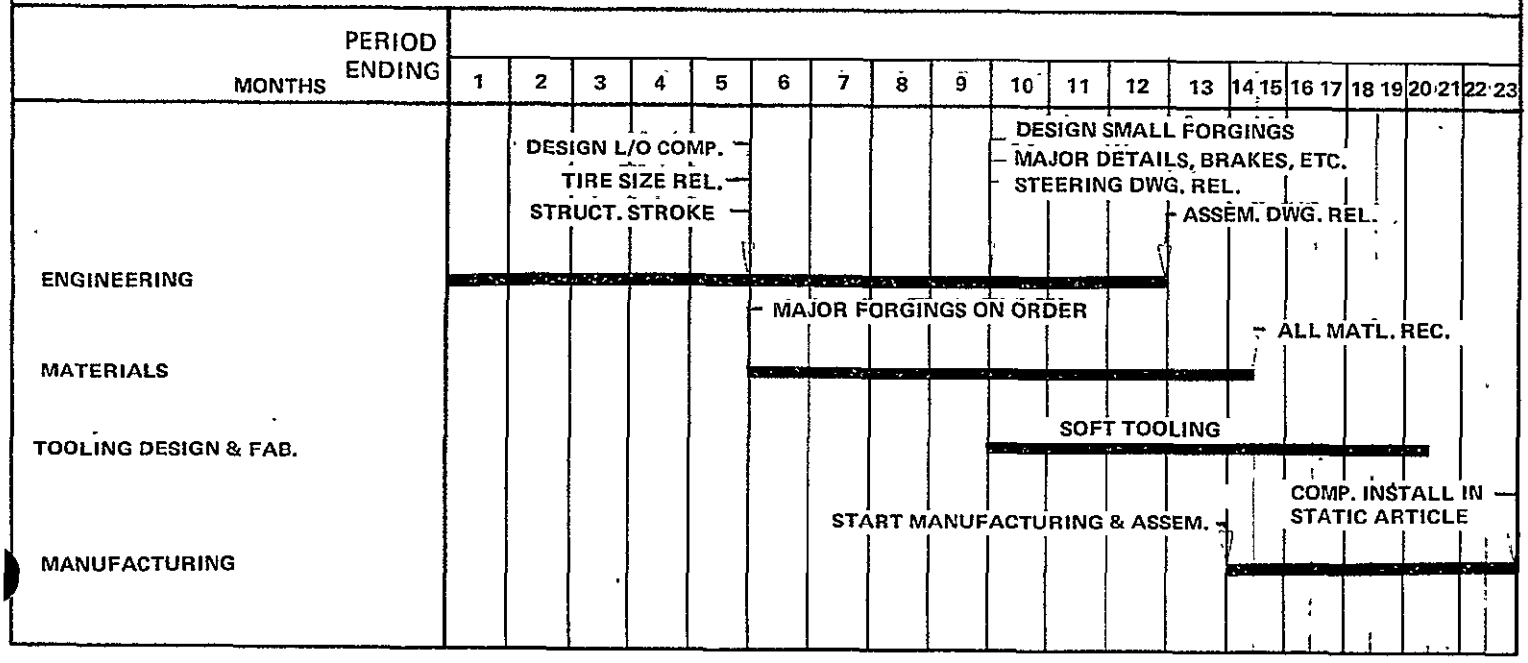
TASK TITLE NOSE GEAR (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.2)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.2.8

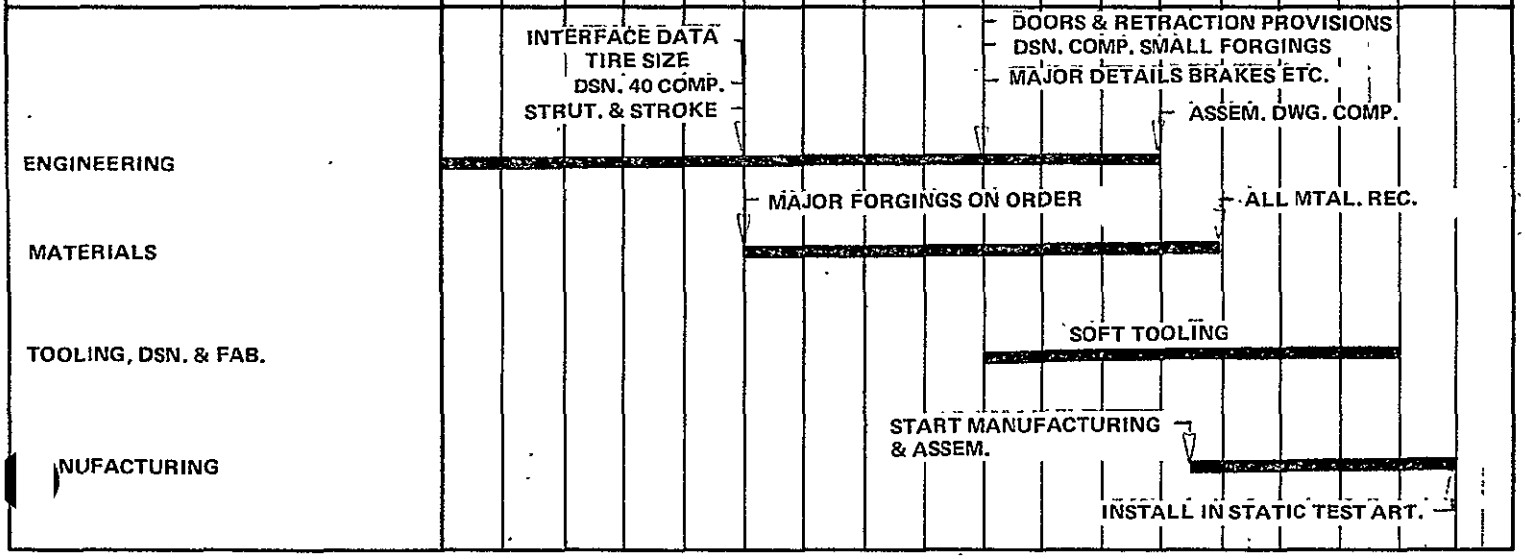
TASK TITLE MAIN GEAR (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.2)

TASK SCHEDULE MILESTONES



PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.3

TASK TITLE PRIMARY CRYOGENIC STORAGE (STAGE I)

LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned, reusable, i.e., winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landings by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to

TASK SCHEDULE MILESTONES

PERIOD ENDING

SEE LOWER LEVELS FOR DETAIL SCHEDULES

maximum capability depending on mission requirements.

NASA has specified that GFE Main Engines will be provided which burn cryogenic propellants (LH_2, LO_2) for both Stage I and Stage II ascent. A means is required, therefore, to store these propellants prior to launch, then to utilize them in Stage I for liftoff and Air Vehicle ascent through staging, at which time Stage I engines will be throttled while Stage II will fire with subsequent stage separation. Stage I will then shut down and coast to its apogee for entry position and subsequent reentry. In addition to main engine propellants, secondary storage capability is required for exoatmospheric attitude control propulsion (ACPS) using reaction type thrusters and to provide auxiliary power units (APUs) for secondary power required prior to liftoff through the landing phase.

Thus, cryogens (LH_2 and LO_2) are required for main engines, for ACPS and for APUs. Storage of these cryogens is concept dependent. For the baseline concept, consider main LH_2 and LO_2 tanks supply the main engine only and that secondary LH_2 and LO_2 tanks supply ACPS and APUs. Further, consider main tanks, only, as integral structure (WBS ID 1.4.2) and secondary tanks as separate, non-integral elements. Based upon these assumptions, WBS ID 1.4.3 consists only of secondary cryogen propellant storage tanks as noted on Figure 1.4-W-3. Other combinations, however, should not be ruled out.

Constraints placed upon all primary cryogenic storage include need for careful integration of propellant requirements to: (a) maximize utilization for safe, normal and aborted missions, (b) take advantage of the cryogen temperatures for heat sink properties, (c) ensure spillage or vapors are either safely trapped or vented overboard so as to prevent undesired hazards, (d) manifold feed lines and vent lines to allow flexibility of utilization as well as to reduce weight,

(e) monitor propellant status for efficient reserves requirements, and (f) notify both crews if emergencies are present while in the mated configuration. System effectiveness constraints specifically include: (1) safety, (2) reliability, (3) maintainability, and (4) quality assurance. The on-off requirements of ACPS engines must be considered in tank design, sumps, valving, and duct interfacing.

II. ASSEMBLIES DEFINITION

As stated above, an assumption is made that main propellant storage tanks to feed main ascent engines are integral with structure and that secondary storage tanks are required to supply ACPS and APUs. Based on these assumptions, the assemblies under WBS ID 1.4.3 are as follows:

1.4.3.1	Integration and Assembly
1.4.3.2	Main LH_2 Storage Tank*
1.4.3.3	Main LO_2 Storage Tank*
1.4.3.4	Secondary LH_2 Storage Tank (ACPS/APU)
1.4.3.5	Secondary LO_2 Storage Tank (ACPS/APU)

(*See Airframe and Structure, WBS ID 1.4.2.5 (Fuselage))

III. FUNCTIONAL DESCRIPTION

The secondary cryogenic storage tanks must provide sufficient capacity to handle the liquid propellant needs (changed to gases for operations of Attitude Control Propulsion System (ACPS) and Auxiliary Power Units (APUs) as required by mission demand. Pad activities are assessed to be handled by ground supplies until that point in the countdown where tanks will be filled, topped, and made ready for liftoff. Major provisions of the secondary tankage, in addition to storage, include fill lines for ground filling, drain lines, and vent and relief lines and controls. Insulation may be required to both maintain liquid temperatures as well as prevent frost buildup on tank exteriors. A tradeoff will exist as to whether

propellants require pressurization for positive expulsion or can be gravity fed to their feed lines. In the baseline concept, secondary tanks are gravity fed while main tanks are pressure fed. The desig of the cryogenic storage tanks, both main and secondary, needs to be closely integrated, together with using subsystems, in Phases C and D as follows:

A. Phase C Go-Ahead through PDR. Depending on end item (CEI) breakdown of Stage I, completion of preliminary design from Phase B will result in a Part I specification affecting primary cryogenic storage. Detailed definitions will specify performance, interfaces, and effectiveness required of this subsystem. Upon approval of CEI Part I, final design can proceed.

B. PDR to CDR. In this phase, design and development will proceed to the point where CEI Part II can be prepared (see Para. VI for tests affecting this phase).

C. CDR to Qualification Testing. Release of drawings to manufacturing will allow final Integration and Assembly to be performed to build the Structural Test Vehicle, prototype tank assemblies for proof, thermal and dynamic testing, and Flight Test Vehicles to be used for Pre-Flight, Ferry Test, Horizontal Flight Test, Single Element Vertical Flight Test, and Mated Flight Test programs. Qualification will be finally granted through DD 250 (or equivalent) buyoff when Primary Cryogenic Storage, as well as all other elements of Stage I, prove they meet specification to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Level I and II requirements affecting Primary Cryogenic Storage are stated in WBS Dictionary Element 0.0 and will not be repeated here. In addition to those cited, standard spacecraft design practice (adapted also to standard aircraft design practice) will apply to Primary Cryogenic Storage through choice of strong, lightweight

materials which can be fabricated within the state-of-the-art (aluminum for example). Supporting structure should consider the effects of thermal transfer to both minimize incoming heat loads from ascent as well as heat losses from the tankage into other structure and subsystems. Accessibility to tank exteriors and interiors must be provided to ensure structural and functional integrity throughout Program life. Environmental loads (thrust, lateral motions, engine pull-downs, pressurization, etc.) must be designed for through tank stiffness, tank shape, and outlet/inlet sizing. Baffling, if required to minimize slosh forces, must not trap liquids unnecessarily. For immediate start capability, a known capacity reservoir must be provided in the ratios of fuel-to-oxidizer required for mission profile needs. Outlet ducts to using subsystem feed line interfaces must meet the sizing imposed by user requirements. Fill and drain lines should be sized in accordance with both horizontal and vertical utilization needs. Pressure regulation should be provided which is compatible with total mission profile requirements. Purge capability must be provided.

V. INTERFACES

The Primary Cryogenic Storage Subsystem interfaces with other Stage I subsystems as follows (see Interfacing WBS Dictionary elements for interface descriptions).

Main Tankage (See 1.4.2.5)	Interface	Secondary Tankage	Interface
LH_2/LO_2 Tankage	. 1.4.4.2, Main Propulsion . 1.4.11, Display and Controls . 1.4.10, Data Management	LH_2/LO_2 Tankage	. 1.4.4.3, ACPS Propulsion . 1.4.6.2, Power Source (APUs) . 1.4.2.5, Fuselage . 1.4.11, Displays and Controls . 1.4.10, Data Management . 1.4.5.6, Flight Control Electronics

Interfaces to other Program elements include the following: (a) 2.5/2.6, Launch and Recovery Equipment; (b) 3.0/8.0; Maintenance Equipment, (c) 4.0, Systems Test, Evaluation, Mockups; (d) 5.0, System/Program Management; (e) 6.0, deliverable Data; (f) 9.0, Initial Spares and Repair Parts; (g) 10.0, Training; (h) 11.0, Industrial Facilities; and (i) 12.0, Operations. In addition, the mass properties of Stage II (WBS ID 1.3) with Payload (WBS ID 1.2) affect Primary Cryogenic Storage, as well as total Stage I mass properties (WBS ID 1.4).

VI. TEST REQUIREMENTS

Primary storage tank testing (Main and Secondary tanks) will be tested as single components and assemblies under WBS ID 1.4.2.5 and 1.4.3 as well as under WBS ID 4.2. System tests of these tanks will be conducted under WBS ID 4.2., 4.6, and 4.7. Mockups will be included under WBS ID 4.9.

VII. REFERENCES

(To be added)

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.3.4

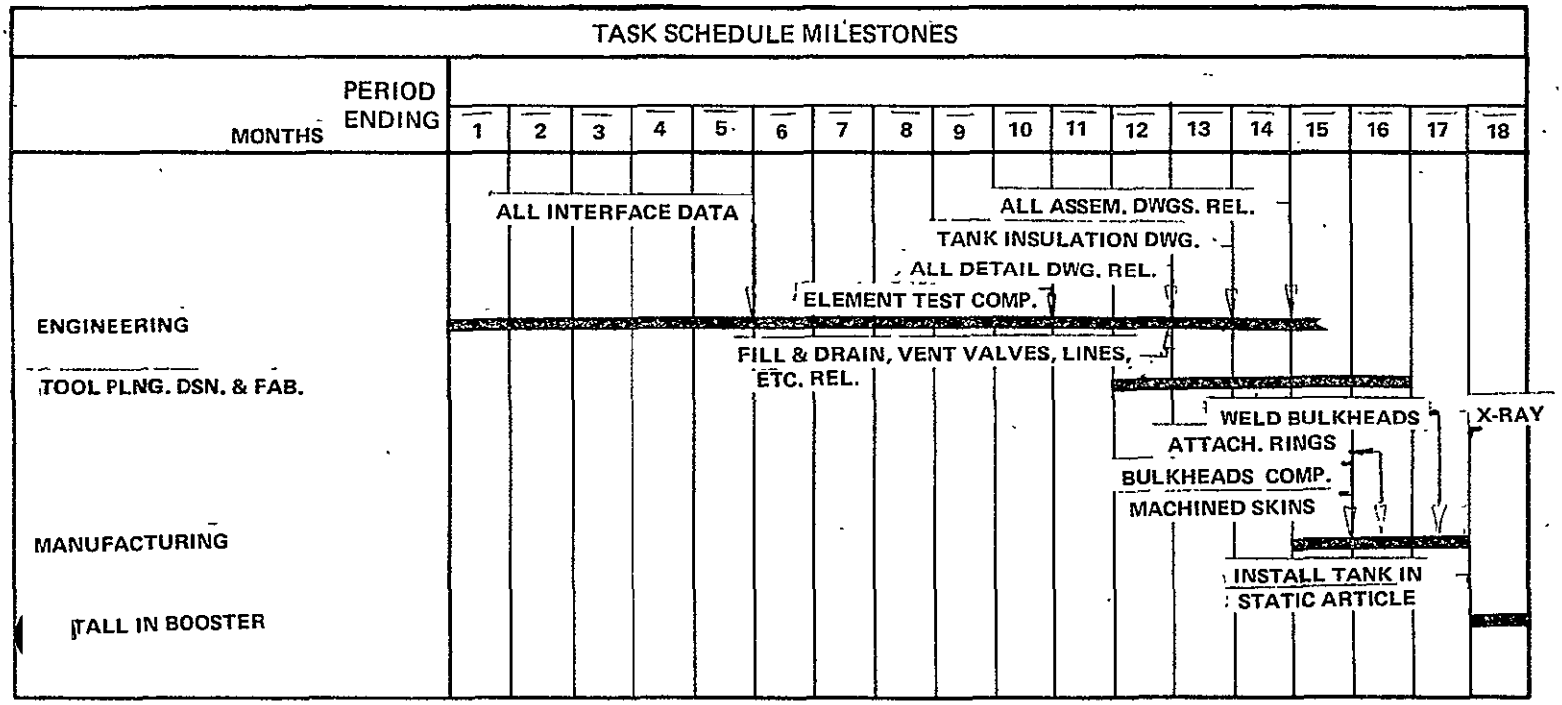
TASK TITLE SECONDARY LH_2 TANK (ACPS/APU) (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.3)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE PROGRAM PROGRAM

WBS NO. 1, 4, 3, 5

TASK TITLE SECONDARY LH_2 TANK (ACPS/APU) (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.3)

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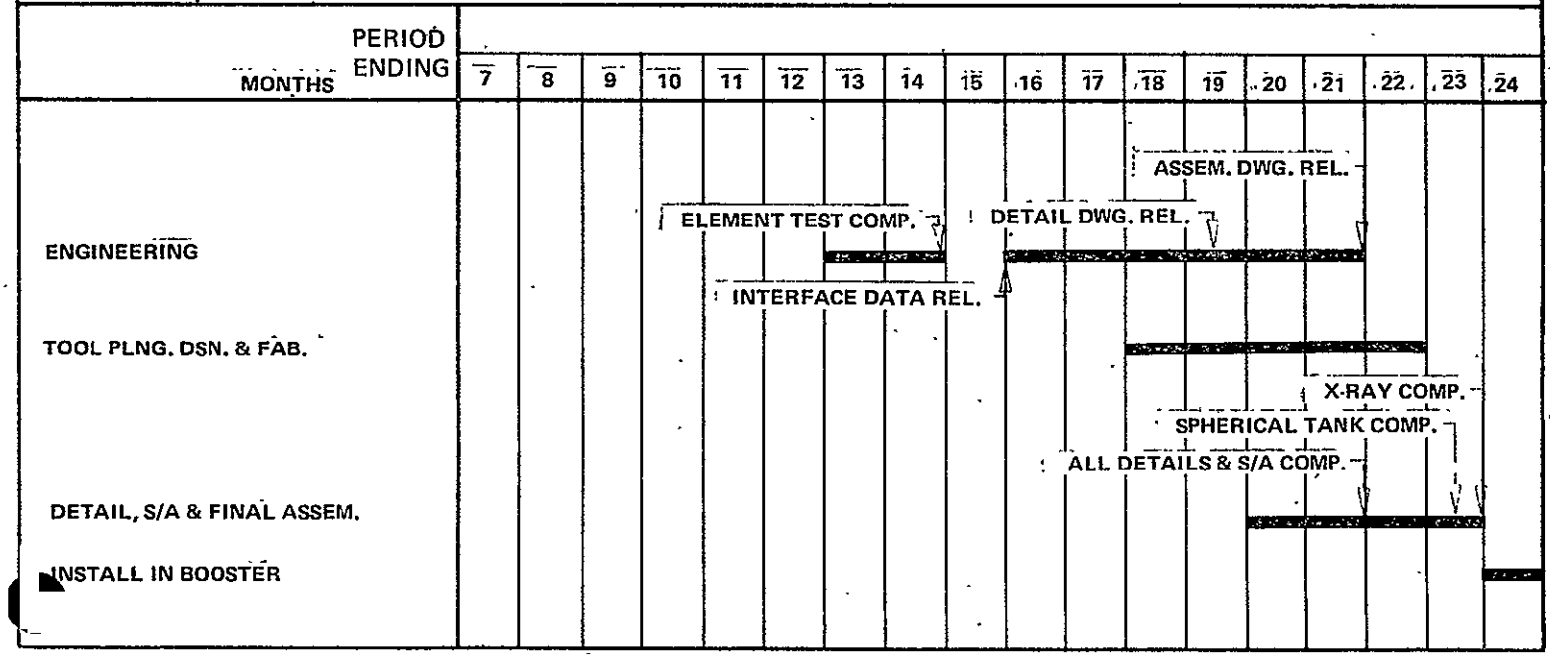

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.4

TASK TITLE PROPULSION & POWER PLANT (STAGE I)

LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned, reusable, i.e. winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landings by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to maximum

TASK SCHEDULE MILESTONES

PERIOD ENDING

SEE LOWER LEVELS FOR DETAIL SCHEDULES

capability depending on mission requirements.

To meet these requirements, the propulsion and power plant for Stage I must provide properties and characteristics compatible with the total flight spectrum (pre-launch to touchdown and runout, taxi to purge and safe point, then ferry flight to the turnaround facility). Baseline design for airport approach shall be go-around capability (WBS ID 0.0, Para. IV. A. 8). In addition, Stage I shall be capable of returning to the launch site (WBS ID 0.0, Para. IV. A.10).

For abort capability, intact abort after liftoff is required for both stages, with a safe landing resulting from this abort mode.

Constraints on Stage I Propulsion and Power Plant, in addition to mission performance over a specified lifetime, include the following: (1) maintainability, (2) reliability, (3) safety compliance, (4) operability, (5) environmental compatibility, (6) human factors acceptability, (7) quality assurance, (8) commonality and/or exchangeability between vehicle tail numbers, and (9) cost minimization through use of proven technology, good design practice, good production practice and thorough flight qualification prior to achieving operational status.

II. ASSEMBLIES DEFINITION

The specific choice of propulsion and power plant assemblies is, in a sense, dependent on stage configuration. A ground rule for baseline design is use of GFE main ascent engines in both Stage I and Stage II. Other elements of main propulsion and other propulsion requirements, however, are CFE and are subject to design concepts furnished by Stage I and Stage II contractors. The elements which comprise Stage I Propulsion and Power Plant are thus generalized below and are subject to modification based upon specific concept selection. (See Figure 1.4-W-3 for WBS showing this subsystem).

1.4.4.1	Integration and Assembly
1.4.4.2	Main Propulsion
1.4.4.3	Auxiliary Propulsion (ACPS/APU)
1.4.4.4	ABES Propulsion

III. FUNCTIONAL DESCRIPTION

Stage I propulsion and power plant provides the required thrust to: liftoff and accelerate the Space Transport Air Vehicle with up to maximum payload to a point in the ascent trajectory where staging can occur; throttle main propulsion thrust while Stage II ignites and develops throttled thrust; then, after separation, shutdown and coast using reaction control thrust to maintain attitude control while maneuvering for entry. During reentry, reaction controls will be blended with aerodynamic controls as the sensible atmosphere is penetrated until sufficient atmosphere exists for lift and drag to enable full aerodynamic control to be utilized. Reaction controls can then be shut down. At a point in the return leg where power is again required to enable control of landing, air-breathing engine thrust will be required. With engine deployment accomplished, power-on go-around and landings can be achieved to the point of origin landing site or to an alternate site if required. Ferry flights, if required, will also utilize the air-breathing engine system (ABES) as will all horizontal and vertical test flights.

In addition to Main Propulsion, attitude control propulsion (ACPS), and air-breathing propulsion (ABES), a need exists for on-board secondary power (electrical and hydraulic). The auxiliary power unit (APU) is a standard means of providing the power source for such secondary power and is associated with that subsystem. Since a requirement exists for such power throughout a mission (pre-launch through touchdown, runout, taxi park, and shutdown), the gases used to provide such power, in the baseline concept, are derived from secondary cryogen tanks, then warmed to the gaseous state, along with ACPS gases, to meet the requirements of ACPS and APUs. Thus, the Auxiliary Propulsion System (APS) is conceived as the third assembly (Main Propulsion, Auxiliary Propulsion, ABES Propulsion) which forms Stage I Propulsion and Power Plant. The APUs are included, however, under Secondary Power (WBS ID 1.4.6) since they are integrated with the hydraulic and electrical power assemblies which are part of that subsystem.

Due to the requirement for long operational life, with quick turnarounds at the turnaround facility, maintainability, as well as reliability and safety, must be built into the Propulsion and Power Plant subsystem. Inspection of propulsion engines, feed systems, pressurization systems, structural mounting, lubrication, valving, venting, gagings, etc. must be available to ground personnel to verify flight readiness (pre-launch) and integrity for next mission (post-flight). If normal maintenance cycles call for remove and replace, modularity must be designed into the assembly at normal break points. This practice must be available through field level (intermediate level) and depot level maintenance to prevent long delays between normal and emergency maintenance cycles. Similarly, ABES propulsion (specifically engine assemblies) must be easily inspected and removable/replaceable per engine recycle specification. ABES fuel tanks, venting, filling, ducting, and pressurizing needs must consider accessibility for inspection, servicing, removal and replacement per specification.

To achieve operational status, the propulsion and power plant for Stage I will be verified in the RDT & E phase by following the steps briefed below:

A. Phase C Go-Ahead Through PDR - GFE Main Engines are assumed to be in development prior to Phase C go-ahead. Depending on end item (CEI) breakdown of Stage I, completion of preliminary design will result in a set of Part I specifications affecting Propulsion and Power Plant. Interface to Structure will be recognized for Main Propulsion Tankage requirements and to Primary Cryogenic Storage for ACPS/APU Secondary Tankage requirements. Part I specifications will detail performance for each propulsion assembly, will specify interfaces, and call for Category I and II tests needed to ensure operational readiness. Upon approval of appropriate CEI Part I's, final design can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II's can be prepared. (See Para. VI for tests affecting this phase.)

C. CDR to Qualification Testing - Release of drawings to engine manufacturers will enable prototypes to be built for single and cluster engine firings to prove thrust, vibration and acoustic levels (Main Engines, ACPS Engines) as well as shutdown/startup and throttling for those engines which are required to have these capabilities. At an appropriate point, PFRT will be performed, evaluated and accepted by NASA and by the Stage I contractor. Due to certain commonalities between the GFE furnished Stage I and Stage II main engines, single engine tests may suffice for both Stage I and Stage II. Similarly, prototype ABES engines may be built to prove thrust levels, throttleability, vibration, and acoustic levels are within specification and tolerance levels. At an appropriate point, PFRT may be held on airbreathing engines for evaluation and acceptance. Following PFRT, flight test engines can be built, incorporating any changes resulting from single engine/cluster engine firings, which will be phased into Flight Test Vehicle (FTV) Integration and Assembly lines as appropriate. As appropriate to the Master Phasing Plan, FTVs will - after receiving factory acceptance - conduct Pre-Flight, Ferry Flight, Horizontal Flight, Single Element Vertical Flight, and Mated Flight Test operations to determine integrated performance, safety, reliability and maintainability acceptability.[1] Retrofit to production vehicle status will occur as appropriate to each FTV built and tested. Qualification will finally be granted through DD 250 (or equivalent) when propulsion and power plant, as well as all other Stage I subsystems, prove they meet specifications to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Level I and II requirements affecting Propulsion and Power Plant are stated in WBS Dictionary Element 0.0, and will not be repeated here. In addition to those cited, standard aircraft and spacecraft design practice will apply to Propulsion and Power Plant to design engines, feed systems, propellant and/or fuel utilization systems, vent and relief

[1] Single element Vertical Flight Test, in accordance with current NASA planning, will consist of tie-down Static Firings, only. This is subject to review in Phase C/D.

systems, fill and drain, dump, ignition, shutdown, throttling, etc. which meet performance, operational life, safety, reliability, maintainability, commonality and exchangeability, and other mission requirements without sacrificing other subsystem requirements. Choice of materials must, in addition to consideration of light weight, include consideration of the operational environment (temperature, pressure, vibration, acceleration/deceleration, design loads, natural environment). Without sacrificing integrity, it must be recognized that certain parts will fail and/or wear out even with scheduled maintenance and must be therefore periodically inspected and refurbished without compromising operational schedules. Thus, nozzles, throats, igniters, etc. subject to both high heat loads and vibration/acoustic levels must be removed when their normal lifetime approaches completion. Removal and replacement of these components and/or parts is required. Thus, their design should be in accordance with the analysis, specification thereof and approvals given in systems engineering and NASA reviews. Detail design requirements affecting the above will be specified as applicable in affected CEI Part I's when generated.

V. INTERFACES

Stage I Propulsion and Power Plant physically or functionally interfaces with nearly all other subsystems of Stage I as follows:

STAGE I SUBSYSTEM	PROPULSION AND POWER PLANT MAJOR INTERFACES WITH SUBSYSTEM NOTED
1.4.2, Airframe and Structure	. Mounting (All) . Extend/Retract (ABES) . Thermal Protection (All) . Propellant Tanks (Main Engines)
1.4.3, Primary Cryogenic Storage	. Tankage (ACPS/APU)

STAGE I SUBSYSTEM	PROPULSION AND POWER PLANT MAJOR INTERFACES WITH SUBSYSTEM NOTED
1.4.5, Flight Control	. Thrust Vector Control (Main Engines) . On/off & Selection (ACPS) . Thrust Level (ABES) (Autopilot Mode)
1.4.6, Secondary Power	. Hydraulic power for Main Engine TVC . Hydraulic power for ABES Engines Extend/Retract . Electrical Power for Engine ignition, shutdown, control (All)
1.4.8, Guidance and Navigation	. Vehicle position and velocity for determination of steering commands (Main Engines, ACPS)
1.4.9, Communications and Navaids	. Range and bearing for cruise (ABES) . Az, El, Range for autopilot landing (ABES)
1.4.10, Data Management	. Propulsion and Power Plant Status (All) . Mission Sequencing (Main, ACPS, ABES) . Mission Profile Storage, Comparison, Display (All)
1.4.11, Displays & Controls	. Flight Controls & Displays - Throttle (ABES) - Abort (Main) - Attitude Control - ABES Deploy & Fuel Management . Vehicle Checkout (All) . Subsystem Status & Monitor (All) . Fire Detection & Control (ABES)

In addition to the above, Stage I Propulsion and Power Plant interfaces with Stage II (WBS ID 1.3) through the mass properties imposed on Stage I performance requirements and on the throttleable thrust available from Stage II Main Engine for a normal staging sequence as well as an aborted staging sequency (status must be provided Stage I on Stage II propulsion capability from liftoff to normal staging point). For ground interfaces, Propulsion and Power Plant interfaces with WBS ID 2.0 for Command and Control, Launch and Recovery operation; with WBS ID 3.0/8.0 for ground support requirements (maintenance); with WBS ID 4.0 for test, evaluation and mockups; with WBS ID 5.0 for System/Program Management interfaces; with 6.0 for deliverable Data requirements; with WBS ID 9.0 for initial spares and repair parts; with WBS ID 10.0 for crew and ground training, with WBS ID 11.0 for Industrial Facilities (Production, Inventory, Logistics, Turnaround); and with WBS ID 12.0 for Operations and Services. An inherent interface also exists with Payload (WBS ID 1.2) for the requirement to deliver Stage II with its payload to the staging point in accordance with the various payload options and mission objectives.

VI. TEST REQUIREMENTS

Category I and II tests will be conducted on Propulsion and Power Plant as follows. Component and assembly tests will be generally conducted under WBS 1.4.4 or at a lower level thereto. Single and cluster engine tests (prototype and possibly flight test vehicle engines) will be conducted under WBS ID 4.2. Single element tests (pre-flight, ferry test, horizontal flight test, vertical flight test) will be performed under WBS ID 4.6. Mated flight tests will be conducted under WBS ID 4.7. Mockups as appropriate will be provided under WBS ID 4.9.

VII. REFERENCES

(To be added.)

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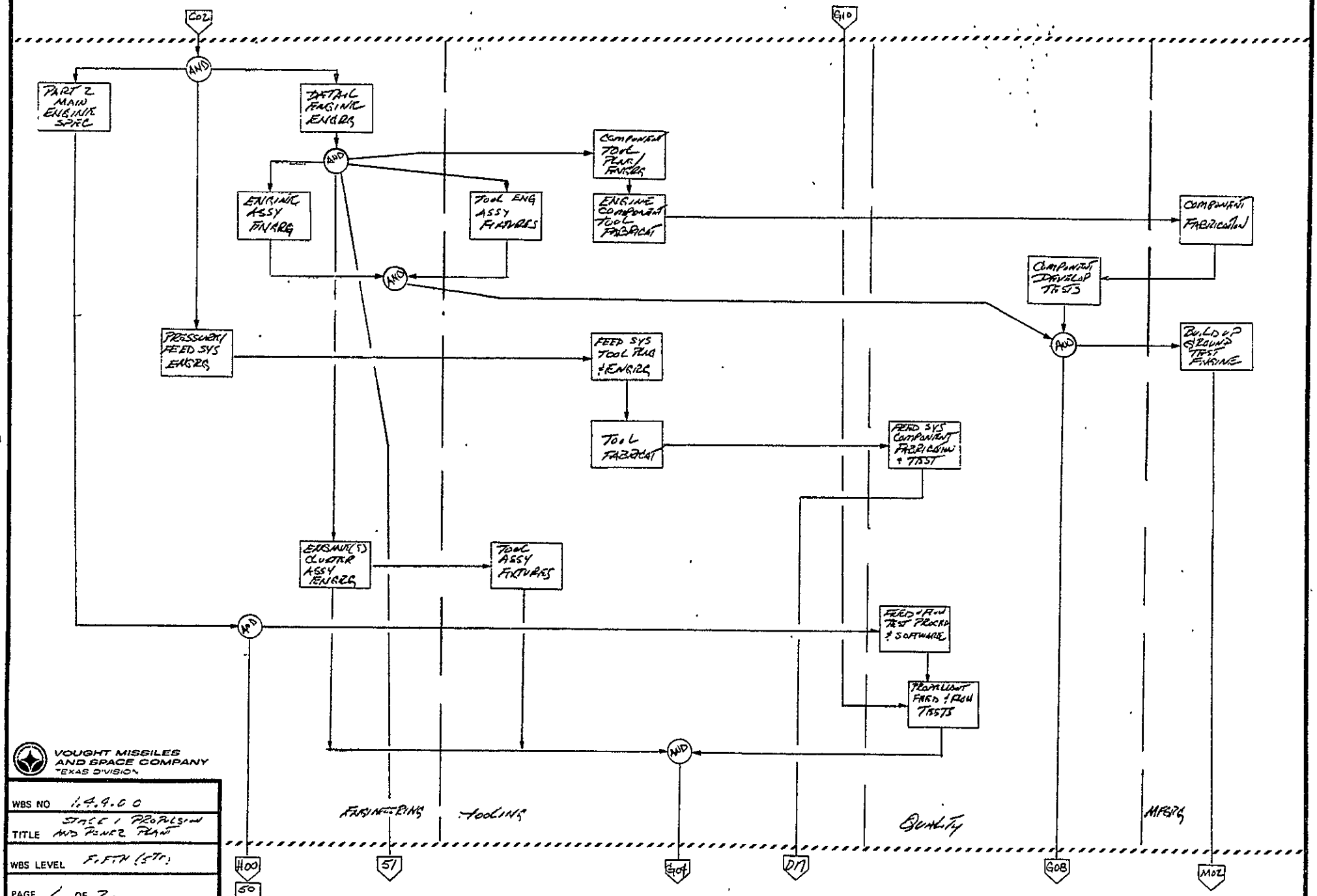

OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

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WBS LEVEL	FIFTH (5TH)
PAGE	1 OF 2
DATE	6 JUN 71

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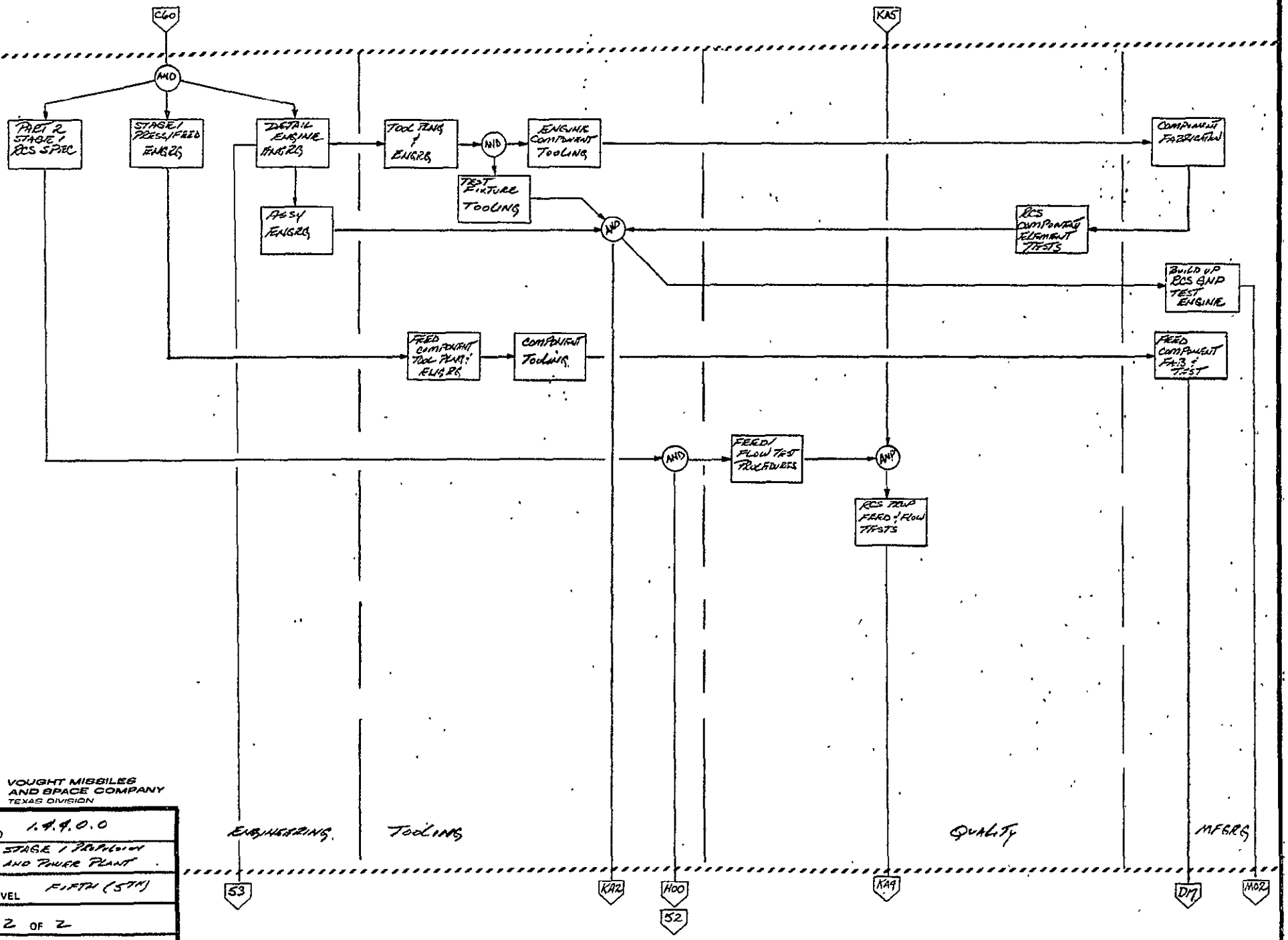


OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.4.4.0.0
TITLE	STAGE 1 PROPULSION AND POWER PLANT
WBS LEVEL	FIFTH (5TH)
PAGE	2 OF 2
DATE	6 JUN 71

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.4.2

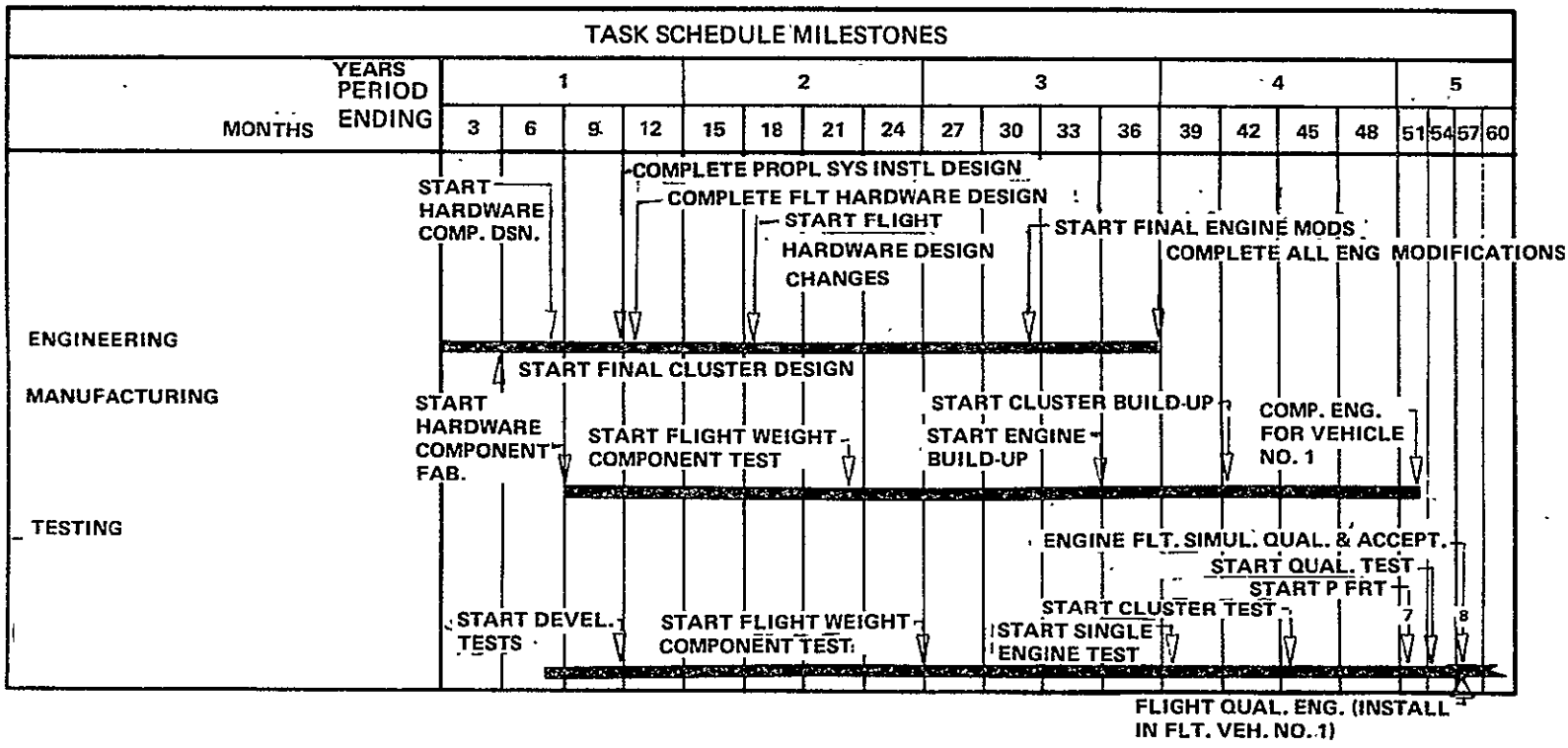
TASK TITLE MAIN PROPULSION (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.4)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.4.3

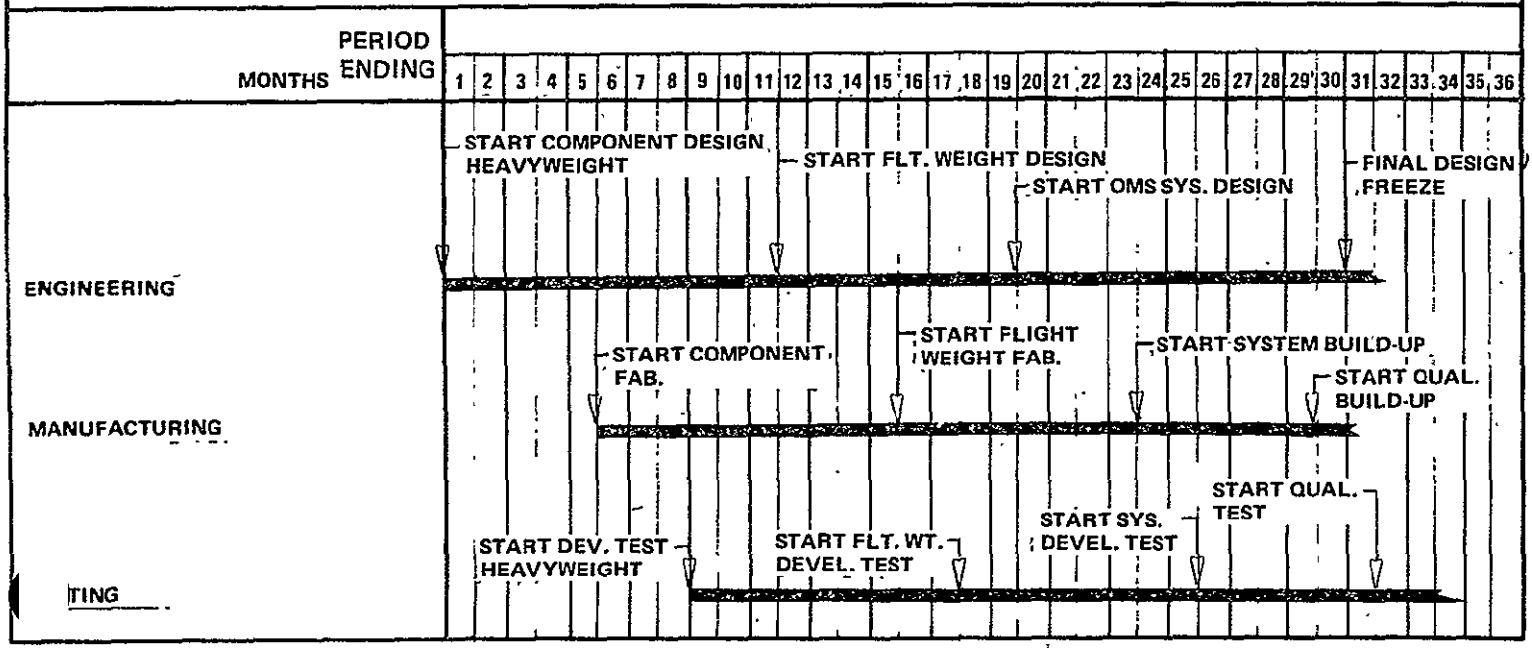
TASK TITLE AUXILIARY PROPULSION (ACPS/APU) (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.4)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.4.4

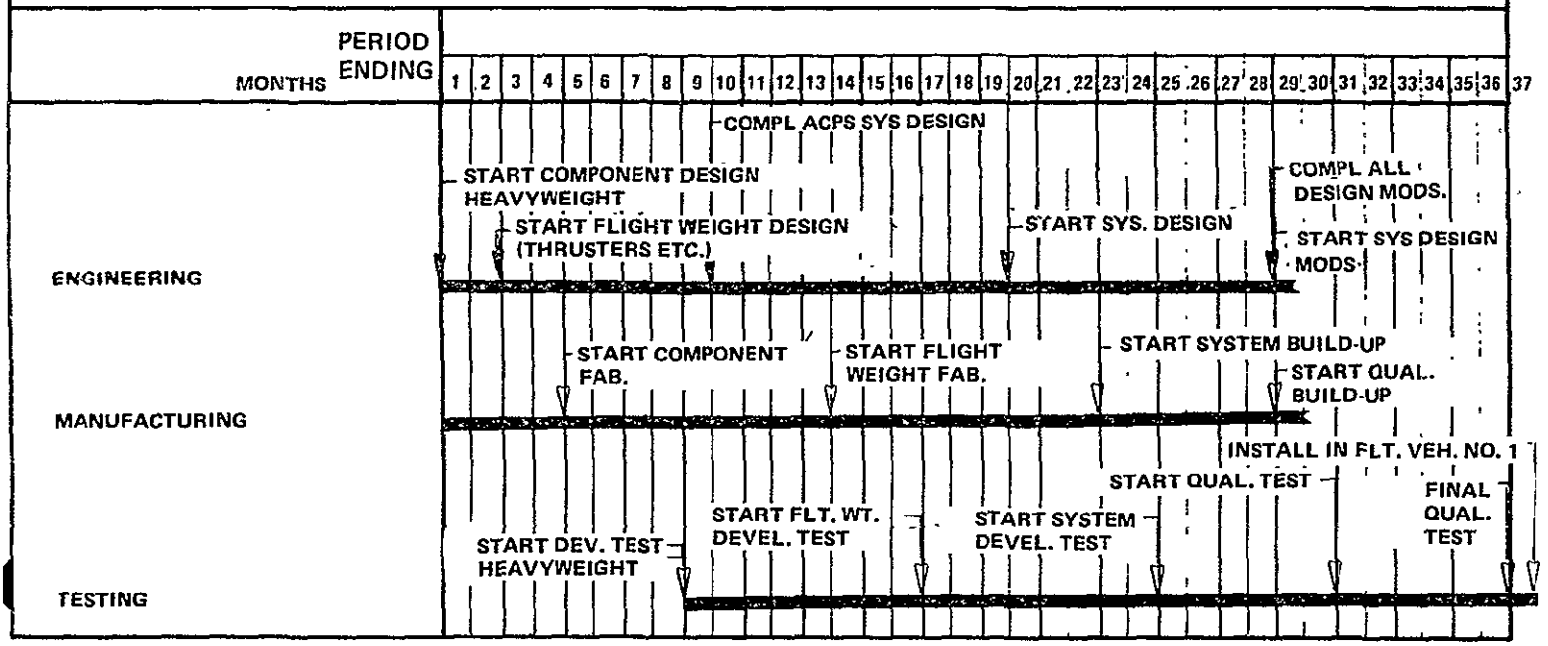
TASK TITLE ABES PROPULSION (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.4)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.5

TASK TITLE FLIGHT CONTROL (STAGE I)

LEVEL 5, Subsystem Level

WBS DICTIONARY

1. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned, reusable, i.e., winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landing by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to maximum capability, depending

TASK SCHEDULE MILESTONES

PERIOD ENDING

SEE LOWER LEVELS FOR DETAIL SCHEDULES

on mission requirements.

To assist in meeting the above requirements, the Flight Control subsystem of Stage I must provide properties and characteristics compatible with the total Stage I flight spectrum (pre-flight activities, launch activities, ascent in the Air Vehicle configuration, separation of Stage II, exoatmospheric maneuvers to achieve position for entry to desired landing site, reentry into the sensible atmosphere, transition to and through the transonic regime, subsonic cruise, deploy onboard air-breathing engines if required for approach or go-around, conduct final approach, flare, touchdown, run-out, and parking on the airport ramp for post-flight servicing). On-board air-breathing propulsion will be required for ferry flight.

The specific properties and characteristics required of Flight Control are to control: (1) Air Vehicle attitude and maneuvers from liftoff to staging; (2) Stage I attitude during staging while Stage II is separating; and (3) Stage I attitude and maneuvers following staging until entry, approach, and landing are completed, including taxi to the ramp and parking for post-flight activities. Flight Control is also required for all ferry flights and for all test flight operations.

Constraints on Stage I Flight Control, in addition to mission environment capability through a specified lifetime, include the following: (1) maintainability, (2) reliability, (3) safety compliance, (4) operability, (5) human factors acceptability, (6) quality assurance, (7) commonality and/or exchangeability between vehicle tail numbers and (8) cost minimization through use of proven technology, good design practice, good production practice, and thorough flight qualification prior to achieving operational status.

II. ASSEMBLIES DEFINITION

The specific assemblies which form Stage I Flight Control are concept dependent. For the baseline concept, the following assemblies are specified. These are subject to modification based on selected concept configuration definition. (See Figure 1.4-W-3 for WBS)

1.4.5.1	Integration and Assembly
1.4.5.2	Main Engine Control (TVC)
1.4.5.3	ACPS Control
1.4.5.4	Aerodynamic Controls
1.4.5.5	Ancillary Controls
1.4.5.6	Flight Control Electronics

III. FUNCTIONAL DESCRIPTION

The major functions of flight control are: (1) to control Air Vehicle attitude and direction in a normal or abort mode while the Air Vehicle is lifting off and accelerating to the separation point (control is achieved by vectoring the main engine nozzles in pitch, roll and yaw as called for by Data Management programs); (2) to augment vehicle control as required at a point in the ascent trajectory by actuating elevons to assist in providing required pitch and roll moments call for by Data Management; (3) to stabilize the Air Vehicle during Stage I throttling/Stage II startup and subsequent staging by holding main engine nozzles steady or in a controlled motion as called for by Data Management computations; (4) to phase in ACPS propulsion after staging and main propulsion shutdown in order to control maneuvers to and through Stage I apogee in order to align the vehicle with desired return heading as called for by Data Management; (5) to blend ACPS propulsion with aerodynamic control surfaces during reentry in order to complete maneuvers and stabilize the vehicle through the transition phase and into the transonic and high subsonic Mach Number regions where only aerodynamic control is required and ACPS can be shut down; and (6) to control attitude and maneuvers using aerodynamic controls for the approach, go-around if required, flare, touchdown and roll-out. In addition to the above flight controls, ancillary controls of a mechanical nature will be provided to control ABES engine deployment, landing gear extend, and nose gear steering and braking. An additional mechanical control included in Flight Control ancillary controls is actuation of the retract function of the Stage I - Stage II separation mechanism following Stage II translation away from Stage I during the staging sequence. To accomplish these functions, propulsion flight controls, aerodynamic controls, ancillary controls, and flight control electronics must be provided which both act

on command (Data Management or crew) and act in a feedback mode, where feedback includes air data sensing (endoatmosphere) and rate and acceleration sensing (exo and endo atmosphere).

To achieve operational status, the Flight Control Subsystem will be verified in the RDT & E phase by following the steps briefed below:

A. Phase C Go-Ahead Through PDR - Depending on end item (CEI) breakdown of Stage I, completion of preliminary design will result in a Part I specification affecting flight controls. Detailed definitions will specify performance, interfaces, and effectiveness required of this subsystem. Upon approval of CEI Part I, final design can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II can be prepared. (See Para. VI for tests affecting this phase).

C. CDR to Qualification Testing - Release of drawings to manufacturing will allow final integration and assembly to be performed to build the Structural Test Vehicle and Flight Test Vehicles to be used for Pre-flight, Ferry Test, Horizontal Flight Test, Single Element Vertical Flight Test, and mated Flight Test programs. Qualification will finally be granted through DD 250 (or equivalent) buyoff when Flight Control, as well as all other Stage I subsystems, prove they meet specification to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Level I and II requirements affecting Flight Control are stated in WBS Dictionary Element 0.0, and will not be repeated here. In addition to those cited, standard aircraft and spacecraft design practice will apply to Flight Control in the choice of adequate servomechanism design,

gyros, electronic circuitry, wiring, packaging, accelerometers, etc. which meet environmental constraints, vehicle rates, and mission life. Where insulation materials are required to protect components, same will be compatible with analyzed thermal, static and dynamic loads expected in both test and operations. Interface control must be established to ensure inputs and outputs are both compatible with Flight Control requirements and with the interfacing subsystems. Due to long life requirements, maintainability requirements must be analyzed to ensure components subject to failure or wear (normal or imposed) are readily inspectable, checkable, and replaceable with minimum down time. Additional design and mission requirements will be specified in CEI Part I's when generated.

V. INTERFACES

Flight Control interfaces with other Stage I subsystems as follows: (1) Secondary Power (WBS ID 1.4.6), to provide the hydraulics necessary to actuate servomechanisms; (2) Airframe and Structure (WBS ID 1.4.2), for mounting actuators to interface with aerodynamic and ancillary controls; (3) Propulsion and Power Plant (WBS ID 1.4.4), for thrust vectoring Main Propulsion engines, for on/off control of ACPS Propulsion, and for deploy/retracting ABES Propulsion; (4) Crew Control (WBS ID 1.4.11) for inputting manual flight control commands; (5) Data Management (WBS ID 1.4.10), for inputting automatic commands based upon Guidance and Navigation and Communications and Navaids intelligence, and for providing the data bus and Acquisition, Control and Test (ACT) units which transmit automatic or manual commands and feedbacks; (6) Stage II (WBS ID 1.3) via data bus for backup stage separation; (7) Environmental Control and Life Support (WBS ID 1.4.7), to provide environmental control of sensitive assemblies and components, and, (8) Displays and Controls (WBS ID 1.4.11) for display and control of Flight Control status, actions, and results. In addition to Air Vehicle interfaces, Stage I Flight Control interfaces with GSE (WBS ID 2.5 and 2.6, 3.0 and 8.0); with test, evaluation and mockups (WBS ID 4.0);

with System/Program Management (WBS ID 5.0); with deliverable Date (WBS ID 6.0); with Initial Spares and Repair Parts (WBS ID 9.0); with Training (WBS ID 10.0); with Industrial Facilities (WBS ID 11.0); and with Operations (WBS ID 12.0). These interfaces are spelled out in the cited WBS Dictionary element descriptions as applicable.

VI. TEST REQUIREMENTS

Single component/assembly/subsystem development tests will be conducted under WBS ID 1.4.5 as required. Combined subsystem tests (static, dynamic, thermal, proof and integrated) will be performed under WBS ID 4.2. Single element flight tests will be performed under WBS ID 4.6. Mated flight tests will be conducted under WBS ID 4.7. WBS ID 4.9 provides the required mockups.

VII. REFERENCES

(To be added.)

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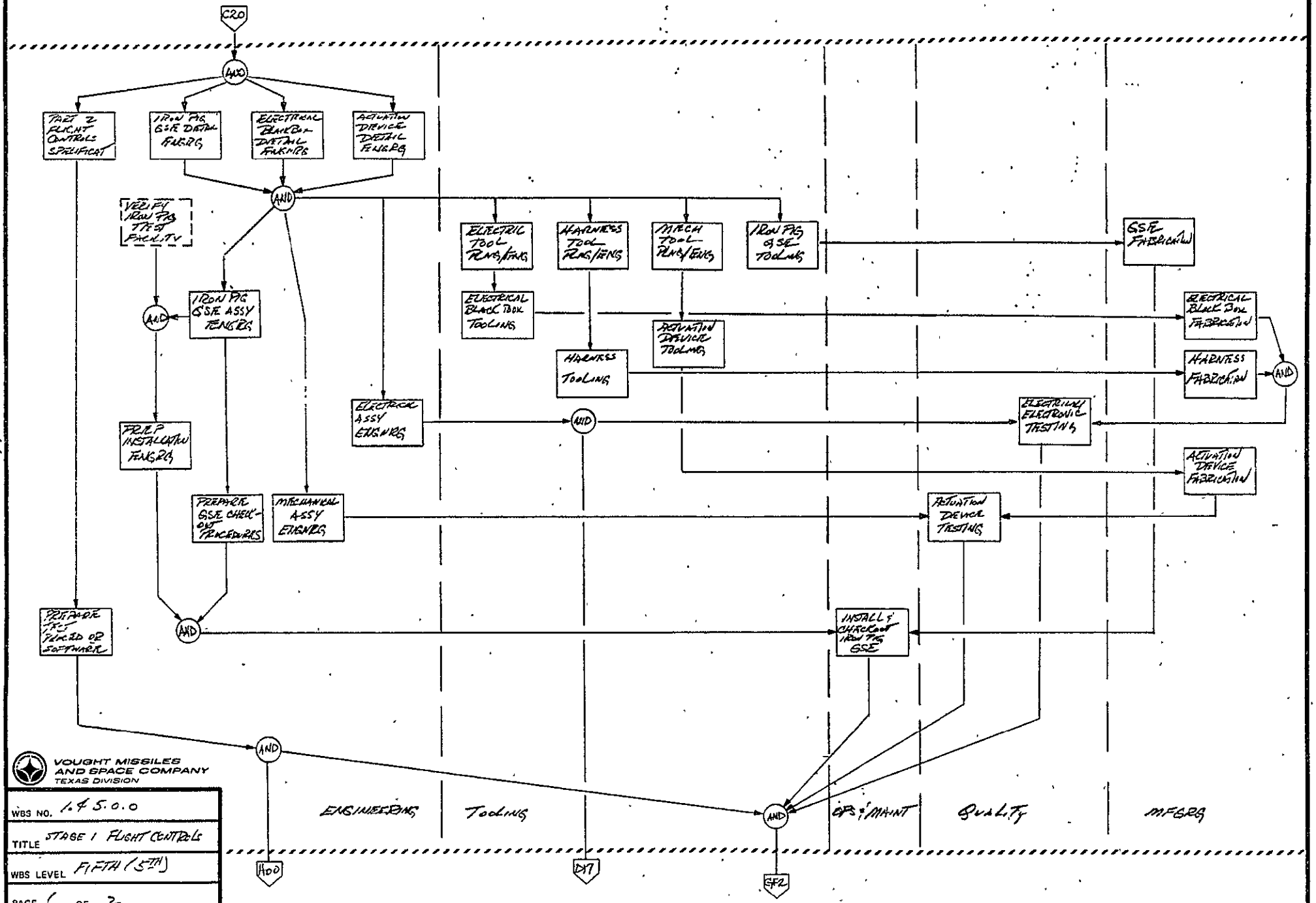

VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO.	1.4 5.0.0
TITLE	STAGE 1 FLIGHT CONTROLS
WBS LEVEL	FIFTH (5TH)
PAGE	1 OF 2
DATE.	26 MAY 71

ENGINEERING | TOOLING | EPS & MAINT | QUALITY | MFGRG

H00 | D17 | GF2

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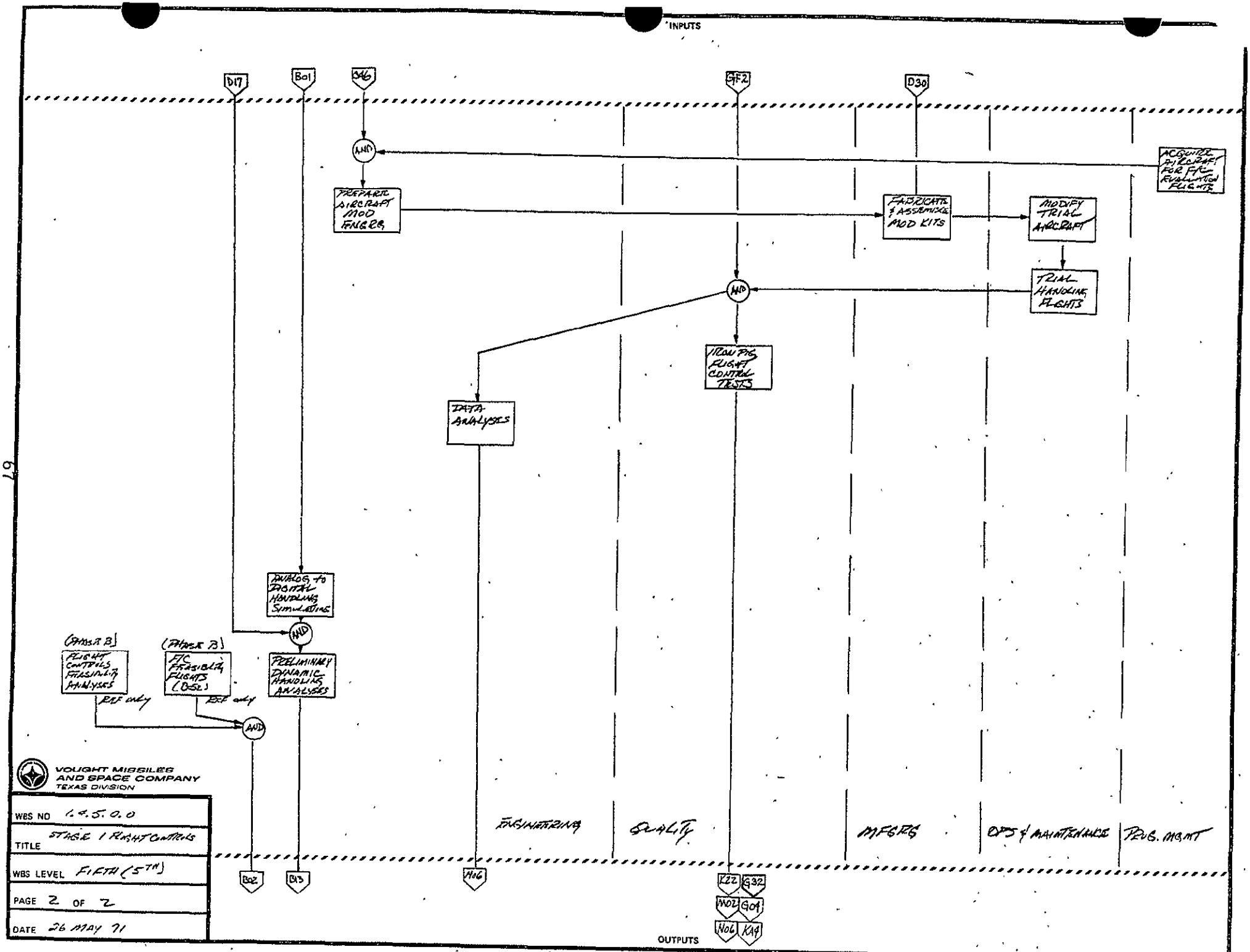
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FABRICATE & ASSEMBLE MOD KITS
MODIFY TRIAL AIRCRAFT
ACQUIRE AIRCRAFT FOR F/C EVALUATION FLIGHTS
TRIAL HANDLING FLIGHTS
AND
ITCU FIG FLIGHT CONTROL TESTS
DATA ANALYSES
DUPLOS TO DIGITAL HANDLING SIMULATING
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(PHASE B) FLIGHT CONTROLS FEASIBILITY ANALYSES
REF only
(PHASE B) F/C FEASIBILITY FLIGHTS (DSL)
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PRELIMINARY DYNAMIC HANDLING ANALYSES
AND
VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION
WBS NO 1.4.5.0.0
TITLE STAGE I FLIGHT CONTROLS
WBS LEVEL FIFTH (5TH)
PAGE 2 OF 2
DATE 26 MAY 71
ENGINEERING
QUALITY
MFGRG
OPS & MAINTENANCE
PROG. MGMT
B02
B03
H06
K22
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M02
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N06
K49
OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.5.2

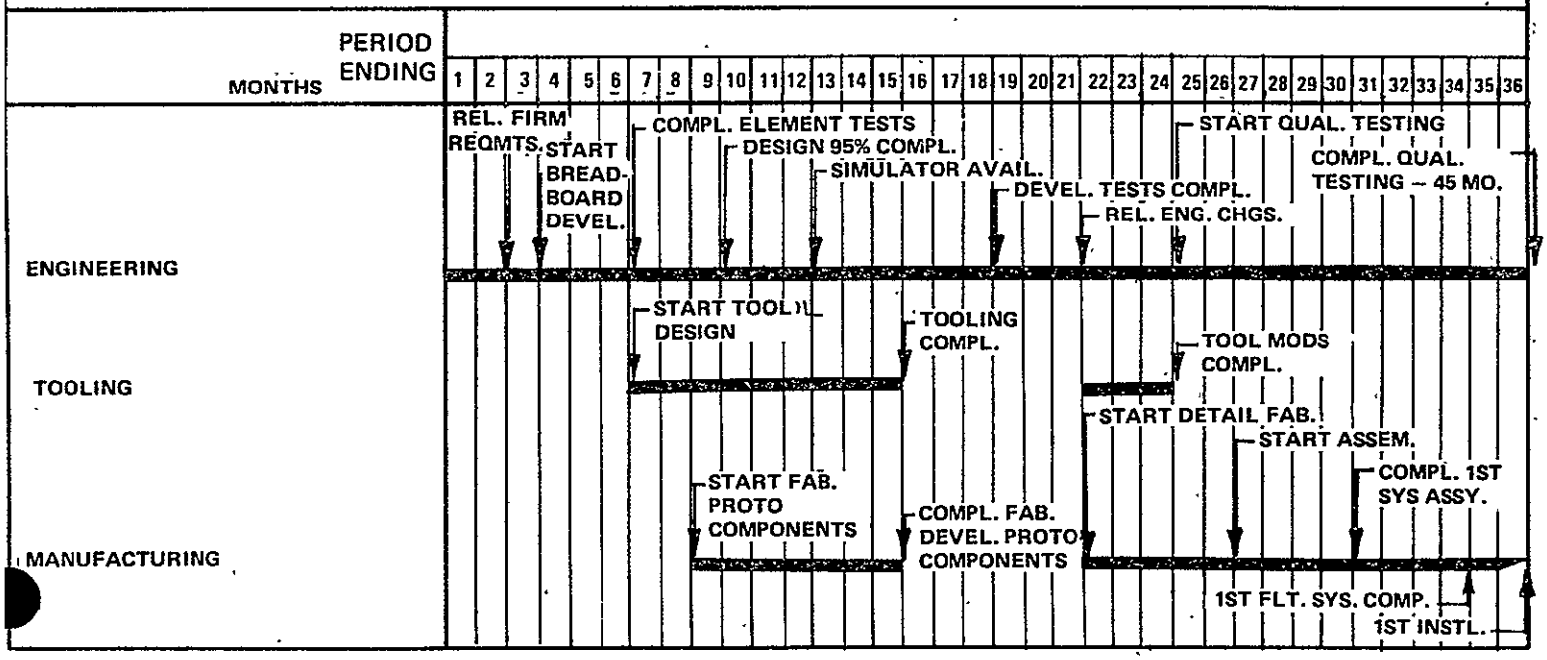
TASK TITLE MAIN ENGINE CONTROL (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.5)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.5.3

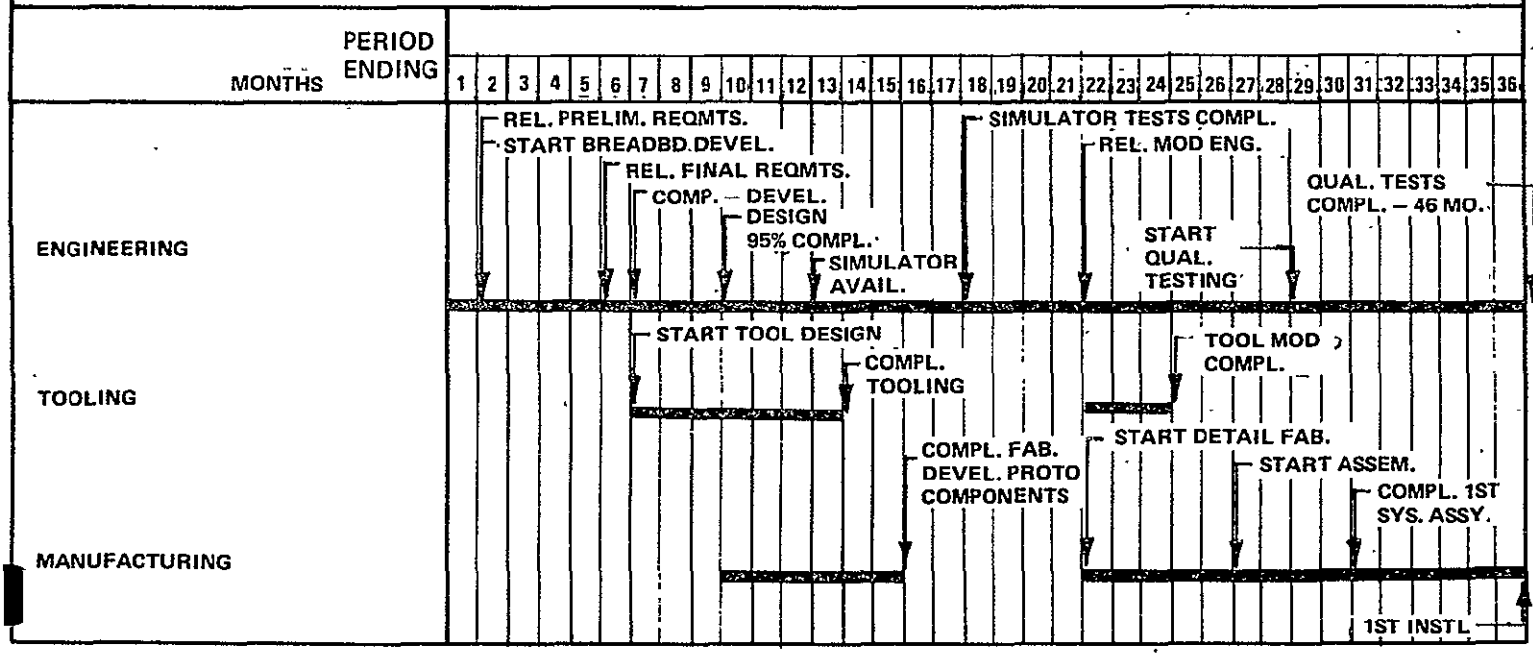
TASK TITLE ACPS CONTROLS (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.5)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.5.4

TASK TITLE AERODYNAMIC CONTROLS (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Description not provided. See WBS Dictionary Element 1.4.5)

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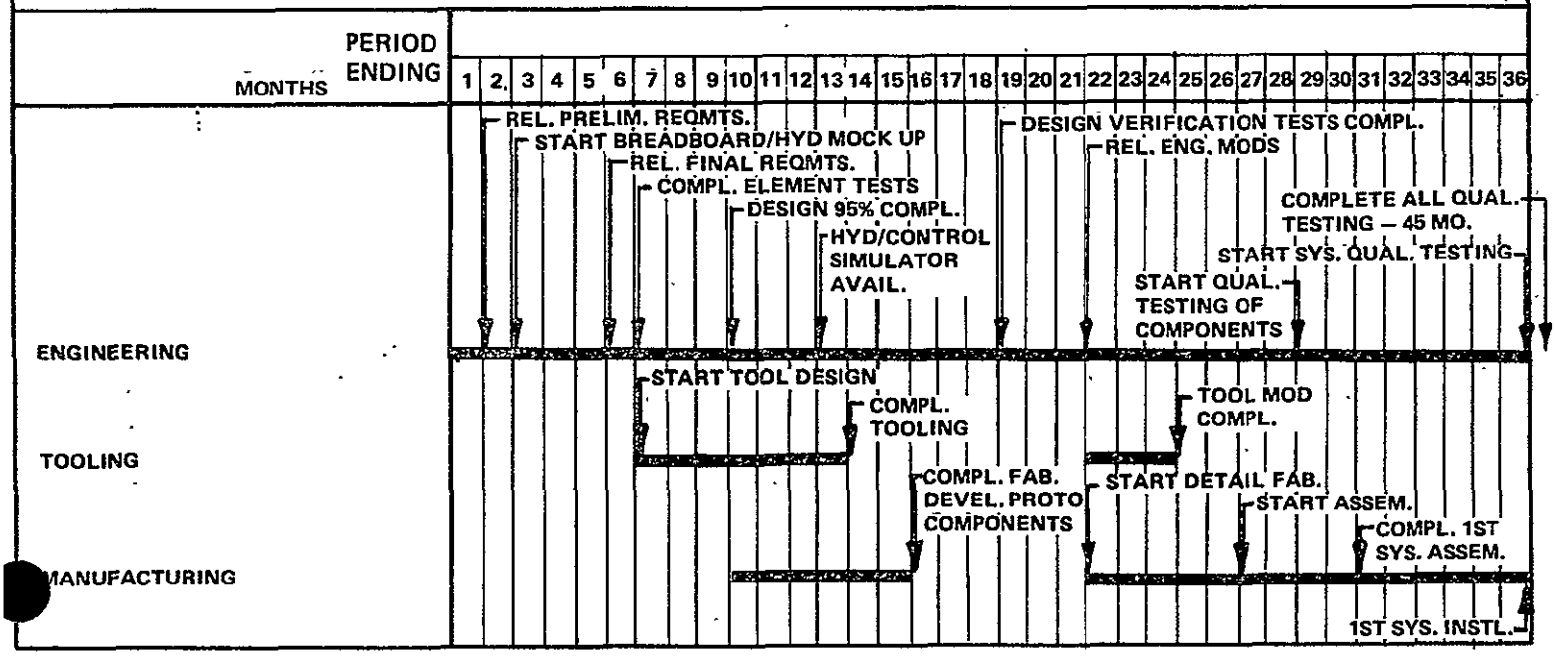


VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.5.5

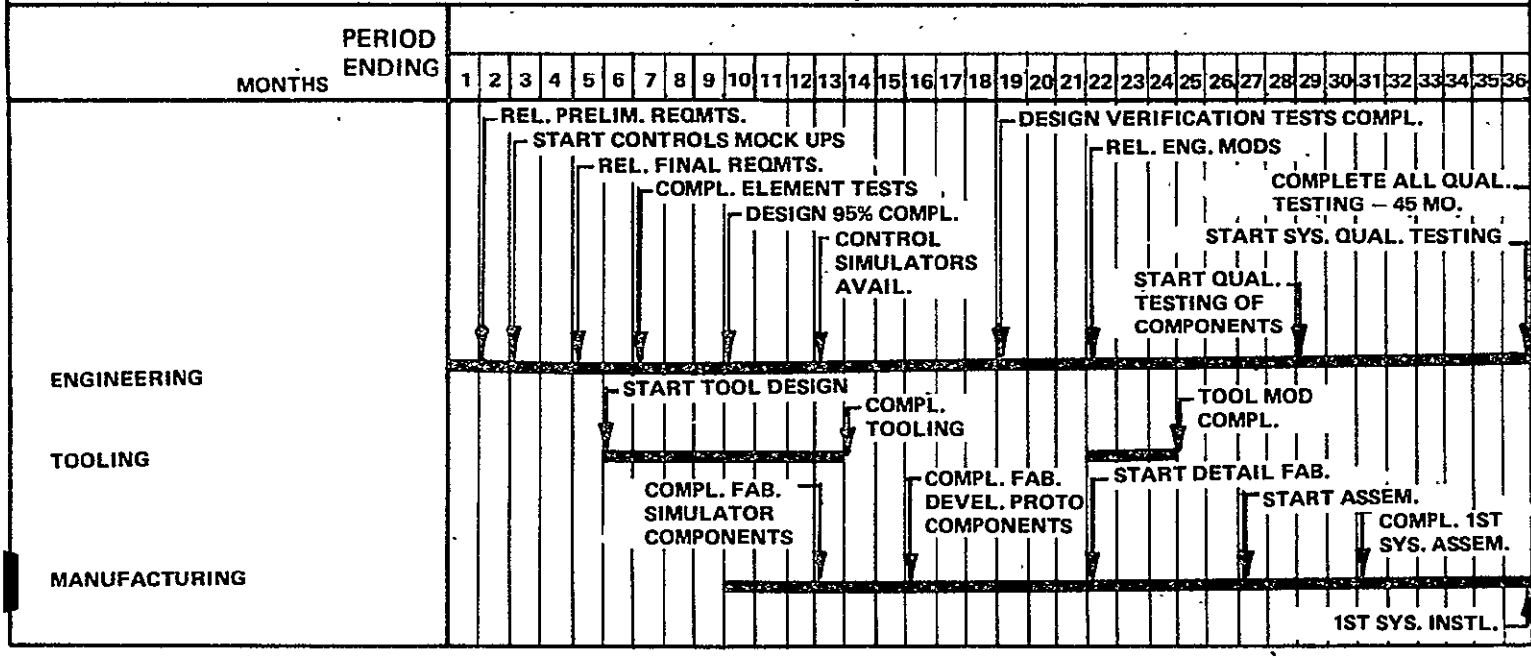
TASK TITLE ANCILLARY CONTROLS (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.5)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.5.6

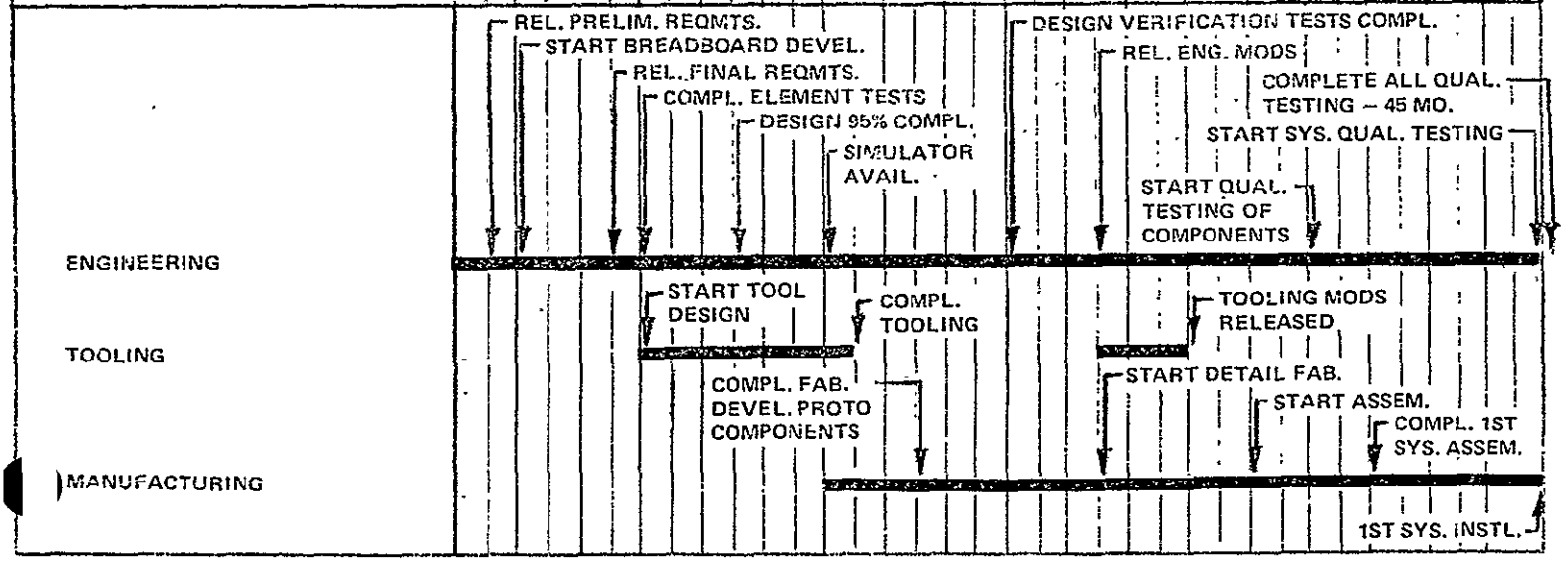
TASK TITLE FLIGHT CONTROL ELECTRONICS (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.5)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.6

TASK TITLE SECONDARY POWER (STAGE I)

LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned, reusable, i.e. winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landings by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to maximum

TASK SCHEDULE MILESTONES

PERIOD ENDING

SEE LOWER LEVELS FOR DETAIL SCHEDULES

capability depending on mission requirements.

To assist in meeting these requirements, the Secondary Power Subsystem for Stage I must provide properties and characteristics compatible with the total flight spectrum (pre-launch to touchdown and runout, taxi to purge and safe point, then ferry flight to the turnaround facility, if required.

Secondary Power is required to provide all on-board Stage I power required to operate electrical and electronic equipments and to operate mechanical actuators needed to vector main engines, actuate aerodynamic controls, and actuate ancillary equipments such as stage separation mechanism retraction, landing gear extend/retract, steering, brakes, and ABES Propulsion engine deployment/retraction. All Stage lighting required for interior and exterior requirements will be provided by Secondary Power, either as a source of energy therefore or as an assembly. Constraints on Stage I Secondary Power, in addition to meeting performance requirements and providing capability with mission environment through a specified lifetime, include the following: (1) maintainability, (2) reliability, (3) safety compliance, (4) operability, (5) human factors acceptability, (6) quality assurance, (7) commonality and/or exchangeability between vehicle tail numbers, and (8) cost minimization through use of proven technology, good design practice, good production practice, and thorough flight qualification prior to receiving operational status.

II. ASSEMBLIES DEFINITION

The choice of assemblies required to form the Secondary Power Subsystem is, in a sense, concept dependent. The assemblies listed below, and shown on Figure 1.4-W-3, are, however, basic to any transport type airplane, and fit within the mission of such a vehicle in a combined space/atmospheric environment.

1.4.6.1	Integration and Assembly
1.4.6.2	Power Source
1.4.6.3	Hydraulic Power Generation and Distribution
1.4.6.4	Electrical Power Generation and Distribution
1.4.6.5	Lighting

III. FUNCTIONAL DESCRIPTION

The Secondary Power Subsystem provides the power source and electrical and hydraulic power required for operation of electrical, electronic and mechanically actuated subsystems, assemblies and components aboard Stage I. Ground power will be applied to the Secondary Power connections as needed for periods when on-board power sources are non-active. At an appropriate point in the launch countdown, on-board power sources will be activated and then supply all necessary secondary power throughout the mission. Such power will include power to operate electrical and electronic equipments throughout flight, provide main engine ignition, vector main engine nozzles, shutdown main engines, enable staging, cyclically ignite and shut down ACPS engines as required for vehicle stabilization and maneuvers through apogee and reentry, provide power for communications capability, enable ABES engine deployment, enable gear deployment, and enable nose gear steering and main gear braking. Secondary power for ferry flight will enable electrical/electronic equipment operation as well as provide hydraulic power required for flight controls and gear operation.

All Stage lighting needed for external beacons, for external visibility, and for internal visibility, will be provided as required.

To achieve operational status, the Secondary Power Subsystem will be verified in the RDT & E phase by following the steps briefed below:

A. Phase C Go-Ahead Through PDR - Depending on end items (CEI) breakdown of Stage II, completion of preliminary design will result in a Part I specification affecting Secondary Power. Detailed definitions will specify performance, interfaces, and effectiveness required of this subsystem. Upon approval of CEI Part I, final design can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II can be prepared. (See Para. VI for tests affecting this phase)

C. CDR to Qualification Testing - Release of drawings to manufacturing and to materiel will allow final Integration and Assembly to be performed in order to build prototypes and flight test articles needed to test components, assemblies, subsystem, combined subsystems and systems. At an appropriate point, qualification will be provided to conduct flight test needed to demonstrate integrated performance: Pre-Flight Tests, Horizontal Flight Tests, and Vertical Flight Tests (both single element and mated). Retrofit to production vehicle status will occur as appropriate to each Flight Test Vehicle (FTV) when compliance with specification has been demonstrated. Qualification will finally be granted through DD 250 (or equivalent) buyoff when Secondary Power, as well as all other subsystems, have thus demonstrated proof of meeting all specifications to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Level I and II requirements affecting Secondary Power are stated in WBS Dictionary Element 0.0, and will not be repeated here. In addition to those cited, standard aircraft and spacecraft design practice will apply to secondary power in the design of Auxiliary Propulsion Units (APUs) and power takeoffs, hydraulic components (pumps, controls, lines, accumulators, fluids, filters, valves, etc.), electrical components (alternators, controls, buses, relays, switches, circuit breakers, fuses, wiring and connectors, motors, panels, J-Boxes, lighting, etc.) and batteries. Where possible, standard aircraft design should be followed in selecting operating pressures for hydraulic power distribution and in selecting voltages, frequency and phases for electrical power distribution. The need to provide compatibility of Secondary Power assemblies and components with the operating environment (temperature, pressure, static and dynamically induced vibration) will require use of special materials, insulations and designs to resist this environment over the test and operating life of each vehicle. In addition, grounding of electrical

components will be required in accordance with standard design practice to ensure safe operations. Filtering to prevent EMI interference will be required, both to prevent Electrical Power and Distribution from interfering with other subsystem operation as well as to prevent other subsystems from affecting electrical assembly operations. This applies to lighting as well as to power.

To ensure critical components may be inspected and serviced following the mission, maintainability shall be designed into Secondary Power as required to verify integrity as well as to easily and quickly remove and replace components, modules, or assemblies which require scheduled and/or unscheduled maintenance and refurbishment.

Detail design requirements affecting the above will be specified as applicable in affected CEI Part I's when generated.

V. INTERFACES

Secondary Power as appropriate, interfaces with all other subsystems in Stage I. In addition, Secondary Power interfaces with Stage II (WBS ID 1.3.6) for backup stage separation power. Interfaces with other Program elements are as follows: (1) with WBS ID 2.0 for launch and recovery ground power, (2) with WBS ID 3.0/8.0 for peculiar and common maintenance support, (3) with WBS ID 4.0 for testing Secondary Power and for mockups of and involving Secondary Power, (4) with WBS ID 5.0 for system/program management, (5) with WBS ID 6.0 for deliverable data on Secondary Power, (6) with WBS ID 9.0 for Secondary Power initial spares and repair parts, (7) with WBS ID 10.0 for training crews (flight, ground) on operations and maintenance of Secondary Power, (8) with WBS ID 11.0 for industrial facilities affecting Secondary Power, and (9) with WBS 12.0 for Operations involving Secondary Power. These interfaces will be spelled out as applicable in referenced elements.

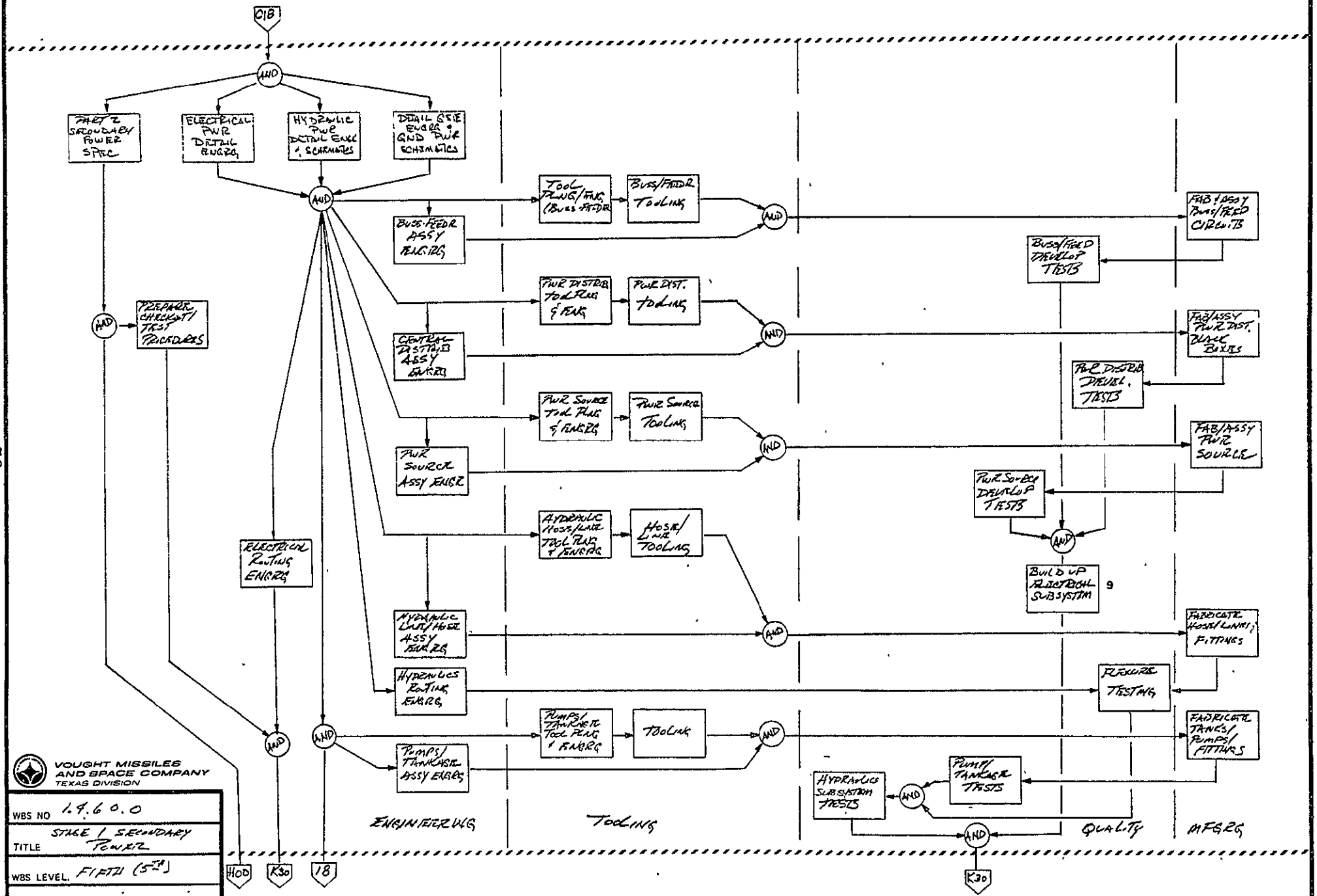
VI. TEST REQUIREMENTS

Category I and II tests will be conducted on the Secondary Power Subsystem as follows. Components, assemblies and single subsystems development tests will be generally conducted under WBS ID 1.4.6 or lower levels thereto. Combined subsystem or assembly tests will be performed under WBS ID 4.2. System level tests will be conducted under WBS ID 4.6 and 4.7. Mockups as appropriate will be provided under WBS ID 4.9.

VII. REFERENCES

(To be added.)

INPUTS

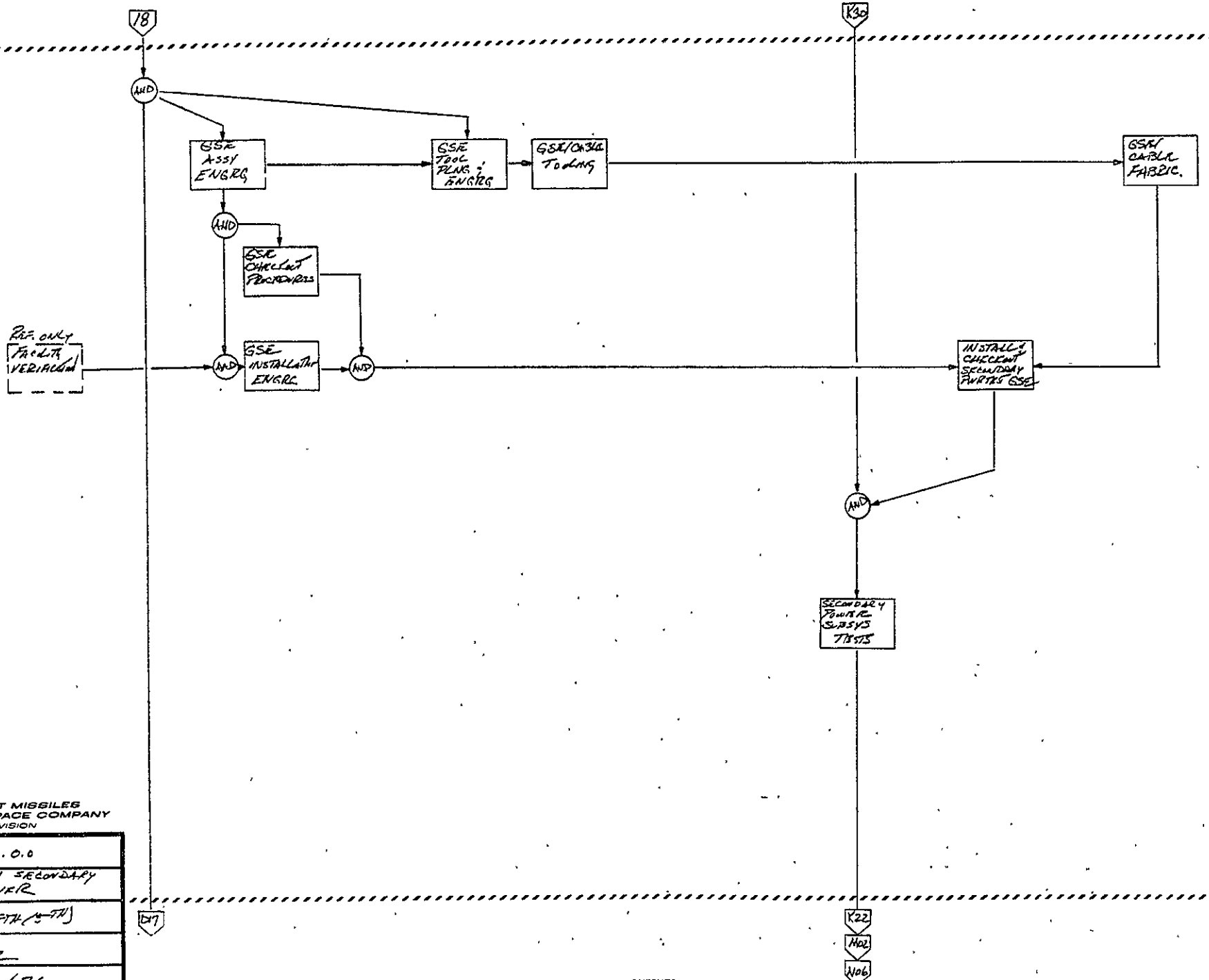


VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.4.6.0.0
TITLE	STAGE I SECONDARY POWER
WBS LEVEL	FIFTH (5TH)
PAGE	1 OF 2
DATE	4 JUN 71

OUTPUTS

INPUTS



OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.4.6.0.0
TITLE	STAGE 1 SECONDARY POWER
WBS LEVEL	FIFTH (5TH)
PAGE	2 OF 2
DATE	4 JUN 71

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.6.2

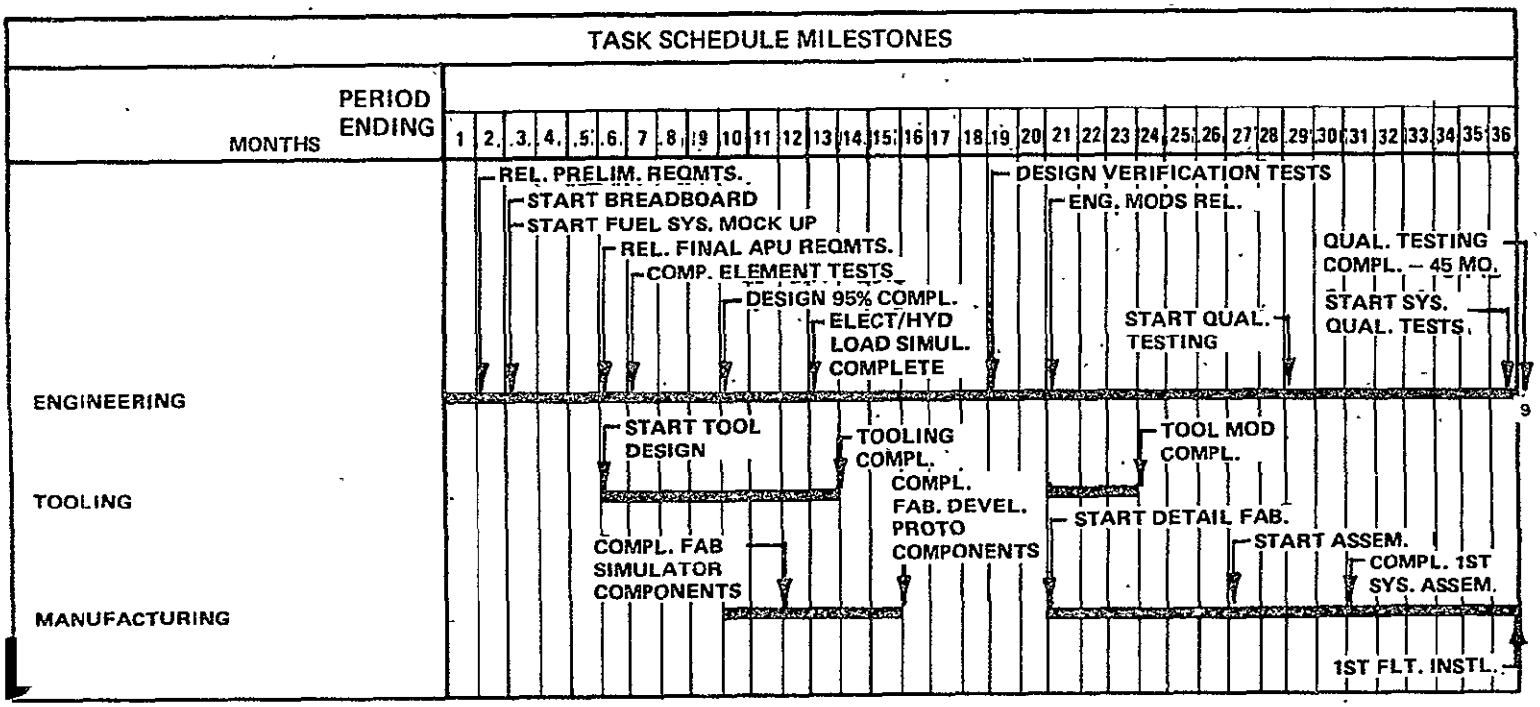
TASK TITLE POWER SOURCE (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.6)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.6.3

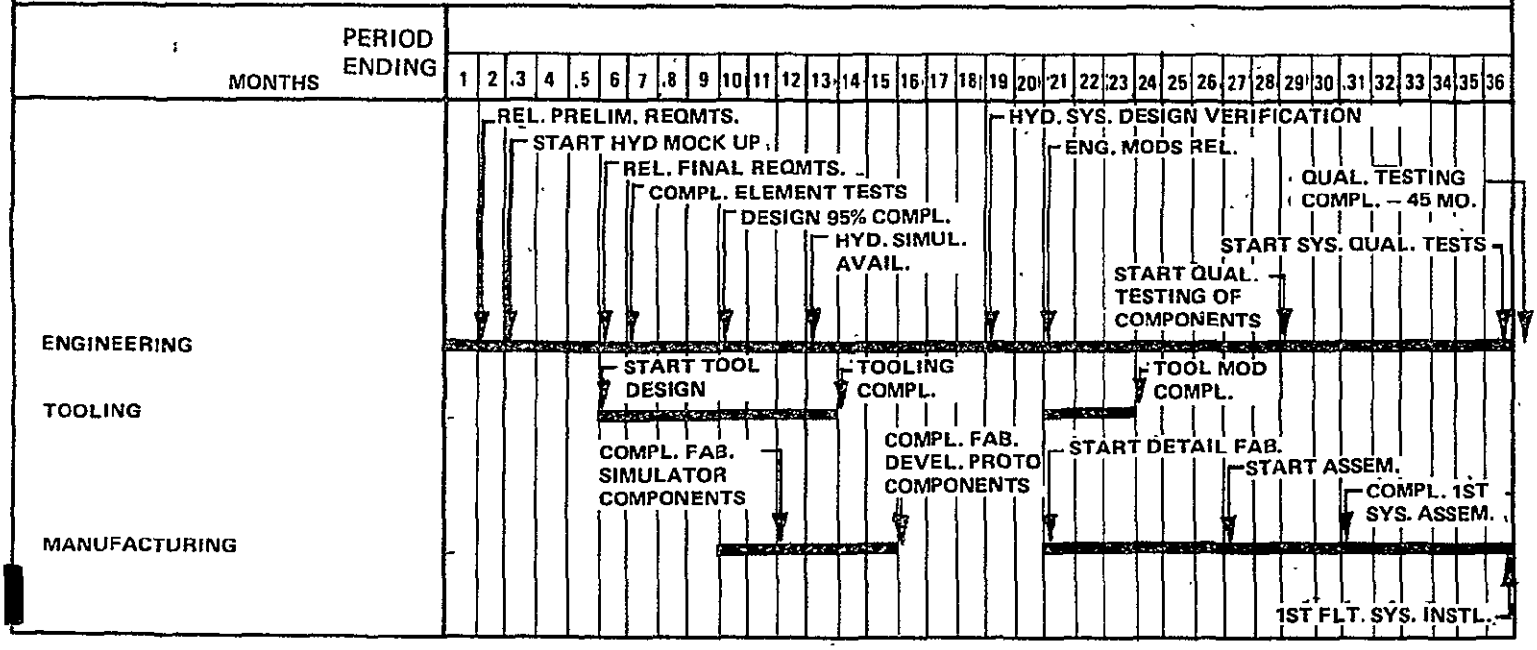
TASK TITLE HYDRAULIC POWER GENERATION & DIST. (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.6)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.6.4

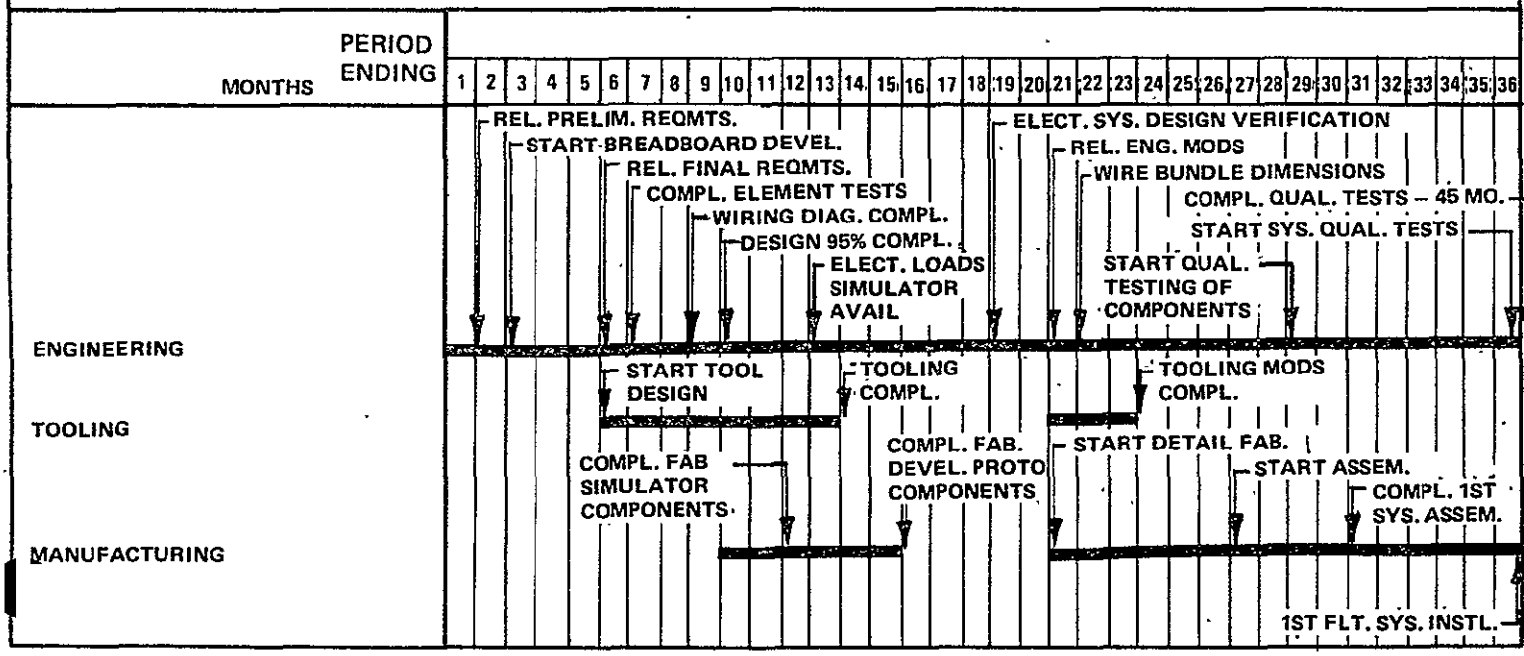
TASK TITLE ELECTRICAL POWER GENERATION & DIST. (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.6)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.6.5

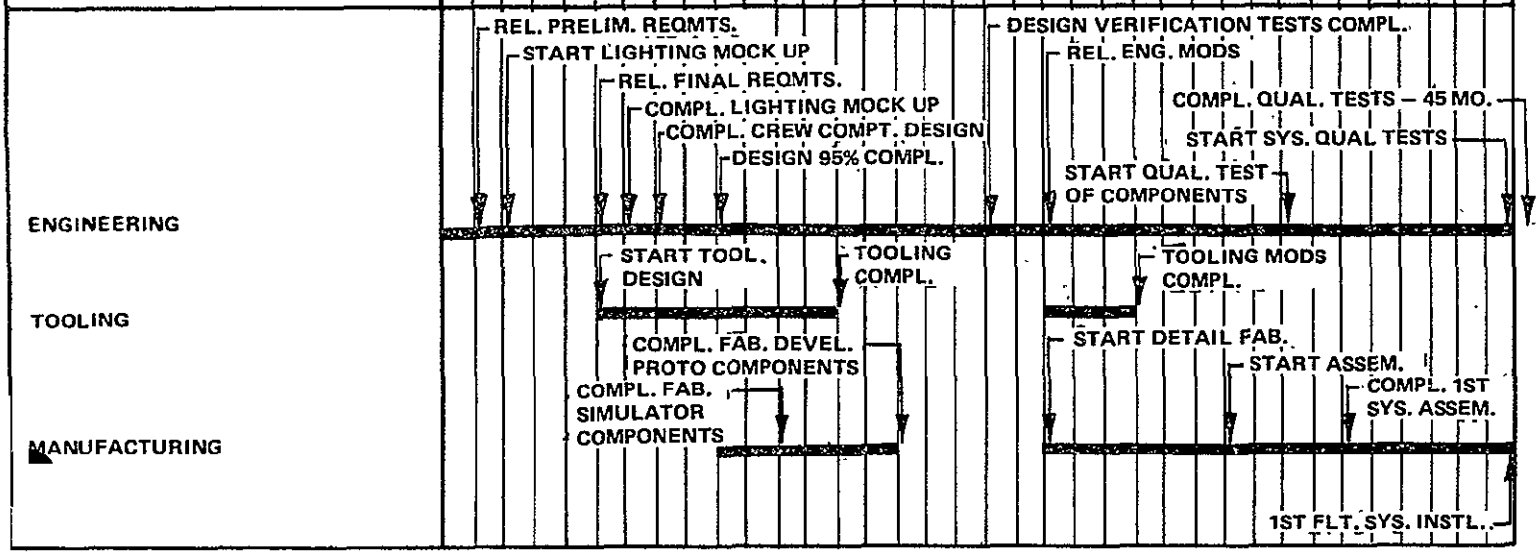
TASK TITLE LIGHTING (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.6)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.7

TASK TITLE ENV. CONTROL & LIFE SUPPORT (STAGE I)

LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned, reusable, i.e. winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landings by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to maximum capability depending on mission requirements.

TASK SCHEDULE MILESTONES

PERIOD ENDING

SEE LOWER LEVELS FOR DETAIL SCHEDULES

To assist in meeting these requirements, Stage I Environmental Control and Life Support Subsystem (ECLSS) must provide properties and characteristics compatible with Stage I flight spectrum (pre-launch activities, launch activities, ascent in the Air Vehicle Configuration, staging, cruise to apogee and maneuver for entry, reenter, cruise, approach and land, followed by safe and purge operations). For ferry flights, and all flight test operations, ECLSS must also provide the required environmental control and life support.

Specifically, Stage I ECLSS shall provide the crew with a shirtsleeve environment through Stage I's portion of the Space Transport mission (WBS Dictionary Element 0.0, Para. IV. A.9) and provide as necessary control of the Stage I vehicle environment affecting subsystems. These requirements shall ensure non-hazardous conditions exist before, during and following a mission, such as pre-flight, in-flight and post flight purging of potentially explosive gases. In addition, conditioning of temperature/pressure sensitive components and modules shall either be incorporated into the design of such components and modules and/or provided by ECLSS to ensure subsystem operation within design allowables and tolerances. Where a potentially hazardous condition may occur, in spite of good design practice, a means to remove the hazard, either by venting, by blanketing the area with non-combustion environment (such as nitrogen blanket) and/or by fire extinguishing means shall be provided.

Constraints on Stage I ECLSS, in addition to mission environment compatibility through a specified lifetime, include the following: (1) maintainability, (2) reliability, (3) safety compliance, (4) operability, (5) human factors acceptability, (6) quality assurance, (7) commonality and/or exchangeability between vehicle tail numbers, and (8) cost minimization through use of proven technology, good design practice, good production practice, and thorough flight qualification prior to achieving operational status.

II. ASSEMBLIES DEFINITION

The choice of assemblies for Stage I Environmental Control and Life Support is, in a sense, concept dependent. For the baseline concept, the following assemblies are defined. These are subject to modification based upon final concept selection. (See Figure 1.4-W-3 for WBS)

1.4.7.1	Integration and Assembly
1.4.7.2	Conditioned Air
1.4.7.3	Purge, Vent and Fire Control

III. FUNCTIONAL DESCRIPTION

The baseline concept for Stage I ECLSS is based on the short lifetime of its portion of the Space Transport mission. The environment for the crew and sensitive equipment located in the equipment bay (part of the crew station pressure vessel, WBS ID 1.4.2.5) is established prior to launch through providing ground-supplied conditioned air to the pressure vessel, then controlling that environment through ascent, separation, cruise to apogee and reentry point, and reentry into the sensible atmosphere when ABES engines are deployed and powered up. During cruise back to the landing site, ram air from fuselage-mounted engine intakes will pass through precoolers to air cycle refrigeration packages for conditioning and ducting to the crew/equipment compartment. Compartment pressure in the ascent/reentry phase is lowered to and held at a pressure satisfactory for crew and equipment operation. Heat loads from equipment are removed by heat exchangers and cold plate techniques. For air circulation in the pressure vessel, fans are provided. Refrigerated air ducts are insulated to maintain temperature and inhibit frost buildup. Emergency oxygen is provided for crew requirements. Relief packs are supplied.

For control of inboard liquids, gases and vapors around cryogen and fuel tanks, a nitrogen purge concept is used in the baseline design. This concept operates only during pre-launch and is supplied from ground sources. Distribution in-board is via a manifold system paralleling the tank areas and main engine mounting to both prevent frost buildup

as well as provide an inert blanket in this volume. Venting following liftoff throughout the flight profile is accomplished by modulating valves in the tank compartments and in landing gear wheelwells.

Fire protection is provided through sensors to detect and warn of such hazards as well as providing a means to extinguish fires in potential sources for fire (ABES engines, APUs, APS turbopumps, heat exchanger gas generators for ACPS/APUs, and electronic/electrical equipment areas). Crew station fire detection/extinguishing capability is also required.

Non-flammable materials are specified for areas where fire could inadvertantly occur.

