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STOL TACTICAL AIRCRAFT INVESTIGATION. VOLUME I. CONFIGURATION DEFINITION

J. Hebert, Jr., et al

General Dynamics

Prepared for:

Air Force Flight Dynamics Laboratory

May 1973

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STOL TACTICAL AIRCRAFT INVESTIGATION

VOLUME I + CONFIGURATION DEFINITION

J. Hebart, et al

Convair Aerospace Division of
General Dynamics Corporation

TECHNICAL REPORT AFFDL-TR-73-21

May 1973

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Air Force Flight Dynamics Laboratory
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

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13. ABSTRACT
This report summarizes the preliminary vehicle-sizing activities of Part 1 and documents the subsequent Part 2 design update that was based on related studies, wind tunnel tests, and flight simulations conducted during the "STOL Tactical Aircraft Investigation." The lift/propulsion concepts under consideration were:

1. Externally Blown Flap (EBF)
2. Mechanical Flap Plus Vectored Thrust (MF/VT)
3. Internally Blown Flap (IBF)

The Part 1 designs were based on 1970 state-of-the-art technology and powered by scaled derivative engines that use existing cores.

The three preliminary designs for the lift/propulsion concepts were then updated to complete the Part 2 studies. The resulting point designs were based on data from 1,100 hours of wind tunnel tests, aerodynamic and stability-and-control methodology development, and stability and flight control technology studies.

The technology developed by Convair Aerospace during the "STOL Tactical Aircraft Investigation has shown that an advanced medium STOL transport could be designed and produced that would be lighter and more efficient than the AMST prototype. Recommended Phase II technology programs cover the areas of low speed aerodynamics, propulsion, terminal area operation, structure and material, and design.

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STOL TACTICAL AIRCRAFT INVESTIGATION

VOLUME I + CONFIGURATION DEFINITION

J. Hebert, et al

Convair Aerospace Division of
General Dynamics Corporation

FOREWORD

The Configuration Definition Report summarizes the configuration design activities of the Convair Aerospace Division of General Dynamics Corporation under USAF Contract F33615-71-C-1754, Project 643A, "STOL Tactical Aircraft Investigation." This contract was sponsored by the Prototype Division of the Air Force Flight Dynamics Laboratory. The USAF Project Engineer was G. Oates (PT) and the Convair Aerospace Program Manager was J. Hebert. This research was conducted during the period from 7 June 1971 through 31 January 1973.

These studies, conducted during Part 1 of the contract, summarize the state-of-the-art designs for the selected lift/propulsion concepts, which were then used as a point of departure for configuration design development conducted during Part 2. The principal contributors were C. Whitney, R. E. Johnston, G. B. Nicoloff, E. C. Laudeman, G. F. Campbell, A. Mattia, B. Bracka, W. Service, H. Stocker, and T. Draper.

This report was originally submitted by the author on 28 February 1973 under contractor report number GDCA-DHG73-001.

This report has been reviewed and is approved.

E. J. Cross Jr.

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ABSTRACT

This report summarizes the preliminary vehicle-sizing activities of Part 1 and documents the subsequent Part 2 design update that was based on related studies, wind tunnel tests, and flight simulations conducted during the "STOL Tactical Aircraft Investigation." The lift/propulsion concepts under consideration were:

1. Externally Blown Flap (EBF)
2. Mechanical Flap Plus Vectored Thrust (MF/VT)
3. Internally Blown Flap (IBF)

The Part 1 designs were based on 1970 state-of-the-art technology and powered by scaled derivative engines that use existing cores. The selected preliminary designs are summarized in Table 1. A leading-edge flap and three trailing-edge flaps (one for each lift/propulsion concept) were defined for these designs.

Table 1. Preliminary Designs

	EBF	MF/VT-2	IBF-2
Engine	GE13/F2B	GE13/F2A	STF-369
Wing area (ft^2)	1,550	1,635	1,785
Mid-mission Weight (lb)	134,200	145,500	152,450
Rated Thrust (lb)	18,600	23,175	22,837
T/W	0.555	0.637	0.599
W/S (lb/ft^2)	86.6	88.9	85.41
Takeoff Distance (ft)	2,000	2,000	2,000
Landing Distance (ft)	980	1,240	1,175

The EBF design with a modified wing trailing edge was then used as a baseline and materials were selected for the structural components. A structural description is included for the baseline airframe (i.e., wing, fuselage, and empennage).

The three preliminary designs for the lift/propulsion concepts were then updated to complete the Part 2 studies. The resulting point designs were based on data from 1,100 hours of wind tunnel tests, aerodynamic and stability-and-control methodology development, and stability and flight control technology studies. The updated point designs are summarized in Table 2.

Table 2. Point Designs

	EBF	MF/VT	IBF/VT
Engine	GE13/F2B	GE13/F2A	STF-369
Wing Area (ft^2)	1,550	1,550	1,700
Mid-mission Weight (lb)	125,700	126,300	133,000
Rated Thrust (lb)	15,075	14,965	13,275
T/W	0.480	0.474	0.400
W/S (lb/ft^2)	81.1	81.5	78.24
Takeoff Distance (ft)	2,000	2,000	2,000
Landing Distance (ft)	1,530	1,850	1,810

The technology developed by Convair Aerospace during the "STOL Tactical Aircraft Investigation" has shown that an advanced medium STOL transport could be designed and produced that would be lighter and more efficient than the AMST prototype. Recommended Phase II technology programs cover the areas of low speed aerodynamics, propulsion, terminal area operation, structure and material, and design. The improvements that would result from a Phase II program are:

Low Speed Aerodynamics	Improve high-lift system i.e., cost, mechanical complexity, reliability
Supercritical Aerodynamics	Improve cruise mach number or wing volumetric efficiency
Advanced Structural Concepts	Reduce structural weight
Composite Materials	Reduce structural weight
Control System	Reduce mechanical complexity, improve engine out, incorporate fly-by-wire, canard design optimization
Advanced Technology Engine	Lower specific fuel consumption and higher thrust/weight
Landing Gear System	Crosswind capability, rough field operation, lower cruise drag

TABLE OF CONTENTS

TABLE OF CONTENTS, Contd

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS, Contd

LIST OF ILLUSTRATIONS, Contd

LIST OF FIGURES, Contd

LIST OF TABLES

LIST OF TABLES, Contd

NOMENCLATURE

Symbol		Units
A	Time Delay	Sec
AEO	All Engine Operative	
A_n	Load Factor for Takeoff and Landing	Ft/Sec
b	Wing Span	Ft
BPR	By Pass Ratio	
c	Wing Chord	In.
c_1/c	Extended Chord Ratio	
C_D	Drag Coefficient	
$C_{D_{min}}$	Minimum Drag Coefficient	
$C_{f_{equiv}}$	Equivalent Skin Friction Coefficient	
C_L	Lift Coefficient	
$C_{L_{CR}}$	Cruise Lift Coefficient	
$C_{L_{max}}$	Maximum Lift Coefficient	
C_μ	Blowing Momentum Coefficient	
C_{μ_J}	Blowing Momentum Coefficient of Engines	
$C_{\mu_{TE}}$	Blowing Momentum Coefficient of Trailing Edge Flap	
DLC	Direct Lift Control	
e	Airplane Efficiency Factor	
EBF	Externally Blown Flap	
f	Equivalent Parasite Area	Sq Ft

NOMENCLATURE, Contd

Symbol		Units
F_D	Ram Drag	Lb
F_G	Gross Thrust	Lb
F_{GW}	Wing Gross Thrust	Lb
FPR	Fan Pressure Ratio	
g	Acceleration of Gravity	Ft/Sec^2
h	Altitude	Ft
IBF	Internally Blown Flap	
IBF/VT	Internally Blown Flap Plus Vectored Thrust	
IGE	In Ground Effect	
MF/VT	Mechanical Flap Plus Vectored Thrust	
n_{AP}	Approach Load Factor	Ft/Sec^2
n_{LO}	Liftoff Load Factor	Ft/Sec^2
OEI	One Engine Inoperative	
OPR	Overall Pressure Ratio	
P_{T_2}/P_{T_o}	Total Pressure Recovery	
R/S	Rate of Sink	Ft/Min
SFC	Specific Fuel Consumption	
S_W	Wing Area	Sq Ft
TAS	True Airspeed	Kt

NOMENCLATURE, Contd

Symbol		Units
TF	Turbofan	
TIT	Turbine Inlet Temperature	Deg
TOGW	Takeoff Gross Weight	Lb
T/W	Thrust to Weight Ratio	
V	Velocity at Obstacle	Kt
V_{AP}	Approach Velocity	Kt
V_{CO}	Climbout Velocity	Kt
V_{F}	Engine Failure Recognition Velocity	Kt
$\bar{V}_{H}$	Horizontal Tail Volume	
V_{LO}	Liftoff Velocity	Kt
V_{MCA}	Minimum Control Velocity Out of Ground Effect	Kt
V_{MCG}	Minimum Control Velocity in Ground Effect	Kt
V_{O}	Zero Velocity	Kt
V_{R}	Rotation Velocity	Kt
V_{S}	Stall Velocity	Kt
$V_{SINK\ TD}$	Sink Speed at Touchdown	Kt
V_{TD}	Touchdown Velocity	Kt
V_{TH}	Threshold Velocity	Kt
V_{TO}	Takeoff Velocity	Kt

NOMENCLATURE, Contd

Symbol		Units
$\bar{V}_V$	Vertical Tail Volume	
W/S	Wing Loading	Lb/Sq Ft
α	Angle of Attack	Deg
γ_{AP}	Approach Flight Path Angle	Deg
δ_f	Trailing Edge Flap Deflection	Deg
e	Downwash Angle	Deg
$\dot{\theta}$	Rotation Rate	Deg/Sec
μ_B	Braking Friction	
$\mu_{\bar{R}}$	Ground Friction	
$\frac{W_a\sqrt{\theta_2}}{\delta_2}$	Correct Engine Airflow	Lb/Sec

SECTION 1

INTRODUCTION

The overall objective of the Part 1 design effort was to conduct a preliminary vehicle-sizing activity to establish baseline configurations for the STOL Tactical Aircraft Investigation. These preliminary baselines were used for the takeoff and landing studies and as a point of departure for wind tunnel test planning and flight control technology activities. The lift/propulsion concepts studied were:

1. Externally Blown Flap (EBF)
2. Mechanical Flap plus Vectored Thrust (MF/VT)
3. Internally Blown Flap (IBF)

This report summarizes the design activities for the three-month and six-month configuration reviews, as indicated in Figure 1-1. The reviews were held at the Convair Aerospace Division in San Diego on 14 and 15 September 1971 and at Wright-Patterson Air Force Base on 17 December 1972. Appropriate information is included to clarify specific questions raised by the Air Force Review Team.

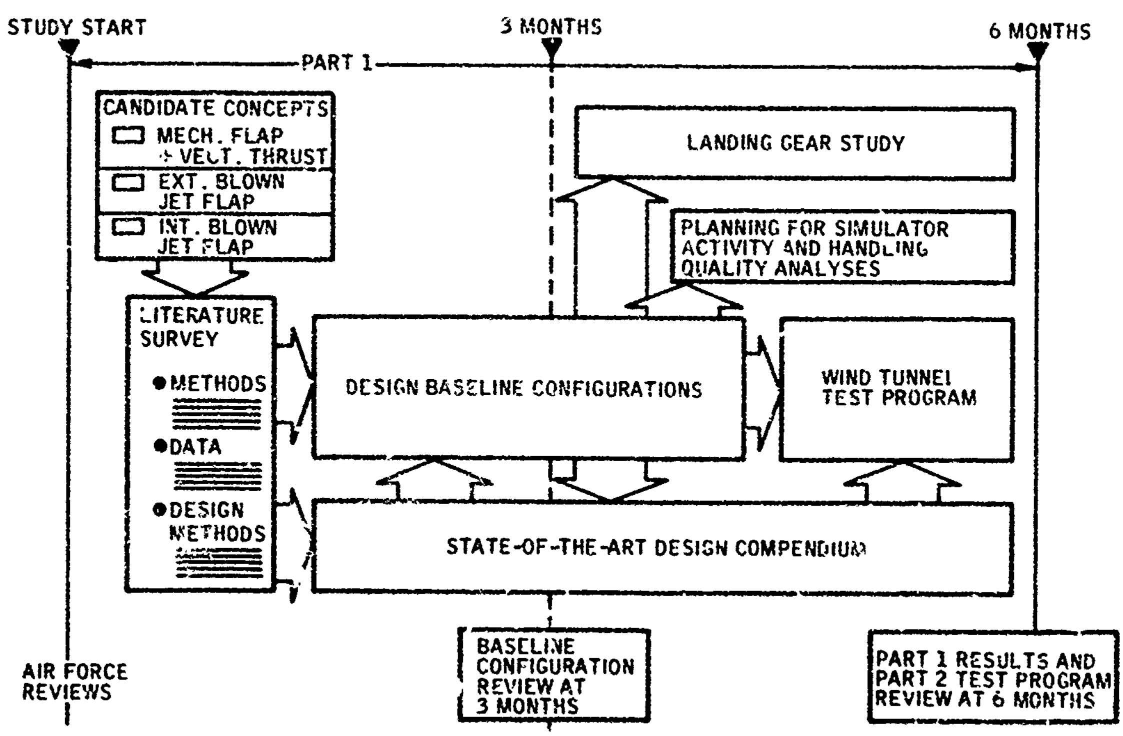


Figure 1-1. Phase 1, Part 1 - Studies and Analyses

The baseline configuration designs meet the "MST Design Requirements" supplied by the Air Force Flight Dynamics Laboratory on 13 July 1971. These vehicle designs are based on current state-of-the-art technology and use projected propulsion data for derivative engines using existing cores. The baseline configurations were considered as starting points for further configuration parametric studies. Additional work was indicated in the areas of engine cycles, lighter weight thrust-vectoring devices, engine arrangements, and blowing engines for the high-lift and control systems. Configuration and performance tradeoff studies were conducted on the EBF baseline configuration.

The results of the wind tunnel and flight simulation studies were subsequently used as indicated in Figure 1-2 to update the selected baselines from Part 1.

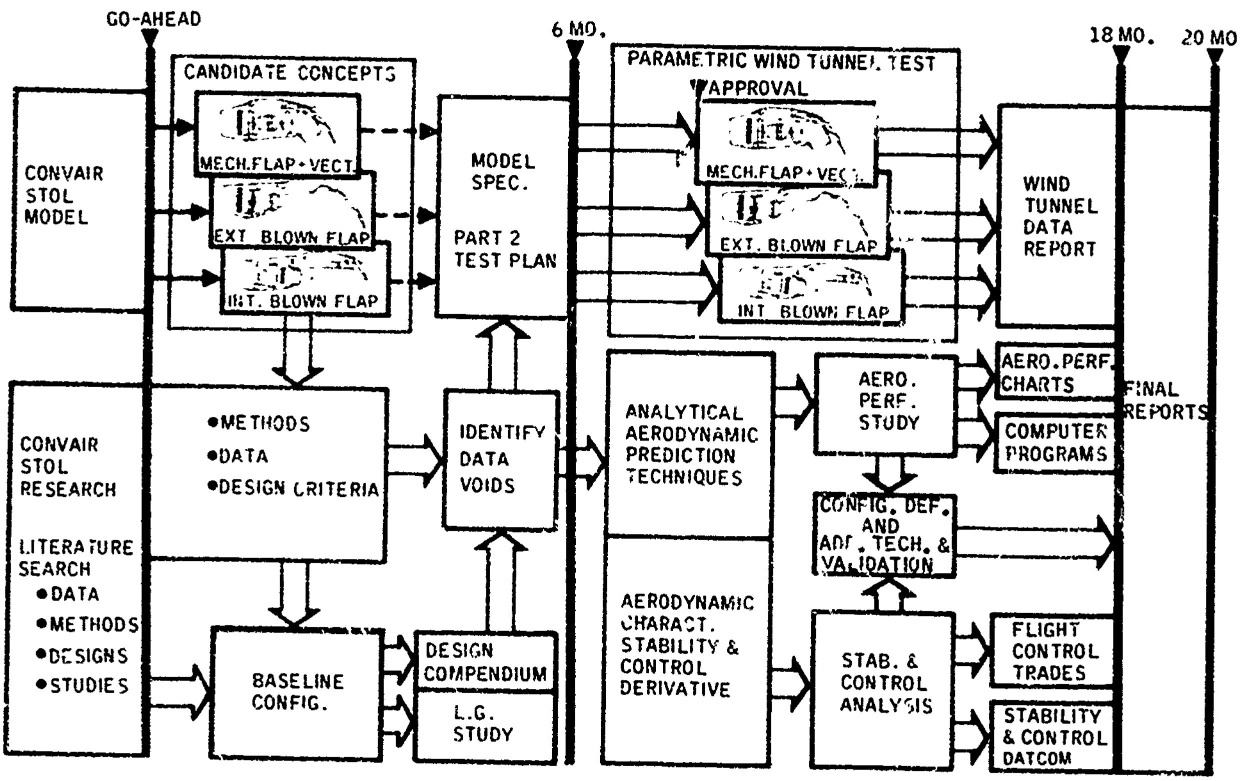


Figure 1-2. Convair Aerospace Program Summary

SECTION 2

GUIDELINES

Specifications and design requirements for the STOL Tactical Aircraft Investigation are given in References 2-1, 2-2, and 2-3. Specific mission profiles, design characteristics, and takeoff and landing ground rules are covered in this section.

2.1 DESIGN CHARACTERISTICS

The following design characteristics were supplied to Convair Aerospace in Reference 2-1.

1. Maximum design takeoff gross weight: 160,000 lb.
2. Cargo compartment size: 12 by 12 by 45 ft (maximum length 55 ft).
3. Crew: pilot, copilot, navigator, and loadmaster.
4. Propulsion: Derivative engines using existing core.
5. Miscellaneous features:

   a. Aerial refueling.
   b. Pressurized crew and cargo compartments.
   c. Noise: 115 PNDB at 500 ft.
   d. Vulnerability survivability: maximum protection and fail safety.
   e. Maximum evasive maneuverability.
   f. Satisfactory engine-out control.
   g. Three-engine takeoff from assault strip.
   h. Antiskid brakes.
   i. Wheel drive for ground handling (not included on baselines or point designs).
   j. Design sink speed of 10 ft sec.
   k. Self-contained offload capability.
   l. Drive-on loading capability.
   m. 463L compatibility.
   o. Airlift:

      58,000 lb at 2.5g (once)
      44,000 lb at 2.5g (several)

2.2 MISSION PROFILES

The 500-n.mi. tactical delivery mission and the range mission profiles are shown in Figure 2-1. The ground rules used to calculate the vehicle characteristics for these mission profiles are:

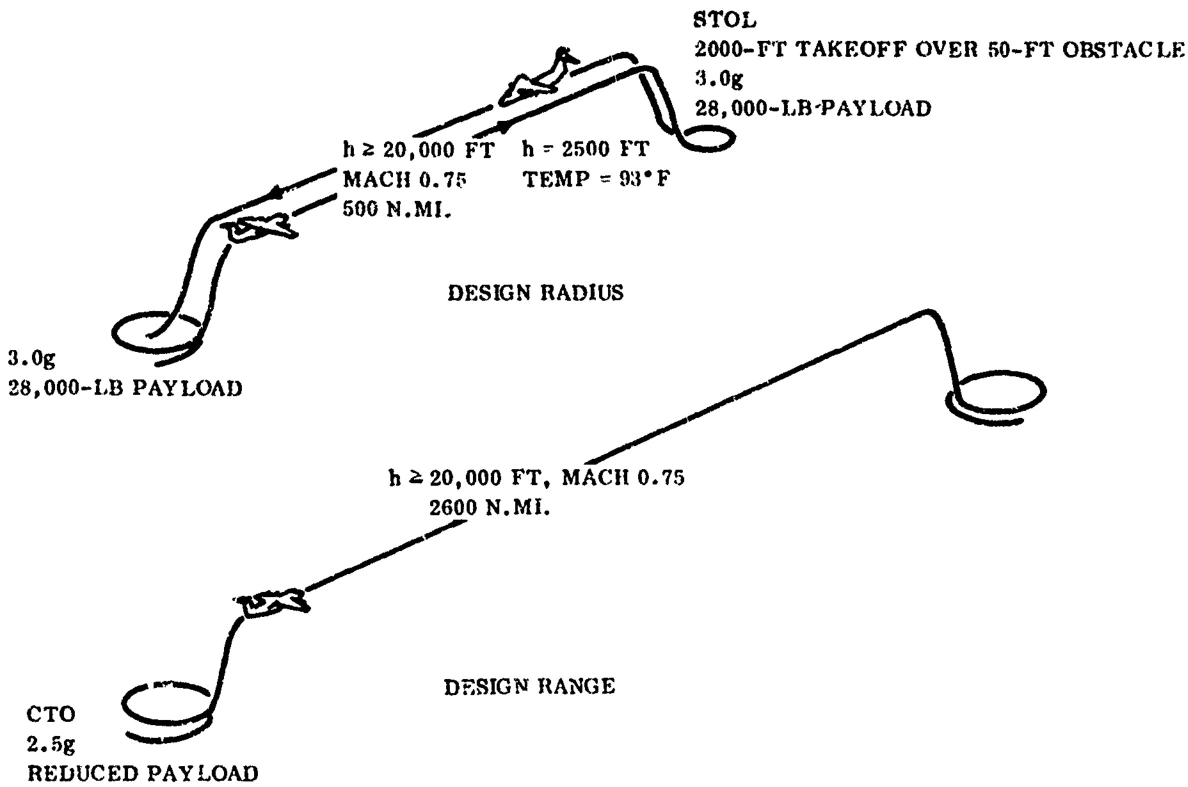


Figure 2-1. Mission Profiles

1. 500-n.mi. tactical delivery mission:

   a. Payload = 28,000 lb.
   b. Load factor = 3.0g.
   c. Fuel burned for warmup, takeoff, and acceleration to climb speed is assumed equivalent to five minutes at maximum continuous power on cruise engines.
   d. Climb on course to the altitude for best long-range cruise.
   e. Cruise at best speed and altitude for long-range cruise to the radius point.
   f. Descent with no fuel used or distance gained.
   g. Land and offload design payload and reload 28,000 pounds of payload.
   h. Warmup, takeoff, and accelerate to climb speed assumed equivalent to five minutes at maximum continuous power with cruise engines.
   i. Climb on course to the altitude for best long-range cruise.
   j. Cruise to the point of origin at best speed and altitude.
   k. Descent with no fuel used or distance gained.
   l. Reserve fuel assumed equivalent to 20 minutes at the speed for maximum endurance at sea level.

2. Design range (unrefueled):

a. Reduced payload.
b. Load factor = 2.5g.
c. Fuel burned for warmup, takeoff, and acceleration to climb speed assumed equivalent to five minutes at maximum continuous power with cruise engines.
d. Climb on course to the altitude for best long-range cruise.
e. Cruise at best speed and altitude for long-range cruise to the radius point.
f. Descent with no fuel used or distance gained.
g. Reserve fuel assumed to be equivalent to 20 minutes at the speed for maximum endurance at sea level.

2.3 TAKEOFF AND LANDING GROUND RULES

The Part 1 ground rules are discussed in Volume III and are shown in Figures 2-2 and 2-3. The altitude is 2500 feet on a 93.4°F day (MIL-STD-210A Hot Day) and the critical field length is the actual field length, 2000 feet.

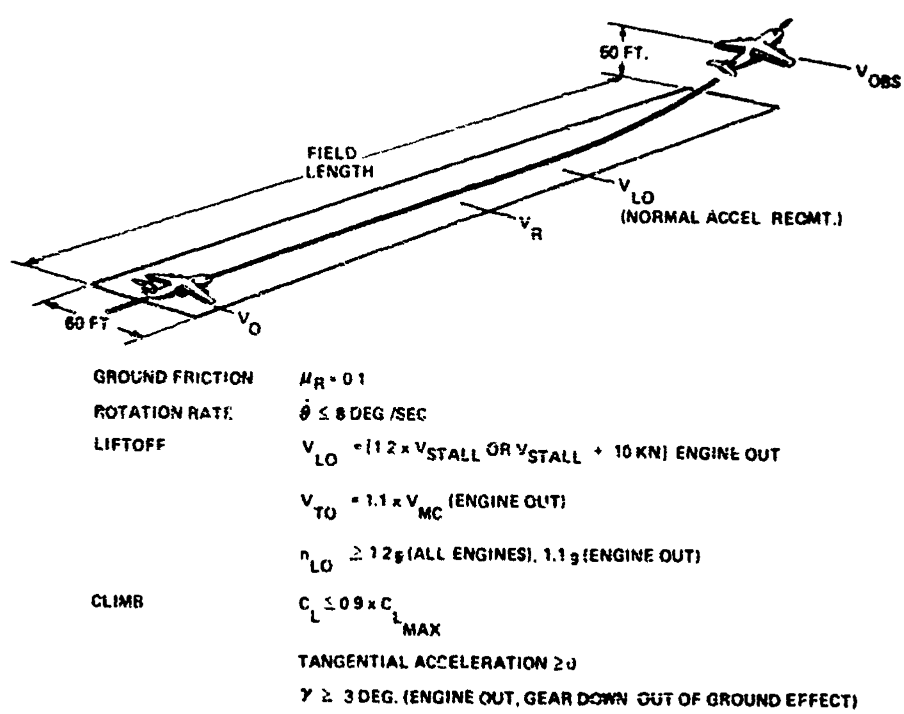
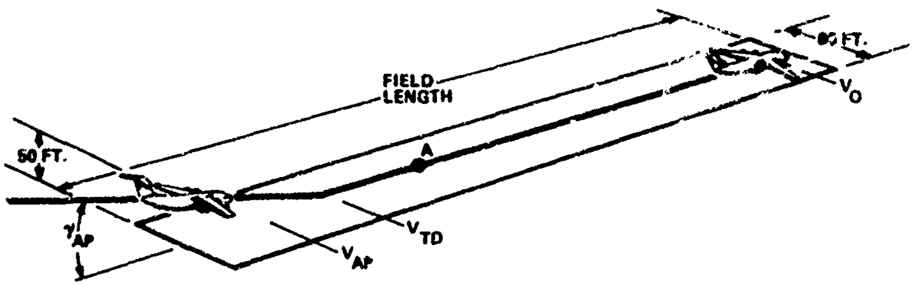


Figure 2-2. Part 1 Takeoff Ground Rules



APPROACH	WAVEOFF CAPABILITY AT OBSTACLE, CHANGES IN POWER SETTING, FLAP DEFLECTION, & THRUST VECTOR ANGLE ONLY
	n_{AP} = 1.2g (ALL ENGINES), 1.1g (ENGINE OUT) AT V_{AP}
	γ_{AP} SUCH THAT PILOT CAN KEEP TOUCHDOWN POINT IN VIEW & AIRPLANE TOUCHES DOWN MAIN GEAR FIRST
	$V_{AP} \geq 1.1 \times V_{MC}$ (ENGINE OUT)
	$\geq 1.1 \times V_S$ (ENGINE OUT)
	$\geq 1.2 \times V_S$ (ALL ENGINES)
	$\dot{\theta} \leq 8$ DEG./SEC.
TOUCHDOWN	LAND WITHOUT FLARE
	$V_{SINK\ TD} \leq 2/3 \times V_{SINK\ DESIGN\ FOR\ LG}$
BRAKING DEVICES ON	A, TIME DELAY OF { 2 SECONDS FOR REVERSE THRUST; 1 SECOND FOR BRAKES & SPOILERS }
BRAKING FRICTION	$\mu_B = 0.25$

Figure 2-3. Part 1 Landing Ground Rules

SECTION 3

PROPULSION

The engine tradeoff analysis was based on the medium tactical transport design guidelines, engine manufacturer's STOL engine data, and results from Convair Aerospace preliminary design and performance. The analysis was performed to develop the range of engine parameters for use in the engine selection studies, with the results as tabulated in Table 3-1. The engines reviewed that meet the Table 3-1 criteria are listed in Table 3-2 for each of the engine companies supplying study data, together with definitive specification information. Blowing air as required for lift augmentation will be supplied from the cruise engines or from a separate auxiliary compressor.

The range of bypass ratios for IBFs is severely constrained if a single high-pressure fan is employed. At a desired pressure ratio of 2.5, the bypass ratio is limited to below 3.0 because of the greatly increased engine weight. Cruise specific fuel consumption also suffers from this choice, since the bypass ratio is not optimized to this condition.

3.1 CHOICE OF STUDY ENGINES

The following engine selections were made to satisfy the study need for representative engines only. The MF/VT engine features are shown in Figure 3-1. The representative engine is the GE13/F2A modified to incorporate thrust vectoring and reversing. Figure 3-2 shows the essential features of the GE13/F2B, which was chosen to represent the EBF propulsion lift system. The IBF engine selections are the STF-369 and the RB419-03, which have a thrust split between high-pressure blowing and fan plus core air. The essential features are shown in Figure 3-3.

The only gas turbine compressor offered in the size range desired is the RB176-11. A description of this unit is presented in Figure 3-4. The installation of this gas turbine compressor unit in a typical STOL aircraft is discussed in Section 5.

3.2 ENGINE PERFORMANCE

Performance is presented for the representative engines selected for each lift system type. Installed part-power performance was estimated in all cases for altitudes up to 40,000 feet, ISA. Installed performance at takeoff power was estimated at a 2500-foot altitude on a 93° F day.

Basic installation assumptions included inlet performance, exhaust nozzle, scrubbing drag, bleed, and power extraction. The pressure recovery used for the selected GE13 series engines is shown in Figure 3-5. This data was adjusted to the correct airflow scale for each engine.

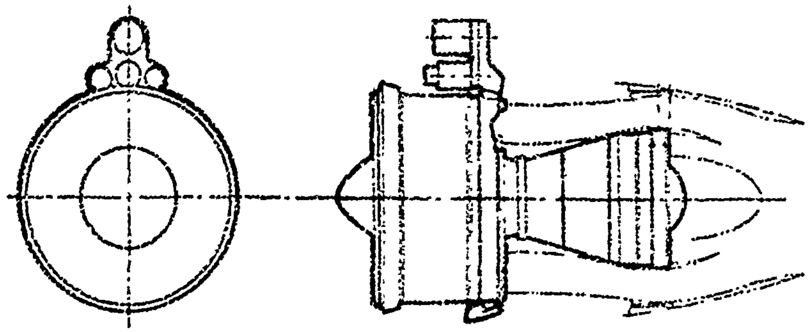
Table 3-1. Engine Selection Criteria

Application	Technology Base	Cycle Description					Installation Requirements per Engine				Subsystem Requirements
		Type	BPR	FPR	OPR	TIT (°F)	Thrust* (lb)	Blowing Air (lb/sec)	Bleed Air (lb/sec)	Power (hp)	
Externally Blown Flap	Derivative of Current Programmed Engine or IOC 1978-80	TF	2-20	1.1-1.7	18-25	2000-2500	18,000-20,000	80-100	2-3	200-300	Thrust Reversal & Auxiliary GTC
		Split Fan	1-1.2 / 2-16	2-3 / 1.2-1.5	18-25	2000-2500	18,000-20,000	20-25	2-3	200-300	Thrust Reversal
Mechanical Flap Plus Vectored Thrust	Same	TF	2-7	1.2-1.6	18-25	2000-25000	20,000-25,000	80-100	2-3	200-300	Thrust Reversal, Vectoring & Auxiliary GTC
		Split Fan	1-1.2 / 2-7	2-3 / 1.2-1.6	18-25	2000-2500	20,000-25,000	20-25	2-3	200-300	Thrust Reversal and Vectoring
Internally Blown Flap	Same	TF	6-8	1.5-1.7	18-25	2000-2500	20,000-25,000	350-450	2-3	200-300	Thrust Reversal and Auxiliary GTC
		TF	2-2.5	2-3	18-25	2000-2500	23,000-28,000	90-120	2-3	200-300	Thrust Reversal
		Split Fan	2-1.3 / 2-6	2-3 / 1.2-1.3	18-25	2000-2500	23,000-28,000	90-120	2-3	200-300	Thrust Reversal

*Assuming a 4-engine aircraft

Table 3-2. Candidate Engine Selection

Company	Spec Date	Designation	Thrust (lbs)	SFC	BPR	Weight (lbs)	Length (in.)	Diameter (in.)	Compression Ratio	Development Status
General Motors Allison	6/70	PD351-48	21,650	0.383	5.25	2635	103.0	62.0	24.8	GMA100 Derivative
		PD351-49	23,630	0.330	8.2	3100	113.0	72.0	21.8	GMA100 Derivative
		PD351-45	24,470	0.288	10.74	3752	112.0	82.0	18.2	GMA100 Derivative
		PD351-3	21,650	0.404	4.6	2510	95.4	59.0	24.8	GMA100 Derivative
		PD351-4	21,650	0.427	4.0	2480	94.8	57.2	24.8	GMA100 Derivative
General Electric	12/70	GE13/F3A	21,000	0.388	5.0	2800	92.0	65.8	23.8	F101 Derivative
	12/70	GE13/F3B	21,320	0.385	5.1	2800	92.0	65.8	24.1	F101 Derivative
	12/70	GE13/F2A	22,640	0.355	6.4	3010	94.4	72.1	23.3	F101 Derivative
	12/70	GE13/F2B	22,860	0.355	6.5	3010	94.4	72.1	23.4	F101 Derivative
	12/70	GE13/F4B	23,950	0.328	8.0	3310	96.2	77.5	22.4	F101 Derivative
Pratt & Whitney	8/70	STF362	20,000	0.317	9.0	3095	97.0	67.0	18.0	1978-80 IOC
	8/70	STF369	20,000	0.528	2.5	3065	92.0	56.0	21.0	1978-80 IOC
	8/70	STF405	20,000	0.422	3.5/2.0	4305	142.9	69.5	20.0	1978-80 IOC
	8/70	STF419	20,000	0.281	12/0.62	2685	133.0	94.5	23.6	1978-80 IOC
	8/69	STF337	20,000	0.370	6.0	2700	84.0	61.0	20.2	1978-80 IOC
	12/70	STF402	20,000	0.409	5.0	2600	99.3	57.6	25.0	JTF22 Derivative
Rolls Royce	9/70	RB419-03	19,190	0.386	6.0	4090	183.0	80.0	19.5	1978-80 IOC
	8/70	RB176-11	(74 lb/sec at 2.14 P.R.)			1700	126.0	32.0	4.5	RB162/Spey
	11/68	Spey512	19,720	0.53	5.7	4812	211.0	82.0	19.0	Spey Derivative

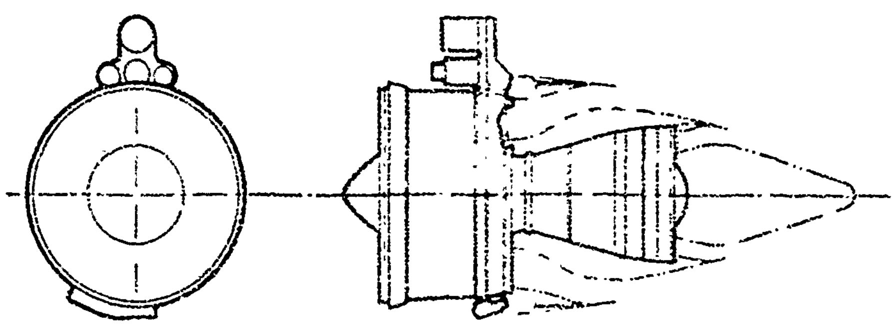


GE-13F2A

LONG COWL, MIXED FLOW

THRUST	22,640 LB
SFC	0.355
BYPASS RATIO	6.4
FAN PRESSURE RATIO	1.5
OVERALL PRESSURE RATIO	23.3
LENGTH	94.4 IN.
MAX DIAMETER	72.1 IN.
WEIGHT	3,010 LB

Figure 3-1. Selection for Mechanical Flap Plus Vectored Thrust

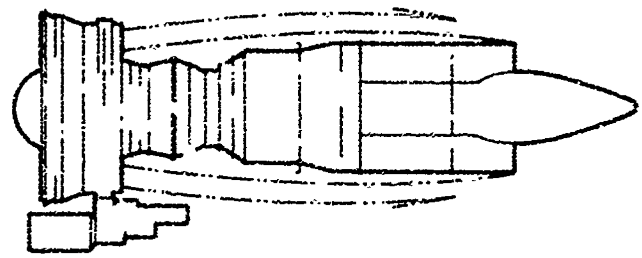


GE-13F2B

SEPARATE FLOW TURBOFAN

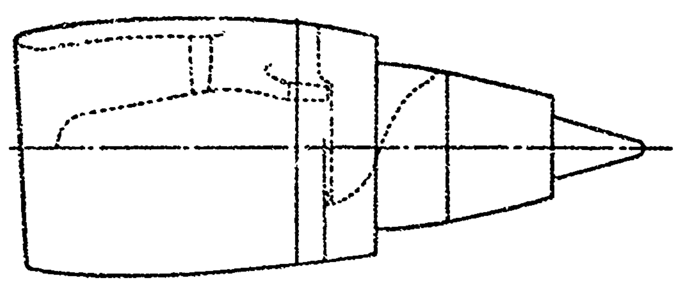
THRUST	22,860 LB
SFC	0.3[illegible]2
BYPASS RATIO	6.5
FAN PRESSURE RATIO	1.6
OVERALL PRESSURE RATIO	23.1
LENGTH	91.1 IN.
MAX DIAMETER	72.1 IN.
WEIGHT	[illegible],610 LB

Figure 3-2. Selection for Externally Blown Flap



STF 369
LONG COWL, SPLIT FLOW

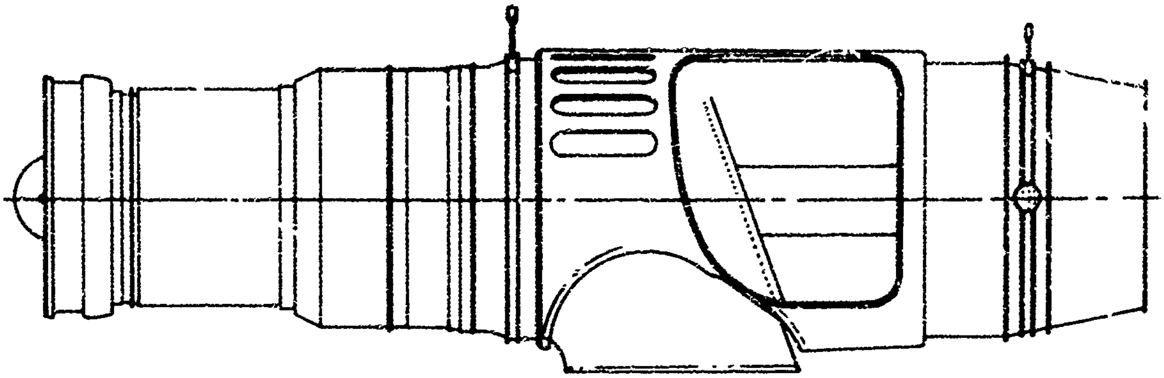
THRUST	20,000 LB
SFC	0.528
BYPASS RATIO	2.5
FAN PRESSURE RATIO	2.45
OVERALL PRESSURE RATIO	21.0
LENGTH	92.0 IN.
MAX DIAMETER	56.0 IN.
WEIGHT	3,065 LB



ROLLS ROYCE RB-419-03
SPLIT FLOW TURBOFAN

THRUST	19,190 LB
SFC	0.386
BYPASS RATIO	~6.0/2.0
FAN PRESSURE RATIO	~1.1/3.0
OVERALL PRESSURE RATIO	20
LENGTH	183 IN.
MAX DIAMETER	79 IN.
WEIGHT	4,117 LB

Figure 3-3. Selections for Internally Blown Flap



ROLLS ROYCE RB-176-11
GAS TURBINE COMPRESSOR

AIRFLOW	74 LB/SEC
PRESSURE RATIO	2.14
RESIDUAL THRUST	1815 LB
FUEL FLOW	4120 LB/HR
LENGTH	126 IN.
MAX DIAMETER	32 IN.
WEIGHT	1700 LB

Figure 3-4. Selected Auxiliary Blowing Air Engine for EBF and MF/VT

Bleed air flow rates were estimated to meet the 150-passenger environmental control system capacity and are shown in Figure 3-6. Power extraction effects on the engines were assumed to be small enough to be neglected in the studies.

Using the installation factors discussed, takeoff performance of the propulsion systems are presented in Figures 3-7 through 3-9. Takeoff performance is presented in Figure 3-7 for the GE13/F2A and the GE13/F2B engines, in Figure 3-8 for the STF369 engine, and in Figure 3-9 for the RB419-03 engine. Bleed airflow rates for lift augmentation are shown in Figures 3-8 and 3-9.

3.3 THRUST REVERSING AND VECTORING

Selections were made from data available with each engine and through communications with engine companies. Table 3-3 summarizes the performance and weights of reversers and vectoring devices to be used with each lift/propulsion concept.

The thrust-vectoring device for the MF/VT concept is designed to be used for thrust reversal also. General Electric offered three-bearing and single-bearing swivel configurations; the single-bearing version was selected on the basis of weight and simplicity. Annular cascades that combined thrust reversal and vectoring at low weight penalties were also selected.

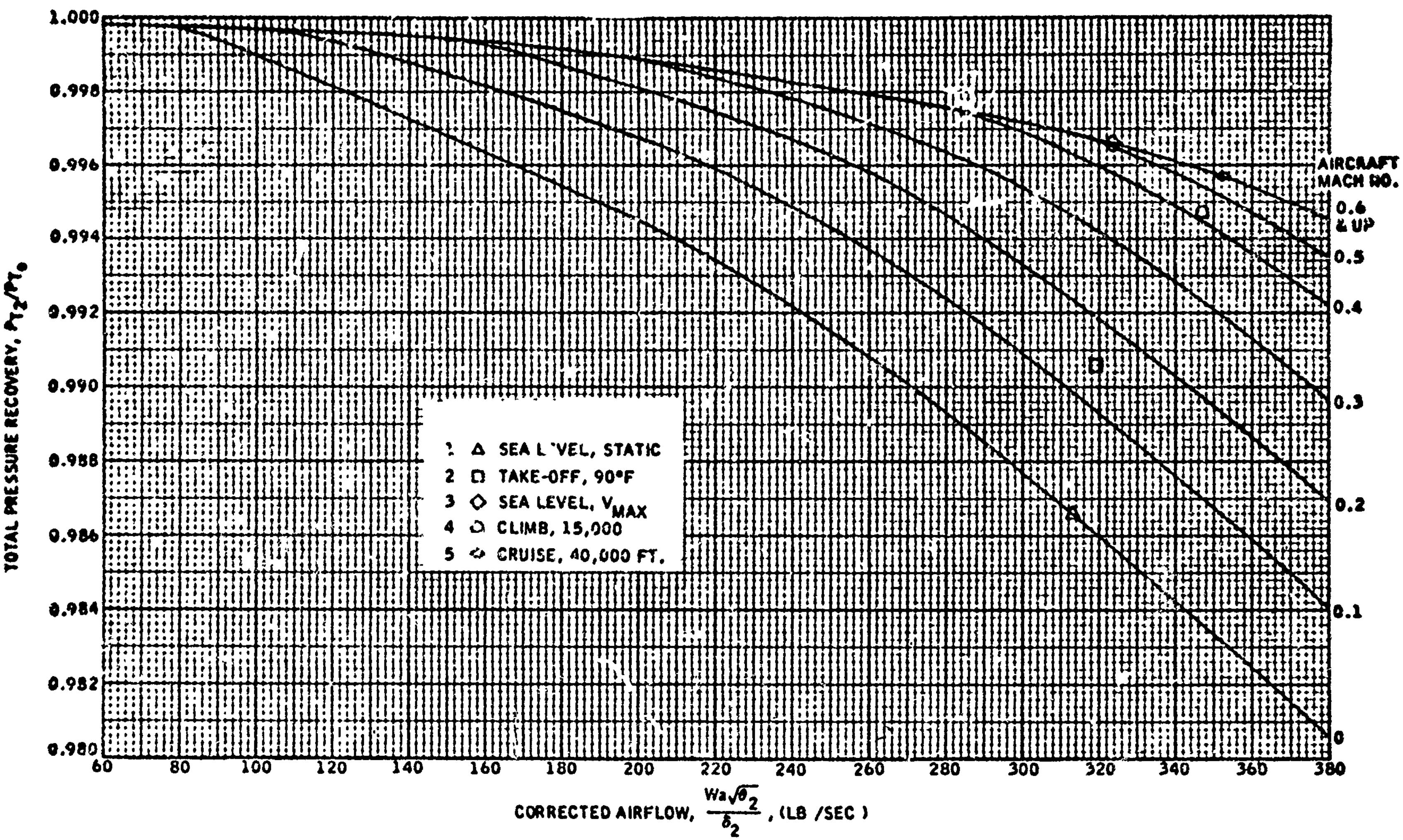


Figure 3-5. STOL Engine Inlet Performance

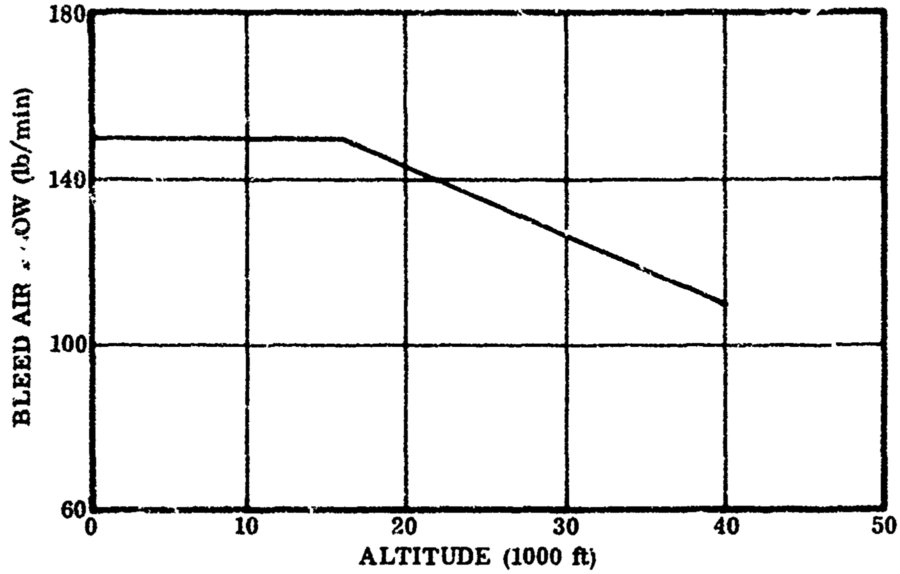


Figure 3-6. STOL Transport Required Bleed Flow for Environmental Control

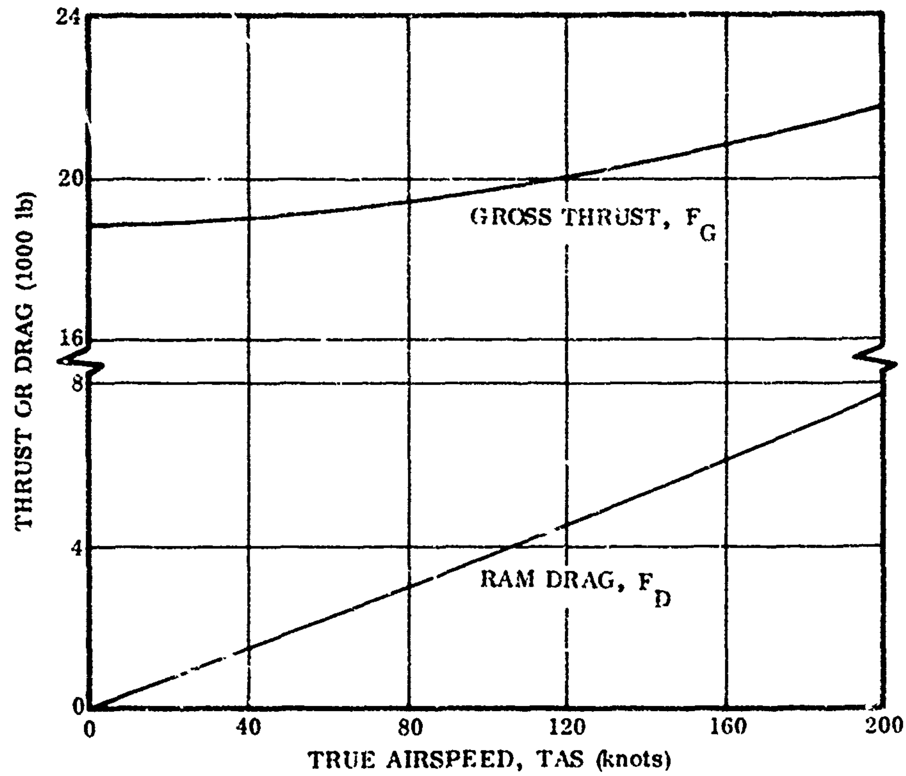


Figure 3-7. GE13/F2A and GE13/F2B Engines at 2500Feet, Hot Day,
Takeoff Power, STT Installation

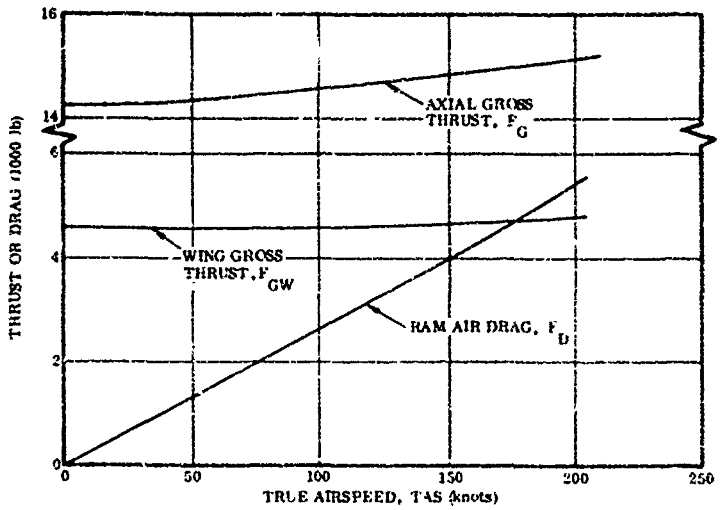


Figure 3-8. STF369 Engine at 2500 Feet, Hot Day, Takeoff Power, STT Installation

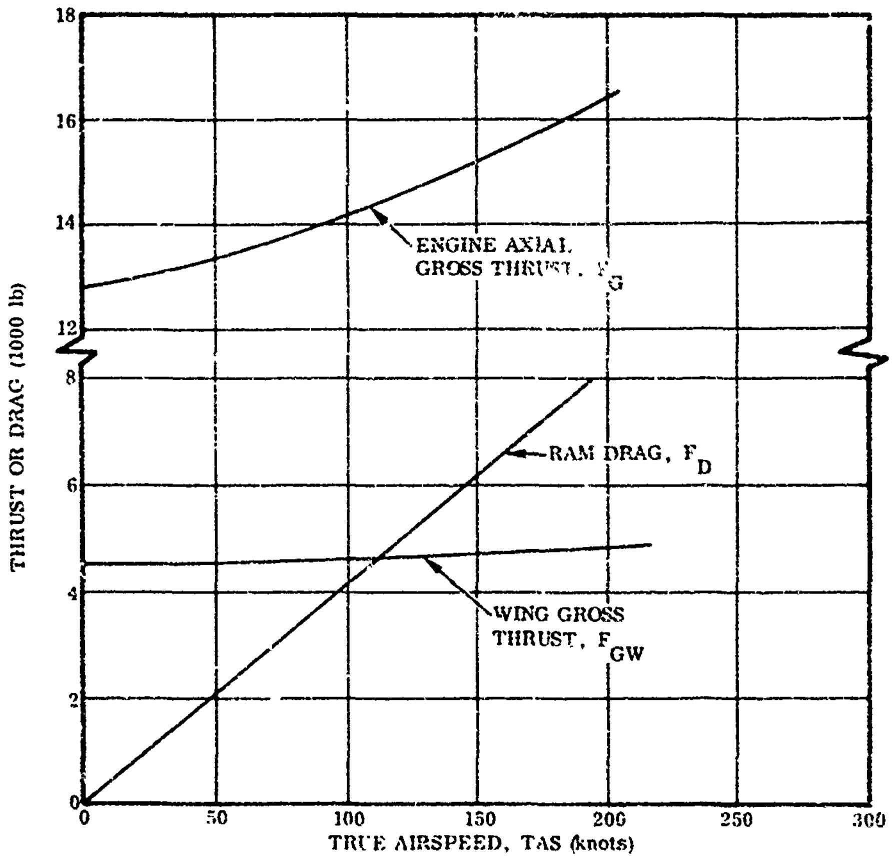


Figure 3-9. RB419-03 Engine at 2500 Feet, Hot Day, Takeoff Power, STT Installation

Table 3-3. Selected Thrust Reversing and Vectoring Devices

Configuration	Type: Primary	Type: Fan	Assumed Reversal (%)	Weight (lb)
Externally Blown Flap	Annular Cascade	Annular Cascade	42	630
	Annular Cascade		42	630
Mechanical Flap Plus Vectoring	Single-Bearing Swivel		40	1570
	Dual Single-Bearing Swivel		40	956
Internally Blown Flap	Reversible Pitch Fan	Fixed Vector Clamshell	35	395
	Annular Cascade		42	630

The three-quarter length GE13/F2B fan cowl is light in weight and satisfies the EBF performance requirements. The annular cascade reverser was selected as the most logical for this engine/cowling arrangement. A discussion with General Electric led to a maximum performance level of 42 percent.

The RB419-03 engine selected for the IBF incorporates a reversible-pitch fan. This system operates with two-position bypass ports in the fan nozzle to reduce lip losses in the reverse flow mode and resulting adverse effects on the gas generator due to reduction in engine inlet pressure. Current Convair Aerospace design studies combine the high-pressure fan air and gas generator exhaust streams, which are collected and reversed together in a single clamshell reverser mounted off the gas generator. This reverser is canted to direct the reversed gases upward and forward, away from the engine inlets. Performance of the clamshell reverser is estimated at 42 percent acting on approximately two-thirds of the thrust, making a net reversal of 35 percent.

The STF-369 selected for the IBF uses an annular cascade reverser that furnished 42 percent reversal.

SECTION 4

AERODYNAMIC DATA BASE

Methodology used to develop the Part 1 data base is discussed in this section. Since current state-of-the-art low-speed prediction methods were not available, test data for similar configurations was used. The primary purpose of the aerodynamic data is to provide baseline information. The Part 1 low-speed data base was updated for Part 2 using the parametric data developed during the 1100 hours of wind tunnel testing.

4.1 MINIMUM DRAG BUILDUP

The low-speed minimum drag coefficient for the three MST configurations is tabulated in Table 4-1 and compared with other vehicles in Figure 4-1. Minimum drag is the sum of three components: skin friction and profile drag, interference drag, and drag of miscellaneous components such as control surface slots, cooling, etc. Skin friction and profile drag of component terms were estimated using the Von Karman flat-plate skin friction coefficient at the component Reynolds number, multiplied by the over-velocity factors determined by Hoerner (Reference 4-1) to account for the thickness effect on pressure distribution of non-flat bodies. The full-scale Reynolds number was assumed to be 1.8 million per foot of component length. Interference drag of the fuselage/tail intersection and the engine-pylon/wing intersection have been taken from Reference 4-1. Wing/body interference was taken from Reference 4-2 as three percent of the wing and fuselage skin friction and profile drag. Miscellaneous drag was assumed to be 12 percent of the skin friction drag of the total aircraft.

4.2 CRUISE TRIMMED POLARS

Trimmed drag due to lift estimated in the subsonic speed range (excluding compressibility effects at high subsonic speeds) are based on the "e" prediction method given by Linden and O'Brimski in Reference 4-3. This method provides increments in "e" for variations in wing aspect ratio, taper ratio, sweep, and thickness ratio from a baseline configuration. It includes a method to estimate the variation in "e" at lift coefficient above the point where the drag polar breaks away from a simple parabolic variation due to separation effects. The method was derived from data correlations on conventional aircraft designs and represents a good approximation of aircraft induced drag using aircraft geometry as a base. When test data is available on similar configurations, this method can be used to correct that data for configuration differences.

