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SERJ-176E-4A

PRELIMINARY ENGINE PERFORMANCE INFORMATION

SUPERCHARGED EJECTOR RAMJET
MACH 0 - 4.5 AIRCRAFT ENGINE

(U)

ADVANCE COPY

26 SEPTEMBER, 1969

MR 20,403B

THE MARQUARDT COMPANY

16555 SATICOY STREET, VAN NUYS, CALIFORNIA 91409

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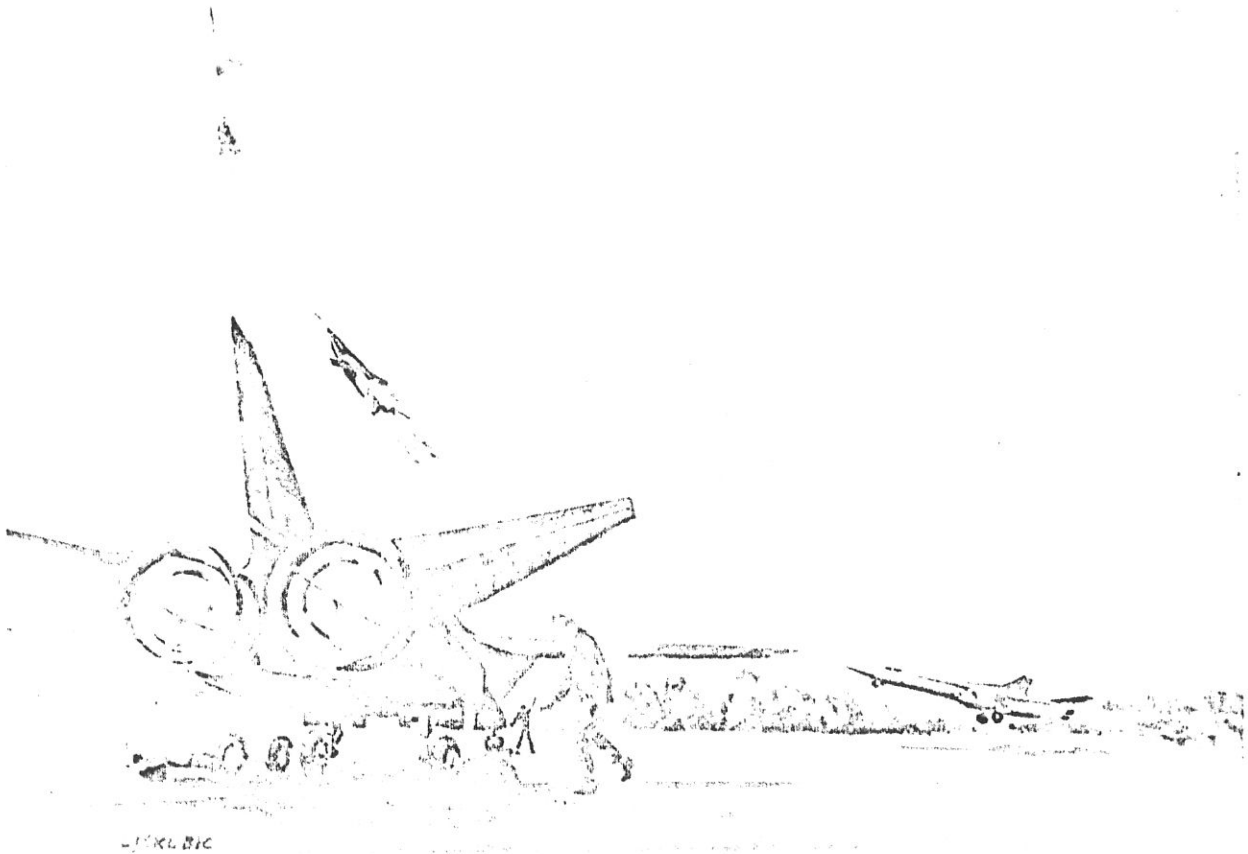
FOREWORD



Low speed/high speed operating flexibility at continuous high performance levels across the entire mission profile is a highly desirable engine characteristic for advanced tactical and strategic aircraft.

The Supercharged Ejector Ramjet (SERJ) engine, a lightweight, highly flexible composite engine in essence combines the cruise fan, the rocket and the ramjet, as elements, in a simple integrated powerplant capable of a wide Mach number range well beyond that for which the turbojet engine is applicable.

The Marquardt Corporation is pleased to present herein preliminary performance data for the SERJ176E-4A engine. This model is the latest in a series of Marquardt high performance manned aircraft engine designs which uniquely combine airbreathing and rocket hardware elements and operating capability to offer particularly advantageous characteristics to the aircraft systems designer.

This specific composite system has been especially directed toward meeting the propulsion requirements of next-generation multi-mission tactical aircraft. The engine design is predicated on current projected advancements in technology available for the 1978-1980 I.O.C.

INTRODUCTION

General

(C) The Marquardt Corporation's SERJ 176E-4A Supercharged Ejector Ramjet aircraft powerplant is a lightweight, highly flexible high speed composite engine. The E-4A engine is rated at 24,600 lb thrust (sea level static-fan ramjet mode) and 51,690 lb thrust in the supercharged ejector mode and has an estimated uninstalled weight of 3250 lbm, (T/W_{SLS}= 7.6 and 15.9 respectively). The engine is approximately 10 ft long and 5 ft in diameter.

(C) The engine is designed for flight speeds of up to Mach 4.5 over the envelope presented subsequently. Propellants are advanced JP-fuel and 90% hydrogen peroxide (for the ejector subsystem).

(U) The engine comprises a supercharger (fan) and gas generator drive subsystem, ejector (rocket type) subsystem providing jet compression, a ramjet or afterburner subsystem, and a fully variable exit nozzle unit. The engine is completely cooled by convective air and radiation means, with the possible exception of regenerative fuel cooling of certain critical exit nozzle portions. The E-4A engine is adaptable to both semi-exposed and buried installation of either the integral or pod type configurations. The fan drive airbreathing gas generator is mounted concentrically in the E-4A, rather than externally as has been shown in previous SERJ engine models (i.e. the E-1, E-2, and E-3 series).

(U) This document provides performance data for the various multi-mode operating regimes of the engine, the engine operating envelope with comments on the data coverage provided in this document, and installation and sea level static rating data.

SERJ 176E-4A Schematic Description

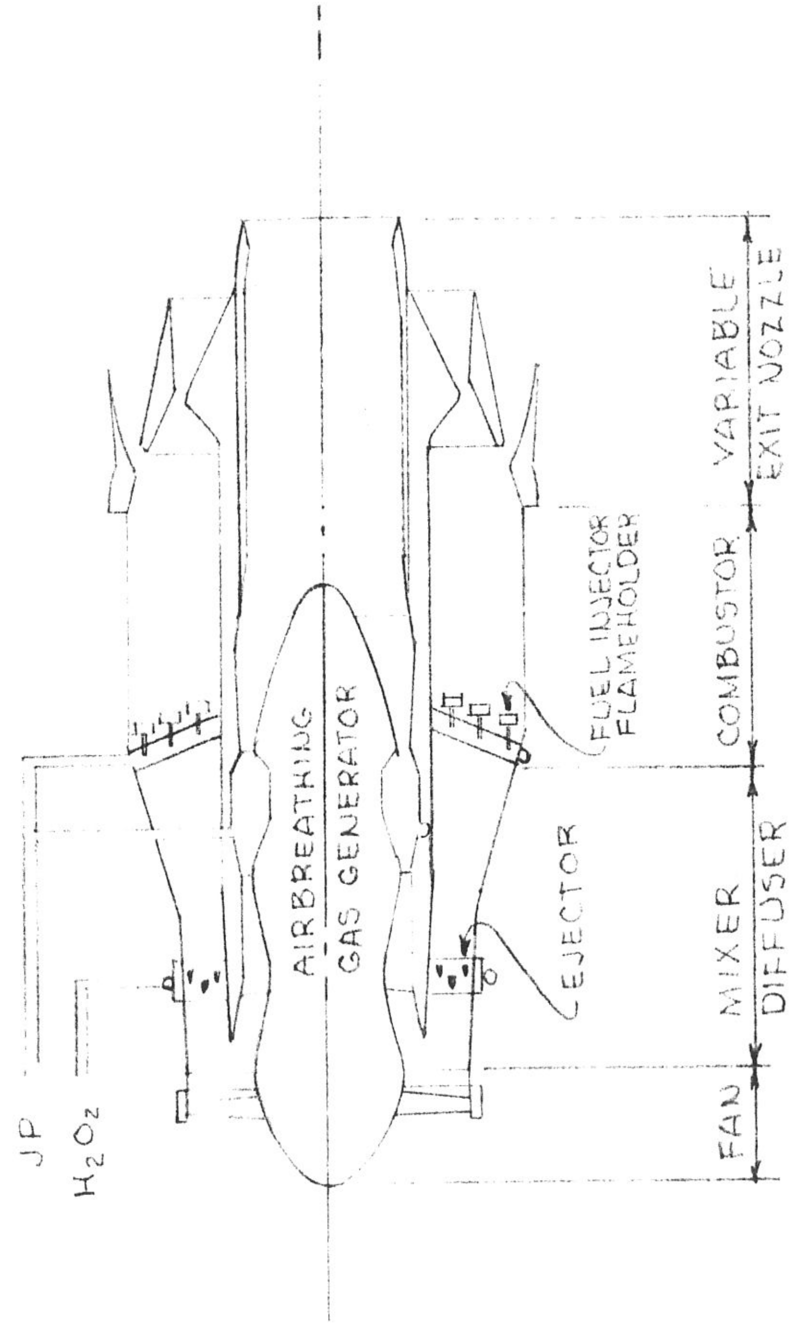
(C) The E-4A can be schematically depicted as shown in the following figure: The front face of the engine is connected with a conventional subsonic/supersonic air induction system. Starting at the engine front face there is a single stage, 2.2 nominal design pressure ratio fan driven by a two-spool gas generator located on the engine centerline. The airstream downstream of the fan is divided with the center portion supplying air to the gas generator and the outside portion supplying air to the (ejector) ramjet portion of the engine. The ratio of ramjet to gas generator airflow is herein termed bypass ratio.

(C) A multiple nozzle ejector subsystem is located just downstream of the lip which divides the airflow as described above. Under the ejector or supercharged ejector modes, the high energy primary exhaust gases evolving from the decomposition of 4000 psi hydrogen-peroxide is mixed with the induced air in a short constant area mixing section (no combustion) to increase significantly the air total pressure and temperature. With the supercharged ejector mode, the ejector then acts as a second compression stage. The mixed gases, including free oxygen from the decomposition of the hydrogen peroxide, are then diffused to provide the highest practical static pressure in the afterburner, or secondary combustor. Hydrocarbon fuel is injected and burned in the afterburner section to consume the oxygen in the induced air and that exhausted by the primary ejector subsystem. The resulting high pressure, high temperature gases are then expanded through a variable exit nozzle.

(C) Energy is extracted from the gas generator airstream by the low pressure turbine to drive the single stage fan. The exhaust products of the gas generator are then passed through a separate variable exit nozzle. The net jet thrust and specific fuel or propellant consumption in this document represent the combined ramjet and gas generator airstreams.

(C) The sea level static thrust and specific impulse in the supercharged ejector mode is approximately 43% higher than the performance of a correctly expanded bipropellant rocket engine, with this augmentation increasing rapidly with increasing airspeed. Short field take-off, carrier take-off without catapult, or even vertical take-off might be accomplished using the supercharged ejector modes, whereas fan ramjet take-off might be used on longer runways. As flight speed becomes sufficient to effect substantial ram recovery in the inlet, or as reduced thrust level is permissible the ejector subsystem is phased off and the engine continues to accelerate or to cruise on fan ramjet power (supercharged ramjet). At higher speeds the fan is windmilled and the engine sustains itself as a conventional ramjet. The ejector primary system may be utilized at any time to provide additional thrust performance upon demand at the indicated specific fuel consumption penalty. Another mode of operation, for very low fuel consumption-low thrust, such as for loiter, involves the fan above with little or no afterburning.

(U) The multimode capability indicated above is one of the significant operating features of the SERJ engine and provides wide operating flexibility to the aircraft designer. The operating modes of the SERJ engine are discussed further in the following section. Specific fuel consumption and thrust performance are presented in graph form in the main body of this document.


JP
H_2O_2
AIRBREATHING
GAS GENERATOR
FUEL INJECTOR
FLAMEHOLDER
EJECTOR
FAN
MIXER
DIFFUSER
COMBUSTOR
VARIABLE
EXIT NOZZLE

SERJ Multimode Operation

(U) Composite engines are highly flexible in that they are capable of operation in a multiplicity of distinct thermodynamic modes.

(U) Four fundamental operating modes are feasible with the Supercharged Ejector Ramjet engine. These are discussed in order of normal usage over a typical flight profile. The initial takeoff high acceleration operation is termed Supercharged Ejector mode and involves simultaneous fan, primary, and afterburning operation.

