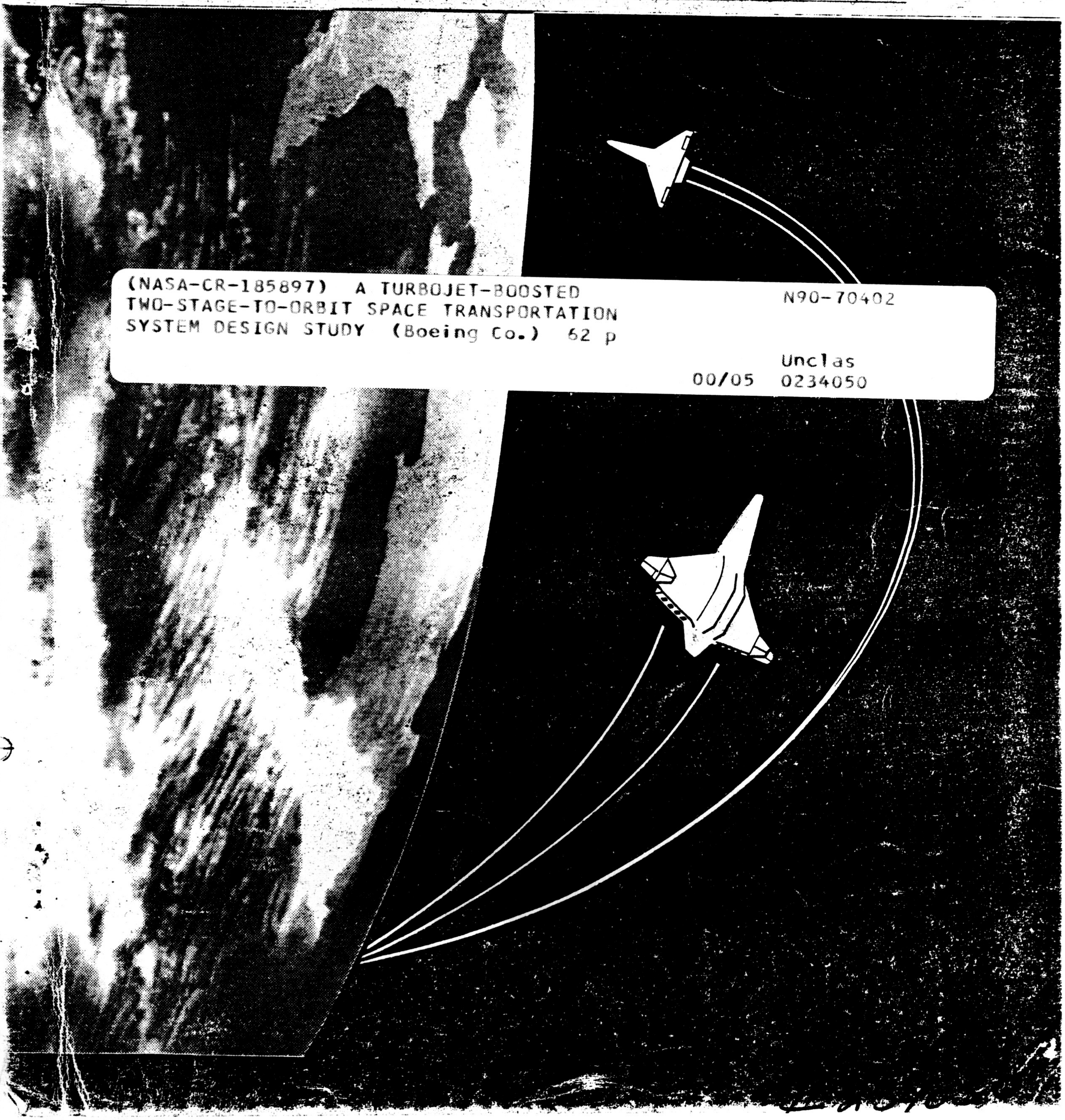
BOEING

D180-20788-1
Technical Proposal

A Turbojet-Boosted Two-stage-to-Orbit Space Transportation System Design Study



TECHNICAL PROPOSAL

A TURBOJET-BOOSTED TWO-STAGE-TO-ORBIT SPACE TRANSPORTATION SYSTEM DESIGN STUDY

D180-20788-1

SUBMITTED TO
LANGLEY RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HAMPTON, VIRGINIA

IN RESPONSE TO
REQUEST FOR PROPOSAL 1-16-3730.0095

TRANSMITTED BY
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BOEING AEROSPACE COMPANY
SPACE SYSTEMS DIVISION
SEATTLE, WASHINGTON 98124

LIST OF FIGURES

1.0 INTRODUCTION

Boeing has been working on advanced fully reuseable earth-to-orbit transportation systems since June of 1972. The company's interest is based on the belief that the evolution toward lower-cost space transportation will continue and that fully-reuseable, airplane-type operations of space vehicles will allow considerable improvement in space transportation cost and flexibility.

Prior to 1972, the Boeing Company participated as a Booster Study Contractor in the development and analysis of two-stage Space Shuttle System Concepts. Activities during this period involved development of aerodynamic data, separation systems, and structural concepts (heat sink approach) that have applicability to support the proposed study.

Singe 1972, Boeing has concentrated on the horizontal take-off and landing Single Stage-to-Orbit systems. Boeing's Advanced Space Transportation activities consist of past and on-going company funded Internal Research and Development Studies and Technology Development and Contracted Studies. The recent contracted studies have included "Advanced Earth Orbit Transporation System Technology Requirements - NASA contract" Reference 1 and "Reuseable Aerodynamic Feasibility and Operations Analysis Studies - Air Force Contract", Reference 2.

The study will be conducted using orbiter vehicle (second stage) configurations that are generic to those developed during the NASA and Air Force funded studies. Extensive technical and operational information has been developed for this class of vehicles, hence insuring a source of viable data on which the study can build and demonstrate comparative performance.

The study will be initiated by defining critical technology levels and design parameters that will then be used to assess system performance of both supersonic and subsonic staging for a two-stage-to-orbit-vehicle system. Utilizing this evaluation, a vehicle system concept will be selected for continued technical analysis, and definition of performance, operational characteristics and life cycle costs.

The study will be conducted under the Program Direction of Andrew K. Hepler. Mr. Hepler has been in charge of the single-stage-to-orbit research and contracted studies since 1972 and has had key assignment on X-20, Supersonic Transport and Subsonic Airplanes. Mr. Howard Zeck, the technical leader of the proposed study has directed the aerodynamic and performance activities of Boeing's single-stage-to-orbit studies and currently a NASA CCV Study contract. Mr. Zeck has directed and performed similar assignments for both subsonic and supersonic aircraft and booster studies. A multidisciplined technical team currently working on Advance Space Transportation systems will support all study activities.

This Proposal is organized in two major sections: The Study Plan and the Technical Approach. The study plan defines our approach for organizing and scheduling tasks, study organization, task assignment within the study organization, and the distribution of effort by task. The technical approach section outlines, for each task in the RFP statement of work, the key problems to be addressed and how Boeing will address them.

2.0 STUDY PLAN

The activities and the organizational approach used to accomplish this study will be a straight forward extension of a highly integrated, multidisciplined supported Advanced Earth-Orbit Transportation Research Program under way at Boeing. Engineers who have been supporting this effort will be assigned and made responsible for handling their discipline in the proposed study effort.

The study requirements are complementary to the Boeing program that has developed a Sled Assist-Horizontal Take-Off-Horizontal Landing Earth-Orbit Transportation System.

Consistent with the RFP Statement of Work, the proposed study is divided into four fully responsive interdependent tasks. The overall task logic is shown in Figure 1

Task I: Analysis and Trade Study--This task as shown in Figure 1 will provide study technology performance data, system component trade studies and design parameters and a top level assessment of the characteristics of three approaches to horizontal take-off-two-stage earth-to-orbit Transportation Systems. The task is initiated by NASA definitions of the system guidelines and constraints. Technology level projections will be established to discipline the ongoing design. Technology and design parameters will be developed to aid in configuring the three concepts proposed for this study. These concepts will be recycled through the technology projection and trade study activities to insure adequate data to support selection of the Task II study system. Further, Critical Technical Problems associated with each concept will be defined, assessed and solutions postulated in support of the Task II System Selection Process.

Task II: Conceptual Design: This task is represented by a network of events (Figure 1) covering configuration definition and analysis, aero-characteristics, weights, and performance for the selected Task II System. The task consists of defining the configuration, defining subsystems performance requirements and environments, selecting subsystem concepts, analyzing and sizing subsystems and calculating total configuration weights. System performance and characteristics to be developed will include take-off and staging technique, velocities, distance, attitudes and altitudes. The output of Task II will (1) provide data to evaluate the potential performance and development of the two-stage-to-orbit horizontal take-off system and (2) provide the system data to develop Task 3 Operational Characteristics and Life Cycle Costs and the Task 4 Technology Requirements and Development Plan.

Task III: Utility and Economic Analysis - This task (Figure 1 will develop the operational characteristics and life cycle costs of the system defined by Task II activities. The operational analysis will include definition of ground handling activities and required manning, earth logistics approach (self ferry) and orbital payload capabilities. The data developed under Tasks I and II will be used in developing these system characteristics. Preliminary life cycle costs will be developed for the Task II system utilizing the NASA defined mission model.

Task IV: Technology Assessment - Technology Requirements and Associated Development Plans will be prepared using as a basis the characteristics of the Task II system (See Figure 1). Development Planning for critical aerodynamic

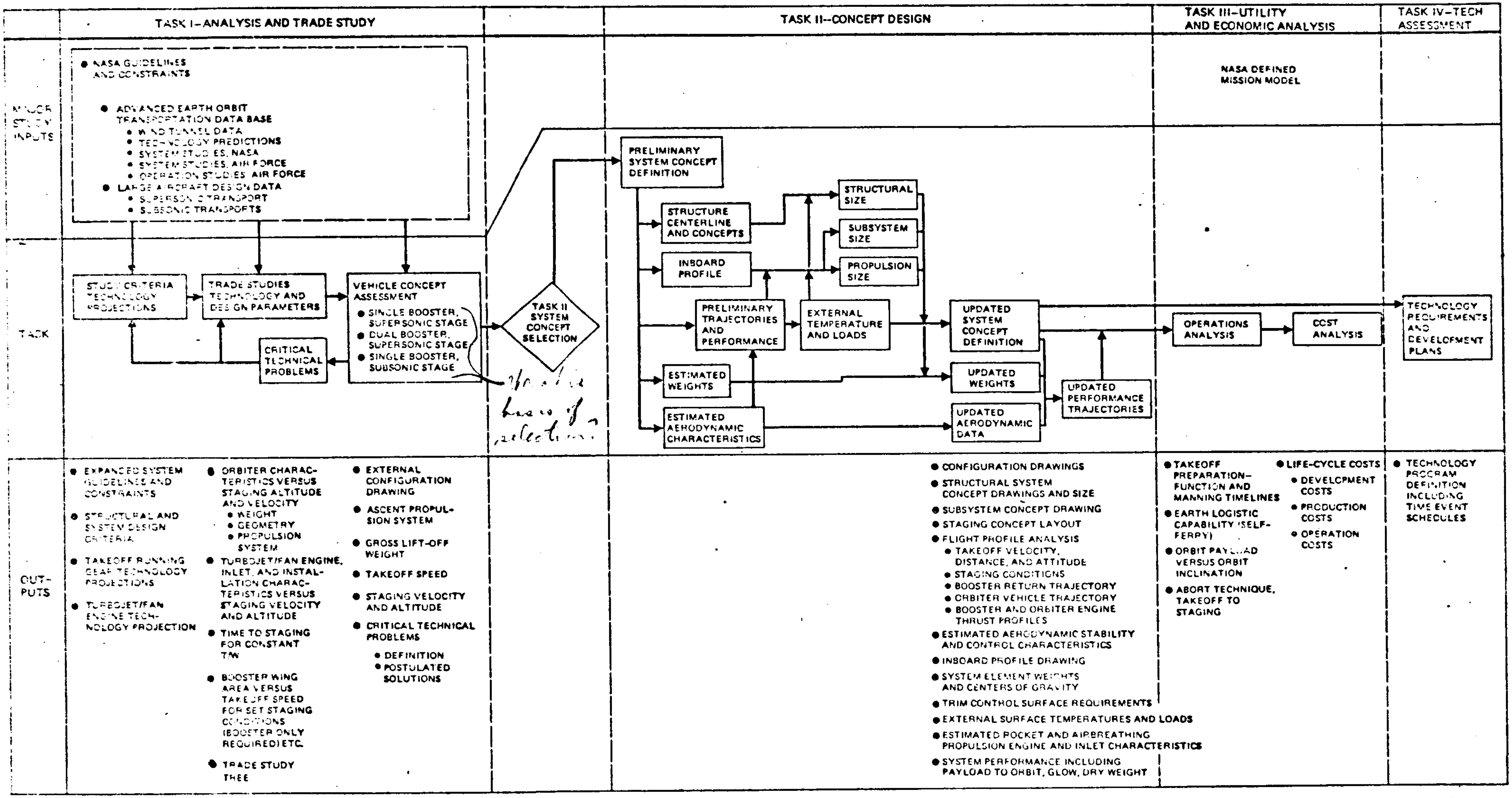


FIGURE 1 -OVERALL TASK FLOW LOGIC

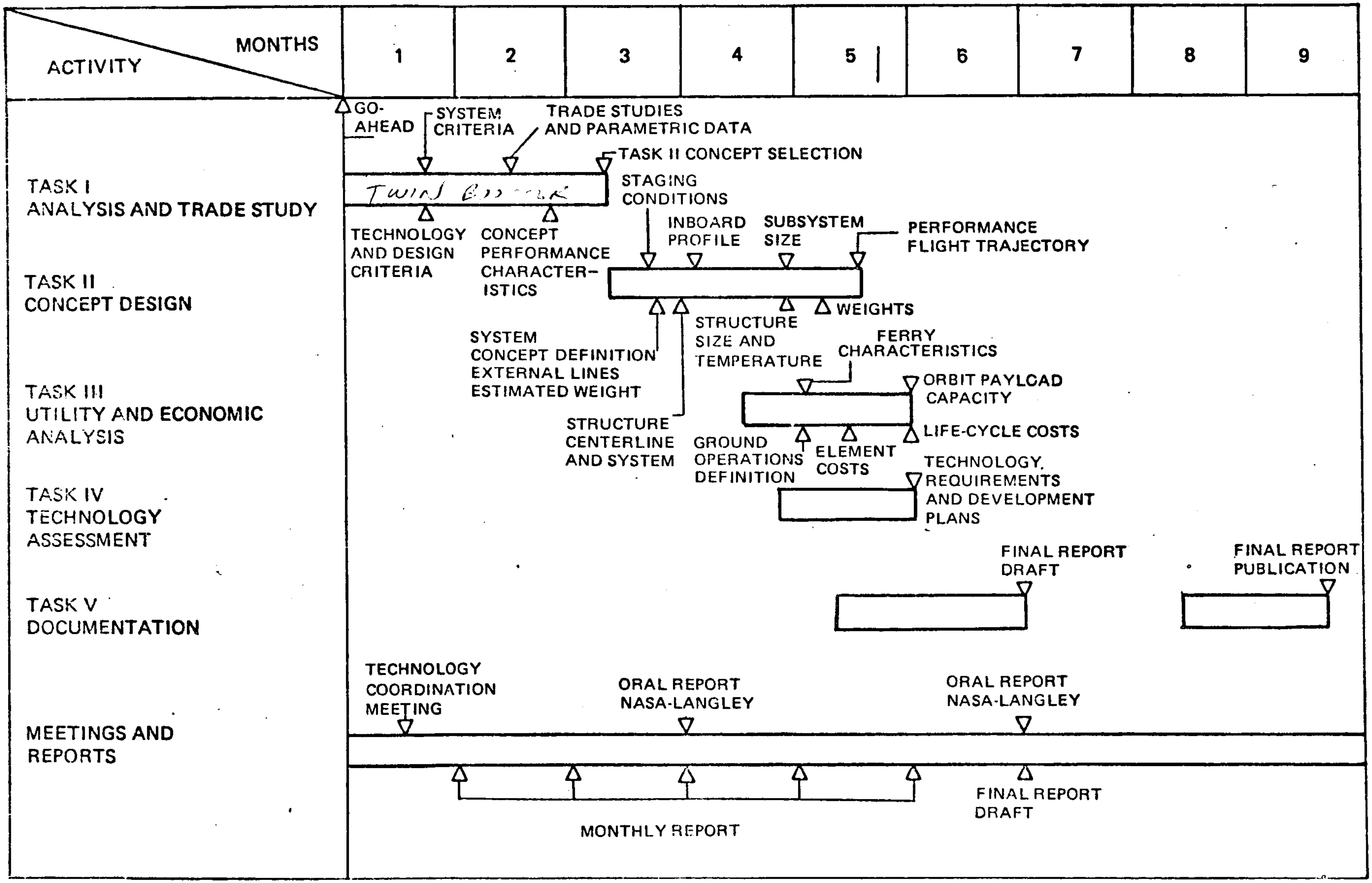


FIGURE 2 – *Study Schedule for Turbojet–Boosted Two-Stage-to-Orbit Space Transportation System Design*

and propulsion technologies shall include time relationships between major events. Technology development capability shall reflect opinions of both Boeing in-house and industry wide experts.

Distribution of Effort - The distribution of study effort will be as follows:

Task I	Task II	Task III	Task IV	Documentation and Report
30%	35%	12%	6%	17%

The master schedule of the major events is shown in Figure 2. Reporting and documentation, including quantities and distributions, will be in compliance with the RFP and as shown in Figure 2 . The study organization is shown in the companion business proposal document D180-20788-2 Business and Cost Proposal.

3.0 TECHNICAL APPROACH

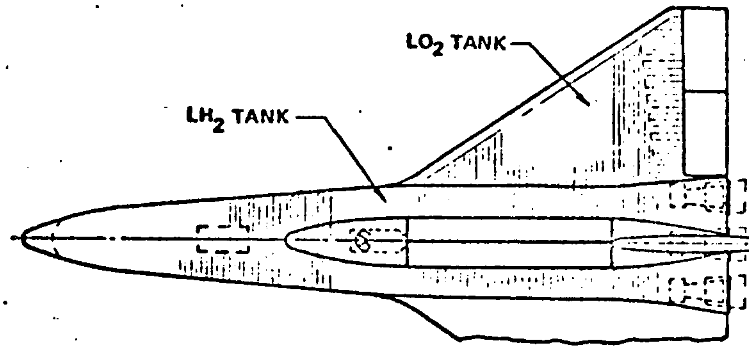
3.1 INTRODUCTION

Through both NASA and Air Force Sponsored studies and Boeing in-house research efforts, a generic family of Single-Stage-to-Orbit (SSTO) fully reuseable, horizontal take-off and horizontal landing vehicles have been developed. Further through these activities both subsystem and structure technology level predictions for the 1990 time period have been made and documented.