A simplified method for estimating aircraft drag-rise characteristics at high subsonic speeds was developed using correlations of test data on a number of aircraft configurations. Drag divergence Mach number can be correlated very well using the

Table 4-1. Minimum Drag Buildup

	MF + VT			IBF			EBF		
	$C_D \sim$ cts	$S_{wet} \sim Ft^2$	$\Delta f_e \sim Ft^2$	$C_D \sim$ cts	$S_{wet} \sim Ft^2$	$\Delta f_e \sim Ft^2$	$C_D \sim$ cts	$S_{wet} \sim Ft^2$	$\Delta f_e \sim Ft^2$
Skin Friction & Profile									
Wing	50.1	2,689	7.765	50.1	2,689	7.765	50.1	2,689	7.765
Fuselage	95.2	5,265	14.756	95.2	5,265	14.756	95.2	5,265	14.756
Landing Gear Pods	14.1	730	2.186	14.1	730	2.186	14.1	730	2.186
Horizontal Tail	18.8	1,115	2.914	18.8	1,115	2.914	18.8	1,115	2.914
Vertical Tail	14.7	833	2.279	14.7	833	2.279	14.7	833	2.279
Engine Pods (4)	28.0	1,184	4.340	27.6	1,040	4.278	19.2	948	2.876
Engine Pylons (4)	4.8	310	0.744	4.8	310	0.744	4.0	190	0.620
Subtotal	225.7	12,126	34.984	225.3	11,982	34.921	216.1	11,770	33.496
Interference									
Wing/Fuselage	4.6	--	0.713	4.6	--	0.713	4.6	--	0.713
Fuselage/Vertical Tail	9.0	--	1.395	9.0	--	1.395	9.0	--	1.395
Vertical/Horizontal Tail	4.0	--	0.620	4.0	--	0.620	4.0	--	0.620
Wing/Pylon/Nacelle (4)	10.4	--	1.612	11.6	--	1.798	11.2	--	1.736
Subtotal	28.0	--	4.340	29.2	--	4.526	28.8	--	4.164
Miscellaneous	20.0	--	3.10	20.0		3.10	20.0	--	3.10
Total*	273.7	12,126	42.42	274.5	11,982	42.55	264.9	11,770	41.06
	C_f = .00350			= .00355			= .00349		

*Held Constant: Wing Area = 1550 Ft^2 Engine Rated Thrust = 22,500 Lb.

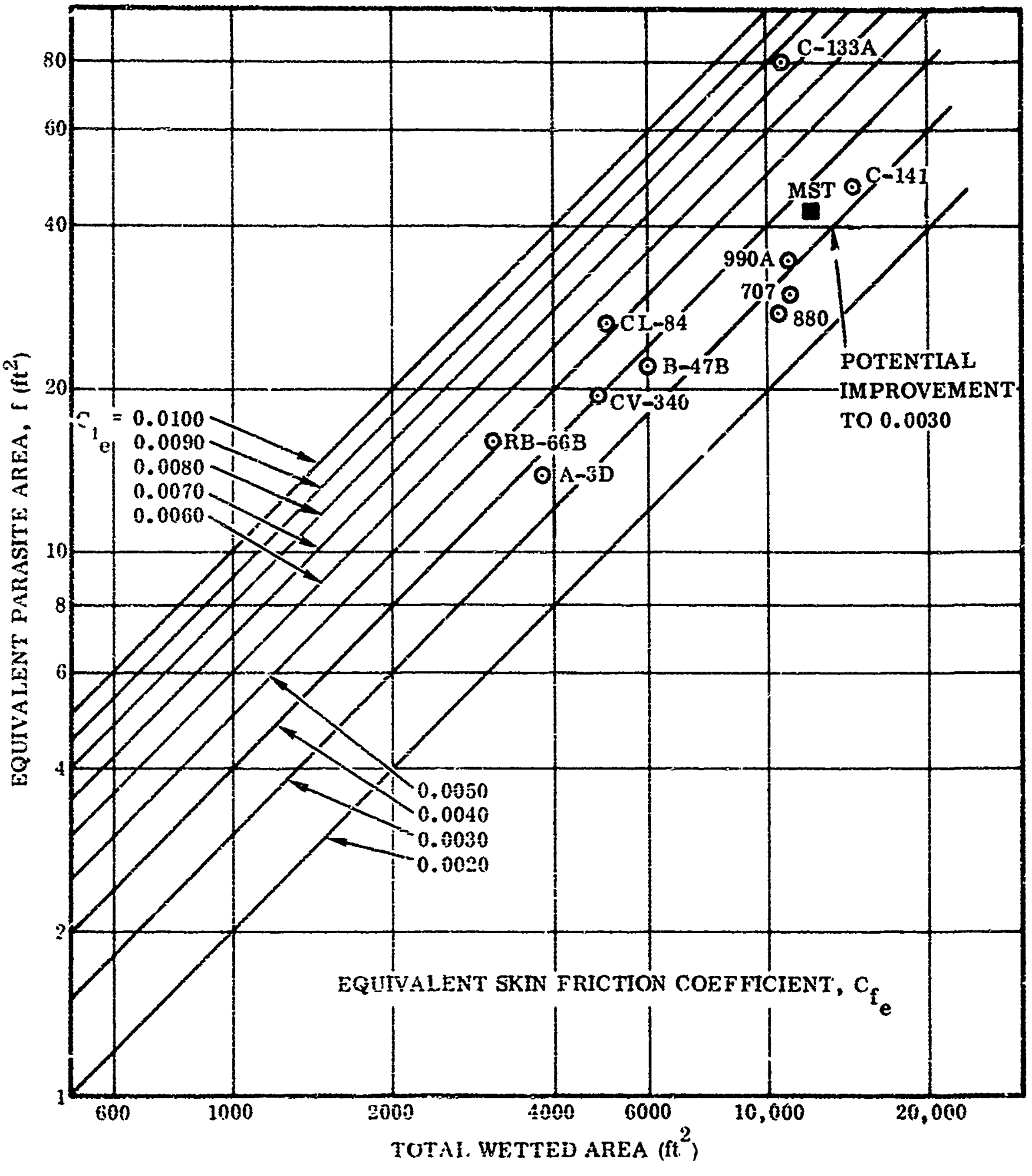


Figure 4-1. Minimum Drag Comparison

reciprocal of the product of aspect ratio, thickness ratio, and the cosine of the quarter-chord sweep angle. This method, along with correlations, was also reported in Reference 4-3. Cruise drag polars and drag-rise characteristics of the baseline configurations are presented in Figure 4-2.

4.3 LOW-SPEED LIFT CURVES AND POLARS

Total lift can be written as the sum of the lift forces on the engine nacelles and pylons plus the lift forces on the wing/fuselage combination. In addition to internal forces (jet reaction in the lift direction) and external pressure lift forces on the isolated nacelle, the nacelle lift forces include the interference effect of the presence of the wing/fuselage on these two force vectors. Wing/fuselage lift forces include the basic power-off lift of the wing flap and fuselage, the effect of any internal blowing on the leading and trailing edges, and the effect on pressure lift due to the presence of the blowing nacelle. The lift on each of the three lift/propulsion concepts can be determined by estimating these effects or using wind tunnel data that includes these effects.

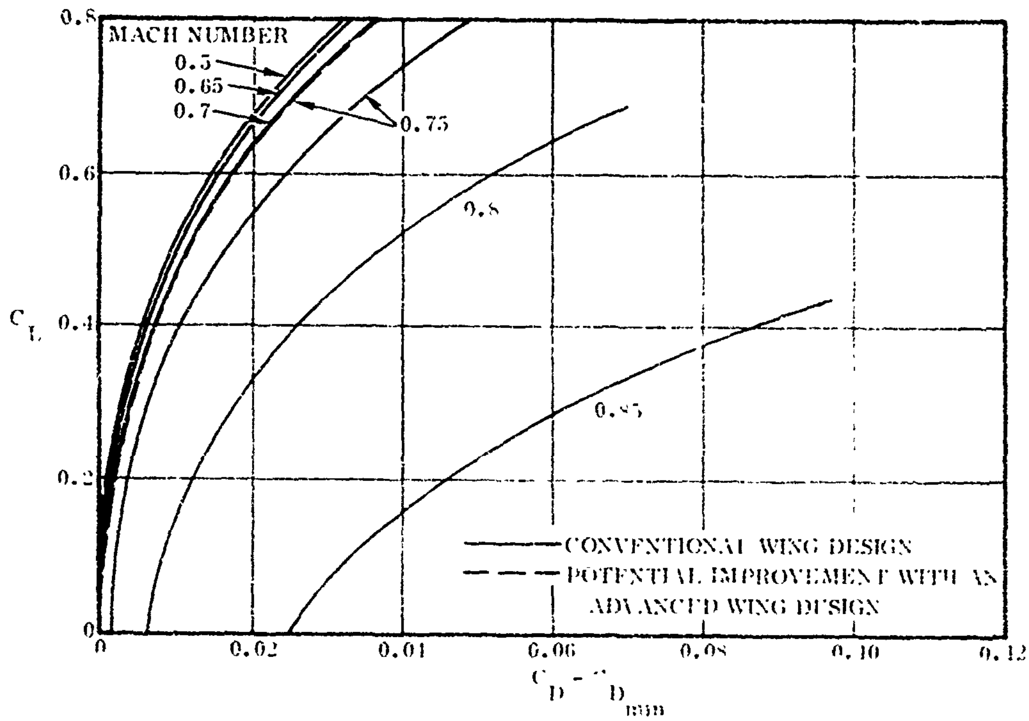


Figure 4-2. Cruise Configuration - Trimmed Data.

For the MF/VT configuration, the pressures on the wing were assumed not to be affected by the presence of the nacelle; therefore, the only lift forces are the power-off lift plus the effects of blowing the wing leading edge. The lift force for the IBF configuration is similar to that of the MF/VT configuration, with the added effect of blowing over the flap. Experimental NASA data, Reference 4-4, from a model similar to the MST EBF configuration was used to estimate the lift characteristics of this configuration.

The drag increment due to flap extension and the influence of power was basically taken from test data on a similar configuration, with a correction applied for aspect ratio differences. Power-off data from Reference 4-4 was used for flaps-down drag on the MF/VT configuration. Power-on data from Reference 4-4 was used for the EBF configuration drag. An analytical approach was taken for the IBF configuration, since a theory is available for this configuration. This theory was developed by Spence as an extension of thin airfoil theory.

Low-speed lift curve drag polars for the baseline configurations are presented in Figure 4-3 for MF/VT, Figure 4-4 for EBF, and Figure 4-5 for IBF.

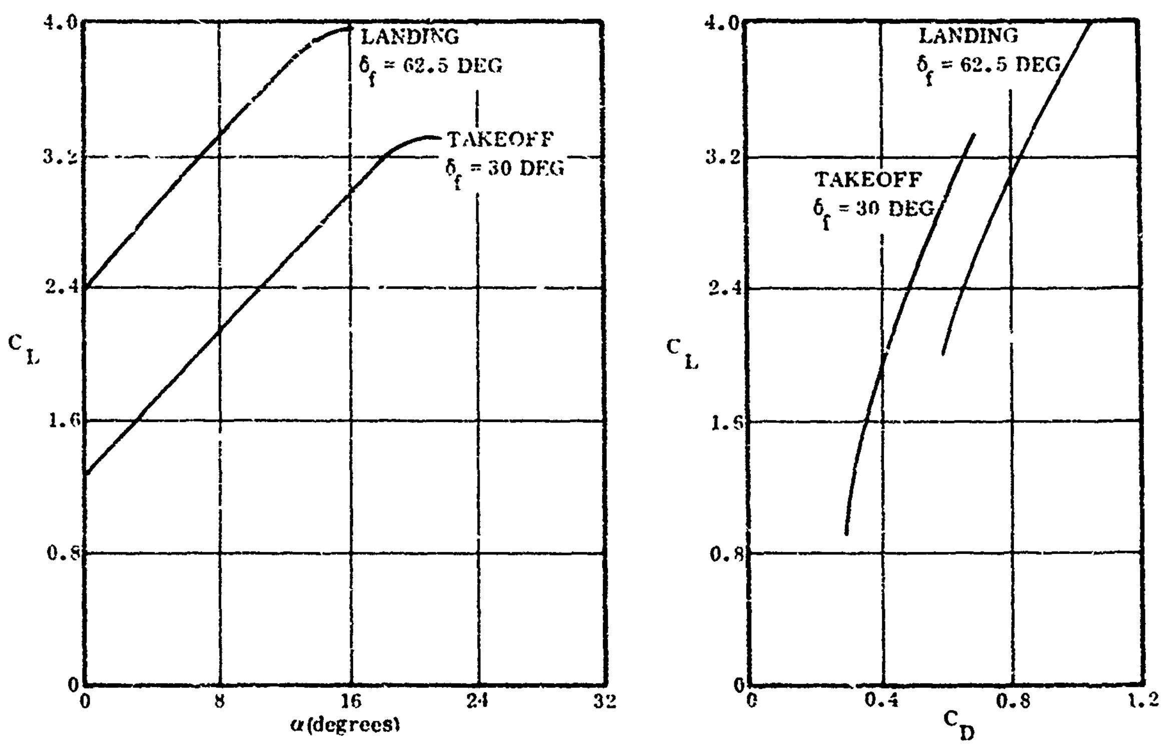


Figure 4-3. MF/VT Low-Speed Trimmed Data, Part 1

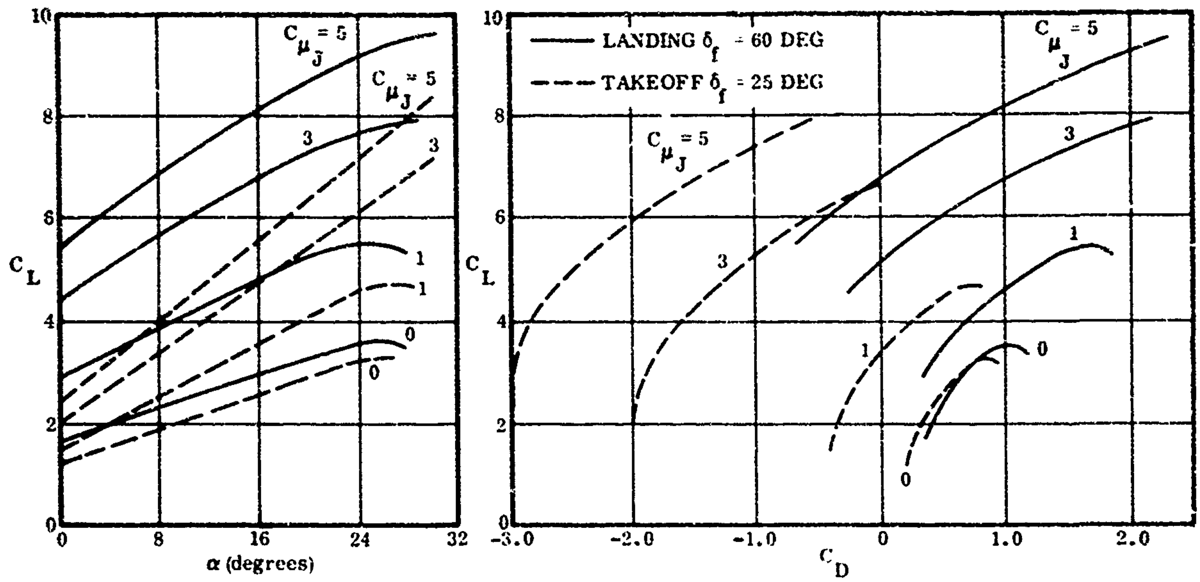


Figure 4-4. EBF Low-Speed Trimmed Data, Part 1

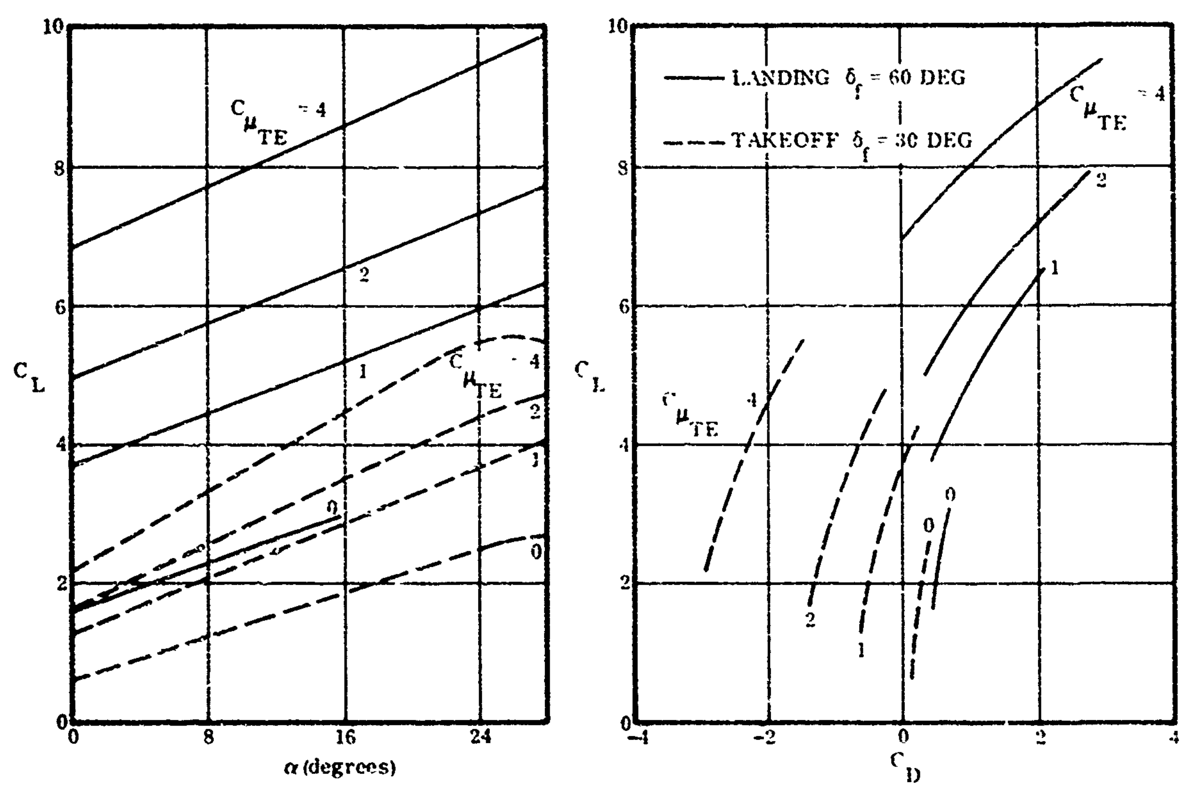


Figure 4-5. IBF Low-Speed Trimmed Data, Part 1

SECTION 5

PRELIMINARY DESIGNS

The overall objective of the preliminary design effort was to conduct a vehicle sizing activity to establish baseline configurations for the STOL Tactical Aircraft Investigation. The lift/propulsion concepts studied were EBF, MF/VT, and IBF.

5.1 BASELINE CONFIGURATIONS

Initial designs were covered during the three-month configuration review indicated in Figure 5-1. The review was held at the Convair Aerospace Division in San Diego on 14 and 15 September 1971.

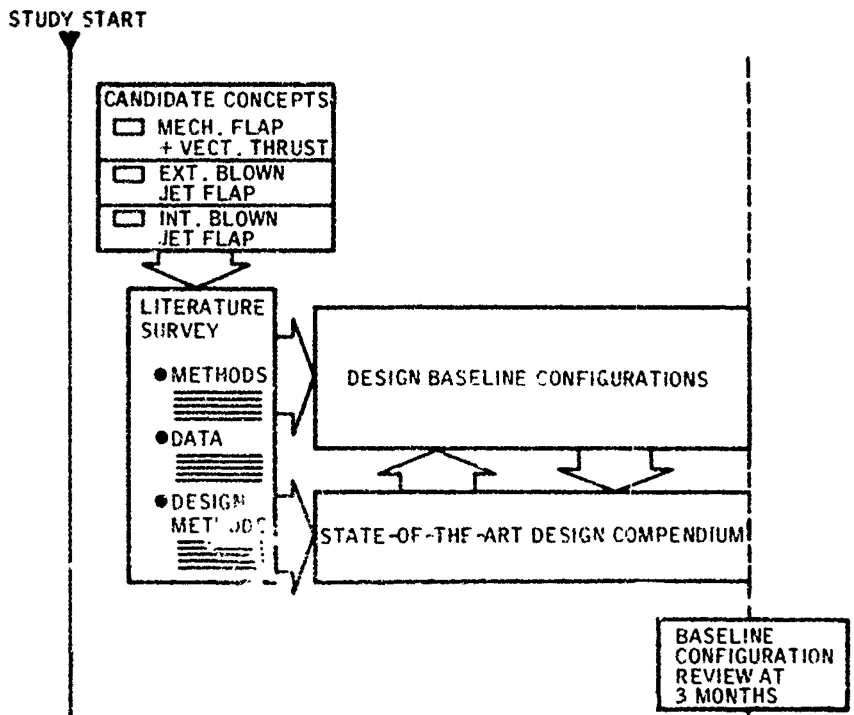


Figure 5-1. Phase 1, Part 1 Studies and Analyses

These baseline configuration designs met the MST Design Requirements supplied by the Air Force Flight Dynamics Laboratory on 13 July 1971. These vehicle designs are based on current state-of-the-art technology and use projected propulsion data for derivative engines using existing cores.

The data presented in Table 5-1 represents the vehicle sizing activities that generated configurations to meet the design requirements, and is representative of the lift/propulsion concepts and projected engine efficiencies. General arrangements for these point designs are shown in Figures 5-2, 5-3, and 5-4.

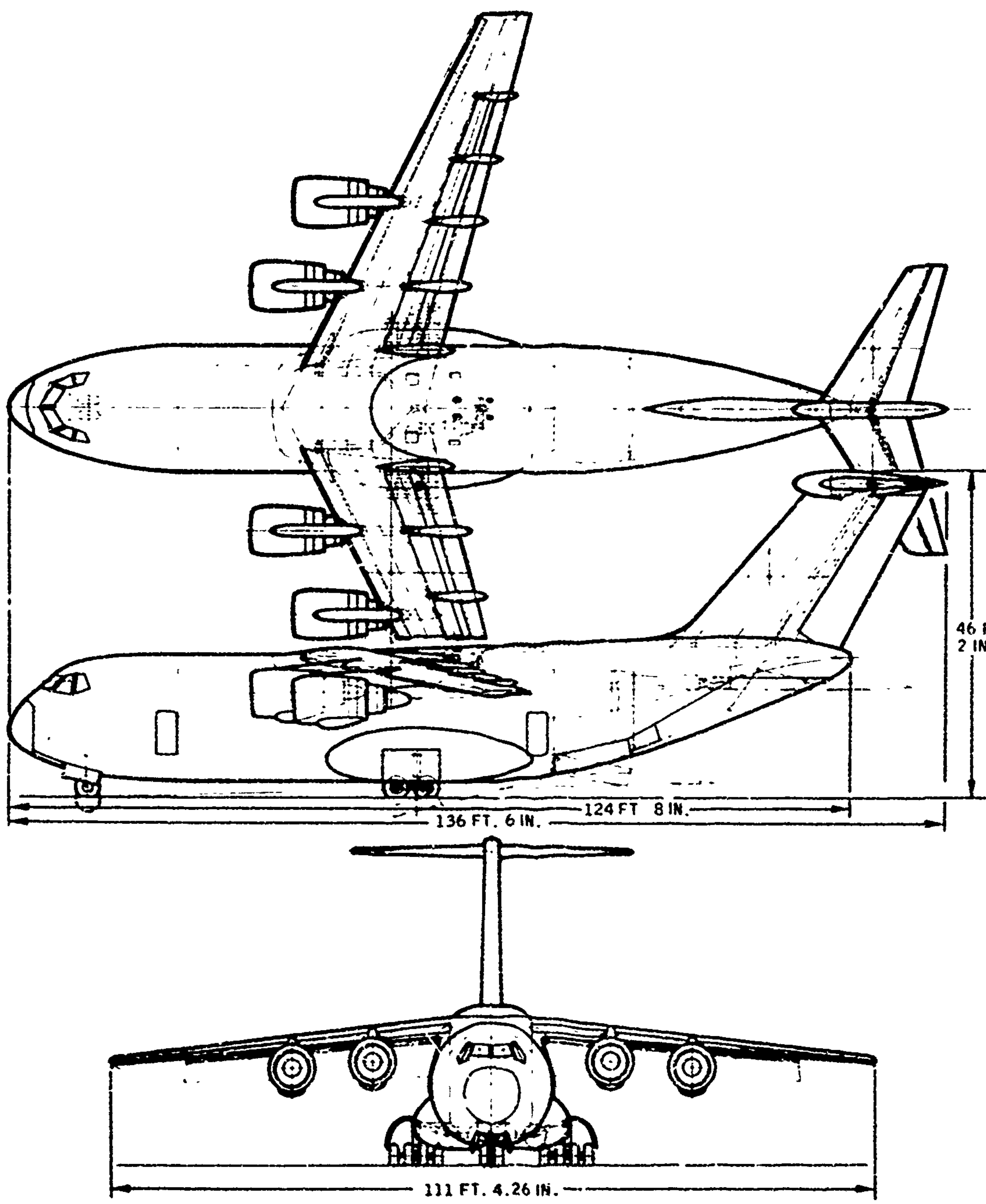


Figure 5-2. General Arrangement of EBF Design

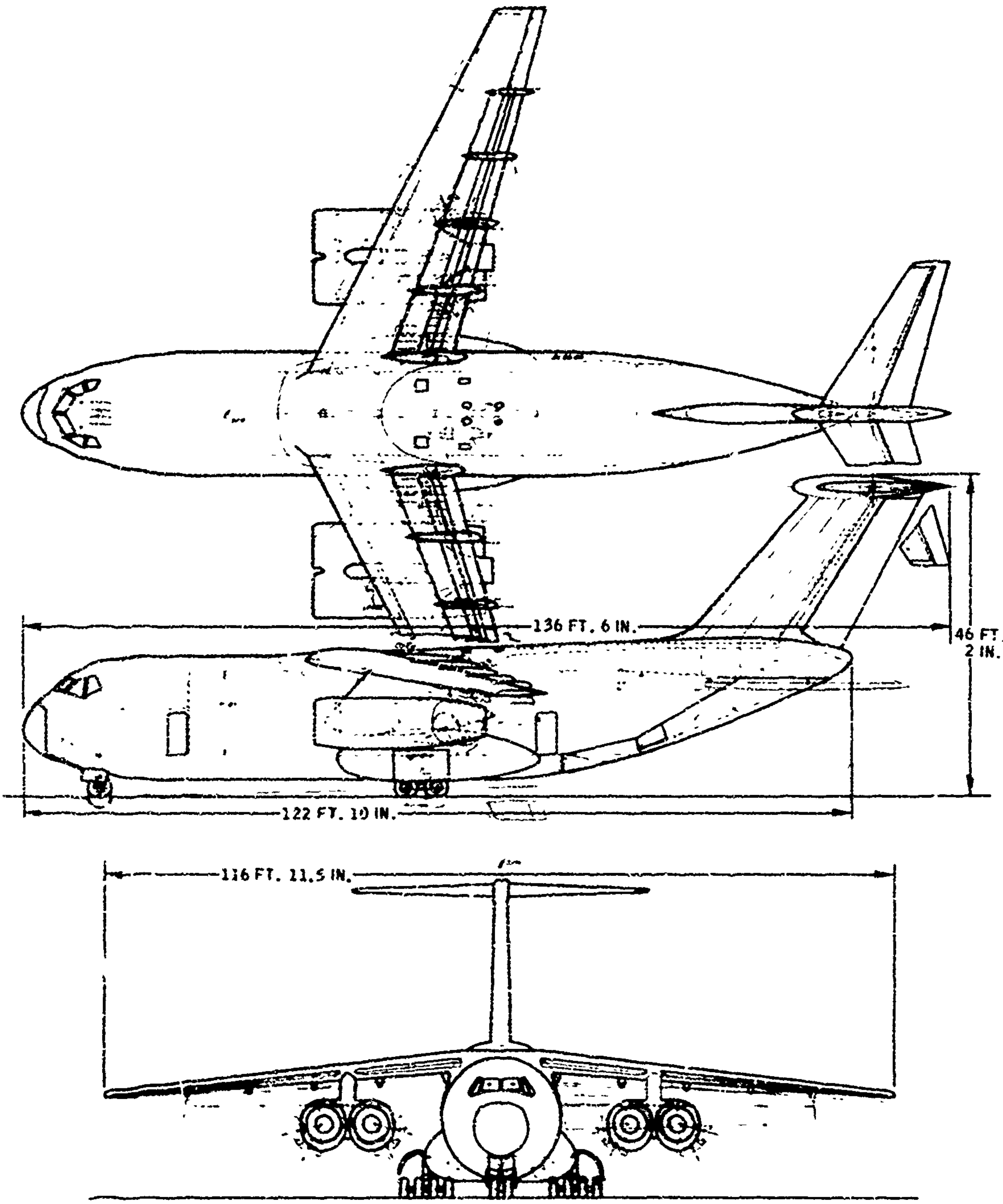


Figure 5-3. General Arrangement of MF/VT Design

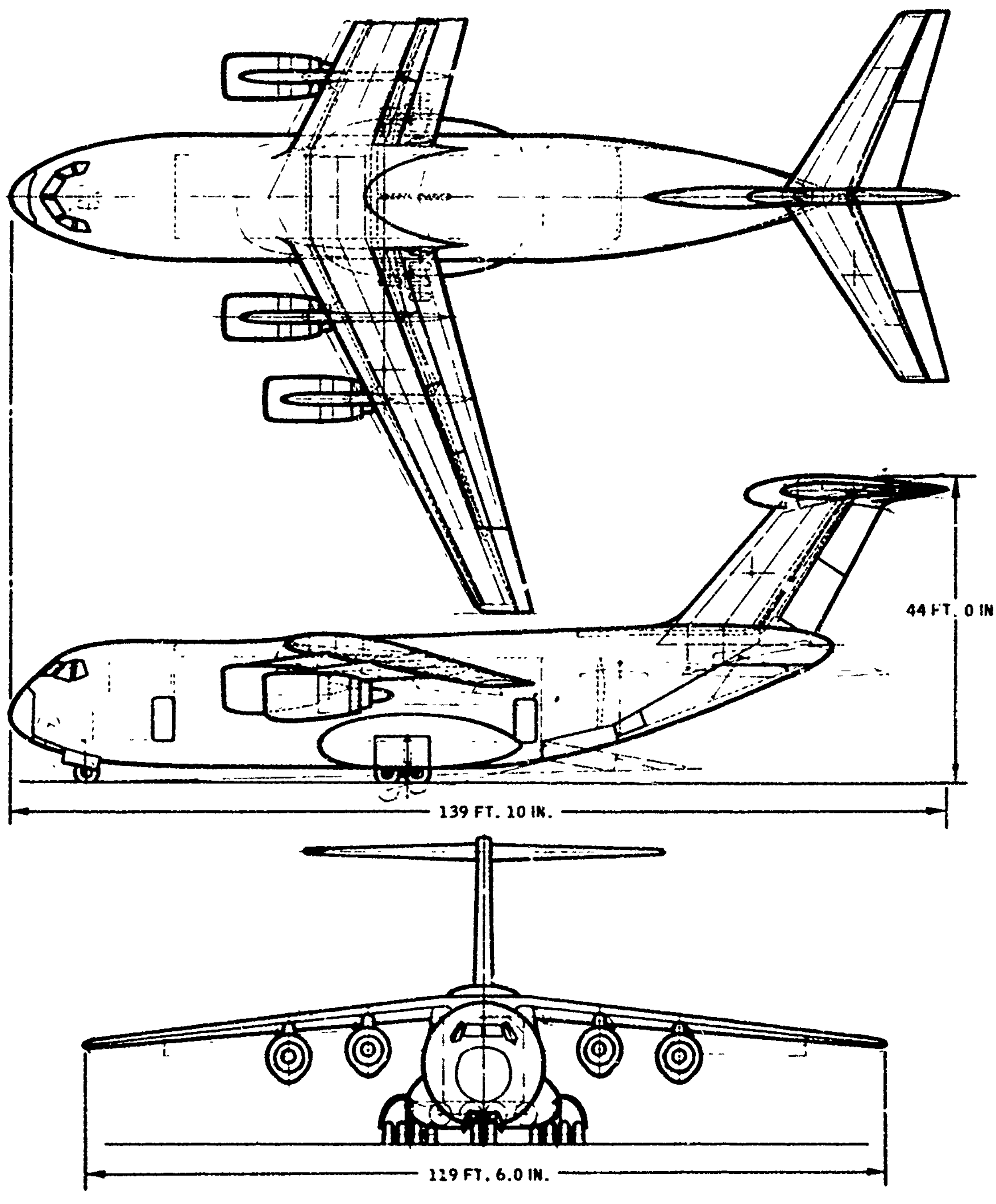


Figure 5-4. General Arrangement of IBF Design

Table 5-1. MST Candidate Aircraft - Point Designs

	EBF	MF/VT	IBF-1
Engine	GE13/F2B	GE13/F2A	RB419-03
Wing Area (ft^2)	1550	1710	2160
Takeoff Gross Weight (lb)	148,200	168,750	198,200
Mid-mission Weight (lb)	134,200	153,500	179,800
Rated Thrust (lb)	18,600	24,750	28,125
T/W	0.555	0.645	0.627
W/S (lb/ft^2)	86.6	89.8	83.2
Takeoff Distance (ft)	2000	2000	2000
Landing Distance (ft)	990	1280	1120

5.1.1 ADDITIONAL BASELINE. Additional point designs were investigated after the three-month review to answer specific questions raised by the Air Force Review Team. These designs are summarized in Tables 5-2 and 5-3.

Table 5-2. Mechanical Flap Designs

	MF/VT-2*	Mechanical Flap
Engine	GE13/F2A	GE13/F2B
Wing Area (ft^2)	1635	1865
Takeoff Gross Weight (lb)	159,900	158,700
Mid-mission Weight (lb)	145,500	144,400
Rated Thrust (lb)	23,175	21,488
T/W	0.637	0.595
W/S (lb/ft^2)	88.9	77.43
Takeoff Distance (ft)	2000	2000
Landing Distance (ft)	1240	1380

* Twin nozzles on each nacelle for thrust vectoring/reversal.

Table 5-3. IBF Designs

	IBF-2	IBF-3
Engine	STF-369	GE13/F2B/RB229-03
Wing Area (ft^2)	1785	1550
Takeoff Gross Weight (lb)	170,300	150,200
Mid-mission Weight (lb)	152,450	135,800
Rated Thrust (lb)	22,837	13,500 (22,500)
T/W	0.599	0.729
W/S (lb/ft)	85.41	87.61
Takeoff Distance (ft)	2000	2000
Landing Distance (ft)	1175	1090

The baseline designs selected from Part 1 studies to be updated during Part 2 activities were the EBF with GE13/F2B engines, the MF/VT-2 with GE13/F2A engines, and the IBF-2 with STF-369 engines. The mechanical flap design provides an alternative to the powered-lift configurations.

5.1.2 TRADEOFF STUDIES. Limited-scope studies were performed to assess the impact of configuration and performance variables on the design gross weight of the medium STOL transport. These studies, except for field length tradeoffs, were performed on the EBF configuration that had a constant wing area of 1550 $ft.^2$ Wing area and engine size were allowed to vary for the takeoff field length tradeoff so that the vehicle would satisfy both the mission equipment and the STOL requirements.

The performance design tradeoff studies covered the following variables.

1. Assault field length (± 500 ft).
2. Design cruise speed (± 0.1M).
3. Design mission radius (± 250 n.mi.).
4. Mission (from Hi, Hi to Hi, Lo, Lo, Hi).
5. Penetration speed (400 knots at sea level for 50 n.mi.).

The results of these takeoff studies are shown in Figure 5-5 as percentage changes in design gross weight.

The configuration design tradeoff studies covered the following variables.

1. Bypass ratio (2 to 10).
2. Aspect ratio (6 to 10).
3. Wing sweep (15 to 35 deg).
4. Cargo compartment length (-10 ft).
5. Cargo loading (drive-through).

Figure 5-6 shows the effect of engine bypass ratio on design takeoff gross weight. A minimum design gross weight was indicated for a bypass ratio range from 4.0 to 6.5. Bypass ratios less than 4.0 suffered from higher specific fuel flows and those greater than 6.5 were penalized because of higher engine and engine installation weights. The results of the remaining design studies are shown in Figure 5-7 as percentage changes in design gross weight.

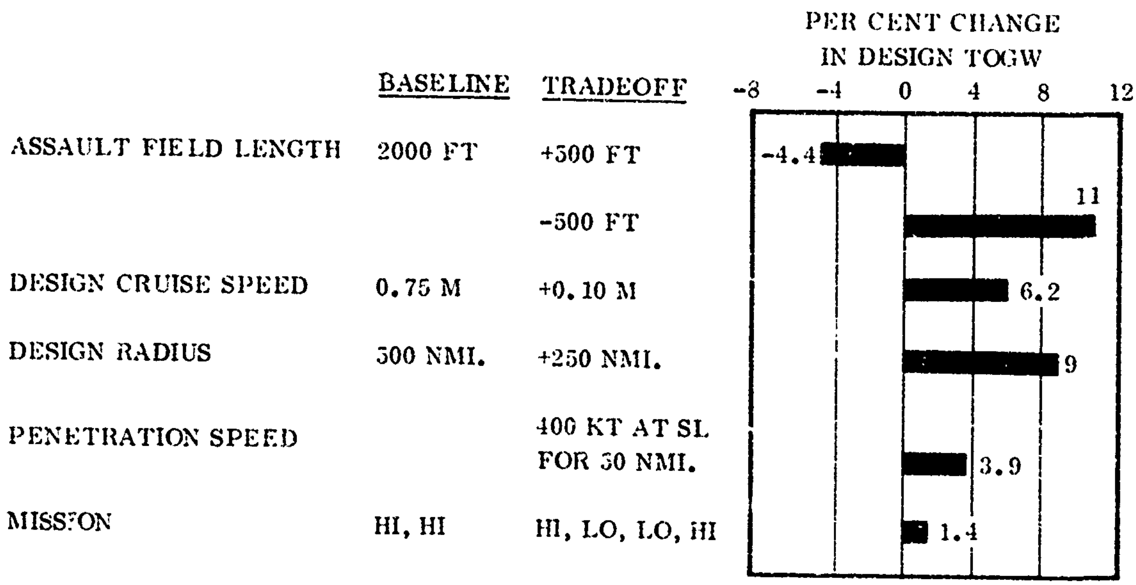


Figure 5-5. Performance Design Tradeoffs

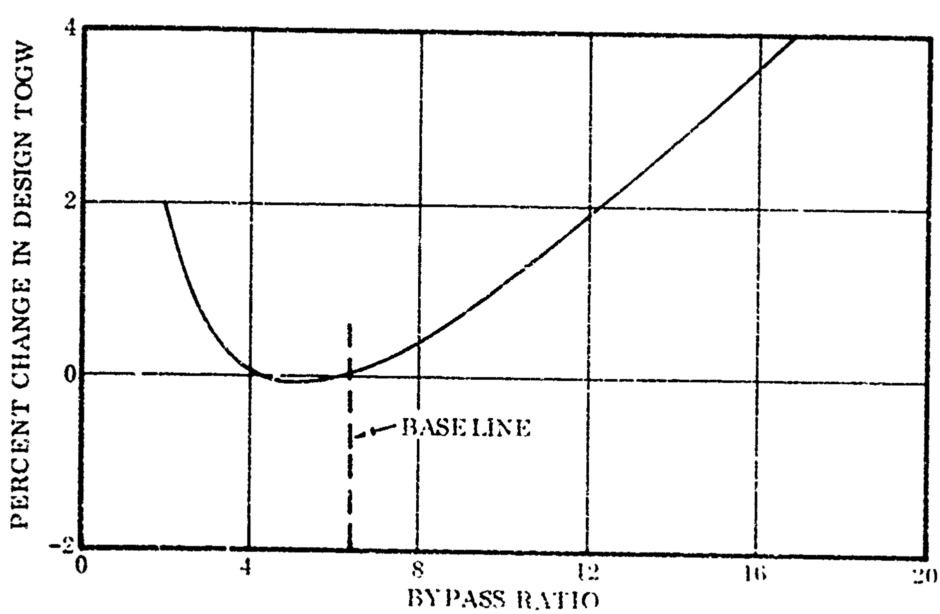


Figure 5-6. EBF Bypass Ratio Tradeoff

	BASELINE	TRADEOFF
ASPECT RATIO	8	6
		10
WING SWEEP	25 DEG	15 DEG
		35 DEG
CARGO COMPARTMENT LENGTH	55 FT	45 FT
CARGO LOADING	AFT	DRIVE-THROUGH

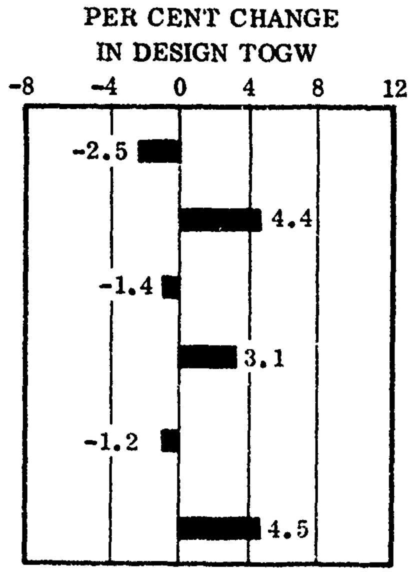


Figure 5-7. Configuration Design Tradeoffs

Results of a limited study of thrust vectoring is shown in Figure 5-8. The dual single-bearing nozzle thrust deflection concept was selected for the baseline MF/VT-2 configuration. Figure 5-9 shows the general arrangement and geometry of the thrust-vectoring nozzles. In this concept, the mixed gas flow of the engine is collected in a plenum chamber and exhausted through the twin nozzles, arranged symmetrically in a horizontal plane. The nozzles are mounted to the circular plenum chamber exits with bearings that permit nozzle rotation through the lower 180-degree sector for lift thrust vectoring and thrust reversals. Symmetric operation of the nozzles to ensure a balanced force system is through a dual-output hydraulic drive unit located in the nacelle behind the plenum chamber and between the nozzles.

Selection of the twin-nozzle thrust deflector was made on the basis of the following advantages.

1. Single system for lift and reverse thrust deflection.
2. Low system complexity - few moving parts.
3. Based on existing technology.
4. Thrust vectoring system functionally separate from engine.

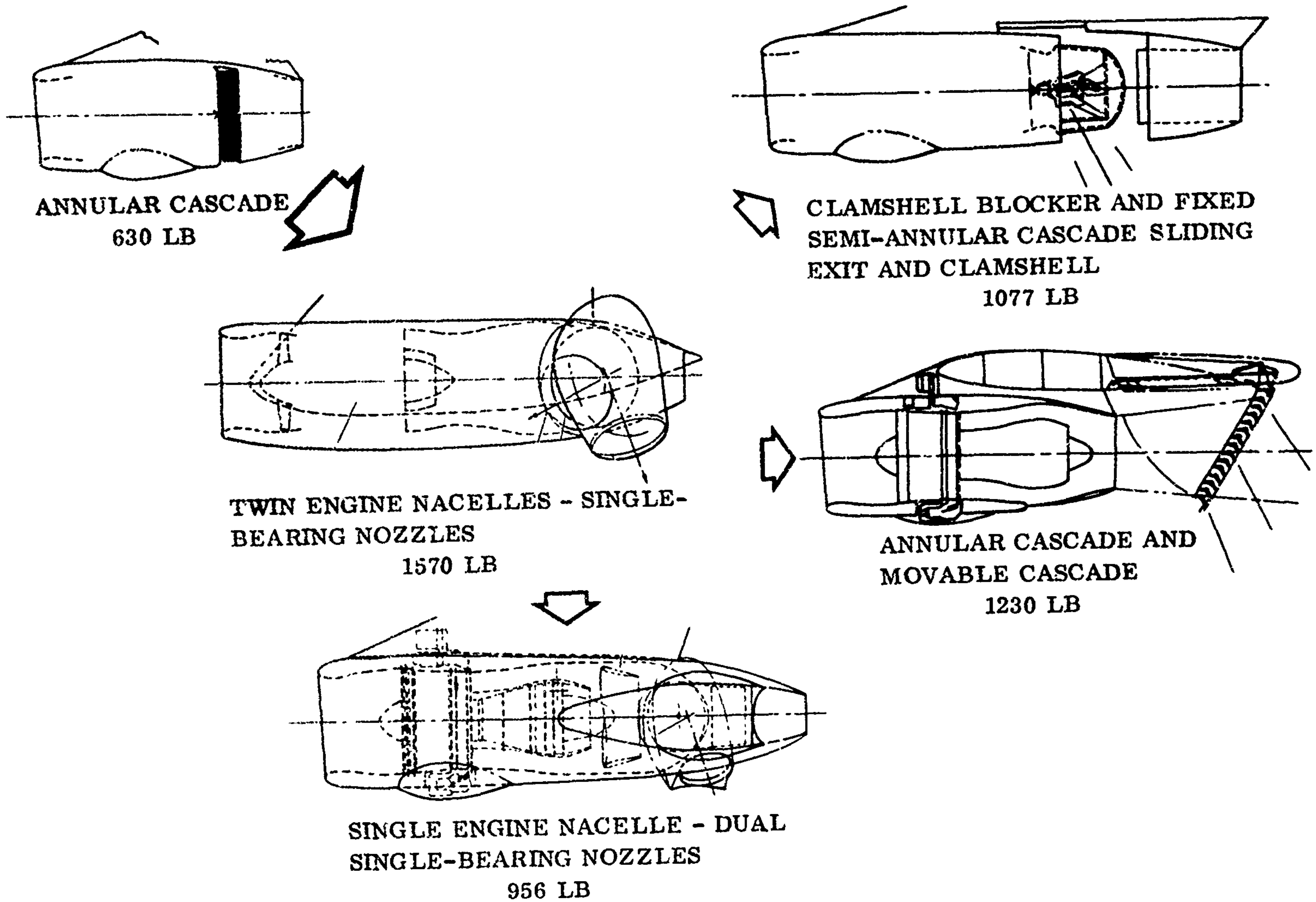


Figure 5-8. Comparison of Thrust Reversing and Vectoring Devices

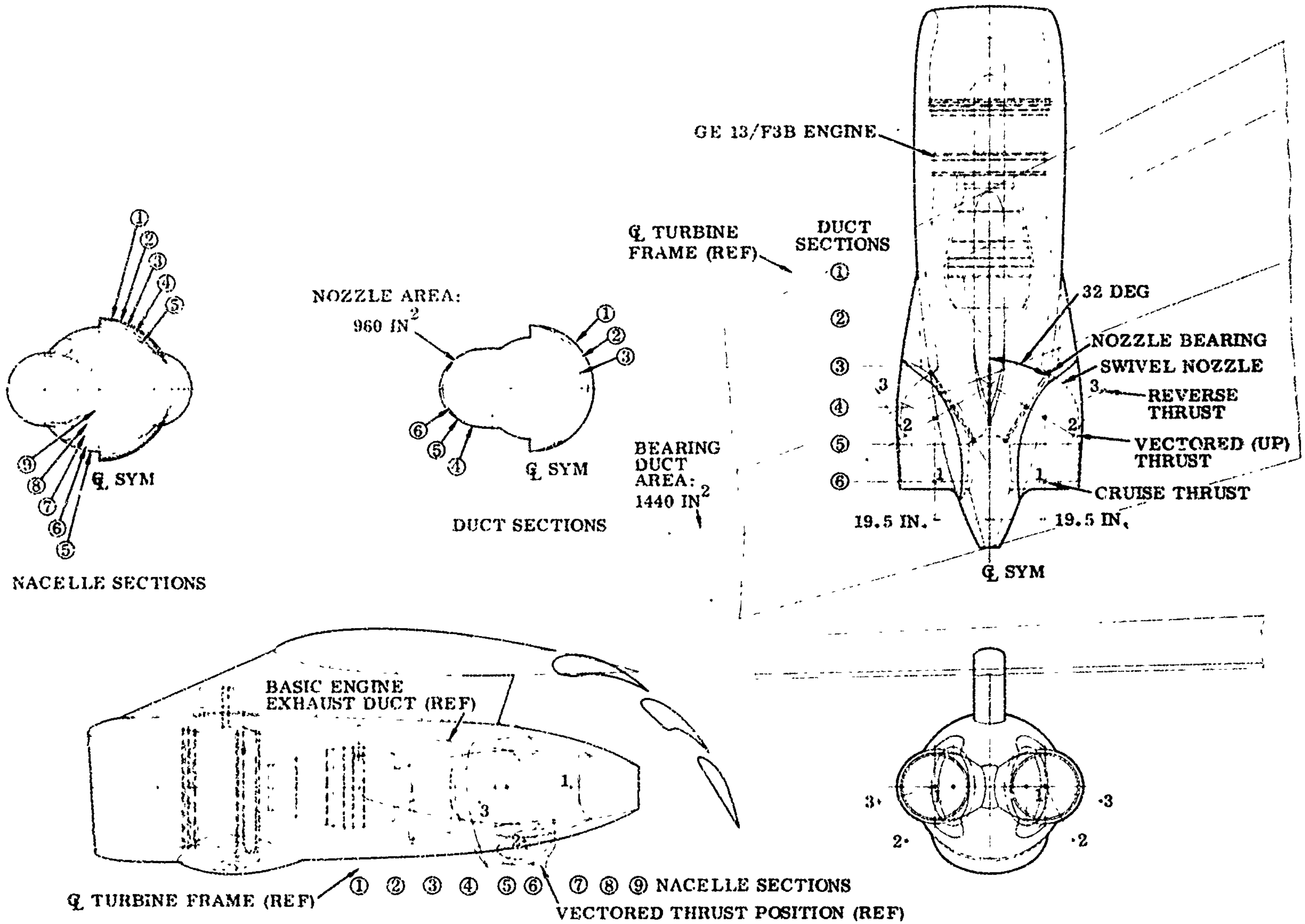


Figure 5-9. Dual Single-Bearing Nozzle Thrust Deflector (GE113 F3B Engine)

5. Low system weight - 960 lb/engine.

6. Clean aerodynamic nacelle.

7. Acceptable internal losses due to scrubbing and flow torquing.

8. Variable vector angle.

Figure 5-10 is a vector diagram illustrating the potential uncorrected lift and forward or reverse thrust components available with specific rotational angles of the nozzles. As shown, the thrust-vectoring system selected offers a wide range of forward thrust components at high lift thrust levels. By varying the bearing plane angle from that of the baseline configuration (90 degrees), lift thrust components can be increased.

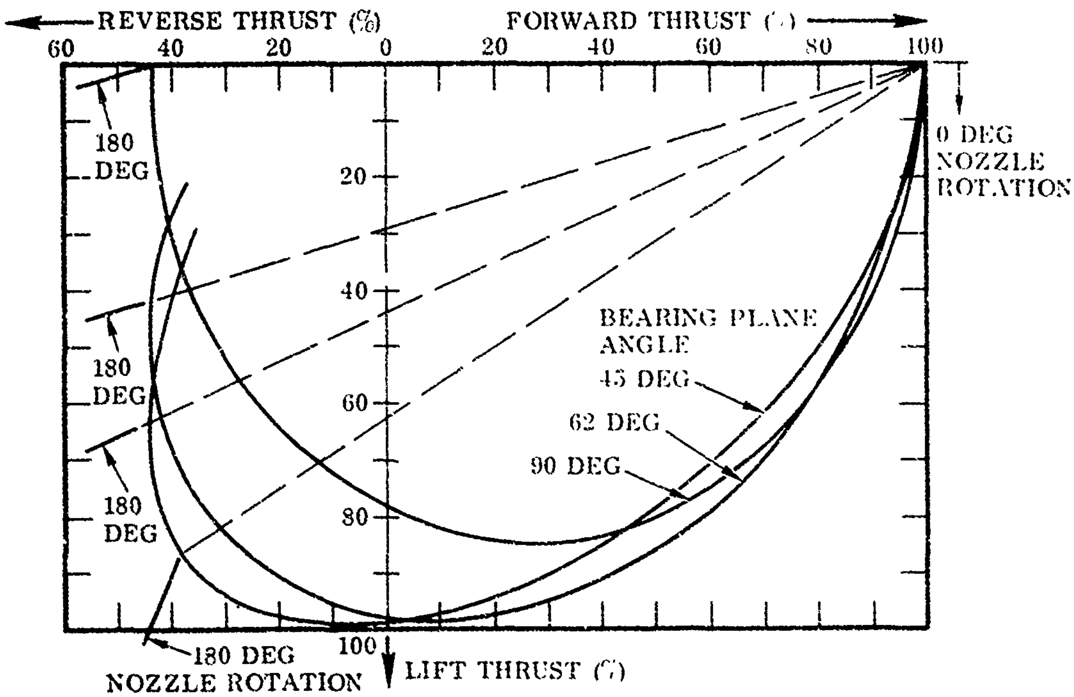


Figure 5-10. Thrust Vector Diagram (Uncorrected) Dual Single-Bearing Nozzle, Bearing Duct Angle = 58 Degrees

5.2 HIGH-LIFT SYSTEM

The high-lift systems for each lift/propulsion concept of the baseline configurations were defined as shown in Figures 5-11 through 5-14. The variable-geometry, blown wing leading-edge flap shown in Figure 5-15 is used on all baseline configurations in combination with their respective trailing-edge flap systems.