(C) For conversion to the Fan/Fan Ramjet mode the ejector unit is phased out and fan and afterburner are operating to provide propulsion. As flight speeds approach Mach 3.0 to 3.5, the fan pressure ratio contribution has become nil while ram recovery temperature has reached a point that fan windmilling is advantageously performed. The engine then continues operation as a ramjet (ramjet mode), accelerating to cruise condition. On the other hand at low flight speeds, such as subsonic loiter, the afterburner is phased out and the engine operates as a high bypass ratio turbo-fan.

(C) The final mode is the Ejector mode comprising ejector operation with afterburning with the fan remaining unpowered. This mode would be called upon in case of instantaneous emergency thrust requirements (super-performance) during moderate to high flight speed operation. SERJ thus has the ability to convert instantly from a cruising ramjet condition to a high thrust augmented rocket operation for attack maneuvering, defensive evasion, or other super-performance needs.

(U) It will be noted that the engine performance data which comprises the basic content of the document is in fact organized by engine operating modes, namely:

1. Supercharged Ejector Mode.
2. Fan/Fan Ramjet Mode.
3. Ramjet Mode.
4. Ejector Mode (Super-performance).

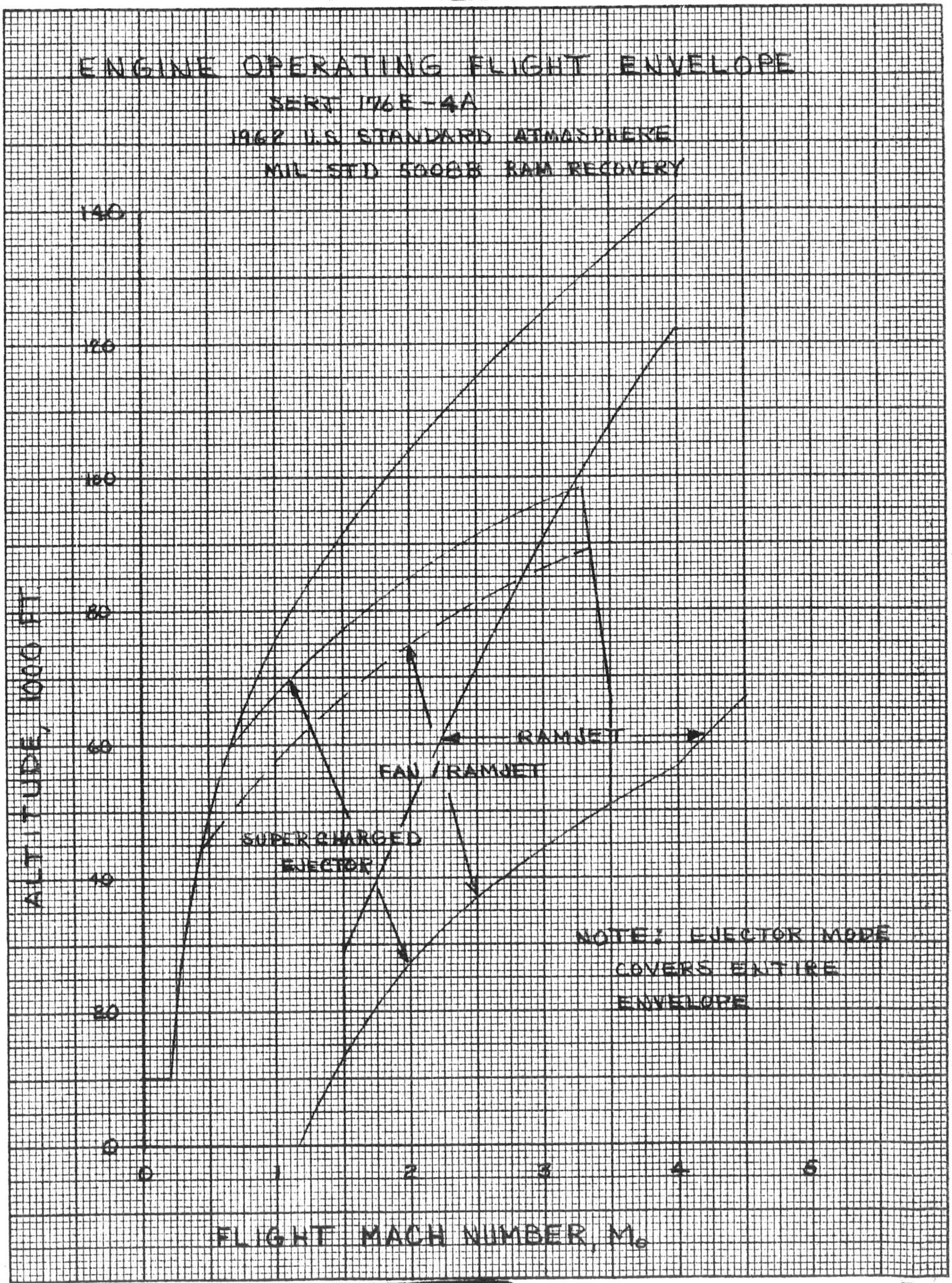
SERJ Operating Envelope

(U) The nominal SERJ 176E-4A engine operating envelope appears on the following page with a differentiation by the operating modes previously described. The envelope as described is preliminary and remains considerably flexible in the instance of special airframe company requirements.

(C) This chart shows the operating capability of the engine from zero to Mach 4.5 and from sea level to 140,000 feet altitude, operating with individual mode limits as indicated. As can be seen at the various Mach number conditions, typically more than one operating mode is available, the basic determinant here being thrust demand, with the actual mode selection and power setting being made in view of maximizing economy of operation to satisfy this demand. The ability to increase altitude significantly is accomplished by using the ejector mode either directly, or at very low hydrogen peroxide flow settings which provide an enhanced oxygen environment in the combustor during ramjet operation.

(U) It should be emphasized that the operating map revealed here is strictly nominal in the sense that specific characteristics of the map would be a function of individual aircraft user requirements. At the expense of some additional complexity and/or weight the engine can be tailored to other specific operating ranges. As an observation, the multi-mode operating conditions reflected on the map are to be contrasted with the capability of a single mode device such as a dry turbojet or a two-mode device such as an afterburning turbojet which in general provides significant compromise of performance at any given Mach number/altitude condition because of the lack of independent, locally optimized subsystems as in SERJ. Thus SERJ fan mode performance is distinctly superior in subsonic loiter to that achieved by a supersonic turbojet system.

(U) The specific performance data which are subsequently presented does not necessarily conform to the envelope for the various engine operating modes shown.


ENGINE OPERATING FLIGHT ENVELOPE
SERJ 176E-4A
1962 U.S. STANDARD ATMOSPHERE
MIL-STD 5008B RAM RECOVERY
ALTITUDE, 1000 FT
140
120
100
80
60
40
20
0
0
1
2
3
4
5
FLIGHT MACH NUMBER, M_0
RAMJET
FAN / RAMJET
SUPERCHARGED EJECTOR
NOTE: EJECTOR MODE COVERS ENTIRE ENVELOPE

SERJ Installation and Sea Level Static Rating Information

(U) The SERJ 176E-4A external envelope dimensions, center of gravity location and mounting points are presented in the next following figure.

(C) The nominal sea level static engine rating for the SERJ 176E-4A is summarized below:

	Supercharged Ejector Mode	Fan/Ramjet Mode
Engine thrust	51,690 lbf	24600.0
Engine total airflow	268.0 lbm/sec	268.0
Fan bypass ratio	3.57	3.57
Engine JP-fuel flow	28.8 lbm/sec	16.0
Engine hydrogen peroxide flow	105.0 lbm/sec	0.0

(C) The maximum ejector subsystem hydrogen peroxide flow rate is 105 pps. 90% H_2O_2 has been utilized in performance calculations herein. Proportional throttling of the primary flow is feasible, and the specific impulse and thrust trends with primary throttling over a range of 0-100% are presented herein for the Supercharged Ejector mode.

(C) Estimated engine uninstalled weight and sea level static thrust/weight ratio information is given below for an assumed 130 psia maximum engine internal pressure (P_{T_2}) at a flight Mach number of 4.5.

	Uninstalled Weight lbm	Engine Thrust/Wt. Ratio (sea level static)	
		S/E Mode	F/RJ Mode
Advanced materials basis	3250	15.9	7.58

SERJ Performance Data Bases

(U) The engine specific impulse and thrust data are given on a "net jet" basis which includes air induction inlet momentum penalty, but does not include external drag such as cowl, induced, friction or spillage drag.

(U) Data is predicated on the standardized inlet pressure recovery presented in Specification MIL-E-5008B.

(U) Realistic component and process efficiencies have been utilized throughout the computations. These data can be made available upon request.

(C) The respective flow rates of ejector primary subsystem hydrogen peroxide and combined afterburner and gas generator fuel can be determined as follows:

$$W_{P_T} = F_{n_j} \frac{(SPC)}{3600.0}$$

$$W_{f_T} = W_{P_T} - 105K$$

where

W_{P_T} = total propellant flow, lbm/sec

W_{f_T} = combined afterburner and gas generator fuel flow, lbm/sec

F_{n_j} = net jet thrust, lbf

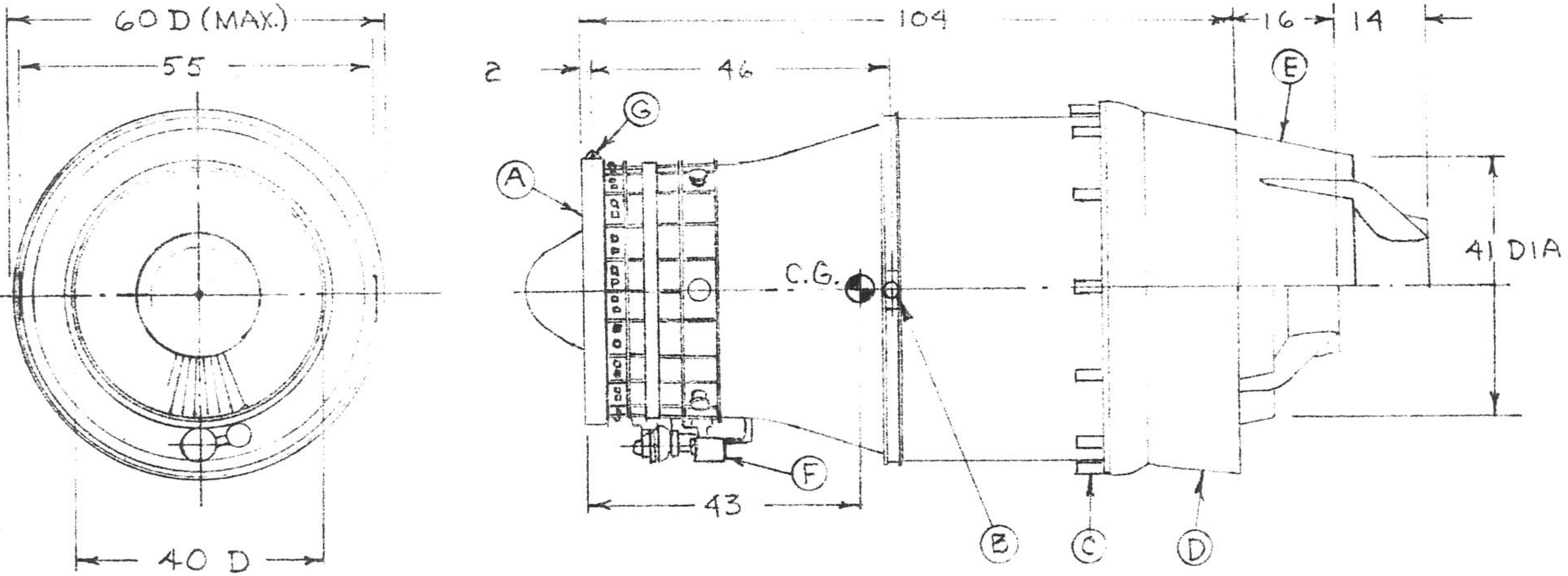
SPC = specific propellant consumption, lbm/hr/lbf

105.0 = primary chamber flow (constant) lb/sec

K = primary flow factor for throttled primary performance data, i.e. for 60 percent of primary flow, K = 0.60, etc.

For modes with no primary operation, $W_{f_T} = F_{n_j} \times \frac{(\text{specific fuel consumption})}{3600.0}$

INSTALLATION SKETCH
SERJ 176E-4A



Ⓐ FAN

Ⓑ THRUST MOUNT

Ⓒ ACTUATORS

Ⓓ ACCELERATION & SUPERSONIC CRUISE POSITION

Ⓔ SUBSONIC CRUISE & LOITER POSITION

Ⓕ PUMPS & CONTROLS PACKAGE

Ⓖ FORWARD STABLIZATION MOUNT

[redacted]

SERJ 176E-4A

SUPERCHARGED EJECTOR MODE
(Fan + Primary + Secondary Combustor)

This Section contains the following data (30 curves):

- Total Airflow (Mach 0-3.5)
- Free Stream Capture Area (Mach 0-3.5)
- Thrust, 100%, 75%, 50%, 25%, 12.5% primary flow, ϕ = 1.0 (Mach 0-3.5)
- Specific Fuel Consumption, 100%, 75%, 50%, 25%, 12.5% Primary Flow, ϕ = 1.0 (Mach 0-3.5)
- Thrust with Primary Flow Throttling, 100-0%, ϕ = 1.0, SL-80000 ft.
- Specific Fuel Consumption with Primary Flow Throttling, 100-0%, ϕ = 1, SL-80000 ft.