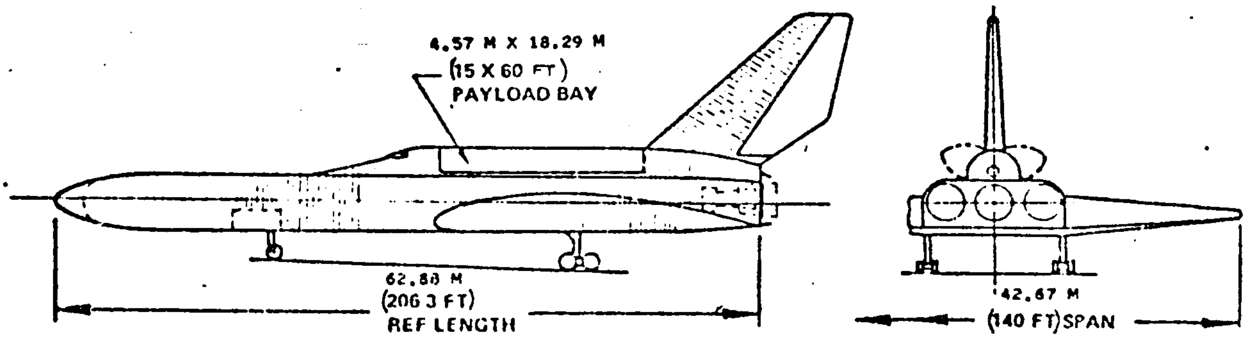
To maximize the effort that can be spent on developing the First Stage Air-breathing Booster for the two-stage system, the orbiting vehicle to be used in the proposed study will be generic to those developed under the above stated studies. For this type of system, there exists significant wind tunnel aerodynamic and thermal data, structural and subsystem concepts and weights and, a set of controlling design criteria and technology projections.

These data have been documented under Reference 1 (NASA Contract) and Reference 2 Air Force Contract. The vehicle developed under Reference 1 is shown in Figure 3 and has an easterly launch payload of 65,000 pounds. The vehicle developed under Reference 2 is also shown and has an easterly launch payload of 27,000 pounds.

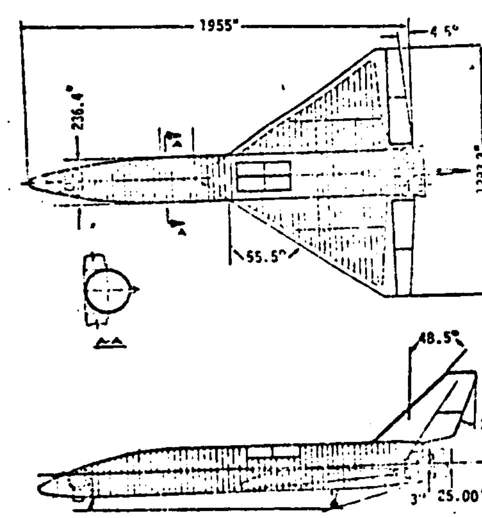
SINGLE-STAGE-TO-ORBIT (SSTO) PL = 65K, EAST



CHARACTERISTICS			
W_{INJ}	=	(319,500 LB)	144,923 Kg
W_P	=	(1,884,000 LB)	854,568 Kg
GLOW	=	(2,203,500 LB)	999,491 Kg
λ'	=	.88	
WING AREA	=	(9,484 SQ FT)	881 M^2
FIN AREA	=	(1,250 SQ FT)	116 M^2
THRUST (VAC)	=	(2,086,050 LB)	9,279 KN
T/W @ LIFTOFF	=	.78	
LIFTOFF SPEED	=	(600 FT/SEC)	183 M/SEC
LANDING	=	V = (157 KNOTS) α = 8°	80.77 M/SEC



REUSABLE AERODYNAMIC SPACE VEHICLE (RASV) PL=27K, EAST



DESIGN DATA

WEIGHTS		
GLOW	1.22×10^5 LB.	
INJECTED	156,860 LB.	
PAYLOAD	10,000 LB. POLAR	
WING		
REFERENCE AREA	5,632 FT.^{2}	
EXPOSED AREA	3,992 FT.^{2}	
CONTROL SURFACE AREA	638.55 FT.^{2}	
ASPECT RATIO	2.05	
SECTION	11.40%	
FIN		
AREA	650 FT.^{2}	
ASPECT RATIO	1.21	
SECTION	8%	
VOLUME/PROPELLANT WEIGHTS		
WING LO_2 TANKS	13,807 FT.^{2}	934,000 LB.
BODY LH_2 TANKS	37,453 FT.^{2}	155,024 LB.
PROPULSION	EXPANSION RATIO	
	50:1	151:1
THRUST (SEA LEVEL)	442,760	---
THRUST (VACUUM)	503,070	524,450

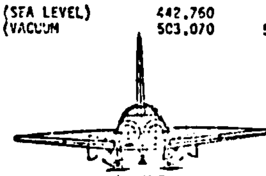


FIGURE 3 - CANDIDATE ORBITER VEHICLES (PAST STUDIES)

The study will be conducted For a single NASA defined maximum orbit payload weight and payload bay size. The technical approach to be followed in accomplishing the study plan events (Figure 2) together with applicable data illustrating background and technical expertise is presented in the following sections.

3.2 TASK I - ANALYSIS AND TRADE STUDY

This task shall be initiated using guidelines and constraints supplied by NASA. This proposal is developed around the criteria set out in Section 2 of Reference 3 .

3.2.1 Study Criteria and Technology Projections

Under Reference 1 Earth-to-Orbit Transportation System Design Criteria was developed that has direct applicability to this proposal. Supplemental criteria applicable to the first stage will be developed using as reference sources Military Specification and Supersonic and Subsonic Large Aircraft Design Criteria. The technology projections will utilize the positions developed and documented in Reference 1 together with similar data to be developed for requirements unique to the first stage vehicle and the staging concepts. Technology forecasting (to the 1990 time period) will be accomplished by application of judgement and experience to current technology status, assessing the theoretical capabilities of the technology under investigation, and utilization of current and projected research and development trends. Technology will include turbojet engines and supersonic turbojet engine inlets. Current technology projections for turbojet engines are illustrated in Figure 12 .

3.2.2. Trade Studies/Technology and Design Parameter

The general nature of a preliminary vehicle conceptual study is first to establish the overall vehicle performance potential through trade studies leading to an optimized feasible baseline configuration. Along with these trades are aerodynamic, propulsion, structural and configuration analyses to identify critical unique problems which may negate the feasibility of the vehicle concept. Where possible, solutions will be postulated to these problems and selectively incorporated into the finalized baseline vehicle design. In some instances, it may not be possible to evaluate in detail the feasibility of such solutions but only propose follow-on technology for research development. The major trade studies are summarized in Figure 4 , as a trade study tree and are discussed in detail in the following sections.

3.2.2.1 Vehicle Performance and Trades - The isolated orbiter performance will be based upon Boeing past and current studies of a horizontal take-off (sled launched) single-stage-to-orbit vehicle (SSTO). Other essential input data for determining overall vehicle performance (i.e. Glow, dry weight and payload to orbit) are a weights breakdown and the rocket engine characteristics. Booster input characteristics both isolated and mated will be estimated by established in-house preliminary design methods. Ascent flight profiles will be determined by well established trajectory computer programs Reference 4 and 5 . Mini-computer programs will be used to perform parametric trade studies which can combine vehicle performance and preliminary life cycle costs in one pass through the analysis.

Any change in the external configuration of the booster/orbiter must first be evaluated in terms of changes to the aerodynamic characteristic of the vehicle before its overall performance can be determined. Thus the Aerodynamic lift and drag of the booster and orbiter in both the isolated and combined configurations will be established prior to trajectory runs. The trajectory runs will determine the best ascent profile from the standpoint of minimizing the fuel/propellant consumed to orbital injection conditions while observing enroute structural/heating constraints of the configuration. Once a preliminary configuration is determined to be feasible, trade studies (See Figure 4) around this baseline can be developed.

Once a preliminary baseline configuration has been established and the data

AERO/PERFORMANCE

AERO:

- o *GLOW VS BOOSTER WING SIZE
- o GLOW VS CONFIG. CONCEPT
- o T.O. DIST VS HIGH LIFT DEVICES

TRAJECTORY

- o *GLOW VS STAGING VELOCITY
- o GLOW VS STAGING ALTITUDE

PERFORMANCE

- o *GLOW VS A/B AND ROCKET SPLIT
- o GLOW VS ROCKET SIZE
- o GLOW VS PAYLOAD
- o T.O. DIST. VS A/B BOOSTER SIZE
- o A/B WT & FUEL VS A/B SIZE
- o VEHICLE PERF. VS LCC

* And Dry Wt.

PROPULSION

AIRBREATHER (A/B):

- o T/W VS CPR AND BPR
- o T & SFC VS CLIMB SCHEDULE
- o WT & SIZE VS THRUST SIZE
- o ENG. PERF. VS TURBOJET AND TURBOFANS

INLETS:

- o INLET TYPE VS DESIGN MACH
- o INLET RECOVERY VS INLET TYPE

CONFIGURATION

CONFIGURATION:

- o LAYOUT VS BOOSTER CANDIDATES
- o LAYOUT VS INLET/PROPULSION INTEG.
- o LAYOUT VS EXIT NOZZLE INTEGRATION

SUBSYSTEM

- o TAKEOFF SPEED VS T.O. GEAR
- o STAGING VELOCITY VS APU, EC, HYDRAULICS

FIGURE 4 - TASK I TRADE STUDY TREE

bank of weight trending compiled, parametric weights can be utilized to establish mass fraction plots of each stage (i.e. λ' = wt prop~~l~~ellant/stage wt.). From past studies, typical λ' trending plots are shown in figure 5. Because of the heavy weights of airbreathing engines and takeoff gear, the λ' for the booster stage will be lower than that of the orbiter. Overall performance can be evaluated in terms of the propellant (or fuel for booster) burned and λ' for booster/orbiter combinations, i.e.

$$PL/GLOW = \left(1 - \varsigma/\lambda'\right)_B \left(1 - \varsigma/\lambda'\right)_O$$

WHERE, PL = PAYLOAD

GLOW = GROSS LIFT-OFF WEIGHT

$$\text{PROPELLANT LOADING, } \varsigma_O = \left(\frac{WT_{PROP}}{GLOW - WT_B}\right)_O, \quad \varsigma_B = \left(\frac{WT_{FUEL}}{GLOW}\right)_B$$

$$\text{MASS FRACTION, } \lambda' = \left(\frac{WT_{PROP}}{WT_{STAGE}}\right)_{B \text{ OR } O}$$

B = BOOSTER

O = ORBITER

This performance relationship is used to establish staging velocity trades. At this point in the study, sufficient trajectory runs and weight trending will have been established to employ a minicomputer program to accomplish many of the vehicle performance trade studies, as illustrated in Figures 5 and 6.

The proper size and number of the A/B engines for the booster stage is one of the most important trade parameters as it has a major effect on take-off field length and fuel requirements for the booster. Such trades are schematically illustrated in Figure 6. Notice that the use of rocket engines "on" during the booster stage phase may enhance the vehicle's overall performance potential and this feature will be explored during the study. The addition of an A/B booster stage will probably permit a reduction in the number of rocket engines for the isolated orbiter stage. The results of the trade studies will provide a basis for selecting a vehicle concept for detail analyses in Task II.

3.2.2.2 Aerodynamics - The isolated orbiter aerodynamic characteristics will be

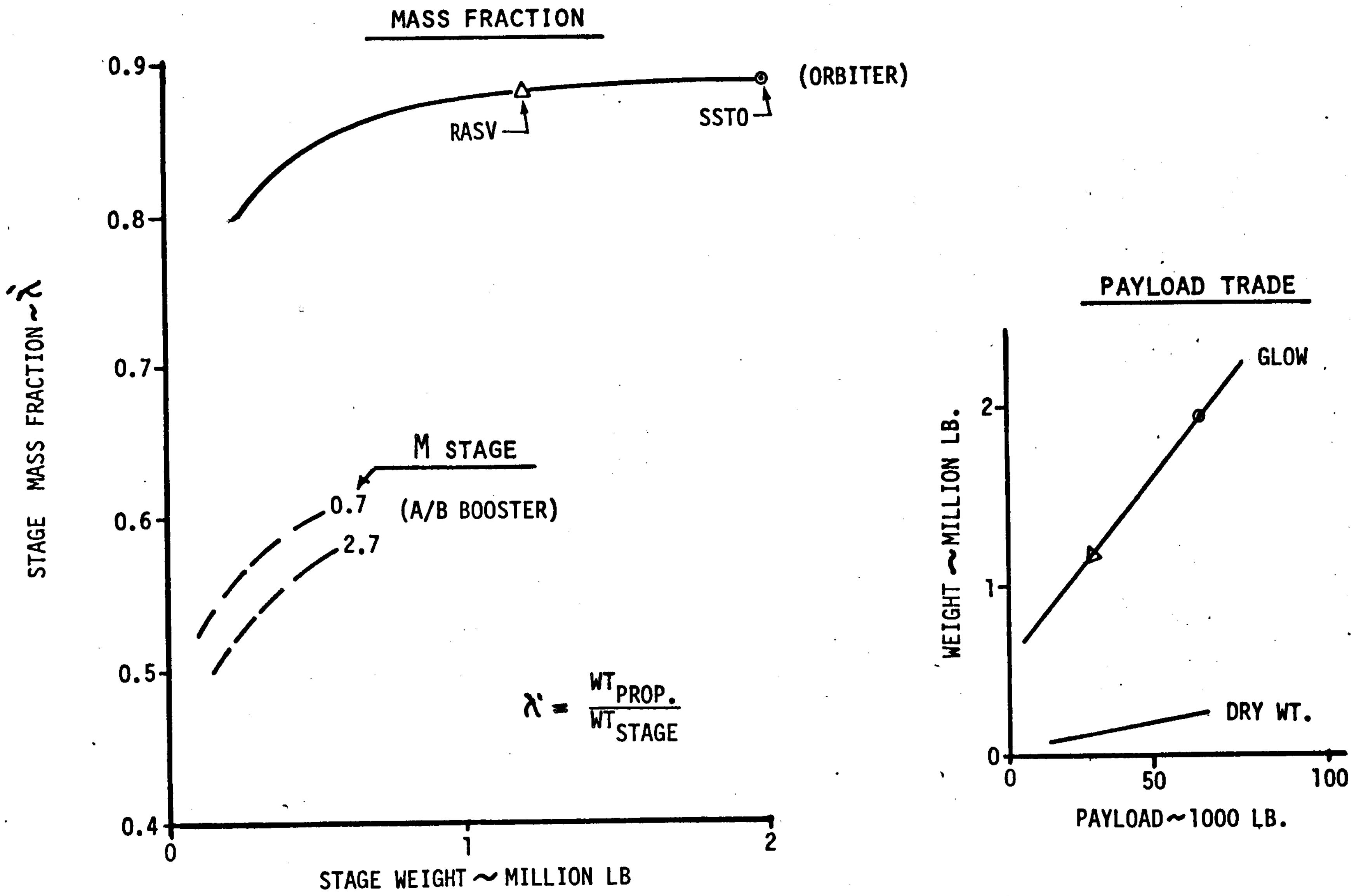


FIGURE 5 - PARAMETRIC WEIGHT/PERFORMANCE TRENDS

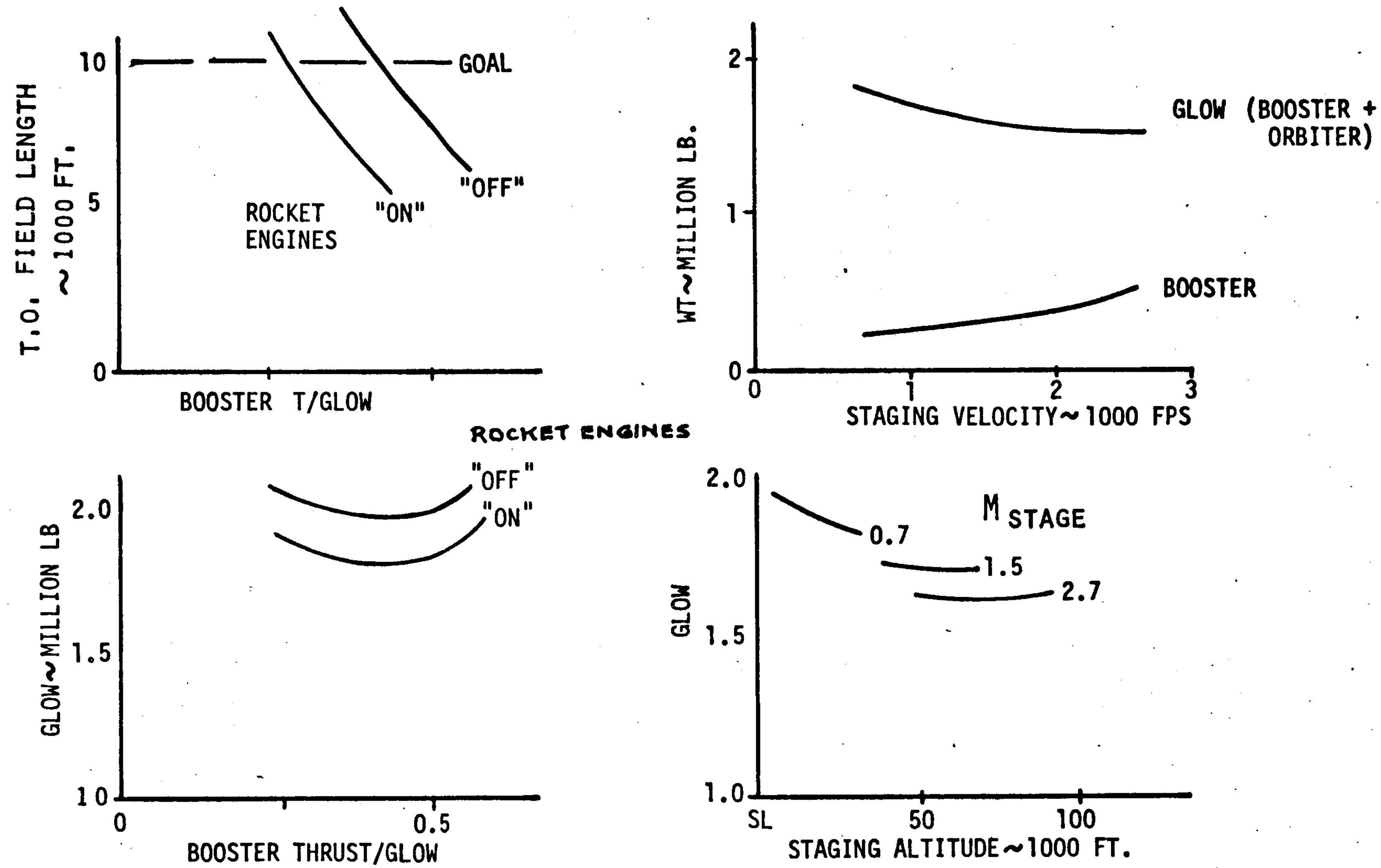


FIGURE 6 -TASK I VEHICLE PERFORMANCE TRADES

based upon Boeing SSTO configurations which have recently been wind tunnel tested at NASA Langley Research Center at speeds ranging from subsonic to high supersonic. The test data of the Boeing SSTO configuration will be available for use in this proposed study. For the isolated booster well established, in-house aerodynamic methods will be used to determine the aerodynamic characteristics of the configurations. See Figure 7 for examples of estimated aerodynamics of various wing/body/configuration from reference 6. These analyses include use of USAF "DATCOM" methods and space shuttle and SADSAC Aerodynamic Data Banks. Mated vehicle and aerodynamic interference effects will be assessed (See Section 3.2.3.1 on Critical Technical Problems for further discussions of these effects). A very important phase of the ascent performance will be the high transonic drag characteristic of the mated vehicles. Use of configuration area cross section variation plots along with empirical transonic drag correlations and computer programs will permit the transonic drag to be estimated with sufficient accuracy for preliminary design purposes. Figures 8 illustrates the type of transonic drag characteristics which will be determined during the study. Thrust (T) and Drag (D) in terms of T/δ and D/δ (where δ = altitude pressure ratio) for airbreathing propulsion for various weight/δ's and versus Mach number is a very useful technique for evaluating climb and acceleration characteristics is also shown on Figure 8.