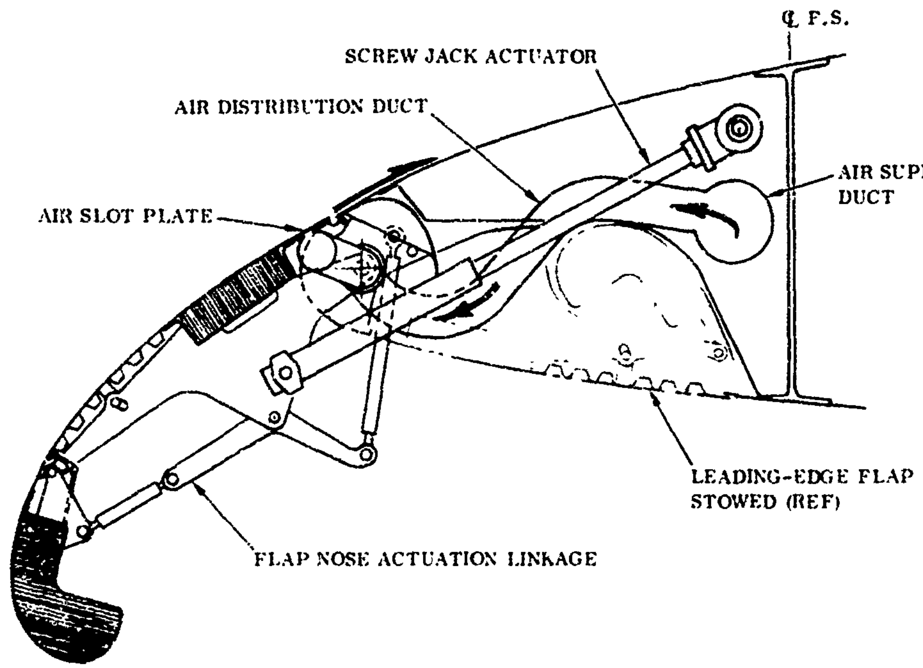


Figure 5-11. Variable-Geometry Leading Edge Flap, Internally Blown

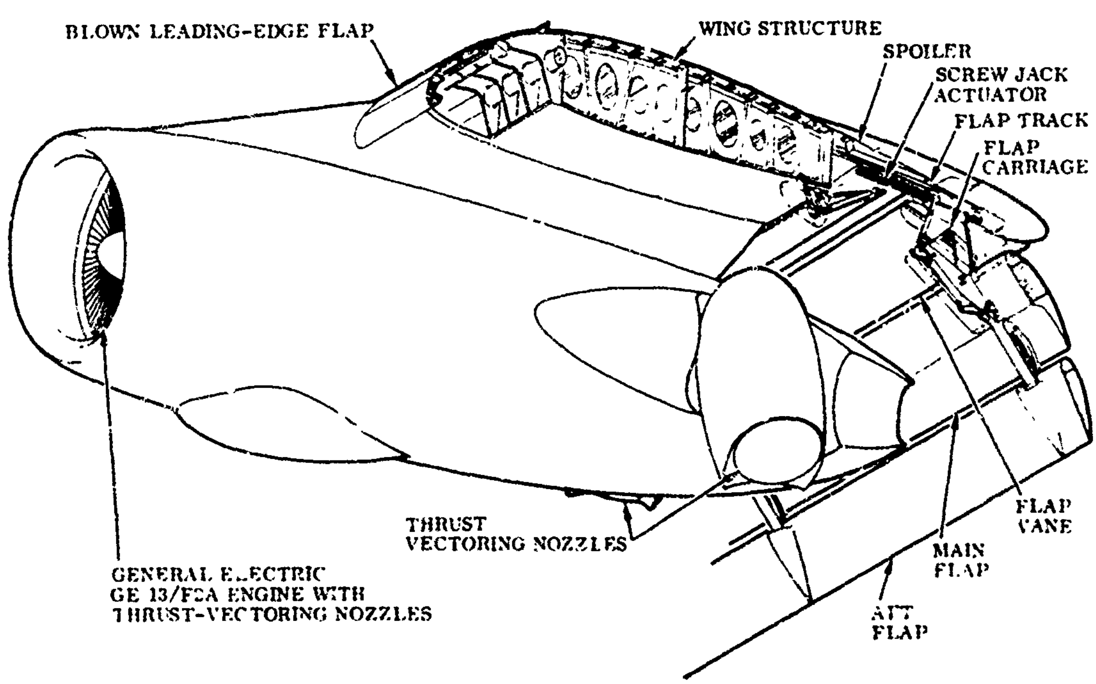


Figure 5-12. MF/VT Triple-Slotted Flap

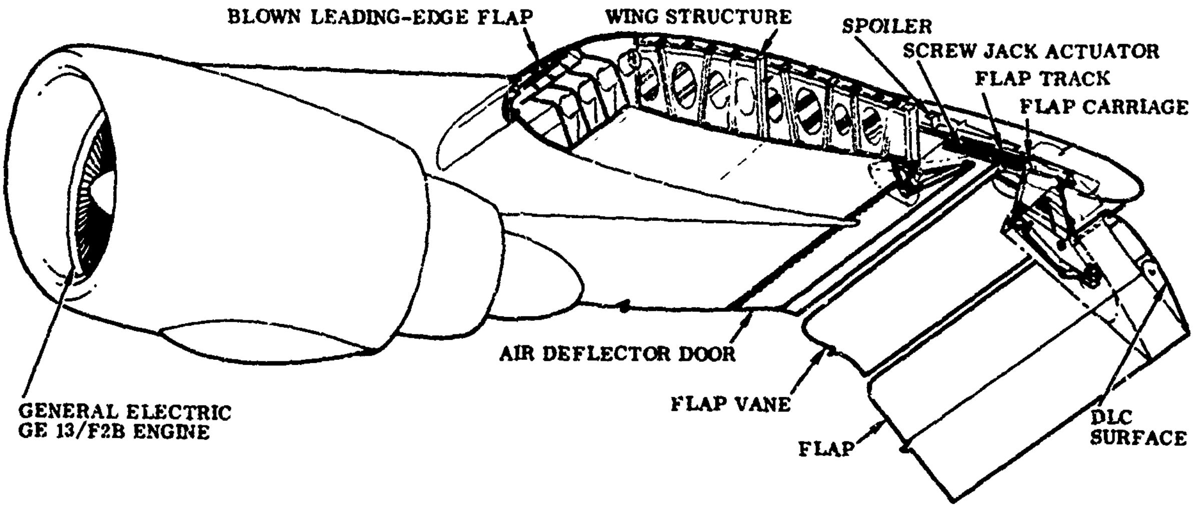


Figure 5-13. EBF Double-Slotted Flap with DLC

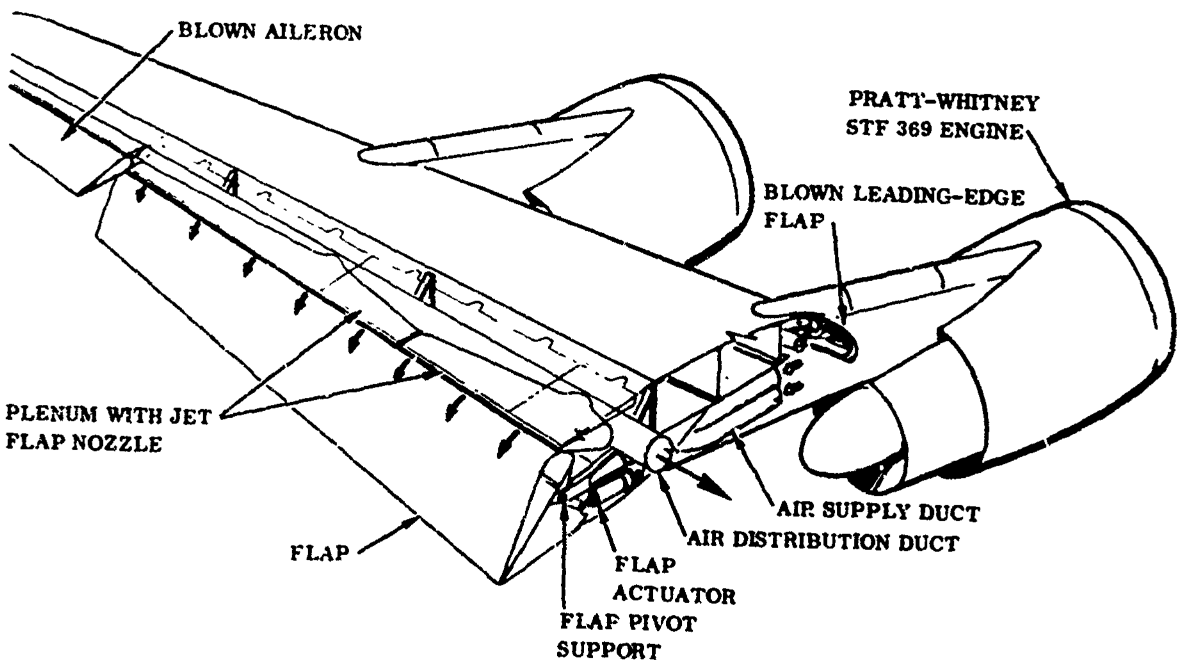


Figure 5-14. Hinged, Single Surface Flap

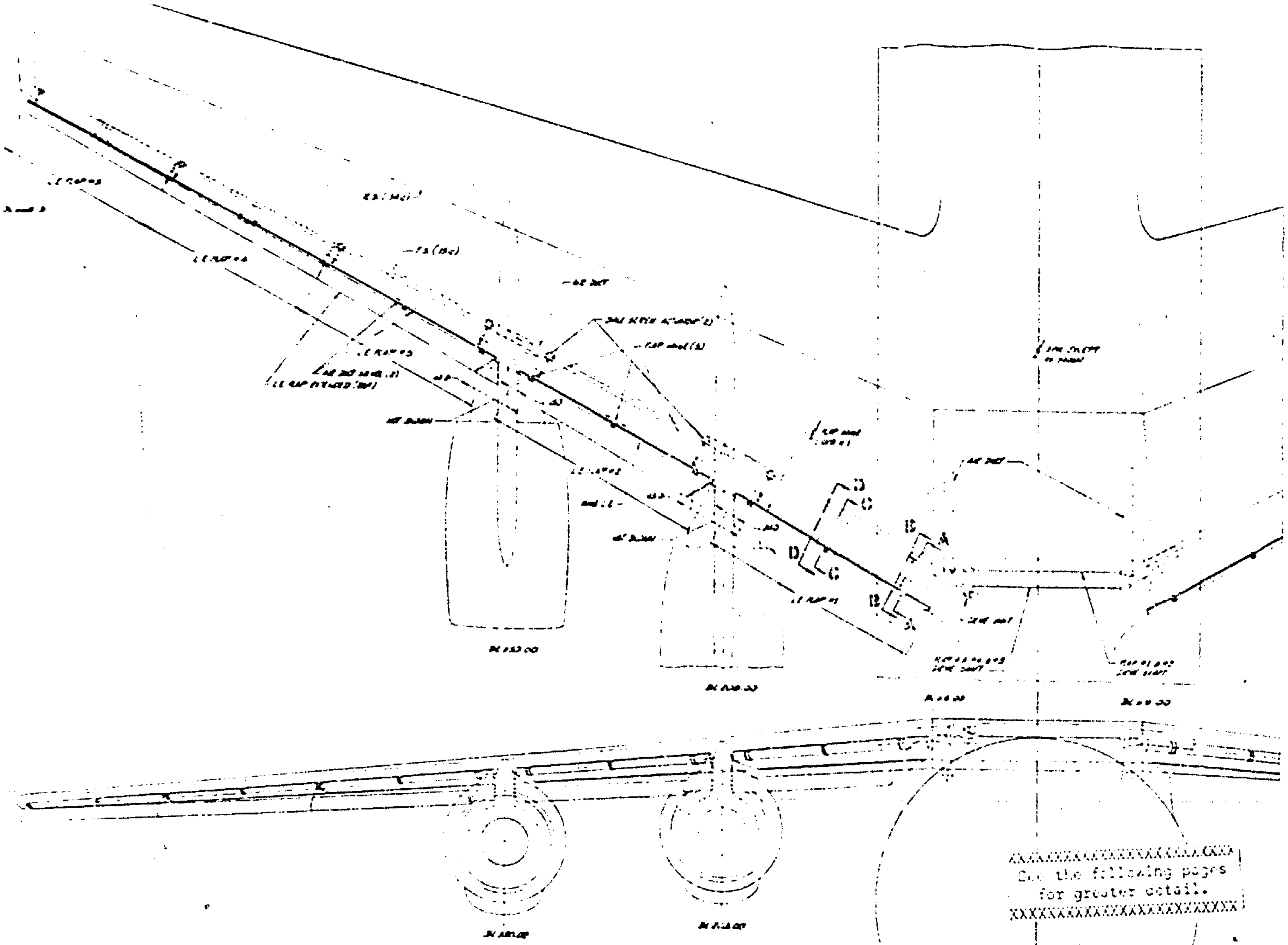


Figure 5-15. Variable-Geometry Leading-Edge Flap, Internally Blown, Sheet 1

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See the following pages
for greater detail.
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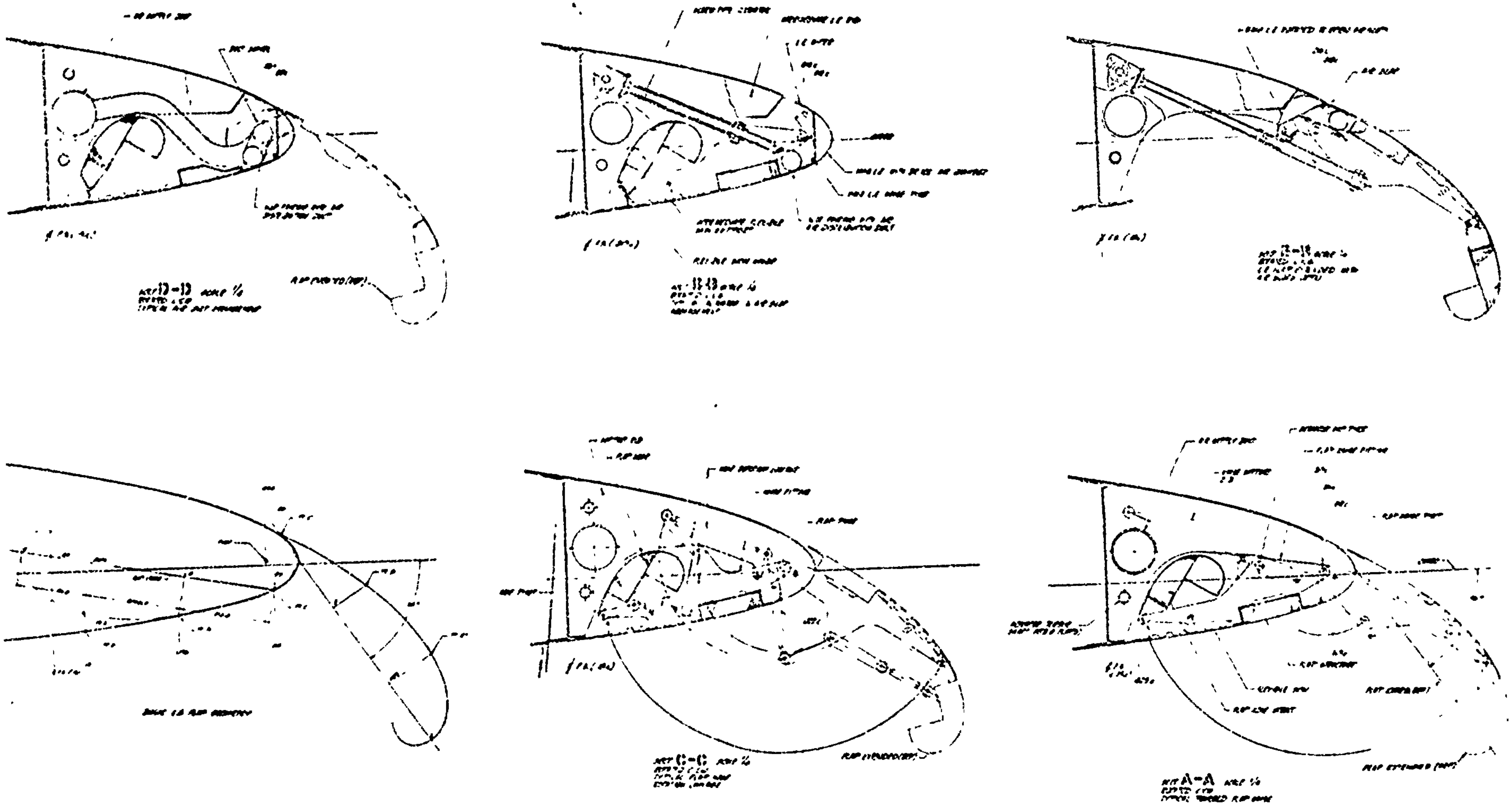

Figure 5-15. Variable-Geometry Leading-Edge Flap, Internally Blown, Sheet 2

5.2.1 WING LEADING-EDGE FLAPS. The internally blown leading edge flap is a variable-geometry device that deploys from the lower leading-edge surface of the wing into a shape about 15.5 percent of the local wing chord in length. Five flap sections are arranged along the full span of the wing. Each section is supported by three hinge fittings, cf which the two end hinges are powered by screw jacks. Figure 5-15 shows the arrangement of the flap system on a typical wing.

Boundary layer control (BLC) air is supplied through a six-inch-diameter duct along the front spar. At each flap section's center hinge support rib, the air is directed into a secondary duct system on the flap that distributes it to an array of slots at the flap's trailing edge (Figure 5-16).

The screw jacks are driven through torque shafts from a single actuator that incorporates hydraulic and electric motors for normal and auxiliary operation, respectively. The actuator has two torque shaft outputs, one for inboard flap sections 1 and 2 and the other for flaps 3, 4, and 5. These actuator output shafts are driven through a differential gear to ensure symmetrical system failure conditions while maintaining the unaffected flap group operative. A system schematic is shown in Figure 5-17.

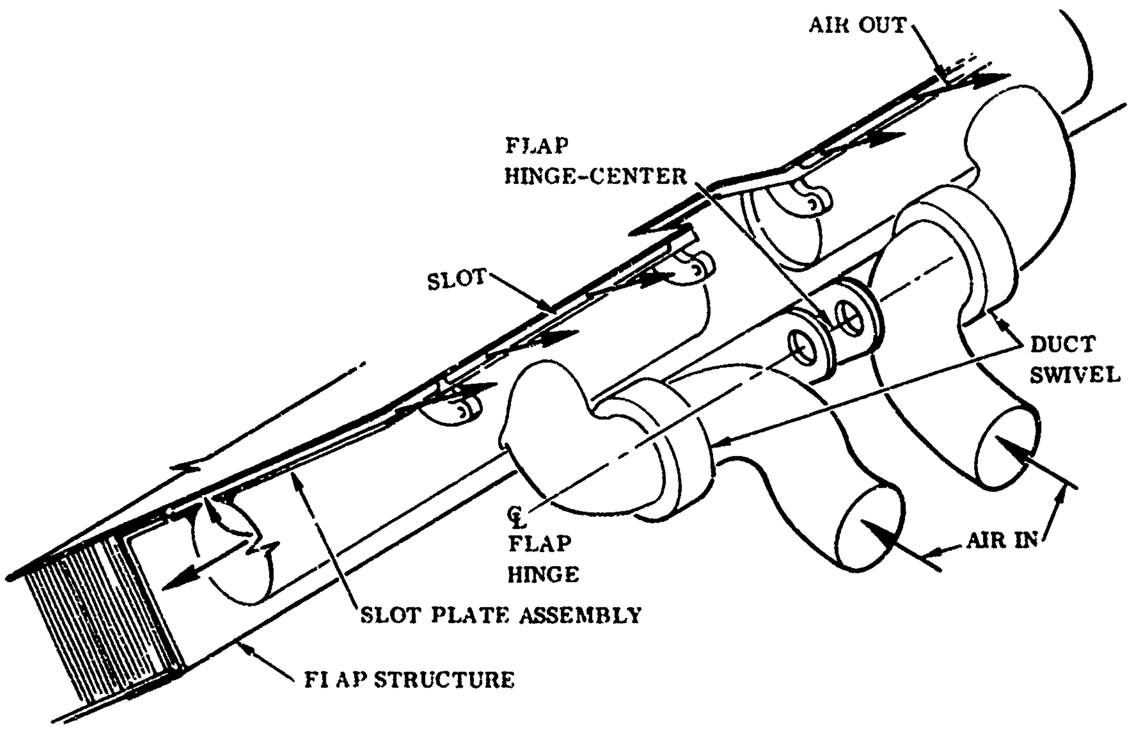

Figure 5-16. Typical Air Slot Arrangement at Trailing Edge of Extended Leading-Edge Flap

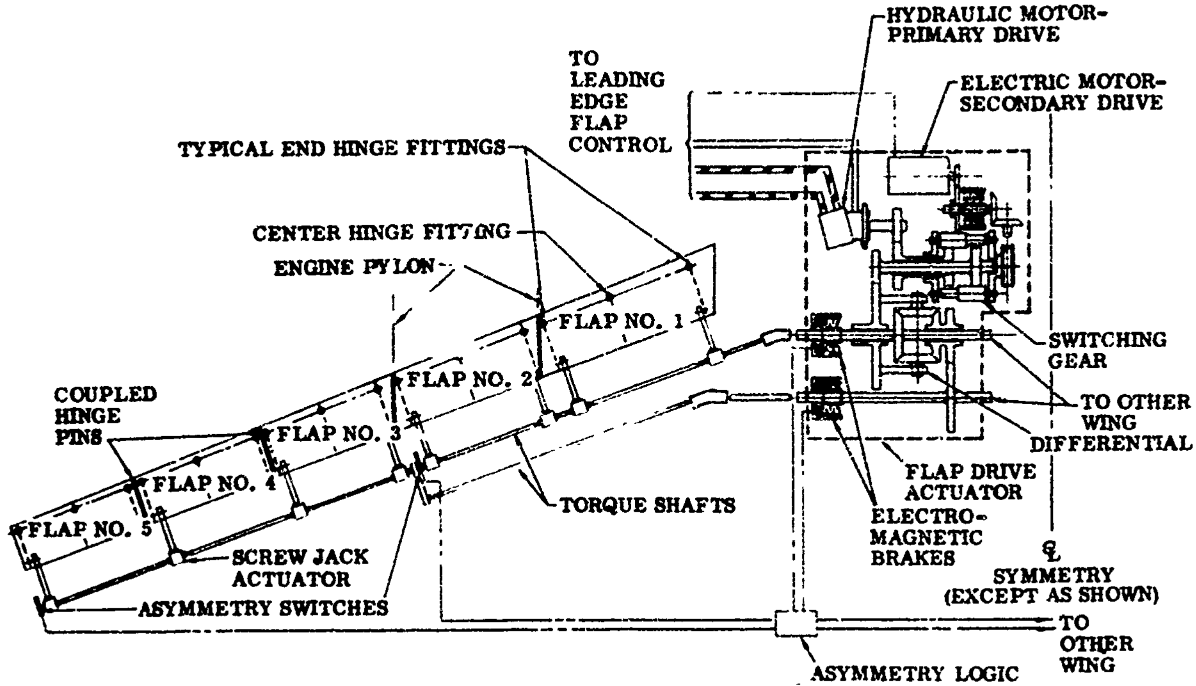

Figure 5-17. Leading Edge Flap System

5.2.2 WING TRAILING-EDGE FLAPS. The trailing-edge flap configurations defined for the lift/propulsion concepts are:

1. Triple-slotted flaps (MF/VT).
2. Double-slotted flaps with direct lift control (EBF).
3. Hinged, single-surface flap (IBF).

All flap configurations extend over 80 percent of the wing span and are sealed against the sides of the fuselage when deflected. When retracted, the triple- and double-slotted flaps occupy 45 percent of the wing chord, the single-surface flap 35 percent.

5.2.2.1 Triple- and Double-Slotted Flaps. These flap configurations are used with the MF/VT and EBF concepts, respectively, and are similar with respect to geometry, flap segment size and shape, support structure, and actuation mechanism. They differ in chordwise arrangement of the main flap. While the main flap of the triple-slotted system consists of two segments that rotate and translate with respect to each other to form the third slot, the aft portion of the main flap of the double-slotted system is hinged to rotate for direct lift control (DLC) operation. When fully extended (landing), the triple- and double-slotted flap configurations produce wing chord increases, c_1/c, of 1.51 and 1.36, respectively.

Both flap system arrangements are shown in Figure 5-18. Spanwise, the flap elements (vane, main flap, aft flap) are sectioned into two structurally separate groups of

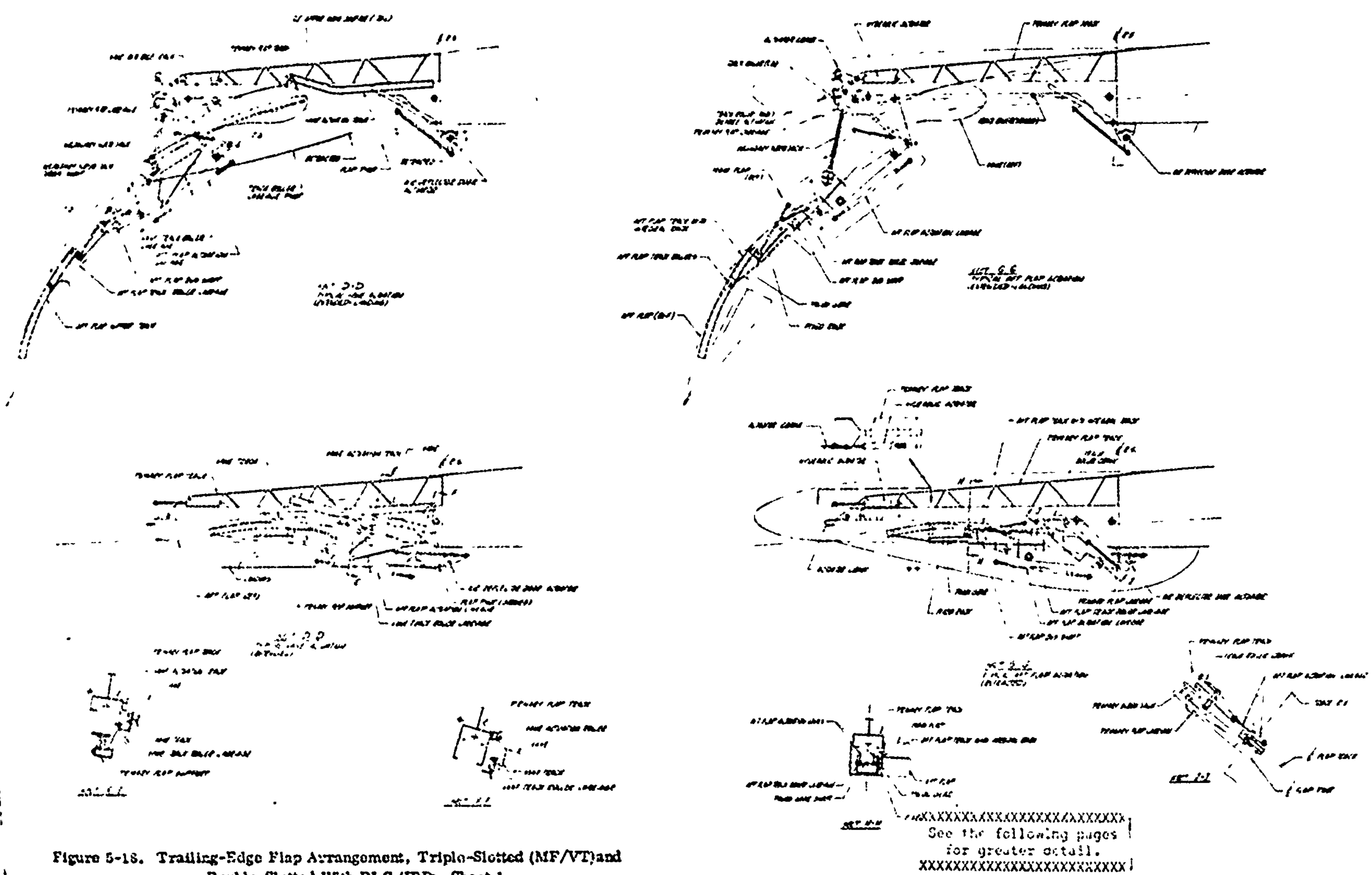

Figure 5-18. Trailing-Edge Flap Arrangement, Triple-Slotted (MF/VT) and Double-Slotted With DLC (IBF), Sheet 1

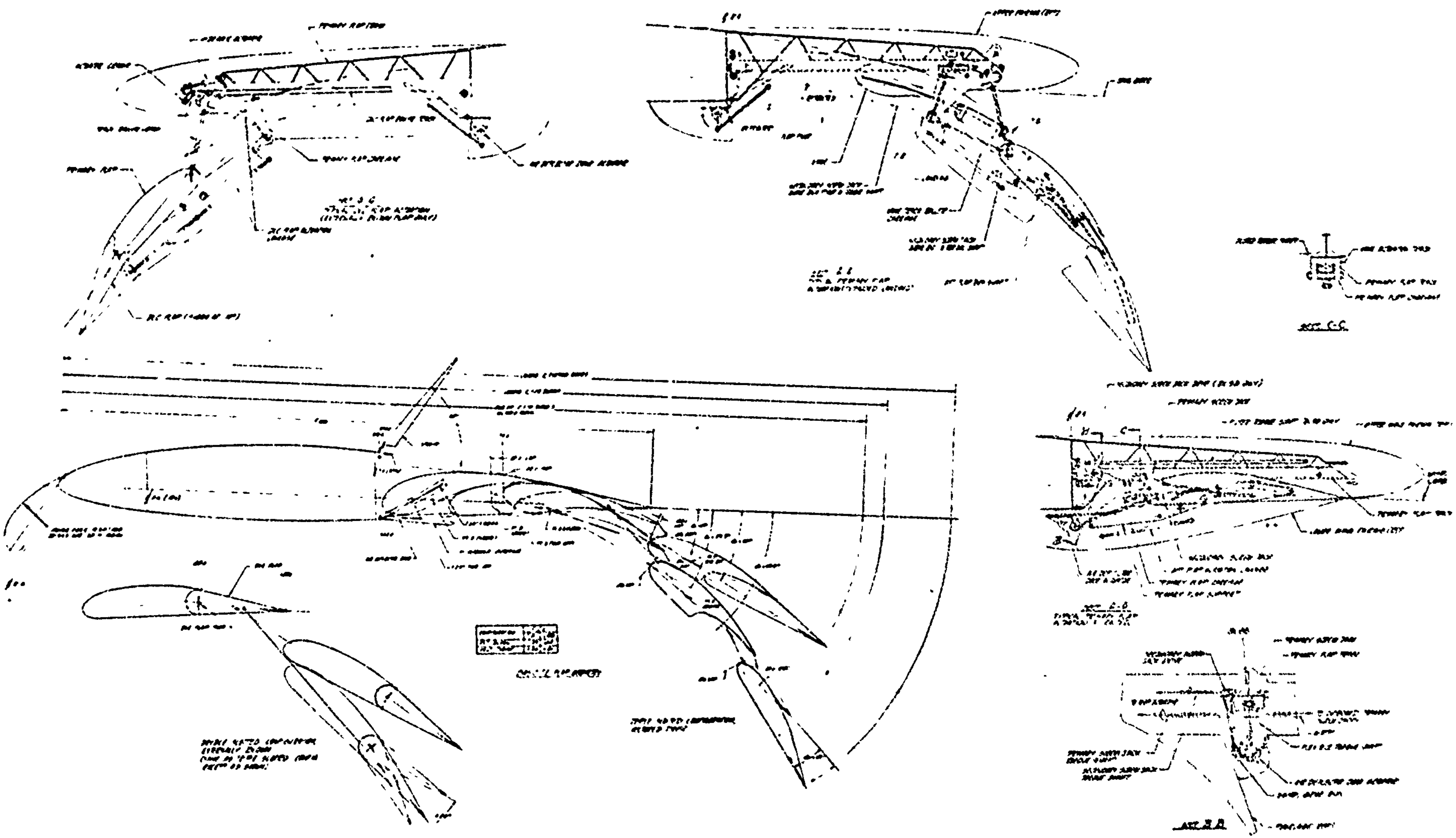

Figure 5-18. Trailing-Edge Flap Arrangement, Triple-Slotted (MF/VT) and Double-Slotted With DLC (IBF), Sheet 2

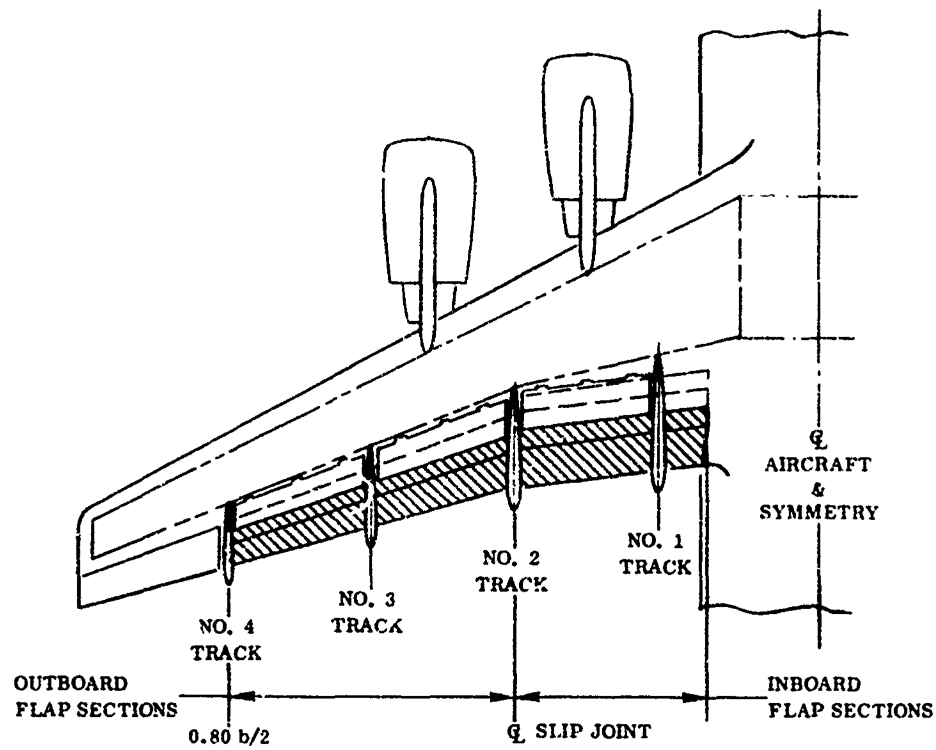

Figure 5-19. Trailing-Edge Flap Arrangement

surfaces for each wing. They are supported by four sets of wing-mounted track and roller carriages, housed in fairings. A slip joint is provided between inboard and outboard flap sections at the No. 2 track, located on the wing between the engine pylons (Figure 5-19). The slip joint is designed to permit sufficient freedom of motion between adjacent flap sections to alleviate the effects of wing bending on the flap as well as to accommodate lateral slippage of flap sections during operation.

The lower wing surface panel aft of the wing rear spar is hinged along its forward edge and is actuated upward during flap extension to improve airflow through the slots of the flaps. At each track, the main flap is supported from a roller carriage. A screw jack actuator between the carriage and main flap rotates the flap while the carriage is moved along the track by another screw jack actuator.

Each main flap support arm is mounted on vane-support track assemblies on pivots. The ends of the vane sections between main flap supports engage their respective track assemblies. Vanes are positioned relative to the main flap by sliding on the tracks and rotating on the track assemblies about their pivots on the main flap support arms.

The aft flap of the triple-slotted configuration is track-and-roller supported from the main flap. It is actuated by a pinion gear that engages a rack on the flap track. The pinnion gear is driven through a linkage by a hydraulic actuator mounted to the aft end of the main flap track. The hinged DLC surface of the main flap of the double-slotted configuration is actuated by a similar linkage/hydraulic-actuator arrangement.

Flap mechanism assemblies are housed in fairings. The upper fairing is fixed to the main flap track, and the lower fairing is sectioned and attached to the flap elements.

5.2.2.2 Hinged, Single-Surface Flap. The flap of the IBF lift/propulsion concept is a hinged, single-element flap whose upper forward surface remains tangent to the jet flap nozzle exit at the wing spoiler's trailing edge throughout its operation (Figure 5-20). This flap is supported by four rotating pivot fittings below each wing and operated by hydraulic actuators. Spanwise, the flap is divided into two structurally separate sections to alleviate the effects of wing bending on the deflected flap. Hydraulic actuators are mounted below the flap pivot fittings and are enclosed by the fairings that house the pivot fittings.

Jet flap blowing air is supplied to the slot nozzle through plenum chambers located between the flap (stowed) and the spoilers on the uppwer wing surface. A distribution duct aft of the rear wing spar collects the blowing air from the engine air supply duct system and routes it to the plenum chambers. The distribution ducts of both wings are interconnected to equalize the air flow.

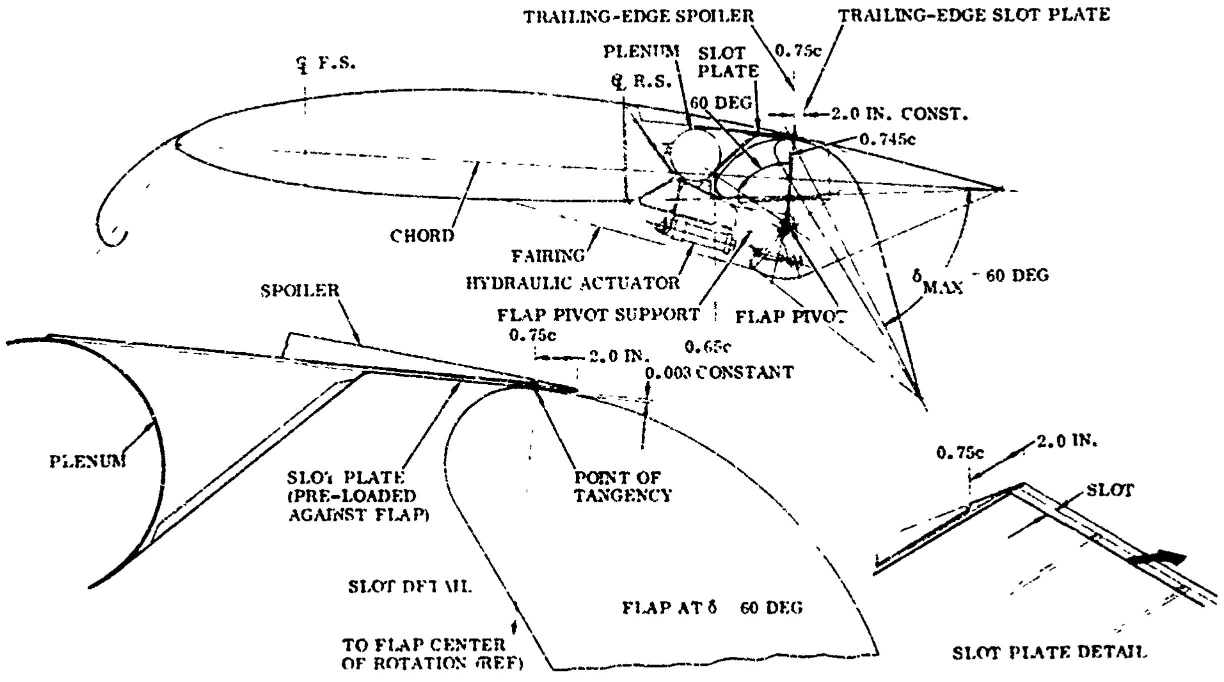

Figure 5-20. Hinged, Single-Surface Flap, Internally Blown

5.3 FLIGHT CONTROL SYSTEMS

The airframes have T-tails with trimable stabilizers and use a combination of ailerons and spoilers for roll. The T-tail is an outgrowth of previous tail-location studies. The lift/propulsive systems create so much downwash that the airstream is virtually independent of wing angle of attack at lower tail locations. This situation is acceptable for control power criteria (such as nose wheel liftoff or stall in ground effect), but is grossly unacceptable for stability. Although augmented static stability would make a lower tail location acceptable, this option was not chosen by Convair Aerospace for the baseline aircraft. The wide-ranging downwash also dictates a trimable stabilizer.

Ailerons, even though they impact the high-lift system, are included with spoilers for two reasons: 1) they are available for trim and 2) the additional rolling moment from blown ailerons will be required for engine-out minimum control speeds for the EBF and MF/VT configurations. The IBF configuration has a lower roll requirement due to cross-ducting, but the spoilers will probably have roll-reversal characteristics up to moderately high deflections due to flow reattachment on the blown flaps.

Characteristics that had first-order effects on tail size were evaluated in establishing the baseline configurations. The decisions were made on tail size including elevator blowing. The most critical aft cg limit for the EBF is that marked Stability with Take-off Flap-High α in Figure 5-21. This curve denotes the pitch-up characteristics (mostly a high $d\epsilon/d\alpha$ effect) that occur at high power settings, takeoff flaps, and high α and that reduce inherent stability. The steep slope of the curve shows that additional tail area is needed to provide inherent stability at aft cg's for this flight condition. With the fairly elaborate SAS required for good flying qualities, this aft cg requirement is somewhat alleviated.

Two forward cg limits are shown in Figure 5-21: nose wheel liftoff and trimming high angles of attack with landing flap. These are shown with and without elevator blowing, indicating that at least some of the tail blowing shown in the data base will be required. The nominal cg on the EBF is 20 percent for a tail area of 367 ft^2.

The goals of the low speed longitudinal SAS development are to:

1. Improve phugoid damping, short period frequency, n_z/α , and $d\gamma/dV$ when controlling through the elevator.
2. Provide a throttle control that controls flight path with minimum disturbance to pitch angle and airspeed.
3. Provide an airspeed control through the flaps with minimum disturbances to pitch angle and angle of attack.

A primary man-in-the-loop simulator task was identified to determine which of the two flight path control schemes results in better performance and pilot acceptance. Figure 5-22 is a block diagram of a preliminary longitudinal control system to meet these requirements.

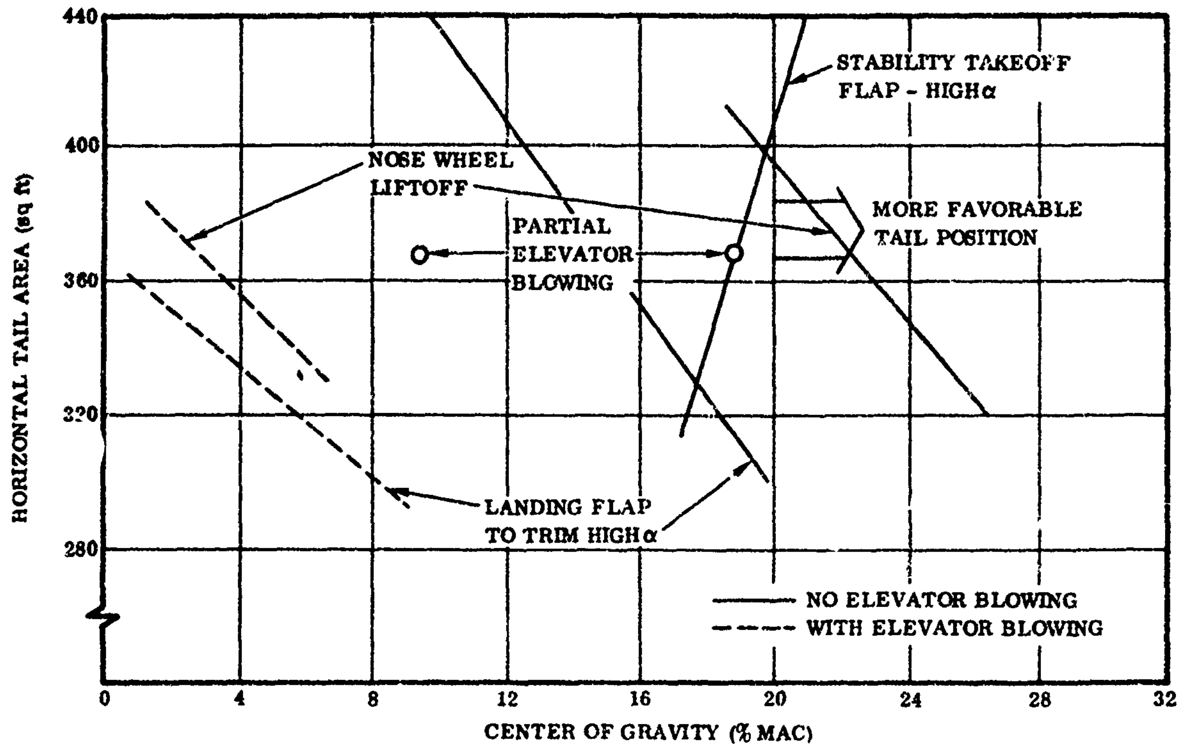

Figure 5-21. EBF Horizontal Tail - cg Criteria.

Longitudinal augmentation has three interrelated loops. The attitude-hold loop employs pitch attitude synchronized to a reference existing at the time of engagement. Rate command augmentation is mechanized using integrated stick force. Attitude feedback (rather than rate) is used because it dampens the troublesome phugoid and increases the frequency of the heavily damped short period. This is shown in the root locus of Figure 5-23. The velocity loop controlling second-segment flap position for flight path stability uses dynamic pressure-sensing synchronized to the reference existing at the time of engagement. A delta airspeed vernier control is included to allow the pilot incremental airspeed adjustment after the mode has been engaged. The angle-of-attack loop commanding throttle position and increasing n_z/α slaves engine power to the α existing at the time of engagement. Additionally, a separate lift control has been provided for augmenting thrust level when the α-hold mode is engaged. Flap and throttle loops have interconnecting signal paths that decouple their effective response in the frequency band between the phugoid and short period.

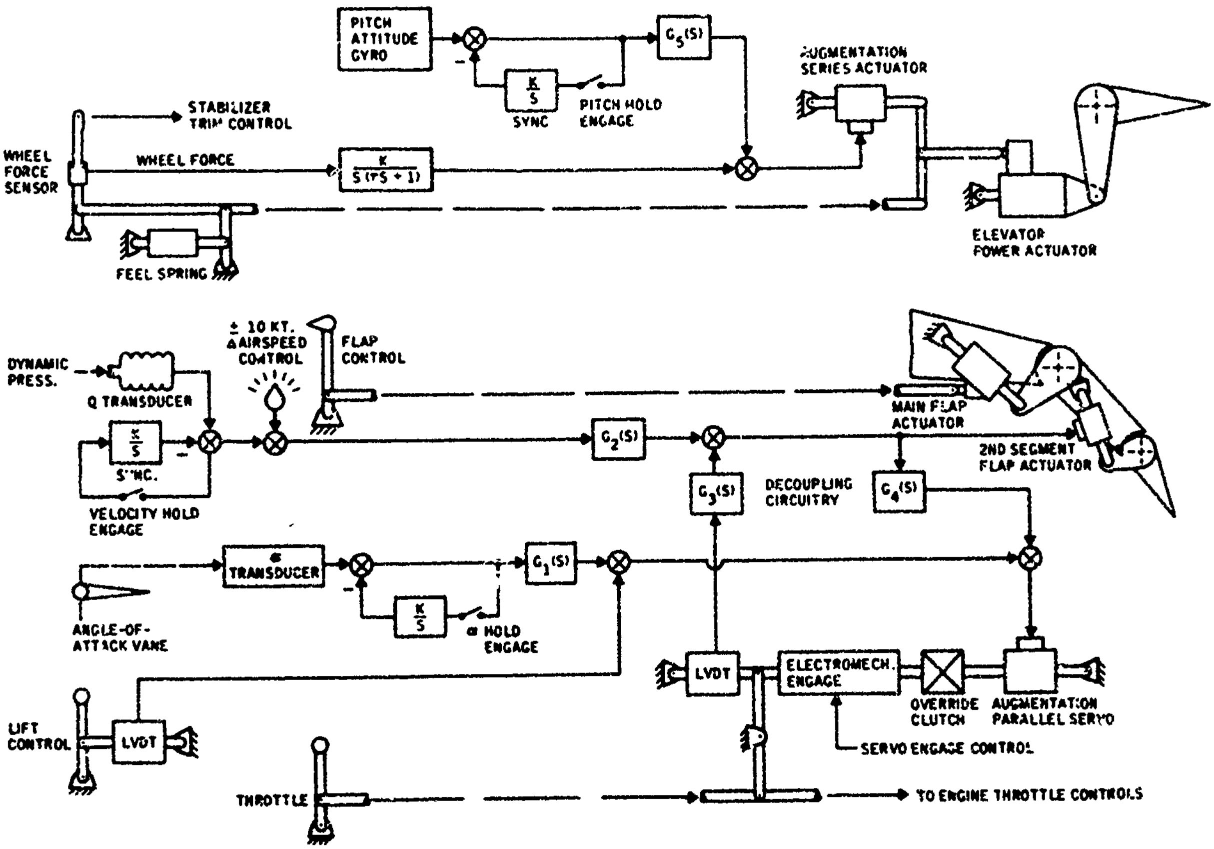

Figure 5-22. Elevator, Flap, and Throttle Augmentation

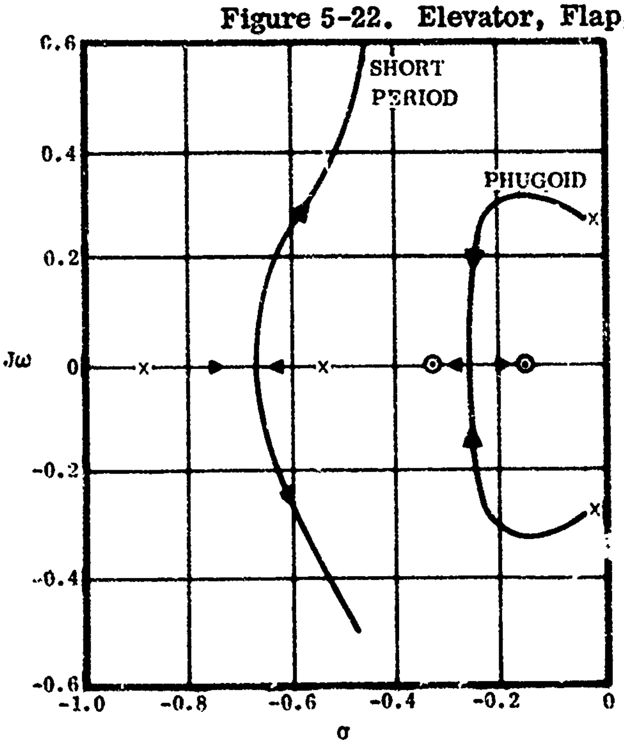

Figure 5-23. Pitch Attitude Root Locus

The lateral/directional augmentation system has two interrelated loops (aileron and rudder) with subordinating lateral control surfaces (spoilers) as shown in Figure 5-24. The spoiler control has a pure mechanical input from the pilot's control wheel and provides no capability for augmentation inputs. A parallel servo has been included in this control linkage to provide for autopilot and pilot-assist modes of operation in the high-Mach regions of flight where aileron surface deflections may be unacceptable for lateral control. An electromechanical mixer provides the summation of speed brake and spoiler lateral surface deflections.

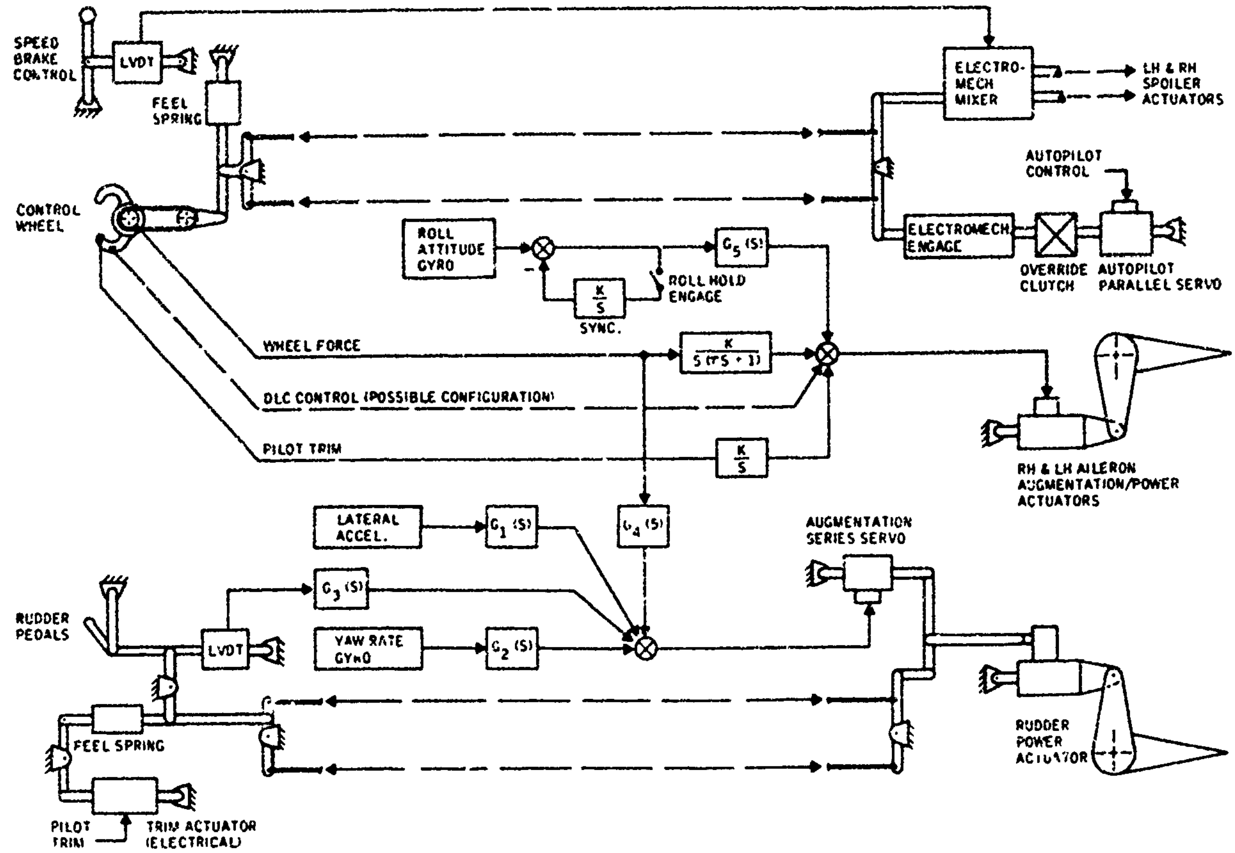

Figure 5-24. Lateral and Directional Augmentation

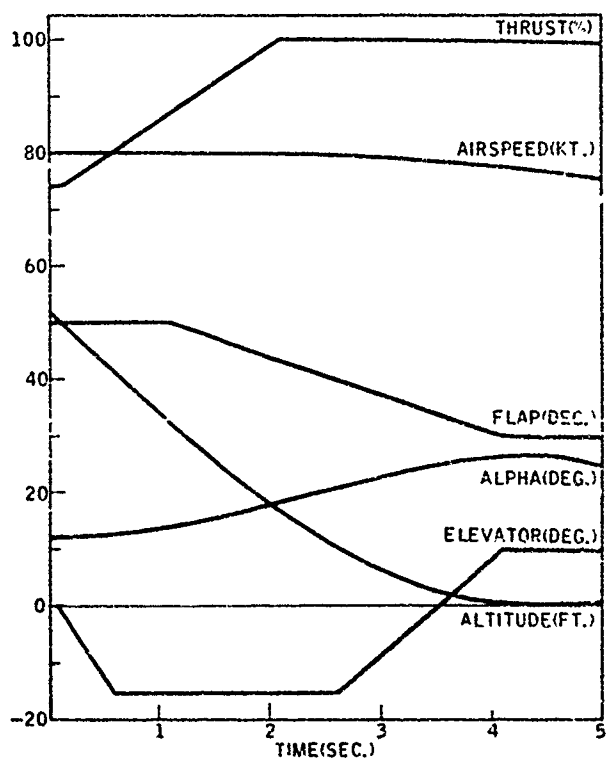

Figure 5-25. Control Sizing

Static directional stability was the basic vertical-tail volume-sizing parameter, although rudder-control power demands could dictate a larger vertical tail if insufficient directional power is available from a reasonably sized rudder.

At a V_{con} set by approach speed, the ailerons and spoilers were sized to trim a critical engine-out while retaining sufficient roll control to meet Level 3 criteria of MIL-F-8785B (30 degrees in 3.6 seconds). The requirement to safely abort a landing from 50 feet was a probable control sizing maneuver. Early Convair Aerospace simulation of an EBF indicated a solution involving rapid rotation to takeoff attitude, followed by a rapid conversion to the takeoff configuration (Figure 5-25). This maneuver will design the flap or vectored thrust retraction speed. It also has a potential impact on the pitch control/augmentation system. All vehicles were configured for five-axis augmentation (elevator, aileron, rudder, flap, and throttle).

Flight control systems for the baseline designs are generally similar. The surfaces are blown and powered from triple hydraulic systems. Signal transmission paths between the input controls and the surface controls are a parallel mechanical/ electrical linkage of control augmentation, except for the aileron controls.

Conventional mechanical control transmission connects the pilot's controls with the servovalves of the hydraulically powered surface actuators. Series servos, in conjunction with wheel-force sensors and inertial instruments, provide parallel control. Power operation of the control surfaces was chosen over manual because it offers the necessary power to deflect the large blown surfaces to the unusually large deflections and rates required for STOL operation.

Dual-segmented elevators provide longitudinal control, with elevator blowing on all aircraft. Longitudinal trim is obtained from the movable horizontal stabilizer. Spoilers and ailerons provide lateral control, and the ailerons are blown on the EBF and MF/VT designs. The IBF design, which has a lower engine-out roll control requirement due to the interconnecting ducting, uses ailerons for lateral trim. All configurations have blown rudders and directional trim provisions.

The baseline augmentation system was configured under the following assumptions.

1. The bare airframe will meet Level 1 criteria for cruise and CTOL except for dutch roll damping at altitude, which will be no less than Level 2.
2. Bare airframe STOL control will be Level 3 because of poor speed/flight-path relationships and inadequate turn coordination.

5.4 BASELINE STRUCTURE

The airframe was designed to meet the requirements of the selected EBF baseline configuration. It uses conventional structural elements and materials that have demonstrated satisfactory performance in previous aircraft structural arrangements. The principal objective was to define a simple structural configuration that will result in a lightweight, long service life, low cost airframe. The design takes full advantage of established fabrication procedures and processes.

The cargo compartment of the fuselage is configured to accommodate the USAF 463L cargo-handling system. A rear fuselage cargo ramp is provided for cargo handling and transfer from ground and truck-bed levels. Structural design criteria are in accordance with applicable sections of MIL-A-008860/8870/8890 series specifications and MIL-STD-1530 (USAF), Aircraft Structural Integrity Program. A structural weight breakdown for the baseline airframe is given in Table 5-4.

Table 5-4. EBF Structural Weight Breakdown

COMPONENT	WEIGHT (LB)
Wing	(20,639)
Skin	5,304
Stringers	2,518
Spar caps	929
Spar webs	1,135
Ribs & bulkheads	1,445
[illegible] & attachments	516
Fixed leading edge & tip	560
Leading edge device (structure)	810
Leading edge device (mechanisms)	664
Fixed trailing edge, etc.	504
Flap surfaces	1,830
Flap supports & mechanisms	2,877
Ailerons & spoilers	887
Doors, fairings, miscellaneous	660
Body	(25,238)
Bulkheads & frames	4,770
Skin	3,778
Stringers & longerons	2,722
Flooring, supports & floor frames	3,400
Cargo rails, restraint, conveyors, etc.	2,407
Pressure bulkhead	600
Windshield & windows	644
Cargo ramp & mechanism	1,535
Aft cargo doors & mechanism	1,270
Entrance, service doors, & mechanism	1,625
Main landing gear doors & fairings	2,102
Fairings, protective finish, miscellaneous	385
Horizontal	(1,411)
Skin Stringers	490
Spar caps	86
Spar webs & stiffeners	56
Ribs & bulkheads	128
Pivot, pitch-trim fittings & supports	72
Leading edge & tip	42
Fixed trailing edge	45
Miscellaneous, doors, fairings	134
Elevators	358
Vertical	(3,489)
Skin Stringers	1,225
Spar caps	290
Spar webs & stiffeners	255
Ribs & bulkheads	400
Pivot, pitch-trim fittings & supports	687
Leading edge, trailing edge	181
Miscellaneous, doors, fairings	98
Rudder	353

5.4.1 MATERIALS. Table 5-5 presents product forms and materials selected for the structural components of the STOL transport baseline. The largest percentage of the airframe is fabricated from 7075 and 2024 aluminum alloys in tempers that combine high strength and adequate toughness with good resistance to stress-corrosion cracking. To enhance corrosion protection, all exterior skins are fabricated from clad aluminum sheet. Within the engine pylons, where elevated temperature requirements (225 to 325°F) dictate, 2024 aluminum alloy in -T8 tempers is specified.