Note: Performance is given in this Section at some flight conditions which are outside of the flight envelope, Figure -7- . Performance for flight conditions outside of the flight envelope should not be assumed in mission analysis.

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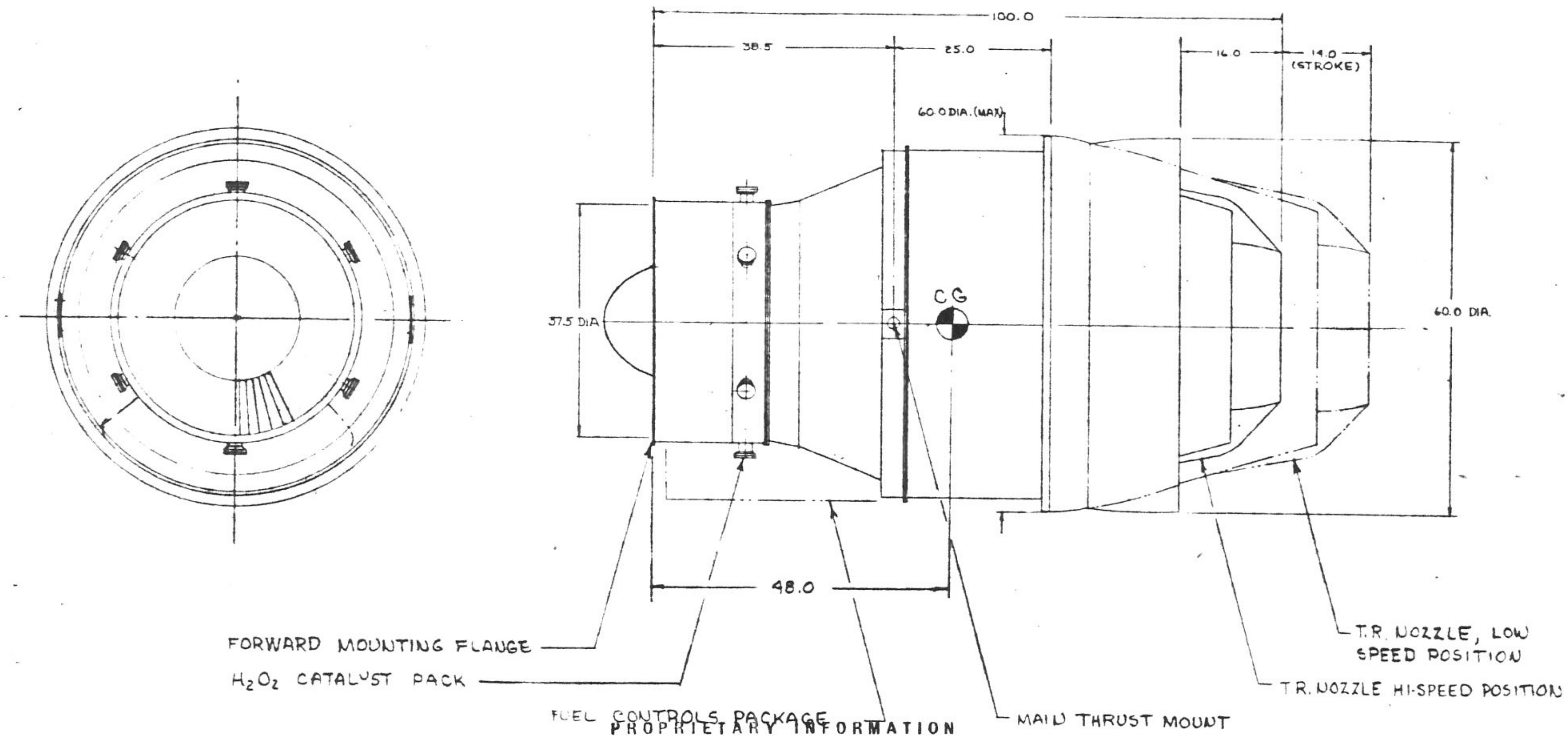
PRELIMINARY



SERJ ENGINE - CONFIGURATION "D"

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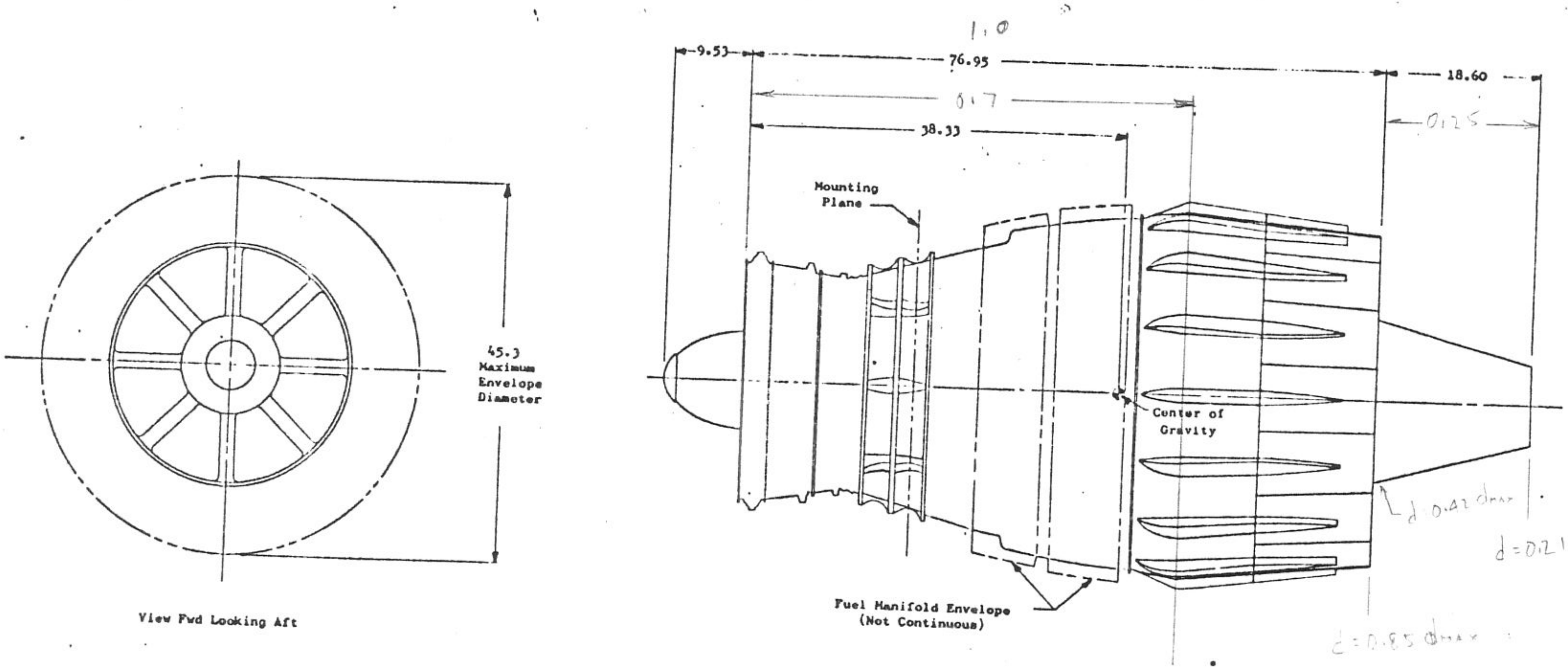