Aerodynamic trade studies will investigate booster wing size, configuration concepts and booster high lift devices as indicated in the trade study tree, Figure 4. The booster wing size must basically be able to support itself (isolated) in take-off, ferry cruise and land in normal and aborted missions and optimistically also provide some assisted lift characteristics during take-off and ascent. This may be possible by favorable wing location and planform of the booster (See Figure 9) which may increase the effective aspect ratio of the mated configuration. Other possibilities include the use of high lift devices on

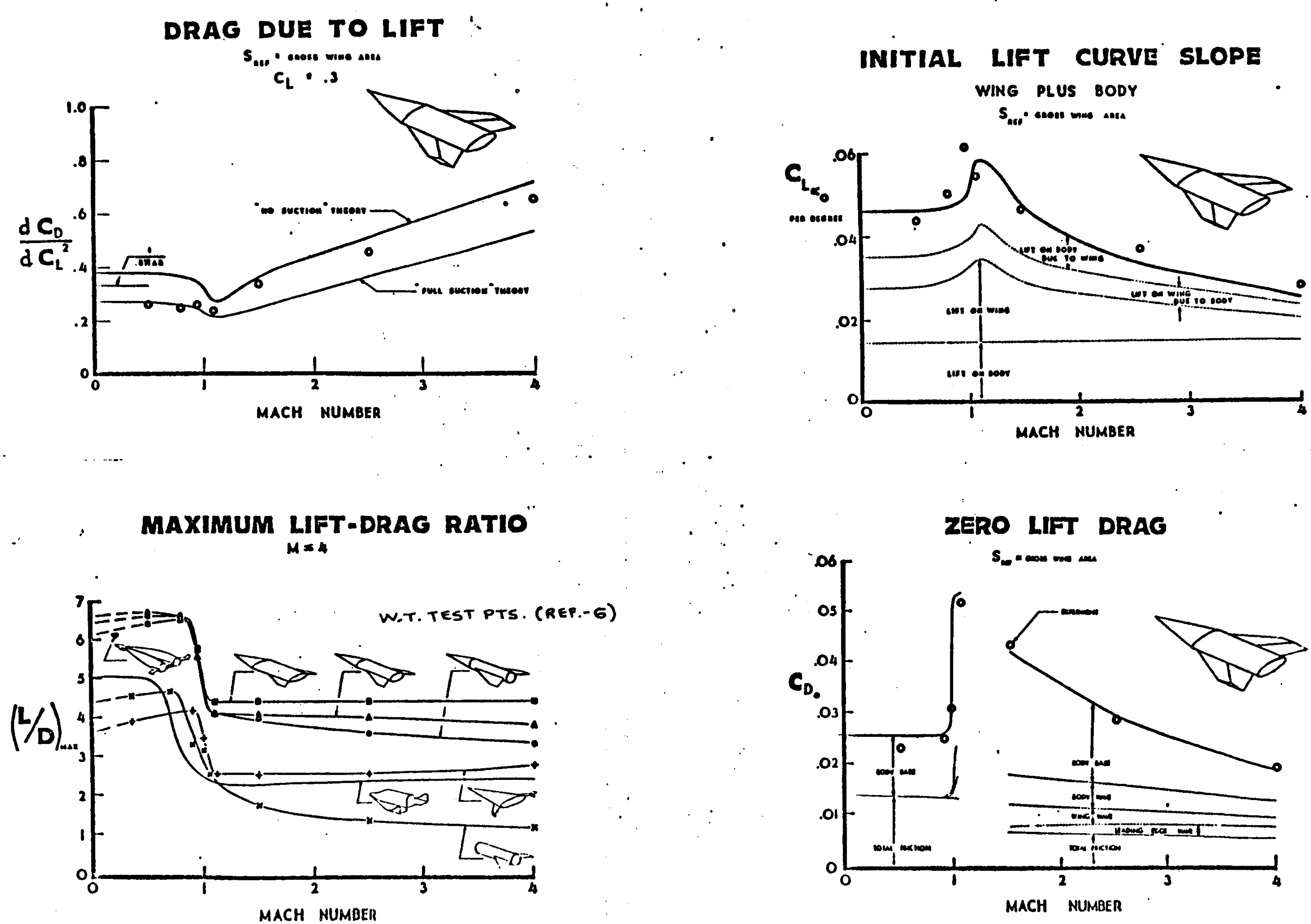
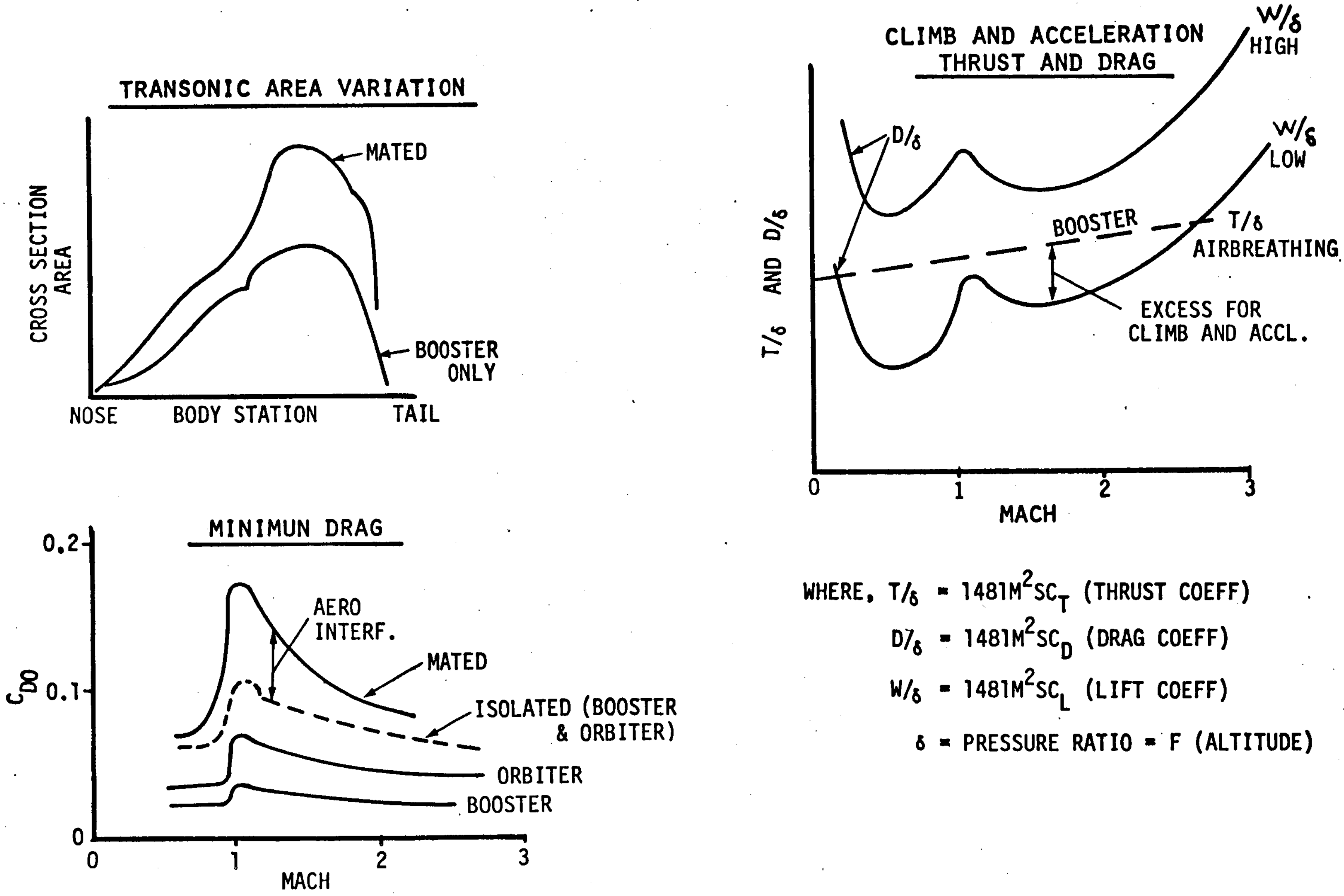


FIGURE 7 -LONGITUDINAL AERODYNAMICS



WHERE, $T/\delta = 1481M^2SC_T$ (THRUST COEFF)

$D/\delta = 1481M^2SC_D$ (DRAG COEFF)

$W/\delta = 1481M^2SC_L$ (LIFT COEFF)

δ = PRESSURE RATIO = F (ALTITUDE)

FIGURE 8 DRAG AND THRUST RELATIONSHIPS

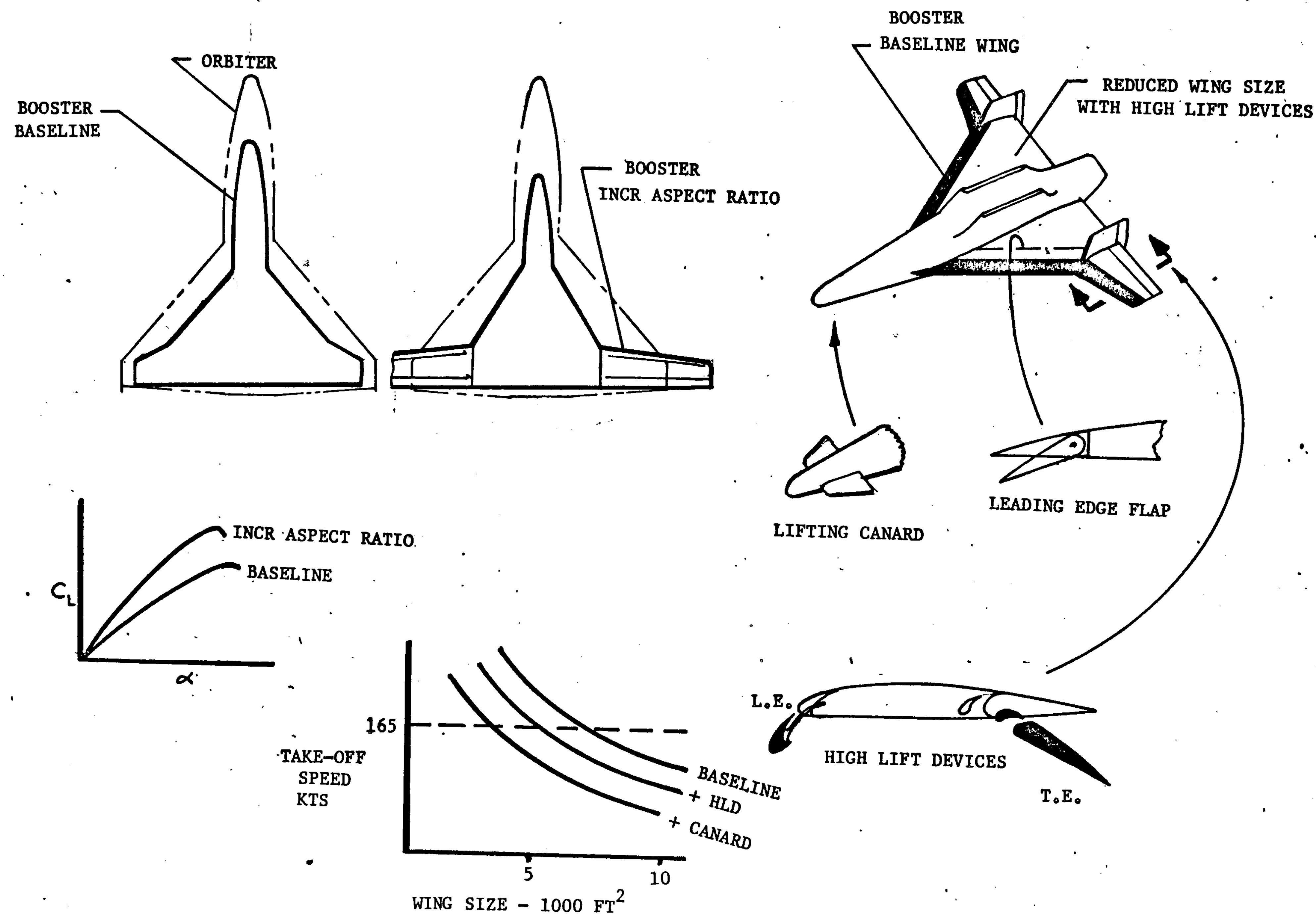


FIGURE 9 - TASK I BOOSTER WING TRADES

the booster to minimize wing size. Also, consideration in these trades will be any unique mated configuration arrangements which appear feasible in solving some of the identified technical problem areas.

3.2.2.3 Airbreathing Inlet/Propulsion - The Boeing Company has the technical tools, capability, and past experience to handle the analysis and selection of airbreathing turbojet/turbofan powered propulsion systems suitable for use as acceleration devices for the shuttle-orbiter carrier.

Boeing Military Airplane Development Propulsion Technology Staff is currently engaged in a series of contracts (references 7 and 8) and company funded IR&D studies to improve and develop new capability in the technology areas of advanced inlets, nozzles and engine cycles.

Trade studies will be made to aid in the engine cycle selection and in the determination of the thrust size required. For cycle selection, famalies of scaleable parametric engines exist for both supersonic and subsonic design applications. Figures 10 and 11 present (as an example for supersonic application) a summary of the performance and geometric and weight data for a family of parametric engines based on SST engine technology. These data are presented for both turbojets and turbofans in an underwing pod installation.

The supersonic engines presented above and those available for subsonic application may be scaled to thrust sizes required for this application using engine scaling correlations derived by Boeing (See Reference 9). Figures 11 and 12 illustrates the results of the correlation on engine weight and length with hardware engine data shown for comparison. Propulsion characteristics will include engine weight, length and maximum diameter as a function of engine thrust size for augmented turbojets and turbofans. Performance trades will be made on takeoff performance , climb and cruise performance utilizing the engine characteristics Figure 13.