To achieve operational status, Stage I ECLSS will be verified in the RDT & E phase by following the steps briefed below:

A. Phase C Go-Ahead Through PDR - Depending on end item (CEI) breakdown of Stage I, completion of preliminary design will result in a Part I specification affecting Environmental Control and Life Support. Detailed definitions will specify performance, interfaces, and effectiveness required of this subsystem. Upon approval of CEI Part I, final design can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II's can be prepared. (See Para. VI for tests affecting this phase.)

C. CDR to Qualification Testing - Release of drawings to manufacturing and to materiel will allow final Integration and Assembly to be performed to build prototype and flight test articles to be used for Pre-Flight, Horizontal Flight Test and Vertical Flight Test programs. Qualification will proceed throughout these phases to verify readiness for next test. Qualification will finally be granted through DD 250 (or equivalent) buyoff when ECLSS, as well as other Stage I subsystems, prove they meet specification to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Level I and II requirements affecting Environmental Control and Life Support are stated in WBS Dictionary Element 0.0, and will not be repeated here except as briefly stated in Para. I, above. In addition to those cited, standard aircraft and spacecraft design practice will apply to ECLSS through choice of components, modules and assemblies which, through integrated design and test, verify their capability to satisfactorily perform the requirements over the stated Program lifetime with minimum downtime other than normal servicing, inspection and refurbishment of parts or components known to have short duration lifetimes (expendables). Use of strong, light weight materials compatible with the mission loads (thermal, pressure, static, and dynamic) and with their interfaces should be selected. Proven technology, augmented with adequate test programs, is preferred over untried techniques. Additional design requirements will be specified as applicable based upon CEI Part I's when generated.

V. INTERFACES

The Environmental Control and Life Support Subsystem (ECLSS) directly interfaces with the crew/equipment station (part of structure, WBS ID 1.4.2.5) and all subsystems included therein, including human interfaces (crew, service and test personnel). In addition, a direct interface exists with those other subsystems, external to the pressure vessel, which require environmental control (principally thermal control) for nominal operation. Indirectly, ECLSS interfaces with the entire vehicle in that requirements affecting safe, effective operation depend on maintaining an environment (hazard-free) which will not degrade mission performance through creation of hazardous fuel/oxidizer/temperature mixtures conducive to explosion, fire or other disaster. In this regard, other subsystems must provide their own controlled environment to the extent possible and practicable (insulation, non-hazardous materials, for example). Integrated design reviews, tests and demonstrations will ensure an effective design. In addition to vehicle interfaces, other interfaces exist with other Program elements as follows: (1) with WBS ID 2.0 for launch and recovery elements, (2) with WBS ID 3.0/8.0 for maintenance and support elements, (3) with WBS ID 4.0 for tests, evaluation and mockups, (4) with WBS ID 5.0 for System/Program management, (5) with WBS ID 6.0 for deliverable Data requirements/provisioning, (6) with WBS ID 9.0 for initial spares

and repair parts, (7) with WBS ID 10.0 for flight and ground crew training, (8) with WBS ID 11.0 for industrial facility interfaces, and (9) with WBS ID 12.0 for Operations interfaces. Referenced WBS Dictionary elements will spell out these interfaces as applicable.

VI. TEST REQUIREMENTS

ECLSS testing will be conducted as required under WBS ID 1.4.7 or lower level tests on ECLSS components, modules, assemblies and subsystem. Combined assembly or subsystem development tests will be conducted under WBS ID 4.2. Flight testing will be conducted under WBS ID 4.6 and 4.7. Mockups will be generated and maintained under WBS ID 4.9.

VII. REFERENCES

(To be added.)

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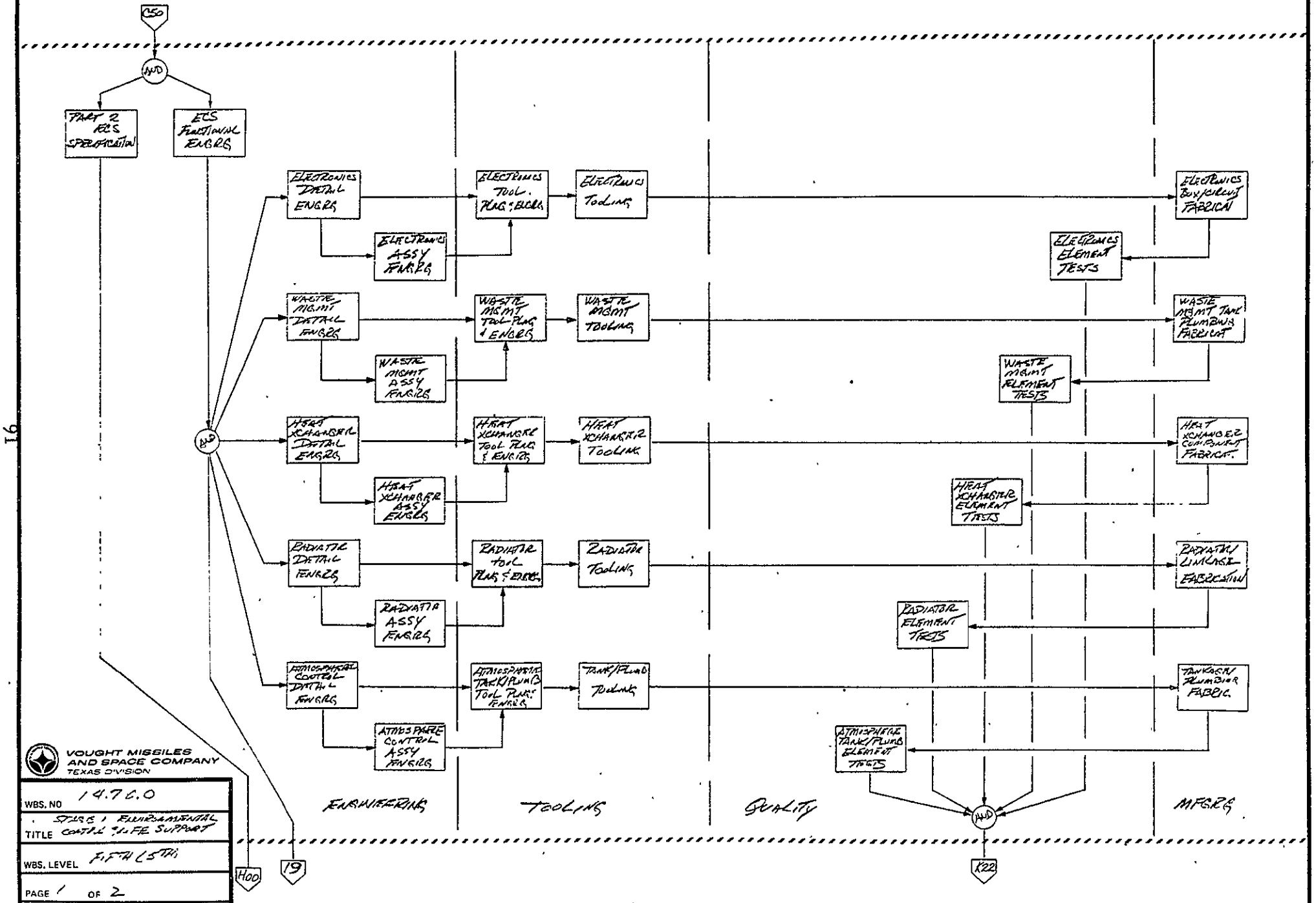


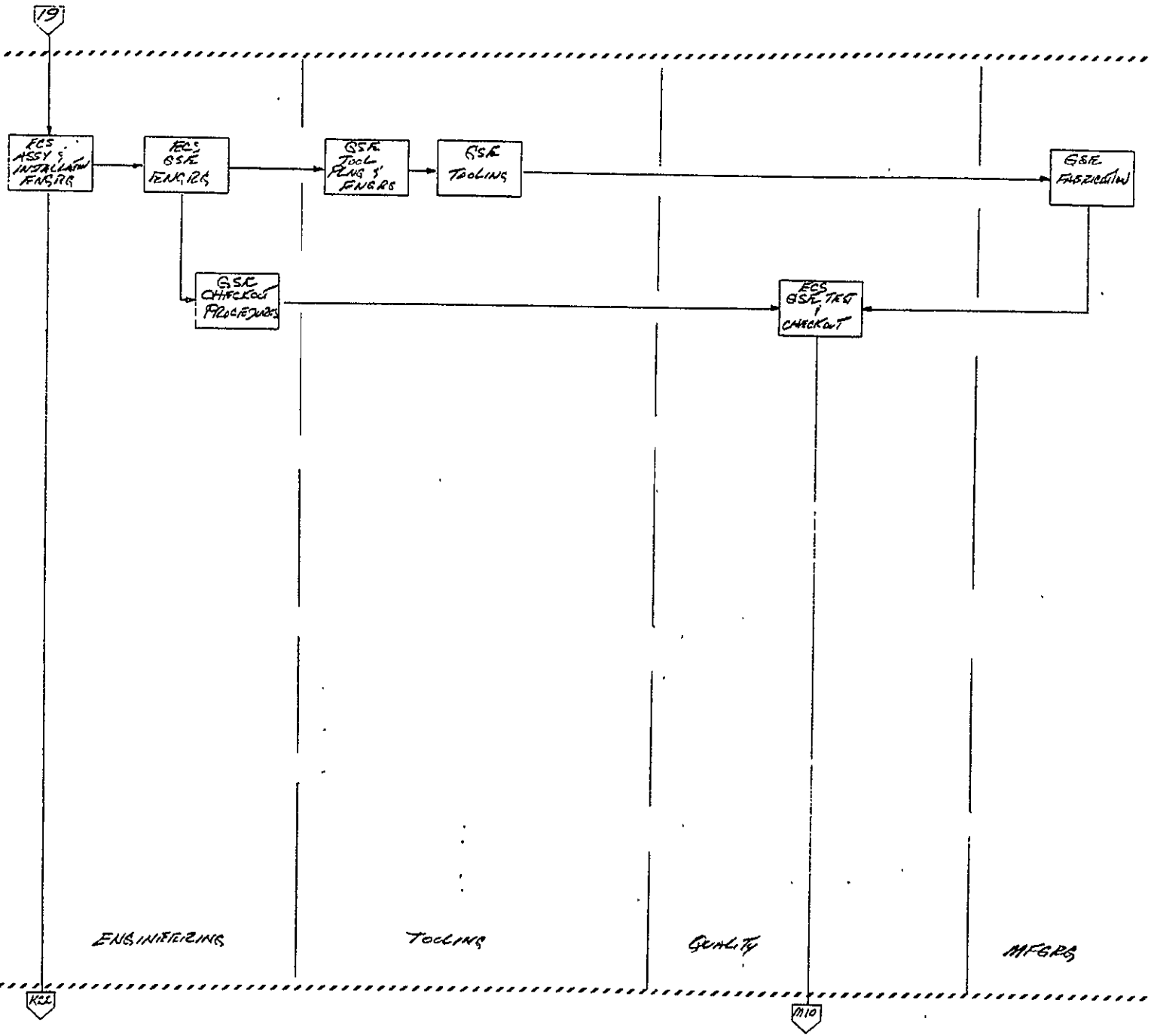
VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS. NO	14.7C.0
TITLE	STAGE 1 ENVIRONMENTAL CONTROL & LIFE SUPPORT
WBS. LEVEL	FIFTH (5TH)
PAGE	1 OF 2
DATE	4 JUNE

OUTPUTS

16

INPUTS



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VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.4 7.0.0
TITLE	STAFF & ENVIRONMENTAL CONTROL & L FE SUPPORT
WBS LEVEL	FIFTH (5TH)
PAGE	2 OF 2
DATE	4 JUN 71

OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.7.2

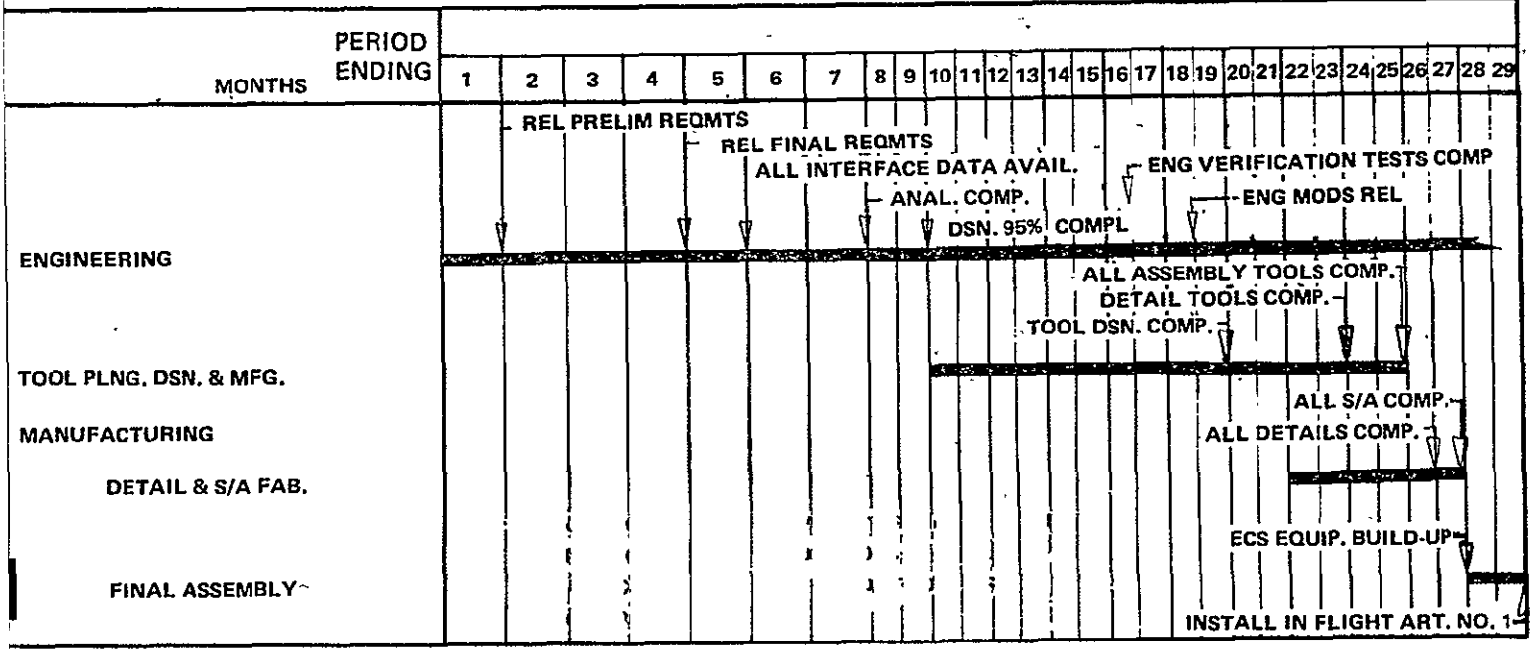
TASK TITLE CONDITIONED AIR (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.7)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.7.3

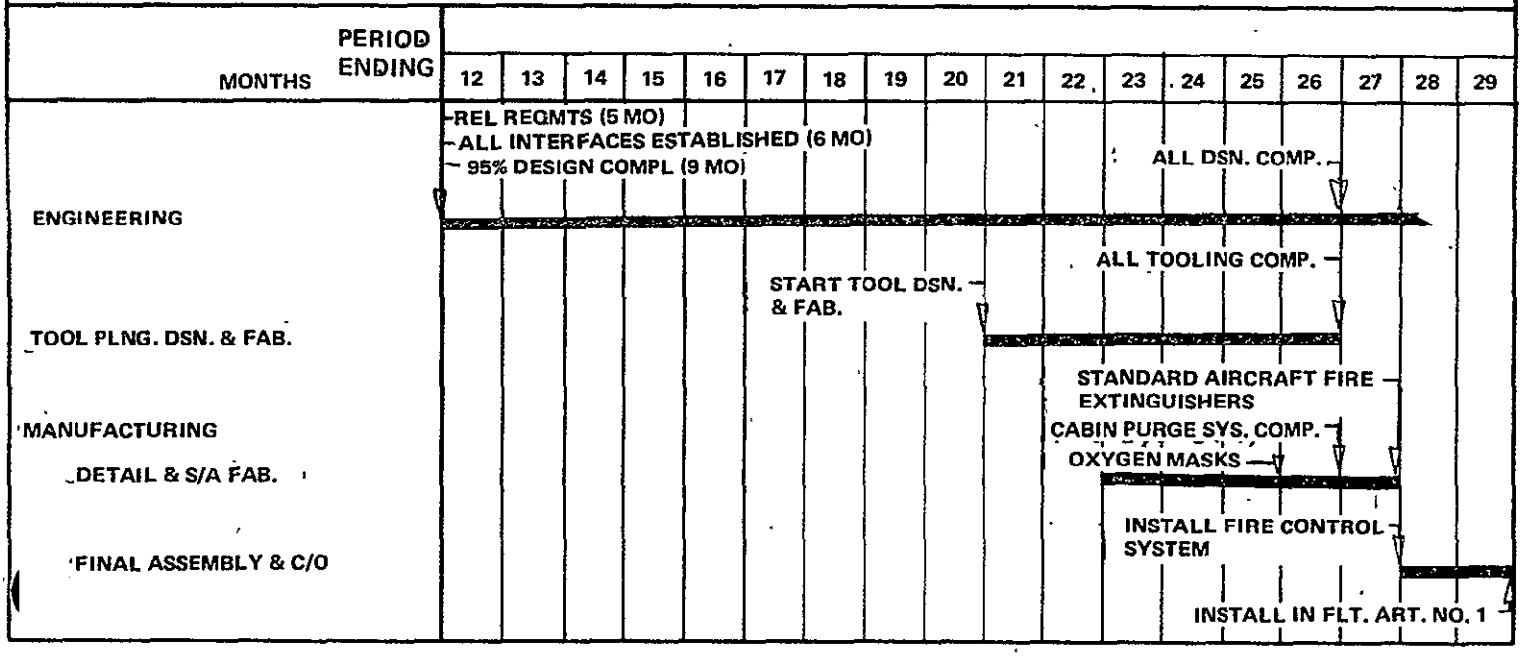
TASK TITLE PURGE, VENT & FIRE CONTROL (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.7)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.8

TASK TITLE GUIDANCE & NAVIGATION (STAGE I)

LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned, reusable, i.e., winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landing by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to maximum capability, depending

TASK SCHEDULE MILESTONES

PERIOD ENDING

SEE LOWER LEVELS FOR DETAIL SCHEDULES

on mission requirements.

To assist in meeting the above requirements, the Guidance and Navigation Subsystem of Stage I must provide properties and characteristics compatible with the total Stage I flight spectrum (pre-flight activities, launch activities, ascent in the Air Vehicle configuration, separation of Stage II, exoatmospheric maneuvers to achieve position for entry to desired landing site, reentry into the sensible atmosphere, transition to and through the transonic regime, subsonic cruise, deploy onboard air-breathing engines if required for approach or go-around, conduct final approach, flare, touchdown, runout, and parking on the airport ramp for post-flight servicing). On-board air-breathing propulsion will be required for ferry flight.

Specific properties and characteristics required of Guidance and Navigation (G & N) are to maintain, from a point in launch countdown through the mission profile of Stage I (Air Vehicle launch, ascent, separation, then Stage I flight completion), accurate current estimates of vehicle position and velocity to enable steering commands to be determined and implemented. To assist G & N in the return leg of flight, navigation aids (part of Communications and Navaids, WBS ID 1.4.9) will be utilized by Data Management computers (WBS ID 1.4.10) in determining steering commands required to achieve the desired landing site. These computers handle all G & N inputs through Stage I flight and transmit commands to Flight Control (WBS ID 1.4.5) for accomplishing necessary vehicle steerage. This automatic mode can be overridden by crew at appropriate points in the Stage I flight profile.

Constraints on Guidance and Navigation, in addition to performance and other subsystem interfaces as well as compatibility with mission environment through a specified lifetime, include the following: (1) maintainability (2) reliability, (3) safety compliance, (4) operability, (5) human factors acceptability (both flight crew and ground crew), (6) quality assurance, (7) commonality and/or exchangeability between tail numbers, and (8) cost minimization through use of proven technology, good design practice, good production practice, and thorough flight qualification prior to achieving operational status.

II. ASSEMBLIES DEFINITION

The specific assemblies used to form Stage I Guidance and Navigation are concept dependent. For the baseline concept, subject to modification by the selected concept, the following assemblies are specified. (See Figure 1.4-W-3 for WBS)

1.4.8.1	Integration and Assembly
1.4.8.2	Inertial Measurement Units
1.4.8.3	Navigation Equipment*
1.4.8.4	G & N Software**

(*See WBS ID 1.4.9.3 for Precision Ranging System (PRS) interface)
(**See WBS ID 1.4.10.5 for this software)

III. FUNCTIONAL DESCRIPTION

In the baseline concept, the Inertial Measurement Units (IMUs) provide the total automatic G &N function from pre-launch through reentry, when the Precision Ranging System (PRS, part of Communications and Navaids) inputs are added to IMU inputs to Data Management for more precise navigation to the selected landing site. By mission phases, the following G & N functions are required to be performed by Guidance & Navigation and by assistance from Communications and Navaids, i.e. PRS.

PHASE	G & N FUNCTIONS	PRS FUNCTIONS
Pre-launch	. Perform Air Vehicle & Stage I targeting . Perform guidance initialization . Align & calibrate inertial reference (gyro-compass techniques) . (Initialize Flight Control Subsystem) . Verify launch data with Stage II . Navigate and target to launch time . Provide display inputs	. (Initialize Comm. & Navaids Subsystem)

PHASE	G & N FUNCTIONS	PRS FUNCTIONS
Air Vehicle Ascent to Separation	. Perform powered flight G & N (IMUs) . (Initiate Stage I abort if required) . Provide abort G & N if required (IMUs) . Provide display inputs	. Provide ranging signals in abort mode if required
Separation and Coast	. Provide separation and coast phase navigation (IMUs) . Provide coast phase guidance (IMUs) . Provide display inputs	
Reentry and Transition	. Provide G & N during reentry (IMUs) . Provide display inputs	. Update position and velocity if ground station in RF view
Cruise, Aerodynamic	. Provide G & N during cruise (IMUs) . Provide display inputs . (FCE input air data for altitude: WBS ID 1.4.5.6)	. Interrogate ground transponders for crosstrack and downtrack data . (Provide radar altimeter data: WBS ID 1.4.9.5)
Approach and Landing	. Provide G & N during approach and landing (IMUs) . Provide automatic landing (IMUs) with manual override capability . Provide display inputs . (FCE input air data for altitude)	. Provide crosstrack and downtrack data . (Provide radar altimeter data)

To achieve operational status, the Guidance and Navigation Subsystem will be verified in the RDT & E phase by following the steps briefed below:

A. Phase C Go-Ahead Through PDR - Depending on end item (CEI) breakdown of Stage I, completion of preliminary design will result in a Part I specification affecting Guidance and Navigation. Detailed definitions will specify performance, interfaces, and effectiveness required of this subsystem. Upon approval of CEI Part I, final design can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II can be prepared. (See Para. VI for tests affecting this phase.)

C. CDR to Qualification Testing - Release of drawings to manufacturint and to materiel will allow final Integration and Assembly to be performed to build the Structural Test Vehicle and Flight Test Vehicles to be used for Pre-Flight, Ferry Test, Horizontal Flight Test, Single Element Vertical Flight Test, and Mated Flight Test programs. Qualification will finally be granted through DD 250 (or equivalent) buyoff when Guidance and Navigation, as well as all other Stage I subsystems, prove they meet specifications to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Level I and II requirements affecting Guidance and Navigation (G & N) are stated in WBS Dictionary Element 0.0, and will not be repeated here. In addition to those cited, standard aircraft and spacecraft electronic design practices will apply to G & N in the choice of rugged, light weight components, modules and assemblies whose accuracy is compatible with maximum duration mission requirements. Environmental and power requirements shall be specified through Interface Control Drawings (ICDs). Similarly, signals to and from interfacing Data Management elements (ACTs, Data Bus, Computers) shall be controlled by ICDs. Procedures necessary for pre-launch gyrocompassing, where external aids are required, shall be established for each intended launch point. Due to

long-life requirements, G & N components, modules and assemblies must be accessible, testable and removable if faulty. Maintenance procedures (WBS ID 5.0) shall verify how these sensitive electronic devices shall be maintained to ensure their integrity throughout the test and operational phases of the program. Detailed design and mission requirements will be specified in CEI Part I's when generated.

V. INTERFACES

Guidance and Navigation directly interface with elements of the Data Management Subsystem (WBS ID 1.4.10) for operational functions; with structure (WBS ID 1.4.2) for location, weight and volume; with Environmental Control and Life Support (WBS ID 1.4.7) for environmental protection; and with Secondary Power (WBS ID 1.4.6) for electrical power. During pre-launch, an interface will exist with Launch Equipment (WBS ID 2.5). Other Program interfaces will include: maintenance (WBS ID 3.0/8.0); test, evaluation and mockup (WBS ID 4.0); system/program management (WBS ID 5.0); deliverable data (WBS ID 6.0); initial spares and repair parts (WBS ID 9.0); training (WBS ID 10.0); industrial facility requirements/provisioning (WBS ID 11.0); and Operations (WBS ID 12.0). These interfaces will be spelled out as applicable in referenced WBS Dictionary elements.

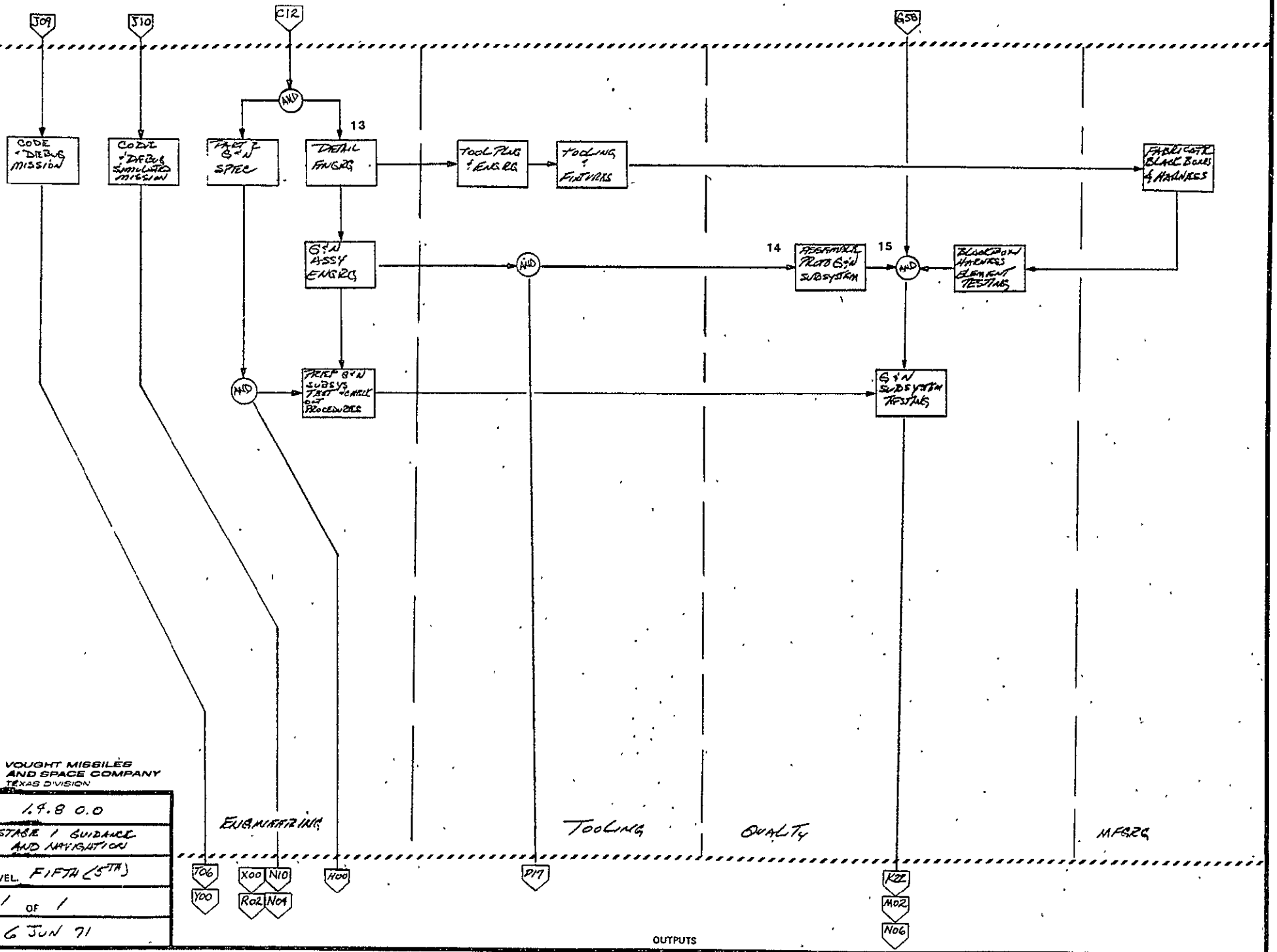
VI. TEST REQUIREMENTS

Individual component, module, assembly and subsystems tests will be conducted as required under WBS ID 1.4.8 or lower levels thereto. Combined assembly and subsystem tests will be conducted under WBS ID 4.2. System tests (Pre-Flight, Ferry Flight, Horizontal Flight, and Mated Flight Test Programs) will be conducted under WBS ID 4.6 and 4.7. Inasmuch as Guidance and Navigation, as specified in previous paragraphs above, is needed for the entire Stage I flight profile, other tests (ferry, horizontal flight) cannot adequately test this subsystem. Simulations may be required, therefore, in these test phases to verify interfaces perform adequately. WBS ID 4.9 provides mockups involving Guidance and Navigations.

VII. REFERENCES

(To be added.)

INPUTS



OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS, NO	1.9.8 0.0
TITLE	STAGE 1 GUIDANCE AND NAVIGATION
WBS LEVEL	FIFTH (5TH)
PAGE	1 OF 1
DATE	6 JUN 71

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.8.2

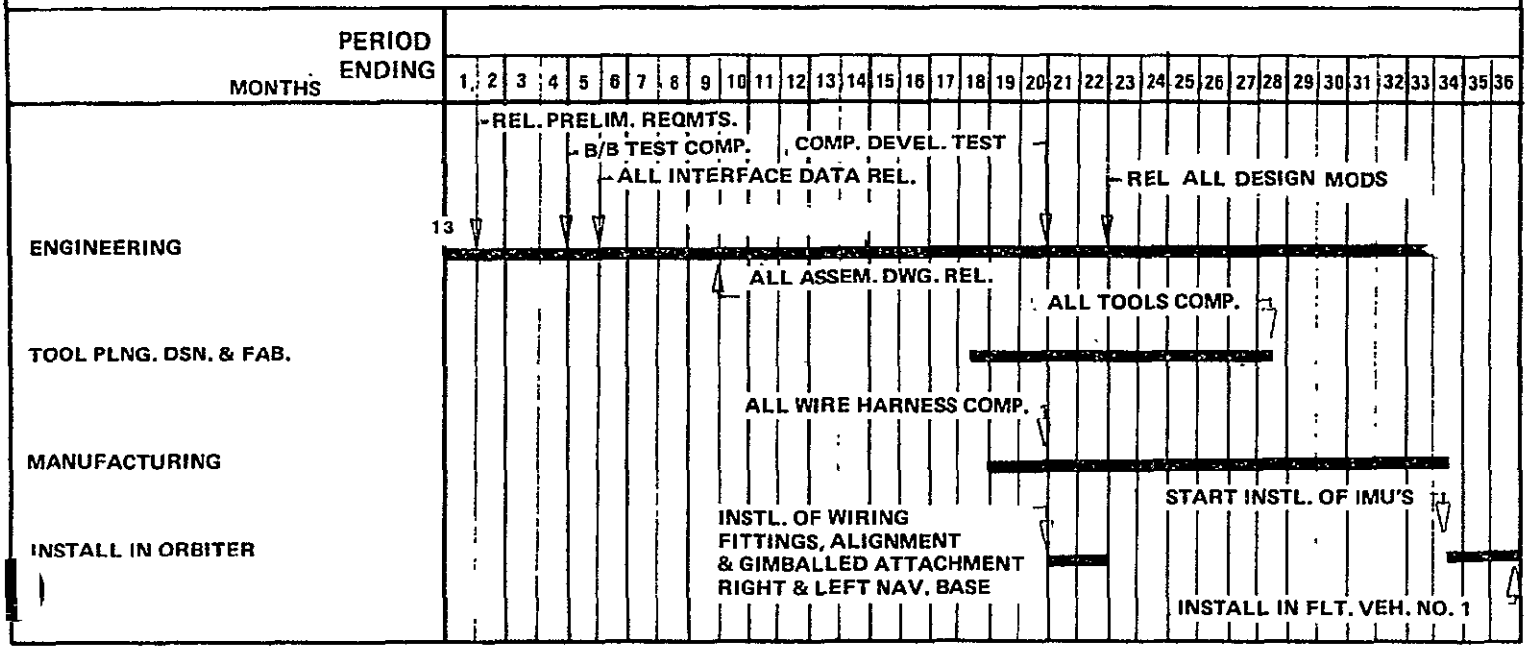
TASK TITLE INERTIAL MEASUREMENT UNITS (IMUs) (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.8)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.9

TASK TITLE COMMUNICATIONS AND NAVAIDS (STAGE I)

LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned, reusable, i.e., winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landing by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to maximum capability, depending on mission requirements.

TASK SCHEDULE MILESTONES

PERIOD ENDING

SEE LOWER LEVELS FOR DETAIL SCHEDULES

To assist in meeting the above requirements, the Communications and Navaids subsystem of Stage I must provide properties and characteristics compatible with the total Stage I flight spectrum (pre-flight activities, launch activities, ascent in the Air Vehicle configuration, separation of Stage II, exoatmospheric maneuvers to achieve position for entry to the desired landing site, reentry into the sensible atmosphere, transition to and through the transonic regime, subsonic cruise, deploy onboard air-breathing engines if required for approach or go-around, conduct final approach flare, touchdown, runout, and parking on the airport ramp for post-flight servicing). On-board air-breathing propulsion will be required for ferry flight.

Specific characteristics which the Communications portion of this subsystem must provide include: (1) two-way voice (ground-to-Stage I, Stage I-to-ground, Stage I-to-Stage II, and intercommunications within Stage I and with ground crews for ground operations); (2) data links (Stage I-to/from-Stage II, Stage I-to-ground); (3) vehicle identification signals for tracking and identification (FAA, Air Traffic Control); and (4) crash type beacon and data recorder.

Specific characteristics which the Navaids portion of this subsystem must provide include: (1) range and bearing between Stage I and the landing sites; and, (2) radar altitude. These characteristics, required for automatic landings, shall be provided to the Data Management computers as called for during a mission or test flight.

Constraints on Communications and Navaids, in addition to performance and other subsystem interfaces as well as compatibility with mission environment through a specified lifetime, include the following: (1) maintainability, (2) reliability, (3) safety compliance, (4) operability, (5) human factors acceptability (both flight crew and ground crew), (6) quality assurance, (7) commonality and/or exchangeability between tail numbers, and (9) cost minimization through use of proven technology, good design practice, good production practice, and thorough flight qualification prior to achieving operational status.

II. ASSEMBLIES DEFINITION

The specific assemblies which form Communications and Navaids are concept dependent. For the baseline concept, the following assemblies are specified. These are subject to modification based on selected concept configuration definition. (See Figure 1.4-W-3 for WBS)

1.4.9.1	Integration and Assembly
1.4.9.2	RF Communications
1.4.9.3	Ranging
1.4.9.4	Voice Communications
1.4.9.5	Navaids

III. FUNCTIONAL DESCRIPTION

In the baseline concept, RF communications are provided (transmission of data and voice and reception of voice) via a UHF subassembly, including voice communications with Air Traffic Control (ATC) stations. An L-Band ATC beacon is provided for identification purposes. For development flight tests, an S-band telemetry link is provided. Ranging signals generated in the ranging unit use S-band transceivers for the interrogation and subsequent reception of ranging signals needed for post-reentry cruise, approach and landing. Voice communications is available to Stage I crew via a Controls and Display (WBS ID 1.4.11) mounted audio center, crew headsets and microphone, in-cabin intercom, and hardline to Stage II. Data is also transmitted between Stage I and Stage II via hardlines. Intercom panels are available to ground crew during ground operation. A radar altimeter is provided for cruise, approach and landing. The crash-type recorder (inputs from Data Management (WBS ID 1.4.10) and crew voice) and self-locating beacon are provided to meet the requirement of WBS Dictionary Element 0.0, Para. IV. B.9.(a).

To achieve operational status, the Communications and Navaids Subsystem will be verified in the RDT & E phase by following the steps

briefed below:

A. Phase C Go-Ahead Through PDR - Depending on end item (CEI) breakdown of Stage I, completion of preliminary design will result in a Part I specification affecting Communications and Navaids. Detailed definitions will specify performance, interfaces, and effectiveness required of this subsystem. Upon approval of CEI Part I, final design can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II can be prepared. (See Para. VI for tests affecting this phase.)

C. CDR to Qualification Testing - Release of drawings to manufacturing will allow final Integration and Assembly to be performed to build the Structural Test Vehicle and Flight Test Vehicles to be used for Pre-Flight, Ferry Test, Horizontal Flight Test, Single Element Vertical Flight Test, and Mated Flight Test programs. Qualification will finally be granted through DD 250 (or equivalent) buyoff when Communications and Navaids, as well as all other Stage I subsystems, prove they meet specification to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Level I and II requirements affecting Communications and Navaids are designated in WBS Dictionary Element 0.0, and will not be repeated here except as noted. In addition to those requirements cited, standard aircraft and spacecraft electronics design practice will apply to Communications and Navaids in the choice of components, modules and assemblies (including antennas, waveguides, coax cable) which both perform their required functions adequately as well as provide rugged, light weight packaging. Compliance with environmental constraints (temperature, pressure, static and dynamic margins) will be satisfied through locating sensitive modules in environmentally conditioned areas and/or providing materials which can tolerate thermal, pressure, and vibrational levels associated with the specified Program life. Self-test capability will be provided where feasible. Maintenance accessibility must be provided for verification of integrity and removal/replacement if required under minimum downtime constraints. Additional design and mission requirements will be specified in CEI Part I's when generated.