Figure 3.0-1. GE14/FZ1 Engine Installation Drawing

Diameter or Length, Inches

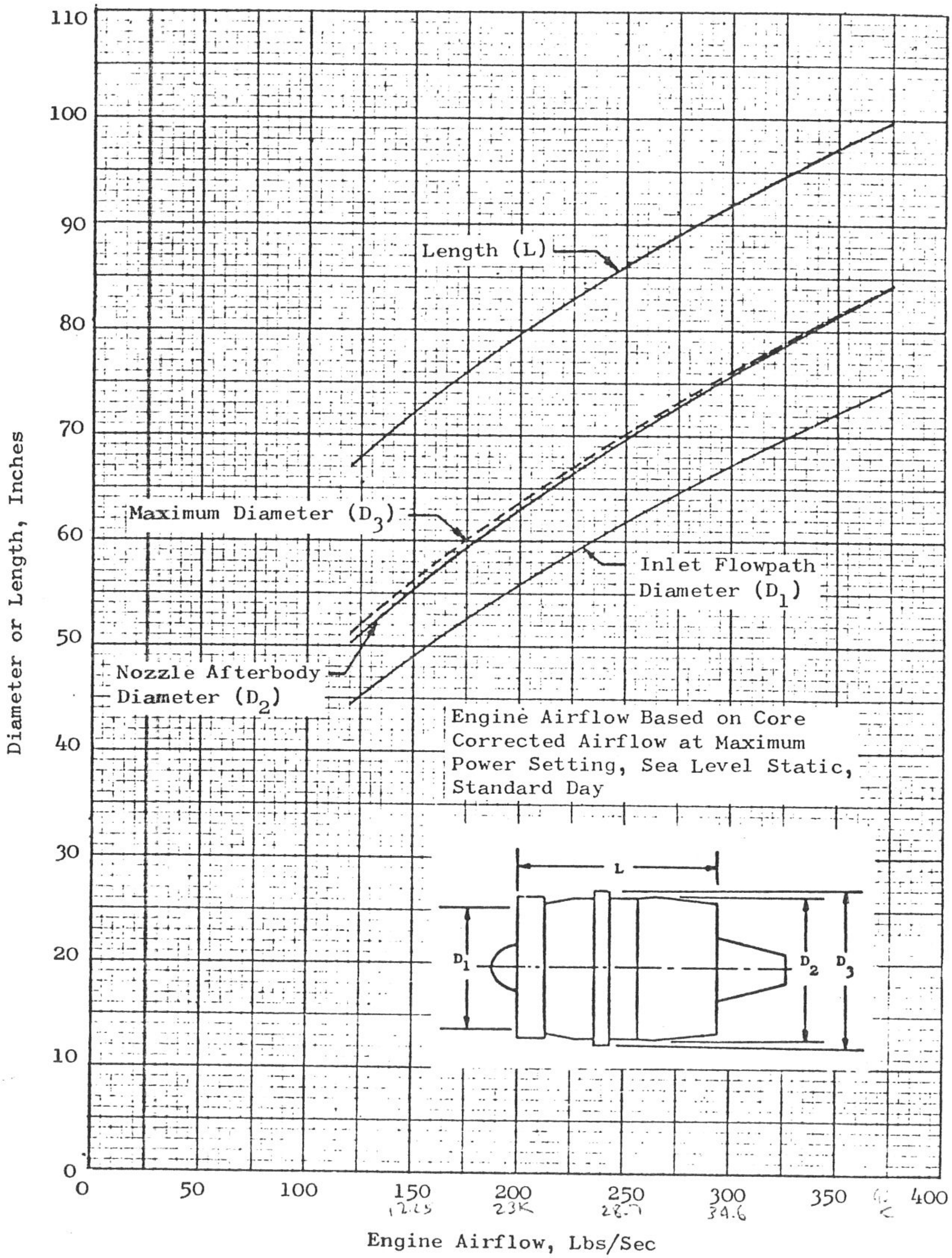


Figure 2. GE14/JZ8 Configuration Scaling Data

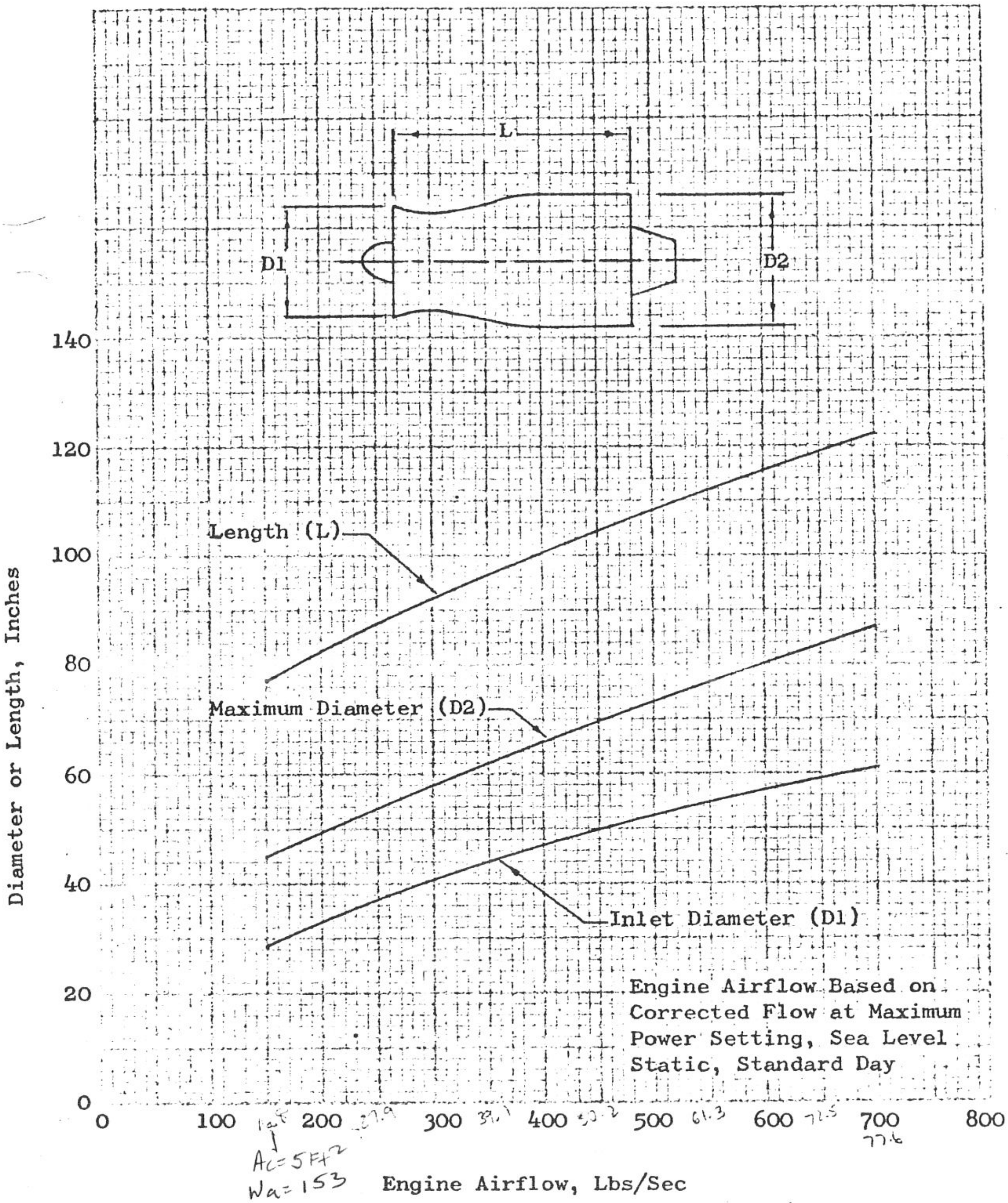
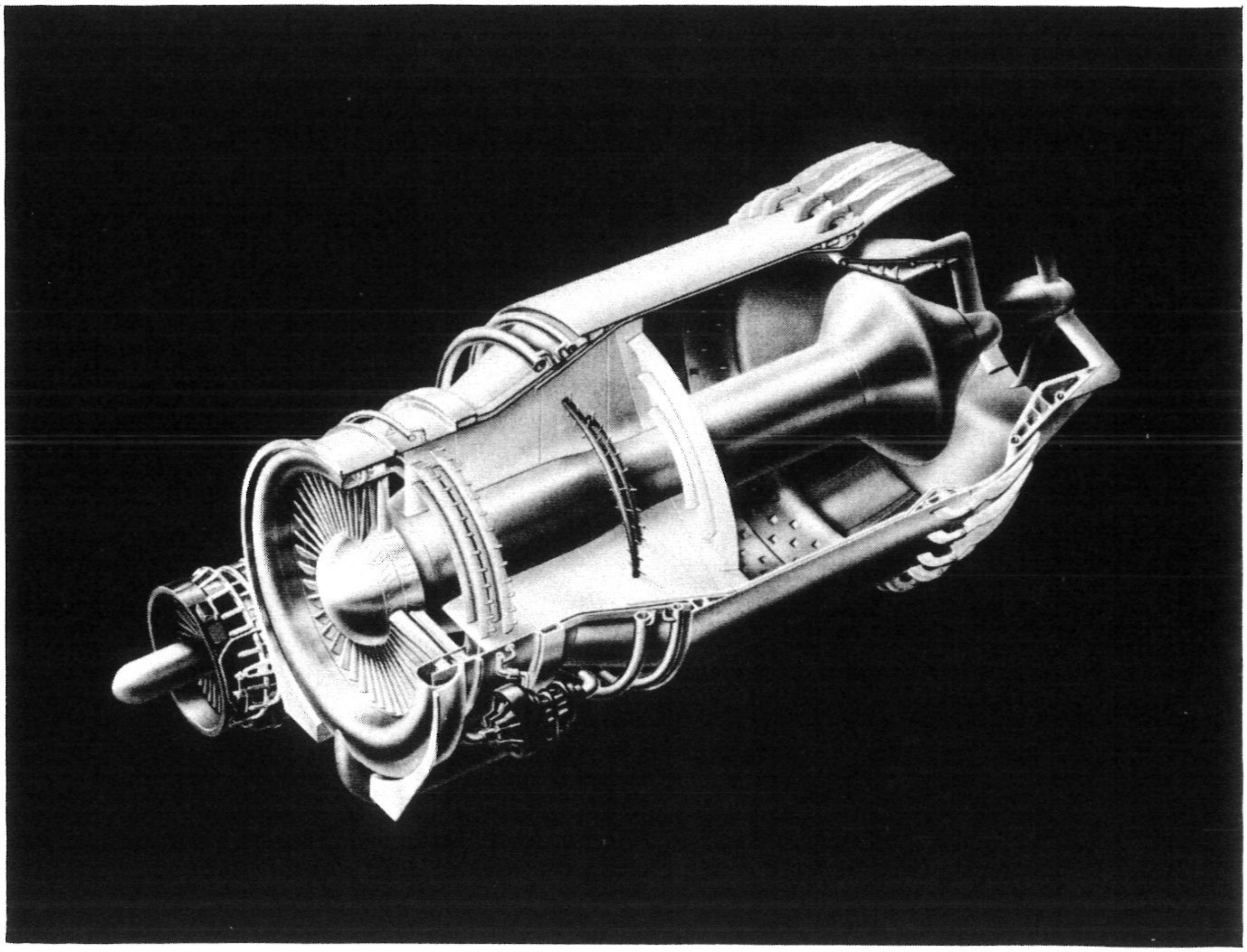


Figure 3.0-2. GE14/FZ1 Engine Configuration Scaling Data

SERJ-176E-1 ENGINE



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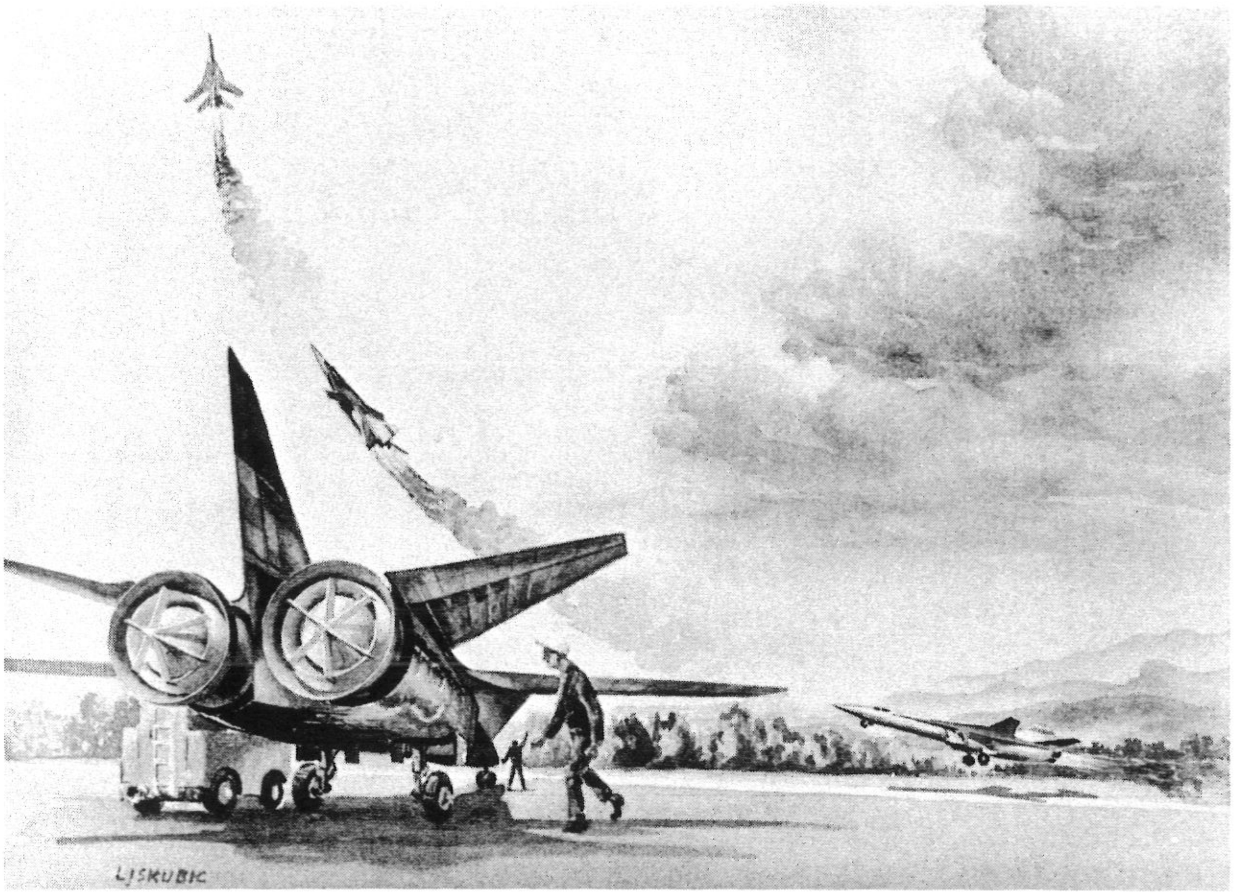
FOREWORD



Low speed/high speed operating flexibility at continuous high performance levels across the entire mission profile is a highly desirable engine characteristic for advanced tactical and strategic aircraft.

The Supercharged Ejector Ramjet (SERJ) engine, a lightweight, highly flexible composite engine in essence combines the cruise fan, the rocket and the ramjet, as elements, in a simple integrated powerplant capable of a wide Mach number range well beyond that for which the turbojet engine is applicable.

The Marquardt Corporation is pleased to present herein preliminary performance data for the SERJ-176E-1 engine. This model is the latest in a series of Marquardt high performance manned aircraft engine designs which uniquely combine airbreathing and rocket hardware elements and operating capability to offer particularly advantageous characteristics to the aircraft systems designer.

INTRODUCTION

General

The Marquardt Corporation's SERJ-176E-1 Supercharged Ejector Ramjet Engine (Model MA176-XEA) aircraft powerplant* is a lightweight, highly flexible high speed composite engine. The E-1 engine is rated at 32,000 lb thrust (sea level static) and has an estimated uninstalled weight ranging from 2650 to 2060 lbm. (T/W_{sls} = 12.1 to 15.6), depending on required availability time and development resources available for the engine. The engine is approximately 8 ft long and 4 ft in diameter.

The engine is designed for flight speeds of up to Mach 4.5 over the envelope presented subsequently. Propellants are advanced JP-fuel and 90% hydrogen peroxide (ejector subsystem).

The engine comprises a supercharger (fan) and drive subsystem, ejector (rocket type) subsystem providing jet compression, a ramjet or afterburner subsystem, and a fully variable exit nozzle unit. The engine is completely cooled by convective air and radiation means, with the exception of regenerative fuel cooling of certain critical exit nozzle portions.

The E-1 engine is adaptable to both semi-exposed and buried installation of either the integral or pod type configurations. The fan drive airbreathing gas generator can be close-coupled or mounted in a remote position from the engine as needed to facilitate integration with the aircraft. In a multi-engine installation it may be advantageous to service two or more engines with a single generator.

This document briefly reviews the SERJ powerplant cycle and the research and development status of the engine. Following this introduction, general data are provided regarding the multimode operating feature of the engine, engine operating envelope with comments on the data coverage provided in this document, and installation and sea level static rating data. Finally, a few notes are provided describing the bases for the performance data to follow.