The Boeing military aircraft experience in inlet and nozzle design and perform-

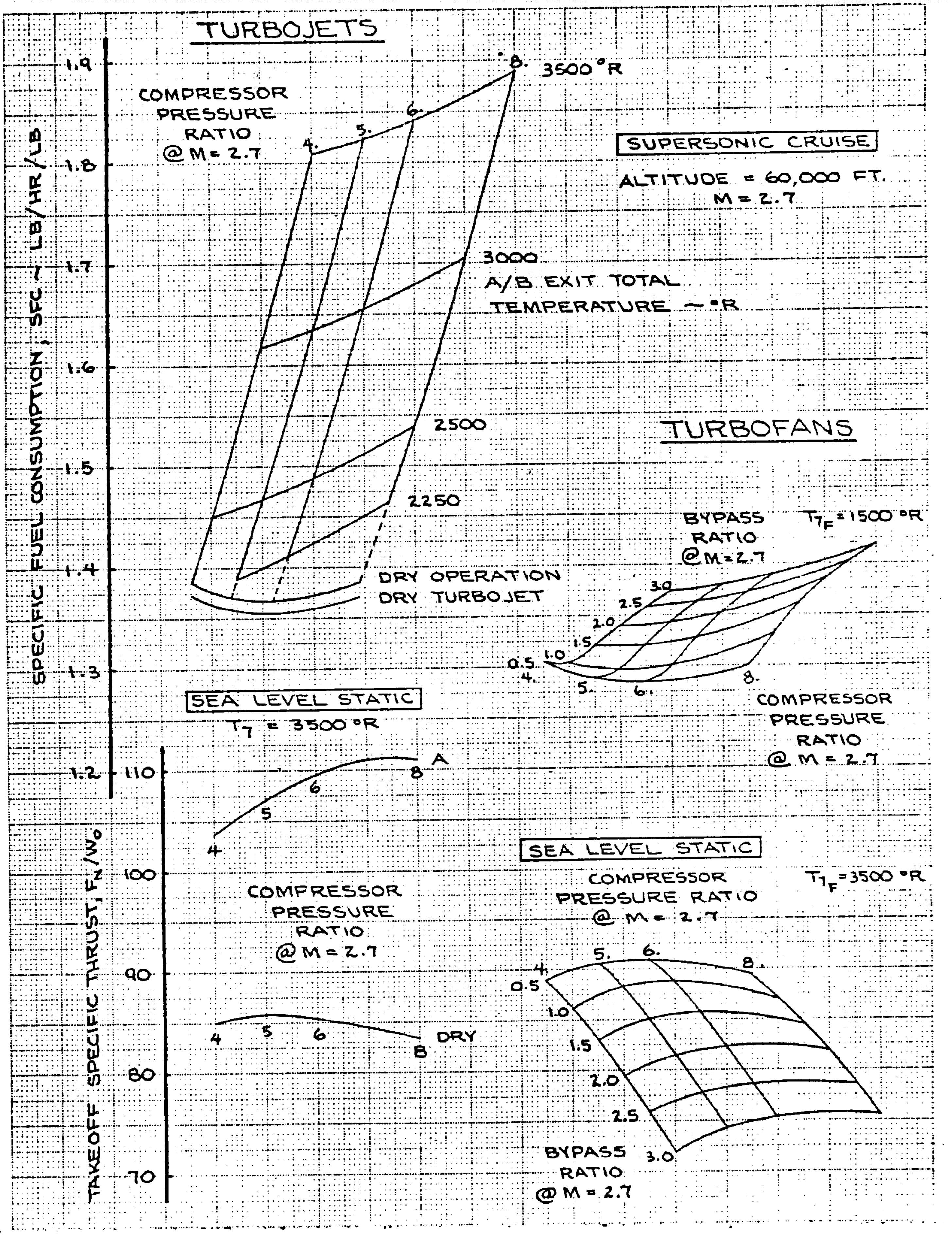


FIGURE 10 - AIRBREATHING-ENGINE PERFORMANCE TRADES

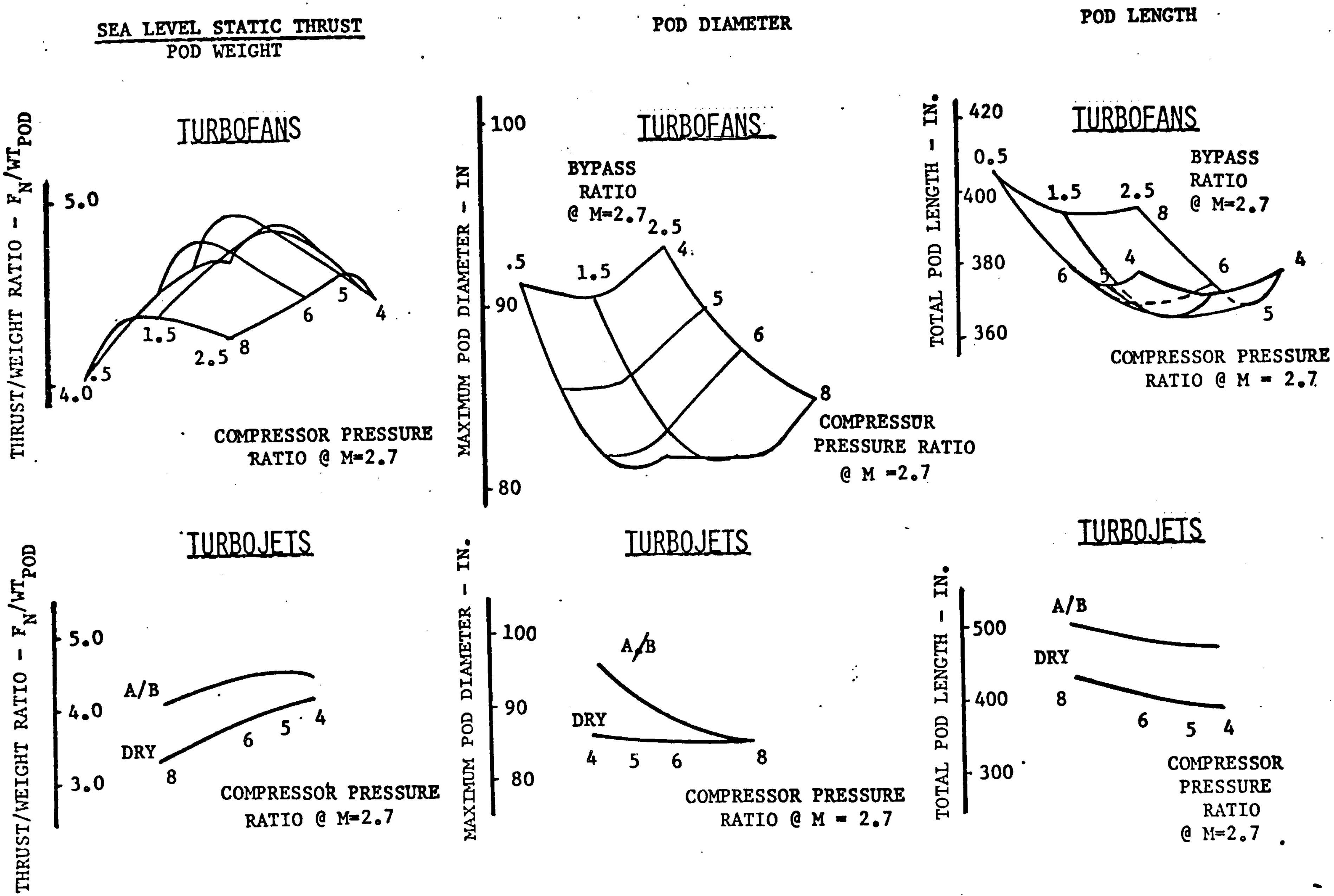
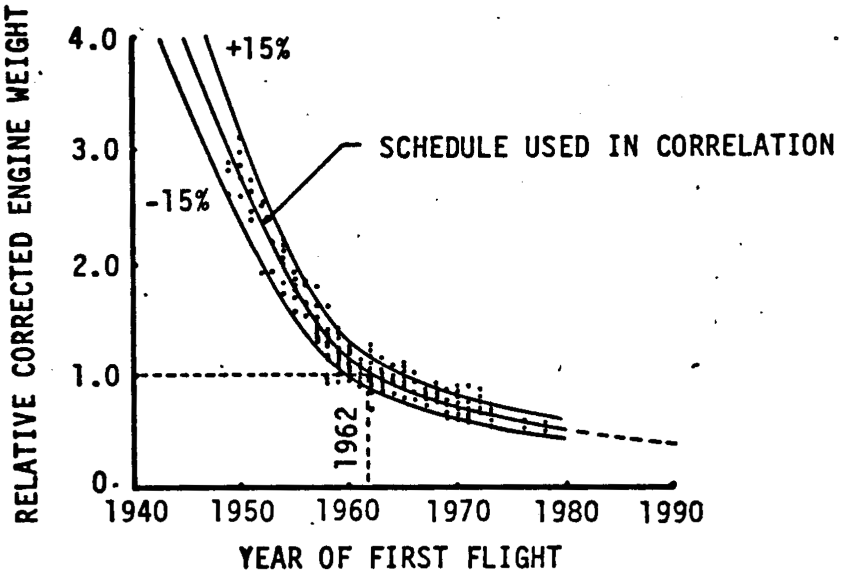
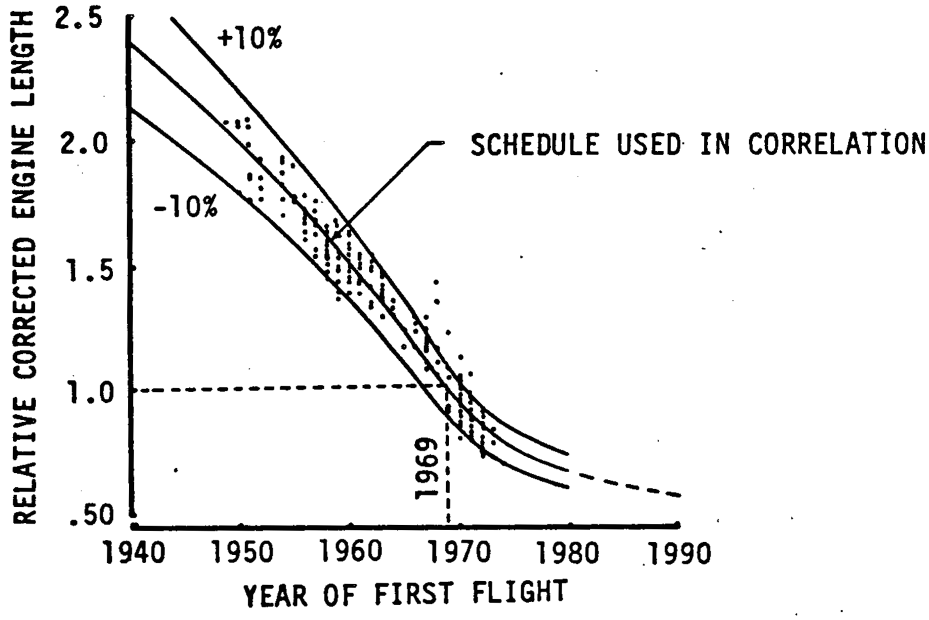


FIGURE 11 - AIRBREATHING-ENGINE WEIGHT AND DIMENSION TRADES



RESULTS OF WEIGHT CORRELATION



RESULTS OF LENGTH CORRELATION

FIGURE 12 -AIRBREATHING-ENGINE SCALING CORRELATIONS

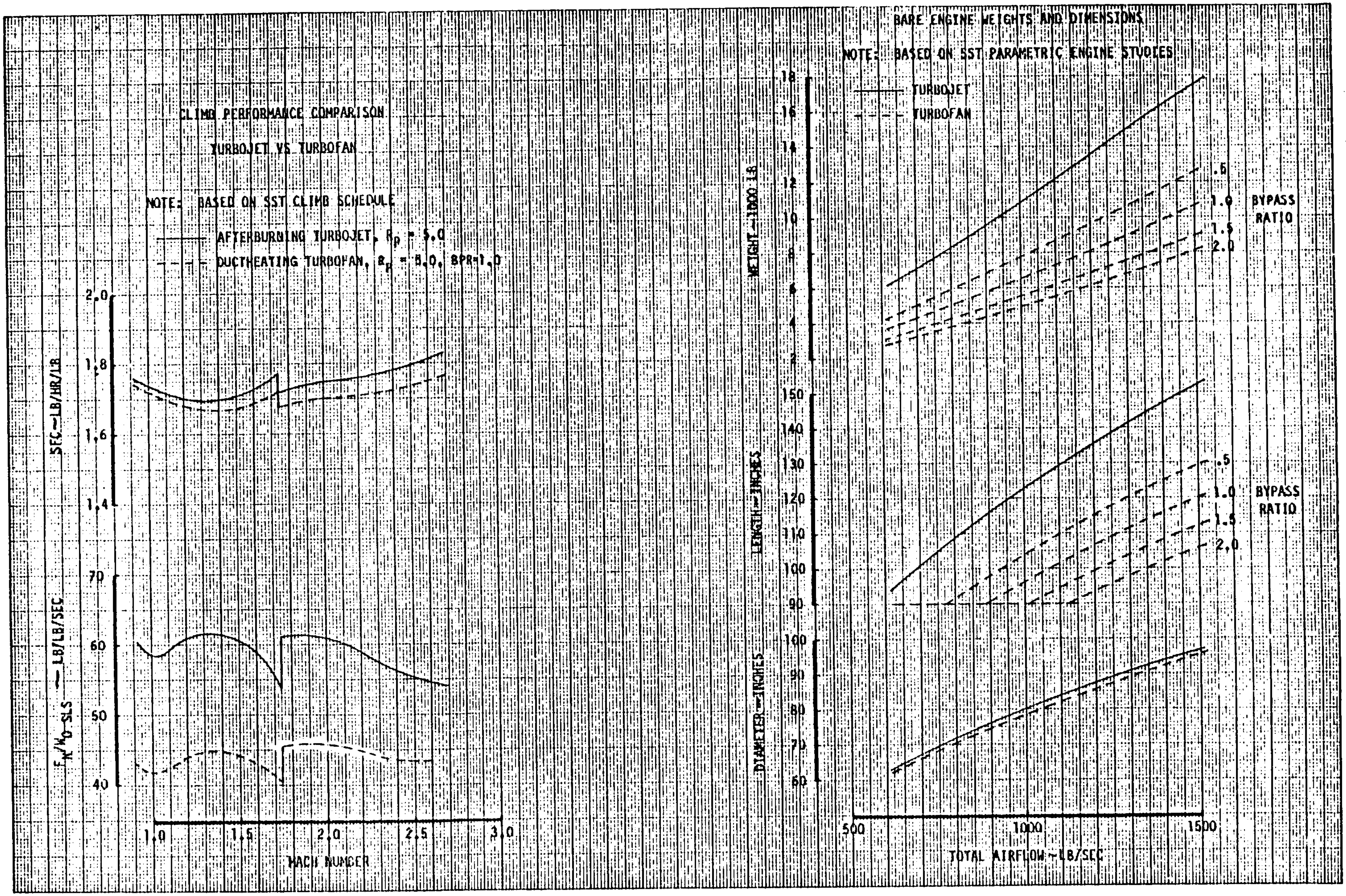


FIGURE 13-CLIMB PERFORMANCE AND WEIGHT AND DIMENSION SCALING

ance analysis will be utilized. Figure 14 presents representative inlets designed for supersonic and subsonic application.

A list of the major inlet/propulsion trades are presented in Figure 4 . Trades on inlet type vs inlet performance will be investigated. Figure 15 illustrates the spectrum of inlets available for investigation presenting pressure recovery as a function of Mach number and inlet type.

Figure 16 presents the various types of exhaust nozzles that could be utilized depending on the vehicle configuration and the integration of the propulsion system with the vehicle.

3.2.3 Critical Technical Problems

A major objective of this study is to identify critical unique problems of the turbojet-booster/rocket-orbiter vehicle system And develop feasible solutions which would be included in the finalized vehicle concept design. Prior to starting this study, it is recognized that mutual aerodynamic interference effects of the mated vehicles and the airbreathing inlet propulsion/configuration interface represent primary technical problem areas. These problems including considerations of the various phases of ascent flight profiles from take-off, transonic acceleration to supersonic staging and separation of the mated vehicles are discussed in the following subsections.

3.2.3.1 Aerodynamic Interference - Two-stage vehicles in a parallel arrangement configuration have been studied in the past and their mutual aerodynamic interference effects determined by wind tunnel tests. Theoretical calculations by Carmichael using Woodward's (Boeing) methods have resulted in restricted areas of agreement. The limited resources of the proposed study only justify a partial undertaking of such theoretical analysis. For the Space Shuttle Piggybacked to a 747 subsonic flow field efforts have been successfully estimated using Boeing's program TEA-230. (Ref. 10). An assessment will be made to uncover any critical technical problem areas caused by aerodynamic interference effects which include;