V. INTERFACES

Communications and Navaids directly interfaces with Data Management (WBS ID 1.4.10) in the automatic mode and with Displays and Controls (WBS ID 1.4.11) in the manual mode. Interfaces also exist with Stage II for voice and data transfer (WBS ID 1.3), with crew, and with the ground (WBS ID 2.0). Communications and Navaids are vehicle-located through the interface with Airframe and Structure (WBS ID 1.4.2). Other Program interfaces include: (1) maintenance and support (WBS ID 3.0/8.0); (2) test, evaluation and mockups (WBS ID 4.0); (3) system/program management (WBS ID 5.0); (4) deliverable Data (WBS ID 6.0); (5) initial spares and repair parts (WBS ID 9.0); (6) training (WBS ID 10.0); (7) industrial facilities (WBS ID 11.0); and (8) Operations (WBS ID 12.0). These interfaces will be spelled out as applicable in cited references.

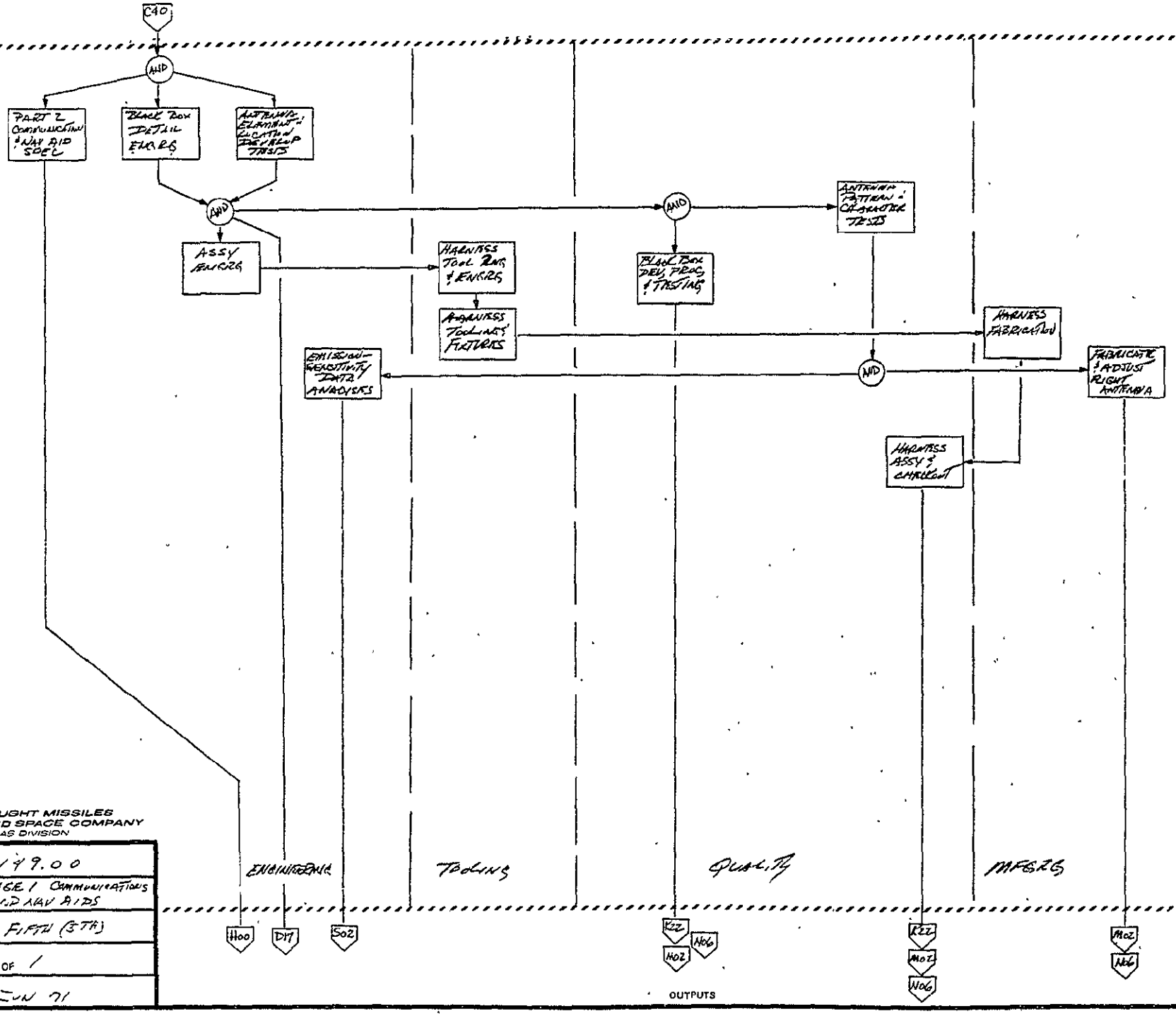
VI. TEST REQUIREMENTS

Single component, module, assembly and subsystem tests as required will be conducted under WBS ID 1.4.9, or lower level thereof. Combined module, assembly and subsystem tests will be conducted under WBS ID 4.2. System tests (Pre-Flight, Ferry, Horizontal Flight Test, Vertical Flight Test) will be conducted under WBS ID 4.6 and 4.7. Mockups will be provided under WBS ID 4.8 for Stage II and under WBS ID 4.9 for Stage I.

VII. REFERENCES

(To be added.)

INPUTS



OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	149.00
TITLE	STAGE I COMMUNICATIONS AND NAV AIDS
WBS LEVEL	FIFTH (5TH)
PAGE	1 OF 1
DATE	6 JUN 71

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.9.2

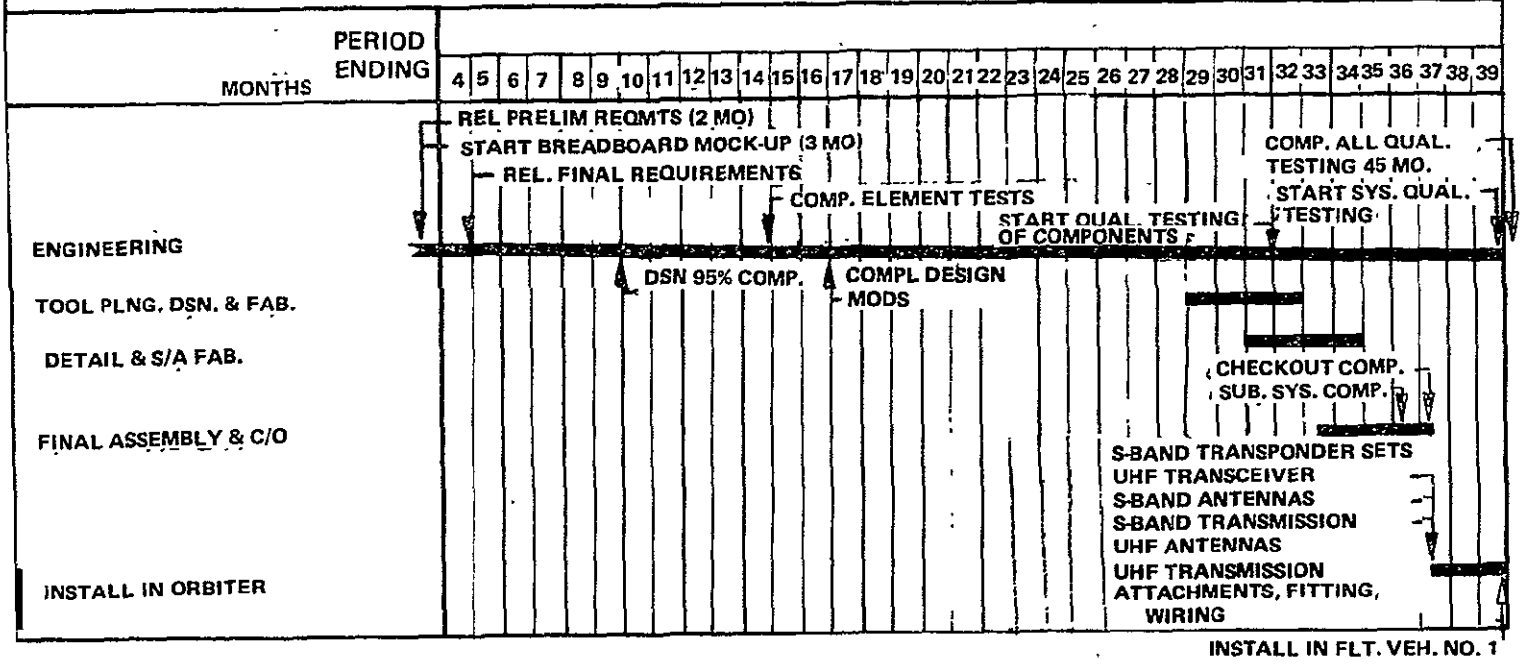
TASK TITLE RF COMMUNICATIONS (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.9)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.9.3

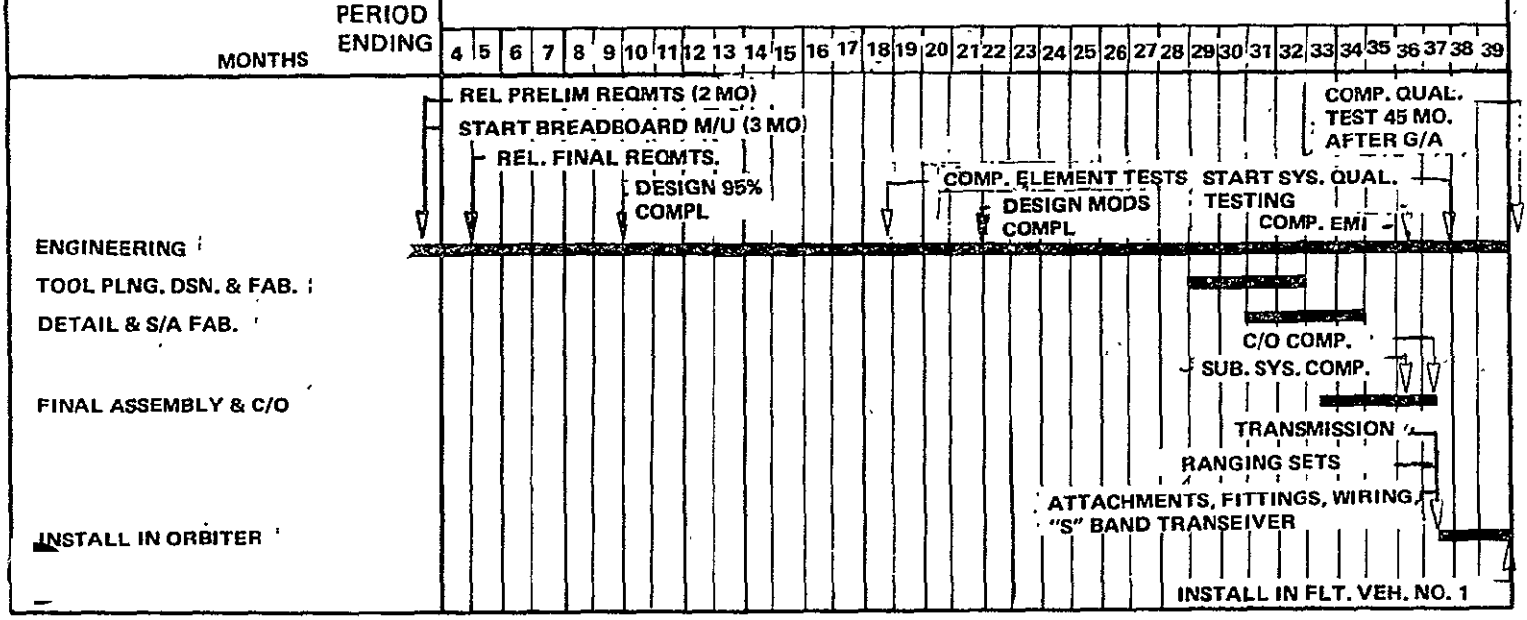
TASK TITLE RANGING (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.9)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.9.4

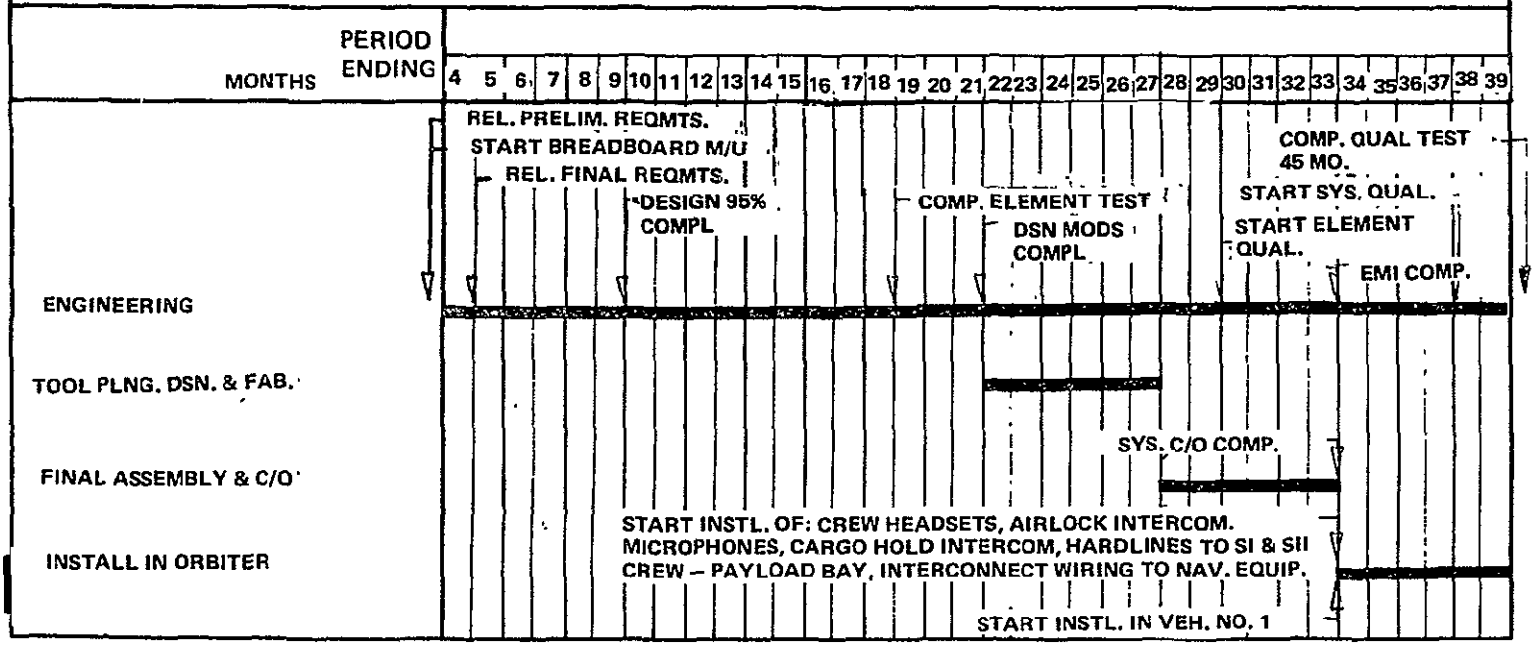
TASK TITLE VOICE COMMUNICATIONS (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.9)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.9.5

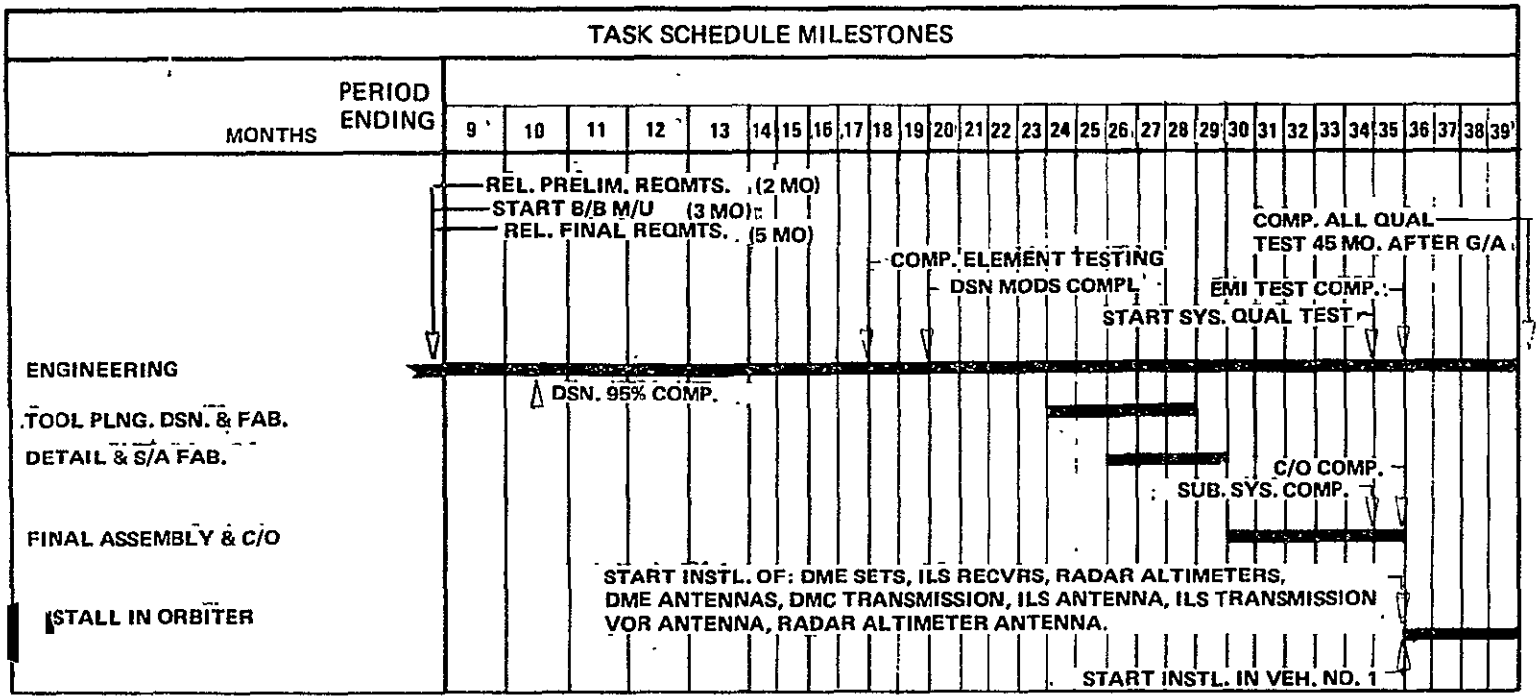
TASK TITLE NAVAIDS (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.9)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.10

TASK TITLE DATA MANAGEMENT (STAGE I)

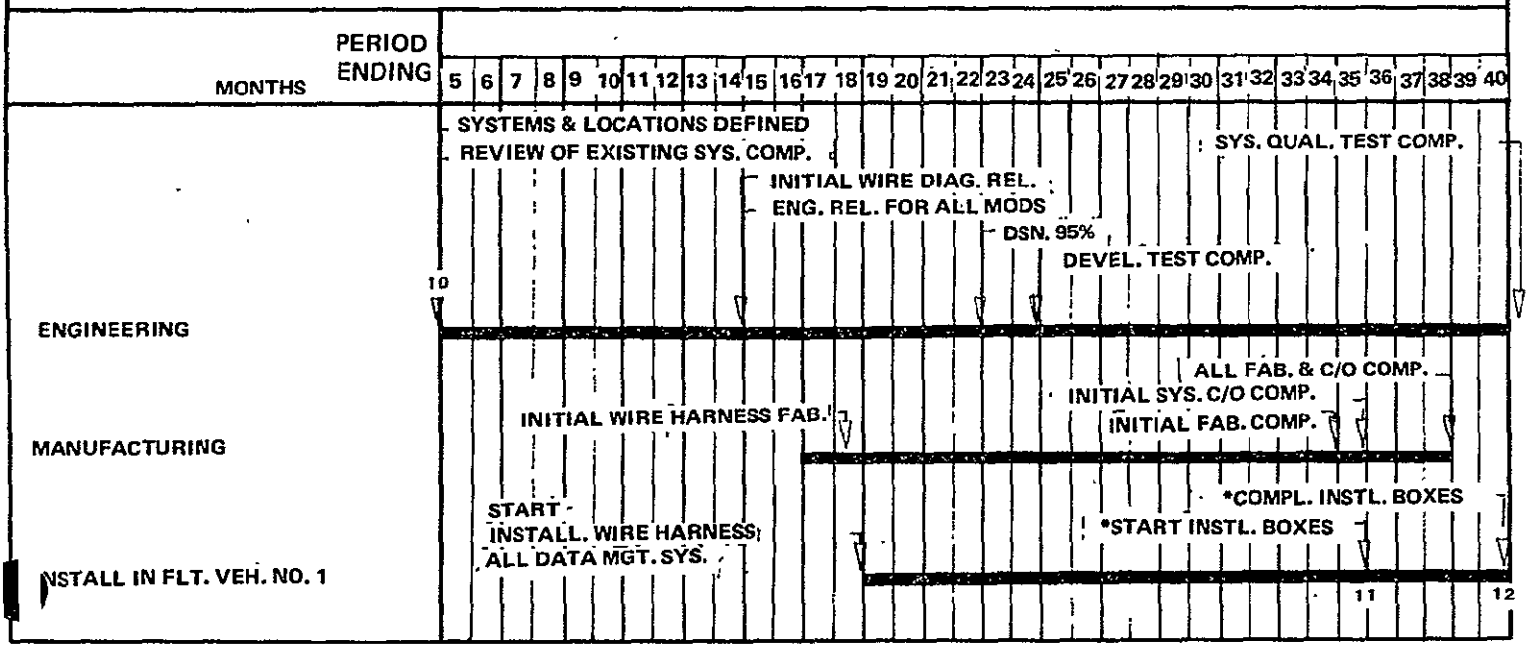
LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned reusable, i.e., winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landing by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to maximum capability, depending on mission requirements.

TASK SCHEDULE MILESTONES



*CENTRAL COMPUTER COMPLEX, SYSTEM CONTROL UNIT, DATA BUS, DIGITAL INTERFACE UNIT, MASS MEMORY, ON BOARD.

To assist in meeting these requirements, a means must be provided to perform Stage I onboard computations, based upon internal vehicle status and capability and upon external information, which will be implemented by appropriate vehicle subsystems to achieve the desired Air Vehicle ascent trajectory, separation sequencing, post-separation sequencing and control of Stage I mission events, and achieve a location, altitude, speed and bearing to enable safe approach and landing. To perform these computations, mission events/trajectory data must be stored in mass memory units and called up as required into the computer memory. In addition, subsystem capabilities must be stored and called up as required into the computer memory. By comparing real time status with stored mission events/trajectory/subsystem capability, Data Management can call for events (ignition, liftoff, guidance and navigation, separation, turn-on, turn-off, maneuvers, etc.) and command these events in the automatic mode. In manual mode, information may be called up by the crew and presented in the form of displays to enable manual flight mode.

In addition to the above, mission data must be stored for post-flight evaluation or transmitted externally for use by ground personnel. For emergency conditions, certain data must be recorded on an aircraft type crash recorder with self-locating beacon (see WBS Dictionary Element 1.4.9).

II. ASSEMBLIES DEFINITION

The various ways of implementing the Data Management requirements are concept dependent. The assemblies listed below are to be considered as baseline, subject to modification based upon selected concept implementation. (See Figure 1.4-W-3 for WBS showing this subsystem.)

1.4.10.1	Integration and Assembly
1.4.10.2	Data Management Computers
1.4.10.3	Data Bus
1.4.10.4	Instrumentation
1.4.10.5	On-Board Software

III. FUNCTIONAL DESCRIPTION

The Data Management Subsystem provides the computer complex, controls, data bus; Acquisition, Control and Test units, instrumentation, mass memory and on-board software required to acquire raw data, convert it to the needed format, and disseminate that data to using subsystems and/or crew for implementing mission events and trajectories for both normal and aborted missions. To achieve this capability, mission requirements must be converted to computer format along with both Air Vehicle and Stage I subsystem capability (thrust, dynamics, propellant supplies; power, environment, energies) as a function of configuration changes (Air Vehicle mass properties at liftoff and subsequent changes as the mission progresses). With inputs from launch coordinates/altitude/time and desired Stage II and payload mission requirements (as well as Stage I mission requirements), the solution to achieving the desired targeting and staging point data may be computed both prior to launch and as the flight progresses. (Stage II will have similar data for its portion of the Space Transport mission.) By comparing real time position information with desired heading, location, and time, the guidance equation is implemented and successful ascent and separation in order for both Stage II and Stage I to continue their separate missions may be achieved. At completion of Stage I's space portion of the mission, computations of real time status, location, speed, altitude, heading, and time may be compared with desired (and/or alternate) landing point information to compute and transmit to using subsystems the information needed for maneuver for entry, reentering, and controlling vehicle energies to achieve the desired transition point energies and thus accomplish either automatic or manual final descent, approach, flare and landing.

To support the Program objective of having on-board capability for computing needed maneuvers and steering commands based on present status of Stage I, Data Management should store Stage I subsystem capability (including Stage II) and compare this with subsystem status (via data bus and Acquisition, Control and Test units (ACTs), which sample instrumentation sensors/transducers incorporated in the various subsystem assemblies and components as required) to continuously compute and transmit to applicable user the required information for data implementation. This capability should be available from some appropriate point in the launch countdown through the end of Stage I's mission.

To achieve operational status, the Data Management Subsystem will be verified in the RDT & E phase by following the steps briefed below:

A. Phase C Go-Ahead Through PDR - Depending on end items (CEI) breakdown of Stage I, completion of preliminary design will result in a Part I specification affecting Data Management. Detailed definitions will specify required performance, interfaces, and effectiveness required of Data Management. Upon approval of CEI Part I, final design of hardware and software can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II can be prepared. (See Para. VI for tests affecting this phase.)

C. CDR to Qualification Testing - Release of drawings and specifications to both manufacturing and materiel will allow final Integration and Assembly to be performed to procure and assemble the various parts, modules and assemblies of Data Management into flight test vehicles (FTVs) which, through Pre-Flight, Ferry Flight, Horizontal Flight, Single Element Vertical Flight and Mated Flight Test programs will verify that Data Management and all other Stage I subsystems properly integrate and perform per specification. Software development will result in compatible flight test software (on-board) to demonstrate data management capability and effectiveness. Qualification will finally be granted through DD 250 (or equivalent) buyoff when Data Management, as well as all other Stage I subsystems, prove they meet specification to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication and begin operational software procurement.

IV. DESIGN REQUIREMENTS

Level I and II requirements affecting Data Management are stated in WBS Dictionary Element 0.0, and will not be repeated here. In addition to those cited, standard spacecraft and aircraft avionics design practice will apply in choice of reliable, low power requirement, light weight

components which, through proper selection of parts, components and modules, result in long-life capability to perform their necessary mission functions. To the extent feasible, componentry should be off-the-shelf standard designs, proven in similar systems to reliably and effectively perform. New designs should be proven through test and simulation in the development phase of the Program. Software will be entirely new and should be designed in modular format, together with a general executive routine, so that subprograms and subroutines evolve and are proven through both ground and flight test simulations. Since both Stage I and Stage II must operate together in the early phases of flight, software integration must be analyzed and designed so that each vehicle can perform the same mission through stage separation if required. Data Management must be compatible with the flight environment. Where componentry is in unprotected areas of the vehicle, analysis and trade studies must be completed to verify that the choice of materials, insulation/or supporting environmental control is defined and provided, then further verified through test for proof of operation in the expected critical environment. Redundancy must be provided in critical assemblies and components to meet the fail operational/fail safe requirements specified in WBS Dictionary Element 0.0 Para. IV. A.21. EMI analysis shall be conducted to verify Data Management is neither susceptible to such interference for successful operation nor generates such interference which may affect other subsystem operations.

V. INTERFACES

Data Management for Stage I interfaces with all other subsystems of the Stage as noted on Figure 1.4-W-3. Payload constraints are stated in WBS Dictionary Element 1.2. Stage I interface with Stage II Data Management will be through hardlines (Data Bus, part of WBS 1.4.10) which pass between Stage I and Stage II interconnect points until separation occurs. In addition, Data Management will interface with GSE through the Data Bus as required. Details on these interfaces are shown in lower levels of WBS 1.4.10. Other Program interfaces exist as follows: WBS ID 2.0 for operational equipment interfaces (Command and Control, Launch, Data Processing, Recovery); WBS ID 3.0/8.0 for maintenance

equipment/software; WBS ID 4.0 for test, evaluation and mockups; WBS ID 5.0 for System/Program Management requirements and controls; WBS ID 6.0 for deliverable Data on Data Management; WBS ID 9.0 for initial spares and repair parts; WBS ID 10.0 for training crews and ground personnel; WBS 11.0 for industrial facilities; and WBS ID 12.0 for operations. These interfaces are spelled out as applicable in referenced WBS Dictionary elements.

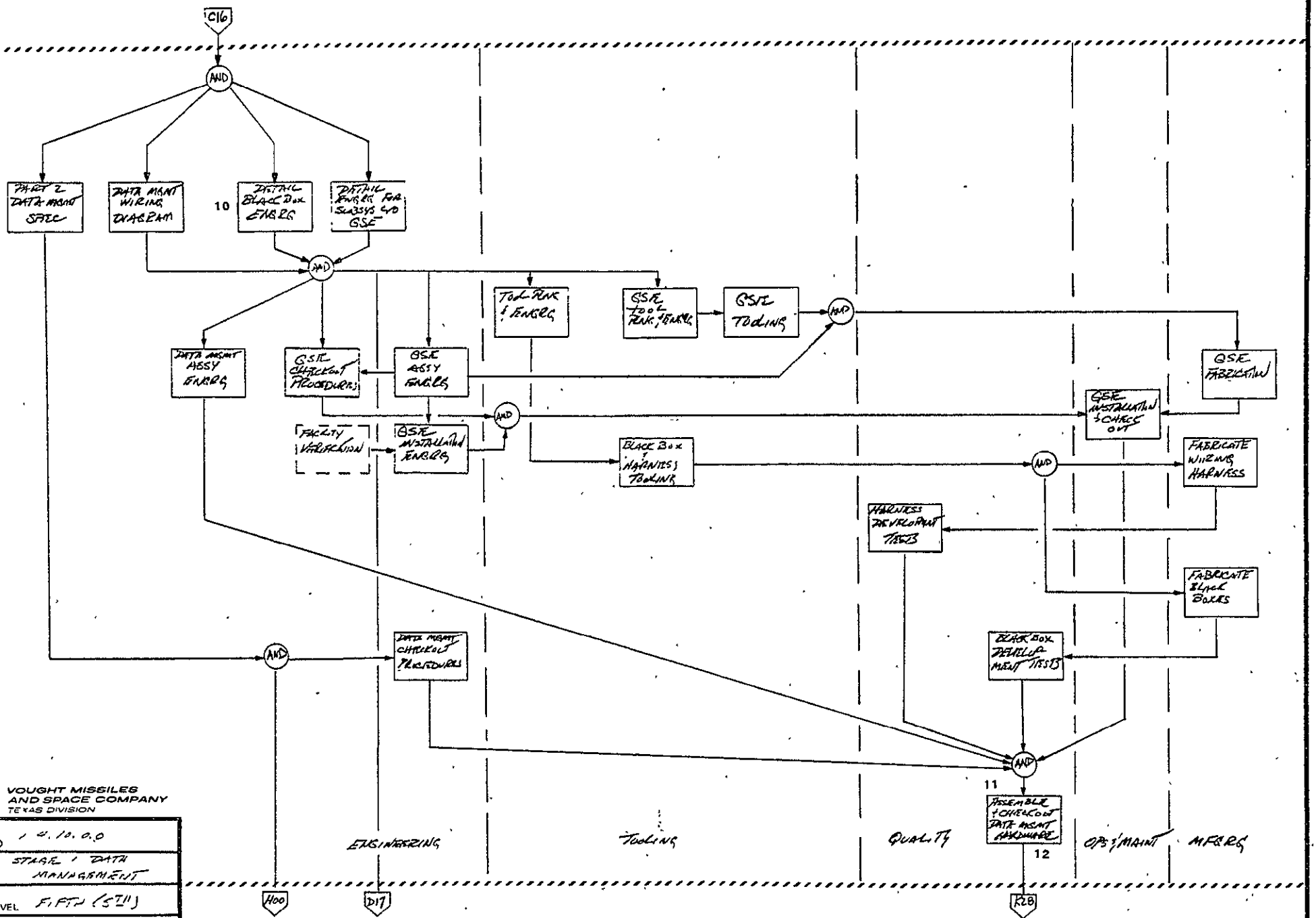
VI. TEST REQUIREMENTS

Development tests of Data Management components, modules and assemblies will be performed under WBS ID 1.4.10 or lower level tasks. Integrated avionics (Guidance and Navigation, Communications and Navaids, Flight Control Electronics, Displays and Controls, and Data Management) will be both breadboarded and prototype tested under WBS ID 4.2, including tests of the integrated flight hardware. WBS ID 4.6 will test integrated Stage I in the series of single element tests (pre-flight, ferry flight, horizontal flight and vertical flight). WBS ID 4.7 will test the mated vehicles in both ground and flight configurations. As required, simulation hardware/software for each Stage must be provided the other Stage at an appropriate point to ensure Stage integration and checkout are verified prior to actual mating.

VII. REFERENCES

(To be added.)

INPUTS



VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.4.10.0.0
TITLE	STAGE 1 DATA MANAGEMENT
WBS LEVEL	FIFTH (5TH)
PAGE	1 OF 2
DATE	4 JUN 71

OUTPUTS

INPUTS

H00

K28

PART 2 GUIDANCE CHECKOUT SOFTWARE SPEC

CDR

CODE & DEBUG

AND

INTEGRATED DAM TEST WITH SOFTWARE

K22 | G04 | K44

M02 | G32

N06

OUTPUTS

ENGINEERING | Qual. Ty

VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.4.10.0.0
TITLE	STAGE I DATA MANAGEMENT
WBS LEVEL	FIFTH (5TH)
PAGE	2 OF 2
DATE	4 JUN 71

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.11

TASK TITLE DISPLAYS & CONTROLS (STAGE I)

LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned, reusable, i.e., winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landing by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to maximum capability, depending

TASK SCHEDULE MILESTONES

PERIOD ENDING

SEE LOWER LEVELS FOR DETAIL SCHEDULES

on mission requirements.

To assist in meeting the above requirements, the Displays and Controls subsystem of Stage I must provide properties and characteristics compatible with the total Stage I flight spectrum (pre-flight activities, launch activities, ascent in the Air Vehicle configuration, separation of Stage II, exoatmospheri maneuvers to achieve position for entry to desired landing site, reentry into the sensible atmosphere, transition to and through the transonic regime, subsonic cruise, deploy onboard air-breathing engines if required for approach or go-around, conduct final approach flare, touchdown, run-out, and parking on the airport ramp for post-flight servicing). On-board air-breathing propulsion will be required for ferry flight.

The specific properties and characteristics which Displays and Controls must provide are: (1) displays and controls to enable the crew to monitor automatic flight status and override the automatic mode if required in order to continue or abort the mission, (2) access to the computer (part of Data Management, WBS 1.4.10) for parameter call-up for monitor and information display; and (3) displays and controls on Stage I subsystem in-flight status to provide the crew with both a monitoring and control capability over subsystems which indicate control is required in order to continue or modify the mission. Pre-launch checkout and monitor is automatically performed via the Data Management Subsystem (WBS ID 1.4.10), with status available to crew using computer access capability provided in Displays and Controls.

Constraints on Displays and Controls, in addition to performance and other subsystem interfaces as well as compatibility with mission environment through a specified lifetime, include the following: (1) maintainability, (2) reliability, (3) safety compliance, (4) operability, (5) human factors acceptability (both flight crew and ground crew), (6) quality assurance, (7) commonality and/or exchangeability between tail numbers, and (9) cost minimization through use of proven technology, good design practice, good production practice, and thorough flight qualification prior to achieving operational status.

II. ASSEMBLIES DEFINITION

The specific assemblies which form the Displays and Controls Subsystem are concept dependent. For the baseline concept, the following assemblies are specified. These are subject to modification based on selected concept configuration definition. (See Figure 1.4-W-3 for WBS)

1.4.11.1	Integration and Assembly
1.4.11.2	Vehicle Flight Control and Displays
1.4.11.3	Computer Access
1.4.11.4	Subsystem Monitor and Control

III. FUNCTIONAL DESCRIPTION

The Displays and Controls Subsystem provides the Stage I flight crew with in-flight displays on the automatic phases of flight; with flight controls to override automatic flight mode and handle manual portions of the mission (approach and landing, if desired; ferry flights); with computer access: and with in-flight status of Stage I subsystems, including controls thereof. Voice links with Stage II and ground are hardwired (WBS Dictionary Element 1.4.9) prior to launch, hardwired with Stage II and through RF links with ground after liftoff until separation, and with ground via RF links through completion of flight. These capabilities enable a man-machine relationship to evolve which is basic to the Advanced Space Transport Program concept, i.e. an automatic capability similar to unmanned spacecraft missions backed up with a manual capability to handle functions which man can best perform.

To achieve operational status, Displays and Controls Subsystem will be verified in the RDT & E phase by following the steps briefed below:

A. Phase C Go-Ahead Through PDR - Depending on end item (CEI) breakdown of Stage I, completion of preliminary design will result in a Part I specification affecting Displays and Controls. Detailed definitions will specify performance, interfaces, and effectiveness required of this subsystem. Upon approval of CEI Part I, final design can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II can be prepared. (See Para. VI for tests affecting this phase.)