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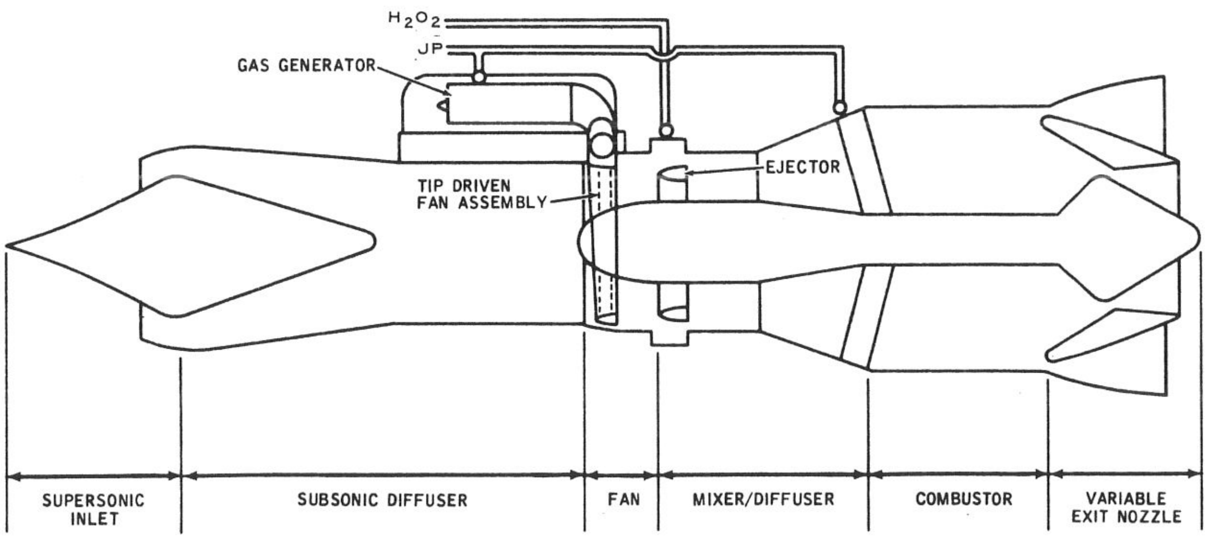
*Frontispiece

SERJ Schematic Description

SERJ can be schematically depicted as shown below: Aft of a conventional subsonic/supersonic air induction system is located the single stage, 1.5 nominal design pressure ratio fan assembly (the inlet diffuser is elongated in the schematic to reflect retraction forward and upward). The multiple nozzle ejector subsystem is located aft of the fan. High energy primary exhaust gases evolving from the decomposition of high pressure hydrogen-peroxide is mixed with induced air in a short constant area mixing section to increase significantly the air total pressure and temperature, and to add additional free oxygen. The mixed gases are then diffused to provide the highest practical static pressure in the afterburner, or combustor. Hydrocarbon fuel is injected and burned in the afterburner section to consume the oxygen in the induced air and that exhausted by the primary gas generator. The resulting high pressure, high temperature gases are then expanded through a variable exit nozzle.



The sea level static thrust and specific impulse of the SERJ is approximately 40 percent higher than the performance of a correctly expanded bipropellant rocket engine, with this augmentation increasing rapidly with increasing air speed. As flight speed becomes sufficient to effect substantial ram recovery in the inlet, or as reduced thrust level is permissible, the ejector subsystem is phased off and the engine continues operating on the supercharged ramjet (afterburning fan). At higher speeds the fan is non-operating and the engine sustains itself as a conventional ramjet. Another mode of operation, for very low fuel consumption-low thrust requirements, involves the fan alone with little or no afterburning, thereby providing

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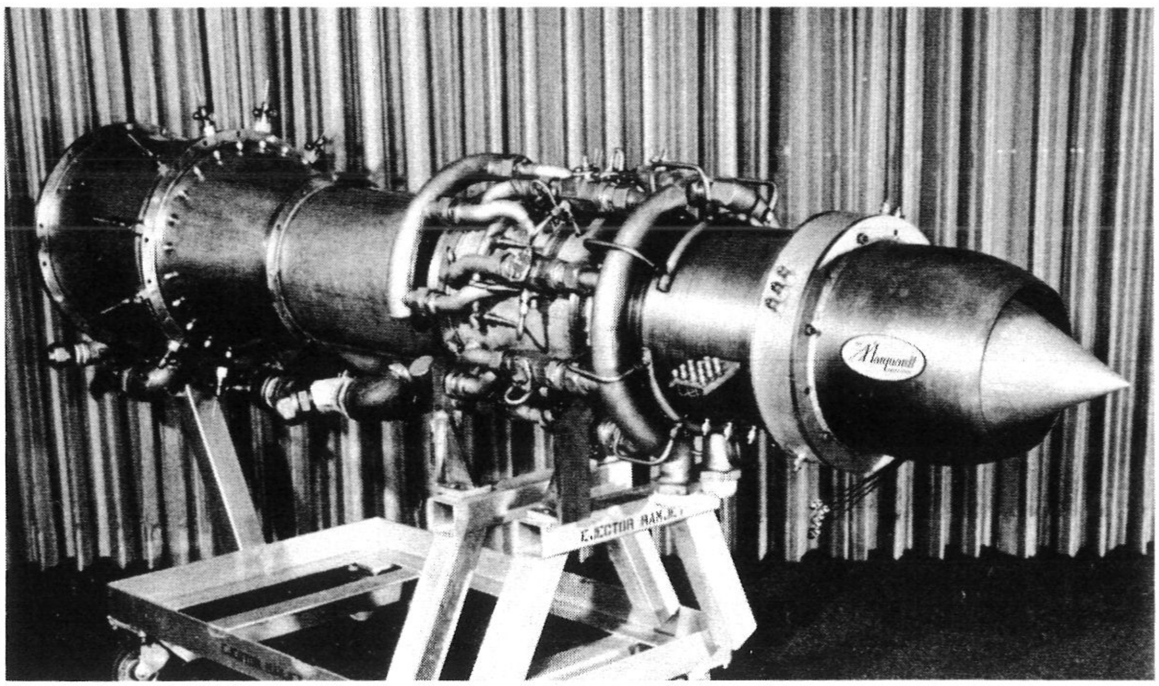
extremely low specific fuel consumption performance for subsonic cruise, or loiter. Also, a high speed ejector-on acceleration mode is available for supersonic emergency thrust requirements.

The multi-mode capability indicated above is one of the significant operational features of the SERJ engine and provides extremely wide ranging operating flexibility to the aircraft user. The operating modes of the SERJ are schematized individually in the discussion to follow. Specific impulse and thrust performance is presented in map form subsequently.

Status of the SERJ Engine

The Supercharged Ejector Ramjet is a company sponsored, further development of Marquardt's Ejector Ramjet (ERJ) propulsion system, now completing its exploratory research phase. Marquardt's current program, under continuing U.S. Air Force, Aero Propulsion Laboratory sponsorship, was initiated in 1962. These analytical and experimental efforts are culminating in the sea level static and freejet simulated high flight speed testing of an integrated inlet/engine subscale propulsion system. A hydrogen-oxygen run series was successfully completed in 1966. A jet fuel-90% hydrogen peroxide test program is scheduled for completion in 1967.

This 18 inch diameter subscale research engine is shown below with a conical spike inlet for freejet simulated high speed (up to Mach 3) testing. Sea level operation will be conducted with a standard bell mouth inlet.



Integration of SERJ's fan subsystem into the ERJ system has been under investigation for a number of years. Supporting experimental programs are planned for both fan subsystem retraction feasibility testing and eventual overall SERJ engine tests at approximately 1/10 scale.

SERJ Multimode Operation

Composite engines are highly flexible in that they are capable of operation in a multiplicity of distinct thermodynamic modes as illustrated in the following figure (Page 6) for SERJ.

Four fundamental operating modes are feasible with the Supercharged Ejector Ramjet engine. These are reflected in the figure in order of normal usage over a flight profile. The initial takeoff high acceleration operation is termed Supercharged Ejector mode and involves simultaneous fan, rocket, and afterburning operation.

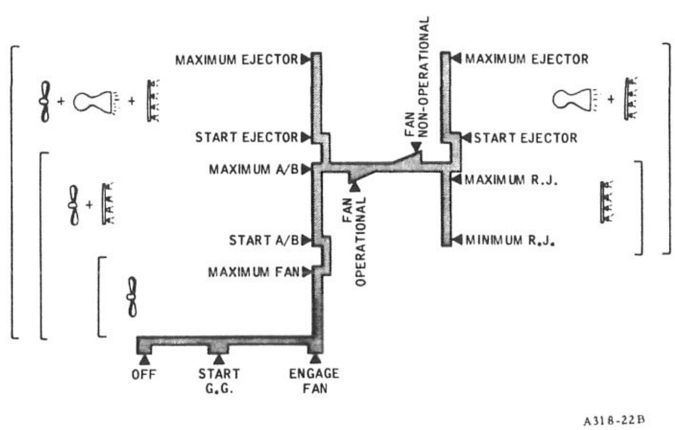
Conversion to the Fan/Fan Ramjet mode is revealed in the second schematic. The ejector unit is phased out and fan and afterburner are operating to provide propulsion. As flight speeds approach Mach 2.5 to 3, the fan pressure ratio contribution has become nil while ram recovery temperature has reached a point that fan retraction is advantageously performed as shown in the third schematic. The engine then continues operation as a ramjet (ramjet mode), accelerating to cruise condition.

The final mode revealed here (lower right) is the Ejector mode comprising ejector operation with afterburning with the fan remaining retracted. This mode would be called upon in case of instantaneous emergency thrust requirements (super-performance) during moderate to high flight speed operation. SERJ thus has the ability to convert instantly from a cruising ramjet condition to a high thrust augmented rocket operation for attack maneuvering, defensive evasion, or other super-performance needs.

It will be noted that the engine performance data which comprises the basic content of the document is in fact organized by engine operating modes, namely:

1. Supercharged Ejector Mode
2. Fan/Fan Ramjet Mode
3. Ramjet Mode
4. Ejector Mode (Super-performance)

As revealed in the sketch to the right it is considered feasible to provide a single pilot input control means for operating the SERJ engine through all modes, and for various throttle settings in each mode. The control concept shown is predicated on forward (upward) movement of the control handle for additional thrust demand. Detents are provided between mode ranges and for fan retract/extend command.



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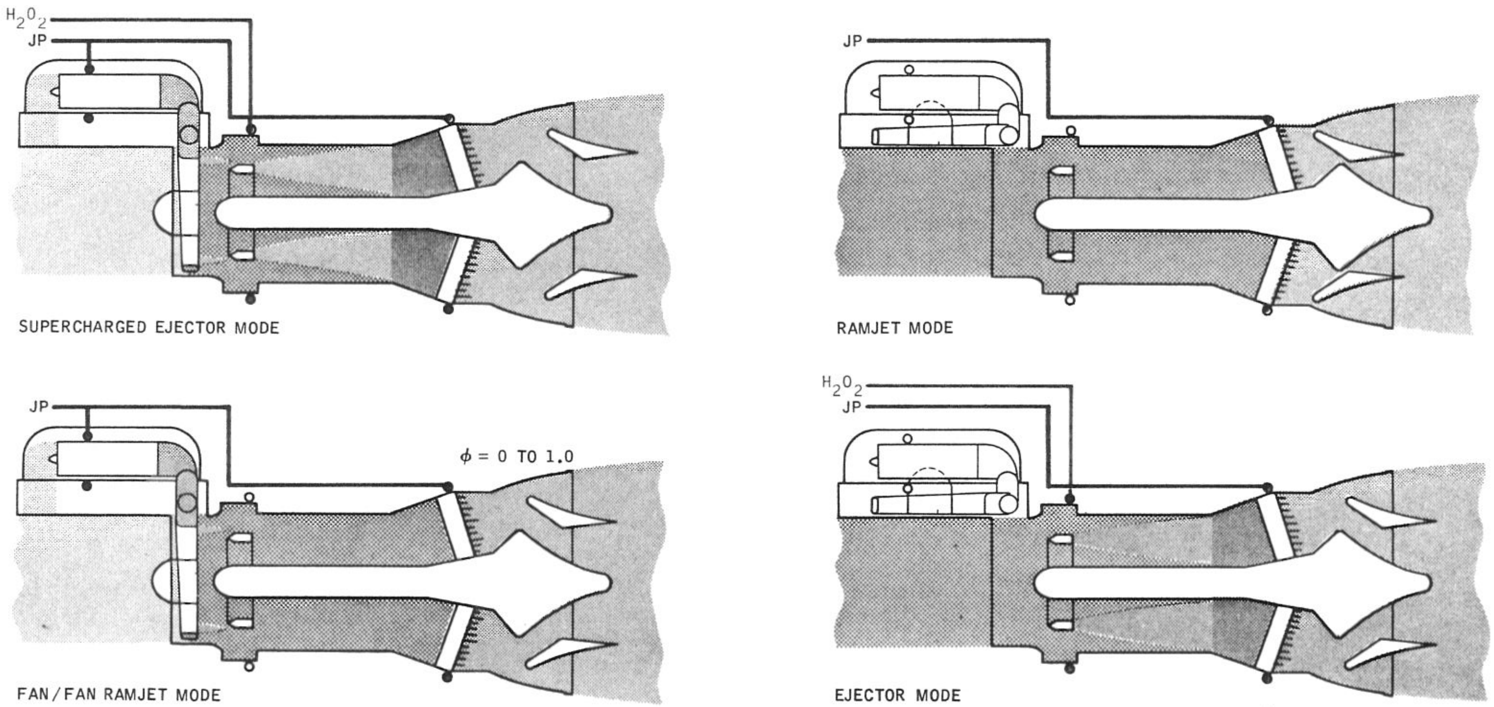
SUPERCHARGED EJECTOR RAMJET (U)

OPERATING MODES

(PUMPING, COOLING AND CONTROL CIRCUITS NOT SHOWN)



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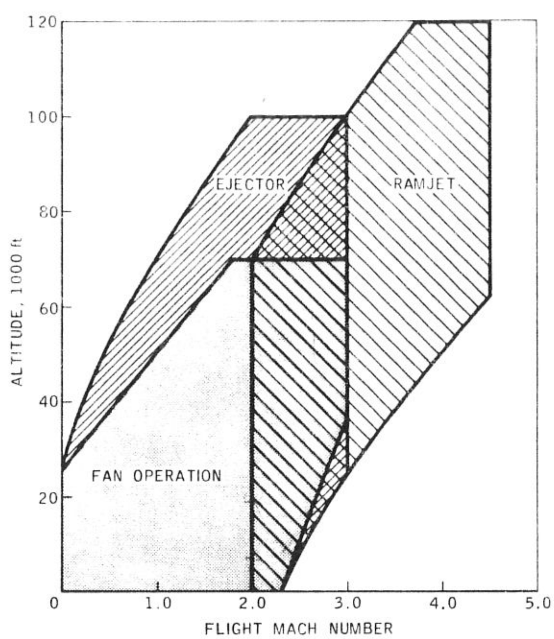
SERJ Operating Envelope

The nominal engine operating envelope appears to the right with a differentiation by the operating modes previously described.* The envelope as described is preliminary and remains considerably flexible in the instance of special airframe company requirements.