Boeing Military Inlet Types

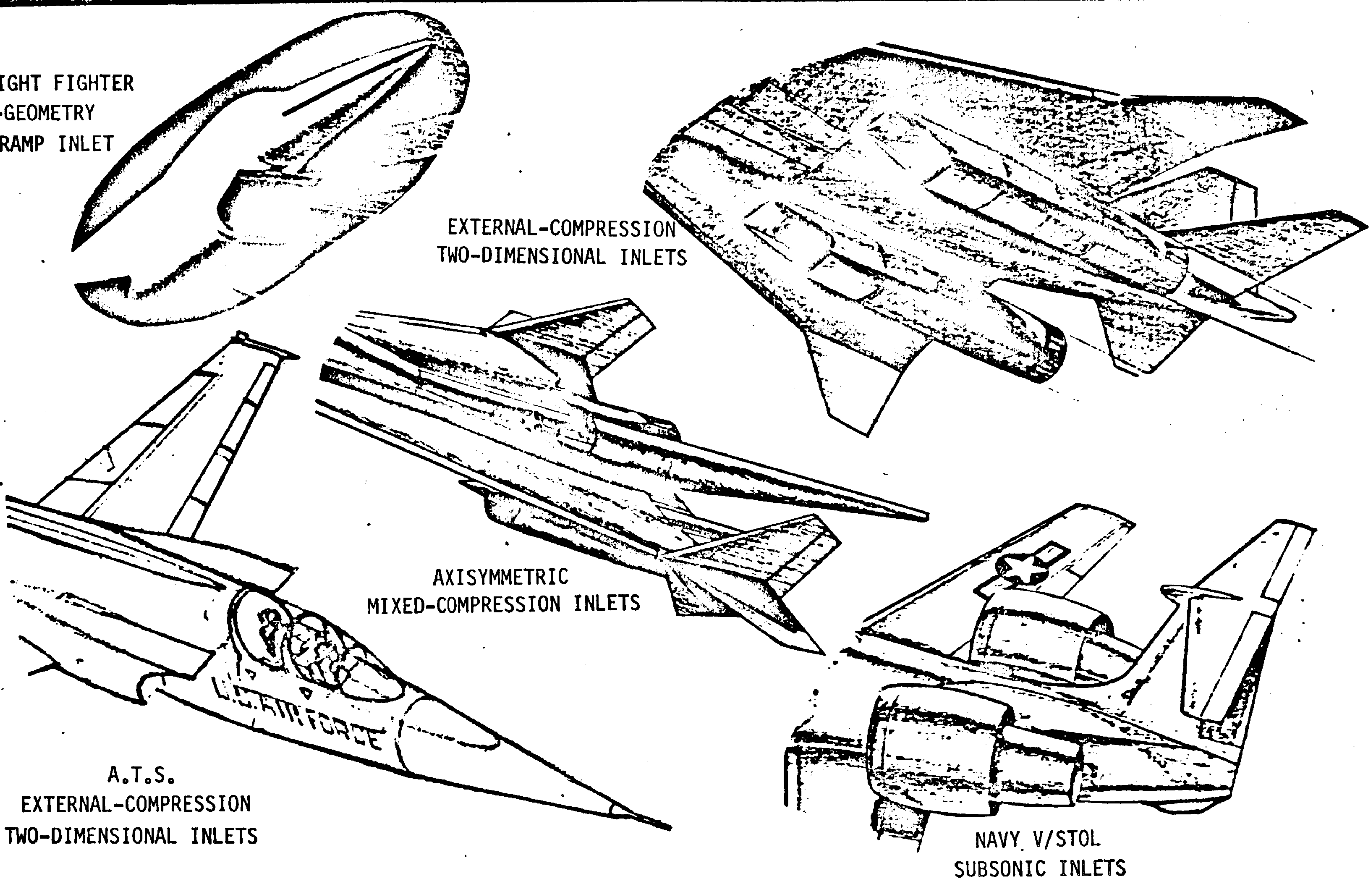


FIGURE 14 INLET APPLICATIONS

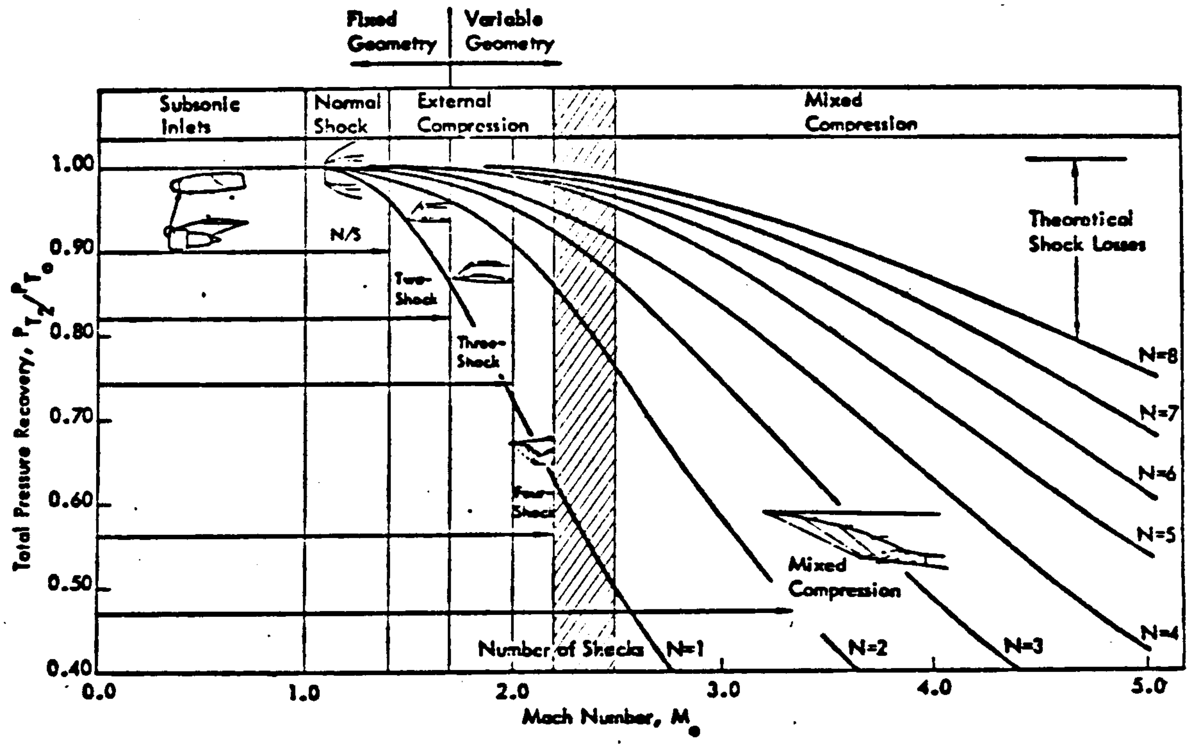


FIGURE 15 -TYPES OF INLETS

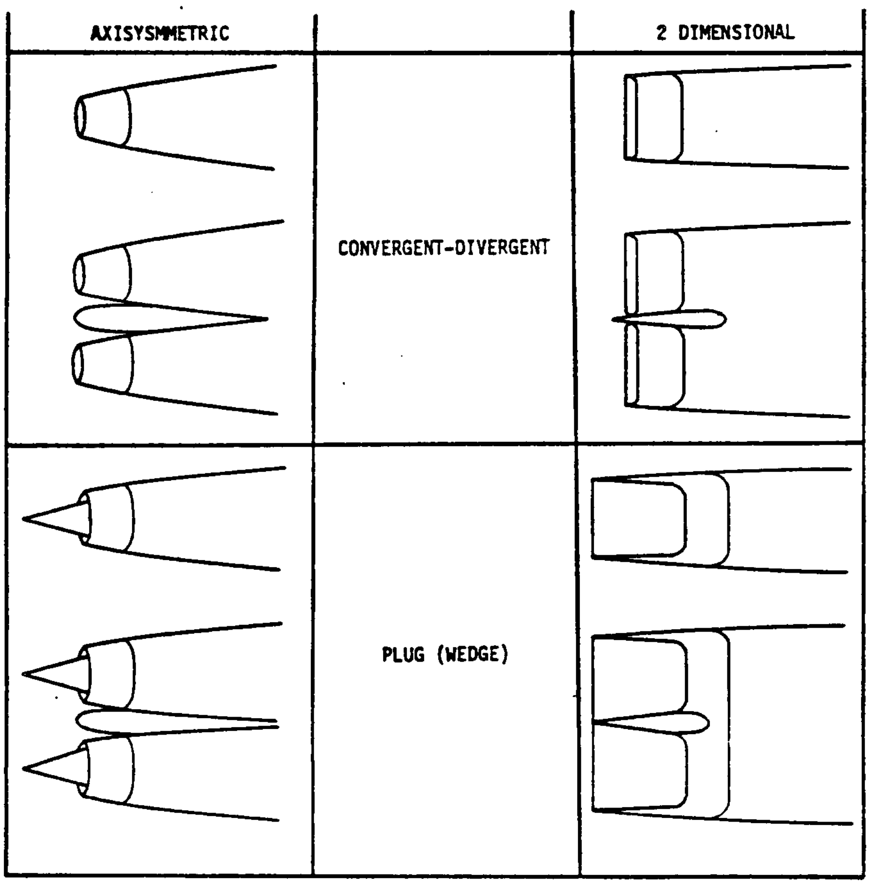


FIGURE 16 -TYPES OF AIRBREATHING-ENGINE EXHAUST NOZZLES

lift and drag levels from subsonic to supersonic speeds, stability and trim characteristics, airbreathing inlet performance and staging considerations. The mated configuration will encounter high aerodynamic drag throughout the transonic speed range and significantly affect the configuration A/B arrangement and number of engines. Use of configuration area variation plots as inputs to zero lift wave drag programs (Boeing TEA 80 - Ref.11) will permit the transonic drag of the mated vehicles to be estimated.

3.2.3.2 A/B Inlet/Propulsion - Potential problem areas exist with the size and number of engines and the size and location of the engine inlet(s) and nozzles effecting the vehicle configuration (i.e. landing gear location, surface heating, vehicle low drag profile). Engine inlet distortion may prove to be a problem, depending on the engine sensitivity to inlet distortion and the flow field entering the inlet. These problems are basically configuration oriented and could be overcome through evaluation with follow-on wind tunnel testing.

3.2.3.3 Subsystems - Thermal Control - The booster configuration is a very high density configuration with very high propulsion and secondary power weight fractions. These combinations indicate a significant technical problem with thermal control within the vehicle. Landing Gear - The large gross weight at takeoff will necessitate study to configure a landing gear arrangement which can be stowed or shrouded while permitting sufficient footprint separation to meet acceptable projected runway and taxiway loadings. High take-off speed contributes to the problem. Secondary Power - The significant demands for secondary power during takeoff, ascent, and separation suggest that a study will be required to establish the optimum balance between booster engine power takeoffs and on-board air breathing secondary power units.

3.2.3.4 Thermal - Flow interactions induced by the close proximity of the booster(s) and orbiter vehicle can result in substantial increases in heating during early ascent. Potentially the most serious problem is that interacting shocks may impinge on the vehicles, resulting in very high increases in heating in localized areas. The severity of the interference heating problem will be strongly dependent on Mach number at staging. Potential vehicle trajectories during ascent may exhibit an ascent altitude - velocity profile for the two-stage configuration which will be much lower than that of previously studied vehicles Reference 1 and 2 resulting in higher heat loads.

3.2.4 Vehicle Concept Assessment

Utilizing the trade studies and design parameter results together with past experience on multi-stage space transportation, three two-stage-to-Orbit Transportation System will be configured. The three proposed concepts are: A single booster-supersonic staging system Figure 17 , a twin booster-supersonic staging system Figure 18 and a subsonic booster-staging system Figure 19. The orbiting vehicle for each system will be a generic derivative of the system shown in Figure 3 . The orbiting vehicle will use LOX-LH_2 fuels, the space shuttle main engine with altitude compensating nozzle and the structural system as depicted in Figure 20. ? FIXED ε ~155:1 ADJUSTED ?

The general approach shall be to minimize the orbiting vehicle total weight at a combination Mach number and altitude then configure the booster to meet take-off and flight-to-staging requirements. This configuration shall then be further optimized for propulsion operation with prime consideration to thrust requirements during transonic flight. For each concept, a configuration drawing shall be prepared. The drawing will define dimensions, ascent propulsion system and staging concept. Mass fractions shall be established for each stage of each concept. The orbiting vehicle mass fractions shall be established using generic data from references 1 and 2 . The first stage mass fractions see figure 5 will be established using standard preliminary design weight prediction techniques. Utilizing these data, system gross lift-off weight, take-off speed and ascent propulsion thrust profiles will be established.

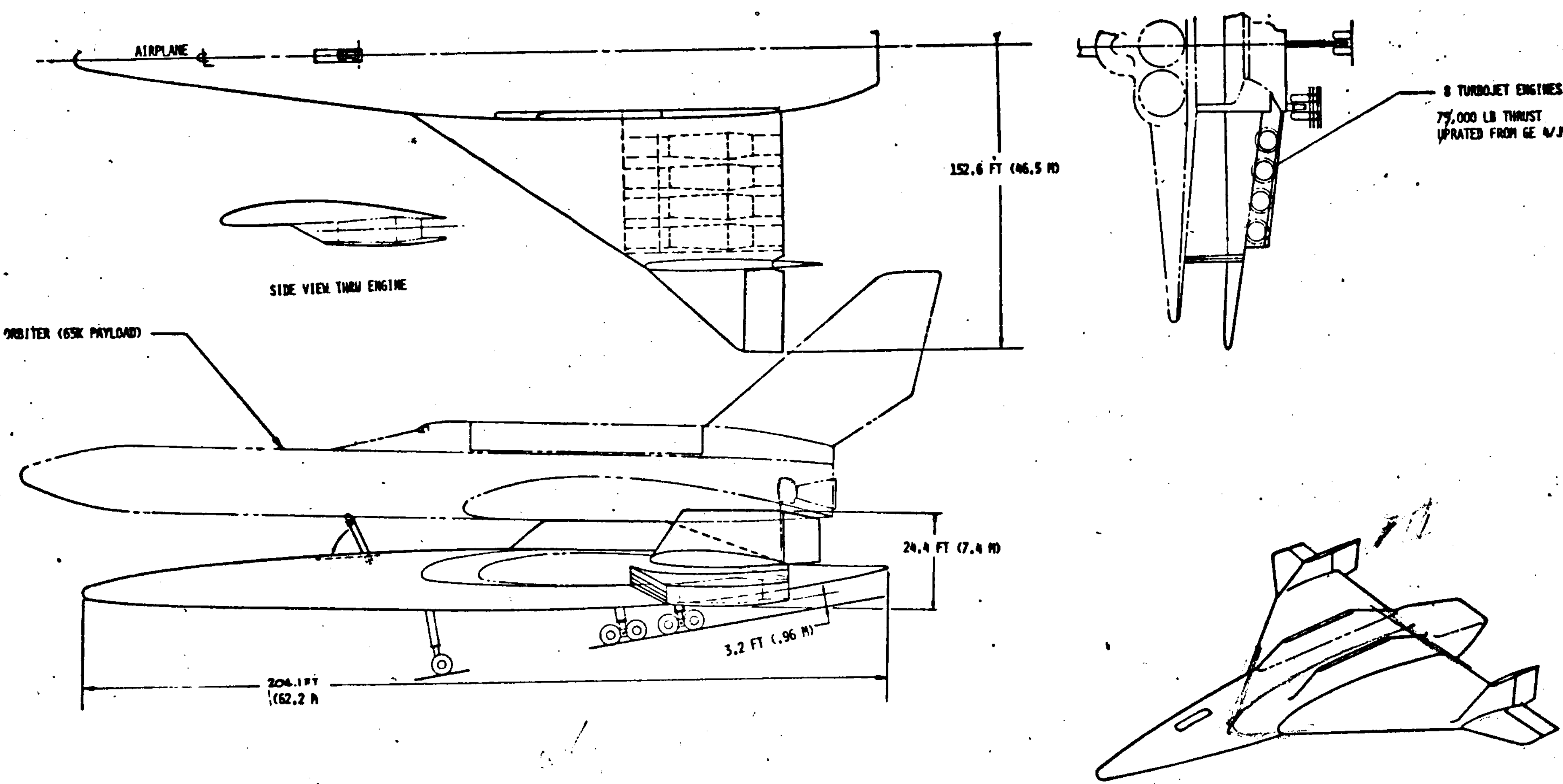


FIGURE 17 - SINGLE BOOSTER TURBOJET WITH ORBITER (PAYLOAD = 65K)

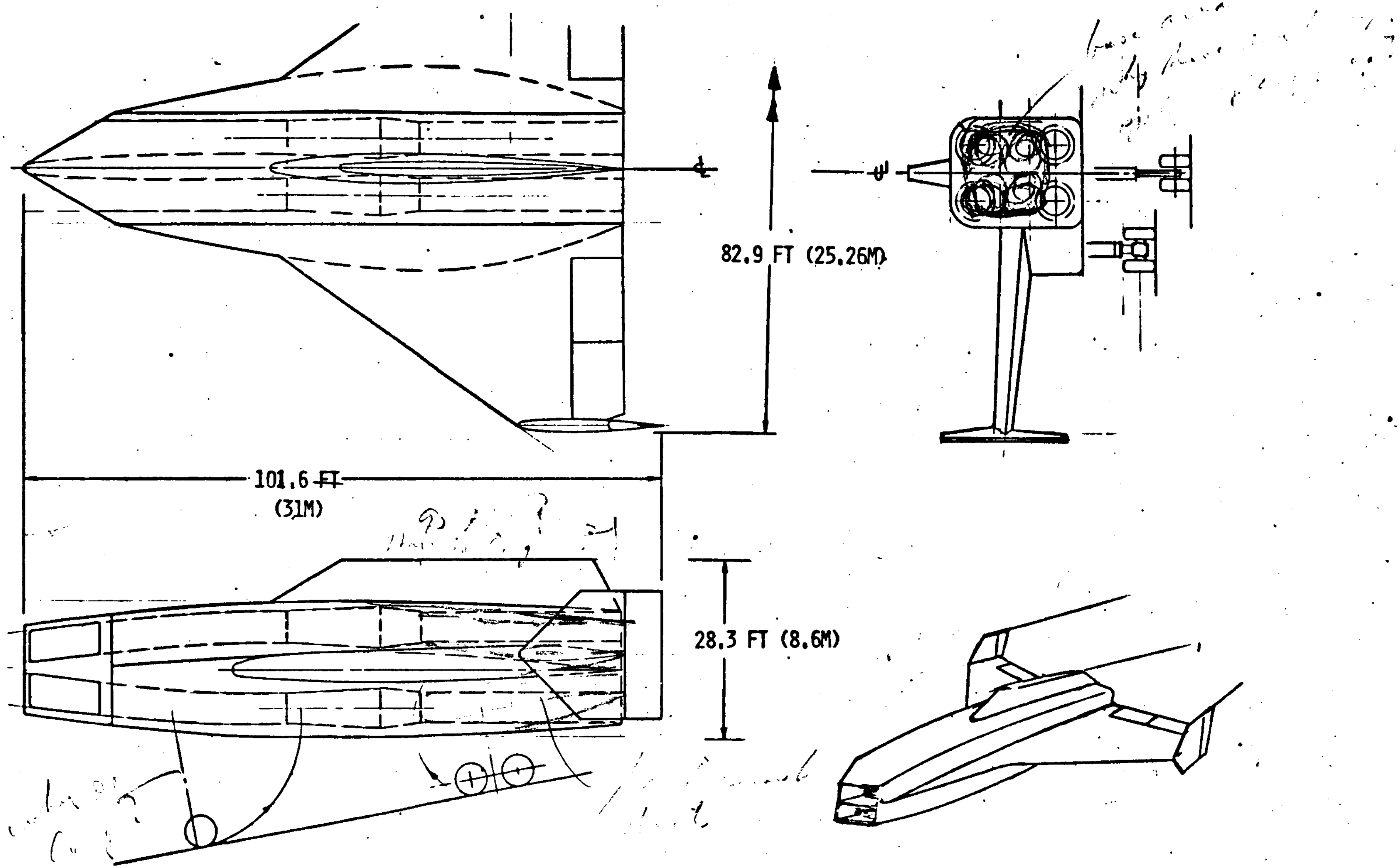
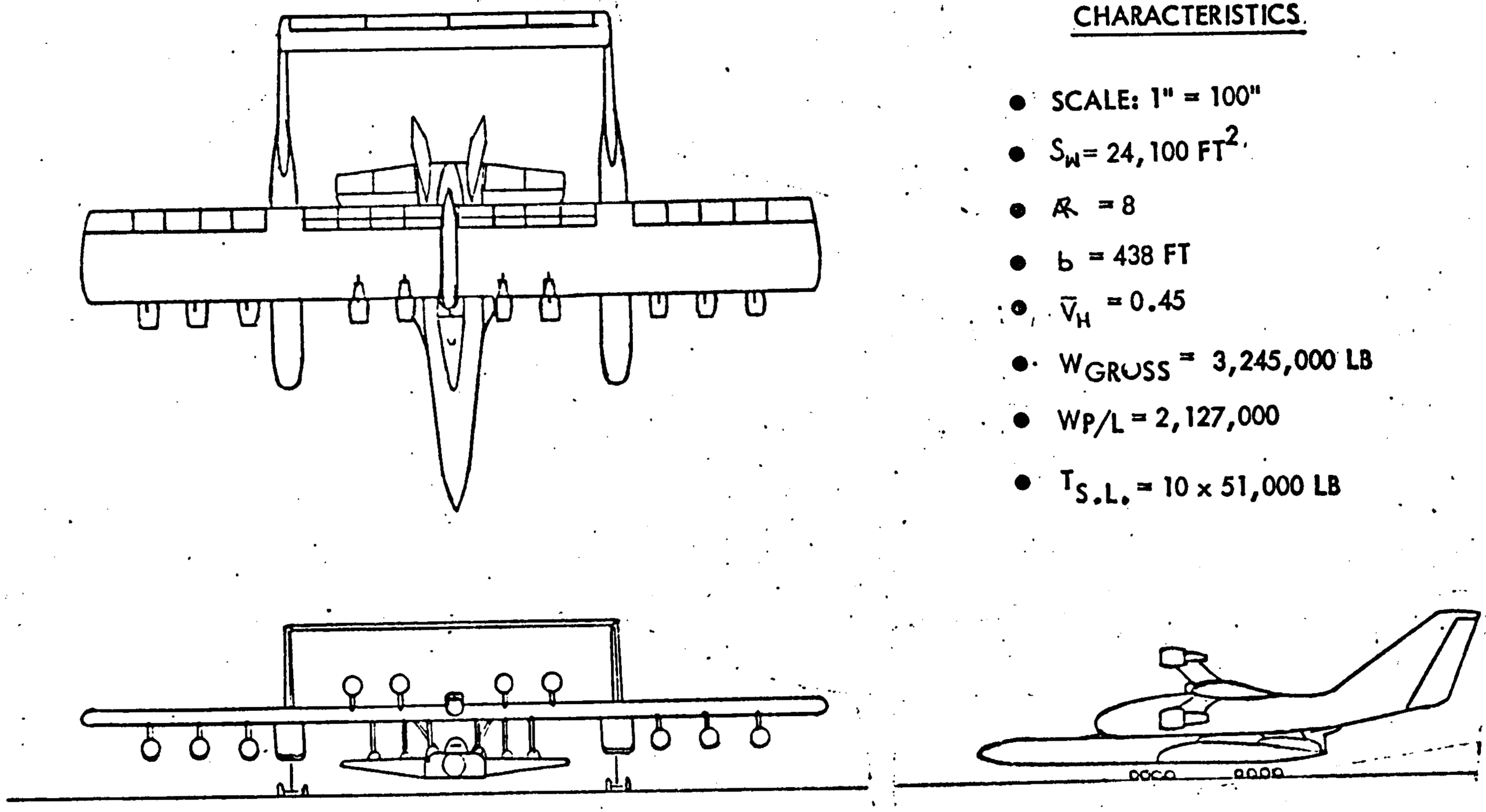


FIGURE 18 - TWIN BOOSTER TURBOJET WITH ORBITER (PAYLOAD = 65K)



CHARACTERISTICS

- SCALE: 1" = 100"
- $S_W = 24,100\ FT^2$
- $Æ = 8$
- $b = 438$ FT
- $\bar{V}_H = 0.45$
- $W_{GROSS} = 3,245,000$ LB
- $W_{P/L} = 2,127,000$
- $T_{S.L.} = 10 \times 51,000$ LB

Figure 19 - SUBSONIC AIR LAUNCHED VEHICLE CONCEPT

A definition and assessment of the critical problem for each concept will be completed. These critical problems will then be analyzed to determine the approach to developing solutions.