Titanium alloys are limited to applications where high strength levels must be maintained at even higher temperatures (350°F). Titanium alloy Ti-8Ae - 1 Mo - 1V in the annealed condition was selected because of its stress-corrosion resistance, fatigue resistance, and high fracture toughness. Titanium is also used for tear stoppers between fuselage skin and frames. Here, material strength and fracture toughness are used to arrest fuselage skin cracks.

High-strength steels are used at points of concentrated load introduction into the airframe; i.e., wing fuselage attachment and landing gear pickup. Steel components having high fatigue loads or whose failure could be catastrophic are fabricated from CEVM 4330V or D6ac. These alloys exhibit excellent stress-corrosion resistance and high fracture toughness at the higher strength levels. Steel components requiring strength levels less than 200 ksi are fabricated from precipitation-hardened stainless steels such as 17-7PH.

Table 5-5. Materials and Product Forms for Baseline STOL Transport Airframe

COMPONENT	PRODUCT FORM	MATERIAL
Wing		
Upper skins	Clad sheet	7075-T6
Upper stringers & spar caps	Extrusion	7075-T6511
Lower skins	Clad sheet	2024-T3
Lower stringers & spar caps	Extrusion	2024-T3511
Spar webs	Sheet	7075-T6
Formed bulkheads & ribs	Sheet & extrusion	7075-T6 & T6511
Machined bulkheads & ribs	Forging & plate	7075-T73
Leading edge skins & ribs	Sheet	7075-T6
Leading edge flap	Sheet	7075-T6
Aluminum fittings	Forging & plate	7075-T73
Steel fittings	Forgings	4330V or D6ac (CEVM)*
Trailing edge flap	Sheet & extrusion	Ti-6Al-4V annealed
Flap vane & spoilers	Sandwich	2024-T81 & honeycomb
Trailing edge flap support tracks	Forgings	4330V or D6ac (CEVM)
Fuselage		
Skins	Clad sheet	2024-T3
Stringers & stiffeners	Extrusion	7075-T6511
Formed frames	Sheet & extrusion	7075-T6 & T6511
Machined frames	Forging & plate	7075-T73
Tear stoppers	Sheet	Ti-8Al-1Mo-1V annealed
Longerons	Extrusion	7075-T6511
Floor beams	Extrusion	7075-T6511
Aluminum fittings	Forging & plate	7075-T73
Steel fittings	Forging	4330V or D6ac (CEVM)
Cargo floor	Sandwich	7075-T6 & end grain balsa core
Windshield	Laminated	Tempered glass
Empennage		
Horizontal stabilizer		
Upper skins	Clad sheet	2024-T3
Lower skins	Clad sheet	7075-T6
Upper stringers & spar caps	Extrusion	2024-T3511
Lower stringers & spar caps	Extrusion	7075-T6511
Vertical stabilizer		
Skins	Clad sheet	7075-T6
Stringers & spar caps	Extrusion	7075-T6
Spar webs	Sheet	7075-T6
Formed ribs	Sheet & extrusion	7075-T6 & T6511
Machined ribs	Forging & plate	7075-T73
Leading edge assemblies	Sheet	7075-T6
Aluminum fittings	Forging & plate	7075-T73
Steel fittings	Forging	4330V or D6ac (CEVM)
Rudder & elevator	Sheet & extrusion	7075-T6 & T6511
Trim & servo tabs	Sandwich	7075-T6 & honeycomb
Horiz. stab. pivot fittings	Forging	4330V or D6ac (CEVM)
Engine pod & pylon		
Skins	Clad sheet	2024-T3
Webs & frames	Sheet	2024-T81 & Ti-6Al-4V annealed
Longerons	Extrusion	2024-T8511
Machined fittings	Plate	2024-T851
Thrust fittings	Forging	4330V (CEVM)

*CEVM = Consummable-Electrode-Vacuum-Arc-Remelt

Composite materials are not used in the baseline airframe structure. Glass cloth reinforced plastic laminates are used for antenna covers, compartment liners, equipment shrouds, and wing and tail tips.

5.4.2 STRUCTURAL DESCRIPTION. The baseline airframe is constructed primarily of mechanically fastened, formed sheet metal with extruded and forged shapes. The design provides for multiple load paths, so that failure of any one structural element will not prevent continued flight and a safe landing. Emphasis has been placed on the avoidance of stress risers. The basic finish system for corrosion protection of the airframe and its components is in accordance with MIL-F-7179. A structural schematic of the baseline airframe is shown in Figure 5-26.

5.4.2.1 Wing. Wing primary structure is a two-spar box beam with stringer-stiffened upper and lower skins and ribs. Attached to the front spar is a leading edge assembly with a full-span, internally blown, forward-rotating flap. The wing trailing edge consists of upper-surface spoilers, double-slotted externally blown flaps, and the outboard aileron.

Wing box spars are of multiple-element, fail-safe design. Upper and lower skins are tapered sheet metal and plate, stiffened by extruded stringers. Removable doors for access to the wing interior are incorporated into the lower wing skins. Ribs are truss-type except for fuel-tight bulkheads or where concentrated loads are introduced into the wing box. These ribs have plate webs with fuel passages where required.

Fuel is stored in the outer wing box, which is sealed at the faying surfaces using MIL-S-8802 scalants. This approach, illustrated in Figure 5-27, has a proven sealing reliability and provides an excellent barrier against corrosion due to dissimilar metal contact. Augmented by MIL-C-27725 coating, it offers high resistance to microbial growth common to jet fuel tanks. Fuel in the center wing box is contained in fuel cells. Installation access to the fuel cells and associated equipment is provided through removable doors in the front spar web.

The fixed portion of the leading edge structure is a rib-stiffened sheet metal assembly with passages between double skins for hot air de-icing. The leading edge contains an internally blown flap that is hinged downward and forward from the fixed leading edge. All mechanisms and air ducting associated with the flap are housed inside the leading edge assembly.

Aft of the rear spar, upper-surface spoilers of sandwich construction are hinged from fittings attached to the rear spar. The spoilers extend spanwise to the internally blown aileron of rib-stiffened, formed sheet metal skin construction. Each aileron is hinged from the wing rear spar by three pivot fittings.

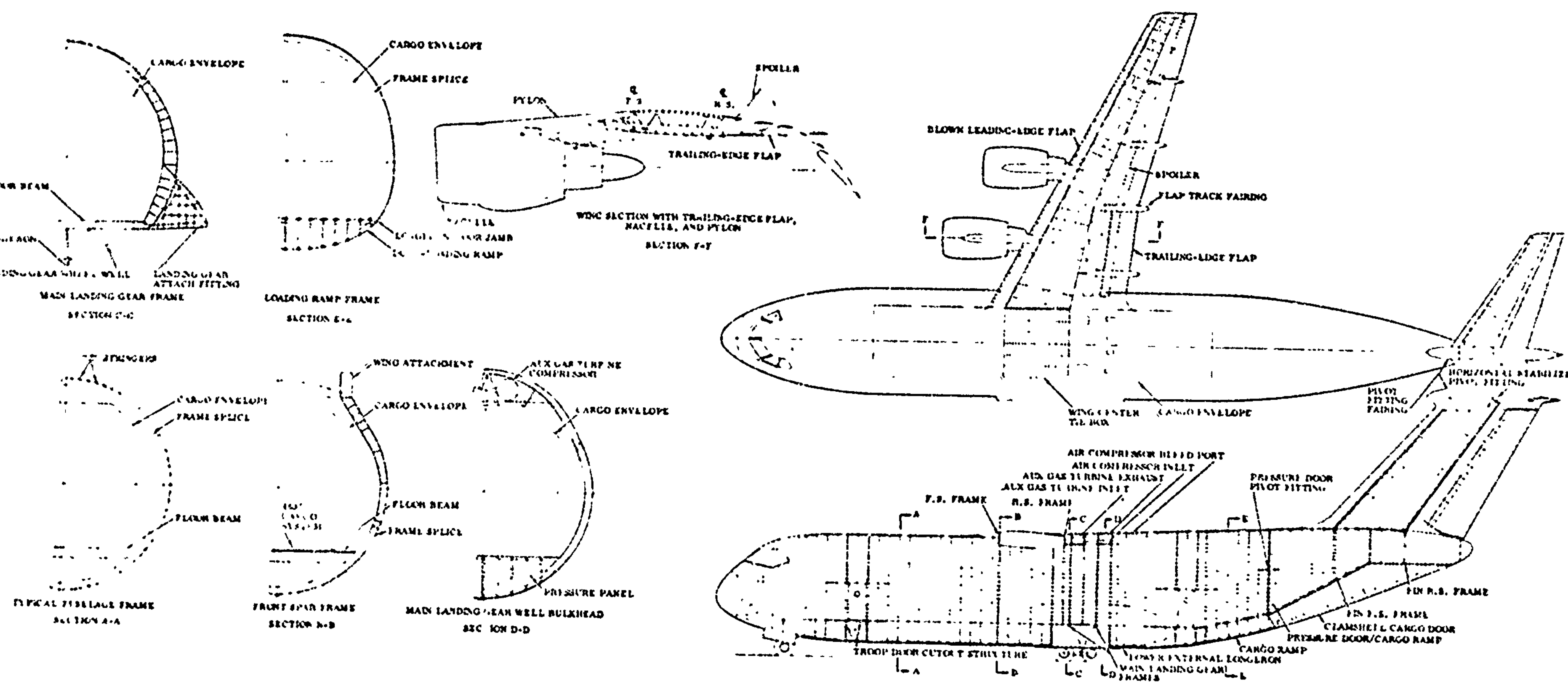

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Figure 5-26. Structural Schematic, Baseline EBF Medium STOL Transport

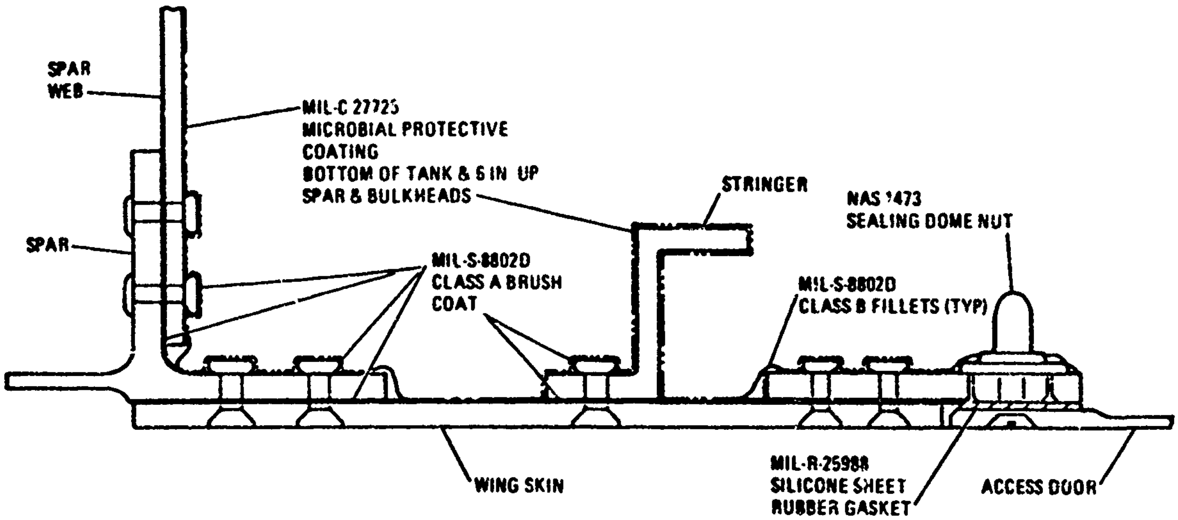


Figure 5-27. Wing Tank Sealing Arrangement

The double-slotted, externally blown trailing-edge flaps consist of two structurally seperate sections per side and are supported from the wing box beam by four sets of roller tracks and carriages. Flap elements, vane, main flap, and DLC surfaces are of rib-stiffened, formed sheet metal skin construction with honeycomb sandwich trailing edges (Figure 5-28). The material of the main flap and DLC surface is titanium alloy because of elevated skin temperatures generated by engine gas flow. Figure 5-29 shows skin temperature distribution on the lower surfaces of the flap elements.

5.4.2.2 Fuselage. The fuselage is a semimonocoque shell of conventional frame/ stiffener/skin construction designed for 8 psi internal operating pressure. The cargo compartment floor is designed to carry 300 lb/ft^2 and is supported by transverse beams in line with fuselage frames. The floor structure incorporates rails and tie-down provisions compatible with existing cargo-handling systems. The cargo compartment and floor extend forward to the personnel entrance door and aft to the cargo ramp (Figure 5-26). The cargo ramp is hinged at floor level from a major fuselage frame and bulkhead and, when up and locked, forms part of the pressurized fuselage shell. A movable pressure bulkhead is located inside the fuselage in line with the aft end of cargo ramp. This bulkhead can be rotated into a horizontal posi-for cargo-handling clearance.

Aft of the ramp, the lower fuselage consists of two symmetrical clamshell doors that open for cargo loading or discharge. The fixed fuselage structure above the cargo ramp and doors incorporates longerons at the ramp and door intersections. These longerons extend aft to a major frame in line with the vertical stabilizer rear spar.

Figure 5-29. Landing Flap Lower Skin Temperature Distribution

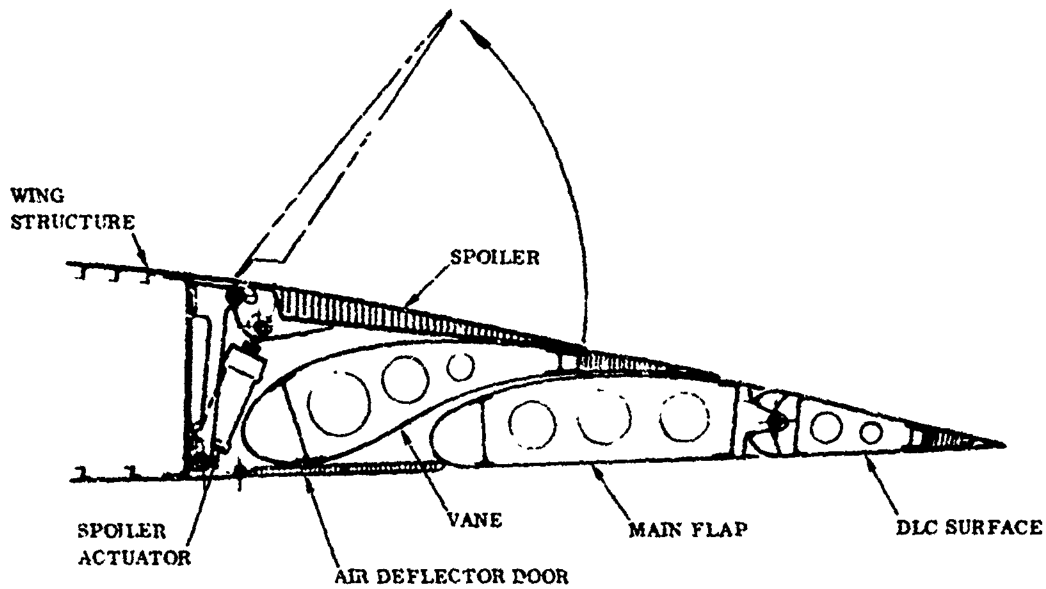


Figure 5-28. Wing Trailing-Edge Hydraulically Actuated Spoiler

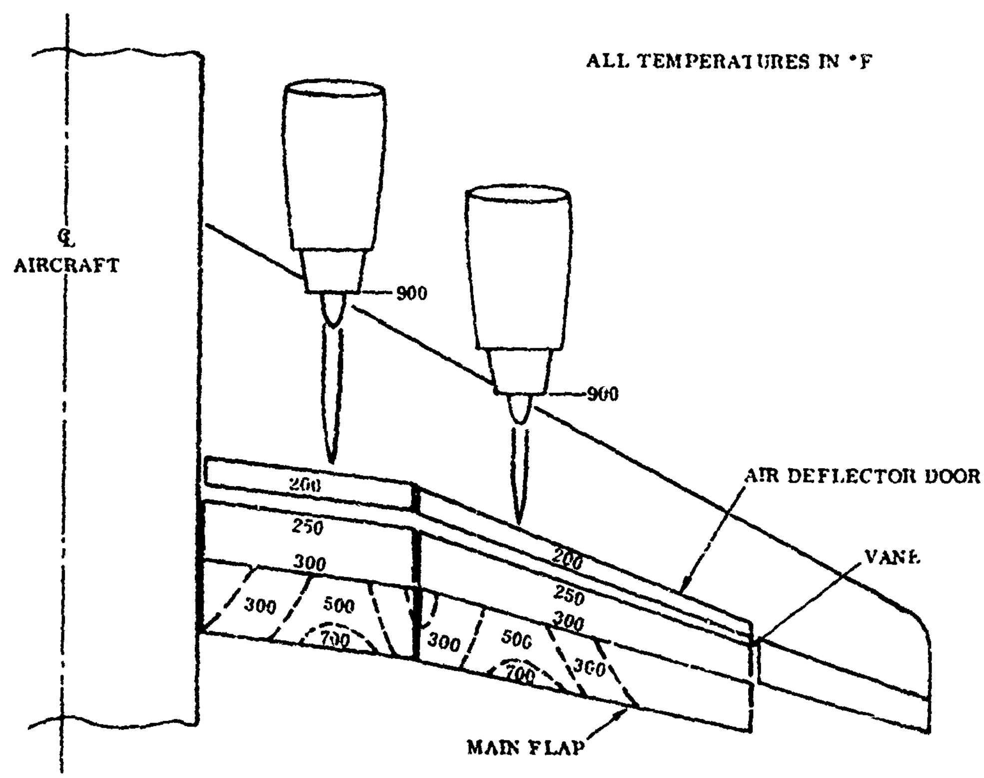


Figure 5-29. Landing Flap Lower Skin Temperature Distribution (Flap at 45 Degrees)

The wing is attached to major fuselage frames and drag longerons. Major frames support the main landing gear (MLG) fittings that extend laterally into the MLG fairings at the bottom sides of the fuselage. MLG wheel wells, with hinged doors, are provided under the floor for the sideways-retracting MLG.

Two upward sliding personnel entrance doors of the full plug type are located on the fuselage left side. These doors are arranged at cargo compartment floor level and are designed to carry pressurization loads when closed.

The flight deck and crew quarters are located above the nose landing gear wheel well, and their common floor extends aft to the forward personnel entrance door. Floor level is about 6.5 feet above the cargo floor and is accessible by a ladder. Flight deck windows are mounted in a frame structure that is integral with the fuselage shell (except for the pilot's and copilot's side windows, which can be opened by a track-guided sliding mechanism). The windshield consists of two windows of bird-proof laminated tempered glass. A midair refuelling receptacle is built into the top of the fuselage immediately aft of flight deck bulkhead.

Aft of the center wing box, an unpressurized compartment is built into the upper portion of the fuselage interior to house the two auxiliary gas turbine air compressors. Transverse floor beams are located in line with fuselage frames. The aft bulkhead of the compartment is removable to permit equipment transfer in and out of the compartment.

5.4.2.3 Empennage. The box beams of the vertical and horizontal stabilizer are each designed with two multiple-element fail-safe spars and stringer-stiffened sheet metal skins and ribs.

Access doors are provided through the top skin of the horizontal stabilizer for assembly and equipment installation. The center section of the stabilizer incorporates two pivot fittings attached to the lower surface near the rear spar. The stabilizer is mounted at the top of the vertical stabilizer using these pivot fittings to allow rotation. An actuator fitting is provided at the front spar of the center section. Blowing air ducts are incorporated between the leading edge of the rudder and elevators and their respective stabilizer box beam rear spars. These ducts deliver blowing air from the air compressors to slotted plenum chambers at the lower surfaces at the leading edge of the elevators and at both sides of the leading edge of the rudder.

The vertical stabilizer box beam is attached to the rear fuselage by a series of tension bolts through the peripheral flange of its lower closing rib. Access doors are located on both sides of the assembly to permit access to equipment mounted inside the box beam and to facilitate its assembly. At its top, near the rear spar, pivot fittings are provided to mount the horizontal stabilizer. A closeout fairing encloses the horizontal/vertical stabilizer junction.

All empennage leading-edge assemblies are of rib-stiffened, formed skin sheet metal construction. Elevators and a rudder, with trim and servo tabs, are hinged from the rear spars of the horizontal and vertical stabilizers.

SECTION 6

CONFIGURATION DEFINITION

The analytical techniques and prediction methods developed during Part 2 were used to update the baseline configuration selected from Part 1. The analysis resulted in a three-view and inboard profile drawing, performance summary, group weight statement, high-lift-system description, structural arrangement, and costs for each of the lift systems under study. Figure 6-1 represents the configuration definition effort.

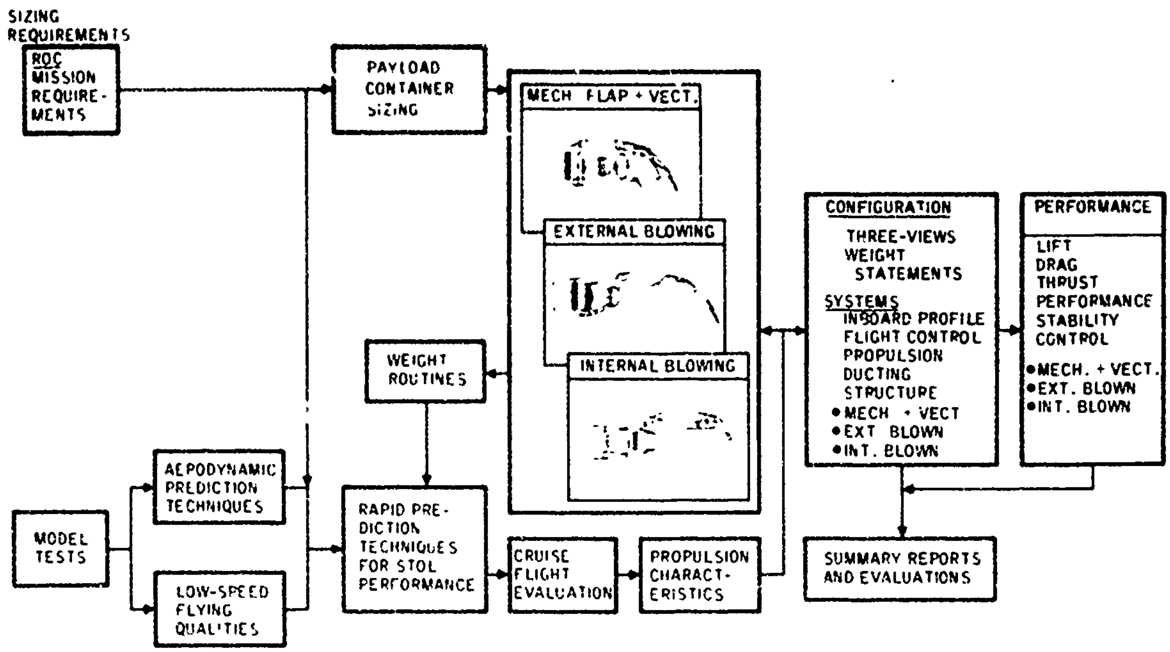


Figure 6-1. Configuration Definition

The sizing requirements for the three configurations (e.g., payload/range, speed, and landing and takeoff distances) will be the same as used for the baseline configurations. Therefore, the cargo compartment and crew quarters should remain the same and should be affected only indirectly by any changes in the wing/propulsion arrangement.

6.1 GROUND RULE REVISIONS AND DATA UPDATE

The takeoff and landing ground rules, the candidate engines and boundary layer control (BLC) air sources, and the aerodynamic data were revised and/or updated as indicated in the following sections.

6.1.1 TAKEOFF AND LANDING GROUND RULES. Revisions to the Part 1 ground rules were supplied by the AFFDL on 28 June 1972. These revisions were an attempt to determine a balance of critical field length. The ground rules used during the configuration sizing described in Section 6 are shown in Figure 6-2.

6.1.2 CANDIDATE ENGINE SELECTION. A tradeoff study to obtain the optimum configuration of engine thrust and wing area was performed during Part 1. The Part 2 propulsion studies are depicted in Figure 6-3. Starting with the Part 1 baseline configuration, Part 2 studies, and wind tunnel test results, the propulsion configurations were reviewed and redefined. The engine cycles were reassessed to meet revised thrust/drag and blowing air requirements. Comparisons at critical operational conditions were made for those few engine types considered representative for this phase of the study.

Parallel propulsion and blowing-air system component reviews were performed, also using Part 2 study and test information. Types of reversers were reviewed and made compatible with new nacelle locations, relocation of thrust vectoring, and/or valving of engine-supplied air for blowing-air systems.

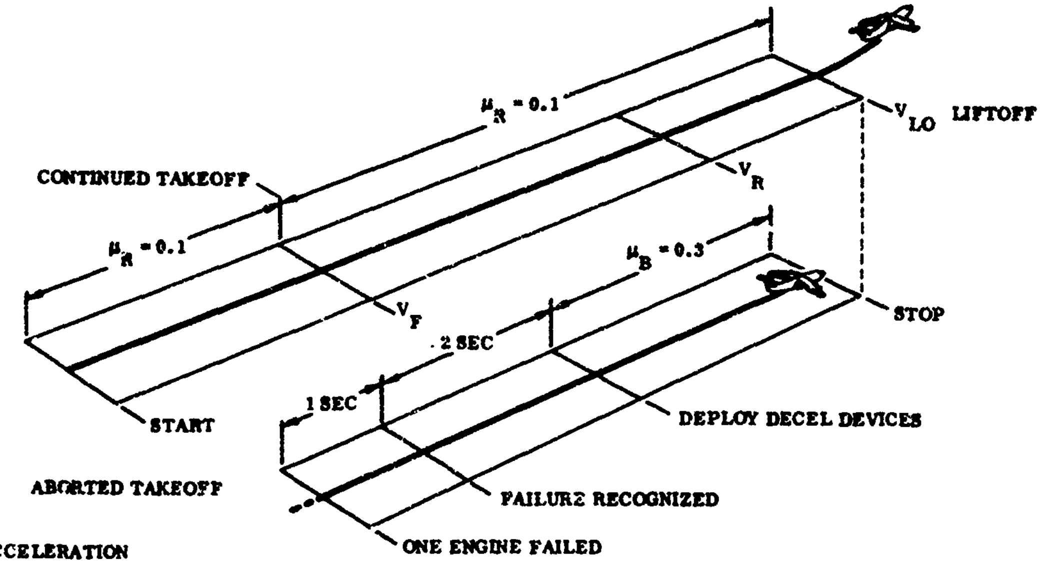
Table 6-1 indicates the candidate engines for both cruise and blowing-air sources. The proposed transport prototype engines have been added plus a Garrett-Airesearch air multiplier as a BLC air source. After a thorough review of the available derivative and prototype engines and the most recent data supplied by the engine manufacturers, the selections for the Part 1 baselines were retained. These are:

EBF	GE13/F2B
MF/VT	GE13/F2A
IBF/VT	STF-369

Based on the revised configurations and resulting data, new installation factors were calculated and the installed performance determined for the selected propulsion systems. A schedule of reverser thrust available was prepared and checked with appropriate engine manufacturers. This data formed the Part 2 propulsion inputs to the selected aircraft performance programs.

The bleed requirements for the flow multipliers on the EBF and MF/VT engines are shown in Figure 6-4. The IBF/VT engine data was shown in Figure 3-8.

6.1.3 LOW-SPEED TRIMMED AERODYNAMIC DATA. The various flap configurations tested during the low-speed wind tunnel tests were examined and reviewed for application to the updated designs, as shown in Figure 6-5 for the EBF and MF/VT configurations. Several that offered a significant performance potential over those used in Part 1 were evaluated and one was selected for each lift/propulsion concept. A variable-camber leading-edge flap plus BLC was used on each concept to furnish higher angle-of-attack performance for takeoff, landing, and go-around.



ACCELERATION

$V_F \geq V_{MCG}$ (OEI).

$V_{LO} \geq 1.05\ V_{MCA}$ (OEI, IGE) WITH $A_N \geq 1.0g$

$\gamma_{V_{LO}} \geq 3$ DEG

$V_R \geq V_F$

$\dot{\theta} \geq 8$ DEG/SEC

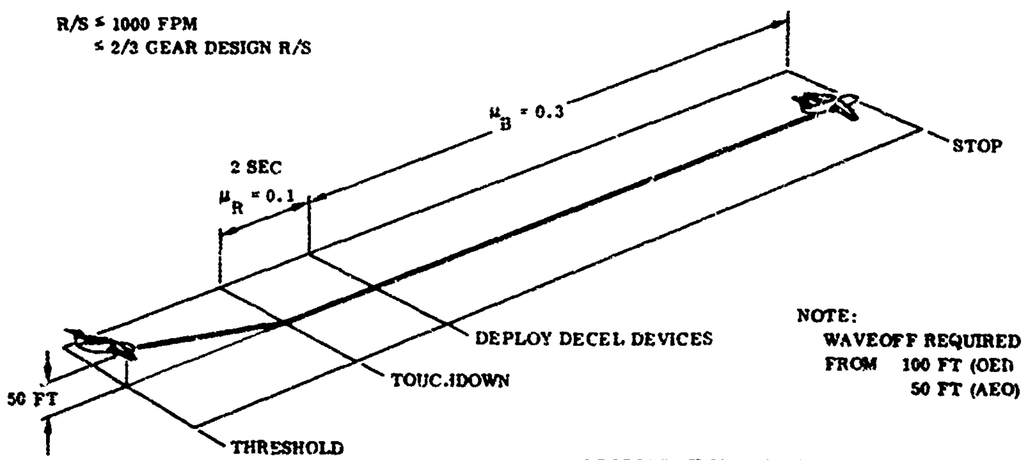
STOP

DECELERATION DEVICES - LIFT DUMPERS, WHEEL BRAKES, THRUST REVERSING

CLIMB OUT

$V_{CO} \geq 1.10\ V_{MCA}$ (OEI, OGE) WITH $A_N \geq 1.30g$

Balanced Field Takeoff Ground Rules for STAI.



MINIMUM CONTROL AND STALL SPEEDS

$V_{TH} \geq 1.1\ V_{MCA}$ (OEI) WITH $1.30g\ A_N$

$V_{TD} \geq 1.1\ V_{MTD}$ (OEI, IGE) $1.15g\ A_N$

DECELERATION DEVICES

LIFT DUMPERS,
WHEEL BRAKES,
THRUST REVERSING ≤ 50% OF 2 ENG MAX THRUST

Landing Ground Rules for STAI.

Note: Revised Ground Rules Supplied by Air Force on 28 June 1972.

Figure 6-2. Part 2 Ground Rules

Table 6-1. Candidate Cruise Engine and Blowing Air Source Selections

CRUISE ENGINES

COMPANY	SPEC. DATE	DESIGNATION	THRUST (LB)	SFC	BPR	WT (LB)	LENGTH (IN.)	DIAMETER (IN.)	COMP. RATIO	DEVELOPMENT STATUS
G.M. ALLISON	6/70	PD361-48	21,850	0.383	5.25	2,835	103.0	82.0	24.0	GMA 100 DERIVATIVE
		PD361-49	23,830	0.330	8.2	3,100	113.0	72.0	21.8	GMA 100 DERIVATIVE
		PD361-45	24,470	0.268	10.74	3,752	112.0	82.0	18.2	GMA 100 DERIVATIVE
		PD361-3	21,850	0.404	4.6	2,510	95.4	59.0	24.8	GMA 100 DERIVATIVE
		PD361-4	21,650	0.427	4.0	2,480	94.8	57.2	24.8	GMA 100 DERIVATIVE
	6/72	955-B-3	21,600	0.354	5.9	2,854	92.7	67.1	24.0	PROTOTYPE ENGINE
GENERAL ELECTRIC	12/70	GE13-F3A	21,000	0.388	5.0	2,800	92.0	65.8	23.8	F-101 DERIVATIVE
	12/70	GE13-F3B	21,320	0.385	5.1	2,800	92.0	65.6	24.1	F-101 DERIVATIVE
	12/70	GE13-F2B	22,640	0.355	6.4	3,010	94.4	72.1	23.3	F-101 DERIVATIVE
	12/70	GE13-F2A	22,880	0.356	6.5	3,010	94.4	72.1	23.4	F-101 DERIVATIVE
	12/70	GE13-F4B	23,950	0.328	8.0	3,310	96.2	77.5	22.4	F-101 DERIVATIVE
	7/71	F-101/F-13A1	18,146	0.556	2.0	2,940	77.0	46.7	26.5	F-101 NON A/B
	6/72	GE13-F10B1	24,000	0.364	6.4	3,425	93.4	73.1	23.4	PROTOTYPE ENGINE
PRATT & WHITNEY	8/70	STF382	20,000	0.371	9.0	3,096	97.0	67.0	18.0	1978-80 IOC
	8/70	STF389	20,000	0.528	2.5	3,066	92.0	56.0	21.0	1978-80 IOC
	8/70	STF406	20,000	0.422	3.5/2.0	4,306	142.9	60.5	20.0	1978-80 IOC
	8/70	STF419	20,000	0.281	12/0.62	2,686	133.0	94.5	23.6	1978-80 IOC
	8/69	STF337	20,000	0.370	8.0	2,700	84.0	61.0	20.2	1978-80 IOC
	12/70	STF402	20,000	0.409	5.0	2,600	99.3	57.6	25.0	JTF22 DERIVATIVE
	6/72	PW-ID	24,450	0.367	6.0	3,450	120.1	67.0	20.2	PROTOTYPE ENGINE

BLOWING AIR SOURCES

COMPANY	SPEC. DATE	DESIGNATION	THRUST (LB)	SFC	BPR	WT (LB)	LENGTH (IN.)	DIAMETER (IN.)	COMP. RATIO	DEVELOPMENT STATUS
ROLLS ROYCE	8/70	RB176-11	(74 LB/SEC AT 2.14 P.R.)			1,700	126.0	32.0	4.5	RB162/SPEY
GARRET AIRESEARCH	8/71	AIR MULTIPLIER	(6.8 LB/SEC AT 2.5 P.R.)			50	18.0	13.4		ENGINE H.P. BLEED DRIVEN

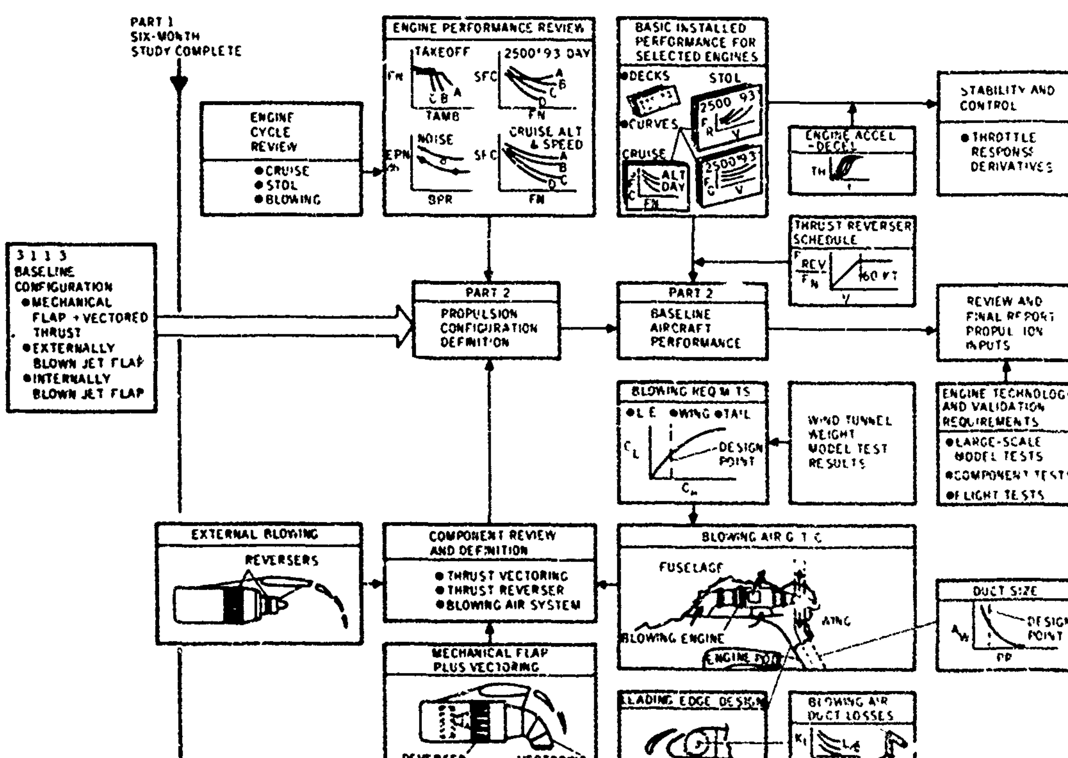


Figure 6-3. Propulsion Studies

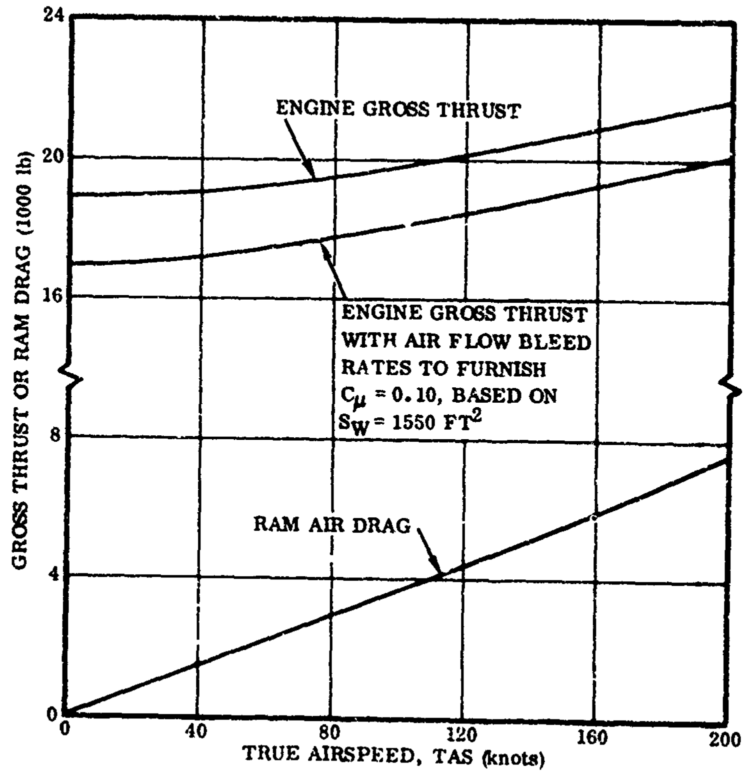


Figure 6-4. GE13/F2A and GE13/F2B - 2500 Feet, Hot Day, Takeoff Power - STT Installation

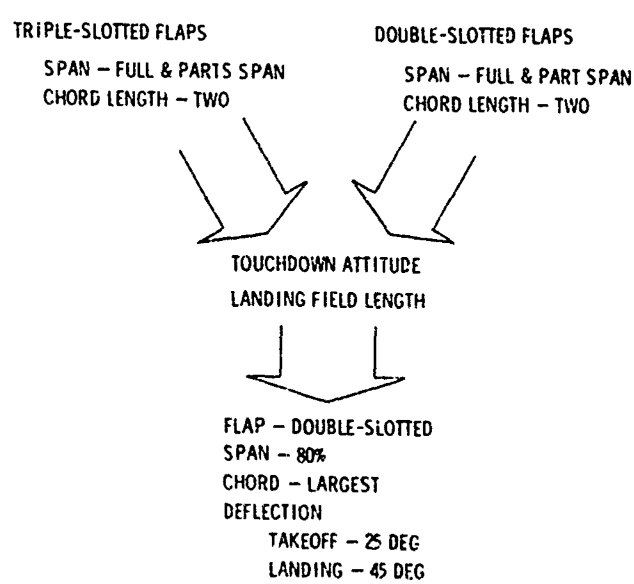


Figure 6-5. Candidate EBF and MF/VT High Lift Systems

The longitudinal and directional trim capabilities required for the selected configurations are indicated in Table 6-2. As shown, the horizontal tail volume increased by 46 percent. Longitudinal trim capability is achieved without blowing with a plain elevator. The vertical tail volume remained the same and directional trim capability is achieved with a 30 percent chord plain rudder. The analysis of the Convair developed wind tunnel data has shown this to be adequate for the engine out case. Additional longitudinal or directional trim capability can be furnished with a simple slot if required. (Convair's design was discussed with AFFDL.)

Table 6-2. Tail Sizing Requirements

Part 1	Updated Designs
$\bar{V}_H = 1.10$	$\bar{V}_H = 1.61$ Additional Stability Trim Capability without Blowing
$\bar{V}_V = 0.13$	$\bar{V}_V = 0.13$ Adequate Directional Trim Capability for Engine-Out

The trimmed low-speed lift curves and drag polars for the updated designs are presented in Figures 6-6 for EBF, 6-7 for MF/VT, and 6-8 for IBF/VT.

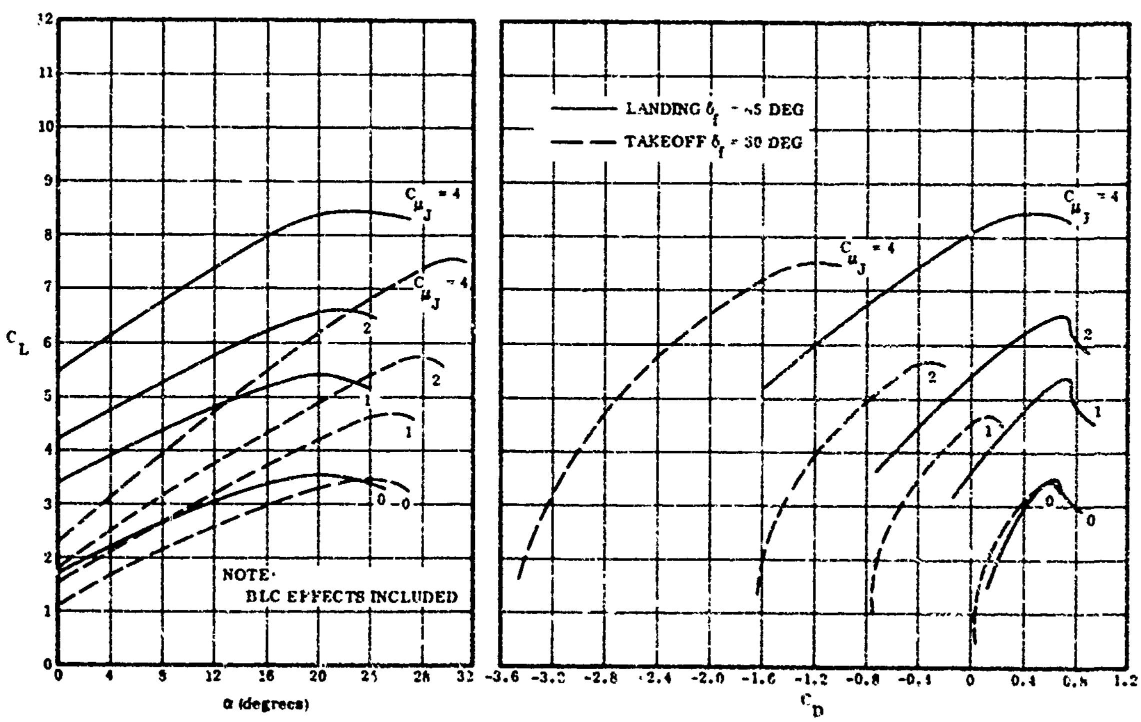


Figure 6-6. EBF Low Speed Trimmed Data, Part 2

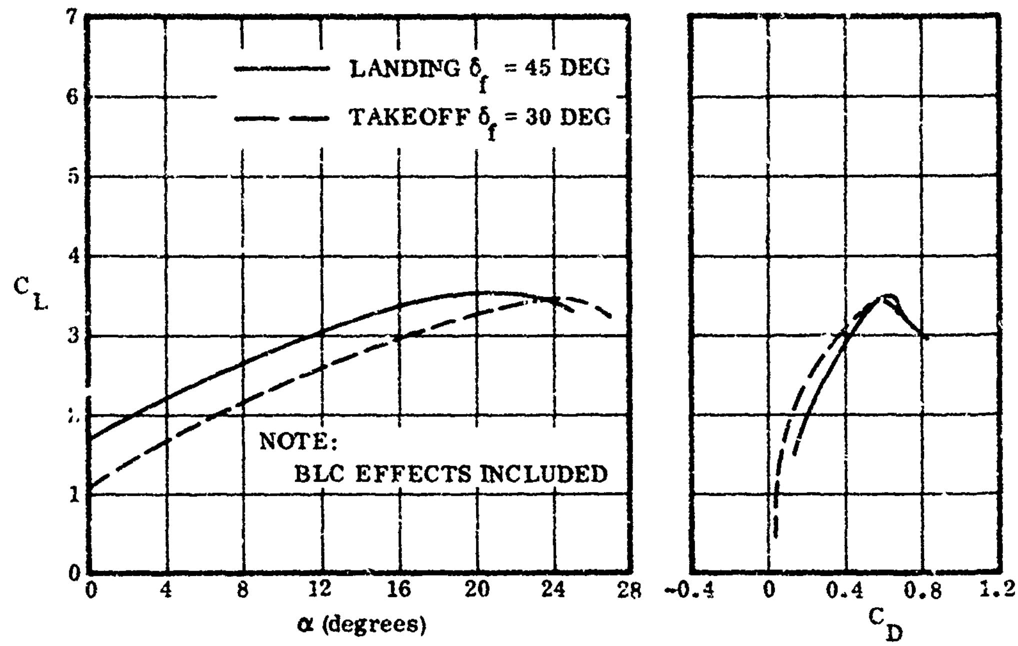


Figure 6-7. MF/VT Low Speed Trimmed Data, Part 2

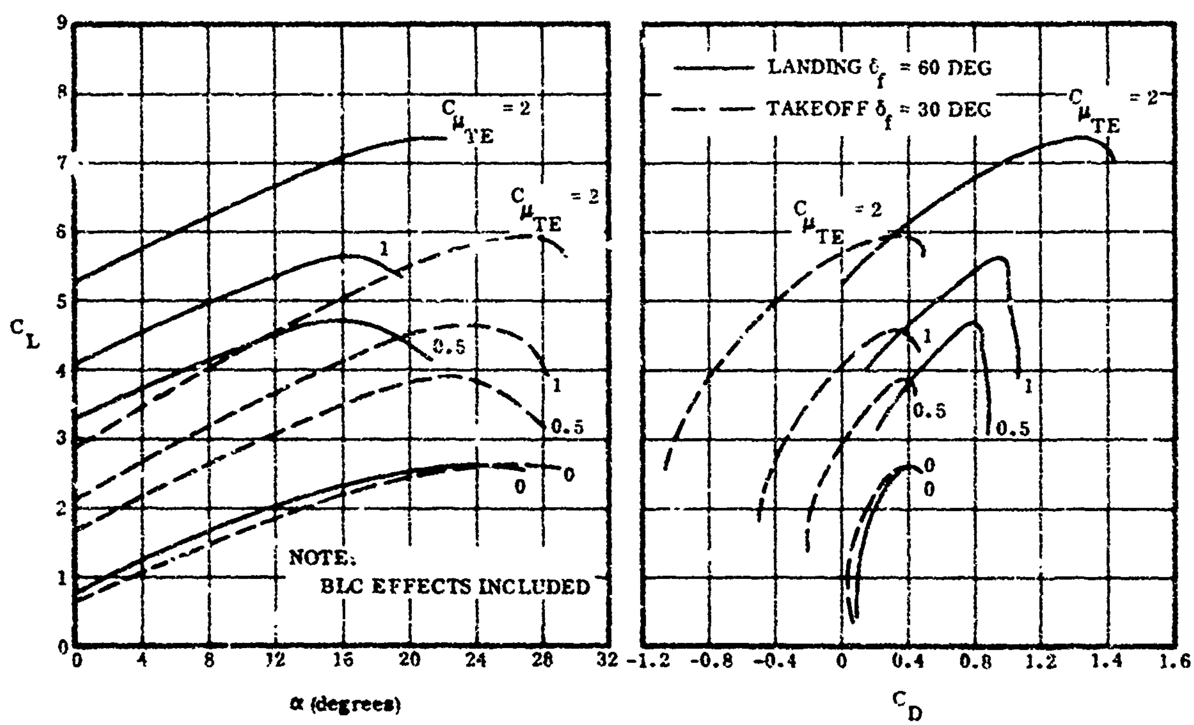


Figure 6-8. IBF Low Speed Trimmed Data, Part 2

6.2 CONFIGURATION SIZING

The configurations selected in Section 5 were updated during this part of the study effort. All mission performance data was computed using the digital computer program described in Reference 6-1. STOL takeoffs and landings were calculated using the digital procedure of Reference 6-2.

6.2.1 DATA UPDATE EFFECTS. The updated designs reflect the following changes.

1. Revised takeoff and landing ground rules, Reference 6-3.
2. Improved aerodynamic powered-lift data base developed from the parametric wind tunnel test data.
3. Control system refinements that reflect the improvements in the data base and controls mechanization.
4. Mechanical and structural design refinements.

These configuration improvements resulted in significant weight savings for all three powered-lift configurations. The largest weight saving is attributable to the takeoff and landing ground rules and the data base. The improvements in takeoff field length are shown in Figure 6-9 for a sample EBF configuration. For this example, the wing area and rated engine thrust were held constant. At the configuration mid-mission weight, the change in ground rules resulted in a 150-foot field length decrease. The improved powered-lift data base significantly decreased the field length by an additional 440 feet.

A potential reduction in cruise drag could be achieved by using part of the available potential improvement shown in Figure 6-10. The cruise Mach number can be increased by using an advanced state-of-the-art wing design (Peaky-type airfoils). Further improvements could be achieved by treatment of the wing/fuselage juncture and the wing tip. A super-critical wing design could furnish either additional internal fuel volume by increasing thickness ratio or additional cruise Mach number capability.

6.2.2 BLC AIR SUPPLY TRADEOFFS. Elimination of the auxiliary compressor as the BLC supply was studied using the EBF configuration as a baseline. This refinement consisted of removing the two auxiliary gas turbine compressors used for supplying air to the wing lead-edge BLC system and supplying the BLC air with scaled Garrett-Airesearch flow multipliers. One flow multiplier is positioned in each engine installation and is driven with engine compressor bleed.

The two EBF configurations of Table 6-3 were sized to achieve the minimum takeoff gross weight design. The design employing flow multipliers is two percent lighter at takeoff gross weight than the design with auxiliary compressors. The flow multipliers were selected as the BLC air supply source on the EBF and MF/VT designs.

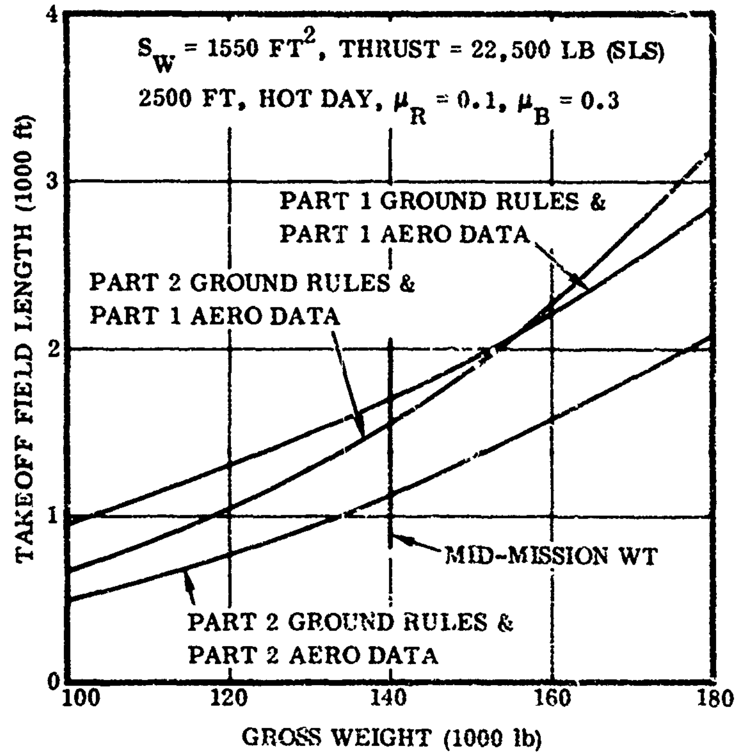


Figure 6-9. Effects of Takeoff and Landing Ground Rules and Improved Aerodynamic Data on EBF Vehicle Sizing

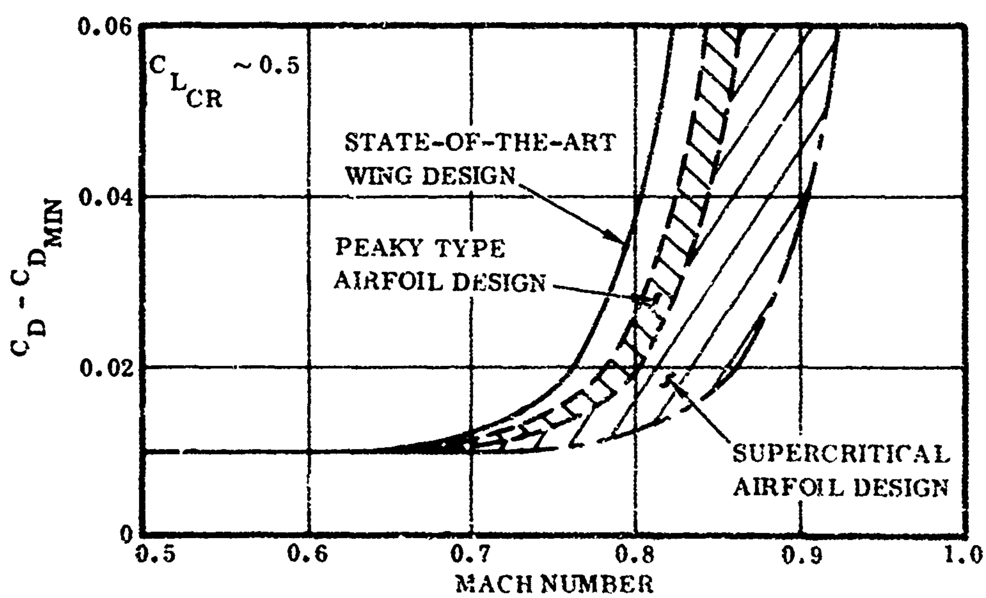


Figure 6-10. Potential Improvements in Cruise Drag

Table 6-3. BLC Air Source Tradeoff, EBF

	BLC Air from Cruise Engines	BLC Air from Auxiliary Compressor
Engine	GE13/F2B	GE13/F2B
Wing Area (ft^2)	1,550	1,550
TOGW (lb)	137,450	140,100
Mid-mission Weight (lb)	125,700	126,480
Rated Thrust (lb)	15,075	14,060
T/W	0.480	0.445
W/S (lb/ft^2)	81.1	81.6
Takeoff Distance (ft)	2,000	2,000

6.2.3 SIZING OPTIMIZATION. The point designs were sized for a 2,000-foot takeoff field at the mid-point of the tactical delivery mission. Sufficient wing fuel volume was required to fly a 2,600 n.mi. unrefueled range mission using internal wing fuel. The range mission is performed at a reduced load factor (2.5 g) and uses the wing center section carry-through structure for fuel tankage. These center section tanks are not used during tactical missions. Since the STOL landing ground rules are not conservative, the 2,000-foot landing field length requirement is not critical.