One observation to be made is that whereas the Ejector Mode is shown as limited to Mach 3.0 and below, higher speed superperformance capability is definitely feasible. It will be noted that, although performance data in the Mach 3.0-5.0 interval are not presented, if requirements so dictate, an extension of mode speed capability will be investigated by Marquardt.

NOMINAL ENGINE OPERATING MODE LIMITS



The specific performance data which is subsequently presented does not necessarily conform to the envelope for the various engine operating modes shown. The data coverage is revealed in the table below:

Altitude (1000 ft)	Flight Mach Number Range: Supercharged Ejector Fan/Fan Ramjet	Ramjet	Ejector
0	0 - 1.5	2-3.0	0-2.0
10	0.2 - 2.0	2-4.0	1.0-2.0
20	0.4 - 2.0	2-4.0	0.9-2.5
30	0.6 - 2.5	2-4.0	0.8-2.5
36	0.7 - 3.0	2-4.5	0.7-3.0
40	0.7 - 3.0		0.7-3.0
50	1.0 - 3.0		0.5-3.0
60	1.0 - 3.0		0.5-3.0
70	1.0 - 3.0		0.5-3.0
80			1.0-3.0
100			1.0-3.0

*Note: "Fan operation" covers both the supercharged ejector and the fan/fan ramjet modes.

SERJ Installation and Sea Level Static Rating Information

The SERJ-176E-1 external envelope dimensions, center of gravity location and mounting points are presented in the next following figure. Fan disposition techniques which include both retraction and non-retraction, such as windmilling, will be examined by Marquardt for the Naval Air Systems Command. An advantage of having the gas generator physically removed from the fan is that it can then be isolated from the high temperature internal environment experienced at high flight Mach numbers. Therefore, a substantial saving in weight can be realized. Further, the need for a sophisticated high temperature gas generator is obviated. Hence, the SERJ-176E-1 engine is predicated on current gas generator performance characteristics, i.e., J-97 or equivalent.

The nominal sea level static engine rating for the SERJ-176E-1 is summarized below:

Engine thrust	32,200 lbf
Engine total airflow	209 lbm/sec
Fan bypass ratio	5.1
Engine JP-fuel flow	21.9 lbm/sec
Engine hydrogen peroxide flow	62.5 lbm/sec

It is noted that ejector subsystem hydrogen peroxide flow is normally held constant at 62.5 lbm/sec for the supercharged ejector and ejector modes. Proportional throttling of this primary flow is feasible, and the specific impulse and thrust trends with primary throttling over a range of 0-100% are presented herein for the supercharged ejector mode.

Estimated engine uninstalled weight and sea level static thrust/weight ratio information is given below for an assumed 100 psia maximum engine internal pressure (P_{T_2}) at a flight Mach number of 4.5. Two weight values are presented: "current materials" e.g., Rene' 41 superalloy and "advanced materials" e.g., silicon carbide filament reinforced titanium composite material.

	Uninstalled Weight lbm	Thrust/Weight Ratio (sea level static)
Current materials basis	2650	12.1
Advanced materials basis	2060	15.6

SERJ Performance Data Bases

The engine specific impulse and thrust data is given on a "net jet" basis which includes air induction inlet momentum penalty, but does not include external drag such as cowl, induced, friction or spillage drag.

Data is predicated on the standardized inlet pressure recovery presented in Specification Mil-E-5008B.

Realistic component and process efficiencies have been utilized throughout the computations.

The respective flow rates of ejector primary subsystem hydrogen peroxide and combined afterburner and gas generator fuel can be determined as follows:

$$W_{P_T} = F_{n_j} \text{ (SPC)}$$

$$W_{f_T} = W_{P_T} - 225{,}000 \text{ K}$$

where

W_{P_T} = total propellant flow, lbm/hr

W_{f_T} = combined afterburner and gas generator fuel flow, lbm/hr

F_{n_j} = net jet thrust, lbf

SPC = specific propellant consumption, lbm/hr/lbf

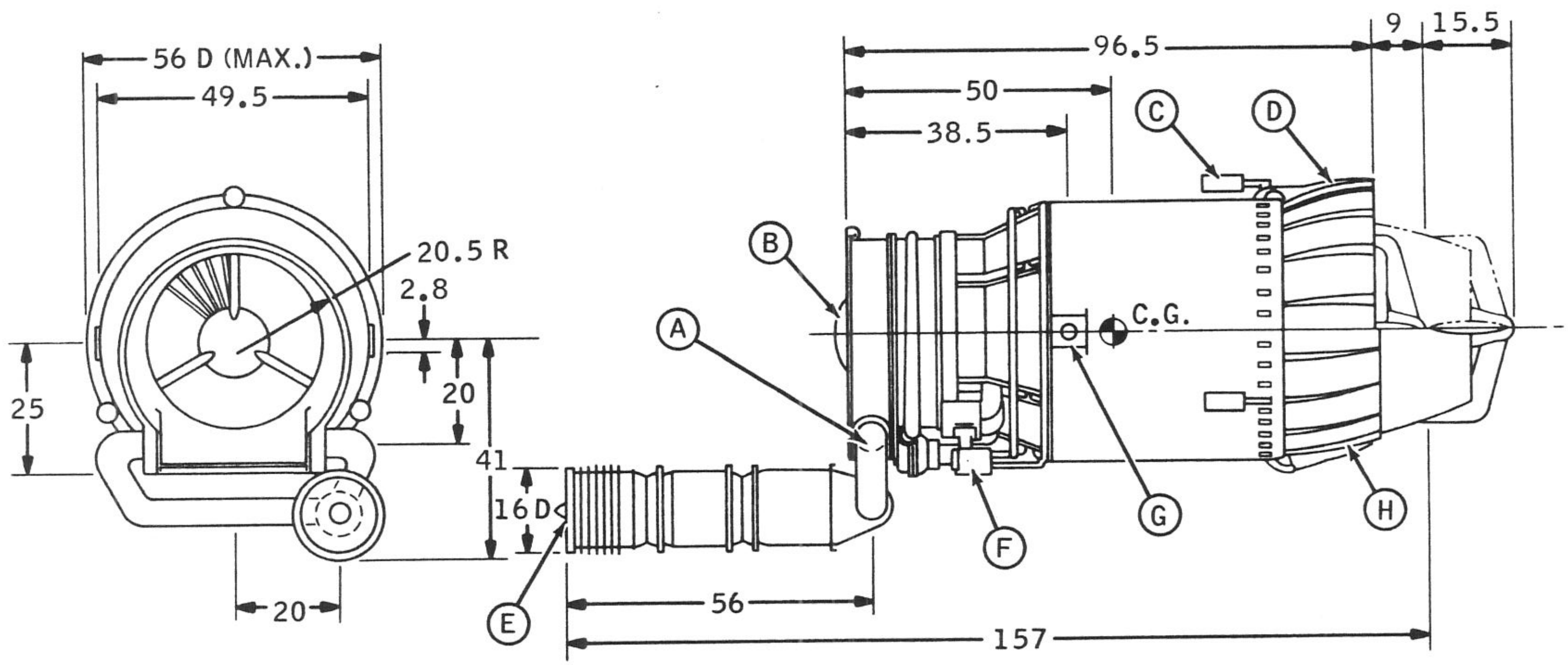
225,000 = primary chamber flow (constant) lb/hr

K = primary flow factor for throttled primary performance data, i.e. for 60 percent of primary flow, K = 0.60, etc.

For modes with no primary operation, $W_{f_T} = F_{n_j}$ (specific fuel consumption)