C. CDR to Qualification Testing - Release of drawings to manufacturing will allow final Integration and Assembly to be performed to build the Structural Test Vehicle and Flight Test Vehicles to be used for Pre-Flight, Ferry Test, Horizontal Flight Test, Single Element Vertical Flight Test, and Mated Flight Test programs. Qualification will finally be granted through DD 250 (or equivalent) buyoff when Displays and Controls, as well as all other Stage I subsystems, prove they meet specification to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Level I and II requirements affecting Displays and Controls are stated in WBS Dictionary Element 0.0, and will not be repeated here. In addition to those cited, standard aircraft and spacecraft design practice, incorporating human factors requirements, will apply to this subsystem in the choice and location in the crew station of the instruments and controls required to provide the flight crew with needed capability. Groupings of displays and controls should be such that they provide both pilot and copilot with redundant controls and displays critical to the mission. Secondary controls and displays, i.e. non-critical items, should be grouped within easy visibility and access but aside from critical items. The design should also take into account the rapidity of decision making required in either monitoring a display and/or acting on display information. During the design phase, both designer and potential user requirements, i.e. astronauts, must be taken into account. Thus, mockups, simulators and actual flight test are a part of the design phase so that, when finally delivered to NASA, the Displays and Controls represent a best compromise between user's needs, available packaging space and volume, subsystem interfacing parameter optimization, reliability, safety, and maintainability. Instrument lighting, as an aid to visibility, is a special design problem, unique to the Advanced Space Transport mission. Final design and mission requirements will be specified in CEI Part I's when generated.

V. INTERFACES

Depending on the specific display or control, the ensemble interfaces with both crew and with every other subsystem of Stage I. Display and control mounting interfaces with Crew Subsystems (WBS ID 1.4.12.3).

Signal control of certain displays is via the Data Bus (WBS ID 1.4.10.3). Manual flight controls (rudder pedals, 3-axis controllers) are hardwired to the controls via Flight Control Electronics. The computer access keyboard and controls are also hardwired. Panel instrument lighting interfaces with Secondary Power (WBS ID 1.4.6). Environmental Control of the operating environment for Displays and Controls is provided by WBS ID 1.4.7. Total available space and volume is provided by the crew station pressure vessel (WBS ID 1.4.2.5). Other interfaces, outside of the Air Vehicle, exist. Launch interfaces exist through WBS ID 2.0. Maintenance is provided by WBS ID 3.0/8.0. Test, evaluation and mockups are provided by WBS ID 4.0. System and program management are provided by WBS ID 5.0. Deliverable Data on Displays and Controls is generated and delivered under WBS ID 6.0. Initial spares and repair parts are fabricated and delivered under WBS ID 9.0. Training is performed under WBS ID 10.0. Industrial facility interfaces are included under WBS ID 11.0. And, Operational interfaces occur under WBS ID 12.0. These interfaces, as applicable are spelled out under referenced WBS Dictionary elements.

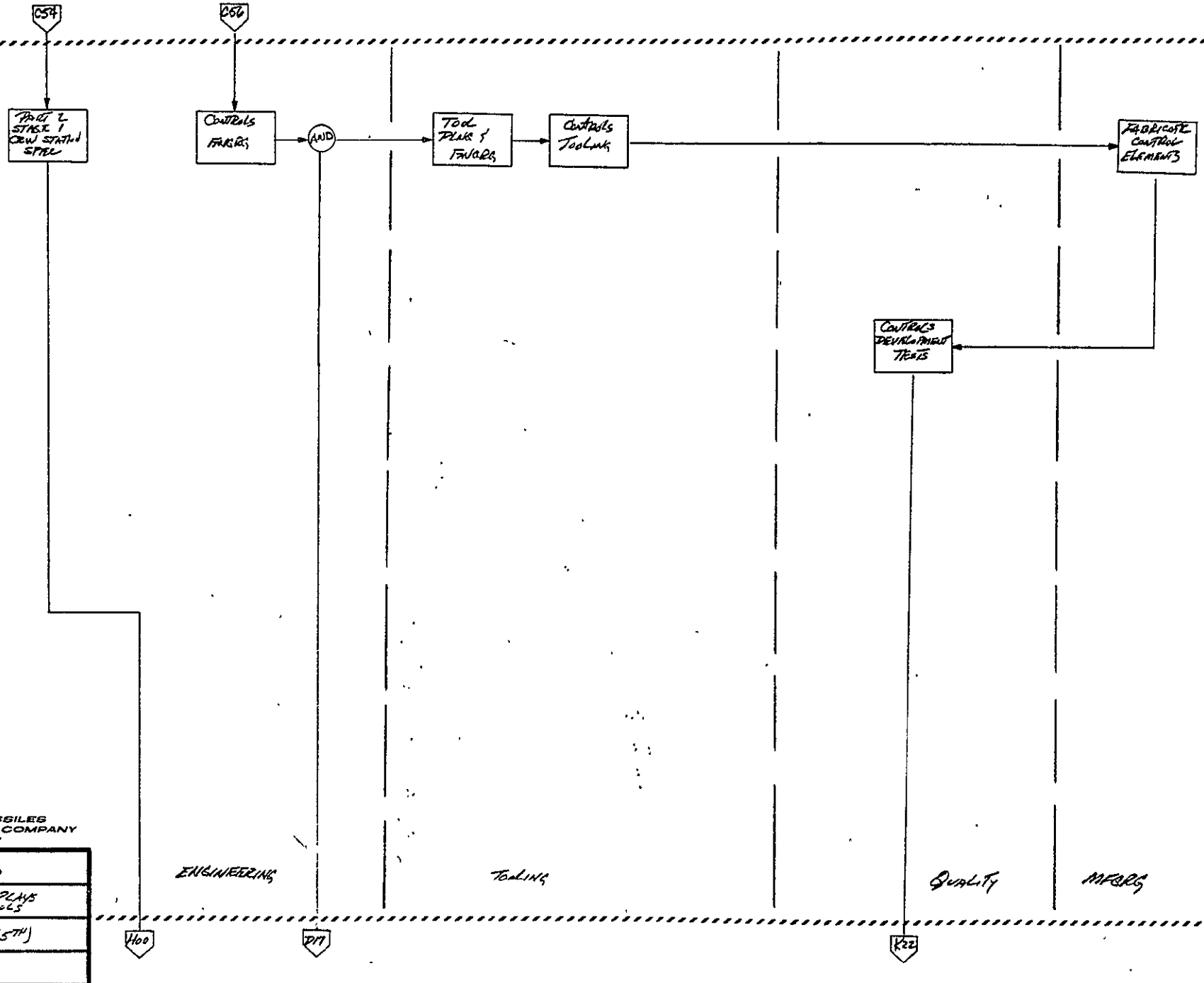
VI. TEST REQUIREMENTS

Component, module, assembly and single subsystem development tests will be performed as required under WBS ID 1.4.11. Combined subsystem development tests will be performed under WBS ID 4.2. Flight test programs will be conducted under WBS ID 4.6 and 4.7. Mockups are provided under WBS ID 4.8 for Stage II and under WBS ID 4.9 for Stage I. Training hardware and saftware is provided under WBS ID 10.0

VII. REFERENCES

(To be added.)

INPUTS



VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.9.11.0.0
TITLE	STAGE 1 DISPLAYS AND CONTROLS
WBS LEVEL	FIFTH (5TH)
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OUTPUTS

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.11.2

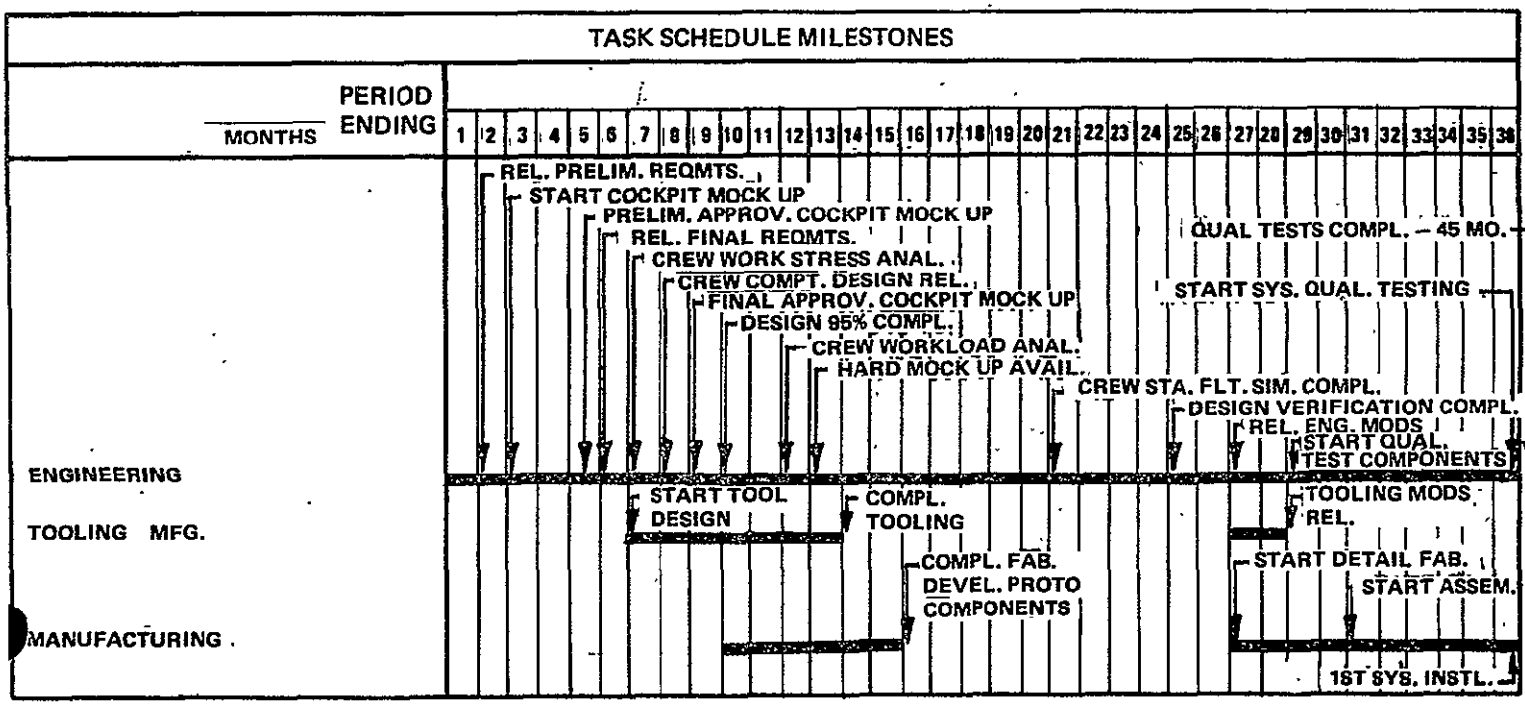
TASK TITLE VEHICLE FLIGHT CONTROL & DISPLAY (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.11)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.11.3

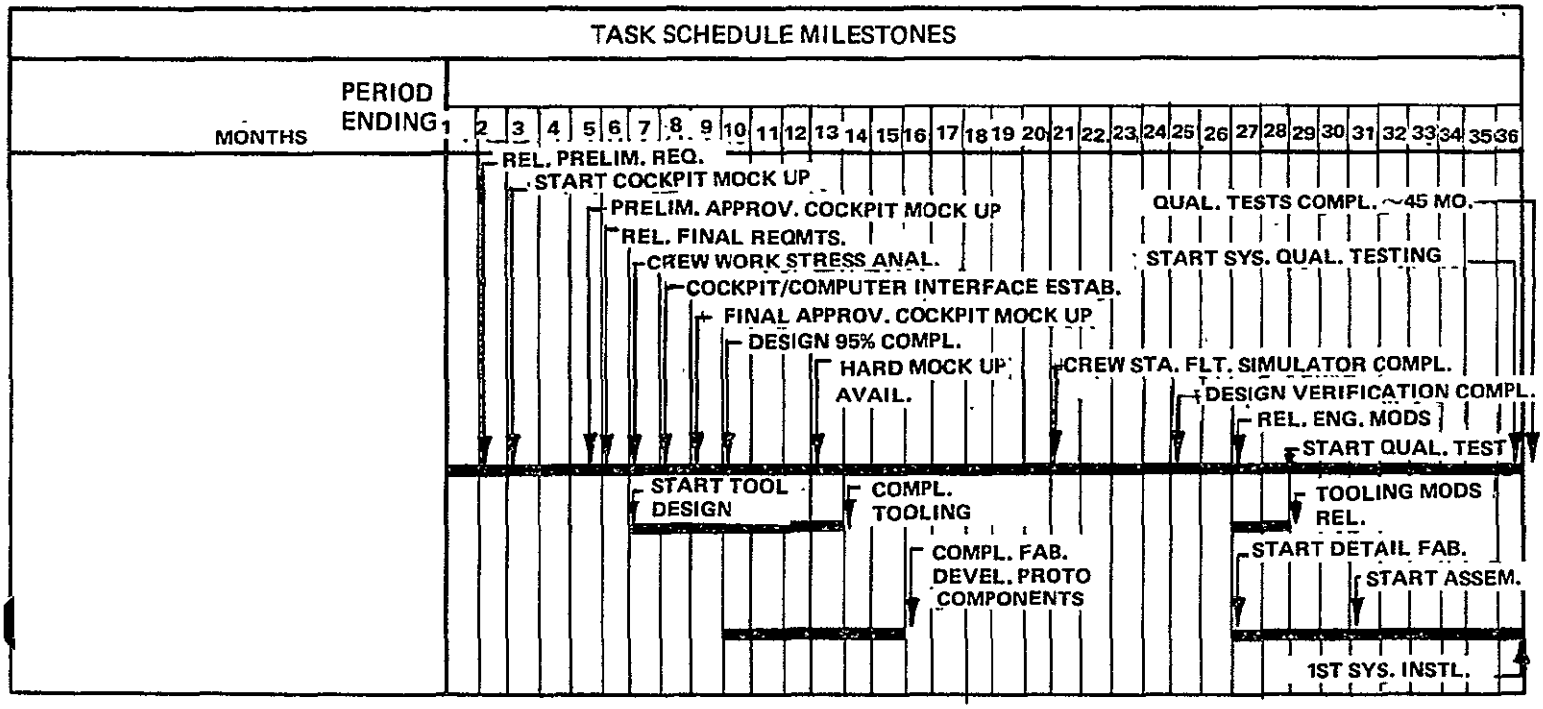
TASK TITLE COMPUTER ACCESS (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.11)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.11.4

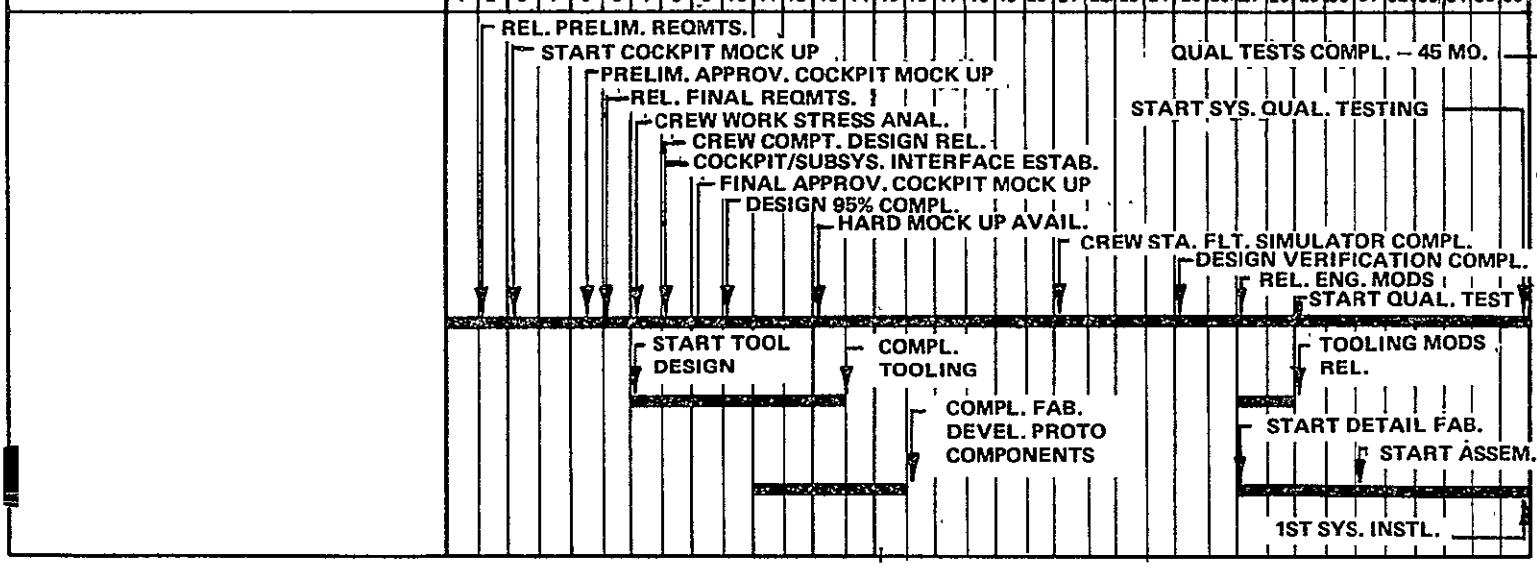
TASK TITLE SUBSYSTEM MONITOR & CONTROL (STAGE I)

LEVEL 6, Assembly Level

WBS DICTIONARY

(Definition not provided. See WBS Dictionary Element 1.4.11)

TASK SCHEDULE MILESTONES



VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.12

TASK TITLE CREW SUBSYSTEMS (STAGE I)

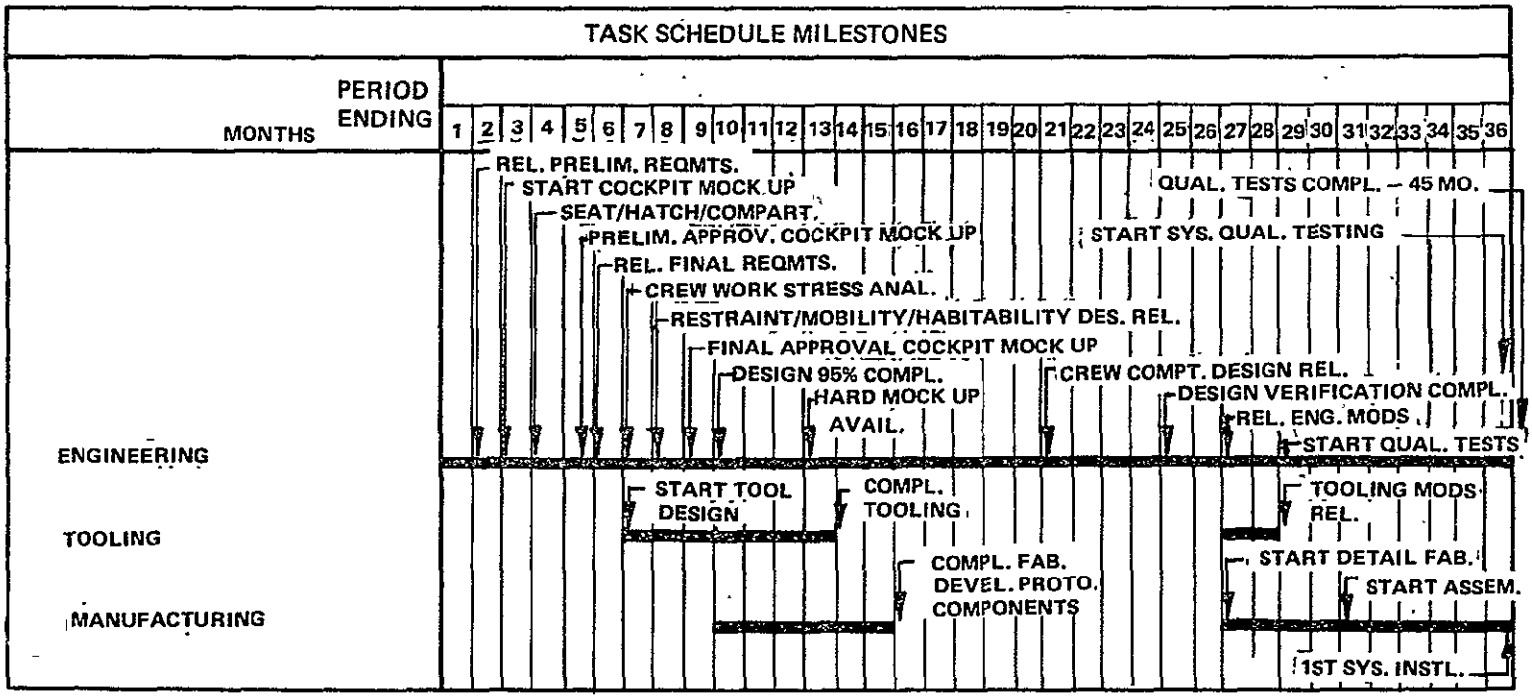
LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

A requirement has been specified (WBS ID 0.0, 1.0, 1.4) for a manned, reusable, i.e., winged, vehicle capable of accelerating Stage II and its payload to a point in the ascent trajectory where staging will occur to enable Stage II and its payload to continue the Space Transport mission (see WBS Dictionary Elements 1.3 and 1.2 for Stage II and Payload, respectively). Following a normal staging, Stage I will position itself for entry, reenter the earth's atmosphere, cruise to a specified or alternate landing site, and land on a conventional runway similar to landing by conventional military or commercial transport type aircraft. Following landing, a purge and safe operation will be conducted, followed by a ferry flight (if required) to the turnaround facility for post-flight maintenance and refurbishment to prepare for the next mission. Payloads aboard Stage II will vary from zero to maximum capability, depending

TASK SCHEDULE MILESTONES



on mission requirements.

To assist in meeting the above requirements, the Crew Subsystems of Stage I must provide properties and characteristics compatible with the total Stage I flight spectrum (pre-flight activities, launch activities, ascent in the Air Vehicle configuration, separation of Stage II, exoatmospheric maneuvers to achieve position for entry to desired landing site, reentry into the sensible atmosphere, transition to and through the transonic regime, subsonic cruise, deploy onboard air-breathing engines if required for approach or go-around, conduct final approach flare, touchdown, run-out, and parking on the airport ramp for post-flight servicing). On-board air-breathing propulsion will be required for ferry flight.

The specific properties and characteristics required of the Crew Subsystems are: (1) to provide the flight crew (pilot, copilot) with furnishings and equipments required for their comfort and functions throughout the mission, during ferry flights, and during flight tests; and (2) to provide the panels and consoles needed for mounting Displays and Controls (WBS ID 1.4.11).

Constraints on Crew Subsystems, in addition to performance and other subsystem interfaces as well as compatibility with mission environment through a specified lifetime, include the following: (1) maintainability, (2) reliability, (3) safety compliance, (4) operability, (5) human factors acceptability (both flight crew and ground crew), (6) quality assurance, (7) commonality and/or exchangeability between tail numbers, and (9) good production practice, and thorough flight qualification prior to achieving operational status.

II. ASSEMBLIES DEFINITION

The specific assemblies which form Crew Subsystems are concept dependent. For the baseline concept, the following assemblies are specified. These are subject to modification based on selected concept configuration definition. (See Figure 1.4-W-3 for WBS)

1.4.12.1	Integration and Assembly
1.4.12.2	Crew Furnishings and Equipment
1.4.12.3	Instrument Panels, Consoles, Controls, Displays
1.4.12.4	Flight Control Equipment*

(*These equipments, in the baseline concept, are included under Displays and Controls, WBS ID 1.4.11.2.)

III. FUNCTIONAL DESCRIPTION

The Crew Subsystems provide the flight crew with the furnishings and equipment required for their comfort as well as to support their functions throughout the mission. In addition, the panels and consoles required for crew Displays and Controls are provided to furnish the interface between man and machine. Included under furnishings and equipment are adjustable seats, storage containers, equipment racks, accomodations, and mobility aids and ladder for access to deck/equipment levels. Access doors, windows, window heatshield, and hatches are part of the primary and secondary structure of the vehicle. Panels and consoles provide both pilot and copilot with a redundant and common capability in the location of displays and controls essential to both the monitor and automatic override capability necessary to manned flight. Oxygen masks are considered part of ECLSS (WBS ID 1.4.7). Emergency and survival equipment are part of the Safety Subsystem (WBS ID 1.4.13). For test flights (RDT & E), escape seats and G-suits will be provided if required.

To achieve operational status, the Crew Subsystems, will be verified in the RDT & E phase by following the steps briefed below:

A. Phase C Go-Ahead Through PDR - Depending on end item (CEI) breakdown of Stage I, completion of preliminary design will result in a Part I specification affecting the Crew Subsystems. Detailed definitions will specify performance, interfaces, and effectiveness required of this subsystem. Upon approval of CEI Part I, final design can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II can be prepared. (See Para. VI for tests affecting this phase.)

C. CDR to Qualification Testing - Release of drawings of manufacturing and materiel will allow final Integration and Assembly to be performed to build the Structural Test Vehicle and Flight Test Vehicles to be used for Pre-Flight, Ferry Test, Horizontal Flight Test, Single Element Vertical Flight Test and Mated Flight Test

programs. Qualification will finally be granted through DD 250 (or equivalent) buyoff when the Crew Subsystems, as well as all other Stage I subsystems, prove they meet specification to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Level I and II requirements affecting Crew Subsystems are stated in WBS Dictionary element 0.0, and will not be repeated here. In addition to those cited, standard aircraft and spacecraft design practice, incorporating human factors consideration, will apply to this subsystem. The special requirements of the mission call for mockups, training and actual flight test experience to ensure that the entire crew and equipment station design is properly integrated, functional, comfortable, accessible, and operable. The Crew Subsystems, along with Displays and Controls, accessible subsystem equipments, Environmental Control and Life Support, Communications, etc. provide an integrated unit for both normal and emergency requirements. Choice of non-flammable, non-toxic, non-hazardous designs which are still rugged enough to tolerate the required Program life utilization are basic design requirements. Since exposed surfaces are subject to wear and tear, economic refurbishment capability must be provided. Serviceability prior to and following a mission must be provided. Color selection is of importance due to variance in radiation levels penetrating the interior during various phases of the mission. Final design and mission requirements affecting Crew Subsystems will be specified in CEI Part I's when generated.

V. INTERFACES

Crew Subsystems basically interface with the Stage I flight crew. Additional Stage interfaces are described above. For interfaces with other Program elements, the following are applicable: (1) with ground test personnel prior to and following a mission (WBS ID 3.0); (2) with system test, evaluation and mockups (WBS ID 4.0); (3) with system and program management (WBS ID 5.0); (4) with deliverable Data (WBS ID 6.0); (5) with Peculiar/Common Support Equipment (WBS ID 3.0/8.0);

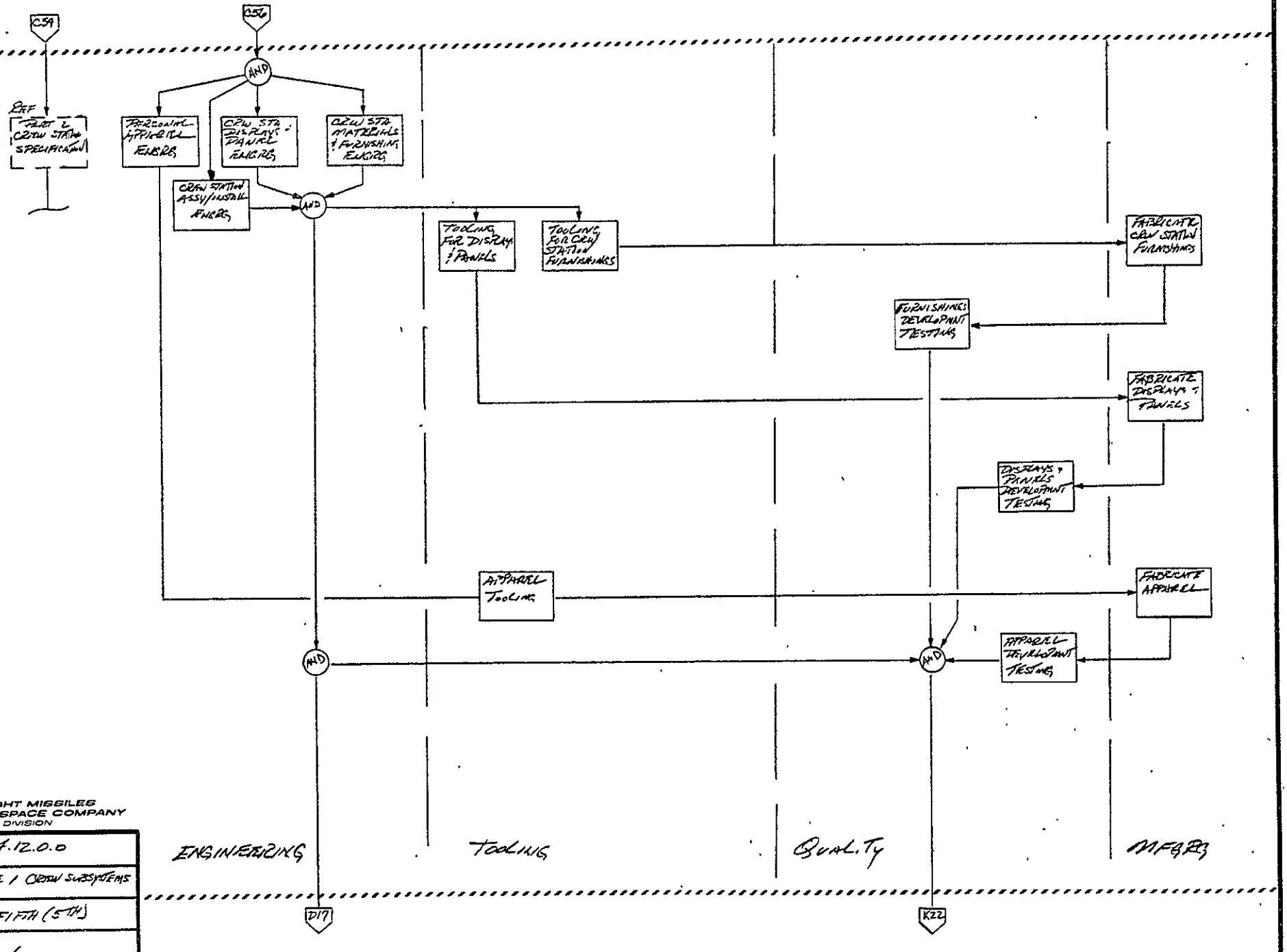
(6) with initial spares and repair parts (WBS ID 9.0); (7) with training (WBS ID 10.0); (8) with industrial facilities (WBS ID 11.0); and (9) with Operations (WBS ID 12.0). These interfaces will be spelled out as applicable in referenced WBS Dictionary elements.

VI. TEST REQUIREMENTS

Single component, module, assembly, subsystem development tests will be conducted under WBS ID 1.4.12 or lower levels thereto. Combined subsystem development tests will be conducted under WBS ID 4.2. System tests will be conducted under WBS ID 4.6 and 4.7. Mockups of Stage II will be provided under WBS ID 4.8, of Stage I under WBS ID 4.9.

VII. REFERENCES

(To be added.)



VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.4.12.0.0
TITLE	STAGE 1 CREW SUBSYSTEMS
WBS LEVEL	FIFTH (5TH)
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DATE	6 JUN 71

VOUGHT MISSILES AND SPACE COMPANY

PROGRAM TITLE ADVANCED SPACE TRANSPORT PROGRAM

WBS NO. 1.4.13

TASK TITLE SAFETY SUBSYSTEM (STAGE I)

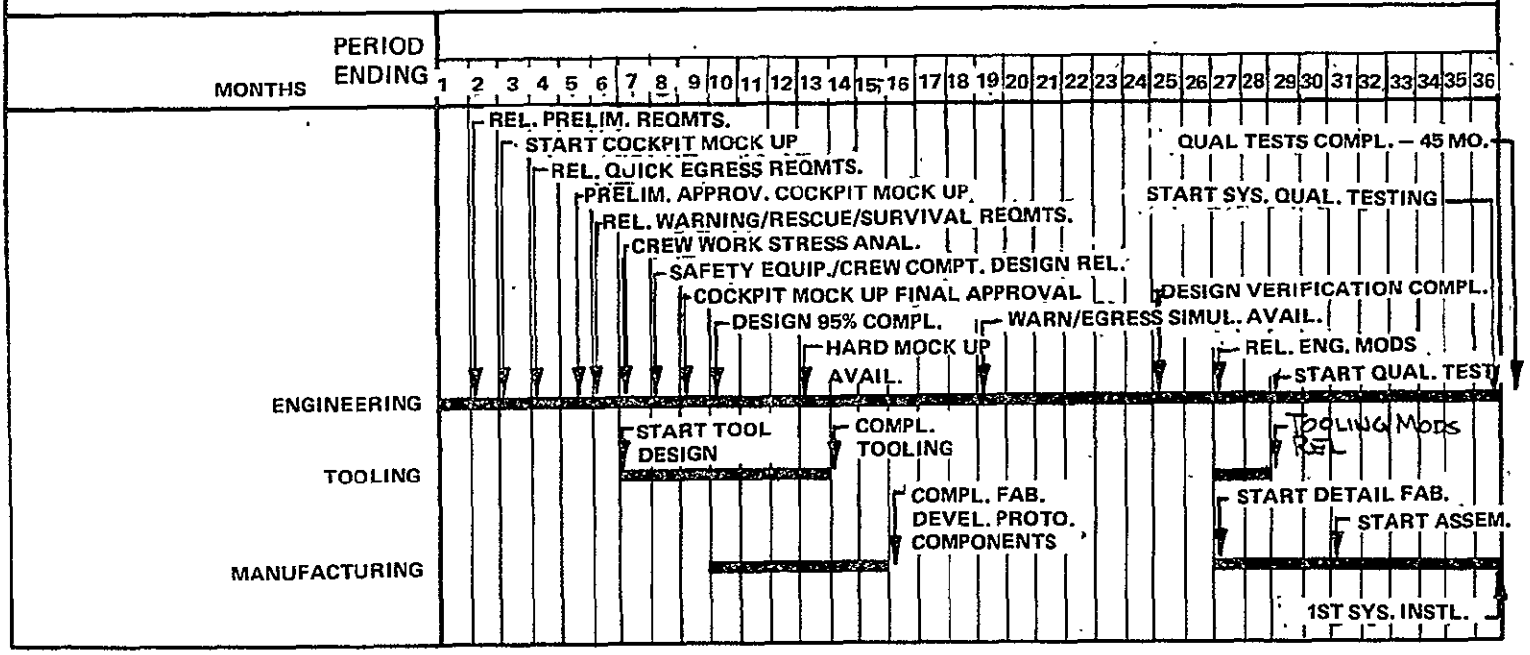
LEVEL 5, Subsystem Level

WBS DICTIONARY

I. REQUIREMENTS

Means are required to ensure the safety of both onboard and externally affected personnel and property associated with, or inadvertently affected by, the Advanced Space Transport vehicle. The mission of this vehicle is defined in WBS Dictionary elements 0.0, 1.0 and 1.3 as these affect both Stage I and Stage II. The basic requirement, therefore, is that safety of the crews, passengers and Air Vehicle are ensured throughout each Stage's mission, including pre-launch and post-flight and that, in turn, Stage I does not impose an uncontrolled hazard on the launch site, the range, nor on the recovery facilities. Compliance with these requirements will be verified prior to committing the Air Vehicle, including Stage I, to operational status.

TASK SCHEDULE MILESTONES



II. ASSEMBLIES DEFINITION

Most of the requirements specified above are met through proper design of other Stage I subsystems:in Data Management (WBS ID 1.4.10) which monitors hazardous conditions in critical subsystems so as to present the hazard and take automatic action, such as abort to a safe position if required; in manual displays and controls to enable pilot action if a hazard develops; in redundancy in critical subsystems to ensure that failures are sensed and transferred to redundant elements to continue the mission; and in design constraints on purging, venting, use of non-flammable, non-toxic, non-hazardous materials and designs in vehicle areas where such conditions might exist. To protect the range (i.e., people, property, etc.) external to the vehicle, a need will exist throughout design, development and test to satisfy Range Safety, FAA, and affected non-U. S. governments that the Air Vehicle and the Stages which are its parts are inherently as safe as any other commercial or military transport aircraft, with proof being demonstrated to those responsible for the safety of others and their properties.

Accordingly, the Stage I Safety Subsystem is defined here to include only those additional onboard equipments required to ensure crew safety, basically on the launch pad prior to liftoff and following an emergency landing. However, as applicable, these same equipments, augmented by ground support, will assist in ensuring safety while the vehicle is on the ground.

The assemblies listed below are thus tentative, subject to modification as needed in the selected concept definition (see Figure 1.4-W-3).

1.3.13.1	Integration and Assembly
1.3.13.2	Crew Safety

III. FUNCTIONAL DESCRIPTION

The baseline concept for Crew Safety includes those additional equipments and procedures required to ensure crew safety while on the launch pad (quick egress capability and warning devices), while in-flight (warning devices), and following an emergency landing (rescue and survival equipment). These same equipments and procedures are needed during flight

test, and so will be developed and refined in that program. Current studies on pad escape are not complete. One proposal includes quick egress through hatches to a rapidly descending tower elevator. Other proposals include using an overboard ladder or rope with capability for rapid descent. For emergency rescue and survival (land or sea), standard ditching and survival gear (radios, rafts, emergency rations, etc.) are candidates.

To achieve operational status, the Safety Subsystem will be verified in the RDT & E phase by following the steps briefed below.

A. Phase C Go-Ahead Through PDR - Depending on end item (CEI) breakdown of Stage I, completion of preliminary design will result in a Part I specification affecting the Safety Subsystem. Detailed definitions will specify performance, interfaces, and effectiveness required of this subsystem. Upon approval of CEI Part I, final design can proceed.

B. PDR to CDR - In this phase, design and development will proceed to the point where CEI Part II can be prepared. (See Para. VI for tests affecting this phase.)

C. CDR to Qualification Testing - Release of drawings to manufacturing and materiel will allow final Integration and Assembly to be performed to build the Structural Test Vehicle and Flight Test Vehicles to be used for Pre-Flight, Ferry Test, Horizontal Flight Test, Single Element Vertical Flight Test, and Mated Flight Test programs. Qualification will finally be granted through DD250 (or equivalent) buyoff when the Safety Subsystem, as well as all other Stage I subsystems, prove they meet specification to the satisfaction of NASA. At some point prior to this, approval may be given to start production vehicle fabrication.

IV. DESIGN REQUIREMENTS

Until this subsystem is fully defined, design requirements are considered tentative. Level I and II requirements affecting this subsystem are stated in WBS Dictionary Element 0.0, and will not be repeated here. For the defined subsystem, standard aircraft and spacecraft design practice, including safety standards as applicable, will apply to this subsystem in the choice of designs, equipment and modules which satisfy the requirement, are light weight yet durable, are stowable to the extent practicable and are fully functional when required. Due to long mission life, inspection procedures must be provided to ensure stowed equipments are periodically checked, serviced and made ready ahead of each mission. Until the analysis of this subsystem is completed, additional requirements must await CEI Part I definition.