The two EBF configurations shown in Table 6-3 were sized during the Part 2 study. These were updates of the Part 1 baseline design. This design revision included:

1. Elimination of aileron, elevator, and rudder BLC blowing.
2. Addition of a leading-edge Krueger flap to the horizontal tail.
3. Increasing the horizontal tail size to compensate for the removal of the elevator BLC blowing.

The wing and flap geometry remained the same as in Part 1. The sizing plot for this configuration is shown in Figure 6-11; the point design and the Part 1 baseline are compared in Table 6-4.

The MF/VT configuration incorporates the design revisions of the selected EBF design. Other design changes include:

1. Replacing the Part 1 triple-slotted flap system with a simpler and lighter double-slotted flap.
2. Replacement of the GE single-bearing thrust vectoring device with a lighter weight, single-position, cascade vectoring system.

The MF/VT configuration was optimized using these criteria. The sizing plot for this configuration is shown in Figure 6-12; the point design and the baseline configuration are compared in Table 6-5.

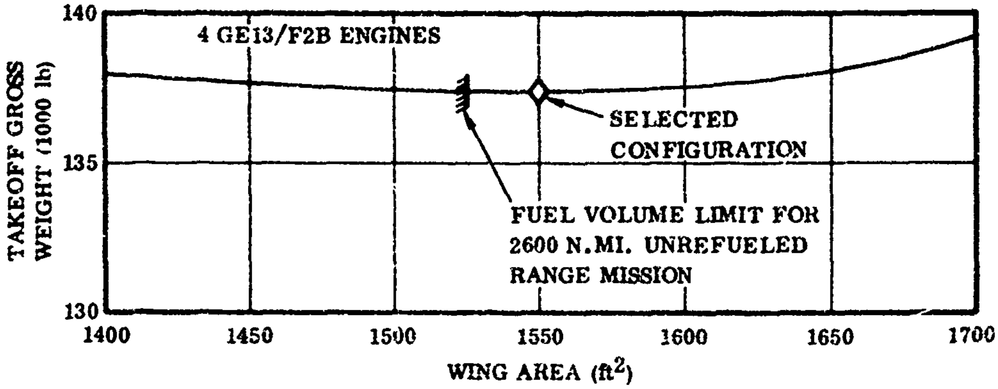


Figure 6-11. EBF Point Design Sizing for 2,000-foot Field

Table 6-4. Comparison of Part 1 and Part 2 EBF Designs

	Part 1 Design	Part 2 Design
Engine	GE13/F2B	GE13/F2B
Wing Area (ft^2)	1,550	1,550
TOGW (lb)	148,200	137,150
Mid-mission Weight (lb)	134,200	125,700
Rated Thrust (lb)	18,600	15,075
T/W	0.555	0.480
W/S (lb/ft^2)	86.6	81.1
Takeoff Distance (ft)	2,000	2,000
Landing Distance (ft)	99[illegible]	1,530

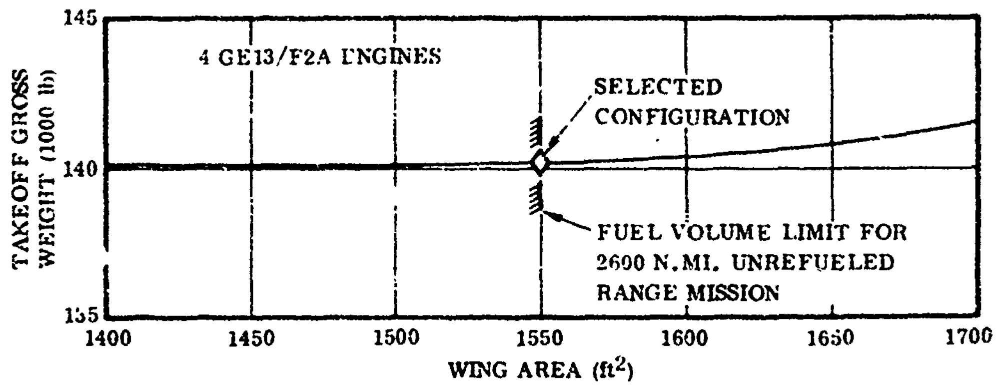


Figure 6-12. MF/VT Point Design Sizing for 2,000-foot Field

Table 6-5. Comparison of Part 1 and Part 2 MF/VT Designs

	Part 1 Design	Part 2 Design
Engine	GE13/F2A	GD13/F2A
Wing Area (ft^2)	1,710	1,550
TOGW (lb)	168,750	140,200
Mid-mission Weight (lb)	153,500	126,300
Rated Thrust (lb)	24,750	14,965
T/W	0.645	0.474
W/S (lb/ft^2)	89.8	81.5
Takeoff Distance (ft)	2,000	2,000
Landing Distance (ft)	1,280	1,850

The basis for the updated IBF configuration is the baseline IBF-2 from Part 1. Even though the STF369 engine is not an optimum engine/airframe/mission match, it provides sufficient high-pressure-ratio/high-flow-rate air to drive the wing leading- and trailing-edge blowing systems. The IBF-2 baseline design was revised by:

1. Eliminating BLC blowing from the aileron, elevator, and rudder.
2. Adding a leading-edge Krueger to the enlarged horizontal tail.
3. Redesigning the trailing-edge high-lift system to reduce weight and increase blowing system efficiency.
4. Adding a thrust vectoring system. This vectoring system is used during the approach and landing flight phases to eliminate undesirable characteristics of the baseline IBF configuration studied on the fixed base simulator, Reference 6-4.

With these design revisions incorporated, the configuration was optimized within the preceeding constraints. The sizing plot for the IBF point design is shown in Figure 6-13; the point design and the baseline IBF-2 are compared in Table 6-6.

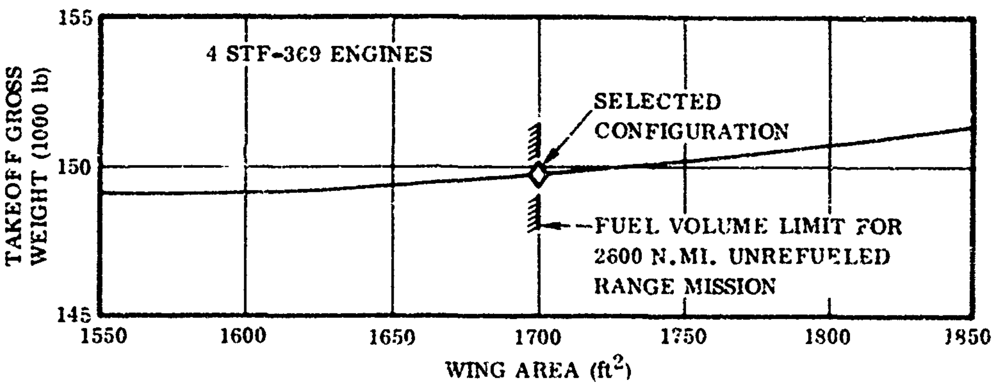


Figure 6-13. IBF/VT Point Design Sizing for 2,000-foot Field

Table 6-6. Comparison of Part 1 and Part 2 IBF/VT Designs

	Part 1 Design	Part 2 Design
Engine	STF369	STF369
Wing Area (ft^2)	1,785	1,770
TOGW (lb)	170,300	149,770
Mid-mission Weight (lb)	152,450	133,000
Rated Thrust (lb)	22,837	13,275
T/W	0.599	0.40
W/S (lb/ft^2)	85.41	78.24
Takeoff Distance (ft)	2,000	2,000
Landing Distance (ft)	1,175	1,810

6.3 POINT DESIGNS

The resulting point designs from the sizing activities are presented and discussed in this section. The three designs have the same cargo compartment used on the Part 1 baseline configurations (12 by 12 by 55 feet). The overall fuselage length has been decreased by three feet. The sized point designs are typical high-wing, T-tail transports with pylon-mounted engines.

6.3.1 INBOARD PROFILE.

The inboard plan and profile drawing for the three designs as shown in Figure 6-14 is provided to amplify major fuselage areas of interest. These areas logically fall into the three categories discussed in the following paragraphs.

6.3.1.1 Nose Section. The nose section (from Fuselage Station (FS) 0 to 260 consists of 1) the flight deck, 2) crew rest area, 3) nose wheel well, and 4) electronic areas.

The flight deck contains provisions for a pilot, co-pilot, navigator, and loadmaster. A crew rest area is located on the same level just aft of the flight deck. This area includes four seats, a folding table, galley, one bunk, and storage areas. Directly below, on the cargo deck level, three additional bunks are provided, along with a lavatory, toiler, shower, and additional crew storage. Access to the electronic racks is also located on the cargo deck level.

A ladder adjacent to the crew entrance door extends from the cargo deck level to the flight deck level and up to the overhead escape hatch. The weather radar and the nose landing gear complete the major components of the nose section.

6.3.1.2 Cargo Section. The cargo section extends from FS 260 to 920. This section provides a cargo envelope 55 feet long, 12 feet wide, and 12 feet high. The cargo floor is designed to a 300 lb/ft^2 loading capability and is compatible with the Air Force 463L loading system. The wing carrythrough structure and its supporting fuselage frames are compatible with the main landing gear cutout area, providing maximum structural efficiency through the mid-fuselage area. A personnel entrance door is located at the rear of the cargo section on the left-hand side.

6.3.1.3 Aft Fuselage Section. The aft fuselage section extends from FS 920 to 1436. This area consists of various doors and ramps necessary for efficient loading and unloading of cargo and vehicles. The main ramp (pivoting at FS 920) has three basic positions: in-flight, truck bed/air drop, and inclined-ramp cargo and vehicle loading. The cargo ramp extension (which also acts as the aft pressure barrier) can pivot at the end of the main ramp for inclined cargo loading or can pivot at Waterline 218 for air drop or truck bed loading. The aft fuselage center cargo door and side clam-shell doors provide clearance for all loading conditions when extended.

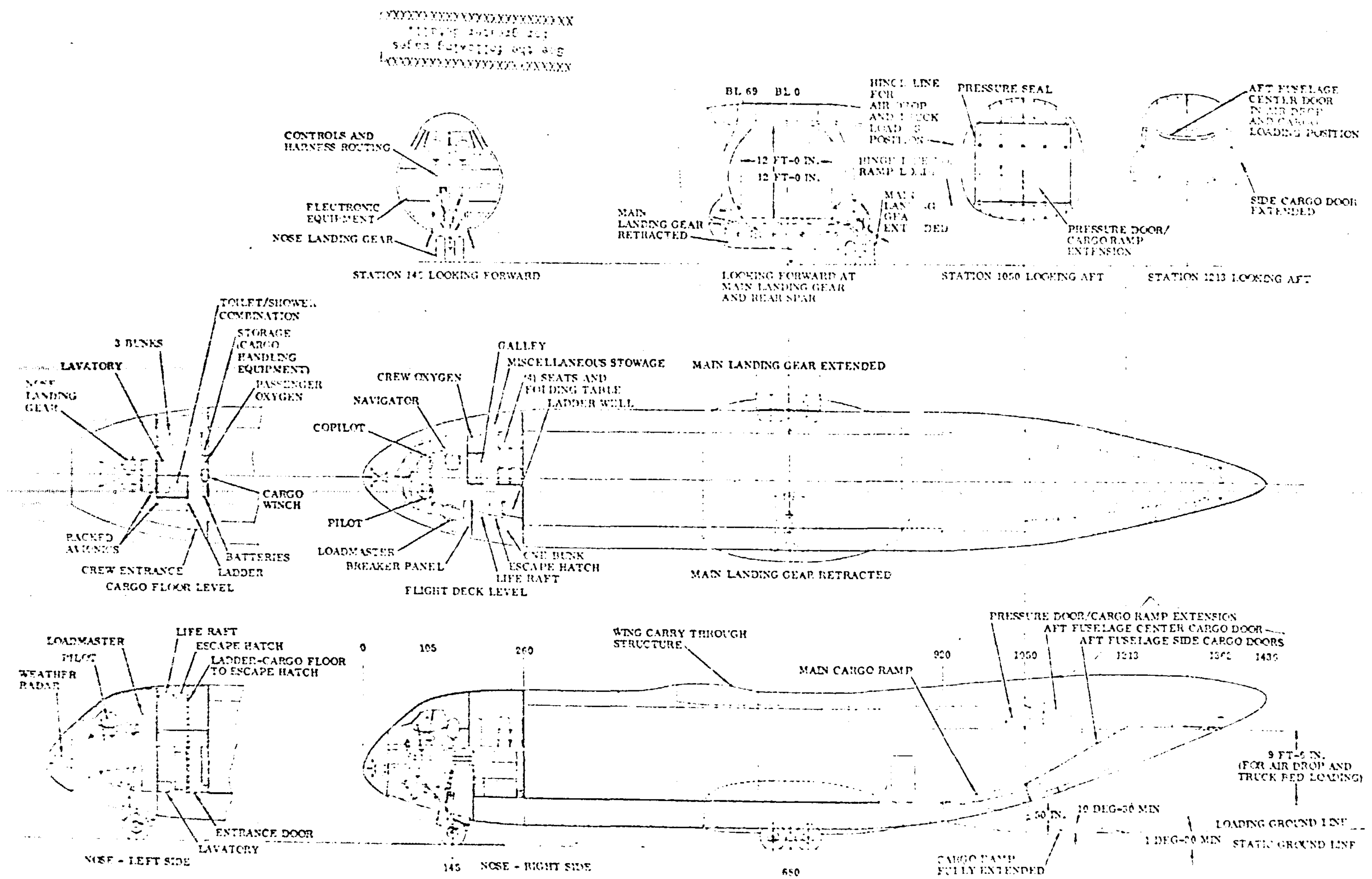


Figure 6-14. Inboard Profile

6.3.2 GENERAL ARRANGEMENTS. The general arrangements for EBF, MF/VT, and IBF/VT point designs are shown in Figures 6-15, 6-16, and 6-17, respectively. The EBF and MF/VT designs use flow multipliers located in each pylon to supply boundary layer control air for the wing leading-edge flap. The IBF design uses bleed air from the high-pressure single-stage fan for both the leading-edge and trailing-edge flaps. The point designs are summarized in Table 6-7.

Table 6-7. Summary of Updated Designs

	EBF	MF/VT	IBF/VT
Engine	GE13/F2B	GE13/F2A	STF369
Wing area (ft^2)	1,550	1,550	1,700
TOGW (lb)	137,450	140,200	149,770
Mid-mission Weight (lb)	125,700	126,300	133,000
Rated Thrust (lb)	15,075	14,965	13,275
T/W	0.480	0.474	0.40
W/S (lb/ft^2)	81.1	81.5	78.24
Takeoff Distance (ft)	2,000	2,000	2,000
Landing Distance (ft)	1,530	1,850	1,810

Mid-mission STOL weights of the EBF and MF/VT are comparable, but the IBF weight is slightly higher because of the engine selection required for takeoff and landing performance. Of the three designs, the IBF had the lowest installed thrust-to-weight ratio and rated thrust. Dimensional data is presented for the EBF in Table 6-8, for the MF/VT in Table 6-9, and for the IBF/VT in Table 6-10.

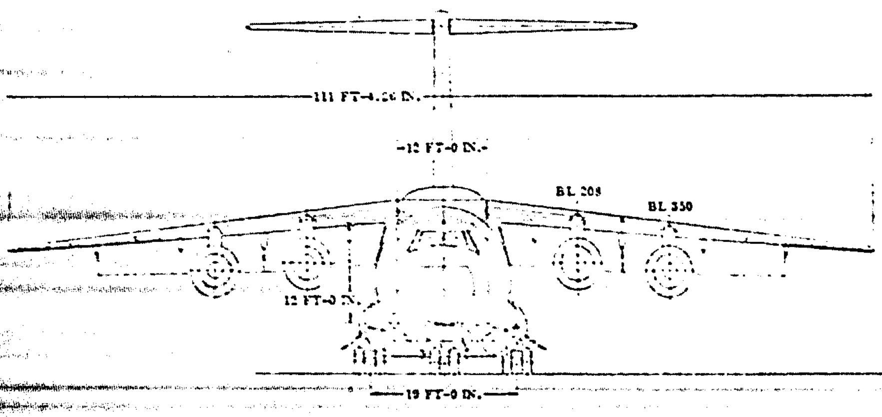
6.3.3 MASS PROPERTIES. The weights data presented herein for Phase I point design is the product of extensive studies in which many design parameters have been varied to arrive at an optimum arrangement. Values calculated have been substantiated using several Convair Aerospace developed methods. These include empirical base as well as feature-penalty analysis.

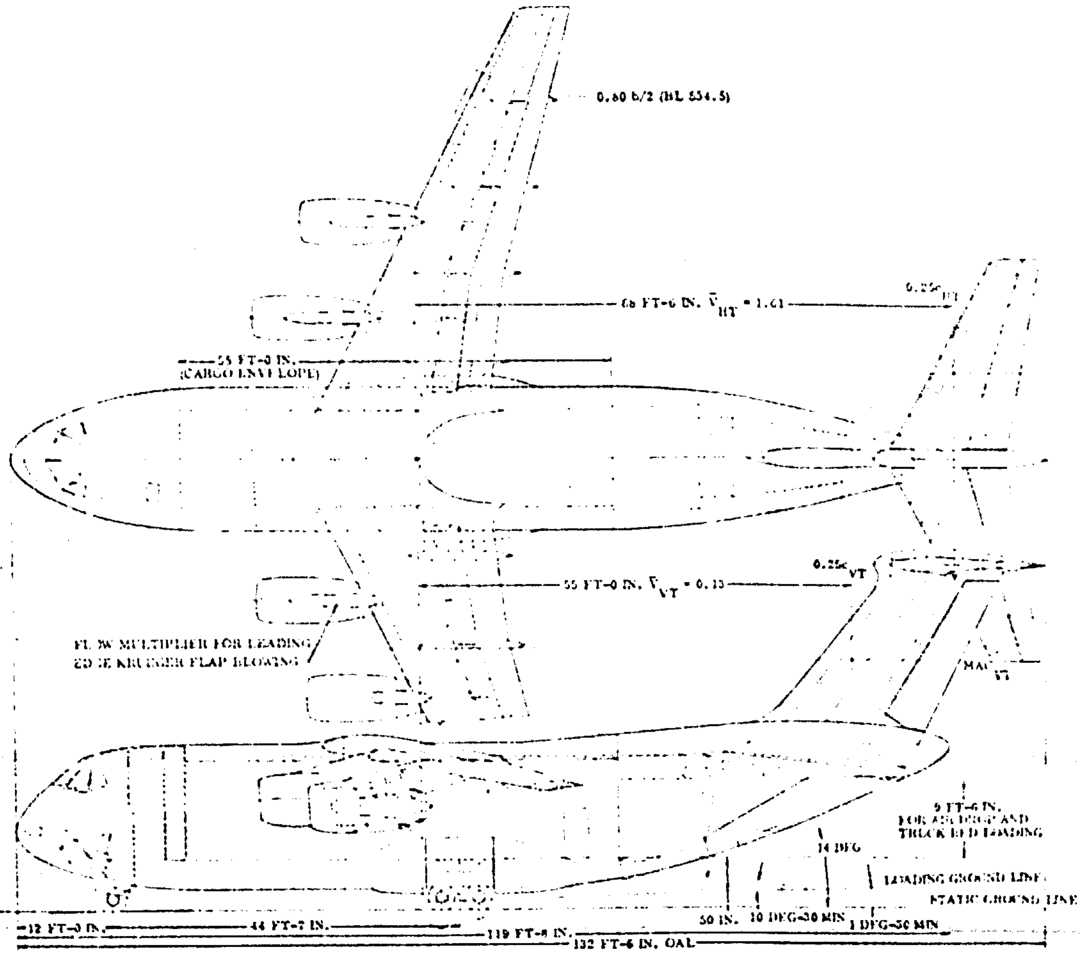
6.3.3.1 Study Procedure. In order to ensure maximum accuracy of weight estimates during the parametric studies, while providing a means of quickly obtaining differential weight effects, two different types of estimating methods were used. Baseline configurations were estimated using feature-penalty analysis. Constants derived from these analyses were used to calibrate an existing interactive computer graphics program containing generalized weight estimating equations. This program and the equations therein were used for configuration scaling from the base point values. Periodic checks, using the feature-penalty analysis, substantiated that the computer graphics equations were providing desired scaling effects. A standard deviation error summary applied to the structural weight of existing in-service aircraft is presented in Table 6-11 for these methods.

GENERAL DATA

		WING	HORIZONTAL	VERTICAL
AREA	(FT^2)	1550	349	406
ASPECT RATIO		8.0	4.50	1.186
TAPER RATIO		0.333	0.40	0.65
SPAN	(FT)	111.36	49.70	22.02
ROOT CHORD	(IN.)	250.61	159.55	269.55
TIP CHORD	(IN.)	83.45	75.74	175.21
MAC	(IN.)	180.27	140.66	[illegible]
THICKNESS AT ROOT	(%)	15.12 AT BL 69	12	12
THICKNESS AT TIP	(%)	10	8	12
INCIDENCE	(DEG)	3.5 AT BL 69	+5 TO -10	-
WING TWIST	(DEG)	-4.5	-	-
DIHEDRAL	(DEG)	-3.5	-	-
SWEEPBACK AT 0.25c	(DEG)	25	25	35

PROPULSION: (4) GE F101 TURBOFAN SCALED TO 15,000 LB SLS THRUST EACH
HIGH-LIFT DEVICES: TRAILING-EDGE DOUBLE-SLOTTED MECHANICAL FLAPS - CONTINUOUS TO 0.80 b/2
LEADING-EDGE EXPANDABLE LOWER SURFACE FLAPS BLOWN BY ENGINE BLEED
MAIN LANDING GEAR - [illegible] (4) WHEEL BOGIE (42.0 DIA × 15.0 WIDE)
NOSE LANDING GEAR - SAME TIRE SIZE
WEIGHT: GROSS = 151,600 LB MID-MISSION AND LANDING = 125,700 LB,
TAKEOFF = 1[illegible]7,450 LB, DESIGN PAYLOAD = 28,000 LB





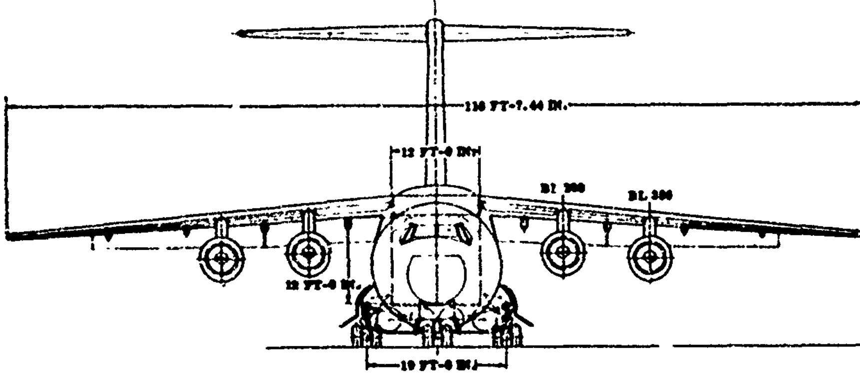
XXXXXXXXXXXXXXXXXXXXXXXXX
See the following pages
for greater detail.
XXXXXXXXXXXXXXXXXXXXXXXXX

General Arrangement of MF/VT Point Design

GENERAL DATA

		WING	HORIZONTAL	VERTICAL
AREA	(FT^2)	1700	632	400
ASPECT RATIO		8.0	4.50	1.300
TAPER RATIO		0.333	0.40	0.65
SPAN	(FT)	116.62	52.33	23.50
ROOT CHORD	(IN.)	262.44	203.16	288.70
TIP CHORD	(IN.)	87.40	81.28	187.00
MAC	(IN.)	189.83	150.92	241.78
THICKNESS AT ROOT	(%)	13.12 AT BL 60	12	12
THICKNESS AT TIP	(%)	10	8	12
INCIDENCE	(DEG)	3.5 AT BL 60	+5 TO -10	-
WING TWIST	(DEG)	-4.5	-	-
DIHEDRAL	(DEG)	-3.5	-	-
SWEEPBACK AT 0.25c	(DEG)	33	35	30

PROPULSION: (4) P&W STF 300 TURBOFAN SCALED TO 13,276 LB SLS THRUST EACH
HIGH-LIFT DEVICES: TRAILING-EDGE SIMPLE PIVOT INTERNALLY BLOWN FLAPS - CONTINUOUS TO 3.00 b/2
LEADING-EDGE EXPANDABLE LOWER SURFACE BLOWN BY ENGINE BLEED
MAIN LANDING GEAR: 1300-16 (4) WHEEL BOGIE (42.0 DIA x 15.0 WIDE)
NOSE LANDING GEAR: SAME TIRE SIZE
WEIGHT: GROSS = 166,490 LB, MID-MISSION AND LANDING = 153,000 LB, TAKEOFF = 169,770 LB, DESIGN PAYLOAD = 20,000 LB



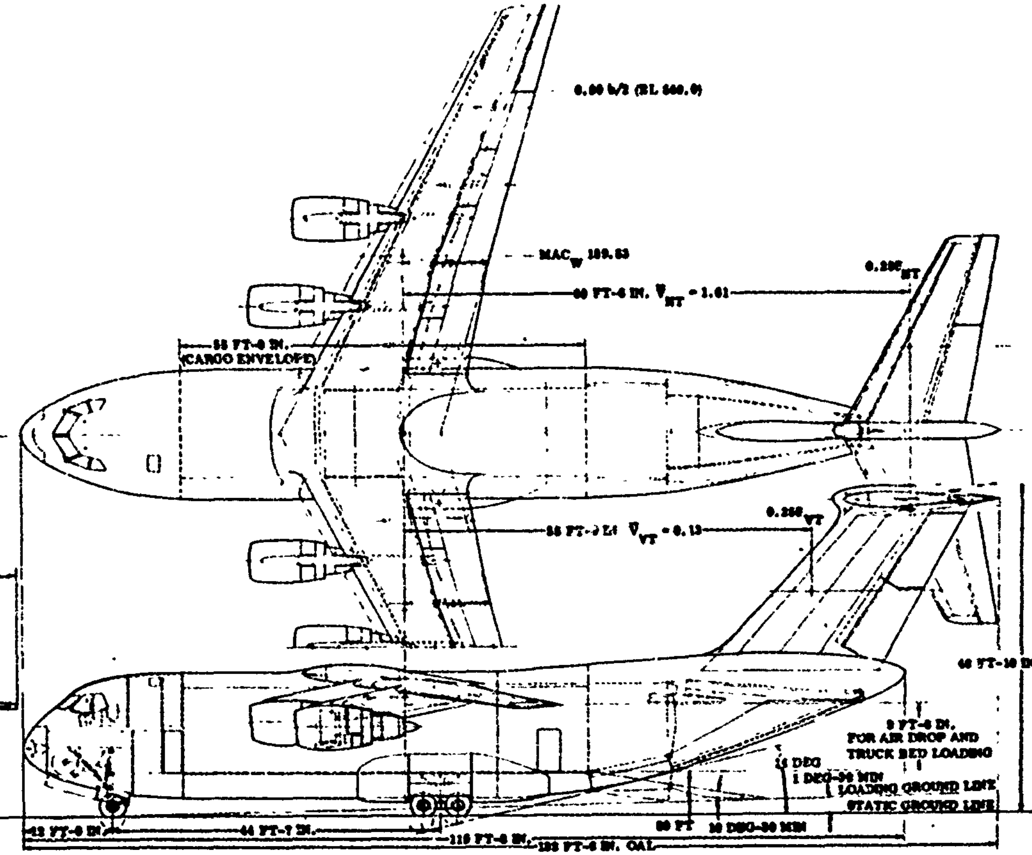


Figure 6-17. General Arrangement of IBF/VT Point Design

Table 6-8. EBF Dimensional Data

Wing		**Horizontal Tail**	
Span	111.36 ft	Span	49.7 ft
Area	1550.00 ft^2	Area	549.0 ft^2
Aspect Ratio	8.00	Aspect Ratio	4.50
Taper Ratio	0.33	Taper Ratio	0.40
Incidence		Deflection	+5 to -10 deg
At Root	3.5 deg	Sweep at c/4	30 deg
At Tip	-1.0 deg	Chord	
Dihedral	-3.5 deg	Root	189.35 in.
Sweep at c/4	25.0 deg	Tip	75.74 in.
Chord		Mean Aerodynamic	140.66 in.
Root (at Aircraft Centerline)	250.60 in.	Airfoil Section	
Tip	83.45 in.	Root	64A012
Mean Aerodynamic	180.97 in.	Tip	64A008
Airfoil Section		Pivot Centerline	$c/4_{MAC}$
Root (at W.S. 69.0)	64A3 (13.12)		
Tip	64A4 10	**Elevator**	
		Span	Full
Leading Edge Device (Variable Camber)		Chord	0.35
		Deflection	+15 to -50 deg
Span	Full	Hinge Line	0.35c
Chord	0.155% c		
Deflection	56 deg	**Vertical Tail**	
		Span	22.0 ft
Trailing Edge Flap		Area	408.0 ft^2
Span	0.80 b/2	Aspect Ratio	1.18
Chord	0.75c	Taper Ratio	0.65
Deflection	45 deg	Sweep at c/4	39.0 deg
		Chord	
Spoilers		Root	269.55 in.
Span	0.80 b/2	Tip	175.21 in.
Chord	0.195c	Mean Aerodynamic	225.72 in.
Hinge	0.548c	Airfoil Section	64A012
Deflection	60 deg		
		Rudder	
Aileron		Span	Full
Span	0.20 b/2	Chord	0.30c
Chord	0.25c	Deflection	±50 deg
Deflection	±50 deg		
Fuselage			
Length	132 ft, 6 in.		
Maximum Width	212 in.		
Cargo Envelope			
Length	55 ft		
Width	12 ft		
Height	12 ft		

Table 6-9. MF/VT Dimensional Data

Wing	
Span	116.96 ft
Area	1710.0 ft^2
Aspect Ratio	8.00
Taper Ratio	0.33
Incidence	
At Root	3.5 deg
At Tip	-1.0 deg
Dihedral	-3.5 deg
Sweep at c/4	25.0 deg
Chord	
Root (at Aircraft Centerline)	263.0 in.
Tip	87.6 in.
Mean Aerodynamic	190.0 in.
Airfoil Section	
Root (at W.S. 69.0)	64A3 (13.12)
Tip	64A4 10
Leading Edge Device (Variable Camber)	
Span	Full
Chord	0.155% c
Deflection	56 deg
Trailing Edge Flap	
Span	0.80 b/2
Chord	0.45c
Deflection	45 deg
Spoilers	
Span	0.80 b/2
Chord	0.195c
Hinge	0,546c
Deflection	60 deg
Aileron	
Span	0.20 b/2
Chord	0.25c
Deflection	±50 deg
Fuselage	
Length	132 ft, 6 in.
Maximum Width	212 in.
Cargo Envelope	
Length	55 ft
Width	12 ft
Height	1[illegible] ft

Horizontal Tail	
Span	49.7 ft
Area	549.0 ft^2
Aspect Ratio	4.50
Taper Ratio	0.40
Deflection	+5 to -10 deg
Sweep at c/4	30 deg
Chord	
Root	189.35 in.
Tip	75.74 in.
Mean Aerodynamic	140.66 in.
Airfoil Section	
Root	64A012
Tip	64A008
Pivot Centerline	$c/4_{MAC}$
Elevator	
Span	Full
Chord	0.35
Deflection	+15 to -50 deg
Hinge Line	0.35c
Vertical Tail	
Span	22.0 ft
Area	408.0 ft^2
Aspect Ratio	1.18
Taper Ratio	0.65
Sweep at c/4	39.0 deg
Chord	
Root	269.55 in.
Tip	175.21 in.
Mean Aerodynamic	225.72 in.
Airfoil Section	64A012
Rudder	
Span	Full
Chord	0.30c
Deflection	±50 deg

Table 6-10. IBF/VT Dimensional Data

Wing		Horizontal Tail	
Span	116.6 ft	Span	53.3 ft
Area	1700 ft^2	Area	632.0 ft^2
Aspect Ratio	8.00	Aspect Ratio	4.50
Taper Ratio	0.33	Taper Ratio	0.40
Incidence		Deflection	+5 to -10 deg
At Root	3.5 deg	Sweep at c/4	30 deg
At Tip	-1.0 deg	Chord	
Dihedral	-3.5 deg	Root	203.16 in.
Sweep at c/4	25.0 deg	Tip	81.26 in.
Chord		Mean Aerodynamic	150.9 in.
Root (at Aircraft Centerline)	262.46 in.	Airfoil Section	
Tip	87.40 in.	Root	64A012
Mean Aerodynamic		Tip	64A008
Airfoil Section		Pivot Centerline	$c/4_{MAC}$
Root (at W.S. 69.0)	64A3 (13.12)		
Tip	64A4 10	Elevator	
		Span	Full
Leading Edge Device		Chord	0.35
(Variable Camber)		Deflection	+15 to -50 deg
Span	Full	Hinge Line	0.35c
Chord	0.155% c		
Deflection	56 deg	Vertical Tail	
		Span	23.68 ft.
Trailing Edge Flap		Area	468 ft^2
Span	0.80 b/2	Aspect Ratio	1.18
Chord	0.35c	Taper Ratio	0.65
Deflection	60 deg	Sweep at c/4	39.0 deg
		Chord	
Spoilers		Root	288.70 in.
Span	0.30 b/2	Tip	187.65 in.
Chord	0.195c	Mean Aerodynamic	241.75 in.
Hinge	0.548c	Airfoil Section	64A012
Deflection	60 deg		
		Rudder	
Aileron		Span	Full
Span	0.20 b/2	Chord	0.30c
Chord	0.25c	Deflection	±50 deg
Deflection	±50 deg		
Fuselage			
Length	132 ft, 6 in.		
Maximum Width	212 in.		
Cargo Envelope			
Length	55 ft		
Width	12 ft		
Height	12 ft		

Tradeoffs were conducted such that no performance increment was computed without inclusion of the weight effect of all variable parameters. That is, the program iteratively revised the total vehicle weight, design loads, wing and tail areas, fuel quantity, engine size, wetted area, etc., until the vehicle was resized to meet mission specifications. The output, either displayed at the graphics terminal or printed, included a group weight statement similar in format to MIL-STD-254, a complete statement of geometry, and a planform layout of the resized vehicle.

6.3.3.2 Weight Derivation. Table 6-12 provides a summary of the weight derived for the externally blown flap configuration. Table 6-13 provides dimensional and structural data for that configuration. Tables 6-14 and 6-15 provide data for the mechanical flap/vectored thrust configuration, and Tables 6-16 and 6-17 provide data for the internally blown flap configuration. In general, weights presented were derived as follows:

1. Structural Group Weights

   Structural weights were estimated using feature-penalty analysis described above.

2. Propulsion Group

   Engine weights have been based on manufacturer scaling data. Thrust reversers have been estimated using weights of other reverser concepts, modified to reflect Convair Aerospace design approach. Fuel system and engine system weights were estimated using feature-penalty analysis.

3. Fixed Equipment

   Fixed equipment weights are those recommended for use by the AFFDL in Reference 6-4.

Table 6-11. Structural Weight - Prediction Methods Standard Deviation Error Summary

Aircraft Class	No. Cases	Wing Bias (%)	Wing Std Dev (%)	Tail Bias (%)	Tail Std Dev (%)	Body Bias (%)	Body Std Dev (%)
USAF Fighters	11	+0.01	5.95	+7.77	19.87	-0.98	5.79
USN Fighters	17	+0.98	5.53	+1.37	18.57	+1.43	6.03
Transports	10	+0.58	3.34	-0.83	9.87	+0.64	3.19
Bombers	6	-0.19	3.15	-4.08	10.72	+0.32	2.94
All Aircraft	44	+0.14	4.81	+1.73	16.41	+0.47	4.98

Aircraft Class	Landing Gear No. Cases	Landing Gear Bias (%)	Landing Gear Std Dev (%)	External Nacelles No. Cases	External Nacelles Bias (%)	External Nacelles Std Dev (%)
USAF Fighters	10	+1.64	6.87	-	-	-
USN Fighters	11	+0.37	13.31	-	-	-
Transports	10	+0.77	11.85	10	+0.41	7.18
Bombers	6	+2.97	7.66	6	-0.31	5.57
All Aircraft	43	+0.83	10.77	16	-0.04	6.43

Aircraft Class	Total Structure No. Cases	Total Structure Bias (%)	Total Structure Std Dev (%)
USAF Fighters	11	+0.33	4.40
USN Fighters	17	+0.05	3.43
Transports	10	+0.31	2.47
Bombers	6	-0.02	1.44
All Aircraft	44	+0.13	3.23

Table 6-12. Weight Summary - Externally Blown Flap Configuration

	Weight (lb)	
Wing Group		20,039
Basic Structure	13,640	
Secondary Structure	700	
Trailing-Edge Flaps	3,708	
Leading-Edge Flaps	972	
Spoilers	269	
Flap BLC System	750	
Tail Group		4,432
Horizontal Tail	2,182	
Vertical Tail	2,250	
Body Group		24,081
Alighting Gear		6,601
Surface Controls		2,051
Nacelle Group		2,790
Propulsion Group		11,661
Engines	7,284	
Thrust Reversers	1,768	
Air Induction	137	
Exhaust System	165	
Cooling System	66	
Lubricating System	24	
Fuel System	1,928	
Starting System	170	
Engine Controls	119	
Auxiliary Power Unit		500
Instrument Group		900
Hydraulic and Pneumatic		900
Electrical Group		1,900
Avionics Group		2,000
Armament Group		700
Furnishings Group		4,000
Air Conditioning and Anti-Icing		1,600
Auxiliary Gear Group		100
Weight Empty		84,255
Basic Operating Items		1,795
Payload		28,000
Usable Fuel		23,400
Takeoff Gross Weight		137,450

Table 6-13. Dimensional and Structural Data, EBF Configuration

1	LENGTH - OVERALL (FT.) 132.5			HEIGHT - OVERALL - STATIC (FT.)				
2		Main Floats	Aux. Floats	Booms	Fuse or Hull	Nacelles – Inboard	Nacelles – Center	Nacelles – Outboard
3	LENGTH - MAX. (FT.)				119.7	10.1		10.1
4	DEPTH - MAX. (FT.)				18.3	6.2		6.2
5	WIDTH - MAX. (FT.)				17.7	5.7		5.7
6	WETTED AREA (SQ. FT.)				5519	237 ea		237 ea
*7	FLOAT OR HULL DISPL. - MAX. (LBS.)							

8	FUSELAGE VOLUME (CU. FT.) PRESSURIZED	TOTAL		
9		Wing	H. Tail	V. Tail
10	GROSS AREA (SQ. FT.)	1550	549	408
11	WEIGHT/GROSS AREA (LBS./SQ. FT.)	12.9	4.0	5.5
12	SPAN (FT.)	111.4	49.7	22.0
13	FOLDED SPAN (FT.)			
14				
15	SWEEPBACK - AT 25% CHORD LINE (DEGREES)	25	25	39
16	- AT % CHORD LINE (DEGREES)			
**17	THEORETICAL ROOT CHORD - LENGTH (INCHES)	250.6	189.4	269.6
18	- MAX. THICKNESS (INCHES)	30.6	22.7	32.3
***19	CHORD AT PLANFORM BREAK - LENGTH (INCHES)			
20	- MAX. THICKNESS (INCHES)			
***21	THEORETICAL TIP CHORD - LENGTH (INCHES)	83.5	75.7	175.2
22	- MAX. THICKNESS (INCHES)	8.4	6.1	21.2

23	DORSAL AREA, INCLUDED IN (FUSE.) (HULL) (V. TAIL) AREA (SQ. FT.)			
24	TAIL LENGTH - 25% MAC WING TO 25% MAC H. TAIL (FT.)	68.5		
25	AREAS (SQ. FT.) Flaps	L.E. Wing 145.4	T.E. 319.2 (Planform	Retracted)
26	Lateral Controls	Slats	Spoilers 177.2	Ailerons 46.0
27	Speed Brakes	Wing	Fuse. or Hull	
28	Flaps	L. E. Horiz. Tail 86.1		
29		Elevators 174.4	Rudder 91.1	

30	ALIGHTING GEAR (LOCATION)	Nose	Main		
31	LENGTH - OLEO EXTENDED - ℄ AXLE TO ℄ TRUNNION (INCHES)	74.0	67.0		
32	OLEO TRAVEL - FULL EXTENDED TO FULL COLLAPSED (INCHES)	25.0	25.0		
33	FLOAT OR SKI STRUT LENGTH (INCHES)				
34	ARRESTING HOOK LENGTH - ℄ HOOK TRUNNION TO ℄ HOOK POINT (INCHES)				
35	HYDRAULIC SYSTEM CAPACITY (GALS.)				

36	FUEL & LUBE SYSTEMS	Location	No. Tanks	****Gals. Protected	No. Tanks	****Gals. Unprotected
37	Fuel - Internal	Wing		1803		5033
38		Fuse. or Hull				
39	- External					
40	- Bomb Bay					
41						
42	Oil					
43						
44						

45	STRUCTURAL DATA - CONDITION	Fuel in Wings (Lbs.)	Stress Gross Weight	Ult. L.F.
46	FLIGHT		137450	4.5
47	LANDING			
48				
49	MAX. GROSS WEIGHT WITH ZERO WING FUEL			
50	CATAPULTING			
51	MIN. FLYING WEIGHT			
52	LIMIT AIRPLANE LANDING SINKING SPEED (FT./SEC.)			15
53	WING LIFT ASSUMED FOR LANDING DESIGN CONDITION (%W)			
54	STALL SPEED - LANDING CONFIGURATION - POWER OFF (KNOTS)			
55	PRESSURIZED CABIN - ULT. DESIGN PRESSURE DIFFERENTIAL - FLIGHT (P.S.I.)			
56				
57	AIRFRAME WEIGHT (AS DEFINED IN AN-W-11) (LBS.)			

*Lbs. of sea water @ 64 lbs./cu. ft.
**Parallel to ℄ of airplane.
***Parallel to ℄ airplane.
****Total usable capacity.

Table 6-14. Weight Summary - Mechanical Flap/Vectored Thrust Configuration

	Weight (lb)	
Wing Group		20,319
Basic Structure	13,359	
Secondary Structure	710	
Trailing-Edge Flaps	3,750	
Leading-Edge Flaps	978	
Spoilers	272	
Flap BLC System	750	
Tail Group		4,489
Horizontal Tail	2,209	
Vertical Tail	2,280	
Body Group		24,232
Alighting Gear		6,734
Surface Controls		2,051
Nacelle Group		3,366
Propulsion Group		12,403
Engines	7,240	
Thrust Reversers	2,515	
Air Induction	136	
Exhaust System	165	
Cooling System	66	
Lubricating System	24	
Fuel System	1,969	
Starting System	169	
Engine Controls	119	
Auxiliary Power Unit		500
Instrument Group		900
Hydraulic and Pneumatic		900
Electrical Group		1,900
Avionics Group		2,000
Armament Group		700
Furnishings Group		4,000
Air Conditioning and Anti-Icing		1,600
Auxiliary Gear Group		100
Weight Empty		86,194
Basic Operating Items		1,806
Payload		28,000
Usable Fuel		24,200
Takeoff Gross Weight		140,200

Table 6-15. Dimensional and Structural Data, MF/VT Configuration

1	LENGTH - OVERALL (FT.) 132.5			HEIGHT - OVERALL - STATIC (FT.)				
2		Main Floats	Aux. Floats	Booms	Fuse or Hull	Inboard	Nacelles Center	Outboard
3	LENGTH - MAX. (FT.)				119.7	10.2		10.2
4	DEPTH - MAX. (FT.)				18.3	6.4		6.4
5	WIDTH - MAX. (FT.)				17.7	6.0		6.0
6	WETTED AREA (SQ. FT.)				5519	296 ea		296 ea
*7	FLOAT OR HULL DISPL. - MAX. (LBS.)							
8	FUSELAGE VOLUME (CU. FT.)		PRESSURIZED			TOTAL		
9						Wing	H. Tail	V. Tail
10	GROSS AREA (SQ. FT.)					1550	549	408
11	WEIGHT/GROSS AREA (LBS./SQ. FT.)					13.1	4.0	5.6
12	SPAN (FT.)					111.4	49.7	22.0
13	FOLDED SPAN (FT.)							
14						25	25	39
15	SWEEPBACK - AT 25% CHORD LINE (DEGREES)							
16	- AT % CHORD LINE (DEGREES)					250.6	189.4	269.6
**17	THEORETICAL ROOT CHORD - LENGTH (INCHES)					30.6	22.7	32.3
18	- MAX. THICKNESS (INCHES)							
***19	CHORD AT PLANFORM BREAK - LENGTH (INCHES)							
20	- MAX. THICKNESS (INCHES)					83.5	75.7	175.2
***21	THEORETICAL TIP CHORD - LENGTH (INCHES)					8.4	6.1	21.2
22	- MAX. THICKNESS (INCHES)							
23	DORSAL AREA, INCLUDED IN (FUSE.) (HULL) (V. TAIL) AREA (SQ. FT.)							
24	TAIL LENGTH - 25% MAC WING TO 25% MAC h. TAIL (FT.)			68.5				
25	AREAS (SQ. FT.) Flaps	L.E. Wing 145.4		T.E. 319.2 (Planform, retracted)				
26	Lateral Controls	Slots		Spoilers 177.2		Ailerons 46.0		
27	Speed Brakes	Wing		Fuse. or Hull				
28	Flaps	L.E. Horiz. Tail 86.1						
29		Elevators 174.4		Rudder 91.1				
30	ALIGHTING GEAR (LOCATION)				Nose	Main		
31	LENGTH - OLEO EXTENDED - ℄ AXLE TO ℄ TRUNNION (INCHES)				74.0	67.0		
32	OLEO TRAVEL - FULL EXTENDED TO FULL COLLAPSED (INCHES)				25.0	25.0		
33	FLOAT OR SKI STRUT LENGTH (INCHES)							
34	ARRESTING HOOK LENGTH - ℄ HOOK TRUNNION TO ℄ HOOK POINT (INCHES)							
35	HYDRAULIC SYSTEM CAPACITY (GALS.)							
36	FUEL & LUBE SYSTEMS	Location	No. Tanks	****Gals. Protected		No. Tanks	****Gals. Unprotected	
37	Fuel - Internal	Wing		1862			5292	
38		Fuse. or Hull						
39	- External							
40	- Bomb Bay							
41								
42	Oil							
43								
44								
45	STRUCTURAL DATA - CONDITION			Fuel in Wings (Lbs.)		Stress Gross Weight		Ult. L.F.
46	FLIGHT					140,200		4.5
47	LANDING							
48								
49	MAX. GROSS WEIGHT WITH ZERO WING FUEL							
50	CATAPULTING							
51	MIN. FLYING WEIGHT							
52	LIMIT AIRPLANE LANDING SINKING SPEED (FT./SEC.)							15
53	WING LIFT ASSUMED FOR LANDING DESIGN CONDITION (%W)							
54	STALL SPEED - LANDING CONFIGURATION - POWER OFF (KNOTS)							
55	PRESSURIZED CABIN - ULT. DESIGN PRESSURE DIFFERENTIAL - FLIGHT (P.S.I.)							
56								
57	AIRFRAME WEIGHT (AS DEFINED IN AN-W-11) (LBS.)							

*Lbs. of sea water @ 64 lbs./cu. ft.
**Parallel to ℄ at ℄ airplane.
***Parallel to ℄ airplane.
****Total usable capacity.

Table 6-16. Weight Summary - Internally Blown Flap Configuration

	Weight (lb)	
Wing Group		21,010
Basic Structure	15,695	
Secondary Structure	830	
Trailing-Edge Flaps	2,209	
Leading-Edge Flaps	1,086	
Spoilers	290	
Flap BLC System	900	
Tail Group		4,967
Horizontal Tail	2,447	
Vertical Tail	2,520	
Body Group		24,720
Alighting Gear		7,185
Surface Controls		2,261
Nacelle Group		3,820
Propulsion Group		13,013
Engines	7,730	
Thrust Reversers	2,378	
Air Induction	142	
Exhaust System	170	
Cooling System	58	
Lubricating System	25	
Fuel System	2,214	
Starting System	177	
Engine Controls	119	
Auxiliary Power Unit		500
Instrument Group		900
Hydraulic and Pneumatic		900
Electrical Group		1,900
Avionics Group		2,000
Armament Group		700
Furnishings Group		4,000
Air Conditioning and Anti-Icing		1,600
Auxiliary Gear Group		100
Weight Empty		89,576
Basic Operating Items		1,894
Payload		28,000
Usable Fuel		30,300
Takeoff Gross Weight		149,770

Table 6-17. Dimensional and Structural Data, IBF Configuration

1 LENGTH - OVERALL (FT.) 132.5			HEIGHT - OVERALL - STATIC (FT.)				
2	Main Floats	Aux. Floats	Booms	Fuse or Hull	Nacelles — Inboard	Nacelles — Center	Nacelles — Outboard
3 LENGTH - MAX. (FT.)				119.7	10.1		10.1
4 DEPTH - MAX. (FT.)				18.3	6.2		6.2
5 WIDTH - MAX. (FT.)				17.7	5.7		5.7
6 WETTED AREA (SQ. FT.)				5519	277 ea		277 ea
*7 FLOAT OR HULL DISPL. - MAX (LBS.)							
8 FUSELAGE VOLUME (CU. FT.)		PRESSURIZED			TOTAL		

	Wing	H. Tail	V. Tail
9	Wing	H. Tail	V. Tail
10 GROSS AREA (SQ. FT.)	1700	632	468
11 WEIGHT/GROSS AREA (LBS./SQ. FT.)	12.4	3.9	5.4
12 SPAN (FT.)	116.6	53.3	23.6
13 FOLDED SPAN (FT.)			
14			
15 SWEEPBACK - AT 25% CHORD LINE (DEGREES)	25	25	39
16 - AT % CHORD LINE (DEGREES)	262.5	203.2	288.7
**17 THEORETICAL ROOT CHORD - LENGTH (INCHES)	32.1	24.4	34.6
18 - MAX. THICKNESS (INCHES)			
***19 CHORD AT PLANFORM BREAK - LENGTH (INCHES)			
20 - MAX. THICKNESS (INCHES)	87.4	81.3	187.7
***21 THEORETICAL TIP CHORD - LENGTH (INCHES)	8.7	6.5	22.5
22 - MAX. THICKNESS (INCHES)			

23 DORSAL AREA, INCLUDED IN (FUSE.) (HULL) (V. TAIL) AREA (SQ. FT.)				
24 TAIL LENGTH - 25% MAC WING TO 25% MAC H. TAIL (FT.) 68.5				
25 AREAS (SQ. FT.)	Flaps	L.E. Wing 159.5	T.E. 285.2 (Planform retracted)	
26	Lateral Controls	Slots	Spoilers 194.3	Ailerons 50.5
27	Speed Brakes	Wing	Fuse. or Hull	
28	Flaps	L.E. Horiz. Tail 99.1		
29		Elevators 200.8	Rudder 104.4	

30 ALIGHTING GEAR (LOCATION)	Nose	Main		
31 LENGTH - OLEO EXTENDED - ℄ AXLE TO ℄ TRUNNION (INCHES)	74.0	67.0		
32 OLEO TRAVEL - FULL EXTENDED TO FULL COLLAPSED (INCHES)	25.0	25.0		
33 FLOAT OR SKI STRUT LENGTH (INCHES)				
34 ARRESTING HOOK LENGTH - ℄ HOOK TRUNNION TO ℄ HOOK POINT (INCHES)				
35 HYDRAULIC SYSTEM CAPACITY (GALS.)				

36 FUEL & LUBE SYSTEMS	Location	No. Tanks	****Gals. Protected	No. Tanks	****Gals. Unprotected
37 Fuel - Internal	Wing		2154		6877
38	Fuse. or Hull				
39 - External					
40 - Bomb Bay					
41					
42 Oil					
43					
44					

45 STRUCTURAL DATA - CONDITION	Fuel in Wings (Lbs.)	Stress Gross Weight	Ult. L.F.
46 FLIGHT		149770	4.5
47 LANDING			
48			
49 MAX. GROSS WEIGHT WITH ZERO WING FUEL			
50 CATAPULTING			
51 MIN. FLYING WEIGHT			
52 LIMIT AIRPLANE LANDING SINKING SPEED (FT./SEC.)			15
53 WING LIFT ASSUMED FOR LANDING DESIGN CONDITION (%W)			
54 STALL SPEED - LANDING CONFIGURATION - POWER OFF (KNOTS)			
55 PRESSURIZED CABIN - ULT. DESIGN PRESSURE DIFFERENTIAL - FLIGHT (P.S.I.)			
56			
57 AIRFRAME WEIGHT (AS DEFINED IN AN-W-11) (LBS.)			

*Lbs. of sea water @ 64 lbs./cu. ft.
**Parallel to ℄ at ℄ airplane.
***Parallel to ℄ airplane.
****Total usable capacity.

6.3.4 PERFORMANCE. Mission performance for the point designs was calculated using the Part 2 ground rules and the original MST requirements; i.e., payload/radius, range, speed, and STOL takeoff and landing distances.

6.3.4.1 EBF Point Designs. The EBF point design was sized using scaled GE13/F2B engines with a rated thrust of 15,075 pounds per engine and a takeoff gross weight of 137,450 pounds for the tactical delivery mission. Estimated mission performance is shown in Tables 6-18 and 6-19. Range/payload and radius/payload plots are shown in Figures 6-18 and 6-19 respectively. Figure 6-20 plots specific range versus gross weight and altitude at the velocity for 99 percent of maximum specific range. Distance and fuel used in climbing from sea level at intermediate power are presented in Figure 6-21, and the STOL takeoff and landing field length versus gross weight is shown in Figure 6-22. STOL performance was calculated using a flap setting of 25 degrees for takeoff and 45 degrees for landing. The landing flap was determined as being the minimum flap deflection that allowed the configuration to stabilize at a reasonable attitude in approach and still meet the 2,000-foot landing field length.

Figure 6-23 shows the waveoff time history of the EBF point design, with all engines operating and with an outboard engine failed. The waveoff performance of this design was investigated using a two-degree-of-freedom digital simulation, which has been verified using piloted simulator data reported in Reference 6-5.