INSTALLATION SKETCH

MA176 - XEA SERJ



Ⓐ TIP TURBINE AND SCROLL

Ⓑ FAN

Ⓒ ACTUATORS AND AFT STABILIZATION MOUNT

Ⓓ ACCELERATION AND SUPERSONIC CRUISE POSITION

Ⓔ AIRBREATHING GAS GENERATOR

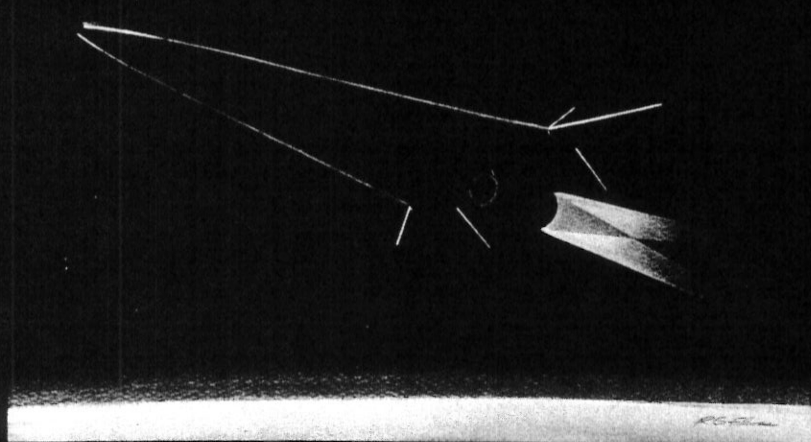
Ⓕ PUMPS AND CONTROL PACKAGE

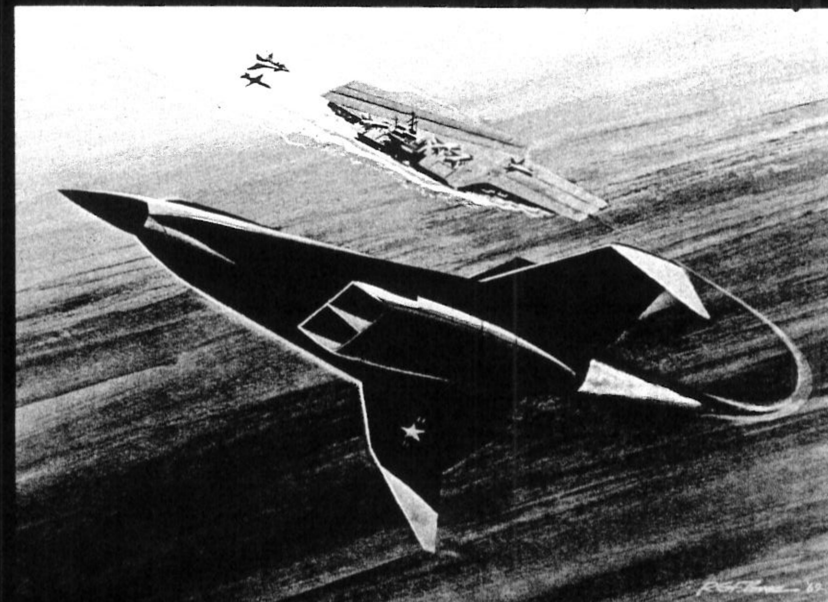
Ⓖ FORWARD THRUST MOUNT

Ⓗ SUBSONIC CRUISE AND LOITER POSITION

CONFIDENTIAL

HYPERSONIC SYSTEMS STUDIES





A STATUS REPORT

BY

GROUP-3
Downgraded at 3-year intervals;
declassified after 12-years

VOUGHT AERONAUTICS DIVISION

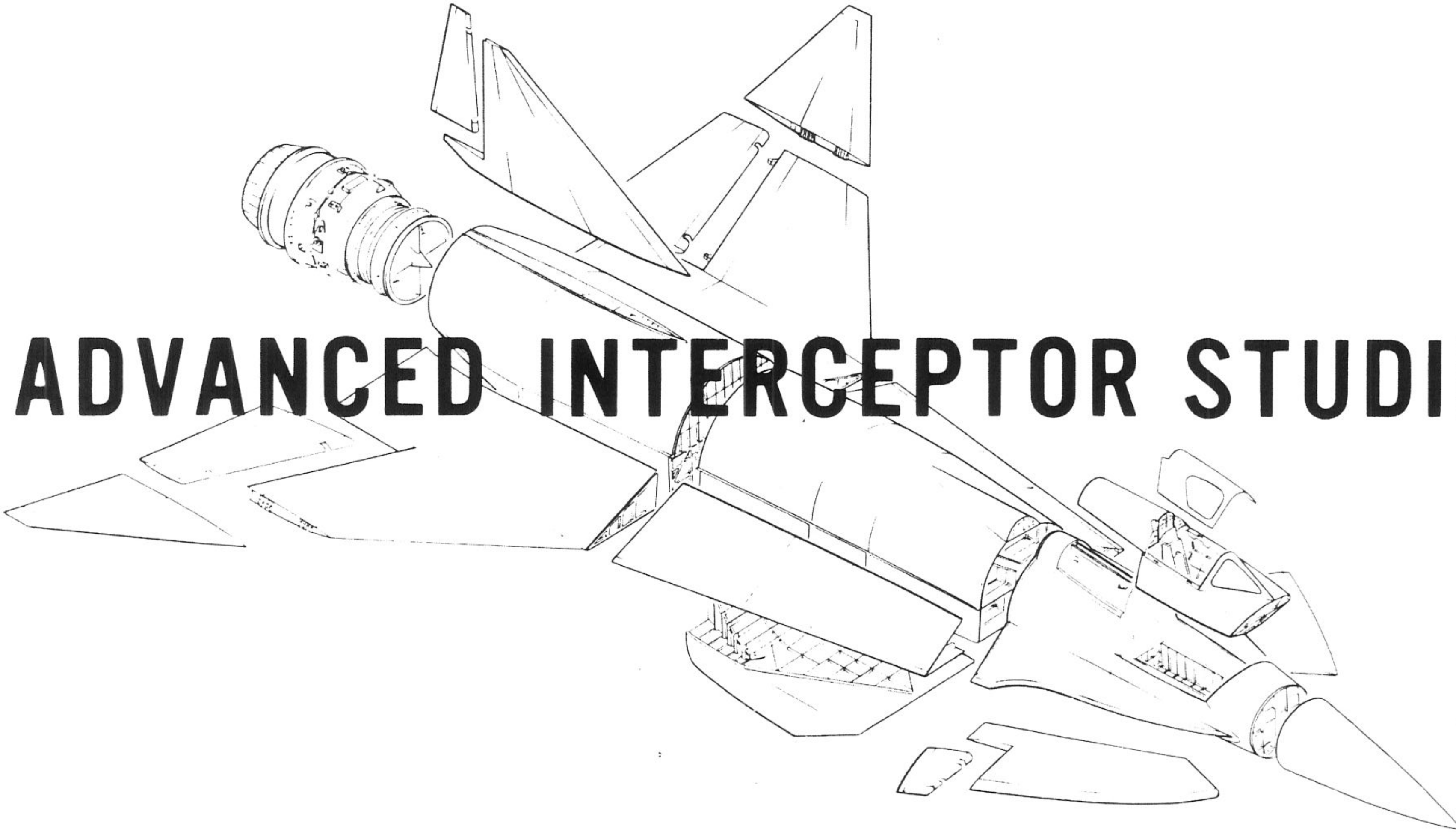
LTV AEROSPACE CORPORATION

CONFIDENTIAL

ADVANCED INTERCEPTOR

VOUGHT AERONAUTICS DIVISION
LTV AEROSPACE CORPORATION

ADVANCED INTERCEPTOR STUDIES



PRESENTATION OUTLINE

PART I
UHTV

- STUDY OBJECTIVE
- SYSTEM CONCEPT
- APPLICATIONS SUMMARY
- DESIGN VERSATILITY FEATURES
- BASIC PERFORMANCE (*)
- MILITARY MISSION PERFORMANCE (*)

PART II
ADVANCED INTERCEPTOR

- STUDY OBJECTIVE
- MISSION DEFINITION
- PARAMETRIC STUDY SUMMARY
  - METHODOLOGY
  - PROPULSION SYSTEMS
  - CONFIGURATIONS
  - RESULTS
  - SUPPLEMENTAL DESIGN INFORMATION
- RELATED AUI PERFORMANCE
- ADLI STUDY RECOMMENDATIONS

*USAF CONTRACT NO. F3361567C1004
REPORT NO. AFAPL-TR-68-16

STUDY OBJECTIVES

1. TO IDENTIFY HIGH PERFORMANCE
   - VEHICLE DESIGN AND OPERATIONAL CONCEPTS
   - PROPULSION CYCLES AND INSTALLATION CONCEPTS
   - VEHICLE/PROPULSION SYSTEM CONFIGURATION CONCEPTS

   COMPATIBLE WITH CURRENTLY PROJECTED ADVANCED INTERCEPTOR MISSION REQUIREMENTS

2. TO IDENTIFY THOSE TECHNICAL AND OPERATIONAL PROBLEM AREAS MOST CRITICAL TO THE SPECIFICATION AND ACHIEVEMENT OF ADVANCED INTERCEPTOR MISSION REQUIREMENTS

ADVANCED INTERCEPTOR

[redacted]

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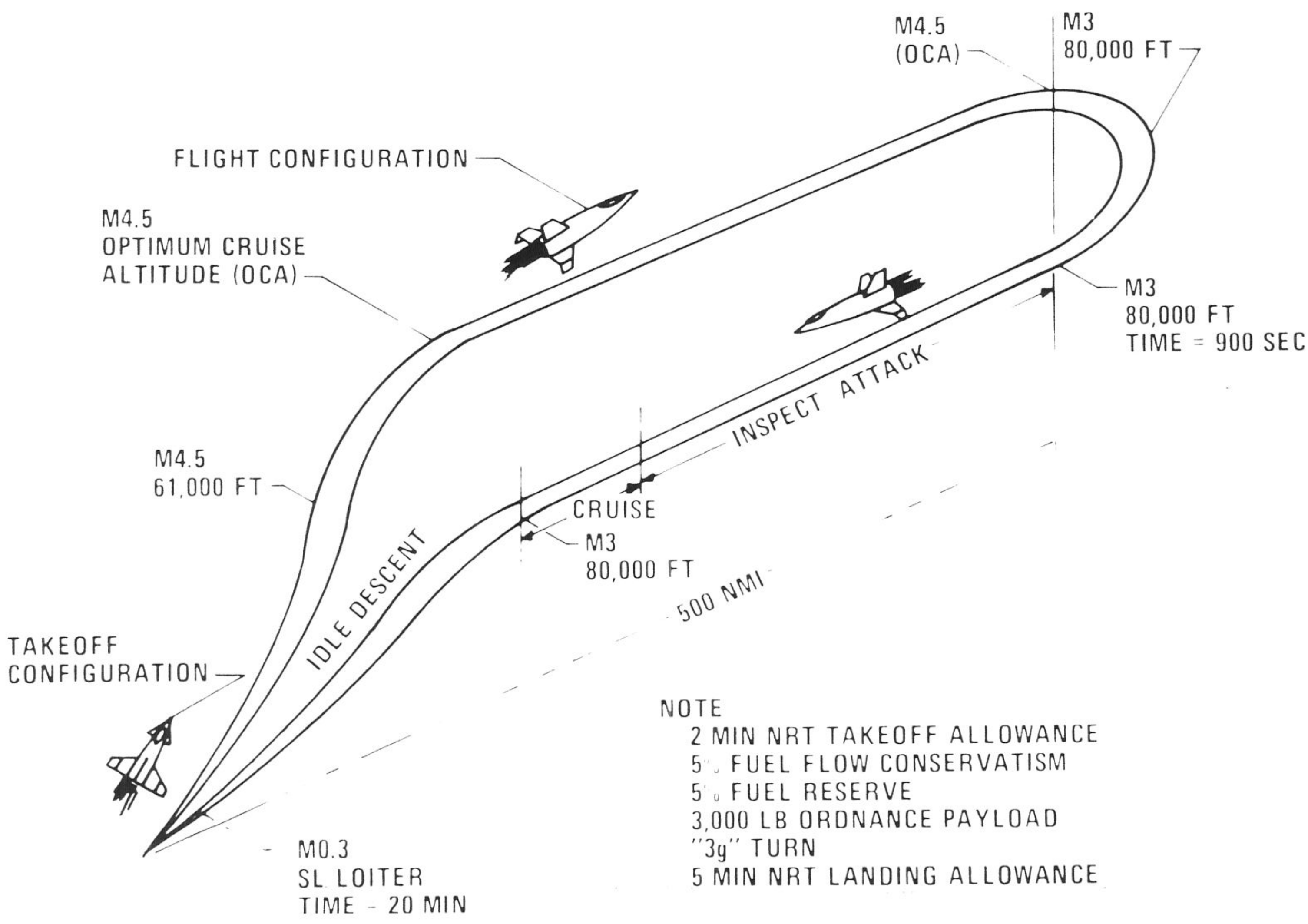
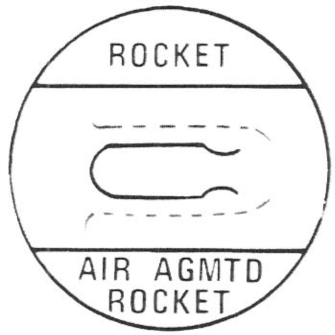
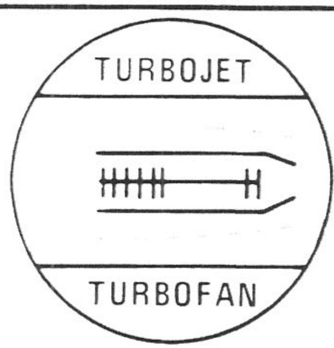
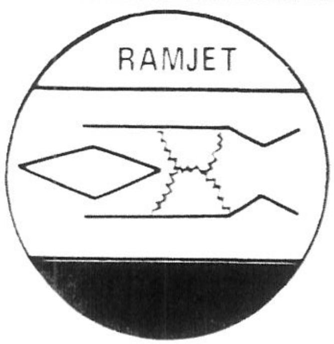
ZAP MISSION PROFILE



NOTE
- 2 MIN NRT TAKEOFF ALLOWANCE
- 5% FUEL FLOW CONSERVATISM
- 5% FUEL RESERVE
- 3,000 LB ORDNANCE PAYLOAD
- "3g" TURN
- 5 MIN NRT LANDING ALLOWANCE

[redacted]

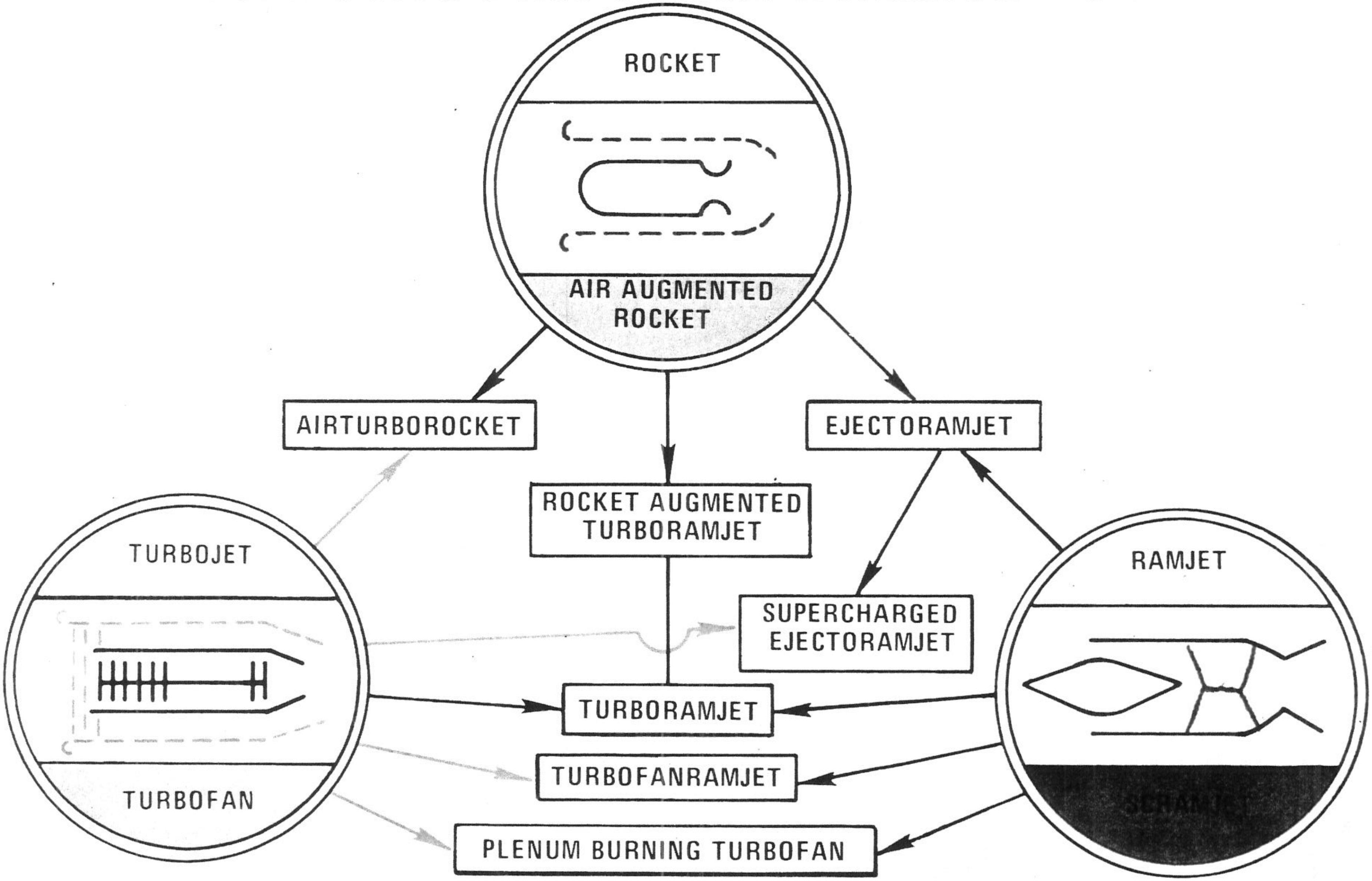
BASIC PROPULSION CYCLES

	MACH RANGE	FUEL CONSUMPTION	THRUST LEVEL	SELF-ACCELERATOR
 ROCKET	0 — ∞ (?)	HIGH	HIGH	YES
AIR AGMTD ROCKET	0 — ∞ (?)	IMPROVED	IMPROVED	YES
 TURBOJET	0 — 4.0	MODERATE OVER MACH RANGE	MODERATE	YES
TURBOFAN	0 — 4.0	IMPROVED AT LOW MACH NUMBERS	IMPROVED AT LOW MACH NUMBERS	YES
 RAMJET	2 — 8	MODERATE OVER MACH RANGE	GOOD AT $3 \lesssim M \lesssim 7$	NO
[redacted]				