Utilizing the total data developed under Task I together with the assessment of each of the three system concepts and their associated critical technical problems, NASA and Boeing faculty shall select a system for further detail definition in Task II.

3.3 TASK II - CONCEPT DESIGN

Using the design parameters together with the general system concept approach developed under Task I, a Task II system configuration drawing shall be prepared. This drawing shall be used to control the preparation of subsystem and structural layouts and in combination with estimated weights and aerodynamic characteristics prepare preliminary flight trajectories.

3.3.1. System and Component Layouts

Inboard profile and structure centerlines and concept utilizing the general system concept definition, structural and subsystem details will be developed and layouts prepared.

The structural system proposed for the orbiting vehicle will be as shown in Figure 20. This system has been extensively analyzed and discussed in Reference 1 and 2. The structural system to be used for the first stage will be dependent on staging velocity and time at speeds greater than approximately Mach 2.0. The structuring approach will consider heat sink as a technique for maintaining structural temperatures, within acceptable material use range. Use shall be made of composite structures to minimize weight where it appears cost effective. Aluminum brazed titanium honeycomb surface panel will be a prime candidate for the supersonic staging, first stage structure system. The honeycomb will provide adequate thermal insulation for the fuel, considering the short time to be spent at supersonic speeds. Design details of major structural components

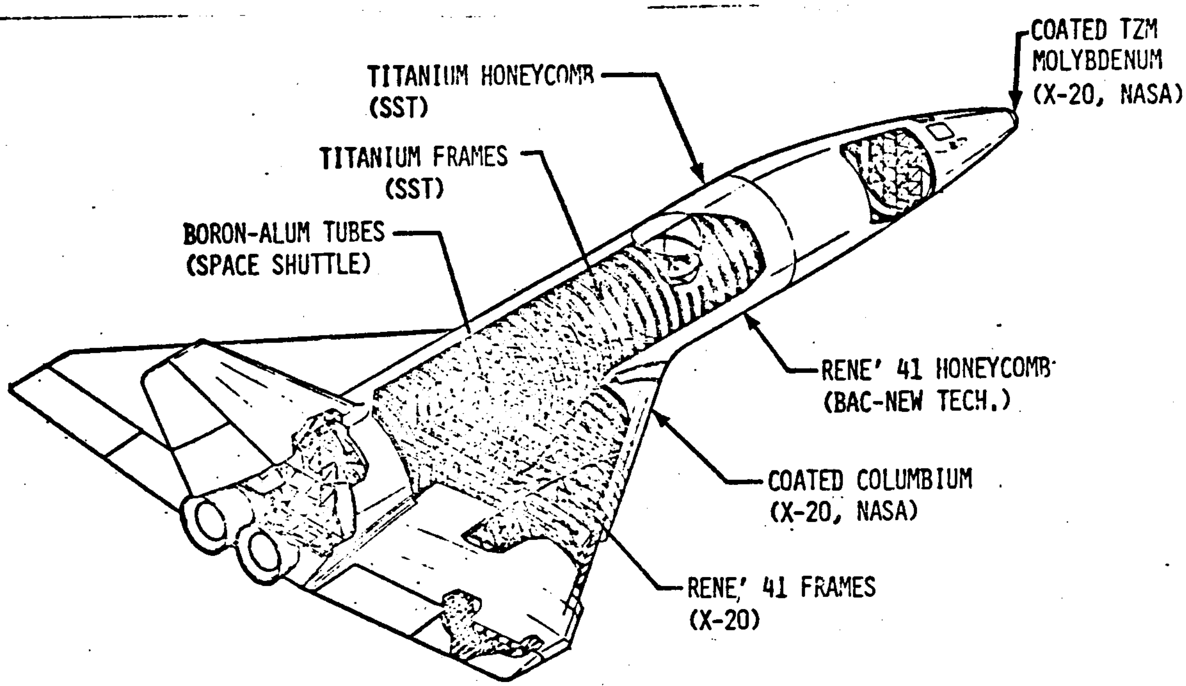


FIGURE 20 - STRUCTURAL CONCEPT

SYSTEM ELEMENT	Weight Pounds
Structure (lbs.)	
Body	
Wing	
Crew Compartment	
Tail Surfaces	
Weight Growth	
Engine Inlets & Nacelles	
Subsystems	
Surface Controls	
Landing Gear	
Ascent Engines	
Fuel Feed	
Tank Pressurization	
Reaction Control System	
Orbit Maneuver System	
Avionics	
Electrical Power and Distribution	
Hydraulic Power and Distribution	
Environmental Control System	
Crew and Provisions	
Weight Growth Allowances	
Fluids	
Ascent/Cruise Fuels	
Flight Reserves	
Reaction Control System	
Orbit Maneuvering System	
Engine Residuals	
Subsystem Fluid Losses	
Payload	
Weight Summation	

FIGURE 21 - WEIGHT STATEMENT

will support structural sizing and demonstrate structural characteristics of the system. Included in the conceptual details will be body, wing, payload bay and control surface cross sections. Design concepts will be prepared for the staging system.

The primary approach to staging will consist of setting up flight conditions that result in load factors greater than one (1) on the orbiting vehicle and through the use of spoilers, etc. reduce the load factor on the first stage to less than one (1). Retention will be terminated through the use of devices, such as tension failure of bolts through gas (explosive) generation system. Staging concepts will be developed to the point that weights and critical development problems may be defined.

Schematic drawings will be developed for each of the major subsystems on the first stage vehicle. Subsystems for the orbiting vehicle will be generic to those outlined in reference 1 and 2 and will use those data sources to establish subsystem concepts and weights. The first stage landing gear system will incorporate the technology projections defined under Task I. The design will follow the conventional approach of wheels and tires, brakes and oleos, incorporating carbon-carbon brake disc pads and advanced composite structures. The gear arrangements will be assessed for runway requirements utilizing Boeing in-house design data. The other subsystem excluding the main propulsion system will utilize concepts as currently under development or projected for use on advanced subsonic and supersonic aircraft. On going in-house and contracted studies will be used as Data sources.

3.3.2 Estimated Weights

This task will be initiated by developing a list of subsystem, structure, fluids and payload elements for each stage. Figure 21 is representative of the system elements to be considered. Weights for each of the system elements shall be estimated using data from references 1 and 2 for the orbiting vehicle and

Boeing in-house preliminary design weight estimating parameters for the First Stage. A weight growth allowance of 10 percent will be applied to all estimates for which weights must be estimated or calculated. A center of gravity location for each of the vehicles will be calculated by first establishing the center of gravity for each subsystem element.

3.3.3 Estimated Aerodynamic Characteristics

The preliminary aerodynamic analysis described in Section 3.2 for Task I will be refined and developed in more detail for the Task II baseline vehicle concept. Whereas, in Task I, most emphasis will be on the lift and drag characteristics necessary to provide inputs for vehicle trajectory performance, the Task II effort will, in addition, include pitching moments and lateral/directional aerodynamics for preliminary evaluations of the vehicle configurations stability and control characteristics. Flight control and abort analysis will only be surveyed for potential problem areas as part of Task IV technology assessment.

Aerodynamic characteristics will be estimated not only for the isolated booster and orbiter but also for the mated configuration. Angle of attack and Mach effects through the entire speed range will be included. These include breakouts of slope of lift curve ($C_{L\alpha}$), drag due to lift (dC_D/dC_L^2), minimum drag (C_{D_0}) and lift/drag ratio (L/D) as illustrated in Figure 7 . Lateral/directional characteristics, taken from wind tunnel data of Boeing's SSTO will be used or modified as necessary to represent the isolated orbiter aerodynamics. Similar characteristics for the mated vehicle will be limited to those aerodynamic characteristics which could influence the feasibility of the vehicle concept and its technology assessment for Task IV.

3.3.4 Preliminary Trajectory and Performance

A representative mission profile format for the two-stage vehicle concept is shown in figure 22, in which the trajectory performance characteristics would

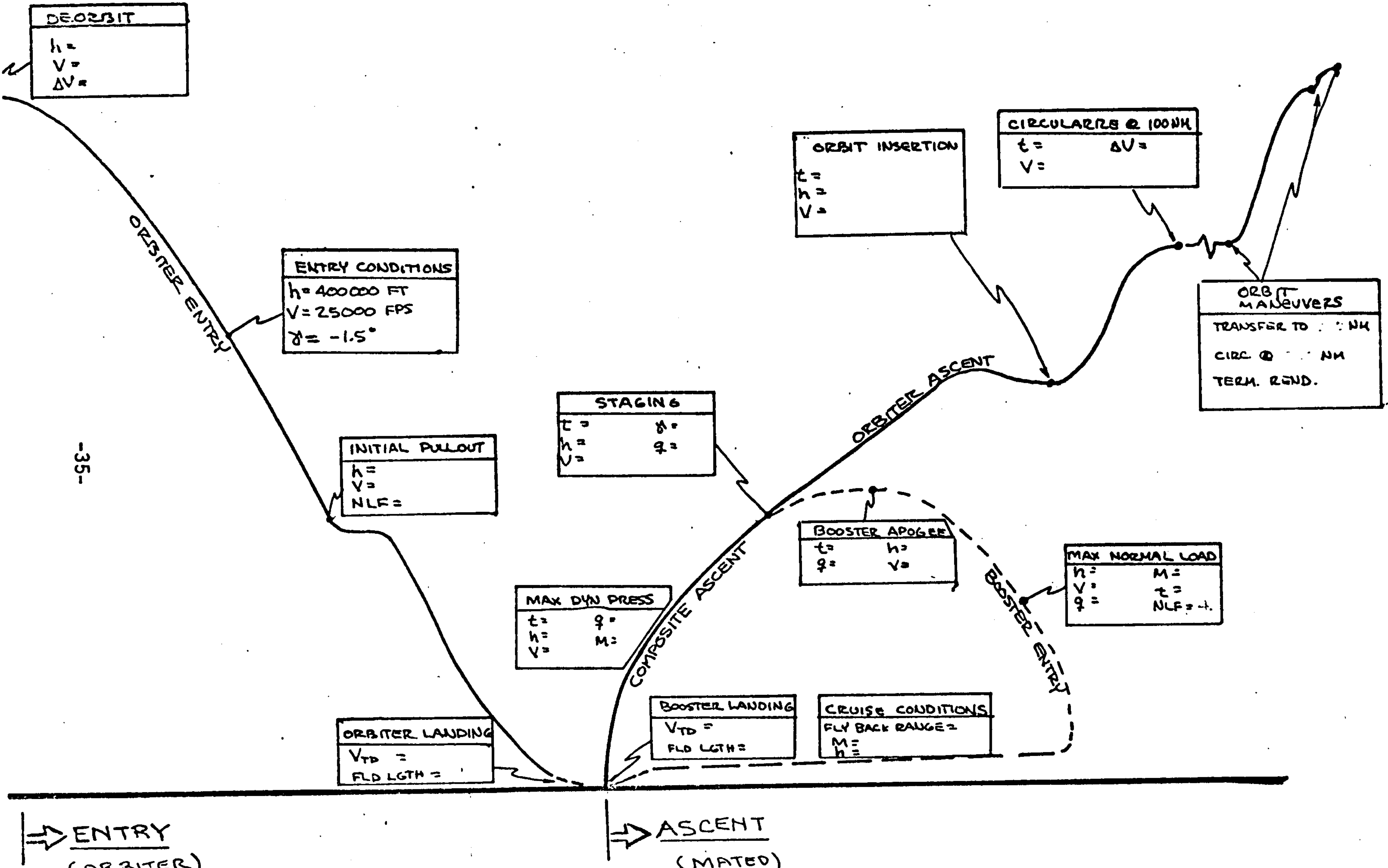


FIGURE 22 - MISSION PROFILE FORMAT

be determined from trajectory computer programs (i.e. References 4 and 5). The A/B booster will optimize at a lower altitude-speed profile than an all-rocket booster because A/B accelerating thrust varies directly with the altitude pressure ratio. For example, from past studies of SSTO systems at M = 2.7 an all rocket booster wants an ascent altitude at this speed of about 90,000 ft. An A/B booster at this altitude may require a prohibitive amount of number of engines or engine weight to accelerate and climb to those conditions. A more realistic altitude could turn out to be 70,000 to 80,000 ft. (Note: Trade studies of Task I will give this answer.) Entry trajectory characteristics for both booster and orbiter will be established for cross range performance, abort, and structural/heating input data.

Vehicle performance will make use of the ascent/entry trajectories to help determine the stage weight, propellant and fuel required, dry weight and payload to orbital conditions and return. These performance analyses include both take-off and landing characteristics of booster and orbiter and establishment of staging conditions of altitude and speed.

3.3.5 External Surface Temperatures and Loads

Thermal analyses will be conducted in sufficient depth to define structural temperatures and gradients required for selecting materials and structural sizing. The type of data to be generated is illustrated in Figure 23 and 24.

3.3.5.1 Aerodynamic Heating - The aerothermodynamic environments will be predicted using basically the same methods as described in Reference 12 , which were used in recent SSTO and RASV studies (References 1 and 2). Boundary layer properties are computed using a momentum integral method and account for three-dimensional effects and pressure gradients. Turbulent heating is based on the Spalding-Chi method, and boundary layer transition is predicted using the RI/SD approach. Internal temperatures and gradients for simple structural cross sections will be computed using the Boeing CHAP program (Reference 13), which in

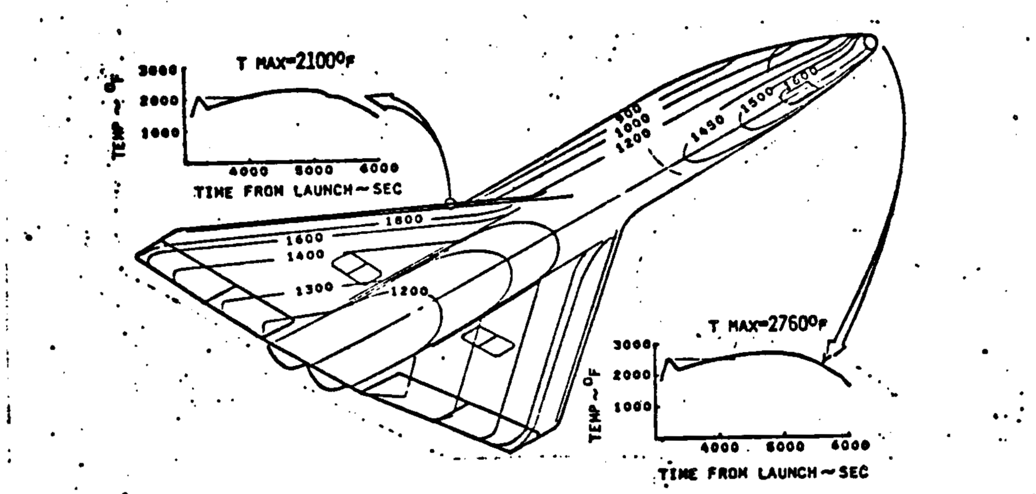


FIGURE 23-RASV EXTERNAL TEMPERATURE DISTRIBUTION

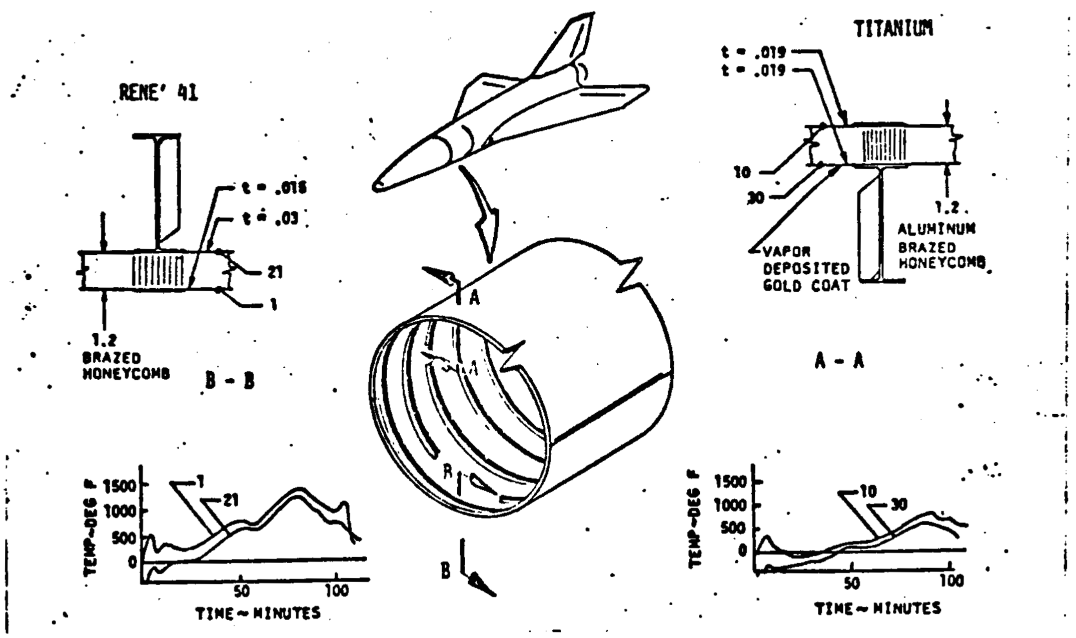


FIGURE 24-RASV STRUCTUAL DETAILS

this application, serves as a one-dimensional thermal analyzer.

3.3.5.2 Aerodynamic Loads - Aerodynamic load distributions will be determined by analysis using the aerodynamic influence coefficient method (Woodward theory) in the subsonic and low supersonic regimes and Newtonian theory in the hypersonic regime. The computations will be performed using a computer program Reference 14 used on the Boeing Supersonic Transport. Other potentially critical loading conditions including launch, captive flight, landing, and ground operations will be analyzed using standard preliminary design loads prediction methods. Data will be developed in the form of local pressure distributions and accelerations.