Table 6-18. EBF Radius Missions

	Tactical Delivery (LF = 3.0g)	Overload Case 1 (LF = 2.5g)	Overload Case 2 (LF = 2.5g)
TOGW (lb)	137,450	154,630	154,630
Payload (lb)			
Outbound	28,000	58,000	44,000
Inbound	28,000	0	
Radius (n.mi.)	500	100	475
Fuel (lb)	23,400	10,580	24,580
Landing at Mid-mission (ft)	1,530	1,850	1,720
Takeoff at Mid-mission (ft)	2,000	910	1,060

Table 6-19. EBF Range Missions

	2600 n.mi. Unrefueled (LF = 2.5 g)	Emergency Return (Engine Out)
TOGW (lb)	154,630	96,275
Payload (lb)	24,180	0
Range (n.mi.)	2,600	500
Fuel (lb)	44,400	10,225
Takeoff Distance (ft)	3,500	1,228

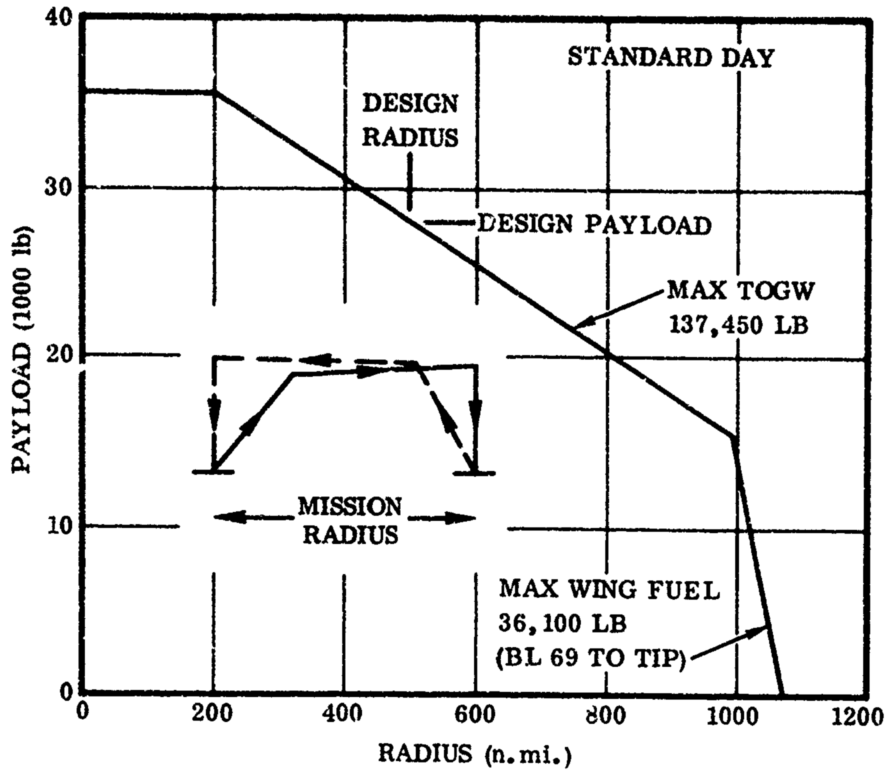


Figure 6-18. EBF Mission Radius Versus Payload

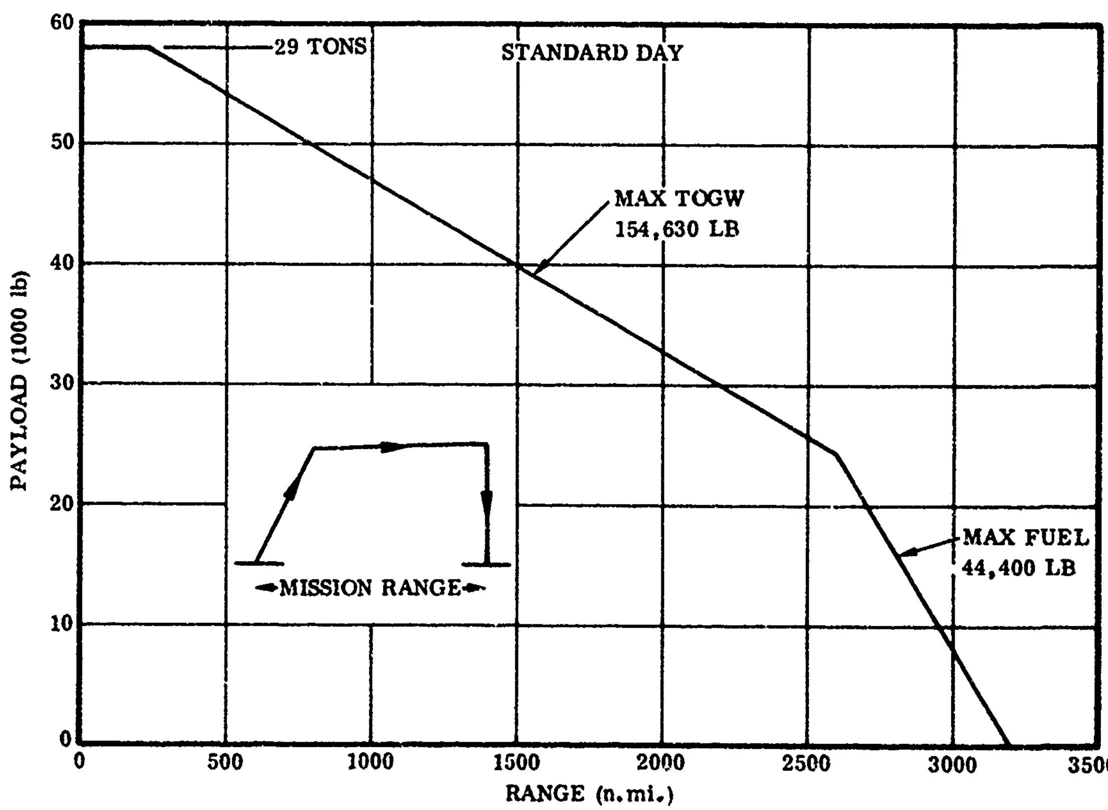


Figure 6-19. EBF Range Versus Payload

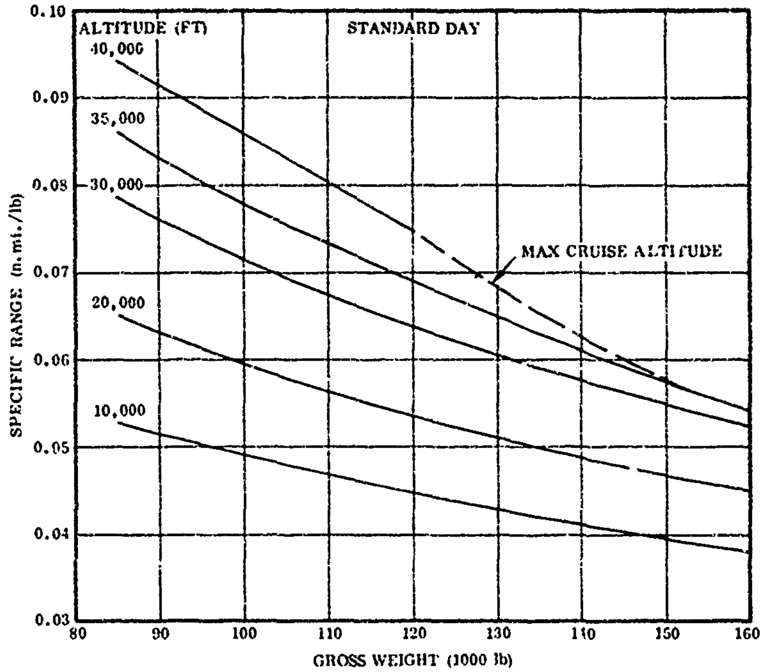


Figure 6-20. EBF Specific Range at Cruise Versus Gross Weight

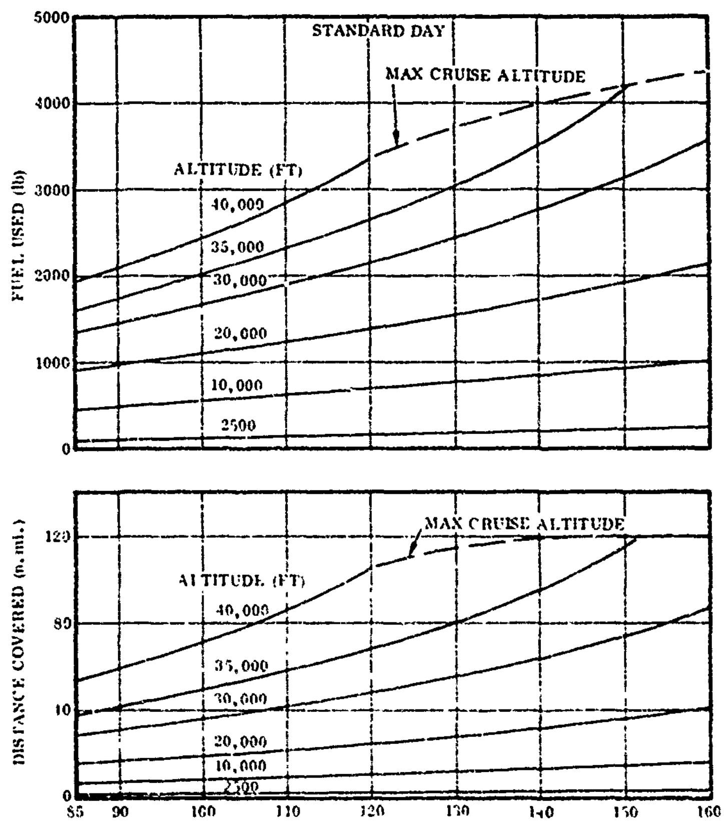


Figure 6-21. EBF Climb Characteristics Versus Gross Weight

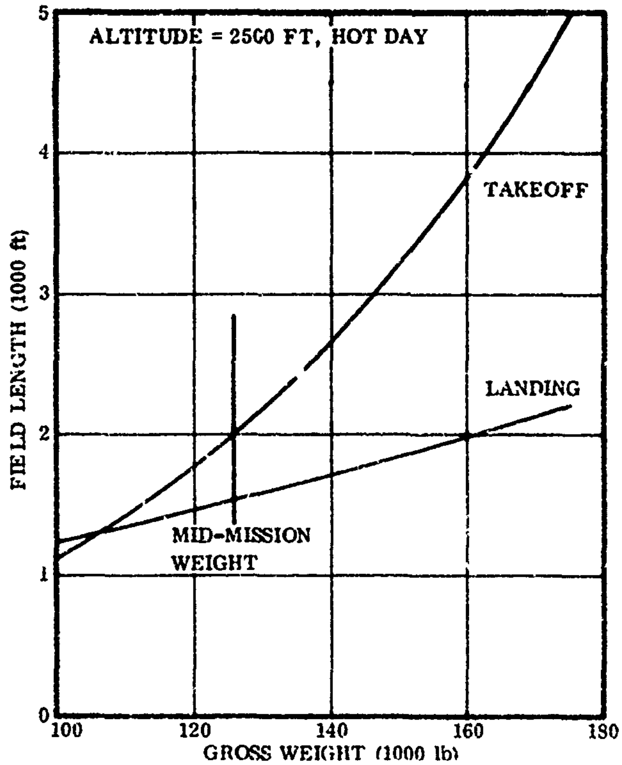


Figure 6-22. EBF Field Length Versus Gross Weight

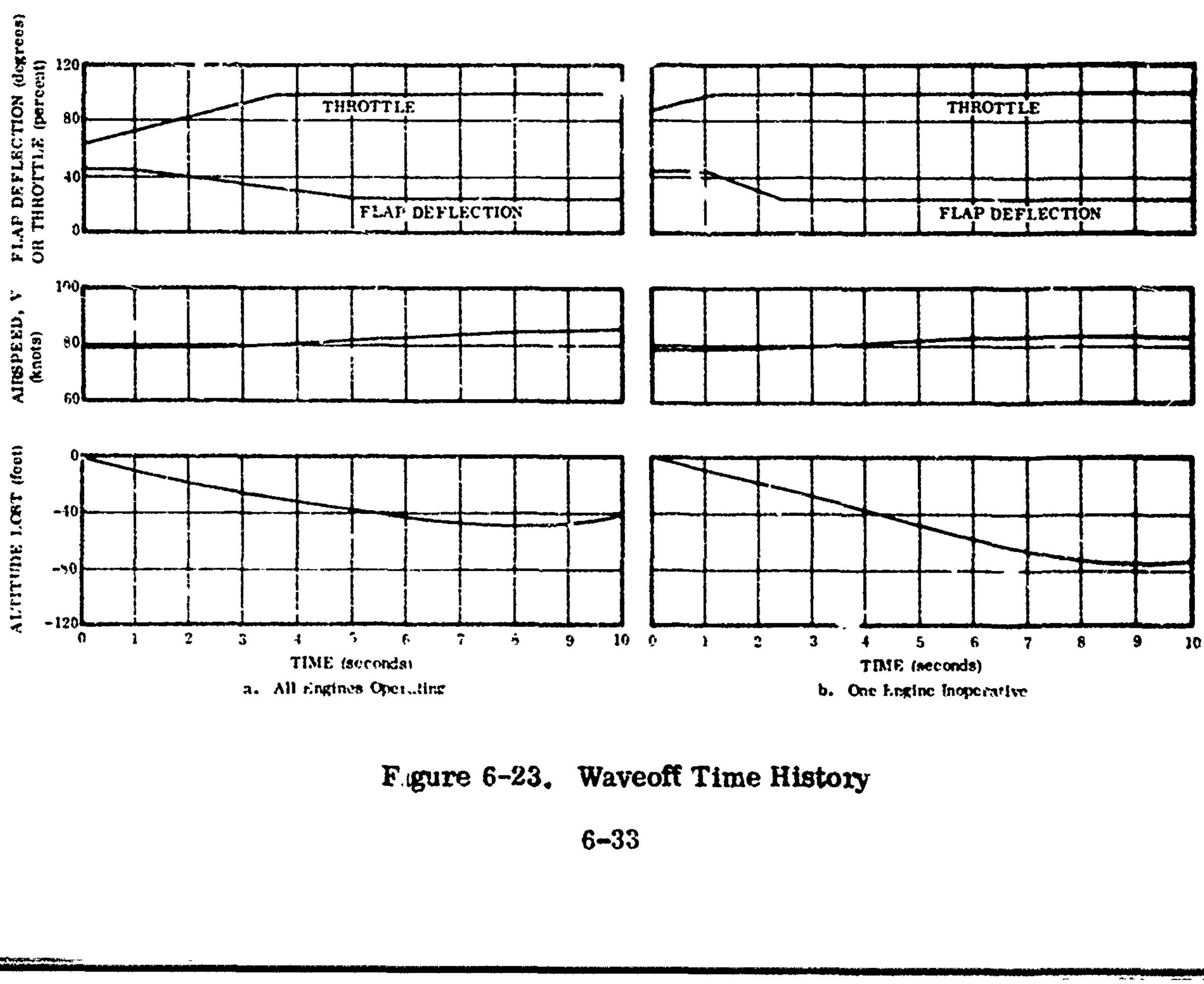


Figure 6-23. Waveoff Time History

6.3.4.2 **MF/VT Point Design.** The MF/VT point design was sized using scaled GE13/F2A engines with a rated thrust of 14,965 pounds per engine and a takeoff gross weight of 140,200 pounds for the tactical delivery mission. Estimated mission performance is shown in Tables 6-20 and 6-21.

Range/payload and radius/payload plots are shown in Figures 6-24 and 6-25, respectively. Figure 6-26 plots specific range versus gross weight and altitude at the velocity for 99 percent of maximum specific range. Distance and fuel used in climbing from sea level with intermediate thrust are shown in Figure 6-27, and the STOL takeoff and landing field length versus gross weight is shown in Figure 6-28. STOL performance was calculated using a flap setting of 25 degrees for takeoff and 45 degrees for landing. Thrust vectoring of 45 degrees is used only during approach and landing flight phases.

Table 6-20. MF/VT Radius Missions

	Tactical Delivery (LF = 3.0g)	Overload Case 1 (LF = 2.5g)	Overload Case 2 (LF = 2.5g)
TOGW (lb)	140,200	157,725	157,725
Payload (lb)			
Outboard	28,000	58,000	44,000
Inboard	28,000	0	0
Radius (n. mi.)	500	120	540
Fuel (lb)	24,220	11,745	25,745
Landing at Mid-mission (ft)	1,850	2,230	2,120
Takeoff at Mid-mission (ft)	2,000	1,000	1,150

Table 6-21. MF/VT Range Missions

	2600 n. mi. Unrefueled (LF = 2.5g)	Emergency Return (Engine Out)
TOGW (lb)	157,725	98,585
Payload (lb)	23,345	0
Range (n. mi.)	2,600	500
Fuel (lb)	46,400	10,405
Takeoff Distance (ft)	3,450	1,362

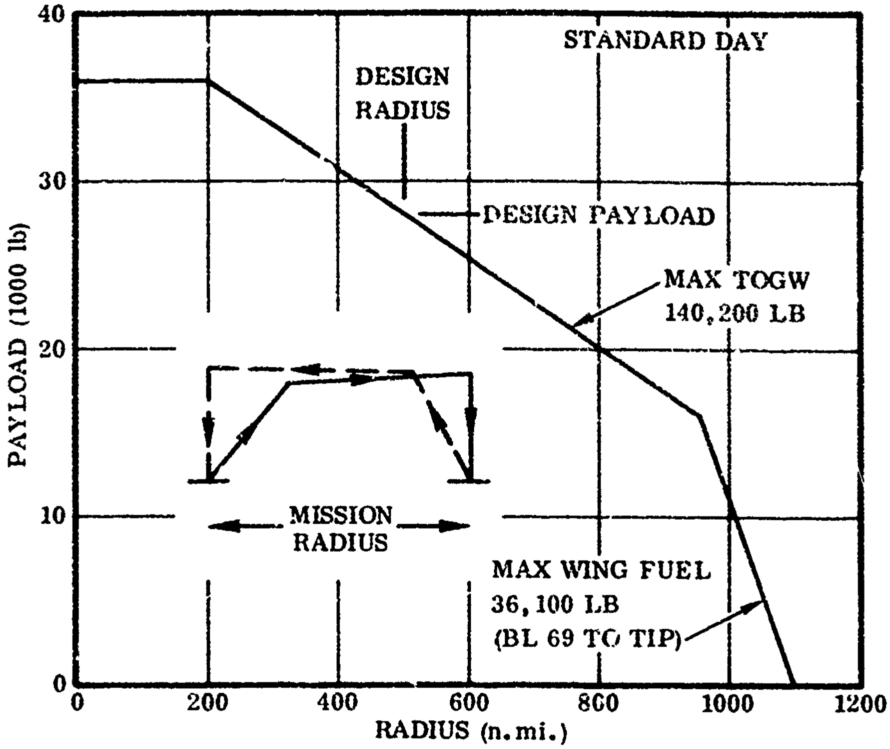


Figure 6-24. MF/VT Radius-Payload

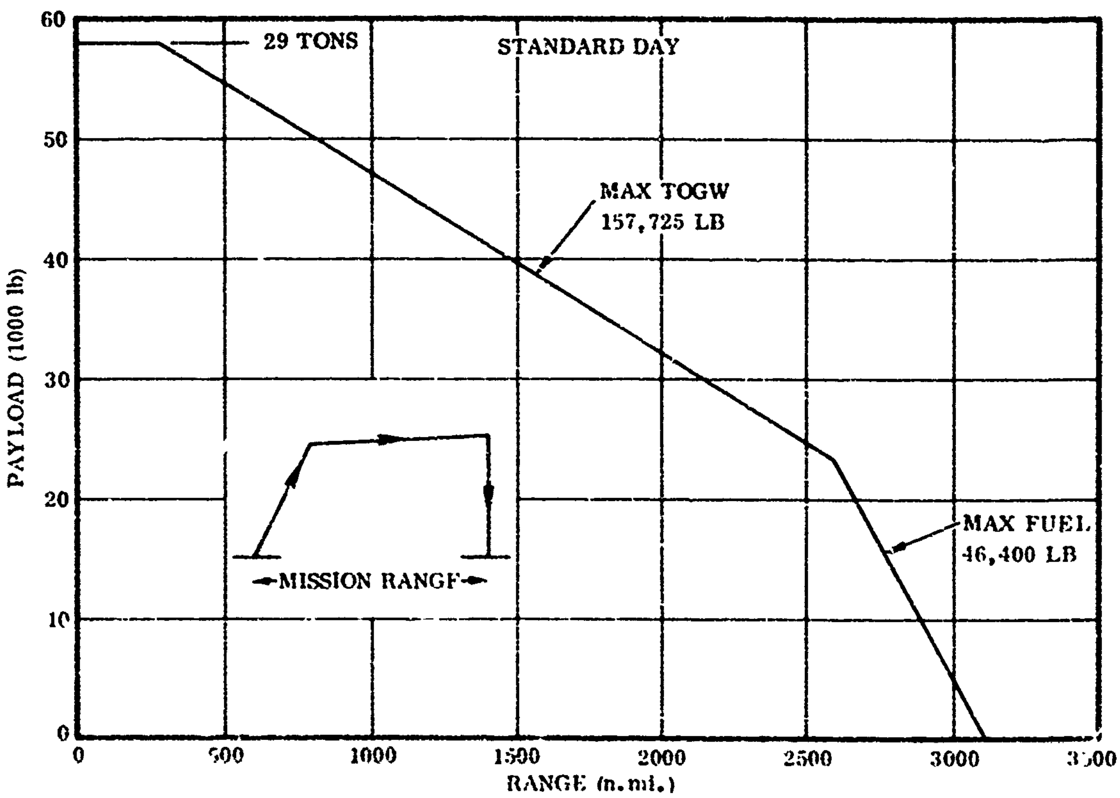


Figure 6-25. MF/VT Range Versus Payload

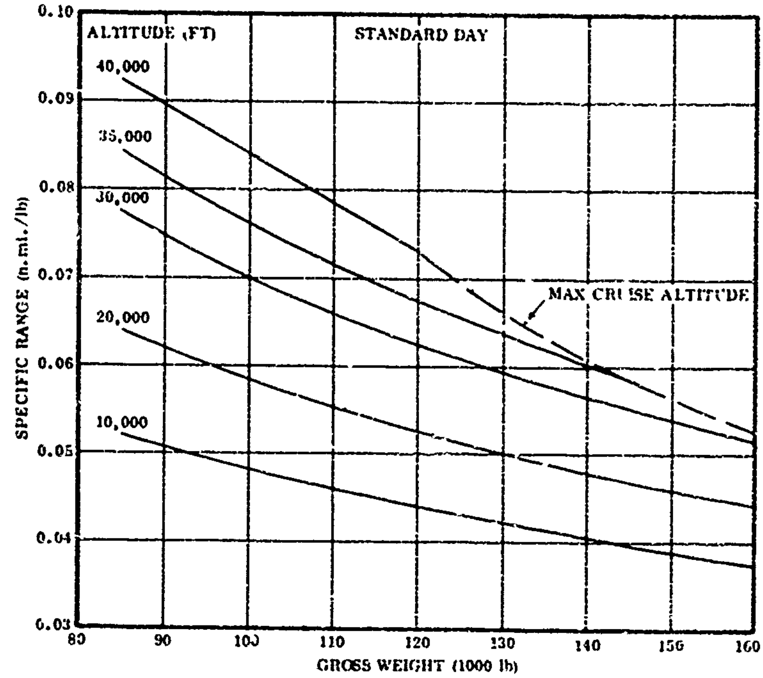


Figure 6-26. MF/VT Specific Range at Cruise Versus Gross Weight

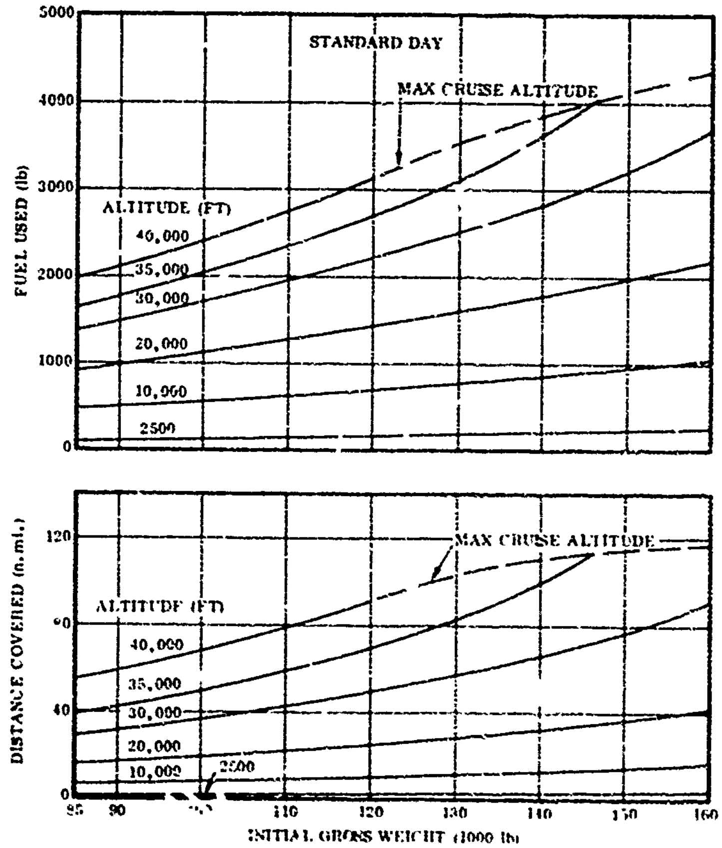


Figure 6-27. MF/VT Climb Characteristics Versus Gross Weight

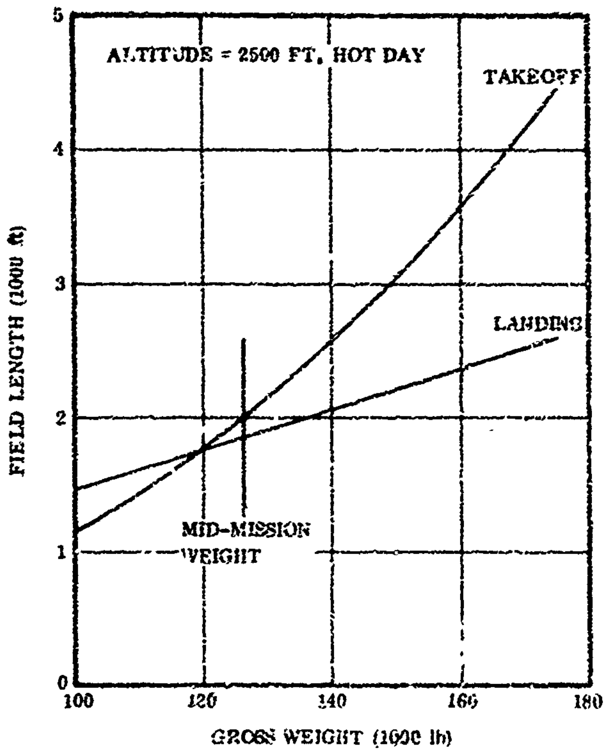


Figure 6-28. MF/VT Field Length Versus Gross Weight

6.3.4.3 IBF/VT Point Design. The IBF/VT point design was sized using scaled Pratt and Whitney STF369 engines with a rated thrust of 13,275 pounds per engine and a takeoff gross weight at 149,770 pounds for the tactical delivery mission. Estimated mission performance is shown in Tables 6-22 and 6-23.

Range/payload and r ˈius/payload plots are shown in Figures 6-29 and 6-30, respectively. Figure 6-31 plots specific range as a function of gross weight and altitude at the velocity for 99 percent of maximum specific range. Distance and fuel used in climbing from sea level using intermediate thrust are shown in Figure 6-32, and the STOL takeoff and landing field length versus gross weight is shown in Figure 6-33. STOL performance was calculated using a flap setting of 26 degrees for takeoff and 50 degrees for landing. The residual fan thrust is vectored to 60 degrees.

Table 6-22. IBF/VT Radius Missions

	Tactical Delivery (LF = 3.0g)	Overload Case 1 (LF = 2.5g)	Overload Case 2 (LF = 2.5g)
TOGW (lb)	149,770	168,490	168,490
Payload			
Outbound	28,000	58,000	44,000
Inbound	28,000	0	0
Radius (n.mi.)	500	200	610
Fuel (lb)	30,300	19,020	33,020
Landing at Mid-mission (ft)	1,810	2,200	2,050
Takeoff at Mid-mission (ft)	2,000	980	1,100

Table 6-23. IBF/VT Range Missions

	2600 n.mi. Unrefueled (LF = 2.5g)	Emergency Return (Engine Out)
TOGW (lb)	168,490	104,780
Payload (lb)	18,190	0
Range (n.mi.)	2,600	13,310
Takeoff Distance (ft)	3,780	1,270

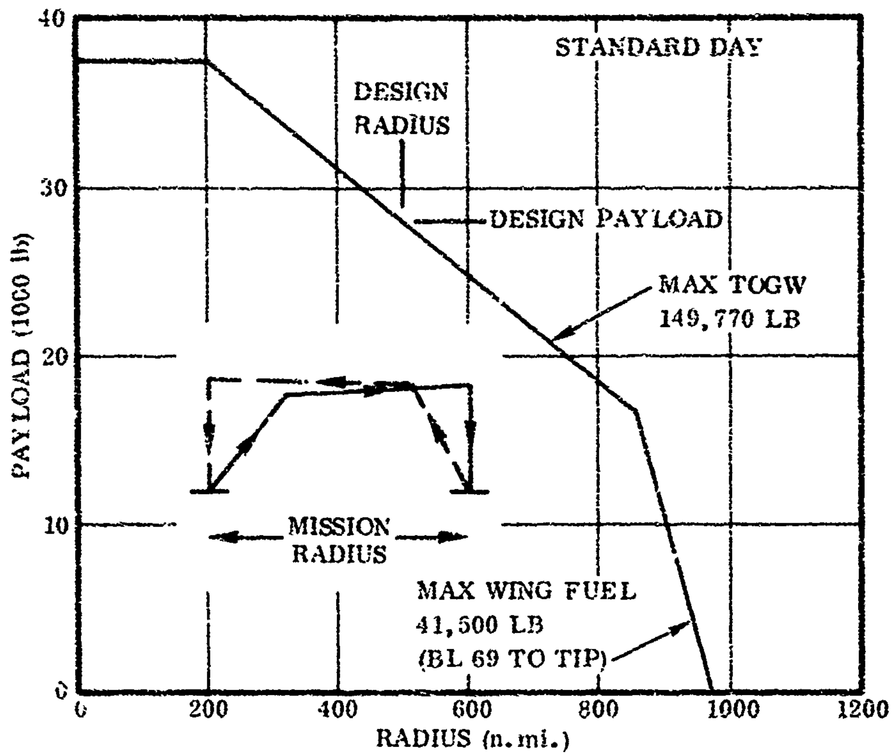


Figure 6-29. IBF/VT Radius Versus Payload

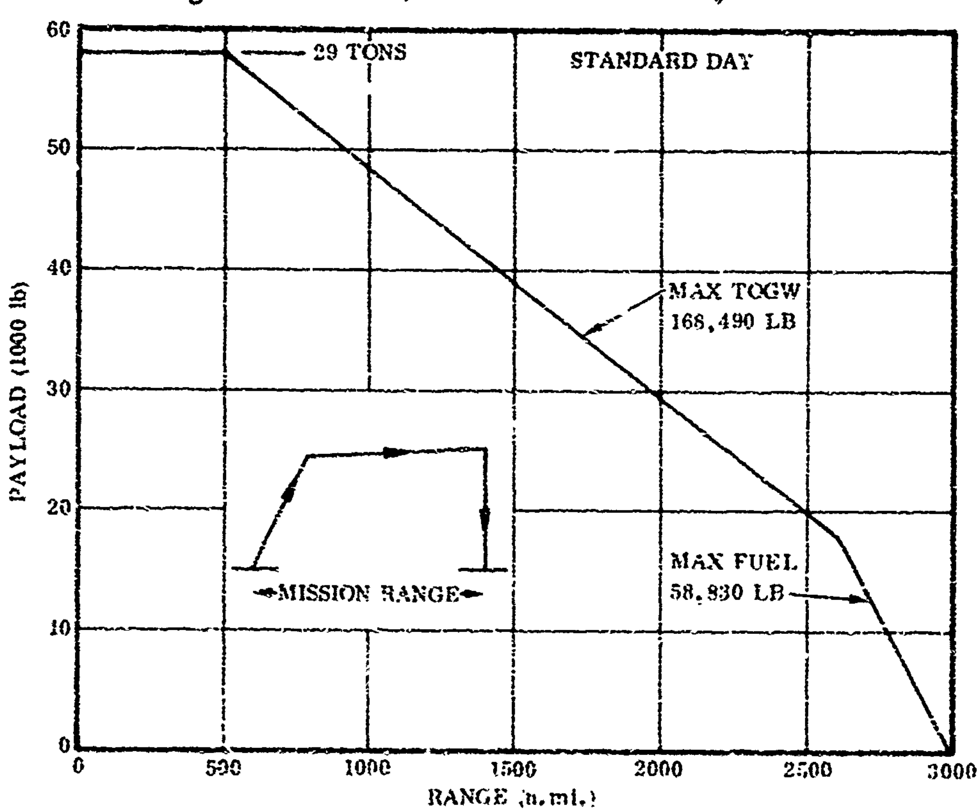


Figure 6-30. IBF/VT Range Versus Payload

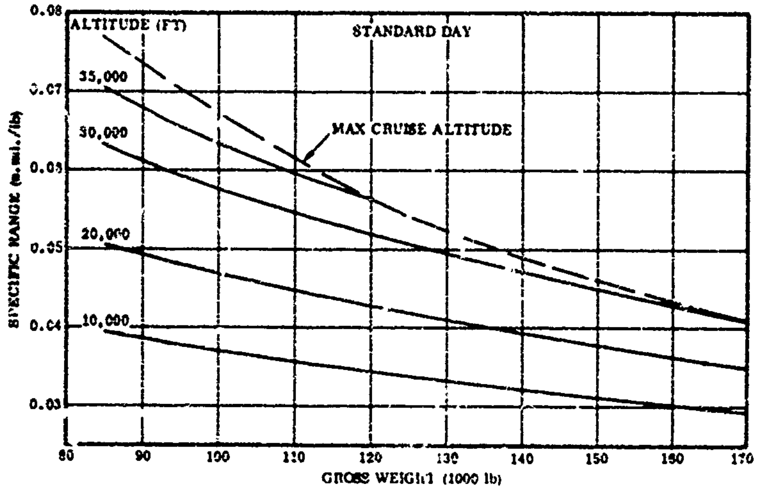


Figure 6-31. IBF/VT Specific Range at Cruise Versus Gross Weight

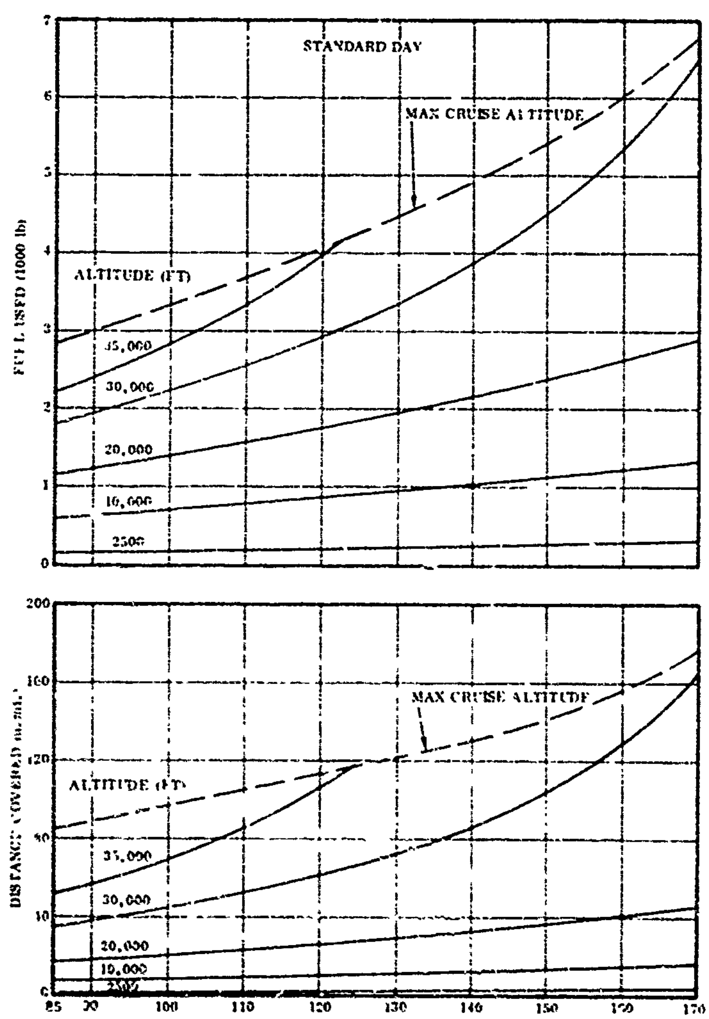


Figure 6-32. IBF/VT Climb Characteristics Versus Gross Weight

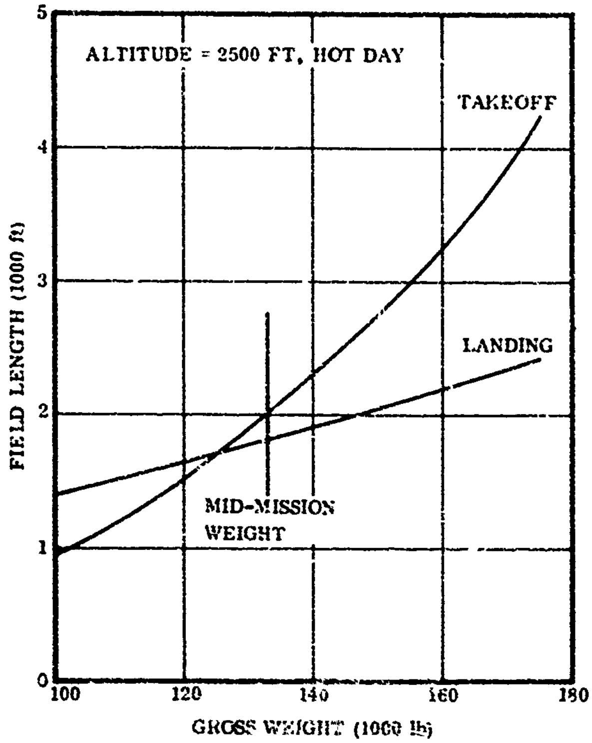


Figure 6-33. IBF/VT Field Length Versus Gross Weight

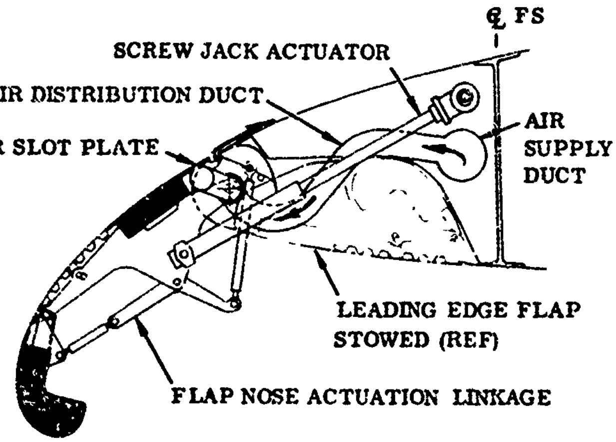


Figure 6-34. Variable Chamber Leading-Edge Flap, Internally Blown

6.3.5 HIGH-LIFT SYSTEMS. High-lift systems for the wing and horizontal tail of each point design have been redefined according to updated requirements and trade-off results. These systems are shown in Figure 6-34 through 6-38 and are discussed in detail in the following paragraphs. Blowing air for the leading-edge flap is still required, but is now supplied by the cruise engines. The requirement for blowing the empennage control surfaces has been eliminated and a leading-edge device (Krueger flap) has been added to the horizontal stabilizer to provide high-angle-of-attack performance to prevent tail stall, (Figure 6-38).

6.3.5.1 Wing Leading-Edge Flap. The internally blown leading-edge flap for all point designs (MF/VT, EBF, and IBF/VT) is identical in geometry, construction, and operation to that of the baseline described in Paragraph 5.2.1. Cruise engines supply BLC air to the distribution duct forward of the front spar, as shown in Figure 6-39 for a typical engine air bleed arrangement. Pressure of the air bled from the fan flow is raised by a turbine-driven compressor (flow multiplier) before introduction into the leading-edge flap BLC duct system.

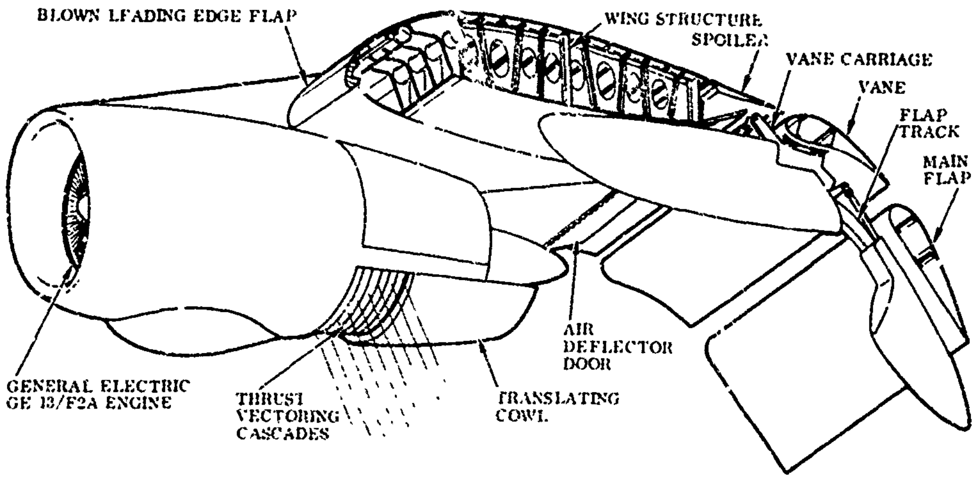


Figure 6-35. MF/VT Double-Slotted Flap

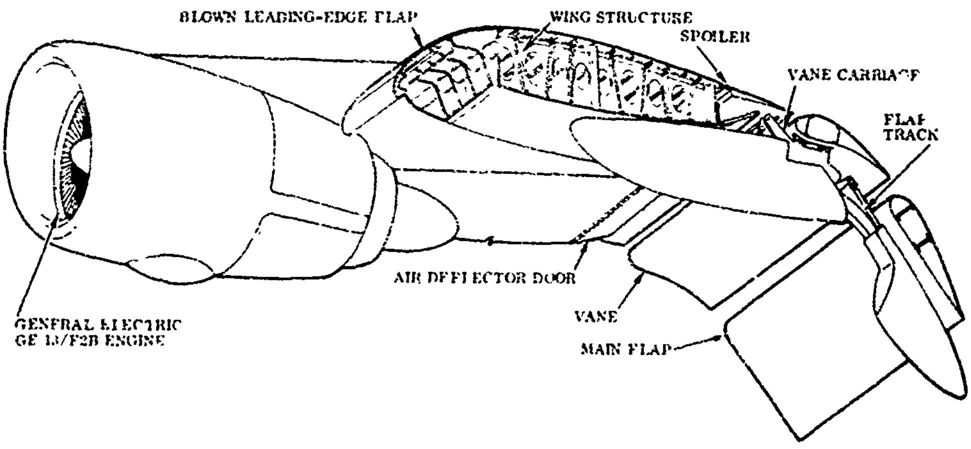


Figure 6-36. EBF Double-Slotted Flap with AUTOSPEED

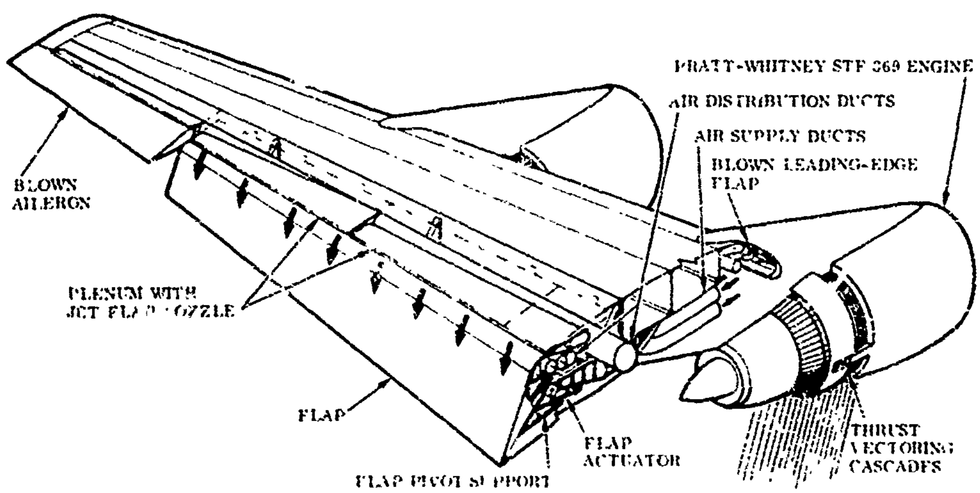


Figure 6-37. IBF/VT Hinged Single-Surface Flap

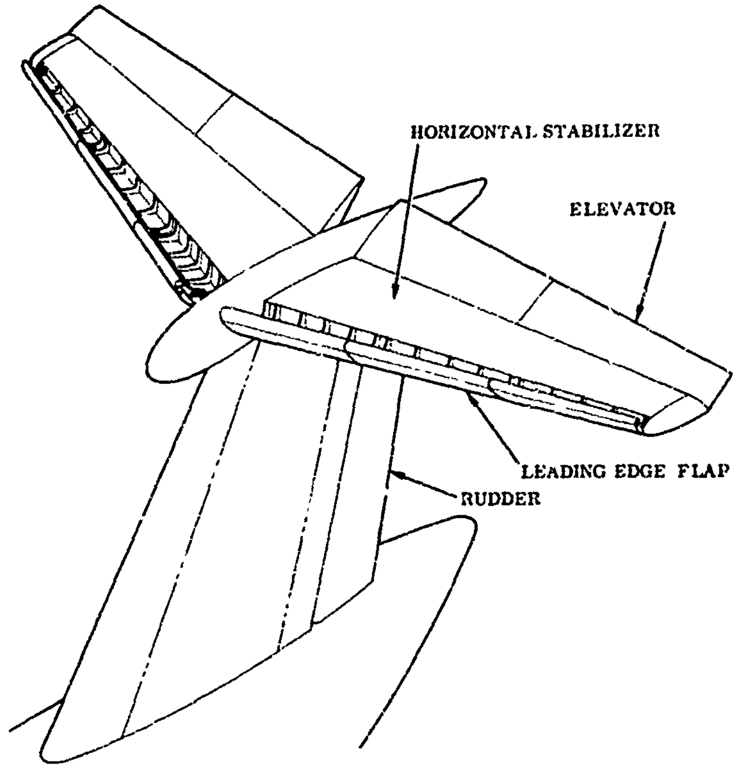


Figure 6-38. Horizontal Stabilizer High-Lift System

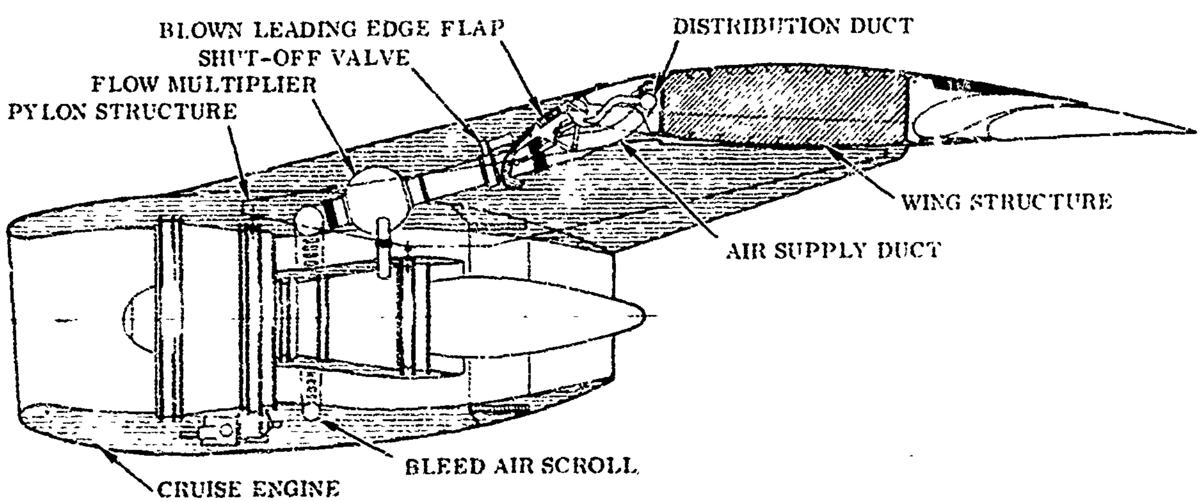


Figure 6-39. Blowing Air Bleed System

6.3.5.2 Wing Trailing-Edge Flaps. The trailing-edge flap configurations for the point designs have been redefined by incorporating the latest performance and flight control requirements:

1. MF/VT: double-slotted flaps
2. EBF: double-slotted flaps with AUTOSPEED
3. IBF/VT: hinged, single-surface flap

In addition to the requirement update, all flap configurations incorporate other design improvements to ensure that the systems will perform efficiently and reliably. The span for each flap configuration remains at 80 percent semi-span. Inboard flap surfaces are essentially end-plated against the fuselage.

6.3.5.2.1 Double-Slotted Flaps. Double-slotted trailing-edge flaps are used on the MF/VT and EBF point designs. For both designs, the structural and mechanical systems of the flaps are identical with respect to geometry, size, shape, and travel. Support structure and actuation mechanisms are similar except for the different design criteria due to loads and operational requirements.

The double-slotted flap used on the EBF configuration is subjected to greater aerodynamic, thermal, and acoustic loading than the MF/VT flap version. Consequently, the double-slotted flap and support structures for the EBF are designed to those requirements and will differ in structural element arrangements and materials.

Functionally, the EBF flap system incorporates an AUTOSPEED capability that permits a ±10 degree high-rate rotation of the flap from the nominal 45-degree landing position. Since the basic flap mechanism for MF/VT and EBF designs positions the flap by rotation between the nominal 30-degree takeoff and 45-degree landing deflections, the AUTOSPEED capability is inherent in the flap mechanism design. Therefore, the flap system on the EBF differs from that of MF/VT by having an AUTOSPEED control subsystem integrated into the basic flap control.

The double-slotted flap produces wing chord increases, c_1/c, of 1.458 and 1.486, respectively, when fully extended to the nominal 30-degree takeoff and 45-degree landing positions. Flap and mechanism geometry is shown in Figure 6-40.

Both double-slotted flap systems (MF/VT and EBF) are shown in Figure 6-41. Spanwise, the flap elements (vane and main flap) are sectioned into two structurally separate groups for each wing. The inboard and outboard flap element groups are joined with a slip joint at the No. 2 track and carriage assembly of the mechanism. This slip joint is designed to permit sufficient freedom of motion between adjacent groups of flap elements to alleviate the effects of wing bending as well as to accommodate lateral slippage during operation.

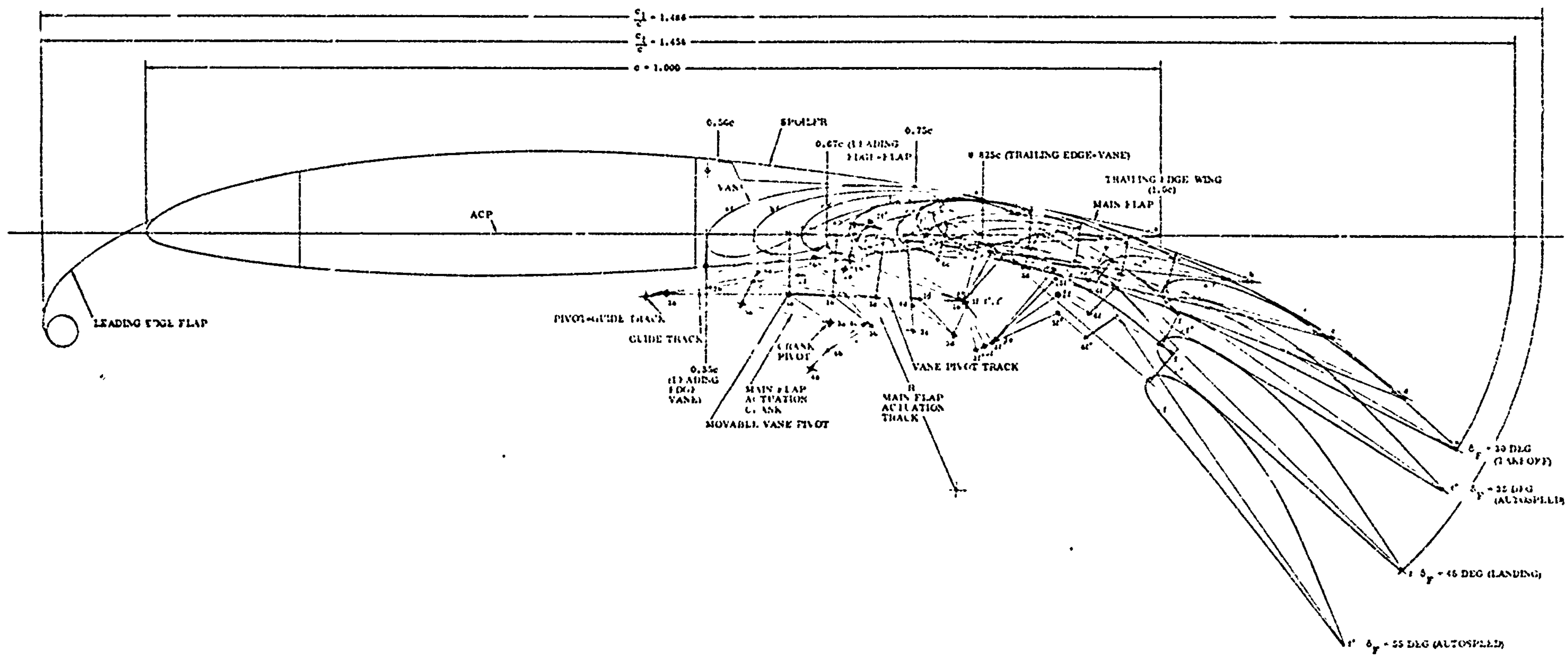


Figure 6-40. Double-Slotted Flap and Mechanism Geometry

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See the following pages
for greater detail.
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See the following pages for greater detail

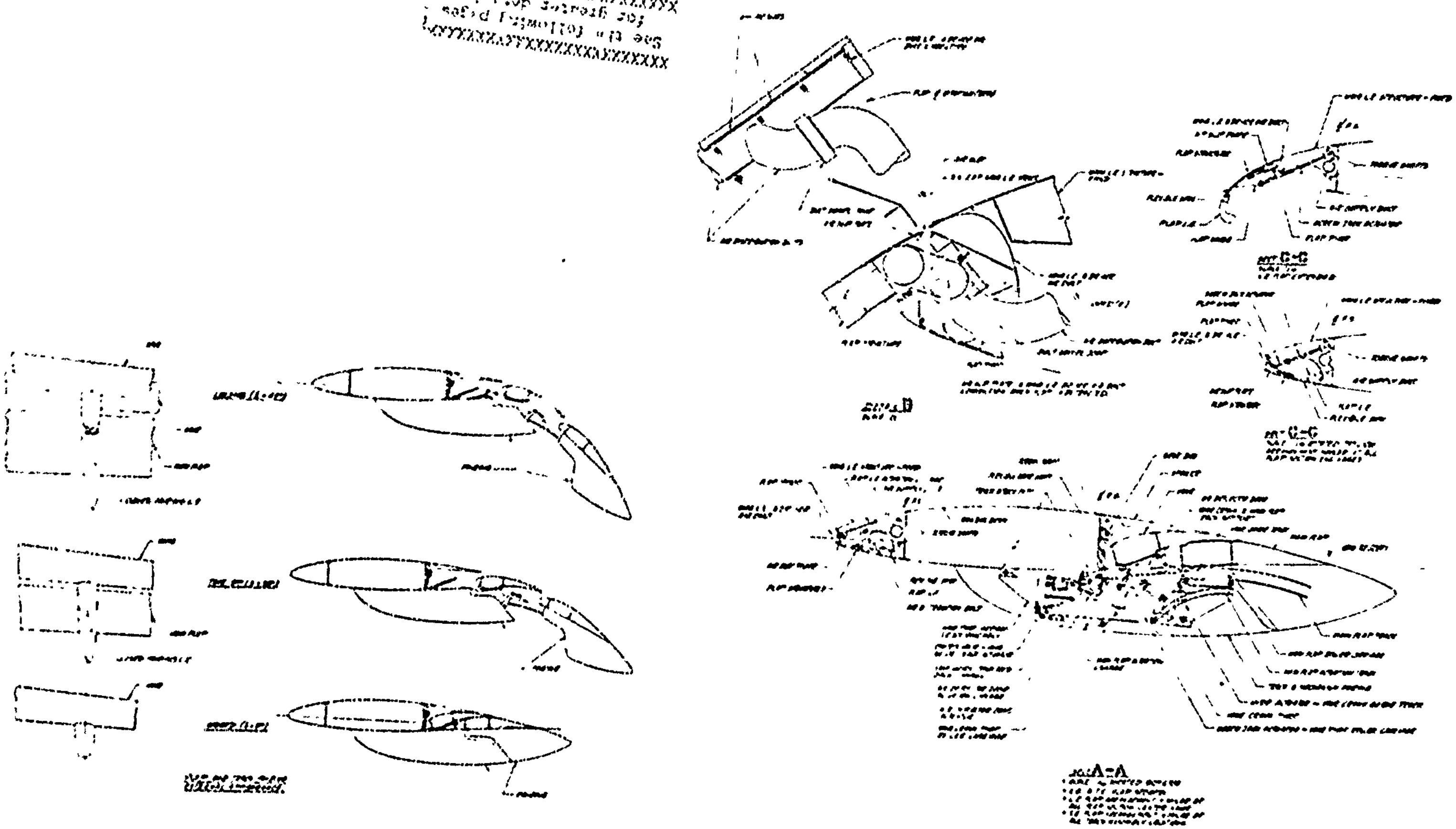


Figure 6-41. General Arrangement, Wing High-Lift System, Internally Blown Leading-Edge and Externally Blown Trailing-Edge Flaps, Updated EBF Baseline, Sheet 1

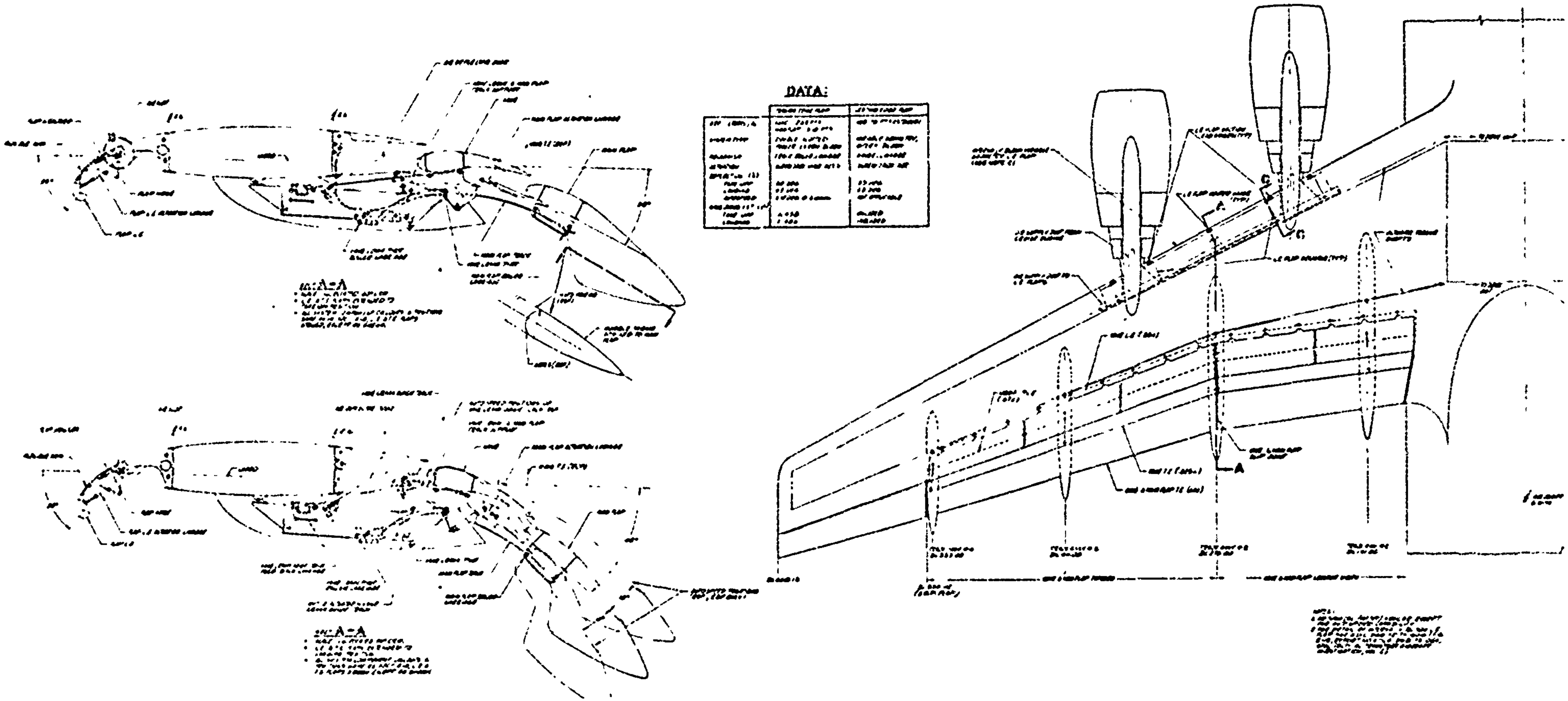


Figure 6-41. General Arrangement, Wing High-Lift System, Internally Blown Leading-Edge and Externally Blown Trailing-Edge Flaps, Updated EBF Baseline, Sheet 2

See the following pages for greater detail.