ADVANCED INTERCEPTOR

VOUGHT AERONAUTICS DIVISION
LTV AEROSPACE CORPORATION

COMPOSITE PROPULSION NOMENCLATURE



CANDIDATE PROPULSION CYCLES

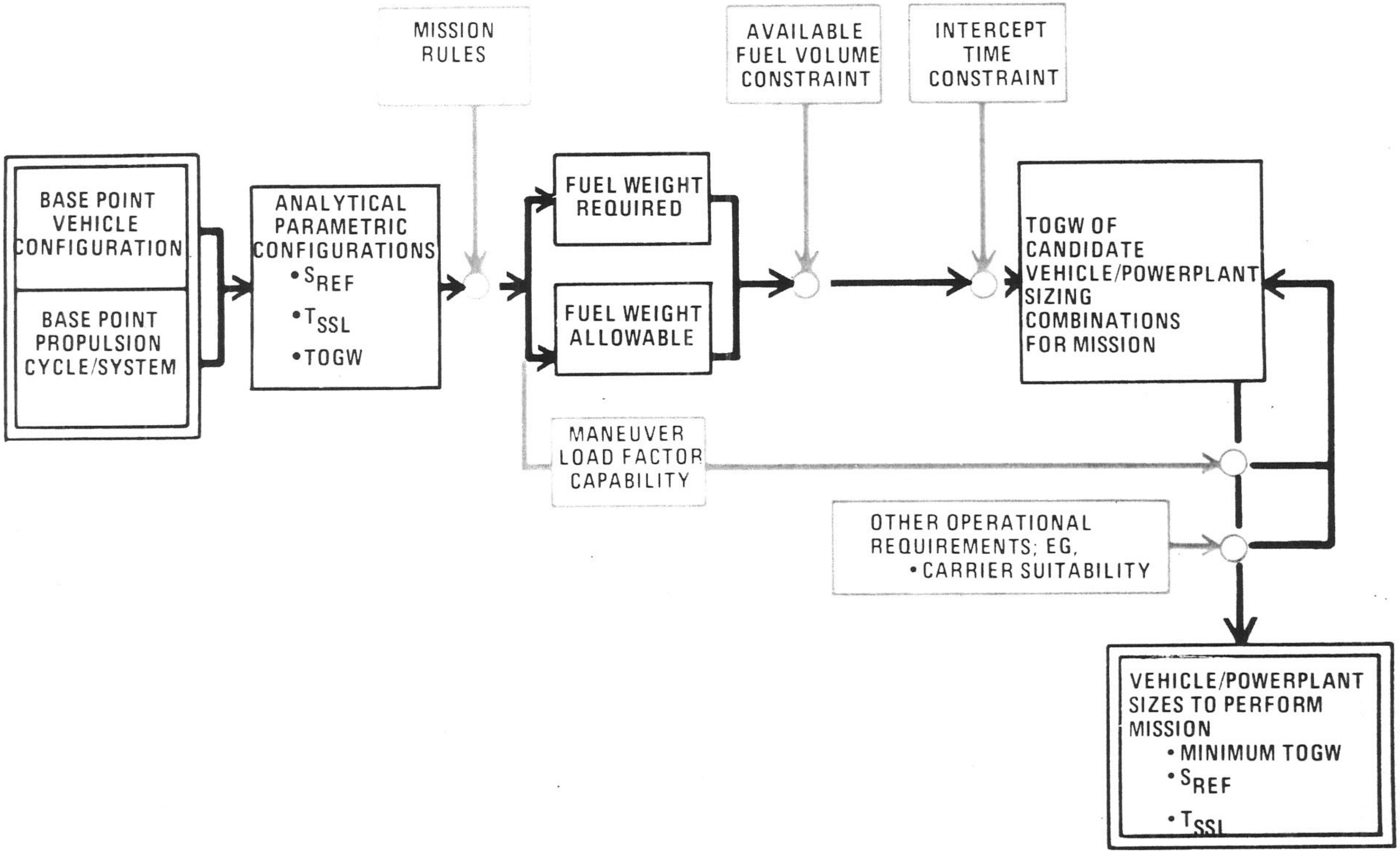
COMPOSITE CYCLES

- SUPERCHARGED EJECTORAMJET
- PLENUM BURNING TURBOFAN
- TURBOJET
- TURBORAMJET
- ROCKET AUGMENTED TURBORAMJET
- AIRTURBOROCKET
- TURBOFANRAMJET
- SUPERSONIC INFLOW TURBOFANRAMJET

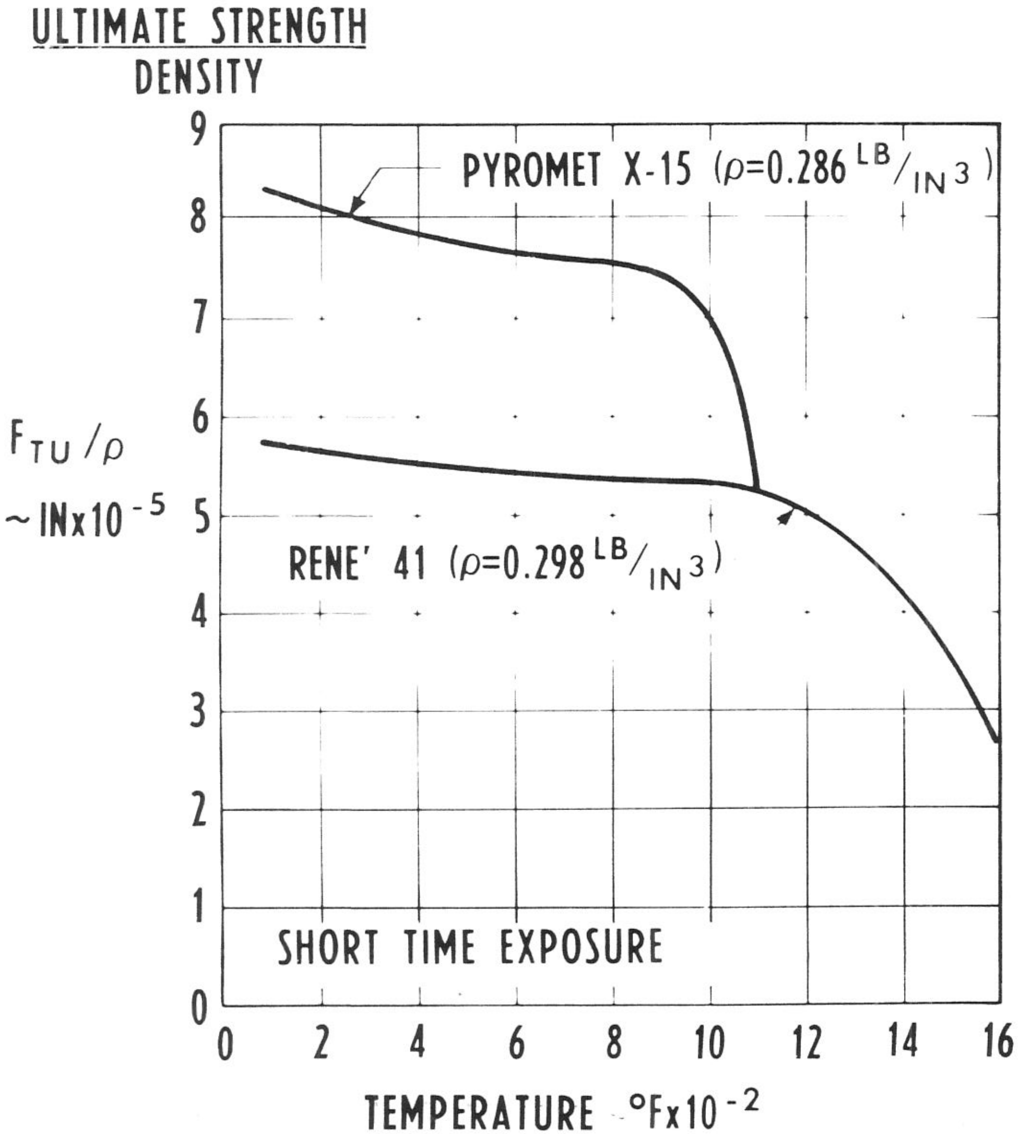
COMBINATION CYCLES

- RAMJET, LIQUID ROCKET, AND TURBOFAN
    1) FIXED INLET DESIGN
    2) VARIABLE GEOMETRY INLET

VEHICLE/PROPULSION SYSTEM EVALUATION METHODOLOGY



BASIC STRUCTURAL MATERIAL CONSIDERATIONS



FOR CONFIGURATION AI-0101A-890
FLYING THE ZAP MISSION:

$$\frac{(TOGW)_{PYROMET}}{(TOGW)_{RENE'}} = 0.81$$

$$\frac{(TOGW)_{RENE'}}{(TOGW)_{PYROMET}} = 1.23$$

DESIGN LOAD FACTOR CONSIDERATIONS

- MIL-A-8861 (ASG) SPECIFICATION (18 MAY 1960) = 7.33 "COLD"
- RESULTANT CAPABILITY AT 900°F:
  - PYROMET X-15 ≈ 6.53 "HOT"
  - RENÉ 41 ≈ 6.81 "HOT"
- ZAP MISSION REQUIREMENT = 3.00 "HOT"

PRIMARY STRUCTURAL MATERIAL	$\frac{[TOGW]_{3.00\ HOT}}{[TOGW]_{7.33\ COLD}}$
PYROMET X-15	0.93
RENÉ 41	0.90

[redacted]L

PROPULSION SYSTEM CHARACTERISTICS

CYCLE \ CONDITION		MAX THRUST/WEIGHT			SPECIFIC FUEL CONSUMPTION		
		BARE	* INSTALLED		INSTALLED		
		SSL	SSL	MACH 3 80,000 FT	SSL MAX T	MACH 3 80,000 FT MAX T	MACH 4.5 CRUISE T
SUPERCHARGED EJECTORAMJET		[redacted]	6.4-8.8	5.5-7.5	9.47	9.77	2.39
PLENUM BURNING TURBOFAN		[redacted]	2.2-3.2	1.4-2.1	3.40	2.36	2.39
TURBOJET		[redacted]	2.5-3.4	0.6-0.9	2.19	2.69	3.23
TURBORAMJET		[redacted]	3.4-5.0	1.3-2.0	1.87	2.41	2.72
ROCKET AUGMENTED TURBORAMJET		[redacted]	9.0-12.2	6.7-9.1	6.98	9.60	2.72
AIRTURBOROCKET		[redacted]	2.7-4.3	1.2-2.0	5.80	2.75	3.15
TURBOFANRAMJET		[redacted]	5.1-6.3	1.2-1.5	2.08	2.30	2.54
SUPERSONIC INFLOW TURBOFANRAMJET		[redacted]	6.3	1.4	2.08	2.51	2.73
COMBINATION RAMJET LIQUID ROCKET TURBOFAN	FIXED INLET	[redacted]	20.1	22.3	14.80	14.00	2.65
	VARIABLE INLET	[redacted]	14.7	16.6	14.80	13.40	2.41

* INCLUDES INLET AND DUCT WEIGHTS FOR CONFIGURATION AI-0101 INSTALLATION

[redacted]L

CRITICAL PROPULSION SYSTEM SELECTION CONSIDERATIONS

- THE NUMBER OF CANDIDATE COMPOSITE AND COMBINATION PROPULSION CYCLES IS FORMIDABLE
- ENGINE T/W PARAMETER IS NOT AN APPROPRIATE INDEX OF POWERPLANT/MISSION COMPATIBILITY
- AIR INDUCTION SYSTEM SIZES AND WEIGHTS ARE OF GREAT CONSEQUENCE IN VEHICLE/CYCLE OPTIMIZATION
- PROPULSION CYCLE SELECTION MAY BE VERY SENSITIVE TO MISSION REQUIREMENTS
- THRUST AUGMENTATION IS A LIKELY REQUIREMENT FOR ADEQUATE HIGH ALTITUDE MANEUVERING "G" CAPABILITY