3.3.6 Structural Size

Structural sizing will be accomplished in sufficient detail to develop subsystem weights. The orbiting vehicle structural sizing will draw on extrapolations from the Single-Stage-to-Orbit Studies of Reference 1 and 2 . These studies have covered vehicles sized to carry 25,000 pounds to 65,000 pounds into easterly orbits. Therefore, parametric sizing data is available.

First stage structural sizing shall be accomplished on representative body, wing and control surface sections and the staging system. Analysis shall be accomplished using principally classical hand analysis solutions. Material properties, structural element allowables and supplemental analysis methods are readily available from Boeing in-house design manuals. Task I Design Criteria and Technology Projections shall control the structural sizing.

3.3.7 Propulsion Size

The integrated propulsion system performance will be assessed for the type(s) and size(s) of inlet, engine and exhaust system selected in Task I trade studies. The installed propulsion system performance calculations will be performed using a computer program developed under contract with AFFDL (Reference 15). This program takes uninstalled engine data, applies corrections for inlet pressure recovery and drag, and nozzle internal losses and nozzle/afterbody drags and

and calculates installed propulsion system performance. Typical installed performance will include takeoff thrust and fuel flow as a function of airspeed and altitude; climb thrust and specific fuel consumption as a function of climb schedule Mach number; and specific fuel consumption as a function of thrust, Mach number and altitude for both supersonic cruise and subsonic cruise conditions.

Uninstalled engine performance will be generated for the engine(s) and thrust size determined in the Task I trade studies. Engine manufacturer parametric engine cycle computer decks are currently in use which provide engine performance, weight and dimensions for engines available in the mid-1980 time period.

The inlet and exhaust systems will be designed in sufficient detail to permit a final performance assessment. Figure 25 presents an external compression inlet designed for Mach 2.5. Inlet pressure recovery and inlet drag maps, represent the outputs from the inlet performance analysis. Inlet performance maps for inlet types illustrated in Figure 15 are available in the Reference 15 data file.

Nozzle internal performance and nozzle/afterbody drag are a function of the engine airflow, the nozzle configuration and the integration of the exhaust system with the vehicle. Figure 25 presents typical exhaust system performance. Examples of some of the current contracts and IR&D studies which represent technology that can be directly applied to the study are provided in references 8 and 12.

3.3.8 Subsystem

The subsystems for the vehicles will be designed and parametrically weighed using Task I Technology Predictions) based on power requirements and duty cycle for the systems which can be compared to similar systems on aircraft, e.g. landing gear, avionics including command control and data, and environmental control. Systems which are unique or which have unique or unusual requirements will be examined in sufficient depth to establish credible weight, performance, and cost. These systems would include booster propulsion control encompassing inlet controls, throttles, after-burners, and fuel feed; orbiter attachment interfaces and separation mechanisms; flight control surfaces and actuation systems; and the

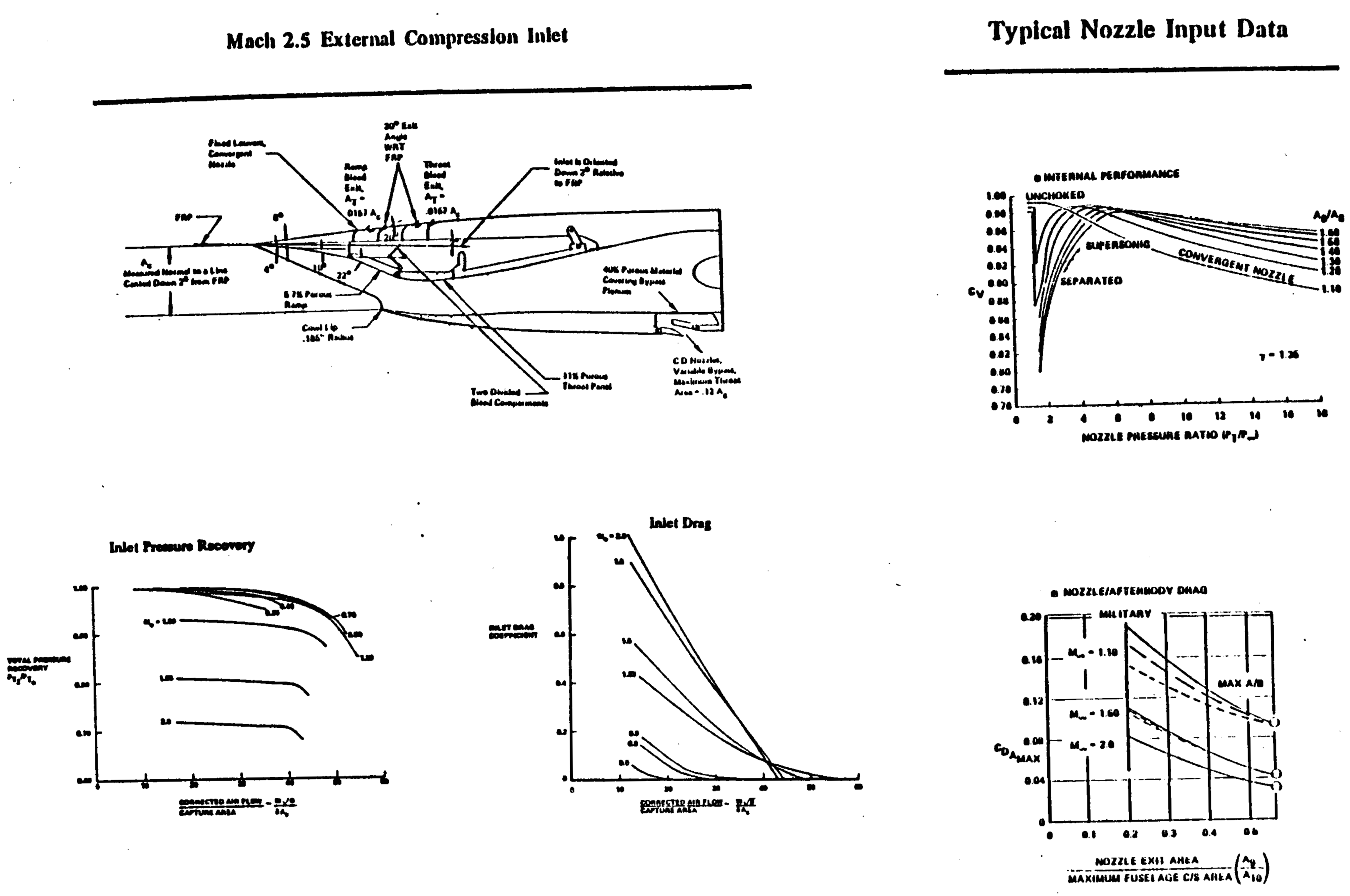


FIGURE 25 - AIRBREATHING-ENGINE INLET AND NOZZLE CHARACTERISTICS

secondary power generation and distribution systems insofar as it is impacted by the unique subsystems. Subsystem design and definition will be performed only to a depth sufficient to assure credible performance and cost.

3.3.9 Updated System Concept Definition

The results of the design cycle as depicted under Task II in the Study Plan Logic Flow Figure 1 will be incorporated into an updated two-stage-to-orbit system concept. A system configuration drawing shall be prepared defining external dimensions and geometric relationships of the two vehicles in the mated position. An inboard profile drawing of each vehicle shall be prepared showing general size and locations of the major subsystems.

3.3.9.1 Updated Weights - The results of the design cycle will be used in redefinition of the weights for each of the system elements as shown in Figure 21 .

3.3.9.2 Updated Aerodynamic Data - After the preliminary vehicle configuration has been evaluated, problem areas uncovered, and proposed modifications incorporated into an updated configuration, a finalized set of aerodynamic characteristics will be determined for use in updated stability and control analysis and vehicle trajectory and performance updates.

3.3.9.3 Updated Vehicle Trajectory and Performance Data - Finalized ascent and entry trajectories will be determined. This includes take-off and landing characteristics of both mated and isolated vehicles (booster and orbiter). The ascent/entry trajectories will be fully described in terms of altitude, velocity, angles of attack, roll, and flight path, dynamic pressure, propellant consumed, and weight versus time.

3.4 TASK III - UTILITY AND ECONOMIC ANALYSIS

This task will consist of two major activities one being an Operations Analysis and the second being the Cost Analysis. The Operations Analysis will cover earth logistics, ground operations including manned time lines, and system mission capabilities.

The Cost Analysis will include development, production and operation costs. Preliminary life cycle costs will be developed using a NASA defined mission model.

3.4.1 Operations Analysis

The operations analysis will be directed toward demonstration of the utility characteristics of the system and its performance flexibility. The background developed in performing a similar assessment of the Reference 2 Systems will be used.

3.4.1.1 Ground Operations - Time lines for the operations required in each of the four phases of recovery, refurbishment, launch preparation, and launch will be prepared to identify total turnaround time as well as manning levels to establish a cost base for these operations. Definition of tasks will be shown only to a level necessary to accomplish this costing.

3.4.1.2 Earth Logistics - Using the finalized updated vehicle characteristics, the self-ferry capabilities will be determined in terms of take-off and landing performance (field length, engine-out, etc.), climbout, cruise altitude and speed, and ferry range. These ferry characteristics will be determined for both the isolated booster and mated to the empty orbiter.

3.4.1.3 Orbital Payload Capabilities - For the updated vehicle configuration orbital payload capabilities will be determined for various orbital altitudes, orbit inclinations and runway headings, as illustrated in Figure 26. Increased orbital capability will employ add on OMS propellant tankage kits similar to that of the Space Shuttle. The A/B booster will permit some flexibility in reaching off-set orbits or flyout to unrestricted launch sites. This capability will be also determined.

3.4.1.4 Abort Capabilities - Abort techniques for the updated vehicle concept will be developed to the extent of uncovering potential problem areas. Intact aborts for return-to-launch site will be explored. Both vehicles (booster and orbiter) will be considered for intact aborts from takeoff to nominal staging velocities.

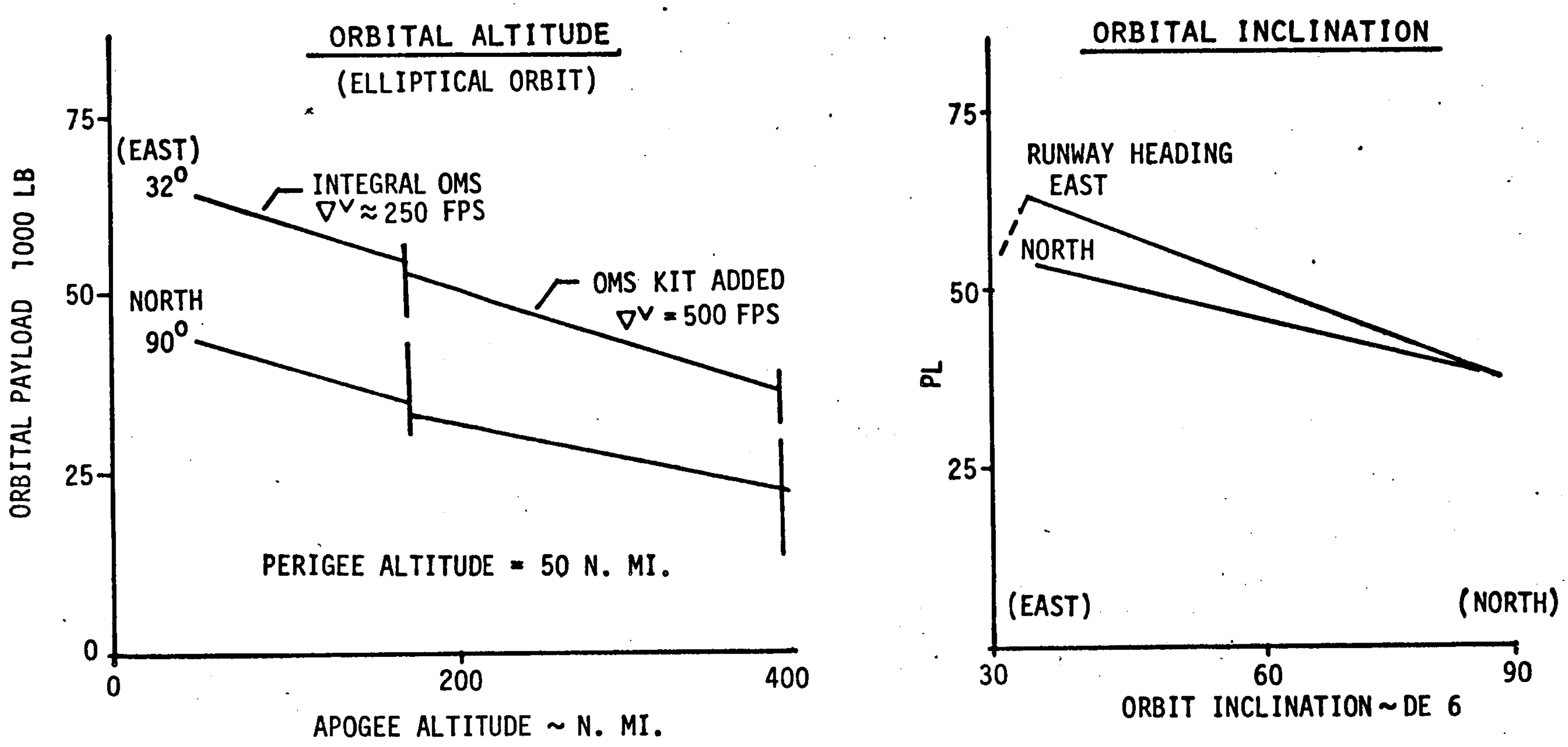


FIGURE 26 VEHICLE ORBITAL PAYLOAD CAPABILITIES

3.4.2 Cost Analysis

Life Cycle Cost Analyses of Advanced Earth-to-Orbit Transportation Systems have been developed and documented by Boeing in References 1 and 2 . This data will be the primary source of costing parameters to be used in developing Life Cycle Costs for the Two-Stage-to-Orbit System.

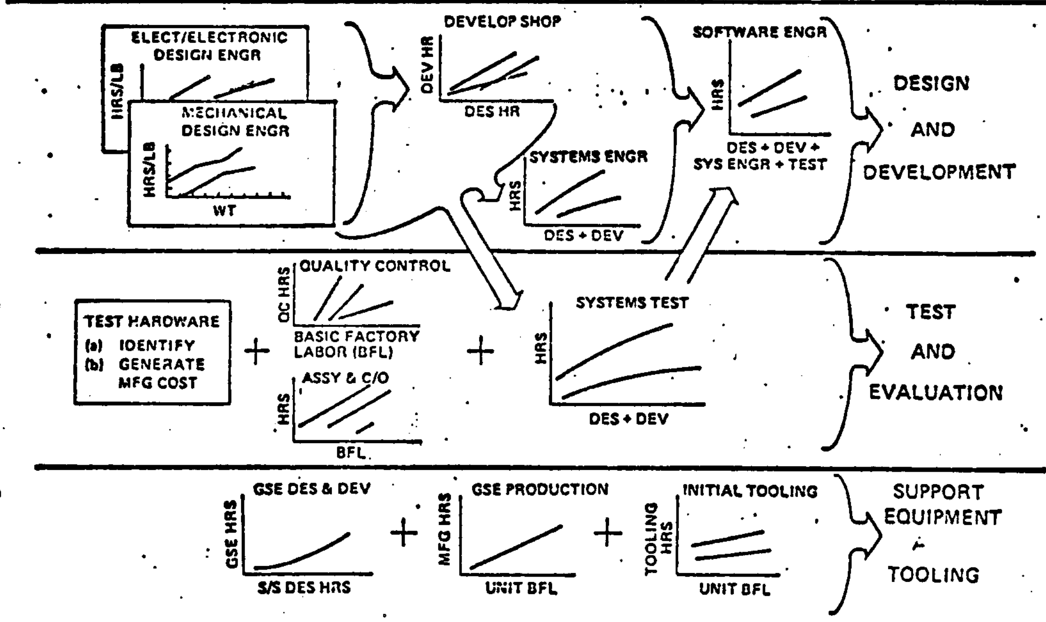
Program groundrules such as the number of flight and test vehicles, amount of support equipment, flight test site activation requirements, subsystem state-of-the art, etc., in conjunction with parameters such as weight, area, material definition, etc., will be input to the Boeing Cost Model which will develop the costs by major program element. Figure 27 illustrates the various inputs which are required by the model and the outputs which can be obtained at any level required. The flow diagram Figure 27 illustrates the build up of DDT&E costs from the constituent functional categories.

The production vehicle costs will be developed by the Boeing Cost Model using a learning curve rate that is characteristic for large aircraft production. Operation costs will be grouped into three segments (1) Flight Hardware, (2) Flight Operations and, (3) Launch Operations. References 1 and 2 in combination with Boeing in-house data on operation costs of large aircraft will be used to develop both fixed and variable costs for each of these segments of the operating costs. NASA will define the traffic model to be used in developing cost per-flight and total life cycle costs.

3.5 TASK IV TECHNOLOGY ASSESSMENT

After completing the Task II Design Study Cycle, each subsystem element will be assessed for status of technology required to meet the subsystem performance objectives. References 1 and 2 provide an extensive data base for defining the technology requirements for the type of orbiting vehicle recommended for use with this study. Development plans which will include definition of sequential dependent events will be prepared for those unique technology requirements resulting from this study.

Boeing PCM Methodology DDT&E



INPUTS AND OUTPUTS (IN GENERAL)

INPUTS

- HARDWARE QUANTITIES
- SCHEDULE
- PRODUCTION RATE
- WEIGHTS, FT^2, DENSITY, THRUST
- % OF OFF-THE-SHELF HARDWARE
- % OF MODIFIED HARDWARE

OUTPUT

- PROGRAM COST IN CONSTANT OR "THEN YEAR" DOLLARS
- SUBSYSTEM COST BREAKDOWN
- MANHOURS BY ORGANIZATION

FIGURE 27-COST MODEL METHODOLOGY

The first stage vehicle subsystems and the staging system will be assessed in detail to establish what major technology developments are required to meet performance objectives. Particular emphasis shall be placed on first stage airbreathing propulsion systems. Development plans defining major events, activities to achieve these events, and activity time flows will be prepared for the critical technology developments.

4.0 REFERENCES

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2. Boeing Aerospace Co: Feasibility Study of Reusable Aerodynamic Space Vehicle (RASV) Air Force (SAMSO) Contract F04701-76-C-0102 - March 1977
3. NASA Langley: Request for Proposal 1-16-3730.0095 for a Turbojet Boosted Two-Stage-to-Orbit Space Transportation System Design Study - September 1977.
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9. Gereni R. P., Ann Roundhill J. P. (Boeing) Correlation of Gas Turbine Weights And Dimensions. AIAA Paper No. 70-669. June 1970.