The inboard and outboard flap element groups of each wing are supported by four track-and-roller-guided carriage assemblies mounted beneath the wing and flap elements. Each flap support and mechanism assembly consists of a vane pivot carriage that is moved along the vane carriage track on rollers by a screw jack actuator. A crank assembly (to which the vane, main flap track, and main flap actuation linkage is mounted) is rotatibly attached to the vane pivot carriage. The forward end of the vane crank engages the vane guide track with rollers. Since the slope of the guide track rises with respect to the carriage track, the entire vane crank, vane, main flap, and flap track assembly is rotated down while being translated aft. Simultaneously, the main flap is moved along its track by the actuation linkage, whose crank is being rotated through engagement of the main flap actuation track with a roller.

Actuation through 30 to 45 degrees and AUTOSPEED positions (EBF point design only) is by a hydraulic actuator that rotates the vane crank guide track, thus rotating the entire vane and flap group. Operation of the crank guide track is controlled by a hydraulic servo linked to the guide track with a position feedback linkage.

The lower wing surface panel aft of the rear spar is hinged along its forward edge and rotated upward during flap extension to improve airflow through the slots of the flap elements. A linkage, driven by a worm gear box located in the vane carriage track, actuates the air deflector door. Power to the air deflector door gear box and to the vane pivot carriage screw jack is transmitted from a spanwise torque shaft behind the wing's rear spar through flexible shafts.

The flap support and mechanism assemblies are housed in fairings below the wing. The aft portion of the fairing, attached to the main flap, is closed off at its forward end to prevent ram pressure build-up within that fairing portion when it is exposed to the slipstream and engine gas flow during high flap deflections.

The spanwise torque shafts behind the rear spars of each wing are powered by a drive unit, located behind the center spar box in the fuselage. Power is supplied by a hydraulic motor, backed up by an electric motor for auxiliary operation. A revolution counter on the torque shaft output of the drive unit indicates flap positions to the vane guide track actuator servo for operation between the nominal 30-degree takeoff and 45-degree landing flap positions.

6.3.5.2.2 Hinged, Single-Surface Flap. The IBF/VT point design incorporates a redefined wing trailing-edge flap that permits installation of the blowing air ducts aft of the rear spar of the wing box beam without compromising the chord length of the flap.

A wiper fairing, arranged concentrically with the center line of rotation of the flap, is attached tangentially to the nozzle lip of the blowing air plenum. This wiper fairing forms the close-out member of the fixed wing trailing-edge structure forward of the flap and creates additional space within the wing contour for blowing air ducts. Figure 6-42 shows a cross-section of the internally blown wing trailing-edge flap.

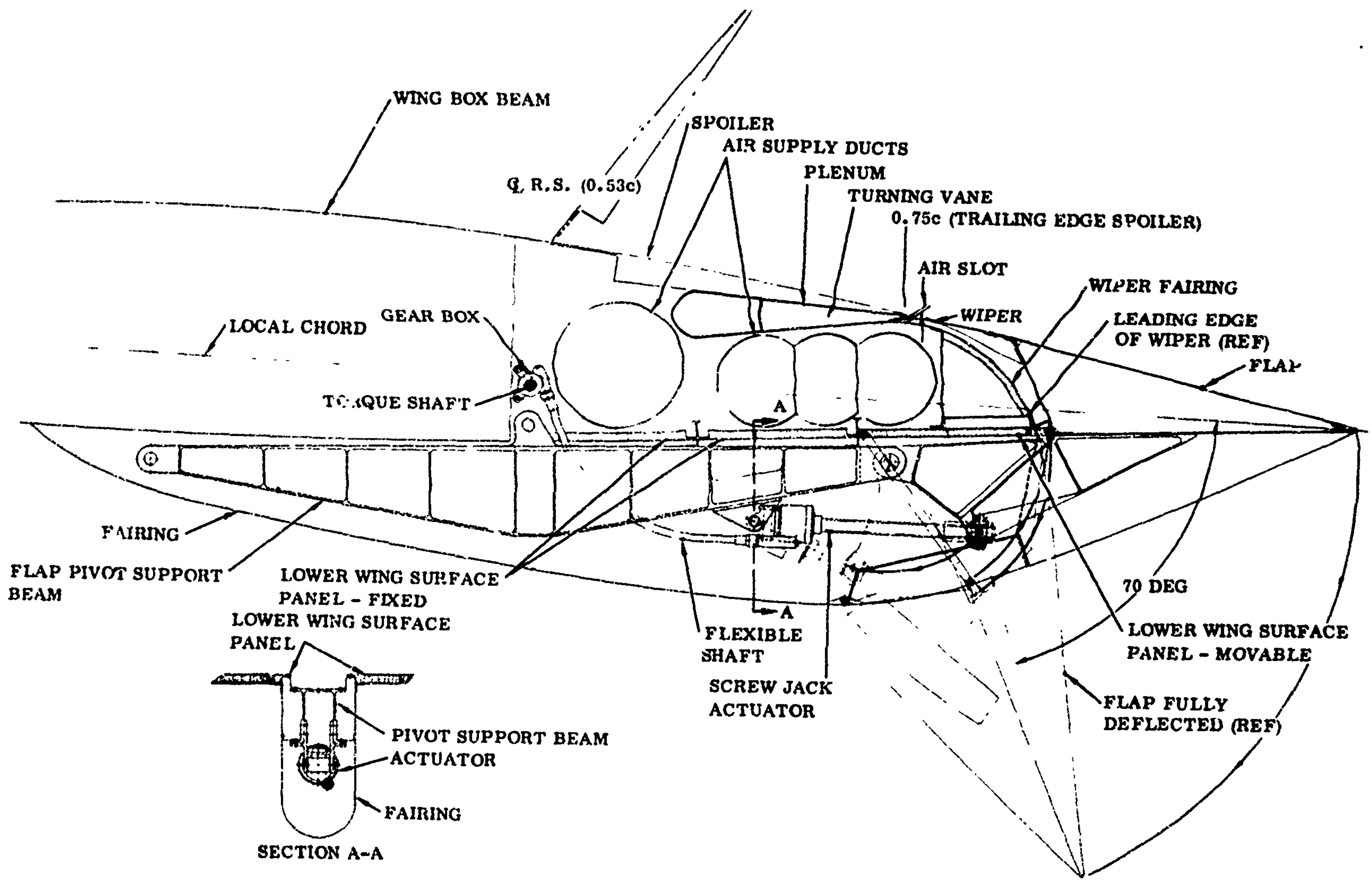


Figure 6-42. Hinged, Single-Surface Blown Flap, IBF/VT

As the flap rotates through its prescribed deflection, the wiper remains in contact with the wiper fairing. The fairing surface is concentric with the flap's centerline of rotation and forms part of the total flap surface to which the air sheet, ejected from the plenum's nozzle, adheres.

The flap is supported by four pivot supports on each wing and is segmented into two structurally separate spanwise sections to alleviate the effects of wing bending on the deflected flap. At each pivot support, a screw jack actuator is used to rotate the flap. Underwing fairings enclose the actuators and pivot support fittings.

Flap blowing air is supplied by the cruise engines through a duct system to the plenum chambers located above the wiper fairing and beneath the wing trailing-edge spoilers. Distribution ducts of both wings, aft of the rear spar, are interconnected to equalize the airflow.

Power to the screw jack actuators at each flap pivot support is transmitted by flexible shaft from a spanwise torque shaft aft of the rear spar. The torque shafts of both wings are driven by a centrally located drive unit that has a hydraulic motor as its primary power source and an electric motor for auxiliary operation.

6.3.5.3 Horizontal Stabilizer Leading-Edge Flap. Horizontal stabilizers of the updated point designs of all lift/propulsion concepts incorporate a full-span Krueger flap in the top surface of the leading edge. Figures 6-43 and 6-44 show a system cross-section and general arrangement, respectively.

Each side of the stabilizer mounts three structurally separate flap sections. A flap section consists of a surface panel that is hinged near the leading edge of the stabilizer from three fittings. The two hinge fittings near the flap's ends incorporate screw jack actuators that rotate the flap open (or closed) while the flap leading-edge actuation linkage is mounted on the center hinge fitting.

The flap leading edge is hinged from the flap's surface panel and is actuated into alignment with it when the flap is being extended. When retracted, the surface panel forms the upper stabilizer leading-edge surface and the flap's leading edge is rotated inward. Synchronous operation of all flap sections is produced by spanwise torque shafts that connect with all screw jack actuators. A hydraulically powered drive unit, located inside the stabilizer center fairing, drives the torque shafts. For auxiliary operation, the drive unit is equipped with an electric motor.

6.3.5.4 Thrust Vectoring. The updated point designs of the MF/VT and IBF/VT point designs incorporate engine thrust vectoring to augment lift. Fixed, annular cascade gas flow diverters have been selected for the thrust vectoring device. Because of their similarity in design to existing engine thrust reversers, the technical risks in the development of these devices appears low. Also, system weight can be kept at a minimum.

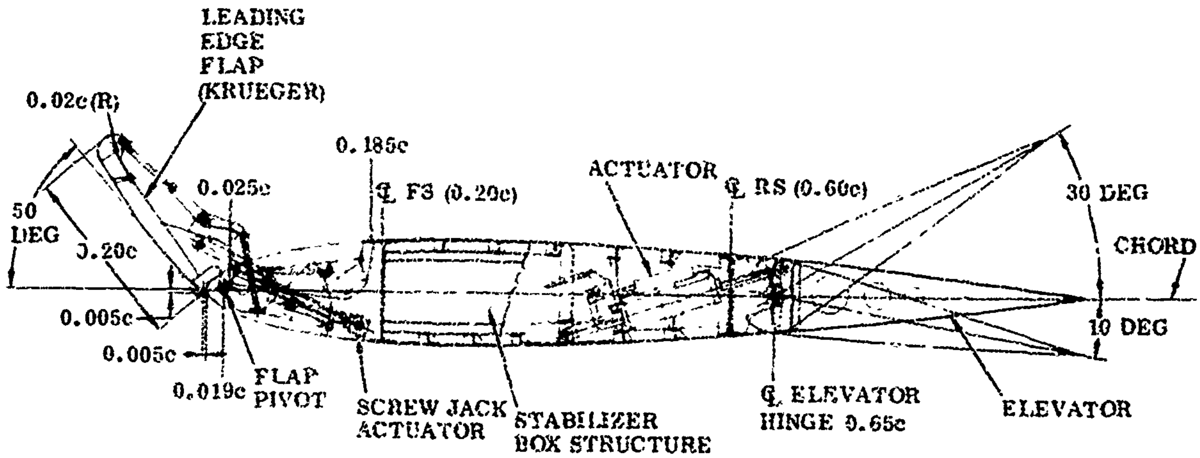


Figure 6-43. Leading-Edge Flap, Horizontal Stabilizer, High-Lift System

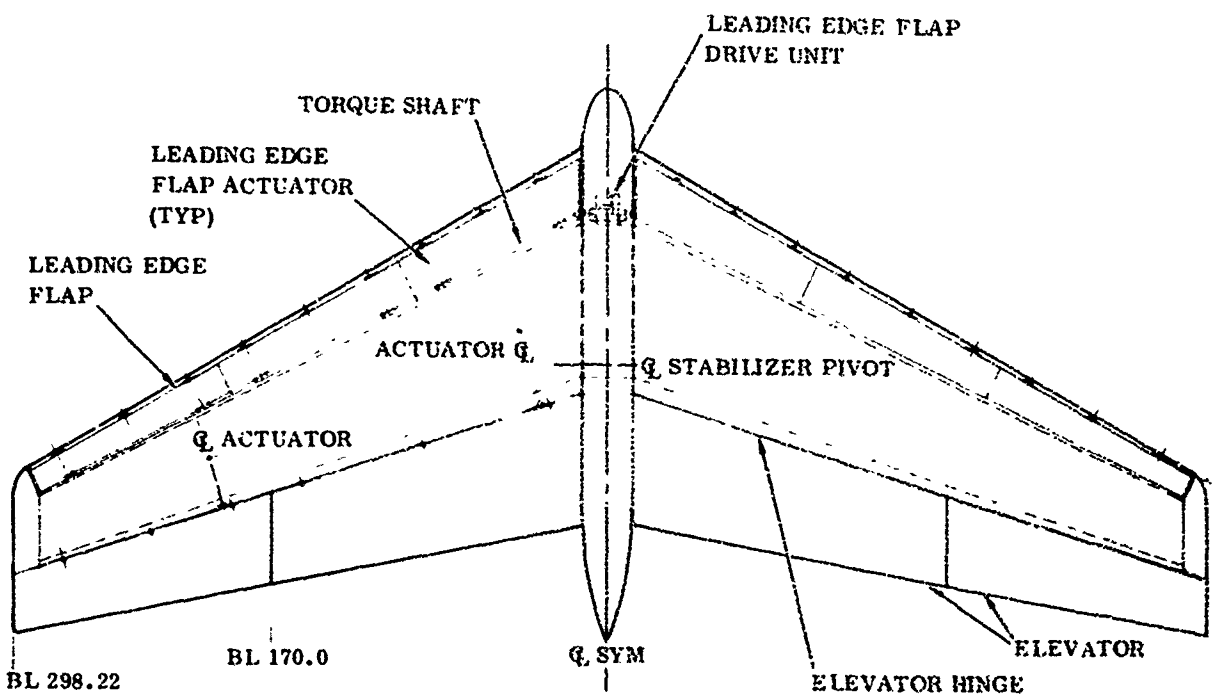


Figure 6-44. General Arrangement, Leading-Edge Flap, Horizontal Stabilizer, High-Lift System

The vectoring cascades are mounted in the nacelle structure in the lower 120-degree sector only. During normal engine and thrust-reversal operations, the vectoring cascades are covered by a translating portion of the nacelle that blocks the gas flow through them. For vectoring operation, the cascades are uncovered by the translating nacelle fairing. Inside the engine duct, peripheral blocker doors divert engine gas flow through the cascades.

The General Electric GE 13/F2A engine of the MF/VT point design is a mixed-flow engine, and the vectoring cascades are located in the nacelle structure aft of the gas generator exhaust to utilize the combined flow. Figures 6-45 and 6-46 show the external appearance of the nacelle and a cutaway of the system, respectively.

For the Pratt-Whitney STF 369 separate-flow engine of the IBF/VT point design, only the fan flow is used for thrust vectoring. Figures 6-47 and 6-48 show the operation of the system. The performance tradeoffs to determine the simplest and lightest vectoring system for the IBF/VT are shown in Figure 6-49. Fan vectoring was selected as the basic system for the IBF/VT. It supplies the required vector thrust so that landing distances are not critical and the aircraft on final approach in the landing configuration is controlable.

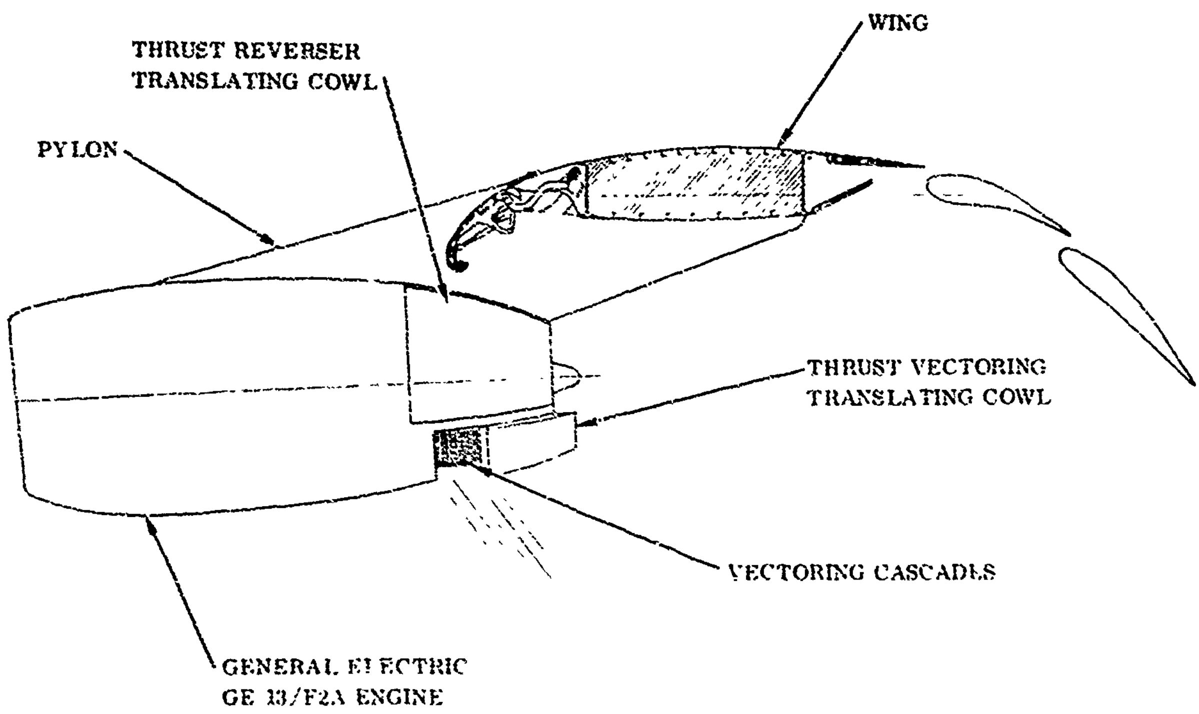


Figure 6-45. MF/VT Thrust Vectoring, Engine Nacelle External Appearance

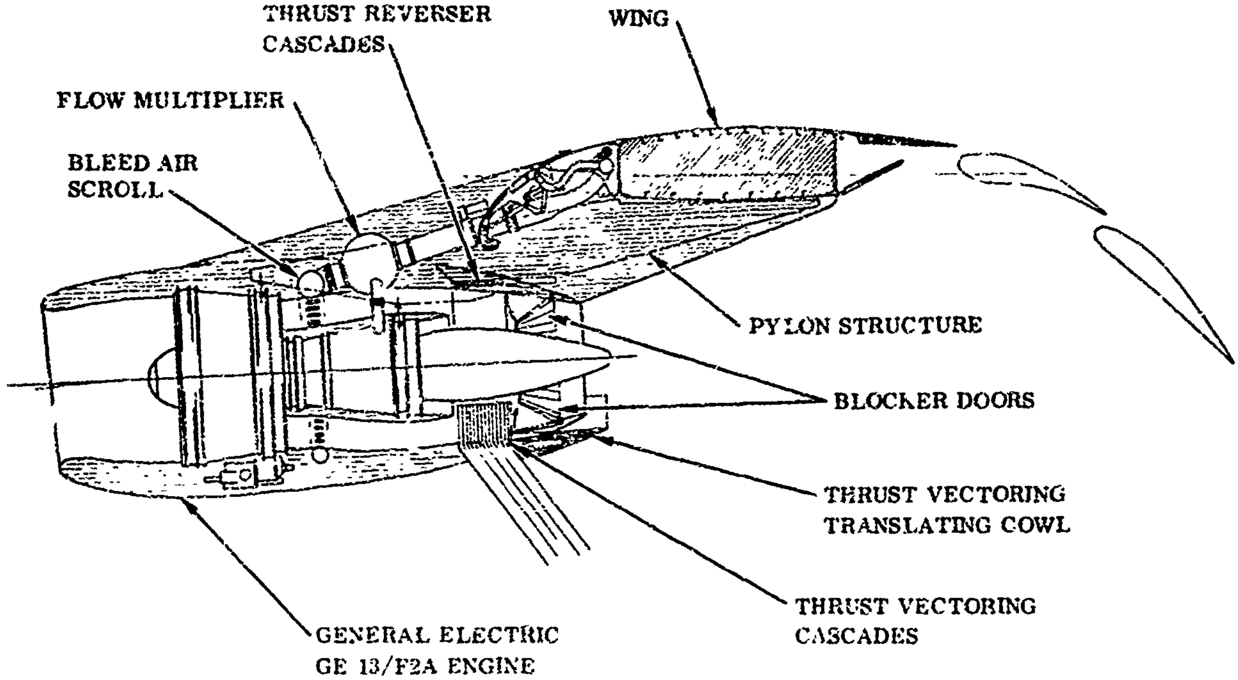


Figure 6-46. MF/VT Thrust Vectoring, System Operation

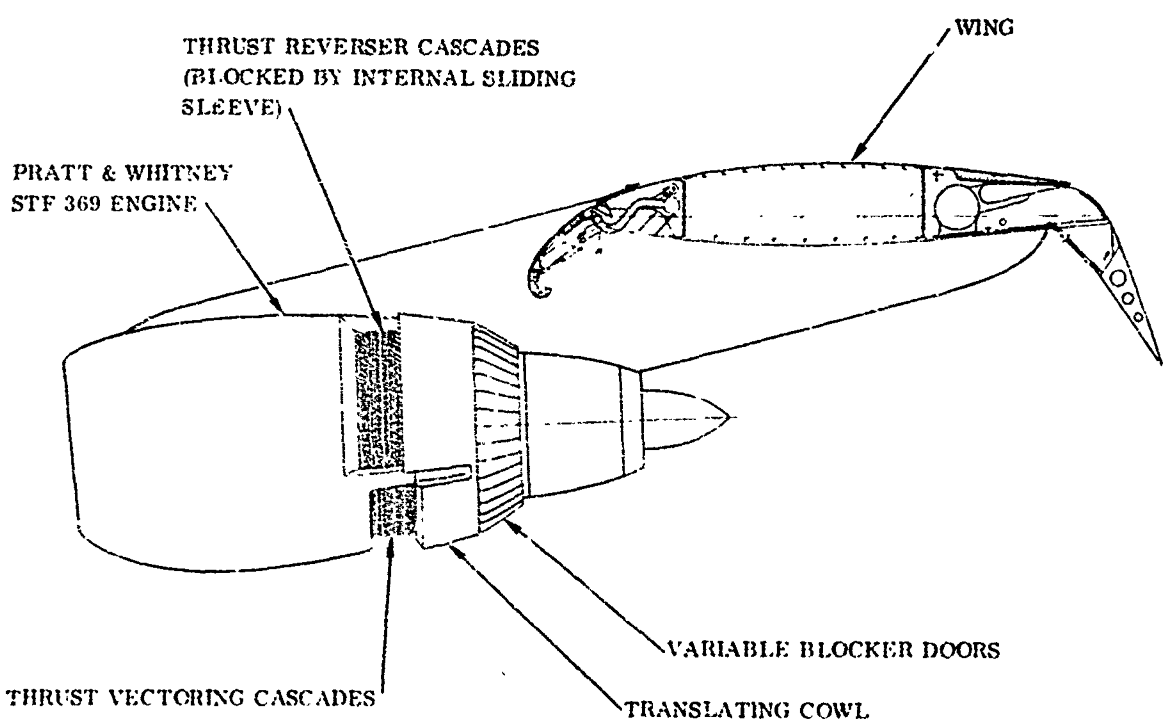


Figure 6-47. IBF Thrust Vectoring, Engine Nacelle External Appearance

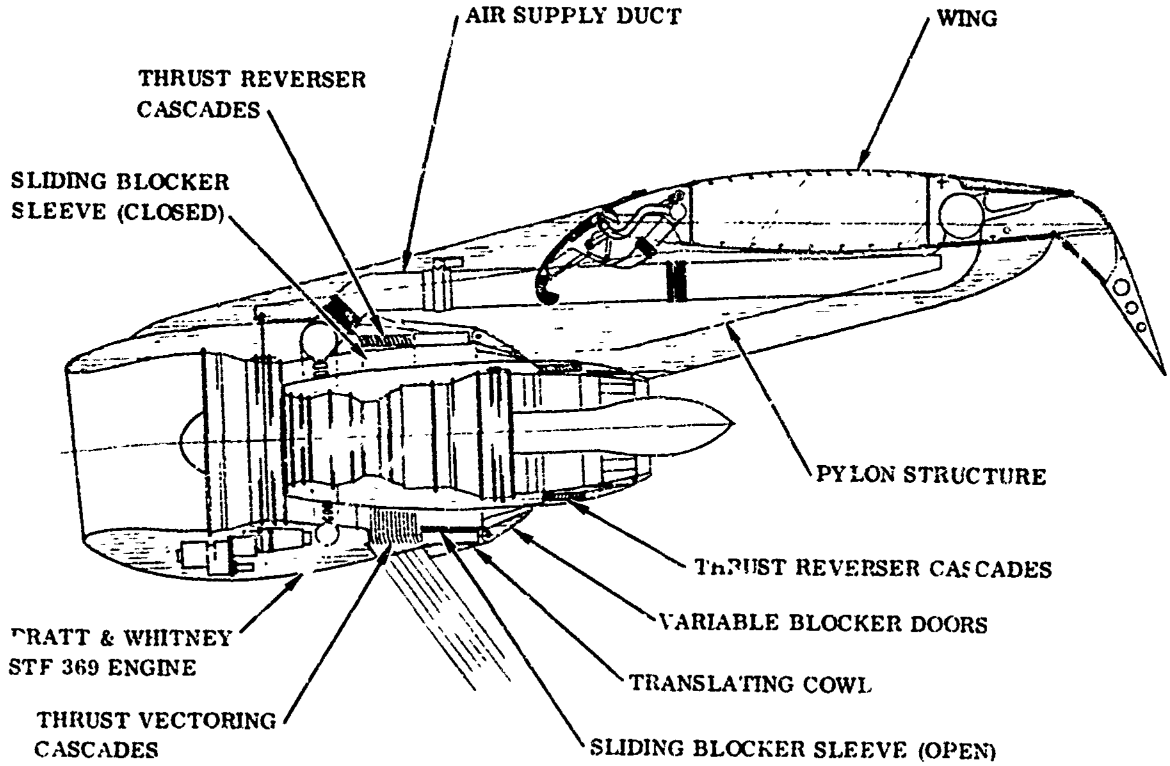


Figure 6-48. IBF Thrust Vectoring, System Operation

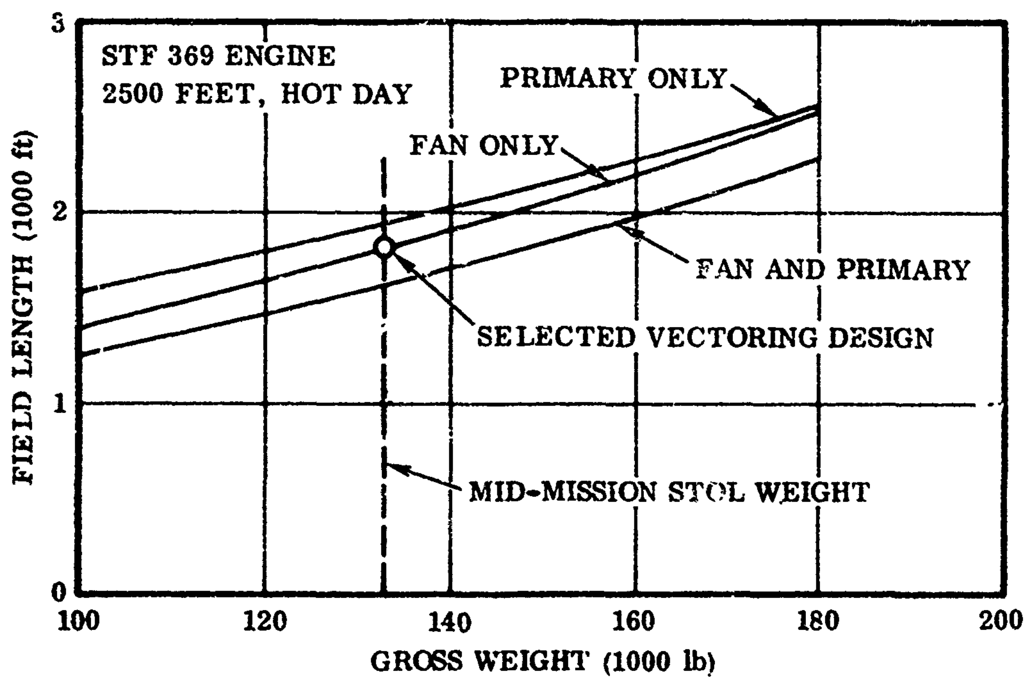


Figure 6-49. Effect of Vectoring the Fan and or Primary Flow on IBF/VT Landing Distances

6.3.6 FLIGHT CONTROL SYSTEM. The flight control system for the EBF configuration has been updated to reflect the latest flight control requirements. This control system with minimum revisions is also applicable to the IBF/VT and the MF/VT configurations. The similarity in the control systems resulted in part from a design objective to keep the pilot tasks as simple as possible. One feature was to avoid the added complexity of a separate thrust-vectoring control lever. Thrust vectoring was slaved to the nominal flap deflection angle for the IBF/VT and MF/VT configurations. The simulated flight evaluations demonstrated that the EBF flight control scheme was suitable for the other two configurations except for the gain changes in the decoupling circuits.

In essence, the revised flight control system is an electrical flight control system with certain secondary control functions provided through conventional hydromechanical methods. The electrical or fly-by-wire system resulted from the control mechanization trade study, which recognized that a number of control parameters are sensed electrically and require switching, scheduling, and filtering to provide the necessary augmentation. A particularly attractive feature of the electrical control concept is its flexibility for adjustment to implement developmental solutions and to adapt to alternate STOL configurations. Other basic advantages include lighter control system weights, improved survivability, and elimination of control friction, hysteresis and compliance problems.

Functional relationships for the fly-by-wire implementation are presented in Figures 6-50 and 6-51. The design very closely follows the baseline EBF flight control scheme except that now the system is implemented electrically. Gains and filter characteristics are probably somewhat different for the three configurations and are shown in general form only. Definition of these values would require further analysis and simulated flight evaluation using the updated configuration data.

Neglecting redundancy for the moment, the implementation of the electrical flight control system should be discussed. In the longitudinal system, Figure 6-50, pitch commands are input with side-by-side center sticks. This preferred type of control device proved suitable to the pilots during the simulator evaluations. However, this type of device is not critical for the fly-by-wire control system and could as easily be a control column with wheel, a single sidestick or even dual sidesticks. Alpha and beta sensors are assumed to be conical airflow-detector-type probes mounted well forward on the fuselage. Power control is provided through a single power lever at each pilot station. If differential power is required for ground maneuvering, it will be achieved with individual power controls that are used only on the ground. The pitch attitude hold function depicted in Figure 6-50 is provided with a pitch rate gyro and an integrator (used for pitch trim changes also). The suitability of this scheme versus the use of an attitude reference is subject to practical factors such as rate gyro threshold and integrator drift characteristics. However, the electrical control format does permit developmental modifications at minimum cost. It can be seen from the lateral-directional system, Figure 6-51, that roll command signals are sent to both the ailerons

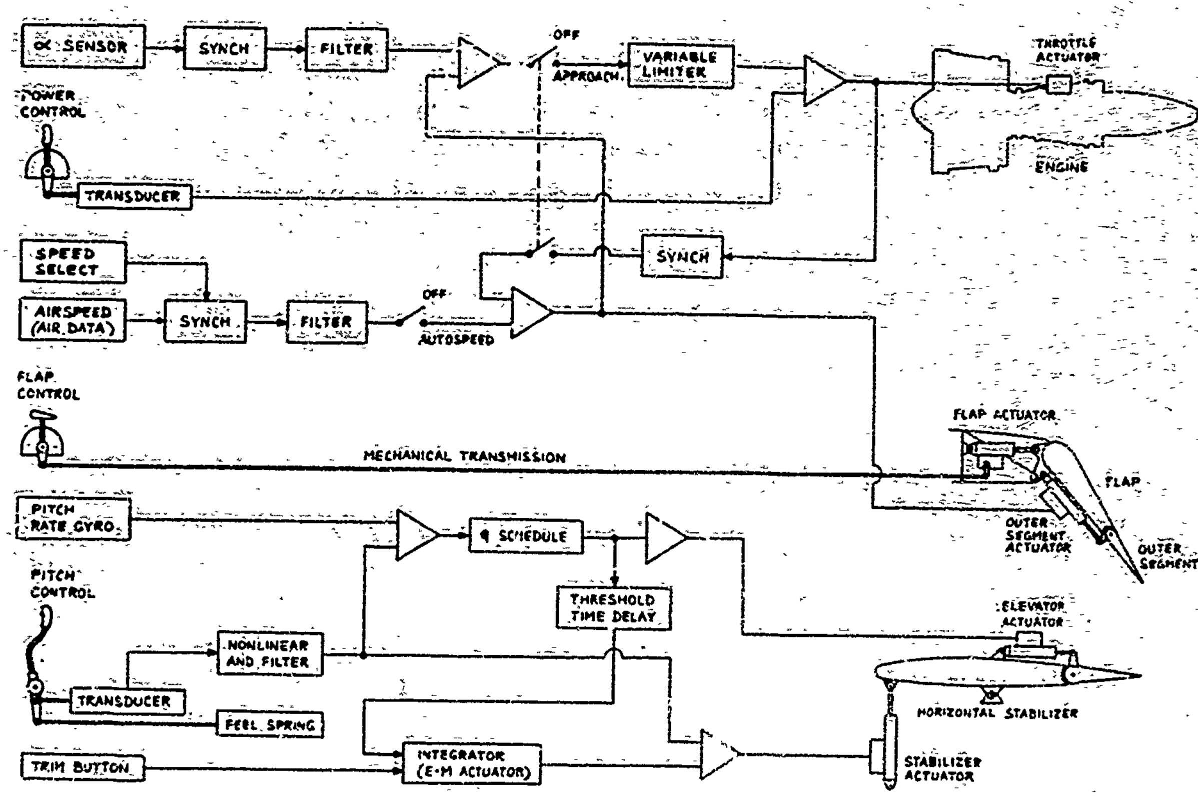


Figure 6-50. Pitch Axis Fly-By-Wire Mechanization

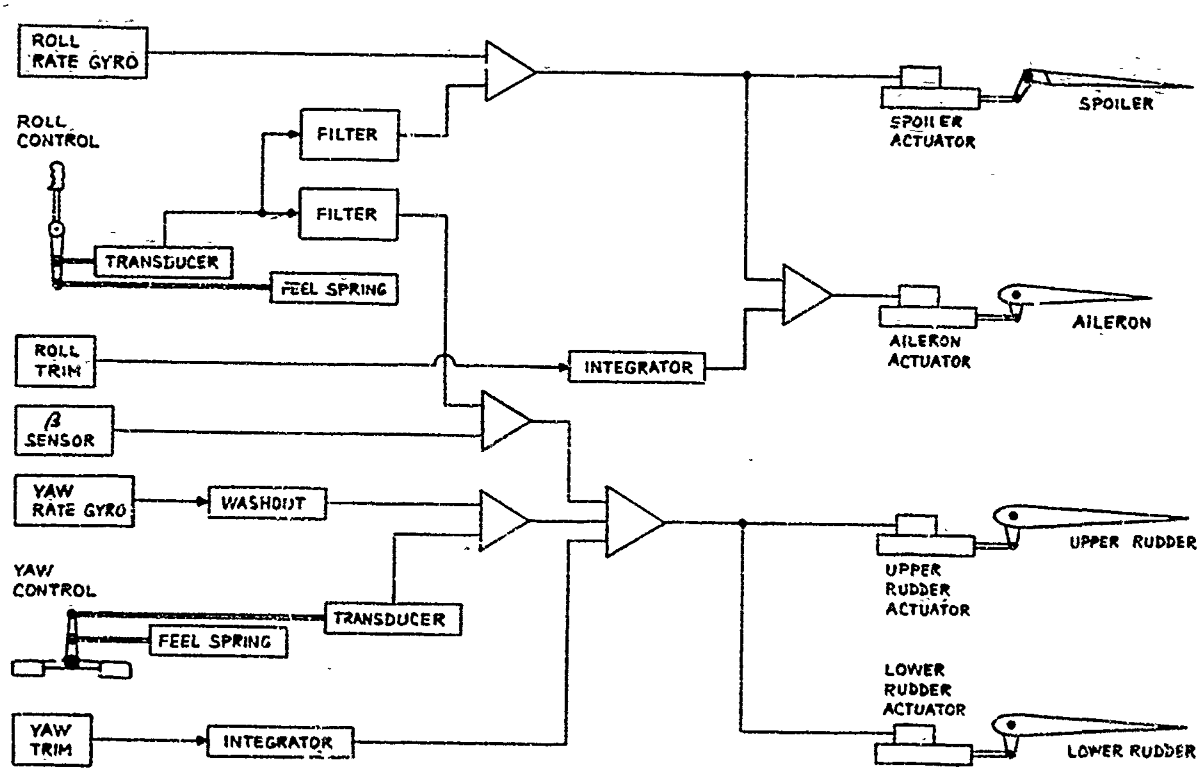


Figure 6-51. Lateral-Directional Fly-By-Wire Mechanization

and the spoilers. Some logic should be employed to reserve spoiler operation until initial aileron deflection has exceeded a limit value (say 2/3 full deflection). This would reduce the loss of lift caused by spoiler deflection except when a large roll control moment is required. Roll attitude-hold was not a preferred mode of roll control in the simulator studies. Low-visibility flight approaches may find such a mode desirable and it could be easily incorporated.

Redundancy mechanization for the fly-by-wire system is based on established practices including techniques proven in flight test and on F-111 production aircraft. The redundancy philosophy for control signal transmission is to provide for quadruple sensor and pilot input signals, quadruple flight control computations with the attendant signal selection, monitoring and logic functions in each flight control computer, quadruple servo actuator electronics, quadruplex servo actuators and reliable, state-of-the-art hydraulic power actuators.

To illustrate the redundancy philosophy for the fly-by-wire control system, Figure 6-52 shows schematically the redundancy implementation for the pitch-axis controls. The general approach is equally applicable to the lateral-directional controls. The system calls for four hydraulic systems capable of being driven from any two engines plus electric motor-driven pump units for flight emergencies. The electric pump units provide hydraulic power for ground checks of hydraulic equipment. Figure 6-53 is a block diagram of the hydraulic power management scheme. The unit marked PTU is a power transfer unit consisting of a hydraulic motor and pump which, when activated, transfers hydraulic energy between systems.

A dedicated four-channel power source provides support to the redundant flight control computers. Excitation voltages are supplied to the electrical flight control components from the flight control computers. Uninterrupted power for the fly-by-wire control system is provided by rechargeable nickel-cadmium flight control batteries which are applied to a channel only when low voltage is sensed. Solid-state switching between the battery and the flight control inverter input is accomplished before the sensed voltage has dropped below the acceptable minimum. Inverter output voltages are essentially uninterrupted by this switching process. Figure 6-54 shows the general arrangement for this noninterruptable flight control power system.

Final locations of all components of the redundant, fly-by-wire flight control system and its supporting subsystems require further analysis and study. However, Figure 6-55 identifies the principal flight control system components and indicates their probable locations in the aircraft. Gyro package locations are shown without consideration to structural modes of vibration which could prove critical. The objective of survivability in a hostile environment is well achieved by the physical separation of the redundant flight control branch components.

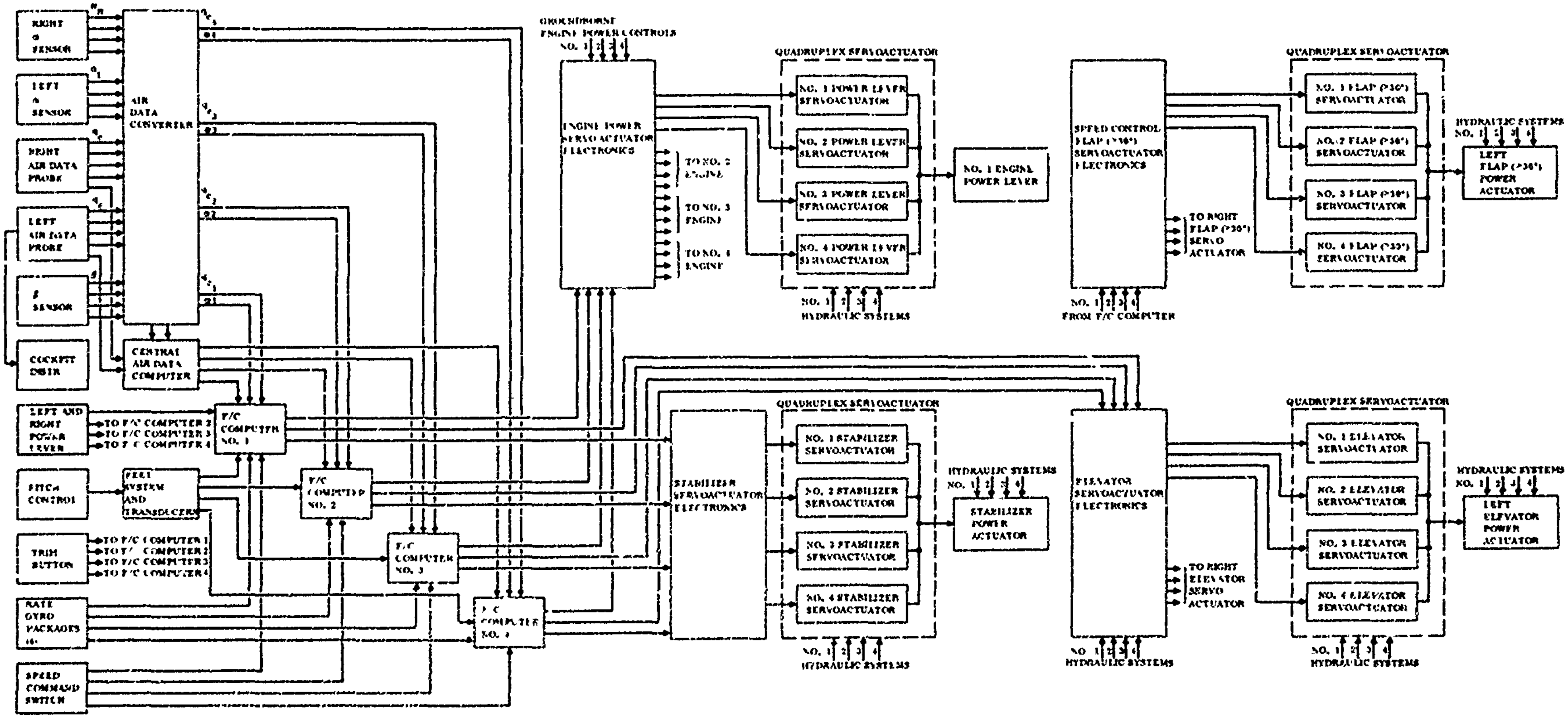


Figure 6-52. Pitch Axis Redundancy Implementation

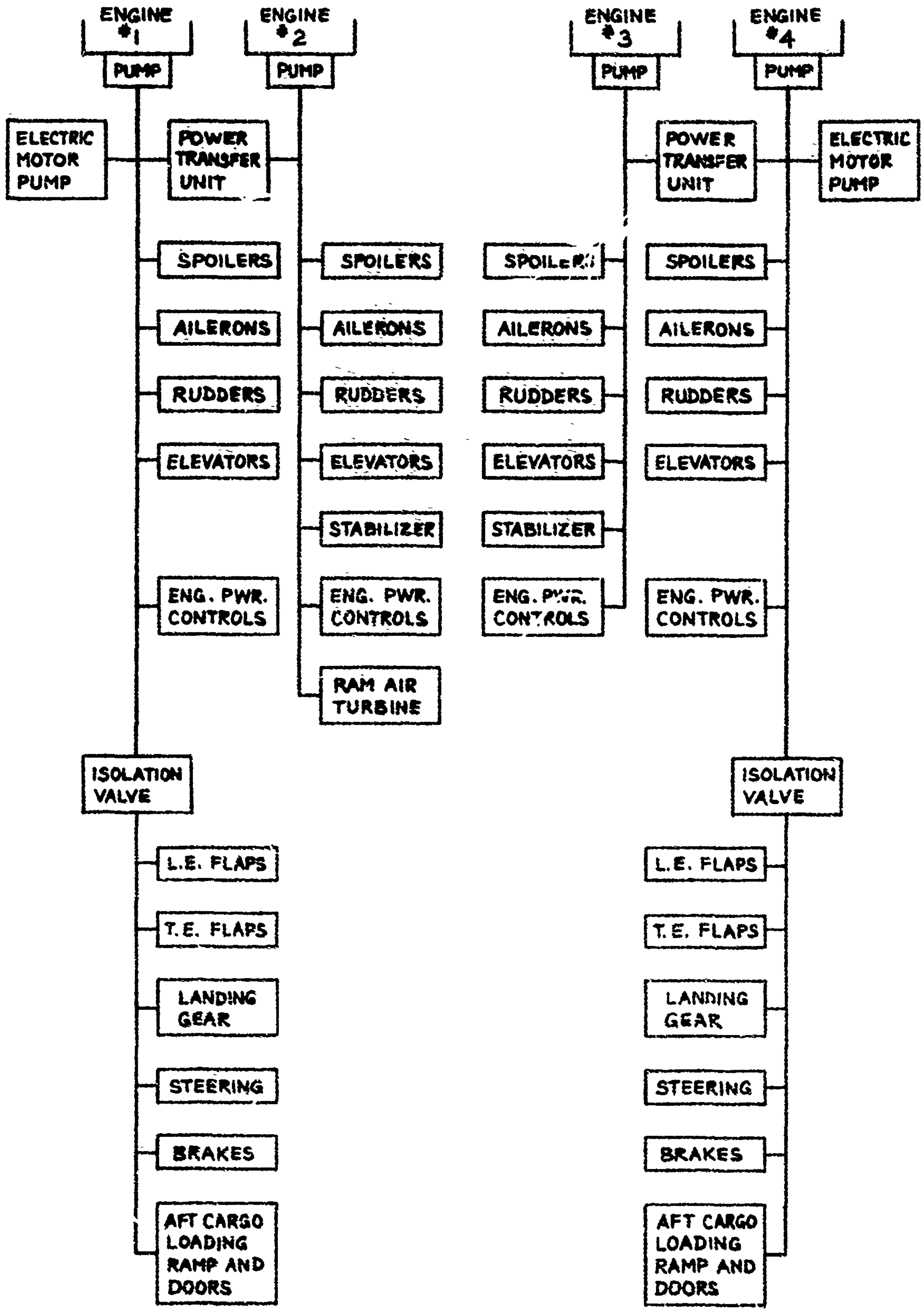


Figure 6-53. Hydraulic Power Systems

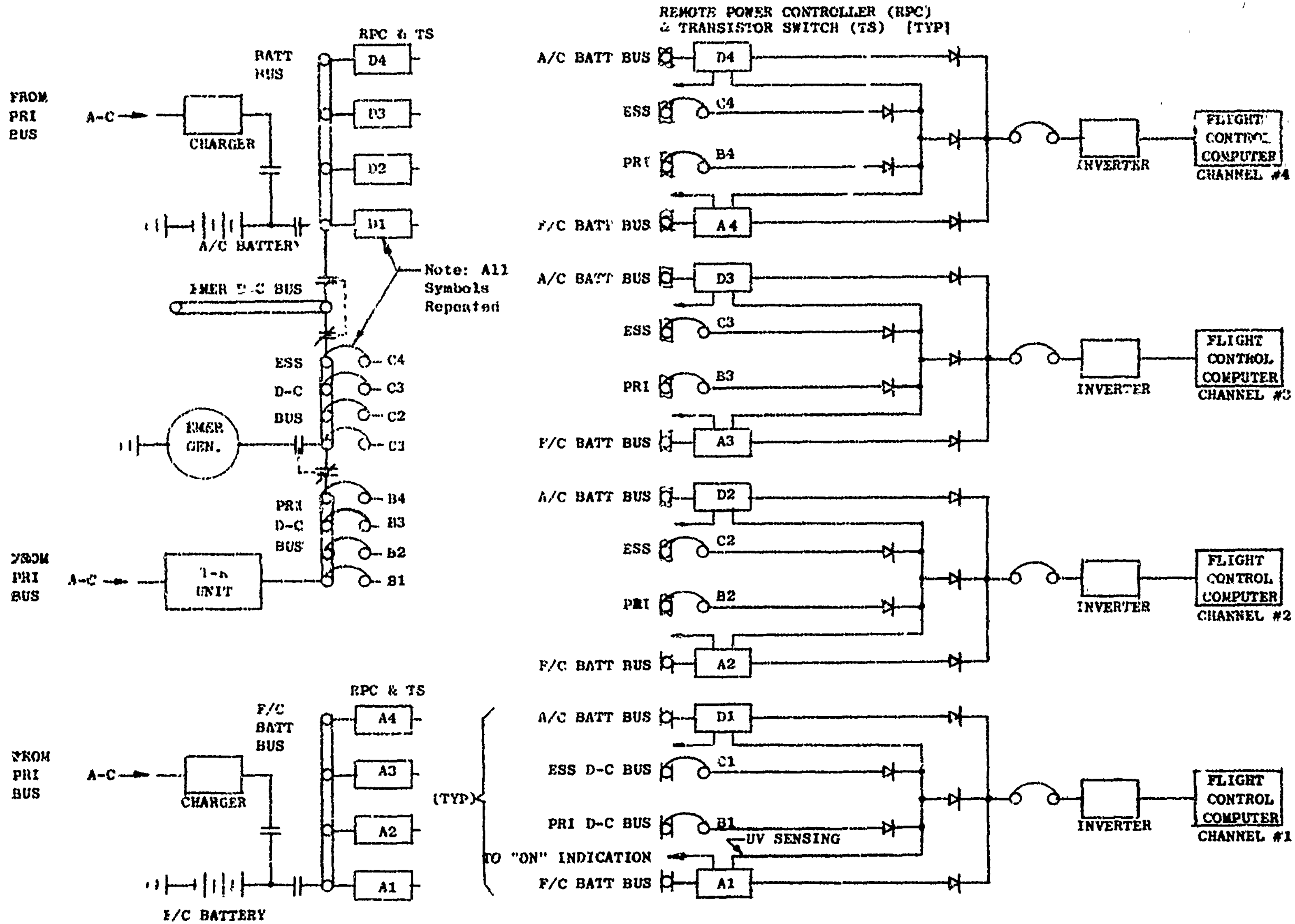


Figure 6-54. Quad Redundant Flight Control Power System

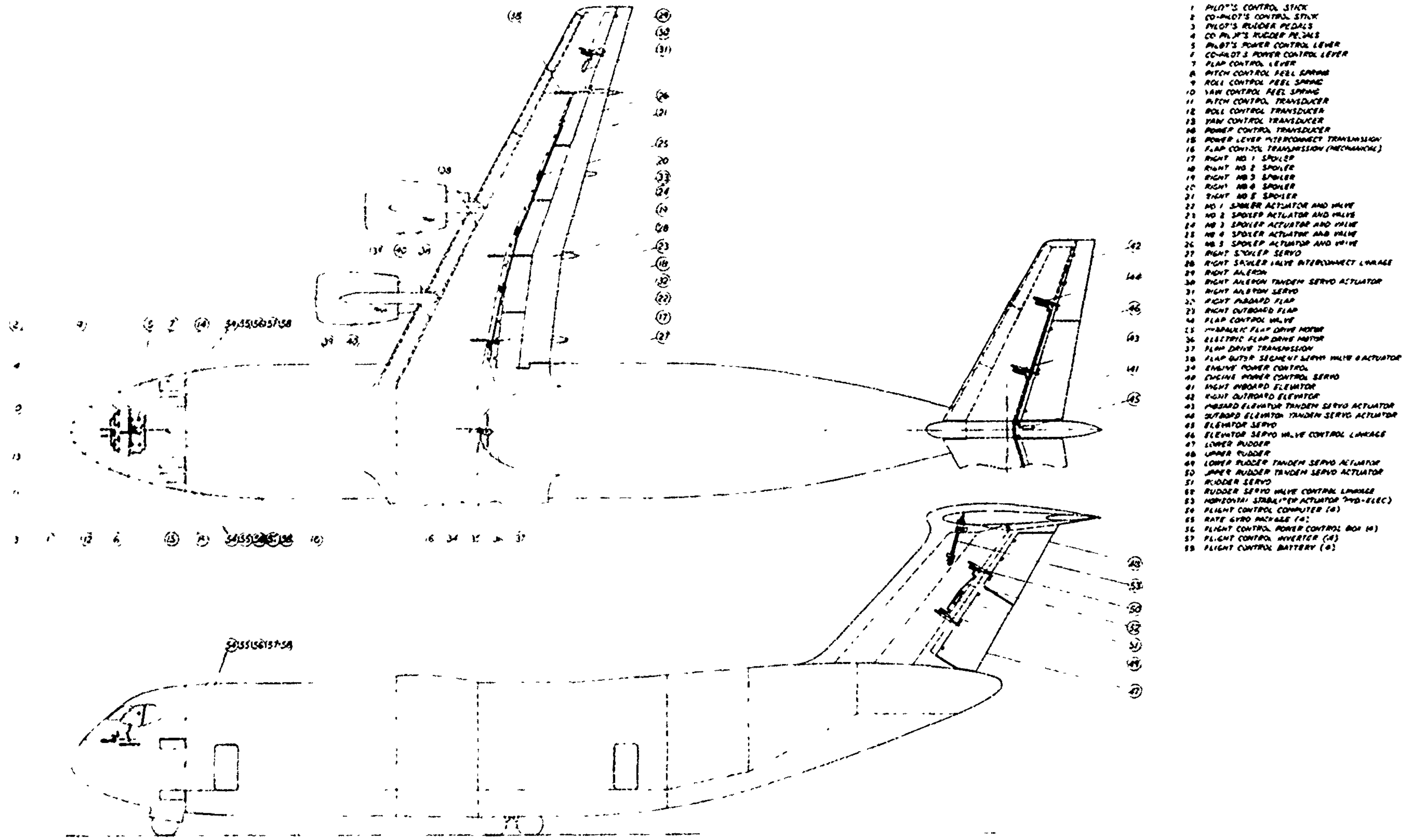


Figure 6-55. Flight Control Equipment Location

6.3.7 POINT DESIGN STRUCTURE. The point design airframe has been designed to meet the updated requirements and criteria. It retains the conventional approach to structural arrangement and elements of the baselines, but takes greater advantage of newer design techniques and materials. In the latter category, the new 7050 aluminum alloy in its various tempers and product forms has made a significant contribution toward a lightweight, full-service-life airframe. The unique properties of this aluminum alloy will be discussed in Paragraph 6.3.7.2

Cargo-handling structural systems (e.g., floor, ramp, and clearance doors) remain unchanged. Because empennage control surface blowing is not used in the point design, all structural provisions and supports for the system components, gas turbine air compressors, ducting, and blowing nozzles have been eliminated with subsequent savings in weight and cost. Since the point designs incorporate four-wheel-bogie main landing gears as compared to six-wheel bogies for the baselines. This signifcantly reduced the wheel well cutouts in the lower fuselage and provides more direct load paths in fuselage bending, shear, tension, and pressurization. A structural weight breakdown of EBF point design is shown in Table 6-24.