V. INTERFACES

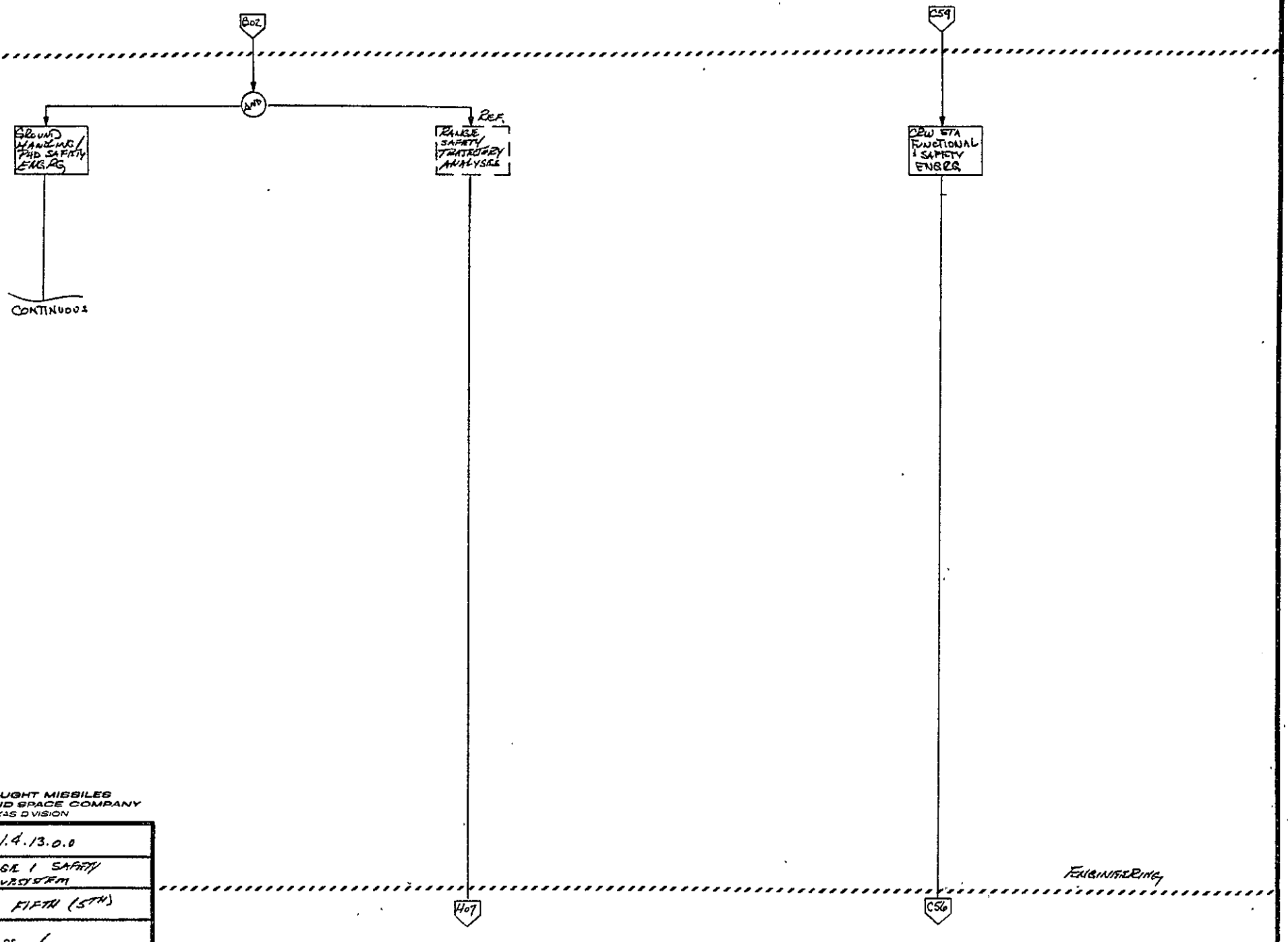
Current on-board interfaces for the Safety Subsystem are the crew of Stage I and the volume allocated to this subsystem in the crew station (WBS ID 1.4.2.5). Depending on where the need for this subsystem exists (launch pad, space, emergency landing), external interfaces will include the launch pad facilities (WBS ID 7.0, if new; or WBS ID 4.7.1.1.1, if existing), the recovery facilities (WBS ID 7.0, if new; WBS ID 4.8.3.1.1, if existing), and others to be defined. Other Program interfaces include operational equipment interfaces (WBS ID 2.0); maintenance interfaces (WBS ID 3.0/8.0); test, evaluation and mockup interfaces (WBS ID 4.0); system and program management interfaces, including safety analysis and specifications (WBS ID 5.0); deliverable Data (WBS ID 6.0); initial spares and repair parts (WBS ID 9.0); training (WBS ID 10.0); industrial facilities (WBS ID 11.0); and Operations (WBS ID 12.0). There interfaces will be spelled out as applicable in referenced WBS Dictionary elements.

VI. TEST REQUIREMENTS

Single component, module, assembly and subsystem tests required to develop the Safety Subsystem will be performed under WBS ID 1.4.13. Combined subsystem development tests will be performed under WBS ID 4.2. System flight tests will be performed under WBS ID 4.6 and 4.7. Mockups will be provided under WBS ID 4.9. Training will be performed under WBS ID 10.0.

VII. REFERENCES

(To be added.)



VOUGHT MISSILES AND SPACE COMPANY
TEXAS DIVISION

WBS NO	1.4.13.0.0
TITLE	STAGE 1 SAFETY SUBSYSTEM
WBS LEVEL	FIFTH (5TH)
PAGE	1 OF 1
DATE	6 JUN 71

APPENDIX

APPENDIX A

BASELINE CONCEPT - STAGE I

A.1 INTRODUCTION

It is noted in Appendix A to Volume II of the Final Report that NASA (MSC) provided VMSC with baseline data from Phase B prime contractors at the outset of the study and requested that such data be used for conceptual information to support the Scheduling Technique Improvement Study.

The Stage II Work Breakdown Structure Dictionary and Scheduling data contained in Volume II utilized the McDonnell Douglas Corporation Phase B Orbiter as an example of current preliminary design thinking for meeting Stage II (orbital stage) requirements.

An example of similar design data on a Stage I (boost stage) concept was also furnished VMSC. This design, termed the Booster by Phase B contractors, is represented by North American Rockwell (NAR) documentation listed in the Bibliography included at the end of this Appendix. VMSC utilized NAR data for conceptual purposes, only, during the study, drawing on certain weight and performance values as needed to support TER analysis.

Highlights of NAR's Phase B design are denoted in the following paragraphs for reader understanding of what VMSC refers to in its report as "Stage I Baseline Concept". Details on NAR's preliminary design concept may be ascertained by reviewing the reports contained in the Bibliography.

A.2 BOOSTER DESCRIPTION (NAR)

The North American Rockwell (NAR) Phase B Booster is a delta wing, manned reusable vehicle designed to accelerate the orbital stage to a point in the ascent trajectory where the Orbiter can ignite its engines, separate from the Booster, and continue its mission. The Booster then shuts down its main engines, coasts to apogee with maneuvers to place it in the entry mode, reenters, cruises to its landing approach mode, deploys its air-breathing engines, and lands.

Figure A-1 illustrates the NAR Phase B Baseline Booster, Configuration B-9T.

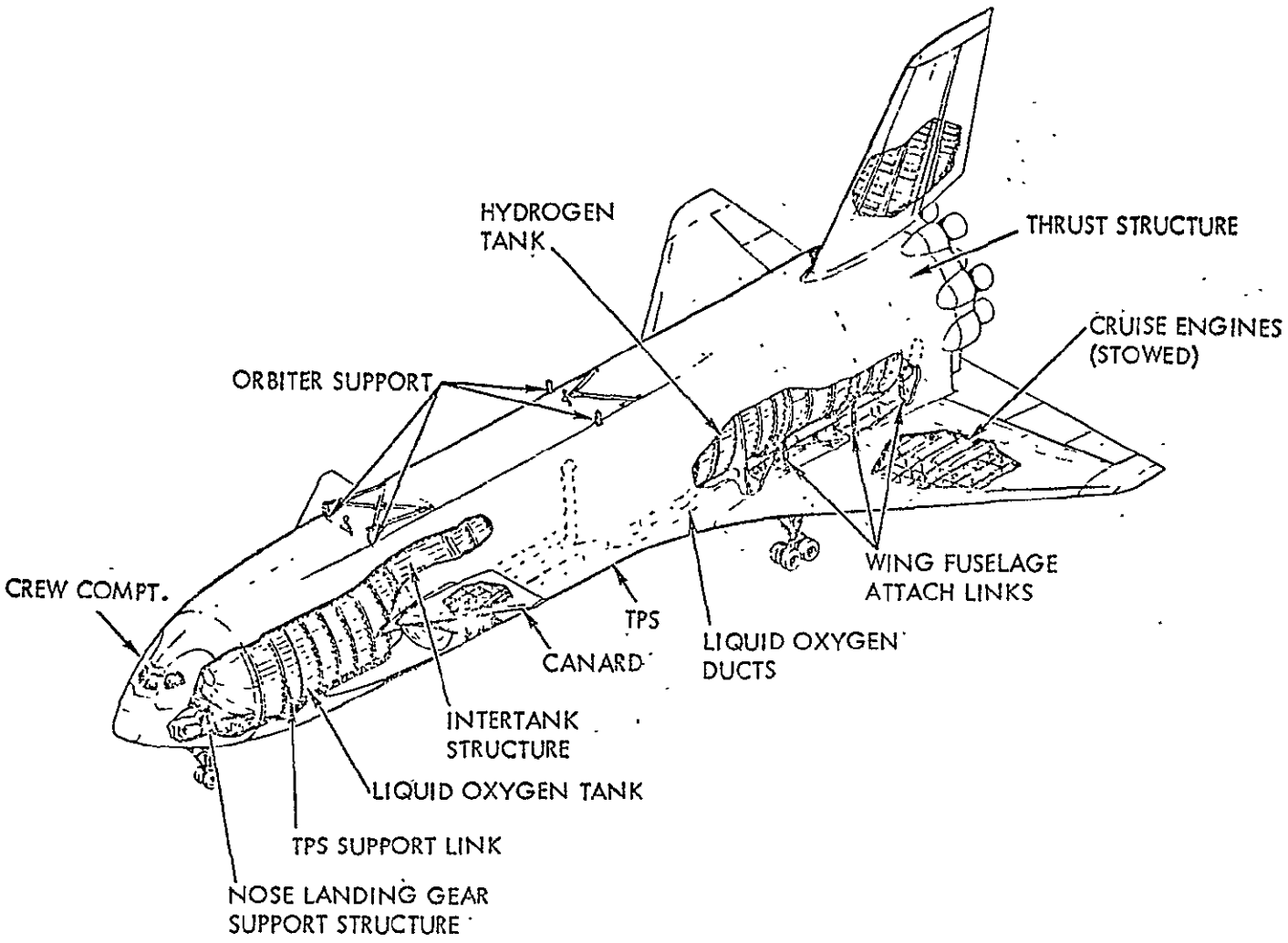


FIGURE A-1. NAR BOOSTER (PHASE B)

Some characteristics of the NAR Phase B Baseline Booster are noted below:

NAR DELTA WING BOOSTER DESCRIPTION

(PHASE B)

.Reference Length* (ft)	243.6
.Wing Span (ft)	150.9
.Runway Height (ft)	93.5
.Basic Structure	
-Primary	Aluminum
-Outer Heat Shield (Skin, including TPS)	Carbon-Carbon, Rene '41, Coated Columbium, Titanium, Inconel 718, HS 188
.Main Engines	12
.ABES Engines	12

*Nose to Main Rocket Engine Gimbal Plane

The design mass properties (weight, only) for the vehicle as a function of mission phase are noted below. Orbiter and Payload weight are not included.

NAR DELTA WING BOOSTER WEIGHT

(PHASE B)

Mission Phase	Weight (lb)
Liftoff	3,936,388
Max Q Condition*	2,674,494
3 G Flight Condition **	1,427,144
Burnout (Entry)	771,564
Start Cruise Return	751,677
Landing (Gear Down)	639,543

* t = 80 sec
h = 41,700 ft
V = 1297 fps
q = 496 psf

** t = 125 sec
h = 104,613 ft
V = 3376 fps
q = 151 psf

NOTE: Separation occurs at (NAR Orbiter):
t = 216 sec
h = 244,784 ft
V = 10,824 fps
q = 5.22 psf

Details on vehicle weight, together with major subsystem quantities and performance, are shown below. Equipment quantities shown as "1" are actually redundant. See NAR report for subsystem redundancies.

NAR DELTA WING BOOSTER PARAMETERS

(PHASE B)

Subsystem	Quantity	Total Weight (lb)	Performance
Wing Group	1	59,717	---
Tail Group (Incl. Canard)	1	18,363	---
Body Group(Incl. Tkg)	1	223,267	---
Refractory Skin Covering	1	60,000	3000°F max(C-C)
Landing	1	29,724	175 kts;10,000 runway
Main Propulsion(LO_2, LH_2)	12(Eng.)	114,117	550K ea (SL)
ABES Propulsion* (JP5)	12(Eng.)	44,300	
Aux. Propulsion (ACPS/ APU)(LO_2, LH_2)	30(Eng.)	10,223	2.1K ea (SL); 1×10^6 restarts
Prime Power (APUs) (O_2, H_2)	4	1,276	517 HP ea
Electr. Conv. & Distr. (Gen, TR, Batt)	4(Gen) 7(TR) 2(Batt)	2,273	20 KVA 120/ 208 VAC 400 Hz; 28VDC 300A
Hydraulic Conv & Dist.	1	2,148	3000 psi
Flight Controls	1	7,410	---
Avionics	1	5,236	---
Environ. Control (Air Cycle, Ram Air)	1	2,945	10 psi, Shirt-sleeve
Personnel Provisions	1	585	---
Growth	--	47,303	---
Dry Weight		628,887	
Personnel (Crew)	2	476	---
Residual Fluids	--	10,180	---
Inert Weight		639,543	
Inflight Losses	--	20,666	
Propellant, Main	--	3,161,845	---
Propellant, ACPS	--	5,500	---
Propellant, ABES	--	108,834	---
Liftoff Weight		3,936,388	

*Deploy at 20Kft; cruise at 10K ft

A.3 BIBLIOGRAPHY

The following North American Rockwell reports were made available to VMSC as baseline data. Information contained in these reports were utilized in the Scheduling Technique Improvement Study as follows:

- Task E - Work Breakdown Structure Dictionary: Conceptual, only
- Task D - TER Development: Weight Performance
- Task C - Scheduling Logic Diagrams: Conceptual, only
- Task B/F - Schedules: Conceptual, only

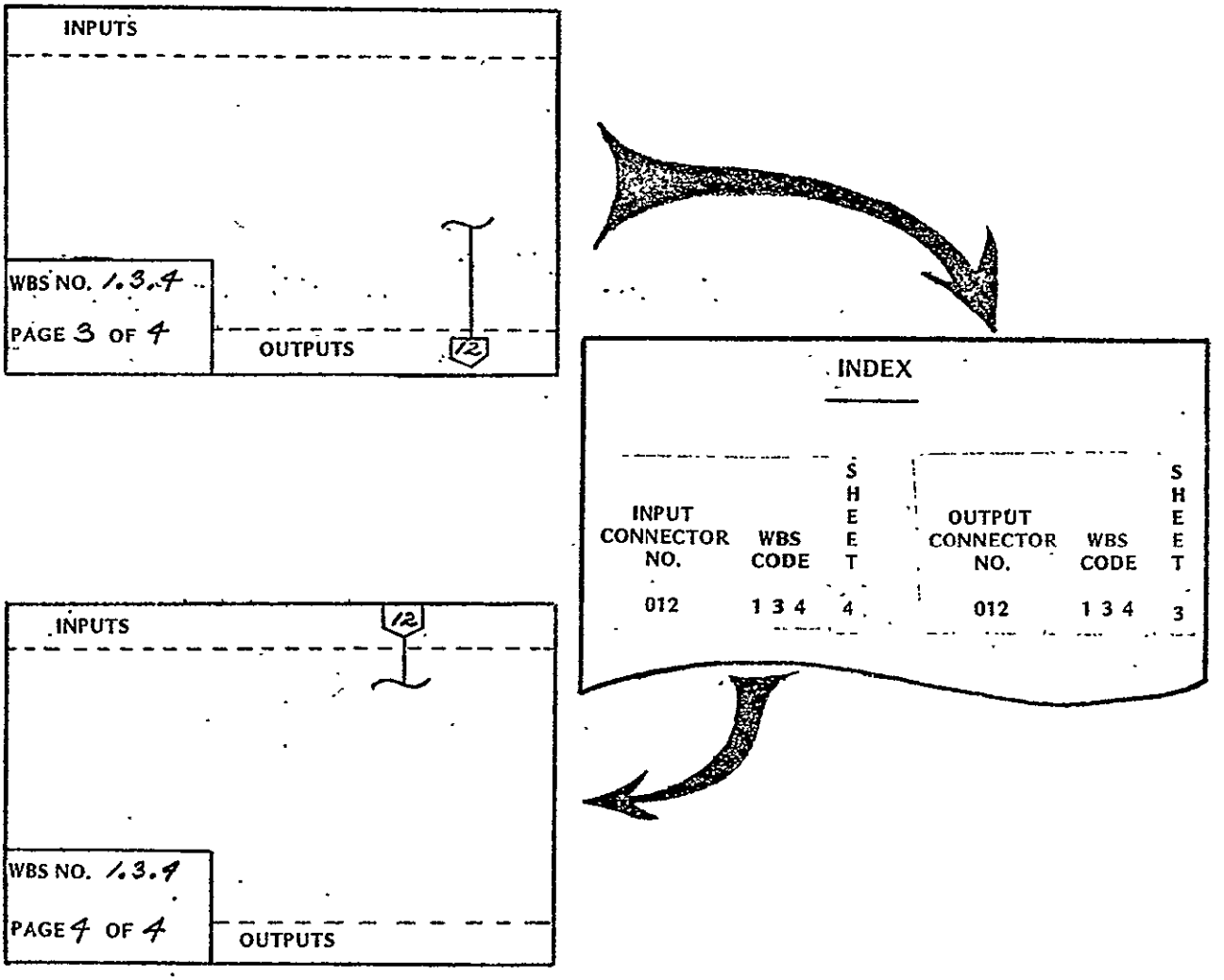
Doc. No.	Title	Date of Publ.
SD 71-114-2	Space Shuttle Phase B Final Report Vol. II. Technical Summary, Book 3. Booster Vehicle Definition	26 Mar 1971
SD 70-403-5	(Misc Data: Systems Mass Properties, Sequence Summary Weight Statement)	1 Jan 1971

APPENDIX B

LOGIC DIAGRAM CONNECTOR INDEX

The trail of logic between WBS elements may be traced by using the alpha-numeric, input/output connectors and the following index as shown below:

SAMPLE



LOGIC SHEET MASTER INDEX OF INPUTS/OUTPUTS

INPUT CONNECTOR NUMBERS	W B S E T	SHEET	OUTPUT CONNECTOR NUMBERS	W B S E T	SHEET
001	0 0 6	2	001	0 0 0	1
002	0 0 0	2	002	0 0 0	1
003	0 0 0	2	003	0 0 0	1
004	0 0 0	2	004	0 0 0	1
005	0 0 0	3	005	0 0 0	2
006	0 0 0	3	006	0 0 0	2
007	0 0 0	3	007	0 0 0	2
008	0 0 0	3	008	0 0 0	2
009	0 0 0	3	009	0 0 0	2
010	0 0 0	3	010	0 0 0	2
011	0 0 0	3	011	0 0 0	2
012	1 3 4	4	012	1 3 4	3
013	1 3 4	4	012	1 3 4	3
014	1 3 4	4	012	1 3 4	3
015	1 3 4	4	013	1 3 4	3
016	1 3 6	2	013	1 3 4	3
017	1 3 7	2	013	1 3 4	3
018	1 4 6	2	014	1 3 4	3
019	1 4 7	2	015	1 3 4	3
020	3 2 5	1	016	1 3 6	1
021	3 2 5	1	017	1 3 7	1
022	3 2 5	1	018	1 4 6	1
023	3 2 5	1	019	1 4 7	1
024	3 2 5	1	020	5 1 6	1
025	3 2 5	1	021	5 1 6	1
026	3 2 5	1	022	5 1 6	1
027	3 2 5	2	023	5 1 6	1
028	3 2 5	2	024	5 1 6	1
029	3 2 5	2	025	5 1 6	2
030	3 2 5	2	026	5 1 6	2
031	3 2 5	2	027	5 1 6	2
032	3 2 5	2	028	5 1 6	1
033	3 4 5	1	029	5 1 6	2
034	3 4 5	1	030	5 1 6	2
035	3 4 5	1	031	5 1 6	1
036	3 4 5	1	032	5 1 6	2
037	3 4 5	1	033	5 3 6	1
038	3 4 5	1	034	5 3 6	1
039	3 4 5	2	035	5 3 6	1
040	3 4 5	2	036	5 3 6	2
041	3 4 5	2	037	5 3 6	1
042	3 4 5	2	038	5 3 6	2
043	3 4 5	2	039	5 3 6	1
044	4 1 8	1	040	5 3 6	2
045	4 1 8	1	041	5 3 6	1
046	4 1 8	1	042	5 3 6	1
047	4 1 8	1	043	5 3 6	2
048	4 1 8	2	044	1 3 4	2
049	4 1 8	2	045	1 3 4	2
050	4 2 8	1	046	1 3 4	2
051	4 2 8	1	047	1 3 4	2
052	4 2 8	2	048	1 3 4	1
053	4 2 8	2	049	1 3 4	1
060	5 1 5	1	050	1 4 4	1
060	5 3 5	1	051	1 4 4	1

A61	5	5	3	2
A61	10	1	2	1
A61	10	3	2	1
A80	0	0	0	1
A80	4	8	1	1
A80	4	8	2	1
A80	4	8	3	1
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A80	4	9	3	1
A80	4	9	4	1
A80	4	9	5	1
A80	4	9	6	1
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A80	10	3	2	1
A80	10	3	3	1
B01	1	3	5	2
B01	1	4	5	2
B01	4	113		1
B01	4	113		1
B01	4	213		1
B01	4	213		1
B01	5	1	5	1
B01	5	3	5	1
B01	5	5	1	1
B01	5	5	2	1
B01	5	5	3	1
B01	5	5	3	1
B01	5	5	3	2
B01	10	1	1	1
B01	10	1	3	1
B01	10	3	1	1
B01	10	3	3	1
B02	1	3	8	1
B02	1	313		1
B02	1	413		1
B02	5	1	1	1
B02	5	1	2	1
B02	5	1	3	1
B02	5	3	1	1
B02	5	3	2	1
B02	5	3	3	1
B02	5	5	1	1
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B04	5	5	2	1
B05	5	5	2	1
B09	4	113		1
B13	1	3	8	1
B13	10	1	1	1
B13	10	3	1	1

B32	1	4	4	2
B33	1	4	4	2
B60	5	5	1	1
B61	5	5	2	1
B61	4	1	4	1
B01	4	2	4	1
B01	4	8	1	1
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B01	4	8	3	1
B01	4	8	4	1
B01	4	8	5	1
B01	4	8	6	1
B01	4	9	1	1
B01	4	9	2	1
B01	4	9	3	1
B01	4	9	4	1
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C12	5	3	5	1
C15	5	1	5	1
C16	5	3	5	1
C17	5	1	5	1
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C39	5	1	5	1
C40	5	3	5	1
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C42	5	3	5	1
C45	5	1	6	1
C45	10	1	1	1
C46	5	3	6	1

B15	4 2 1	1	
C01	1 3 4	1	
C01	3 1 2	2	
C01	5 1 6	1	
C02	1 4 4	1	
C02	3 1 2	2	
C02	5 3 6	1	
C03	1 3 4	3	
C03	5 1 6	1	
C04	1 3 4	2	
C04	3 1 2	3	
C04	5 1 6	1	
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C06	1 3 0	1	
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C09	3 2 6	1	
C09	5 1 6	2	
C10	3 4 2	1	
C10	3 4 6	1	
C10	5 3 6	2	
C11	1 3 8	1	
C11	3 3 3	1	
C11	5 1 6	1	
C12	1 4 8	1	
C12	3 5 3	1	
C12	5 3 6	1	
C15	1 310	1	
C15	5 1 6	2	
C16	1 410	1	
C16	5 3 6	1	
C17	1 3 6	1	
C17	5 1 6	2	
C18	1 4 6	1	
C18	5 3 6	1	
C19	1 3 5	1	
C19	5 1 6	2	
C20	1 4 5	1	
C20	5 3 6	2	
C39	1 3 9	1	
C39	5 1 6	2	
C40	1 4 9	1	
C40	5 3 6	2	
C41	1 3 2	1	
C41	5 1 2	1	
C41	5 1 6	1	
C42	1 4 2	1	
C42	5 3 2	1	
C42	5 3 6	1	
C45	1 3 5	2	
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C45	5 5 3	2	
C45	10 1 4	1	
C46	1 4 5	2	
C46	5 3 1	1	
C46	5 5 3	2	
C46	10 3 4	1	
C49	1 3 7	1	
C49	5 1 6	2	
C50	1 4 7	1	
C50	5 3 6	2	
C53	1 311	1	
C53	1 312	1	
C53	1 313	1	
C46	10 3 1	1	
C49	5 1 5	1	
C50	5 3 5	1	
C53	5 1 5	1	
C54	5 3 5	1	
C55	1 313	1	
C56	1 413	1	
C60	5 3 5	1	
D08	1 3 4	2	
D10	1 3 4	2	
D17	1 3 4	1	
D17	1 3 4	2	
D17	1 3 4	3	
D17	1 3 5	1	
D17	1 3 6	2	
D17	1 3 8	1	
D17	1 3 9	1	
D17	1 310	1	
D17	1 311	1	
D17	1 312	1	
D17	1 4 4	1	
D17	1 4 4	2	
D17	1 4 5	1	
D17	1 4 6	2	
D17	1 4 8	1	
D17	1 4 9	1	
D17	1 410	1	
D17	1 411	1	
D17	1 412	1	
D17	5 1 6	1	
D17	5 3 6	1	
D17	5 5 1	1	
D17	10 1 1	1	
D17	10 3 1	1	
D29	5 1 1	1	
D30	5 3 1	1	
D65	5 3 6	1	
D70	10 3 1	1	
D71	10 1 1	1	
F01	8 2 0	1	
F01	10 1 1	1	
F01	10 1 1	1	
F01	10 1 3	1	
F02	8 4 0	1	
F02	10 3 1	1	
F02	10 3 1	1	
F02	10 3 3	1	
F09	10 1 2	1	
F10	10 3 2	1	
G03	1 3 2	1	
G03	1 3 4	1	
G03	1 3 5	2	
G03	1 310	2	
G04	1 4 2	1	
G04	1 4 4	1	
G04	1 4 5	2	
G04	1 410	2	
G07	1 3 4	1	
G08	1 4 4	1	
G09	1 3 2	1	
G09	3 1 2	2	
G10	1 4 2	1	
G10	3 1 2	2	

C53	5	1	6	1	G11	4	113	1
C54	1	411		1	G12	4	214	1
C54	1	412		1	G31	1	3	2
C54	1	413		1	G31	1	316	2
C54	5	3	6	1	G32	1	4	2
C55	1	311		1	G32	1	416	2
C55	1	312		1	G41	1	3	4
C55	5	1	6	1	G41	1	3	4
C56	1	411		1	G41	1	3	4
C56	1	412		1	G41	1	3	4
C56	5	3	6	1	G48	1	3	4
C60	1	4	4	2	G57	3	3	3
C60	3	1	2	3	G58	3	5	3
C60	5	3	6	1	GF2	1	4	2
D08	4	1	8	1	GF2	1	4	5
D10	4	1	8	1	GF2	3	4	5
D17	1	3	2	1	GF2	5	3	1
D17	1	3	5	2	GF2	5	5	3
D17	1	4	2	1	GF2	8	4	0
D17	1	4	5	2	GF3	1	3	2
D17	5	1	5	1	GF3	1	3	5
D17	5	3	5	1	GF3	3	2	5
D29	1	3	5	2	GF3	5	1	1
D35	1	4	5	2	GF3	5	5	3
D65	8	4	0	1	GF3	8	2	0
D70	8	4	0	1	GH1	1	3	2
D71	8	2	0	1	GH1	8	2	0
F01	10	1	2	1	GH2	1	4	2
F02	10	3	2	1	GH2	8	4	0
F09	10	1	3	1	GK7	1	3	2
F10	10	3	3	1	GK8	1	4	2
G03	4	1	8	2	GP8	5	3	6
G04	4	2	8	1	GP9	5	1	6
G07	4	1	8	2	H00	1	3	0
G08	4	2	8	1	H00	1	3	2
G09	1	3	4	1	H00	1	3	4
G10	1	4	4	1	H00	1	3	4
G11	3	1	2	2	H00	1	3	4
G12	3	1	2	2	H00	1	3	5
G31	1	3	4	4	H00	1	3	6
G32	1	3	4	4	H00	1	3	7
G41	4	1	8	1	H00	1	3	8
G48	4	1	8	1	H00	1	3	9
G57	1	3	8	1	H00	1	310	1
G58	1	4	8	1	H00	1	311	1
GF2	1	4	5	2	H00	1	4	0
GF2	10	3	2	1	H00	1	4	2
GF2	10	3	4	1	H00	1	4	4
GF3	1	3	5	2	H00	1	4	4
GF3	10	1	2	1	H00	1	4	5
GF3	10	1	4	1	H00	1	4	6
GH1	4	3	2	1	H00	1	4	7
GH2	4	4	2	1	H00	1	4	8
GK7	1	3	4	3	H00	1	4	9
GK8	1	3	4	3	H00	1	410	1
GP8	8	4	5	1	H00	1	411	1
GP9	8	2	0	1	H00	5	1	3
H00	1	316		2	H00	5	1	5
H00	1	416		2	H00	5	1	5
H00	3	2	6	1	H00	5	1	6
H00	3	4	6	1	H00	5	1	6
H00	4	5	6	1	H00	5	1	6
H00	4	6	6	1	H00	5	1	6

H09	5	5	2	1	H[illegible]	5	1	6	1
H05	10	1	1	1	H[illegible]	5	1	6	1
H06	10	3	1	1	H[illegible]	5	1	6	1
H07	1	3	8	1	H[illegible]	5	1	6	2
J09	1	4	8	1	H06	5	1	6	2
J10	1	4	8	1	H0[illegible]	5	1	6	2
J10	10	1	4	1	H06	5	1	6	2
J10	10	3	4	1	H06	5	1	6	2
K01	1	3	1	1	H06	5	3	3	1
K02	1	4	1	1	H06	5	3	5	1
K05	1	3	1	1	H06	5	3	5	1
K05	1	4	1	1	H06	5	3	6	1
K07	1	3	1	1	H06	5	3	6	1
K07	1	4	1	1	H06	5	3	6	1
K10	4	1	8	1	H06	5	3	6	1
K14	4	1	8	1	H06	5	3	6	1
K16	1	3	4	2	H06	5	3	6	1
K17	3	1	2	3	H06	5	3	6	1
K21	1	3	1	1	H06	5	3	6	2
K22	1	4	1	1	H06	5	3	6	2
K27	1	31[illegible]		2	H06	5	3	6	2
K28	1	41[illegible]		2	H05	1	3	5	2
K29	1	3	6	2	H05	10	1	4	1
K30	1	4	6	2	H06	1	4	5	2
K33	4	1	6	1	H06	10	3	4	1
K33	4	1	7	1	H07	1	313		1
K33	4	3	3	1	H07	1	413		1
K34	4	2	6	1	J09	1	3	8	1
K34	4	2	7	1	J10	1	3	8	1
K34	4	4	3	1	K01	3	2	5	1
K95	8	2	0	1	K01	4	1	8	1
K95	8	4	0	1	K01	8	2	0	1
K96	8	4	0	1	K02	3	4	5	1
K97	8	2	0	1	K02	3	4	5	1
K98	8	2	0	1	K02	4	2	8	1
KA2	4	2	8	2	K02	8	4	0	1
KA4	4	2	8	2	K02	8	4	0	1
KA5	1	4	4	2	K05	3	2	5	1
KA6	3	1	2	3	K05	8	2	0	1
KB3	8	2	0	1	K07	3	2	5	1
KB4	8	4	0	1	K07	8	2	0	1
KB5	8	2	0	1	K10	1	3	4	2
KB6	8	4	0	1	K10	1	3	5	2
KB7	8	2	0	1	K10	1	310		2
KB8	8	4	0	1	K14	1	3	2	1
KC1	8	2	0	1	K14	1	3	4	2
KC2	8	4	0	1	K14	1	3	5	2
KC3	8	2	0	1	K14	1	310		2
KC4	8	4	0	1	K16	3	1	2	3
KC5	8	2	0	1	K17	4	113		1
KC6	8	4	0	1	K21	1	3	2	1
KC7	8	2	0	1	K21	1	3	2	1
KC8	8	4	0	1	K21	1	3	5	2
KC9	8	2	0	1	K21	1	3	6	2
M01	1	3	1	1	K21	1	3	7	1
M02	1	4	1	1	K21	1	3	7	2
M03	3	2	2	1	K21	1	3	8	1
M04	3	4	2	1	K21	1	3	9	1
M09	3	2	2	1	K21	1	3	9	1
M10	3	4	2	1	K21	1	310		2
M23	3	2	2	1	K21	1	311		1
M24	3	4	2	1	K21	1	312		1
M25	8	2	0	1	K21	3	2	5	1

L26	8 4 6	1	K21	3 2 3 2
M01	4 5 4	1	K21	3 2 3 2
M02	4 6 4	1	K21	3 4 3 2
M03	4 5 3	1	K21	8 2 0 1
M04	4 6 3	1	K21	8 2 0 1
M05	1 3 1	1	K21	8 2 0 1
M06	1 4 1	1	K21	8 2 0 1
M07	4 5 4	1	K21	8 2 0 1
M08	4 6 4	1	K22	1 4 2 1
M09	4 5 3	1	K22	1 4 2 1
M10	4 6 3	1	K22	1 4 3 2
Q01	4 5 6	1	K22	1 4 6 2
Q02	4 6 6	1	K22	1 4 7 1
Q03	4 5 6	1	K22	1 4 7 2
Q04	4 6 6	1	K22	1 4 8 1
Q05	4 5 1	1	K22	1 4 9 1
Q06	4 6 1	1	K22	1 4 9 1
Q09	10 1 2	1	K22	1 410 2
Q10	10 3 2	1	K22	1 411 1
R01	4 5 6	1	K22	1 412 1
R02	4 6 6	1	K22	3 4 5 1
S00	4 5 6	1	K22	3 4 5 1
S00	4 6 6	1	K22	3 4 5 2
S00	4 7 1	1	K22	3 4 5 2
S02	2 5 3	1	K22	3 4 5 2
S02	3 1 2	1	K22	8 4 0 1
S02	4 7 1	1	K22	8 4 0 1
S04	4 7 1	1	K22	8 4 0 1
S06	3 1 3	1	K22	8 4 0 1
S07	5 5 3	2	K22	8 4 0 1
S20	8 1 3	1	K27	1 310 1
T01	4 7 1	1	K27	3 2 5 2
T02	4 7 1	1	K27	3 2 5 2
T05	4 5 6	1	K27	8 2 0 1
T06	4 6 6	1	K28	1 410 1
T07	4 5 6	1	K28	3 4 5 2
T08	4 6 6	1	K28	8 4 0 1
T09	4 5 6	1	K29	1 3 0 1
T10	4 6 6	1	K29	1 3 6 1
T13	4 5 6	1	K30	1 4 6 1
T14	4 6 6	1	K30	1 4 6 1
T15	4 5 1	1	K33	4 3 2 1
T16	4 6 1	1	K34	4 4 2 1
W00	4 7 1	1	K95	5 1 6 1
W03	4 7 1	1	K96	5 3 6 1
X00	4 7 1	1	K97	5 1 6 1
Y00	4 7 2	1	K98	5 1 6 1
Z01	4 7 2	1	KA2	1 4 4 2
Z02	4 7 3	1	KA4	1 4 2 1
Z07	4 7 3	1	KA4	1 4 4 2
Z08	4 7 3	1	KA4	1 4 3 2
			KA4	1 410 2
			KA5	1 4 2 1
			KA5	3 1 2 3
			KA6	4 213 1
			KB3	5 1 6 1
			KB4	5 3 6 1
			KB5	5 1 6 2
			KB6	5 3 6 1
			KB7	5 1 6 2
			KB8	5 3 0 1
			KC1	5 1 0 2
			KC2	5 3 0 2

[illegible]	5	1	6	2
KC4	3	5	6	2
[illegible]	5	1	6	2
KC8	5	3	6	2
KC7	5	1	6	1
KC6	5	3	6	1
KC9	5	1	6	1
M01	1	3	2	1
M01	1	3	4	1
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M01	1	5	4	2
M01	1	3	4	4
M01	1	3	5	2
M01	1	3	6	2
M01	1	3	8	1
M01	1	3	9	1
M01	1	3	9	1
M01	1	3	9	1
M01	1	3	10	2
M01	3	2	2	1
M01	3	2	5	1
M01	3	2	5	1
M01	3	2	5	1
M01	3	2	5	2
M01	3	2	5	2
M01	8	2	0	1
M01	8	2	0	1
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W03	5	5	2	1
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X00	1	4	8	1
Y00	1	3	8	1
Y00	1	4	8	1
Y00	4	7	1	1
Z01	4	7	2	1

202	4	7	2	1	
207	10	1	2	1	
208	10	3	2	1	

FOLDOUT FRAME 1

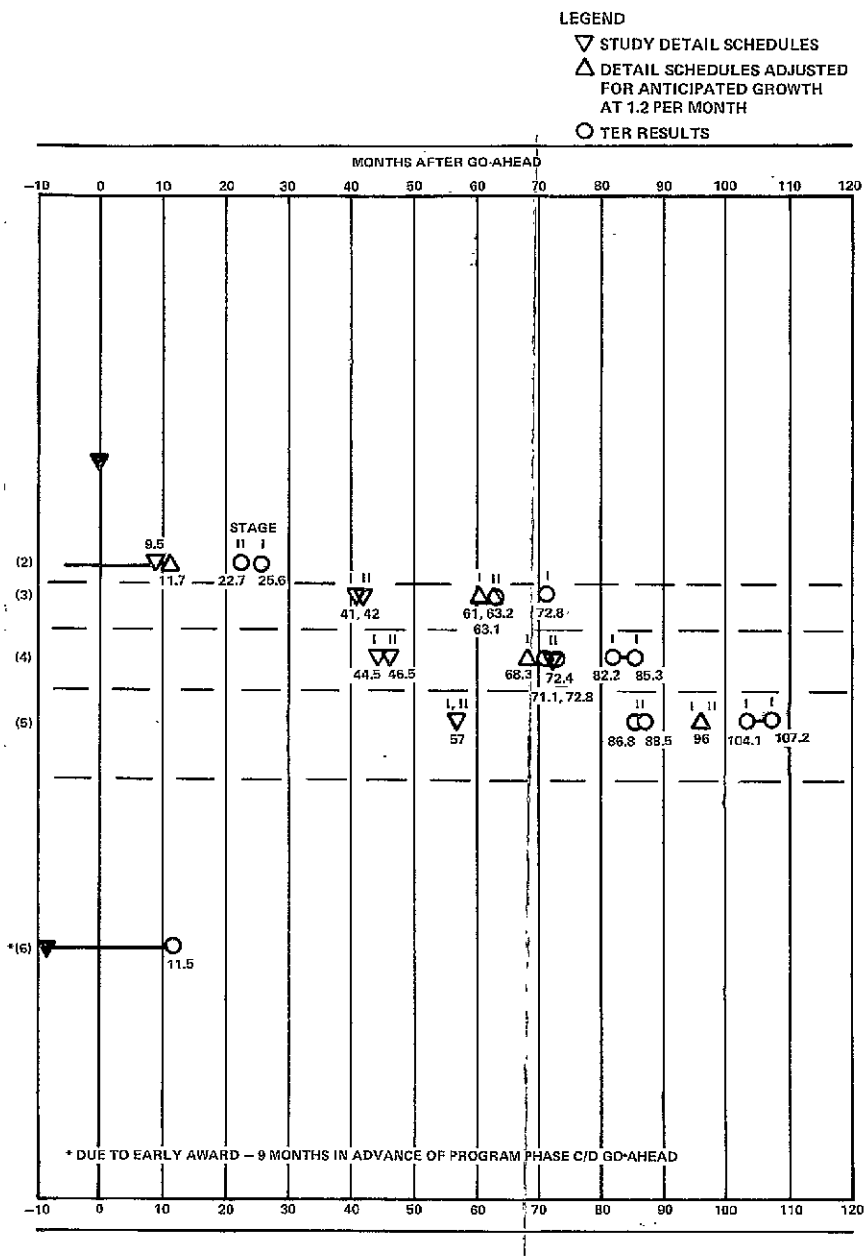
APPENDIX C

COMPARISON OF TER RESULTS WITH DETAIL SCHEDULE/LOGIC RESULTS

Time Estimating Relationships intersect logic and schedules at those points indicated below and within the respective WBS elements. The points of intersection shown below are also identified on those schedules and logic charts containing the particular TER event.