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11. Boeing Co: Zero Lift Wave Drag Program (TEA 80)

12. Boeing Aerospace Co.: Analysis of Hypersonic Aerodynamics Heating Data Obtained on SSTO Configuration ALRS-205, Boeing Doc. D180-19168, 1977.

13. Boeing Aerospace Co.: The Improved Convective Heating and Ablation Program (CHAP). Boeing Doc. D2-126104-1 - Aug. 1974

14. Boyd R. V.: A Unified Analysis Method for the Calculation of the Steady State Aeroelastic Air Load Distribution. Boeing Doc. D6-23828-N, June 1969.

15. Ball, W. H. P.I.T.A.P. Contract (AFFDL) No. F33615-72-C-1580, dated 1972.

APPENDIX

5.1 PERSONNEL AND MANAGEMENT

The management plan for successfully accomplishing the proposed program is given in detail in a companion business proposal document D180-20788-2. This document includes management information as well as contractual, administrative and other details assuring appropriate management controls for accomplishing the proposed program on schedule and within the allotted budget, as well as, for close coordination with and rapid response to customer direction.

5.2 PROGRAM ORGANIZATION

Figure A1 shows the relationship of the proposed program to The Boeing Company organization.

The Satellite and Space Support Organization, under Mr. H. J. McClellan, will have primary responsibility for the proposed program. Specific responsibility for this program has been assigned to the Advanced Space Transportation Product Area under Mr. A. K. Hepler.

The functional organization for the proposed program is shown in Figure A-1 Mr. A. K. Hepler will be the program manager. The program manager has responsibility and authority for all aspects of the program - technical, schedule and cost. He will direct the program and has authority to draw on all company organizations for required support and to extend, modify or cancel work authorization budgets as required. Supported by a cost accountability group and a contract performance unit, he will maintain direct business and technical surveillance of program progress and budget expenditures to ensure compliance with contract requirements and NASA

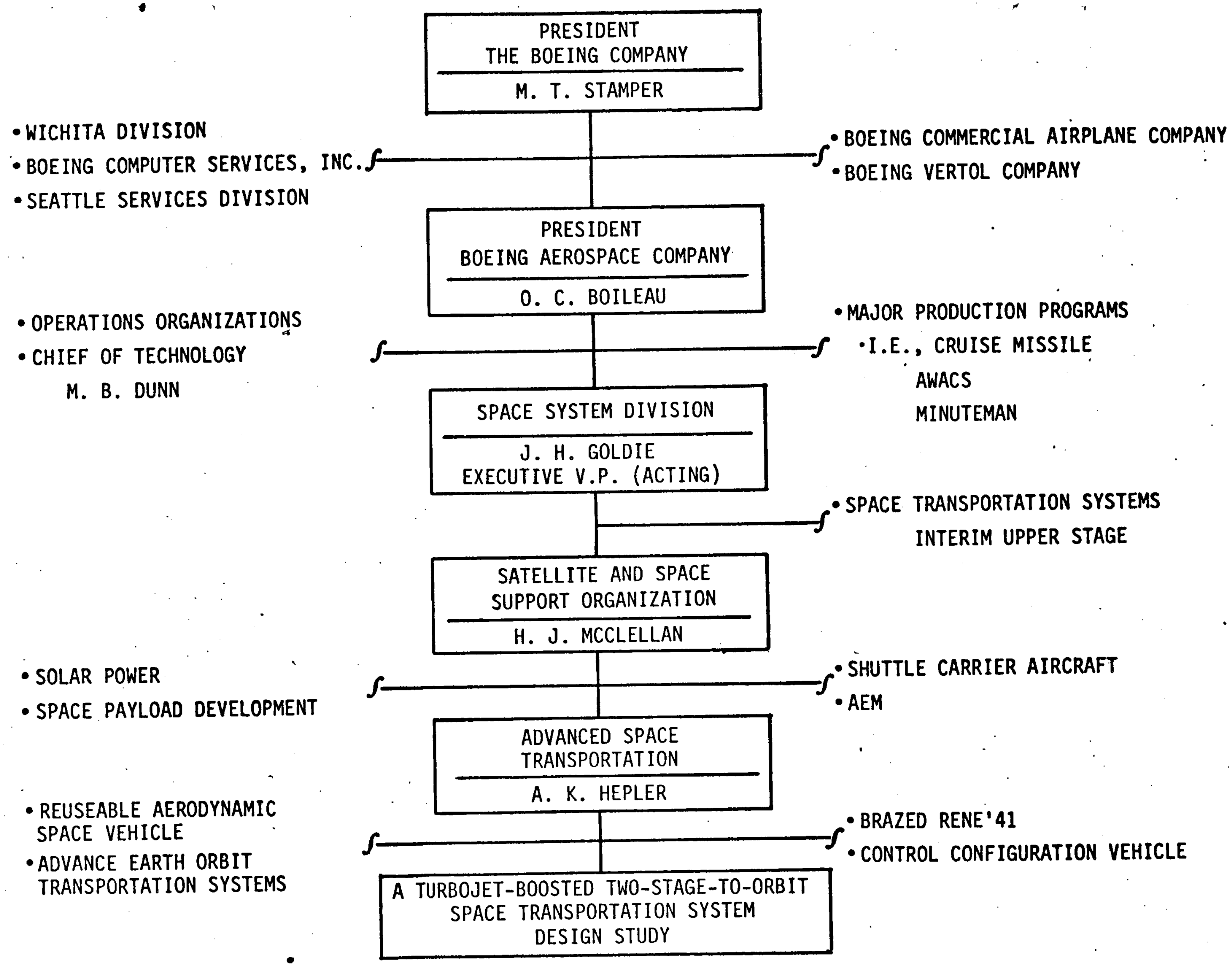

FIGURE A1 : BOEING CORPORATE ORGANIZATION

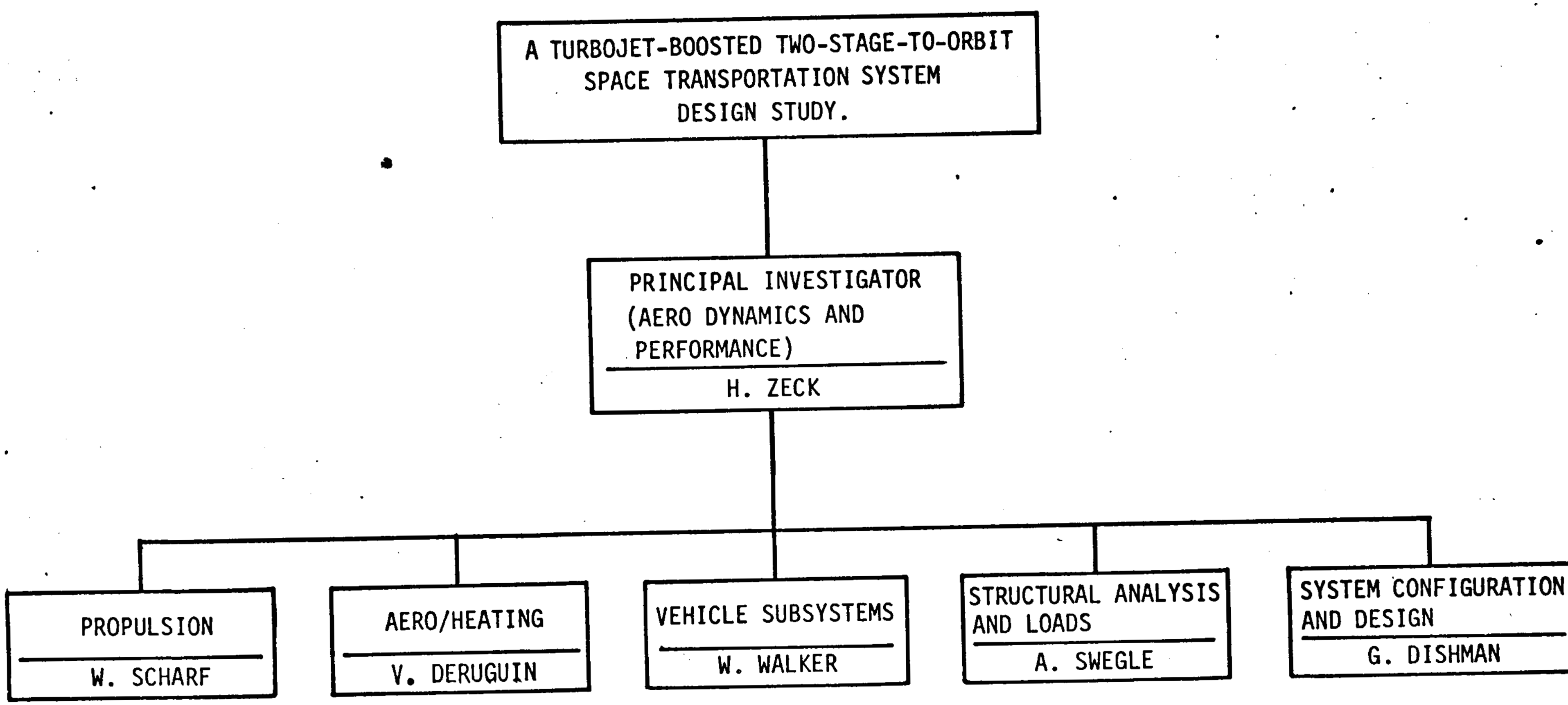

FIGURE A2 : STUDY TEAM ORGANIZATION

objectives. Mr. Zeck will be the principal investigator responsible for performing the study supported by a multi-disciplined team, as shown in Figure A2

5.3 PERSONNEL RESUMES

The proposed program will be accomplished using the personnel whose resumes are included in this section. Each resume describes the individual's experience and qualifications. These individuals are familiar with each other's work in the field of space transportation and associated technology areas, which has led up to the proposed effort. They currently form a team which collectively brings together all of the required special skills for effectively conducting the proposed research design study for a turbojet-boosted two-stage-to-orbit space transportation system.

ANDREW K. HEPLER - Program Manager

BS Aeronautical Engineering, St. Louis University, 1947.

Graduate, Army Specialized Training Program, Oregon State College, 1945.

Graduate Studies, University of Washington, 1949.

Mr. Hepler joined Boeing in 1947 as a structural design engineer. From 1949 to 1957 he was a member of the Structures Staff Stress Group. Since 1957 he has been an engineering manager. His assignments have included stress unit chief of the B-52 and X-20 projects and Supersonic Transport fuselage stress group chief. These assignments have included direct line responsibility for structural system development, analysis and test programs with special emphasis on high temperature structural components for re-entry vehicles. Mr. Hepler directs Boeing's Advanced Earth-to-Orbit (single stage) Transportation studies. Mr. Hepler will be responsible for integration of, and timely compliance with all RFP tasks and for ensuring maximum benefit is obtained from Boeing IR&D activities. He will spend an average of 20 percent of his time on this program.

HOWARD ZECK - Principal Investigator - Aerodynamics and Performance
BS, Aeronautical Engineering, R.P.I., 1942
MS, Aeronautical Engineering, University of Michigan, 1949.
Mr. Zeck has previously worked at NACA, Langley Field, Virginia, in the hydrodynamics section. He has a broad experience in aerodynamics and performance analysis on bombers, commercial jets, boost launch systems and missile systems. These include: AWACS, 707, AGM-X3, SCAD, Space Shuttle, SRAM and advanced earth-orbital space transportation studies conducted internally and under contract to NASA LaRC and USAF/SAMSO. Much of this work was concerned with preliminary design and aerodynamic performance of new configurations. Other accomplishments include development of a theoretical method for determining a slotted-wall test section upon which the Boeing transonic tunnel was designed. Currently he is assigned part time to the NASA CCV study contract as technical leader. Recent assignments included the original preliminary design phase of the CAM program in which he contributed the aerodynamic stability and control inputs for piloted simulations of the Boeing 747 airplane carrying a Space Shuttle orbiter and subsonic flight separation analysis of the orbiter from the 747. Other tasks included development and testing of supercritical airfoils and wing planforms. He also assisted George H. Stoner in preparing part of a UCLA lecture series and writing a book on lunar missions and exploration, 1964, J. Wiley, publisher. Other publications include an AIAA/NASA third manned space flight meeting paper, 1964, coauthoring "Performance and

Cost Analysis of Advanced Rocket/Airbreathing Launch Systems." He is also a member of Sigma Xi honorary society. Mr. Zeck will be responsible for conducting the study supported by appropriate management, financial and technical specialists and will spend approximately 60% of his time on this program.

WILLIAM H. WALKER - Vehicle Subsystems

BS, Mechanical Engineering, University of Washington, 1955

Mr. Walker has been with The Boeing Company for 25 years. He was a project design engineer in the hydraulics group on the KC 135, a lead engineer in the controls group on the 727 and 737, responsible for the design of the electro-hydraulic power control servo actuators, and a lead engineer responsible for the primary and secondary controls for Boeing B-1 proposal study and presentation. He was the responsible project design engineer for all major subsystems for the Flyback Booster, for the Boeing/Grumman Space Shuttle study team. He has been a contributor to the various booster studies conducted by Boeing and has been responsible for the Single Stage to Orbit vehicle subsystem configuration. This has included the ground accelerator vehicle configuration as well as the ground operations plan. His broad design experience has encompassed hydraulics, electro-hydraulic servomechanisms, aerodynamic decelerator devices, environmental control systems, landing gear and related components, secondary power generation and distribution, including air breathing and mono-propellant auxiliary power units, fuel cells, cryogenic propellant OMS and RCS, and flight controls systems including cockpit provisions and crew accommodations. Mr. Walker will be responsible for the vehicle subsystems design and analysis for this proposed study, and will spend approximately 35% of his time on this program.

VLADIMIR DERIUGIN - Aerothermodynamics and Thermal Analysis Diploma (MS), AE, Technical University, Berlin-Charlottenburg, 1942

Post graduate studies: Mathematics, Physics, Aerodynamics, Thermodynamics, and Structural Analysis, University of Washington, 1955 to 1963.

Mr. Deriugin has approximately 30 years experience in engineering and aerospace sciences. He joined the Boeing structures staff as a stress analyst in 1955 and has since worked in research and development and preliminary design support. Beyond stress and loads work, his responsibilities included conducting and supervising development and evaluation of analysis methods for forced convective heat transfer, thermal protection of structures and structural temperature distribution. Mr. Deriugin participated in the preliminary study and proposal phases of advanced re-entry and space vehicles such as the X-20, Viking, Space Shuttle, Space Tug, ELMS, Space Shuttle External Tank, single-stage-to-orbit vehicles, etc. Over the past several years, Mr. Deriugin has also been program manager of twelve contracted research programs with the Air Force and NASA dealing with thermal protection, structural heating, development of analysis methods and design criteria. He has authored, co-authored and supervised the writing of numerous Boeing documents, other professional publications and reports. The recent applicable publication is: "Thermal-Structural Combined Loads Design Criteria Study," by V. Deriugin, E. W. Brogren, C. L. Jaeck, A. L. Brown, and B. E. Clingan, NASA CR-2102, October 1972. Mr. Deriugin will be responsible for aerothermodynamic and thermal analysis and the definition of thermal constraints on the vehicle studied. He will spend approximately 10 percent of his time on this program.

ALLAN R. SWEGLE - Structural Analysis and Loads

BS Civil Engineering, Seattle University, 1951.

Mr. Swegle joined the Boeing Company in 1951. His assignments included seven years in elevated temperatures structural systems development and 17 years in project stress analysis and structural component development. The project assignments included four years on X-20, one year on B-70 wing, and four years on the Supersonic Transport. In each of these programs, Mr. Swegle served as the lead staff stress engineer for the Structural Component Development Implementation Group. He has coordinated and/or conducted structural computer analysis on SST, Space Shuttle wing proposal, Boilerplate Vehicle study, and SSTO. He participated in the folloiwng Space Shuttle or related proposals: Wing (verification), External Tank (development program), Boilerplate Vehicle (wing and fin structural analysis), Tail Cone Subsystem (verification), Carrier Airplane Modification CAM Phase I (verification), Phases II and III (statement of work), and was named principal investigator for a Boeing proposal to develop a Space Shuttle elevon seal. He has conducted computerized structural analysis studies of SSTO to investigate the effects of entry and ascent thermal gradients, tank pressures and landing loads on structural configuration and sizing. He has provided stress support to a Rene' 41 honeycomb sandwich brazing development program. His specific experience especially applicable to the SSTO includes over eight years of experience in development, test, methods of analysis, project stress analysis of brazed/bonded honeycomb sandwich and six years of analysis and development of welded structures. Mr. Swegle's over-all responsibilities have included structural concept definition, stress analysis, test and design requirements, test coordination and documentation. Mr. Swegle will be responsible for structures technology support and assessment and spend approximately 30% of his time on this proposed program.

WILLIAM SCHARF - Propulsion

BS Mechanical Engineering, California State Polytechnic University, 1965

Mr Scharf has been with the Boeing Company for 12 years. He has worked on the design, analysis and evaluation of gas turbine thermodynamic cycles in both the military and commercial aircraft areas. These include: Advanced 747 studies, new commercial aircraft studies, AMSA, FX and US/FRG. He was responsible for production SST installed engine performance and conducted parametric engine studies for the production SST and coordinated Transonic Variant studies. He was the engineer responsible for determining the flyback propulsion requirements and system definition for the Flyback Booster, for the Boeing/Grumman Space Shuttle Study team. Mr. Scharf provided the installed engine performance for the winning MST proposal. He has spent the past five years on the E-3A program performing, installed engine performance analysis and analysis of the engine flight test results. Mr. Scharf will be responsible for propulsion technology support and will spend approximately 40% of his time on this program.

GEORGE A. DISHMAN - System Configuration and Design

Graduate Certificate - Cambridge University - AMIP Production Engineer Degree in Manufacturing Engineering C.E.I. (Tech). British National Technical Degree.

Obtained through the Dehavilland Aeronautical Technical College and the Hatfield Technical College.

After working in the tool design office and/or in the process and tool planning departments of DeHavillando (England) Canadair and AVROE (Canada), Mr. Dishman joined the Boeing Company as a structural designer in 1957 to assist in the wing design of the Advanced 707 (707-320). He subsequently worked on several versions of the 707. He was transferred to the 747 project and as a lead designer, was responsible for the design and release of a substantial part of the 747 wing. After the 747 and the later 747B was in production, he was transferred as a group supervisor to control the design and release of the wing ribs for the Supersonic transport airplane. After completion of this phase of the SST program, he was assigned to a preliminary design group to assist in the detail design of a new "critical wing" transport plane.

He was then moved to the Boeing Space Division to design the wing structure for several versions of flyback space shuttle boosters. Since 1972 he has been responsible for the structural design and configuration of several space projects including the solid motor I.U.S. proposal, the space shuttle orbiter tail cone, the load measurement system for the CAM program and several funded studies for advanced space aircraft. Mr. Dishman will be responsible for the system configuration design and will spend approximately 45% of his time on the program.