TER Number & Description	Point	WBS	Particular TER Event
7.6 Total Program			Phase C/D go-ahead. Note this point is identified as "go-ahead" or "A00" on logic and schedules.
	(1)		Total program 95% airborne engineering design release.
	(2)		Start detail fabrication.
	(3)	4.5.3.0.0 4.6.3.0.0	Rollout first horizontal flight test vehicle.
(7.7) Horizontal Flight Test	(4)	4.5.6.0.0 4.6.6.0.0	Start horizontal flight testing.
	(5)	4.5.6.0.0 4.6.6.0.0	Complete horizontal flight testing; i.e., obtain sufficient data/confidence to commence vertical flight test phase vehicles 1 and 2.
7.2 Liquid Rocket Engines			Go-ahead for the main engine contract. Note — This point precedes Phase C/D go-ahead and is not shown on logic or schedules.
	(6)	5.1.1.0.0 5.3.1.0.0	Completion of the first main engine test. Note — This point and the inherent data contribute to the engine trade-off studies for both Stage 1 (5.3.1.0.0) and Stage 2 (5.1.1.0.0)

FOLDOUT FRAME 2

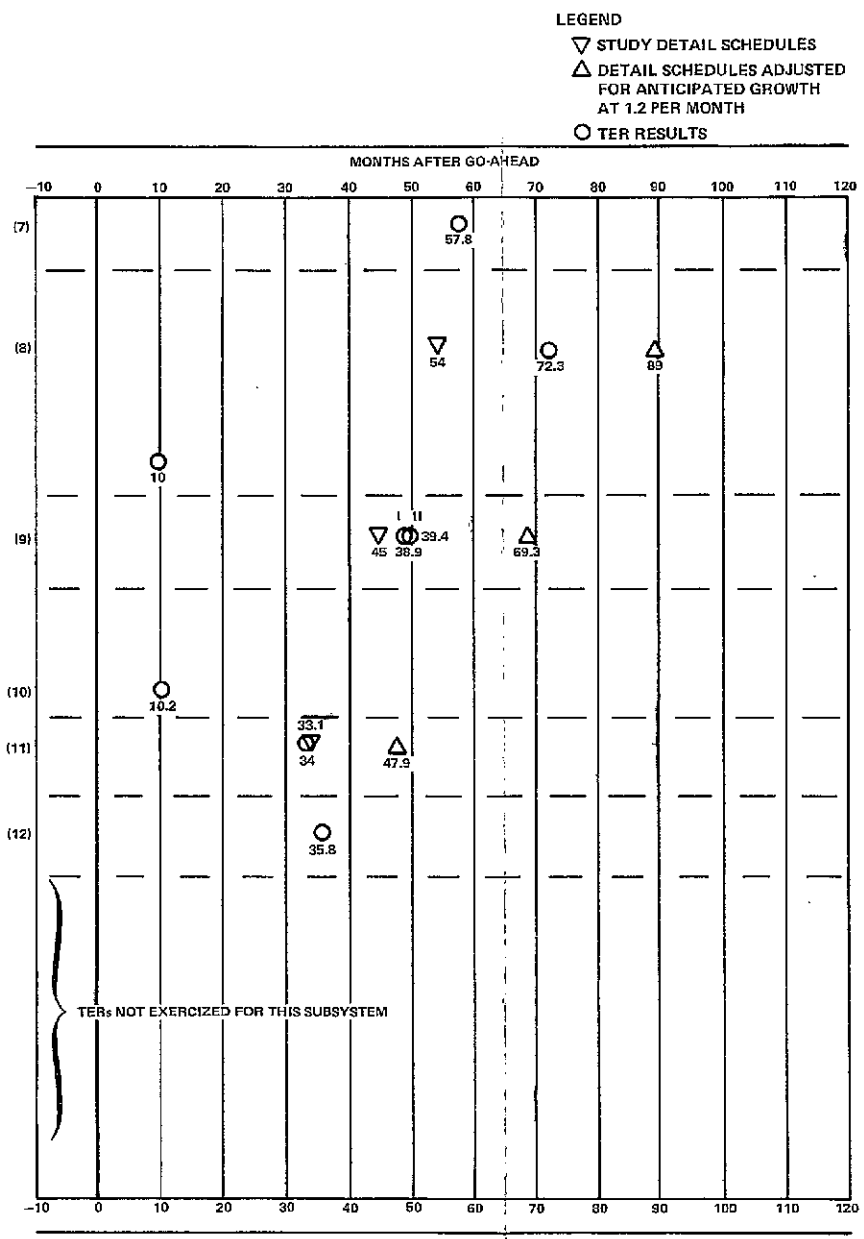


COMPARISON
TERs VS CONVENTIONAL
SCHEDULES/LOGIC

FOLDOUT FRAME 1

TER Number & Description	Point	WBS	Particular TER Event
	(7)	4.1.8.0.0 4.2.8.0.0	Single engine PFRT. Recall the logic displays this point admittedly redundantly for both Stage 1 (4.2.8.0.0) and Stage 2 (4.1.8.0.0).
	(8)	4.1.8.0.0 4.2.8.0.0	Single engine qualification testing complete. Same remarks as above.
7.4 Small Gas Turbine Engines			Go-ahead for auxiliary power unit. Note -- This point is not shown on logic or schedules. Includes 10 months for vendor selection.
	(9)	1.3.6.0.0 1.4.6.0.0	Qualification of auxiliary power unit as necessary to deliver units to program for Stage 1 (1.4.6.0.0) and Stage 2 (1.3.6.0.0)
7.3 Avionics			Phase C/D go-ahead. Note -- This point is identified as "go-ahead" or "A00" on logic and schedules.
	(10)	1.3.10.0.0 1.4.10.0.0	Go-ahead to the vendor for the largest, most complex black box.
	(11)	1.3.10.0.0 1.4.10.0.0	Receipt of the first black box for buildup/ assembly of the data management hardware.
	(12)	1.3.10.0.0 1.4.10.0.0	Receipt of the last black box, thereby completing hardware buildup/assembly.
7.3 Avionics			Phase C/D go-ahead. Note -- This point is identified as "go-ahead" or "A00" on logic and schedules.
	(13)	1.3.8.0.0 1.4.8.0.0	Go-ahead to the vendor for the largest, most complex black box.
	(14)	1.3.8.0.0 1.4.8.0.0	Receipt of the first black box for buildup/ assembly of the prototype guidance and navigation subsystem.
	(15)	1.3.8.0.0 1.4.8.0.0	Receipt of the last black box, thereby completing hardware buildup/assembly

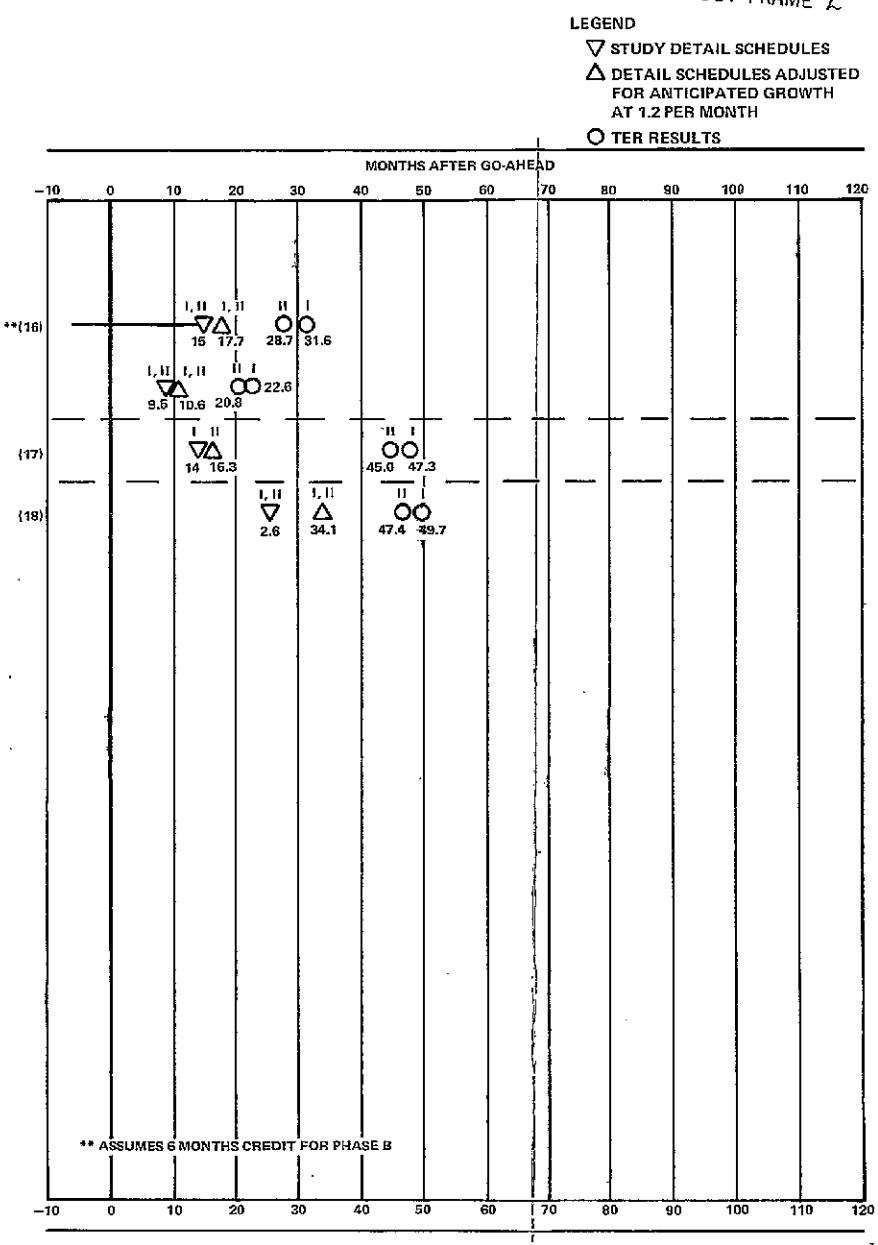
FOLDOUT FRAME 2



FOLDOUT FRAME 1

TER Number & Description	Point	WBS	Particular TER Event
7.1 Structure			Phase C/D go-ahead. Note – This point is identified as "go-ahead" or "A00" on logic and schedules.
	(16)	1.3.2.0.0 1.4.2.0.0	95% structural engineering design release.
			Start detail fabrication. Note – This point does not appear on logic or schedules at the 5th WBS level; it does appear as (2) at program level.
	(17)	4.3.2.0.0 4.4.2.0.0	Complete manufacturing and start assembly of structural test article.
	(18)	4.3.2.0.0 4.4.2.0.0	Complete final assembly of structural test article.

FOLDOUT FRAME 2



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APPENDIX D

LIST OF ABBREVIATIONS, SYMBOLS, TERMS (GLOSSARY)

A

ABES	Air Breathing Engine System. The turbojet engine system used on Stage I and Stage II for powered cruise and ferry flights. (See WBS Dictionary Elements 1.3.4.5, Stage II, and 1.4.4, Stage I)
ACPS	Attitude Control Propulsion System (see also RCS). The propulsion assembly used to maintain vehicle stability or to enable attitude change while the vehicle is out of the sensible atmosphere. (See WBS Dictionary Elements 1.3.4.4, Stage II, and 1.4.4, Stage 1)
ACT	Acquisition, Control and Test (Unit). (See WBS Dictionary Element 1.4.10)
Advanced Space Transport Program	A Life Cycle NASA program defined to design, develop and produce manned, reusable two-stage vehicles whose missions will include delivering and/or retrieving GFE payloads to/from near earth space in support of manned orbiting space stations and space bases, experiments, developments, etc. In addition to vehicles, necessary ground support will also be developed and produced, including the neccessary data, software, training, facilities and investment to commit the Program to 10-year operations. At IOC, the Program is defined to follow a Traffic Model of flights and turnarounds and provides the hardware, software, support and management to complete the designated Life Cycle.
A & E	Architectural & Engineering
Air Vehicle	The assembly of Stage I, Stage II and Payload

GLOSSARY

AMPR/DCPR Weight	Aircraft Manufacturers Planning Report/ Defense Contractor Planning Report - A vehicle weight which excludes the following items from empty weight: Wheels, Brakes Tires, Tubes; Engines; Rubber or Nylon fuel cells; Starters, Propellers; APU's, Instruments, Navigation Equipment; Batteries, Conversion Equipment; Electrical and Flight Control Equipment; Turrets and Power Mounts; Air Conditioning, Pressurization, Anti-Icing; Cameras
APU	Auxiliary Power Unit (see WBS Dictionary Elements 1.3.6.2, Stage II and 1.4.6, Stage I)
ATC	Air Traffic Control (or Controller)
	B
BIT	Built-in Test. A capability designed into on-board equipment to enable it to be interrogated by the on-board computer for status checks prior to or during flight. May also include self-test and a means to perform manual checkout.
	C
Category I Testing	(AFR 80-14) Subsystem Development Test and Evaluation. Consists of development testing and evaluation of the individual components, subsystems, and, in certain cases, the complete system. In addition to qualification, the testing provides for redesign, refinement, and reevaluation, as necessary. Conducted predominantly by the contractor under (government) control.

Category II Testing	(AFR 80-14) System Development Test and Evaluation. Consists of testing and evaluation spanning the integration of subsystems into a complete system, and development tests of the completed system in as near an operational configuration and environment as practicable. Suitable instrumentation will be employed to determine the functional capability and compatibility of subsystems. Category II is a (government) effort with contractor participation, under (government) control. Actual test operation and maintenance should be performed by (using agency) personnel who have received formal system training.
C & C	Command and Control
CCN	Contract Change Notice

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CDR

Critical Design Review. A formal technical review conducted for each contract end item. Purpose is to determine acceptability of detail design, performance, test, and activation characteristics depicted by the design solution specified in Part II Specifications. Establishes that recommended design adequately satisfies end-item design and test requirements, including interface with personnel, facilities and other system equipment. Critical Design Review establishes: (1) compatibility between the CEI and the Part I Specification; (2) compatibility between the CEI and the Total System; (3) Design Integrity by way of review of both analytical and test data; and (4) the agreed-to Part II Specification which is the basis for inspecting the "First Article". Upon the logic charts CDR's have only been identified at those points in software developments where at firm baseline is necessary against which to manage subsequent changes. Software, since it is used to checkout/verify the airborne/ground systems, must have a baseline or "First Article" for software configuration control.

Precise definition of CDR for hardware configuration items within the logic has not been possible because no logical point is available within the study confines to indicate the transition from development to production. Without such a point, the logical placement of a First Article Configuration Inspection (FACI) could not be determined and the absence of a FACI point removes the requirement for a CDR. However, the earliest that a CDR could occur would be at that point during the qualification test program where (1) Part II Specifications would be complete or would be nearing completion; and (2) sufficient considence would have been acquired to permit the "cutting of metal" for qualification hardware. Calendar points reflecting these points have been identified on the detail calendar schedules.

CEI	Contract End Item (also, CI - Contract Item)
CFE	Contractor Furnished Equipment
Coefficient of Correlation	A pure number which expresses the degree of relationship between two variables. It varies between 0, when there is no correlation, and 1 or -1, when there is perfect correlation. Simply stated, it is a measure of how well the independent variables in a multiple regression equation explain variances in the value of the dependent variables.
Common Support Equipment	Maintenance equipment required to support Program operations but which is not directly involved in the operations, and which is common, i.e., presently in DoD or other government inventory in support of other systems or programs and which is available for use on subject programs.
Configuration (End) Item (also, Contract End Item, or Contract Item)	(MIL-STD-881) An aggregation of hardware/software, or any of its discrete portions, which satisfies an end-use function and is designated by the government for configuration management. During development and initial production, CI's (CEI's) are only those specification items that are referenced directly in a contract. CI's (CEI's) are also any reparable item(s) designated for separate procurement during operations and maintenance (O & M) periods.
CONUS	Continental United States
CRT	Cathode Ray Tube
CO_2	Carbon Dioxide
	D
D & C	Displays and Controls

Depot Level	The level of maintenance representing lowest level maintenance performed on a removed end item, its modules, or components. If the faulty component or module contains reparable parts, these parts are repaired in the depot. If the faulty part is a 'throw-away', a new part is installed in the component or module, checkout is performed, and the repaired component or module is sent back to Intermediate Level maintenance for use when required. (See Intermediate Level)
Design Mission	(Phase B, Advanced Space Transport Program). The Stage II mission which is the basis for Phase B design, and which, it is assumed, will remain unchanged for Phase C/D. This mission is a 100 nm due east circular orbit formed by insertion into a 50 x 100 nm orbit, then circularizing. The Air Vehicle (Stage II, Stage I, and Payload) is considered to be launched from a latitude of 28.5 degrees north. (See also Reference Missions.)
Design Release, Program - 95%	That point in time when all documentation which requires fabrication of hardware components/elements for the initial configuration have been conveyed to the performing organization - normally manufacturing.
Design Release, Structure - 95%	That point in time when all documentation which requires fabrication of structural elements for the initial configuration have been conveyed to the performing organization - normally manufacturing.
Detail	A single element part or drawing

DD 250	A government form and checklist, which when completed and signed off by the approved, requesting agency, represents end item delivery of a system or systems is satisfactory to the government. Following DD 250, end items, together with all necessary documentation, can receive approval of all contract compliance and result in an initial operational capability (IOC).
DIU	Digital Interface Unit (See WBS Dictionary Element 1.3.10.5).
DME	Distance Measuring Equipment
DMGE	Depot Maintenance Ground Equipment (see GSE; also, see WBS Dictionary Element 3.0 and 8.0).
DoD	Department of Defense
	E
EAFB	Edwards Air Force Base, California
ECLS	Environmental Control and Life Support
ECLSS	Environmental Control and Life Support Subsystem
ECS	Environmental Control (and Life Support) Subsystem
EMI	Electromagnetic Interference
Empty Weight (Dry Weight)	The dry weight of the vehicle including no useful load or payload.
Endoatmosphere	Inside the sensible atmosphere (See Exoatmosphere).
EVA	Extravehicular Activity

Exoatmosphere	Out of the sensible atmosphere. The specific altitude at which the sensible atmosphere ceases. For purposes of Stage II reentry, consider 300,000 - 400,000 ft altitude as the reentry regime. For purposes of Stage I reentry, an altitude of 142,700 feet is used.
	F
FAA	Federal Aviation Agency
FCE	Flight Control Electronics
fps	feet per second
FSE	Factory Support Equipment. Similar to Ground Support Equipment but non-deliverable (see WBS Dictionary Elements 1.3.1, 1.4.1 and 3.3). FSE supports integration and assembly in handling, transporting, testing and servicing the prototype, flight test or production vehicle fabrication and test functions prior to and during rollout and delivery.
FSN	Federal Stock Number
F-Test	A statistical method for determination of the degree of colinearity which exists between candidate independent variables. The result of F-Tests allow selection of the "best" variable for use when colinearity between candidate variables exists. For example, installed thrust may show a strong relationship and therefore very little or no additional variation will be explained by using both variables rather than just one.
FTV	Flight Test Vehicle. An instrumented Stage (I or II) scheduled for a flight test program. For this study, FTVs are to retrofitted to a Production Vehicle at the end of flight test. (See Production Article)

G

G & N	Guidance & Navigation
GFE	Government Furnished Equipment
GH_2	Gaseous Hydrogen
GN_2	Gaseous Nitrogen
GO_2	Gaseous Oxygen
GSE	Ground Support Equipment, i.e., peculiar and common end item ground hardware/ software required to support the airborne elements in an operating and maintenance sense. Consists of operating ground equipment (OGE) and maintenance and depot maintenance equipment (MGE and DMGE). (See also FSE.) GSE is contract-deliverable.
GSFC	Goddard Space Flight Center

I

I & A	Integration and Assembly
ICD	Interface Control Document (or Drawing). A specification of the physical and functional interfaces between an end-item and other end-items which, due to the nature of the interface, requires formal control. May be both inter-vehicle and intra-vehicle and/or between ground equipment.
ILS	Instrument Landing System
IMU	Inertial Measurement(s) Unit

Integration and Assembly	(MIL-STD-881) The technical and functional activities associated with combining all other equivalent level hardware/software elements into a prime mission product.
Intermediate (Field) Level	The level of maintenance representing maintenance performed on the removed end item. For example, intermediate level maintenance on a vehicle end item (e.g., APU) represents the effort needed to determine which component or module of the faulty APU must be removed and replaced to bring the APU back to satisfactory operation. Testing will determine the faulty component or module. Replacement of the faulty component or module, followed by checkout, will verify that the APU is ready for return to the same or another vehicle when required. Otherwise, the APU is "strapped" as OK and placed 'on the shelf' for use when needed. The faulty component or module, if reparable, is sent to the next maintenance level for test, further maintenance, and checkout. (See Depot Level)
I/O	Input/Output
IOC	Initial Operational Capability
I_{xx}, I_{yy}, I_{zz}	Moments of Inertia in the X, Y, and Z planes of the Stage or Air Vehicle
	J
JP	Jet Fuel, i.e., JP-4, JP-5
	K
KSC	Kennedy Space Center
KUTD	Keep Up-to-Date

L

LCC	Launch Control Center
L/D	Lift-to-Drag Ratio
Level I, II, III Requirement	NASA requirements for the Advanced Space Transport Program resulting from development of Program, System, Subsystem, and support through Phase B.
L/G	Landing Gear
LH_2	Liquid Hydrogen
Life Cycle	The complete Program cycle, including RDT & E, Investment and Operations phases of the program. Equivalent to NASA Phases C (Design) and D (Development and Operations).
Li OH	Lithium Hydroxide
LO_2	Liquid Oxygen
LOS	Line of Sight
Lot I	The first set of detail and sub-assemblies usually cover test parts, prototype parts, and a flight test article
Lot II	The second set of detail and sub-assemblies cover follow-on flight test articles and production articles.
LOX	Liquid Oxygen
LUT	Launch Umbilical Tower (mobile)

M

Major Assembly	An assembly such as a Wing, Aft Fuselage, etc.

MGE	Maintenance Ground Equipment (see GSE; also, see WBS Dictionary Element 3.0 and 8.0)
MIL-STD-881	Military Standard, "Work Breakdown Structures for Defense Materiel Items"
MLG	Main Landing Gear
MSC	Manned Spacecraft Center (NASA, Houston)
MSFC	Marshall Space Flight Center
Multiple Regression and Correlation	A straight time of regression (projection of trend) does not always satisfactorily describe the association between two variables. Frequently, the relationship is too complex to be described by means of a simple straight line (linear) and therefore a curve must be used. The procedure of establishing linear or curve linear relationships between two variables is simple correlation analysis. In addition, fluctuations in a given series are seldom dependent upon a single factor or cause. The measurement of the association between such a series and several of the variables causing these fluctuations or associated with the dependent variable is known as multiple correlation. Multiple correlation consists of the measurement of the relationship or association between dependent variables and two or more independent variables. This procedure is similar to that for simple correlation (one independent and one dependent variable) with the exception that other variables are added to the regression equation.

N

NLG	Nose Landing Gear
nm	nautical miles

O

OEM	Original Equipment Manufacturer
OGE	Operating Ground Equipment (see GSE; also, see WBS Dictionary Element 2.0)
O/I	Organizational and Intermediate Level (Maintenance)
O & M	Operations & Maintenance
OMS	Orbital Maneuvering System. The on-orbit propulsion system used for circularizing Stage II after orbital injection, for translating to a higher orbit, and for providing retro thrust for Stage deorbit. (See WBS Dictionary Element 1.3.4.3)
Organizational Level	The level of maintenance representing maintenance performed on the as-installed end item. For example, organizational level maintenance on a vehicle end item (e.g., APU) represents the effort needed to verify a fault exists on the installed APU, removal and replacement of the APU in the vehicle, then checkout to verify the replaced APU satisfactorily performs its intended function. The faulty APU is then sent to the next maintenance level for test, further maintenance and checkout. (See Intermediate Level, Depot Level)

P

Payload	A Government Furnished Equipment (GFE) package to be delivered to, or retrieved from, near-earth space by Stage II of the Space Transport Air Vehicle (see WBS Dictionary Element 1.2).

PDR	Preliminary Design Review. A formal technical review conducted for each contract end item. Purpose is to evaluate the progress, consistency, and technical adequacy of the selected design and test approach and establish compatibility with program requirements and preliminary design. Establishes Part I Specification, interface drawings, other Systems Engineering documentation, schedules and costs. Preliminary Design Reviews have been assumed to be convened on each Configuration (Contract End) Item sometime shortly after the start of Phase C/D. The period between Go-Ahead to PDR has been assumed to be spent finalizing Part I specifications and mockups and completing any tradeoff studies, analyses, or revisions to document/specification trees as might be required from Phase C/D negotiations. The PDR freezes physical and functional interfaces and establishes: (1) compatibility between Part I Specification and design approach; (2) integrity of the approach and design; and (3) design producability.
Peculiar Support Equipment	Maintenance equipment, services and software which supports the Program operations but is not directly involved in the operations, and which is peculiar to this Program. (See Common Support Equipment)
PFRT	Preliminary Flight Rating Test
Phase B	Definition Phase (NASA)
Phase C	Design Phase (NASA)
Phase D	Development and Operations Phase (NASA)

Planform Area	The profile area of an air vehicle, or segment thereof. For an aircraft, Planform Area is the area based on Top View viewing. For a missile, Planform Area is the area based on Side View viewing.
PMEL	Precision Measuring Equipment Laboratory
Production Article	A Stage (I or II) scheduled to go directly into the Operating phase of the Program. (See Flight Test Vehicle)
PRS	Precision Ranging System
	R
Ramp Time	Encompasses that activity between flight test vehicle rollout and its first flight such as preflight operations, systems checkout and verification, and taxi runs. (See WBS ID 4.5.3 and 4.5.4 for Stage II and WBS ID 4.6.3 and 4.6.4 for Stage I.)
Ratio-Systems Weight/ Empty Weight	The number arrived at by subtracting the weight of the structural subsystem from the empty weight and dividing the remainder by the empty weight: $\frac{\text{Empty Weight-Structure Weight}}{\text{Empty Weight}}$
RCS	Reaction Control System
RDT & E	Research, Development, Test and Evaluation
Reference Missions	(Phase B, Advanced Space Transport Program) The Stage II missions of major interest in addition to the Design Mission. These mission: include: (a) a 100 nm south polar circular orbit (south polar mission), and (b) a 270 nm at 55 degrees inclination orbit (resupply) mission. Insertion of reference missions will be from 50 x 100 nm orbits. (See also Design Mission.

RF	Radio Frequency
RPP	Reinforced Pyrolized Plastic. A matrix of carbon cloth and resin, which when cured, results in a carbon-carbon material with high heat resistance. Used on vehicle leading edges and nose cap to resist ascent and re-entry heating loads for thermal protection of primary and secondary structure and internal subsystems.
	S
S/A	Subassembly. An assembled unit designed to be incorporated with other units in a product.
SARP	The schedule portion of the [illegible]d Space Flight Schedules as presented in OMSF Program Status Review documents.
SAS	Stability Augmentation System. A Flight Control Electronics design concept used to blend Attitude Control Propulsion with Aerodynamic Flight Controls during reentry from exo to endoatmosphere in order to maintain stabilized vehicle control in this flight regime.
SCU	System Control Unit (see WBS Dictionary Element 1.3.10.3).

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SDR	System Design Review. A formal technical review conducted by the contractor when the definition effort has progressed to the point where the program requirements and design approach are more precisely defined from among alternate design approaches, and the contractor has defined and selected the equipment, personnel, test, procedural data, and facilities required. As a product of this review, which is reviewed by the SPO, a technical understanding is to be reached on the allocation of requirements to (1) the system segments identified in the System Specification, and (2) the CEI's identified in Part I Detail Specifications. This review, if conducted late in Phase B or early Phase C, will provide the necessary basis for completion of preliminary design in Phase C.
SE & I	Systems Engineering & Integration
SPADATS	Space Detection and Tracking System. A North American Air Defense Command System headquartered at Ent, AFB, Colorado, which monitors all space objects for SAC et al.

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Specifications	Use of the terms Part I and Part II (see below) presumes a two-step procurement of Configuration (Contract End) Items. The Part I specification is the first part of the Contract End Item Detail Specification and results from the Program Definition Phase (B). Part I specifies the requirements for design, development, and qualification. For purposes of this study, the Part I specification is considered similar/identical to the Development Specification identified in MIL-STD-490. The Part II specification results from the design and development contract and specifies the detail product configuration and acceptance requirements of the item under the design and development contract. The Part II specification typically provides the basis again which the "First Article" is accepted. Part II, for purposes of this study, is considered similar/identical to the Product Function Specification identified in MIL-STD-490. Both Part I and Part II terms have been applied not only to Airborne Configuration Items but also to: -Integrated Checkout and Servicing GSE for the Transport System (Stage I, Stage II and Payload) -Integrated checkout and Servicing Software -On-Board Checkout Software -Integrated Checkout/Assembly Facilities No attempt has been made to distinguish Configuration (Contract End) Items and their specifications into such categories as Critical, Prime Item, Non-Complex, or Requirement Items.

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Specifications (Continued)	Part I - The design statement specified by Systems Engineering for a required contract end item (CEI). Part I includes: the set of requirements; performance; CEI definition (interface requirements, government designation); design and construction requirements; quality assurance provisions; Category I tests required; and Category II tests required. Part I Specifications are usually available for Preliminary Design Reviews (PDRs). Part II - The design statement specified by Design Engineering to satisfy the Part I specifications for a required contract end item (CEI). Part II is a repeat of Part I except to specify the "solution" which has been demonstrated by test to satisfy the requirements. (See Part I). Together, Part I and Part II form the CEI specifications for an end item which can be given to a manufacturer to produce the required end item as a contract deliverable. Part II Specifications are usually available for Critical Design Reviews (CDRs). When a first article is produced, it may be reviewed and approved in First Article Configuration Inspections (FACIs) to enable Category II (System) testing to proceed.
SRA	System Requirements Analysis (see WBS Dictionary Element 5.0).
Stage I	Boost stage of the Space Transport Air Vehicle (see WBS Dictionary Element 1.4).
Stage II	Orbital stage of the Space Transport Air Vehicle (see WBS Dictionary Element 1.3).

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Stage I (or II) System Test and Checkout Specification	A specification which integrates all system test and checkout requirements, criteria, safety, special test, recycle and support considerations into a single, controlled document for the development and conduct of system (Stage I or Stage II) test, checkout, and handling activities. The document specifies design and test configurations for airborne and ground subsystems and facilities associated with each system-level activity.
Static Firing	A full power hold-down test of Stage I or Stage II on the launch pad to verify ascent capability prior to mated flight test.
Structure Weight	The weight of the structural subsystem including fuselage, wings, tail and landing gears.
Systems Weight	Empty weight less structure weight.
	T
TBD	To Be Determined
TER	Time Estimating Relationship
T & H	Transportation & Handling (Equipment)
TPS	Thermal Protection System. The materials and their configuration which covers and protects the Stage from ascent and reentry heating.

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Traffic Model	A 10-year mission model generated by NASA to scope the expected number of flights needed to satisfy the Advanced Space Transport Program operational requirements. Currently, 445 flights are forecast beginning with 10 flights the first year and leveling off to 75 flights, each, in the 9th and 10th years.
Transport System Test and Operations Plan	A master plan that identifies overall test management philosophy, policy and major criteria/requirements relative to test and operational phases of the Transport System. The document provides the top planning within which Stage I and Stage II Test Plans may be developed and also serves to discipline the transition from test/development phase to Operational.
Transport System Test and Checkout Specification	A specification which integrates all test and checkout requirements, criteria, safety, special transport system test, recycle and supports considerations into a single controlled document for development and conduct of total transport system tests. The document provides the exclusive authorized basis for the preparation and execution of all testing performed upon the transport system. (Stage I, Stage II, payload, and support ground systems)
Turnaround Facility	The facility, located at the launch and prime recovery site configured to receive, maintain and prepare Stage I and Stage II for the next mission. (See WBS Dictionary Element 11.0.)
TVC	Thrust Vector Control. The means to control thrust direction by either moving the nozzle (gimballed), or by deflecting the thrust gases, to achieve vehicle pitch or yaw. When nozzles are vectored asymnetically (opposite), roll is achieved. For purposes of this study, TVC means gimballing the nozzles using hydraulic actuators.
Type I Distribution	A frequency distribution or histogram.

U

UHF	Ultra-high Frequency
USB	Unified S-Band

V

VAB	Vertical Assembly Building. A facility for erecting and mating Stage I to Stage II, then mating the Air Vehicle to the Mobile Launch Umbilical Tower for movement to the launch pad.
VHF	Very High Frequency
VMSC	Vought Missiles and Space Company, LTV Aerospace Corporation (Dallas, Texas)
VOR	VHF Omnidirectional Range
VORTAC	VHF Omnidirectional Range/Tactical Air Navigation (Combination)

W

WBS	Work Breakdown Structure
WBS Dictionary	(VMSC) The compendium of WBS Dictionary Elements which, together, establish the complete set of requirements needed to meet Program objectives
WBS ID	Work Breakdown Structure Identification

WBS Dictionary Element	(VMSC) A preliminary Part I Specification for a Work Breakdown Structure element needed to satisfy one or more Program objectives. The element statement also contains a list of the next lower level elements, a functional description of the element, a set of design requirements (if applicable), the direct interfaces with the element, and the tests (if applicable) which must be conducted during the development phase to ensure the element will meet requirements.
Work Breakdown Structure (WBS)	(NASA) A hierachy of levels of hardware oriented (cost) packages. (MIL-STD-881) A product-oriented family tree composed of hardware, software, services and other work tasks resulting from Project Engineering efforts during the development of a defense materiel item, and which completely defines the project/program. A WBS displays and defines the product(s) to be developed and produced and relates the elements of work to be accomplished to each other and to the end product.
W/T	Wind Tunnel
WTR	Western Test Range
	Y
Y_{act}	Y_{actual} is the actual time a previous hardware program required to complete a predetermined schedule milestone. (See Y_{est})

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Y_{est}	$Y_{estimate}$ is the predicted time to complete a predetermined schedule milestone. This prediction is the output of a selected regression equation. Within this report Y_{est} is used to present the estimated time required to complete a given schedule milestone for the Advanced Space Transport Program. Y_{est} is further used to compare to Y_{act} for each program in the historical data base. As pointed out in Section 3, Introduction to Time Estimating Relationships (TERs)* the multiple regression model has the capability of taking the independent variables for each program in the historical data base, processing these variables through the selected estimating equation and printing out a comparison matrix with how long the program actually took (Y_{act}) and what the selected equation predicted the program would have taken (Y_{est}). If the difference between Y_{act} and Y_{est} is small, then the equation is further screened for potential deficiencies and may ultimately be used on estimating equation. (see Y_{act})

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