6.3.7.1 Structural Design Criteria. Structural design criteria for the point designs airframes have been based on applicable sections of MIL-A-008860/8870/8890 series specifications, plus applicable sections of MIL-STD-1530 (USAF), Aircraft Structural Integrity Program. The application of these documents, together with exceptions to, or deviations from the paragraphs noted, are presented in the following listing.

Table 6-24. EBF Point Design Structural Weight Breakdown

COMPONENT	WEIGHT (LB)
Wing	(20,039)
Skin	5,150
Stringers	2,444
Spar caps	902
Spar webs	1,102
Ribs and bulkheads	1,403
Fittings and attachments	500
Fixed leading edge and tip	544
Leading edge devices (structure)	785
Leading edge devices (mechanisms)	645
Fixed trailing edge, etc.	489
Flap surfaces	1,775
Flap supports and mechanisms	2,800
Ailerons and spoilers	860
Doors, fairings, miscellaneous	640
Body	(24,081)
Bulkheads and frames	4,551
Skin	3,605
Stringers and longerons	2,597
Flooring, supports and floor frames	3,244
Cargo rails, restraint, conveyors, etc.	2,297
Pressure bulkhead	572
Windshield and windows	614
Cargo ramp and mechanism	1,465
Aft cargo doors and mechanism	1,212
Entrance, service doors, and mechanism	1,551
Main landing gear doors and fairings	2,006
Fairings, protective finish, miscellaneour	367
Horizontal	(2,182)
Skin, Stringers	758
Spar caps	133
Spar webs and stiffeners	86
Ribs and bulkheads	198
Pivot, pitch-trim fittings and supports	111
Leading edge and tip	65
Fixed trailing edge	70
Miscellaneous, doors, fairings	207
Elevators	554
Vertical	(2,250)
Skin, Stringers	790
Spar caps	187
Spar webs and stiffeners	164
Ribs and bulkheads	258
Pivot, pitch-trim fittings and supports	443
Leading edge, trailing edge	117
Miscellaneous, doors, fairings	63
Rudder	226

1. MIL-A-008860 (USAF), Airplane Strength and Rigidity, General Specification For. Paragraphs in this specification that deal with definition of the structural design and analysis have been used and are listed below; paragraphs dealing with laboratory tests, flight tests, and documentation do not apply to this study.

   3.8 Transient Response. Transient loads due to gusts and landing have been used since they will result in critical design loads for the wing box.

   3.9 Thermal Considerations. The effects of heating due to power plant operation have been considered, since this condition produces critical temperatures for the engine pylon.

   3.13 Flight Loads; 3.14 Landing Loads; 3.16 Repeated Loads and Fatigue. These loads have been used to determine wing box stiffness for critical design loads. This stiffness should be adequate to preclude flutter and divergence in the operating speed envelope.

   3.19 Sonic Fatigue. Sonic fatigue conditions have been considered.

   6.2.2.7 Limit Speed. Figure 6-56 shows a plot of altitude versus maximum speed and dive speed for the point designs.

2. MIL-A-8861A (USAF), Airplane Strength and Rigidity, Flight Loads. Specification paragraphs dealing with the analytical computation of loads have been used and are listed below; paragraphs dealing with laboratory tests, flight tests, and documentation do not apply to this study.

   3.2.1 Balanced Maneuver. The maneuver load factors have been based on the values shown in Figure 6-57.

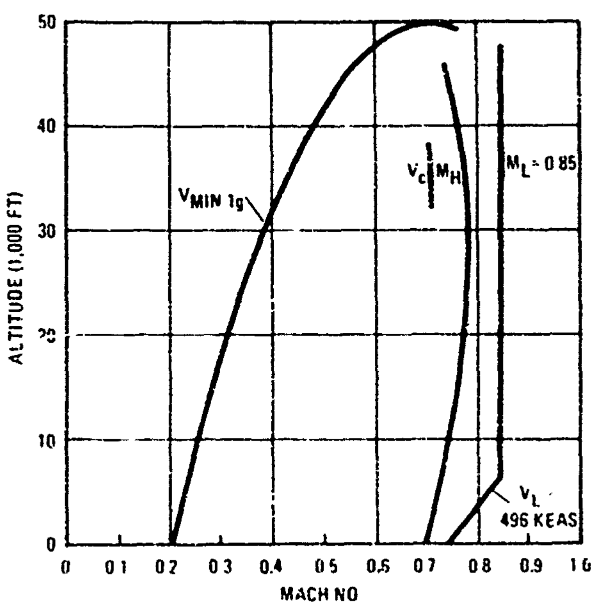


Figure 6-56. Maximum Speed and Dive Speed

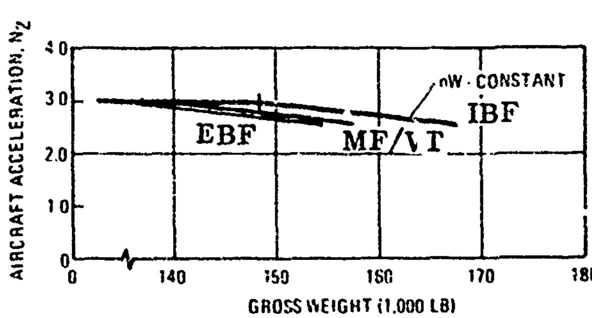


Figure 6-57. Design Load Factor versus Gross Weight

3.19.2 Abrupt Pitching Maneuver; 3.22 Gust Loads. A typical V-n diagram for maneuvers and for discrete gusts is shown in Figure 6-58. Typical plots of limit for a symmetric-maneuver wing shear, bending moment, and torque versus wing span condition at high speed are shown in Figure 6-59.

3. MIL-A-8862A (USAF), Airplane Strength and Rigidity, Landing and Ground Handling Loads. Specification paragraphs dealing with analytical computation of landing loads have been used. Typical plots of steady-state limit wing shear, bending moment, and torque versus wing span for a symmetric two-point landing condition are shown in Figure 6-60. Operation of the STOL transport from rough fields has been accounted for by designing the gear for satisfactory operation for 200 passes on CBR6 or equivalent airfield. This gear design follows that presented in Reference 6-6.

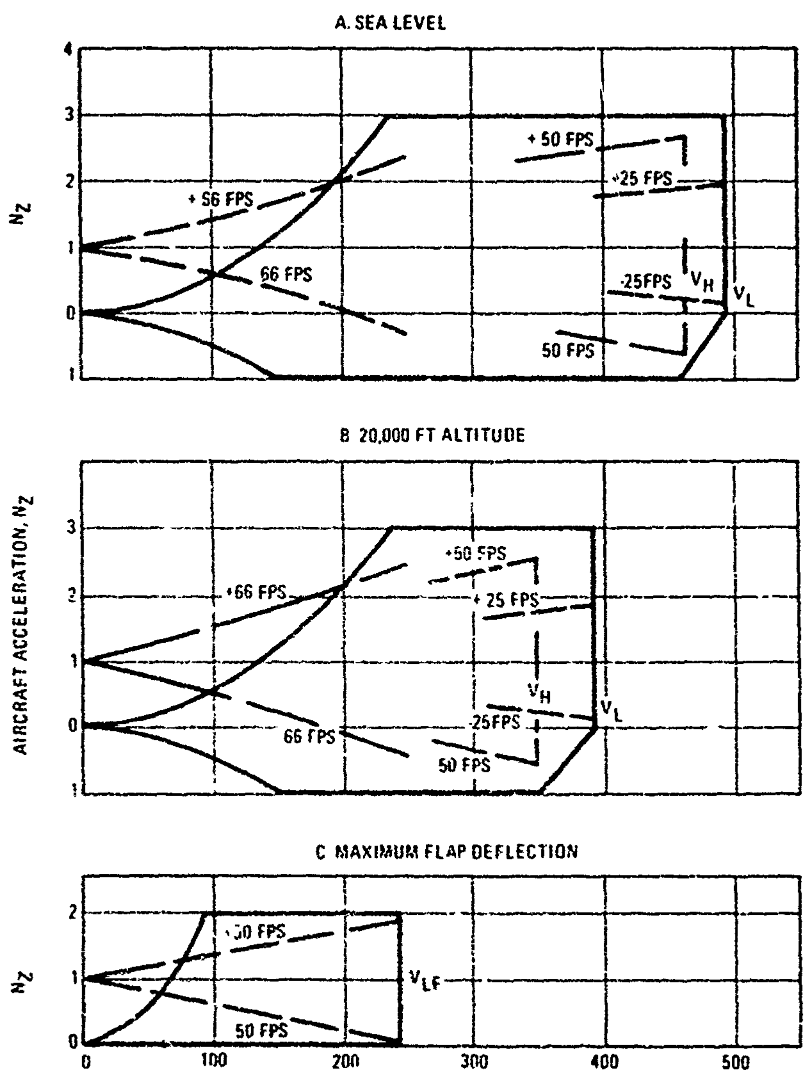


Figure 6-58. V-n Diagrams

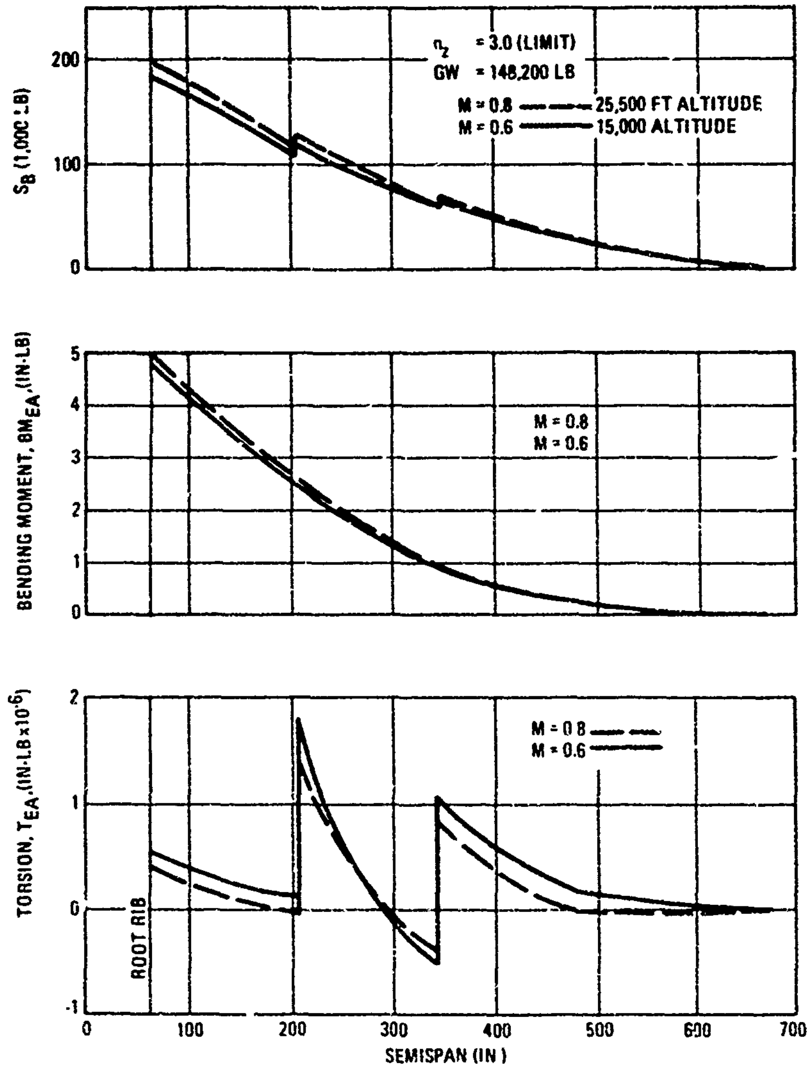


Figure 6-59. Flight Steady-State Limit Wing Shear, Bending Moment, and Torsion

Reference 6-7 states that peak counts and peak loads are less for takeoff than for the taxi condition, primarily because of the increased distances encountered in the taxi condition. Because structural loads are much less than design loads for the taxi condition, taxi loads for all major structural components are accounted for in the fatigue analysis of the structure.

4. MIL-A-8865A (USAF), Airplane Strength and Rigidity, Miscellaneous Loads. Specification paragraphs dealing directly or indirectly with prime structure miscellaneous loads have been used; paragraphs dealing with miscellaneous loads on other airplane components do not apply to this study.

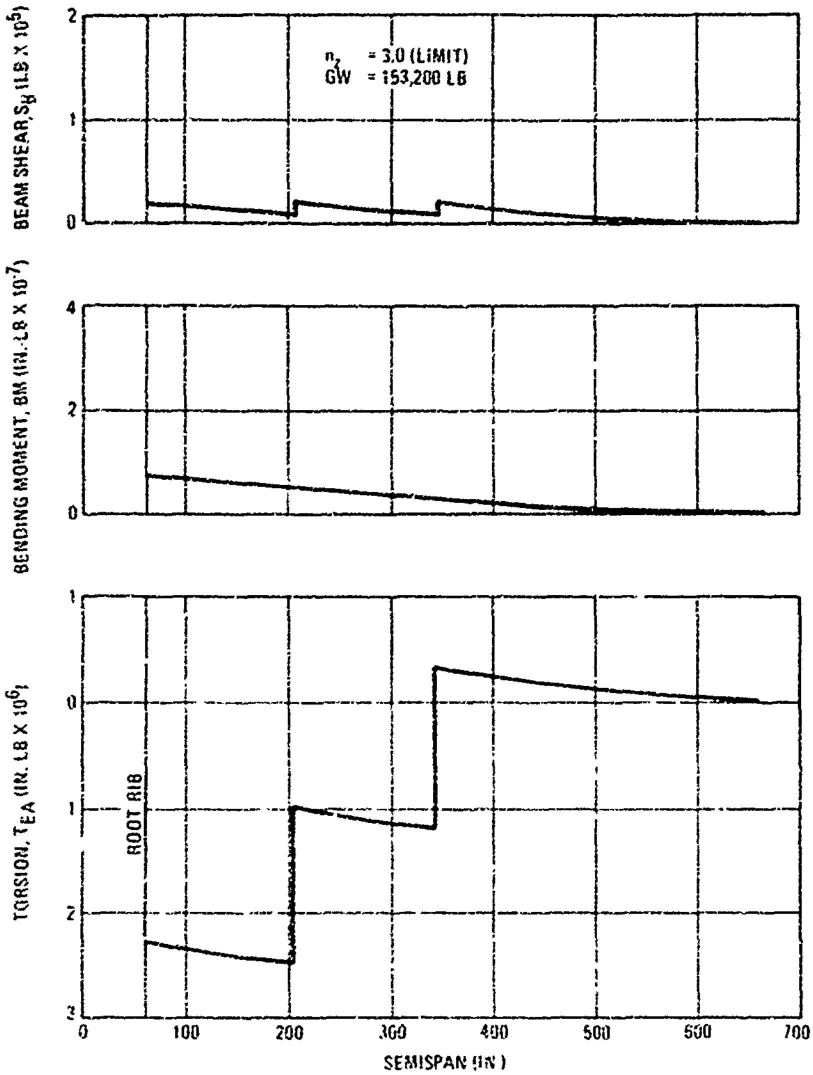


Figure 6-60. Landing Steady-State Limit Wing Shear, Bending Moment, and Torsion

5. MIL-A-8866A (USAF), Airplane Strength and Rigidity Reliability Requirements, Repeated Loads, and Fatigue. Specification paragraphs dealing with structural design and analysis have been used; paragraphs dealing with laboratory tests, flight tests, and documentation do not apply to this study. Minimum life requirements for medium and heavy cargo aircraft, as defined in Table II of MIL-STD-1530 (USAF), have been used. A scatter factor of 4.0 has been applied to the service life. Load factors and cycles in Table VIII of MIL-A-8866A and the occurrences and sinking speeds in Table IX are distributed according to operational mission profiles to determine the spectrum of repeated loads resulting from maneuvers, gusts, fuselage pressurization, and landings.

6. MIL-A-8870A (USAF), Airplane Strength and Rigidity, Flutter, Divergence and Other Aeroelastic Instabilities. Specification paragraphs dealing with detail design requirements and analysis have been used for the updated point design structural configuration; paragraphs dealing with laboratory tests, flight tests and documentation do not apply to this study.

7. MIL-A-8892 (USAF), Airplane Strength and Rigidity, Vibration. Specification paragraphs dealing with vibration prediction and analytical requirements for the structure have been used; paragraphs dealing with equipment, ground tests, flight tests, and documentation do not apply to this study.

8. MIL-A-8893 (USAF), Airplane Strength and Rigidity, Sonic Fatigue. Specification paragraphs dealing with analysis have been used; paragraphs dealing with laboratory tests, flight tests, and documentation do not apply to this study. Sound pressure levels shown in Figure 6-61 have been used for the EBF sonic fatigue design. They are based on References 6-8 through 6-15.

9. MIL-STD-1530 (USAF), Aircraft Structural Integrity Program, Airplane Requirements. Those parts of the MIL-A-008860/8870/8890 series specifications dealing with design requirements and analysis, as noted above have been used; parts of these specifications dealing with laboratory tests, flight tests, and documentation do not apply to this study. In essence, parts of Tasks I and II in Table I of MIL-STD-1530 have been used in this study; Tasks III, IV and V in Table I of MIL-STD-1530 do not apply.

6.3.7.2 Materials. Primary objectives in selecting structural materials for the point design airframes have been:

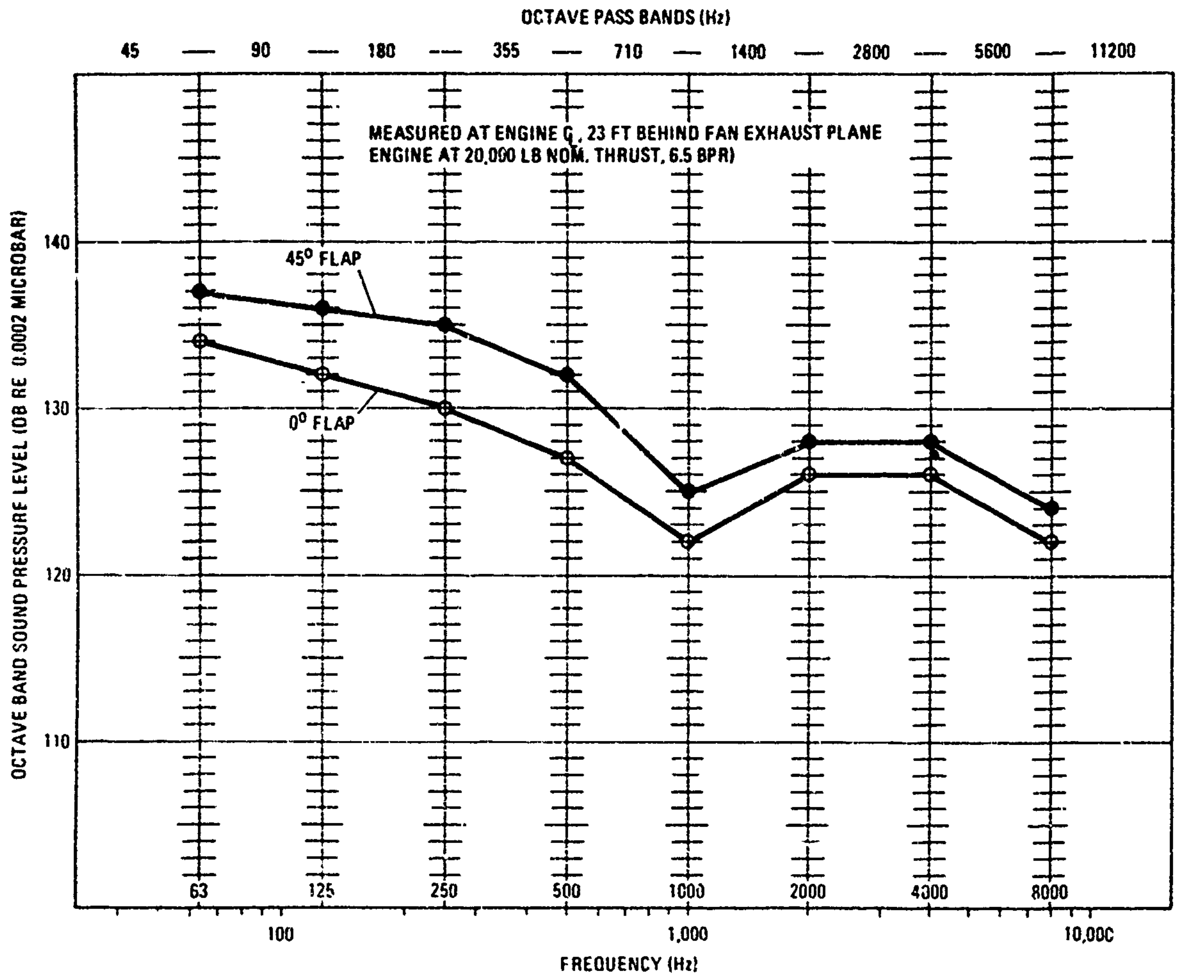
1. Minimum structural weight consistent with design requirement.

2. Superior corrosion and fatigue resistance.

3. Adaptibility for low-cost fabrication.

Table 6-25 presents materials and product forms for the structural components of the airframe.

Most of the airframe is fabricated from 2024 and 7050 aluminum alloys in tempers that combine high strength, fracture toughness, and resistance to stress-corrosion cracking. Clad aluminum sheet is used on all exterior skins and in areas where corrosion-inducing elements may exist. Rationale for selecting materials other than aluminum alloys remains unchanged from that of the baselines (Paragraph 5.4.1).



NOTES
1. SOUND PRESSURE LEVELS ARE FOR CIRCULAR EXHAUST NOZZLES & MAY BE GREATLY MODIFIED BY USE OF RAPID MIXING NOZZLES
2. SOUND PRESSURE LEVELS INCLUDE 6 DB PRESSURE DOUBLING AT FLAP SURFACE FOR SONIC FATIGUE ANALYSES
3. SPANWISE SOUND PRESSURE LEVELS (MULTI ENGINE) MAY BE OBTAINED BY SUPERPOSITION

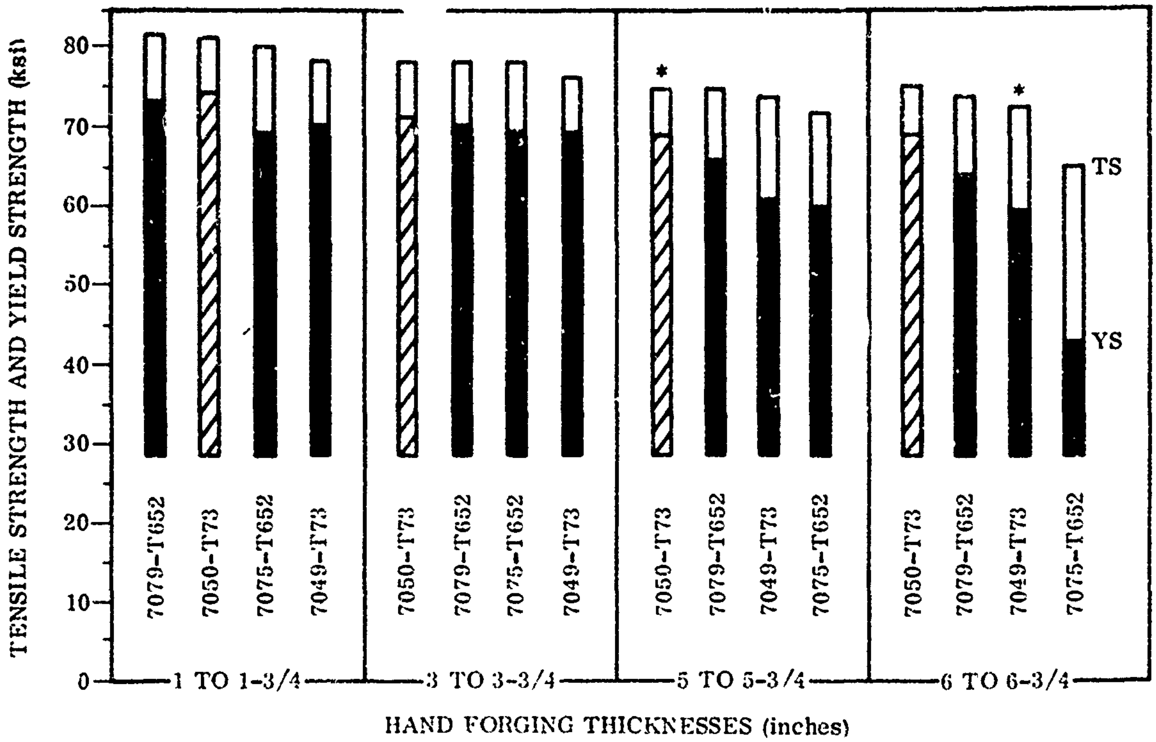
Figure 6-61. EBF STOL Aircraft Sound Pressure Levels (One Engine) at Flap Surfaces

By replacing the 7075 aluminum alloy of the baseline airframe with 7050 aluminum alloy for the EBF point design, Convair Aerospace has taken advantage of the latest developments in metals research. Development of this alloy by Alcoa was supported by Air Force Materials Laboratory. The alloy provides mechanical properties comparable to or higher than those of 7075-T6 and 7079-T6 alloys, but with greatly increased resistance to stress-corrosion cracking. This feature is significant because it allows the designer to work the material to higher stress level (as compared to 7075-T73) with subsequent savings in structural weight. Figure 6-62 compares 7050 plate with other high-strength aluminum alloys. Estimated numerical values of mechanical properties for various product forms and tempers of 7050 alloy are listed in Table 6-26.

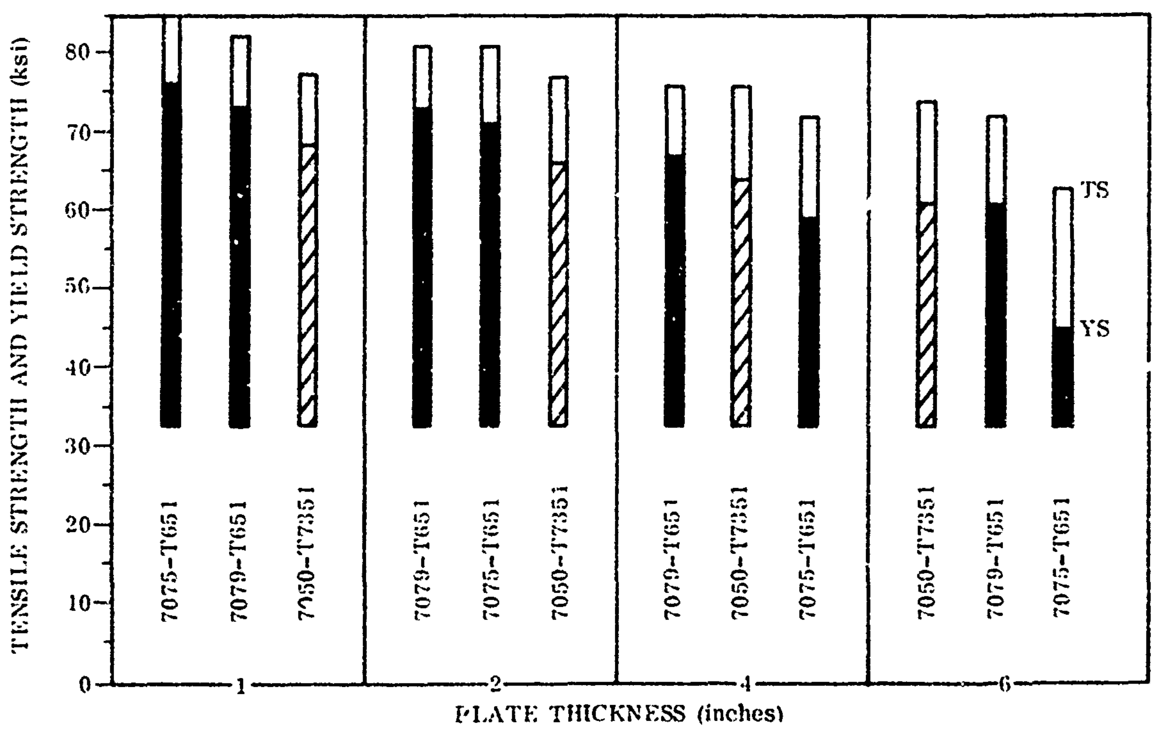
Table 6-25. Material and Product Forms for EBF Point Design Airframe

Component	Product Form	Material
Wing		
Upper skins	Clad sheet	7050-T76
Upper stringers & spar caps	Extrusion	7050-T76511
Lower skins	Clad sheet	2024-T3
Lower stringers & spar caps	Extrusion	2024-T3511
Spar webs	Sheet	7050-T76
Formed bulkheads & ribs	Sheet & extrusion	7050-T76 & T76511
Machined bulkheads & ribs	Foring & plate	7050-T736 & T73651
Leading edge skins & ribs	Sheet	7050-T76
Leading edge flap	Sheet	7050-T76
Aluminum fittings	Forging & plate	7050-T736 & T73651
Steel fittings	Forgings	4330V or D6ac (CEVM)*
Trailing edge flap	Sheet & extrusion	Ti-6Al-4V annealed & 2024-T3 & T8511
Flap vane & spoilers	Sandwich	7050-T76 & honeycomb
Trailing edge flap support tracks	Forgings	4330V or D6ac (CEVM)*
Fuselage		
Skins	Clad sheet	2024-T3
Stringers & stiffeners	Extrusion	7050-T76511
Formed frames	Sheet & extrusion	7050-T76 & T76511
Machined frames	Forging & plate	7050-T736 & T73651
Tear stoppers	Sheet	Ti-8Al-1Mo-1V annealed
Longerons	Extrusion	7050-T76511
Floor beams	Extrusion	7050-T76511
Aluminum fittings	Forging & plate	7050-T736 & T73651
Steel fittings	Forging	4330V or D6ac (CEVM)*
Cargo floor	Sandwich	7050-T76 & end grain balsa core
Windshield	Laminated	Tempered glass
Empennage		
Horizontal stabilizer		
Upper skins	Clad sheet	2024-T3
Lower skins	Clad sheet	7050-T76
Upper stringers & spar caps	Extrusion	2024-T3511
Lower stringers & spar caps	Extrusion	7050-T76511
Vertical stabilizer		
Skins	Clad sheet	7050-T76
Stringers & spar caps	Extrusion	7050-T76
Spar webs	Sheet	7050-T76
Formed ribs	Sheet & extrusion	7050-T76 & T76511
Machined ribs	Forging & plate	7050-T736 & T73651
Leading edge assemblies	Sheet	7050-T76
Aluminum fittings	Foring & plate	7050-T736 & T76511
Steel fittings	Forging	4330V or D6ac (CEVM)*
Rudder & elevator	Sheet & extrusion	7050-T736 & T73651
Trim & servo tabs	Sandwich	7050-T76 & honeycomb
Horiz. stab. pivot fittings	Forging	4330V or D6ac (CEVM)*
Engine pod & pylon		
Skins	Clad sheet	2024-T3
Webs & frames	Sheet	2024-T81 & Ti-6Al-4V annealed
Longerons	Extrusion	2024-T8511
Machined fittings	Plate	2024-T851
Thrust fittings	Forging	4330V (CEVM)*

*CEVM = Consummable-Electrode-Vacuum-Arc-Remelt



* ESTIMATED



TAKEN FROM ALCOA DEFENSE MEMO NO. 4, DATED 31 MARCH 1971

Figure 6-62. Average Mechanical Properties of High-Strength Aluminum Alloys

Table 6-26. Properties for 7050 Aluminum Alloy Products

Form	Sheet (Bare)	Plate				Extrusion		Forgings	
								Die	Hand
Temper	-T76	-T7651		-T73651		-T76511	-T736511	-T736	-T73652
Thickness	0.040 - 0.249	0.250 - 2.50	2.501 - 4.00	0.250 - 3.00	3.001 - 6.00			To 6 Inches	To 8 Inches
F_{tu} (ksi)	78	77	70	73	68	75	75	70	70
F_{ty} (ksi)	68	68	60	66	60	65	67	60	60
F_{cy} (ksi)	69	68	60	65	58	65	66	63	62
F_{su} (ksi)	47	44	43	42	42	40	40	42	42
F_{bru} (ksi)	121 156	120 150	110 135	116 146	105 135	110 140	110 140	100 128	100 130
E_c (10^3 ksi)	10.5	10.6	10.6	10.6	10.6	10.7	10.7	10.4	10.4
MIL-HDBK-5B, Page No.	3-193	3-193	3-193	3-236	3-236	3-204	3-242	3-240	3-241

Fatigue performance of 7050 alloy equals or exceeds that of 7075 and 7079 products. For instance, crack propagation characteristics of 7050-T7351 plate are better than for 7075-T651 and approach those of 2024-T351 and 7475-T6151.

Plane-strain fracture toughness (K_{I_c}) of 7050-T73 plate and hand forgings is superior to established aluminum alloys having similar yield strength. Table 6-27 substantiates this comparison.

Because of its inherent resistance to stress corrosion cracking and exfoliation, the 7050 alloy does not require extensive secondary treatment such as shot peening and surface rolling to improve resistance. This characteristic results in fabrication cost savings without sacrificing airframe structural integrity.

Table 6-27. Average Room Temperature Plane-Strain Fracture Toughness of Several High-Strength Aluminum Alloys

Plane-Strain Fracture Toughness, K_{I_c}, KSI in.

Alloy	Product	Temper	Direction		
			L-W	W-L	T-L
7050	Plate	T7351	36	30	26
	Hand Forgings	T73	34	-	-
2124	Plate	T851	29	23	23
	Hand Forgings	T852	26	18	16
7075	Plate	T651	26	22	16
	Hand Forgings	T652	26	23	17
7079	Plate	T651	27	24	20
	Hand Forgings	T652	30	22	19

Taken from Alcoa Defense Memo No. 4, dated 31 March 1971.

To minimize technical risk, advanced structural composites have not been used in the airframe structure.

6.3.7.3 Structural Description. The point design airframe structural arrangement conforms to the design philosophies established for the baseline structure. Service life requirements of 50,000 flight hours with 25,000 landings and 15,000 pressurization cycles were satisfied by designing the airframe to withstand the loads expected during its full-service life. However, fail-safe features such as multiple-element major components have been designed into the airframe to provide safe flight and landing protection against catastrophic damage resulting from any cause, including combat, accident, or indigenous cracks.

The major areas of refinition of the airframe, because of updated requirements are:

1. Main landing gear wheel well.
2. Empennage.
3. Upper fuselage shell aft of center spar box.
4. Movable pressure bulkhead.
5. Trailing-edge flap support to wing attachment.

These differences from the baseline structure are discussed in the following paragraphs. A structural schematic of the EBF point design airframe is shown in Figure 6-63. The basic finish system for corrosion protection of airframe components is in accordance with MIL-F-7179.

6.3.7.3.1 Wing. Wing structural arrangement is identical to that of the baseline airframe described in Paragraph 5.4.2.1 except for structure and support of the double-slotted externally blown trailing-edge flaps.

For each wing, the vane and main flap are divided into two structurally separate sections joined by a slip joint at the No. 2 flap track assembly. The vanes consist of a two-spar box beam with formed sheet-metal skins and ribs. A contoured sheet-metal leading edge is attached to the front spar. The trailing-edge shape, joined to the rear spar of the vane box beam, is of honeycomb sandwich construction.

Each main flap consists primarily of a two-spar box beam similar to that of the vane. The trailing-edge assembly is of formed sheet-metal skins, stiffened by chordwise ribs. This assembly is constructed of titanium alloy because of elevated skin temperatures generated by the engine gas flow.

Flap track assemblies, four for each wing, are mounted below the wing box beam to fittings on the rear spar and the lower skin at each track position. Reinforced wing box beam ribs are incorporated at track locations to back up the track mount fittings and to distribute the concentrated loads.

Flap track fairings of formed and stiffened sheet metal are attached to lower surfaces of the wing and flap with drag angles.

6.3.7.3.2 Fuselage. Fuselage's structural arrangement is identical to that of the baseline airframe described in Paragraph 5.4.2.2 except for the main landing gear wheel well, upper fuselage shell aft of the wing center spar box, and the movable pressure bulkhead.

The main landing gears with their four-wheel bogies are retracted into wells below the cargo floor. A stiffened web between the floor and lower, external longeron on the centerline of the aircraft separates right and left sides of the wheel well. Together with the external longeron, this web provides bending load continuity in the fuselage

See the following pages for greater detail.

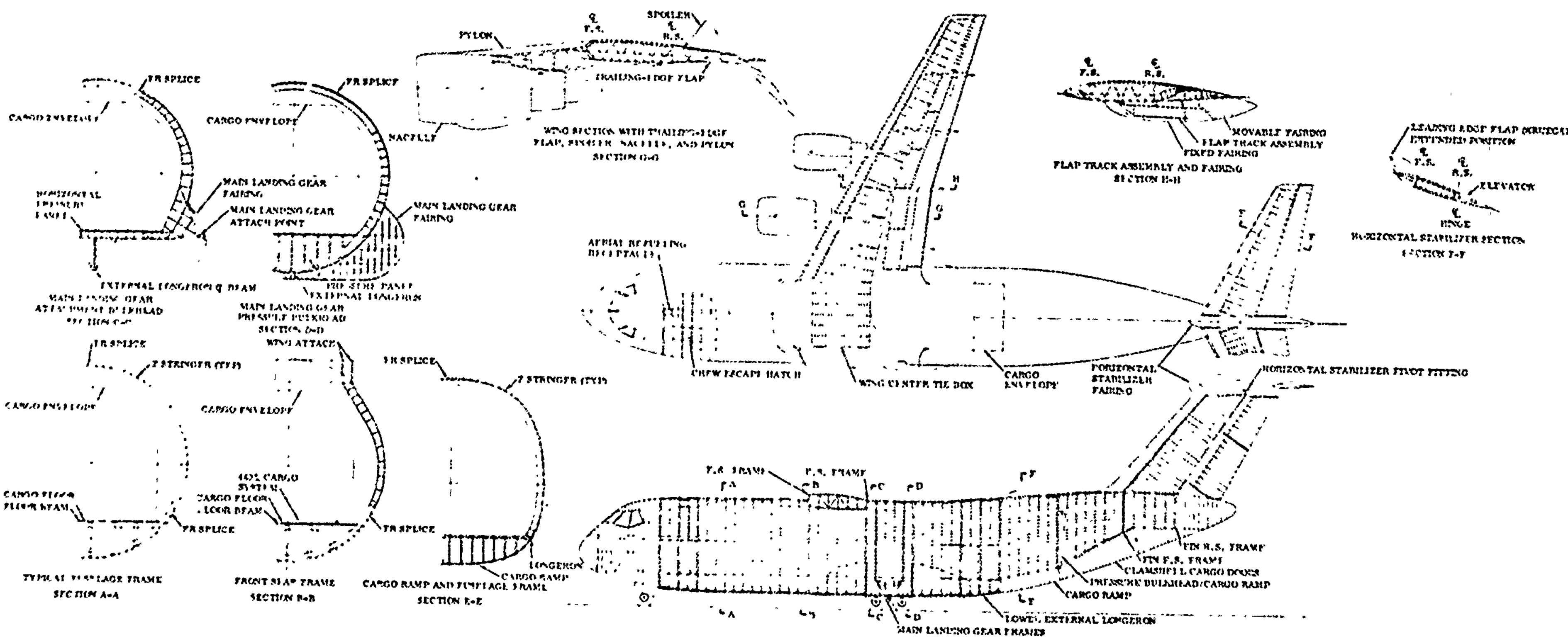


Figure 6-63. EBF Point Design Structural Schematic

shell across the wheel wells. Forward and aft, the wheel wells are closed off by partial bulkheads below the floor. These bulkheads are designed to carry pressurization loads as well as to redistribute fuselage torsional shear around the wheel wells. Each well is covered by a two-segment door hinged from the external longeron.

Since the auxiliary gas turbine air compressors have been eliminated, the upper portion of the fuselage shell aft of the wing center spar box is designed to carry normal fuselage loads only. The basic semi-monocoque fuselage construction (frame/stiffener/skin) is now continued in this area.

The movable rear pressure bulkhead is designed as a cargo-ramp-to-ground extension. The basic structure of the bulkhead is adequate to carry the required 300 lb/ft^2 cargo floor loading, and only the surface exposed to cargo and handling equipment was redesigned for wear resistance.

6.3.7.3.3 Empennage. Empennage structural arrangement is identical to that of the baseline airframe described in Paragraph 5.4.2.3 except for the structural provisions of the control surface blowing system and the horizontal stabilizer leading-edge (Krueger) flap.

With the elimination of the control surface blowing system, the structure of the stabilizers, rudder, and elevators was optimized to the updated requirements. Stabilizer rear spars were moved closer to control surface leading edges to shorten the length of the hinge fittings.

An articulated leading-edge flap was added to the horizontal stabilizer forward of the front spar. Three flap sections are mounted on each side of the stabilizer on hinge fittings assembled into the fixed leading-edge structure. The main surface panel of each flap section is of honeycomb sandwich construction and, when retracted, forms the upper surface of the stabilizer leading edge. The leading-edge segment of the flap is hinged from the main surface panel and is constructed of formed sheet-metal and honeycomb sandwich. When retracted, the leading-edge segment is rotated inward and stowed inside the stabilizer leading edge below the main surface panel.

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

The technology developed by Convair Aerospace during the STOL Tactical Aircraft Investigation has shown that an advanced medium STOL transport could be designed and produced that would be lighter and more efficient than the AMST prototype. Additional technology programs should be implemented and Phase II activities should be broadened to encompass in-depth cruise, low speed aerodynamic, propulsion, terminal area operations, structure and material, and design studies.

Figure 7-1 indicates the recommended Phase II technology areas that would furnish the required technical data base for eventual development of an advanced medium STOL transport. The Phase II programs would contribute heavily to the production of a lighter, quieter, lower cost, more efficient transport.

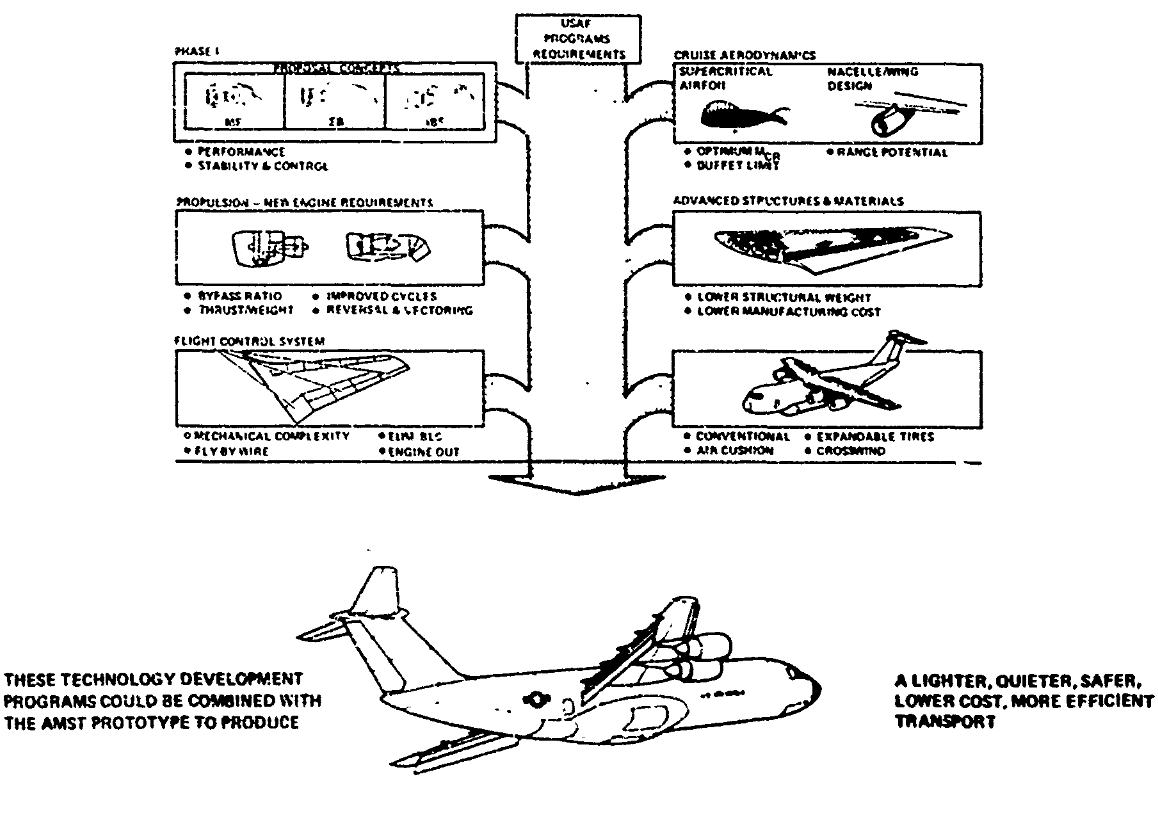


Figure 7-1. Recommended Phase II Technology Areas

Recommended low-speed programs are illustrated in Figure 7-2. Further small- and large-scale low speed wind tunnel testing is required to determine EBF spreading, scale effects, pressures, thrust vectoring and reversal effects, and engine simulation effects (turbofan machinery as opposed to ejectors). The point designs (EBF, MF/VT, and IBF/VT) should be configured and testing on the basic model, i.e., correct horizontal tail size, fuselage contour, etc. Testing of overwing and midwing nacelle positions on the basic model should be accomplished to furnish required parametric data on a comparable basis. The additional data from low-speed testing should then be incorporated to update the methodology developed in Phase I. A feasibility study of a canard design should be vigorously pursued to determine the potential of this concept on a STOL transport. It is also recommended that data from the other two contractors' low speed testing be incorporated into the methodology developed by Convair Aerospace. Further development of the wing-in-jet EBF methodology supplemented with test data from Convair's semispan model should continue.

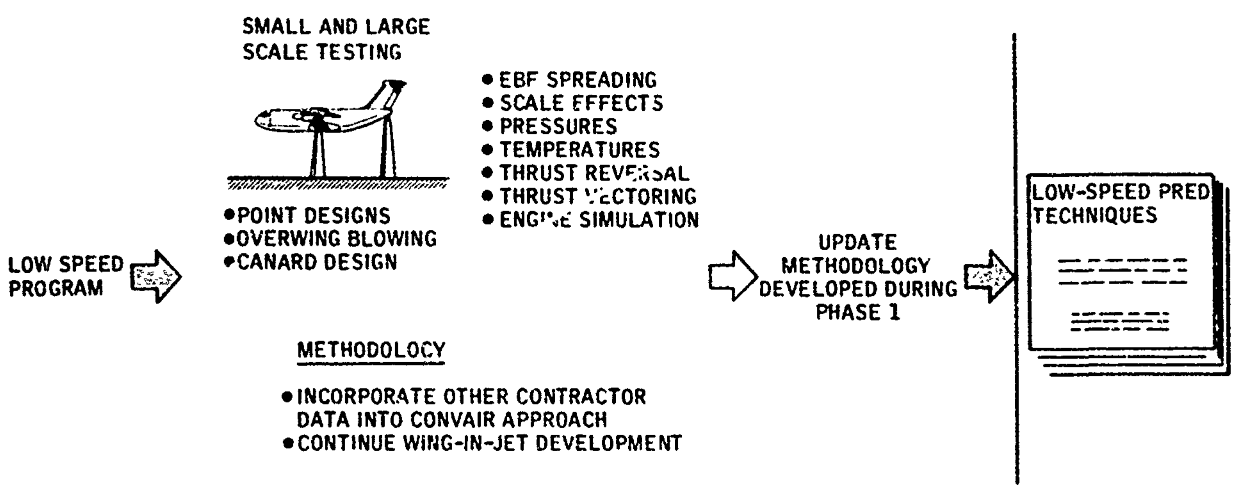


Figure 7-2. Low Speed Technology Programs

Recommended cruise technology programs are shown in Figure 7-3. High-speed testing is required to attain improvements in wing, fuselage, and nacelle design and also to minimize power and interference effects so as not to unduly penalize the point designs generated in Phase I. These cruise effects can easily overshadow the attractiveness of the demonstrated STOL technology advances. The cruise investigations would allow a combination of STOL and cruise technology into a data base that could be used to produce a blended vehicle with attractive low-speed and cruise characteristics.

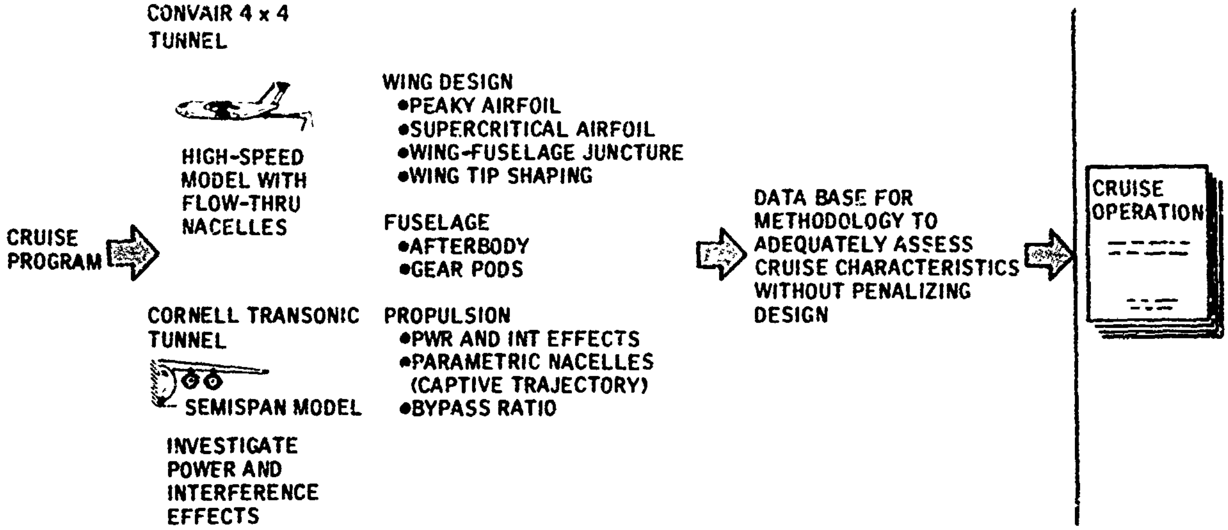


Figure 7-3. Cruise Technology Programs

Parallel propulsion studies are recommended to determine the optimum engine configuration. The point design propulsion systems were based on paper engines with approximately 22,500 pounds of thrust; optimum Phase I point designs required only 66 percent of this thrust capability. This was recognized as being outside the ± 15 percent scaling allowed by the engine manufactures and further illustrates the requirements for the propulsion studies shown in Figure 7-4. The engine cycle should be tailored to reflect the improvement indicated.

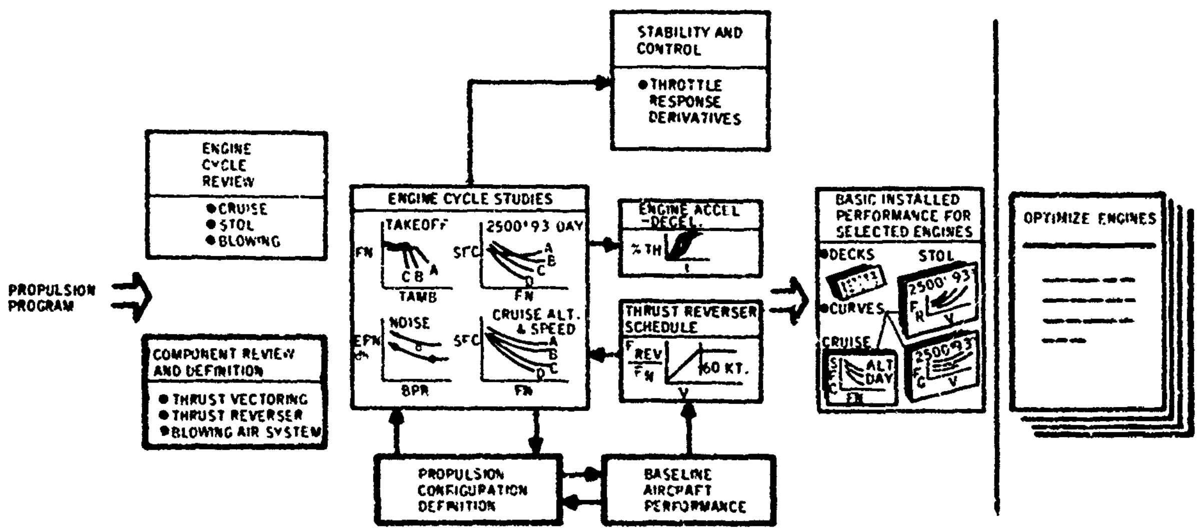


Figure 7-4. Propulsion Technology Programs

Figure 7-5 indicates the recommended terminal area programs that should actively be pursued to eliminate problem areas still actively associated with the design and operation of a military STOL transport. The primary areas of concern are takeoff, approach, and waveoff or landing. The simulation should include gear dynamics and investigate touchdown dispersion.

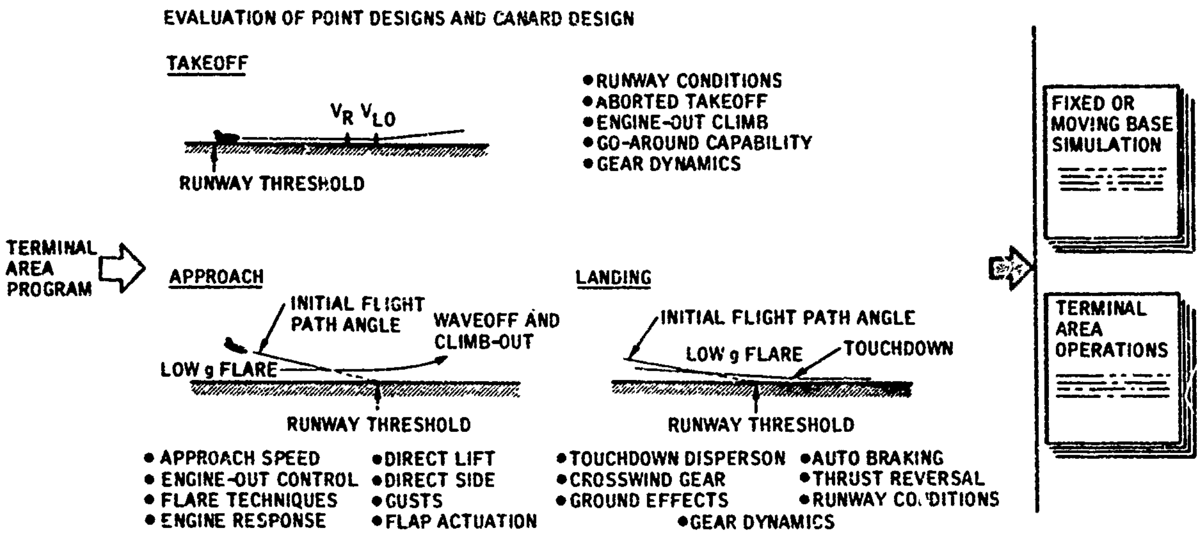


Figure 7-5. Terminal Area Technology Programs

Design and analysis activities that encompass structure and material technologies are illustrated in Figure 7-6. These activities would combine the low-speed, cruise, propulsion, and terminal area technologies into a vehicle design. Advanced material would be investigated and assessed. Cost would also be addressed. The resulting optimized design would fulfill the Phase II program objectives.

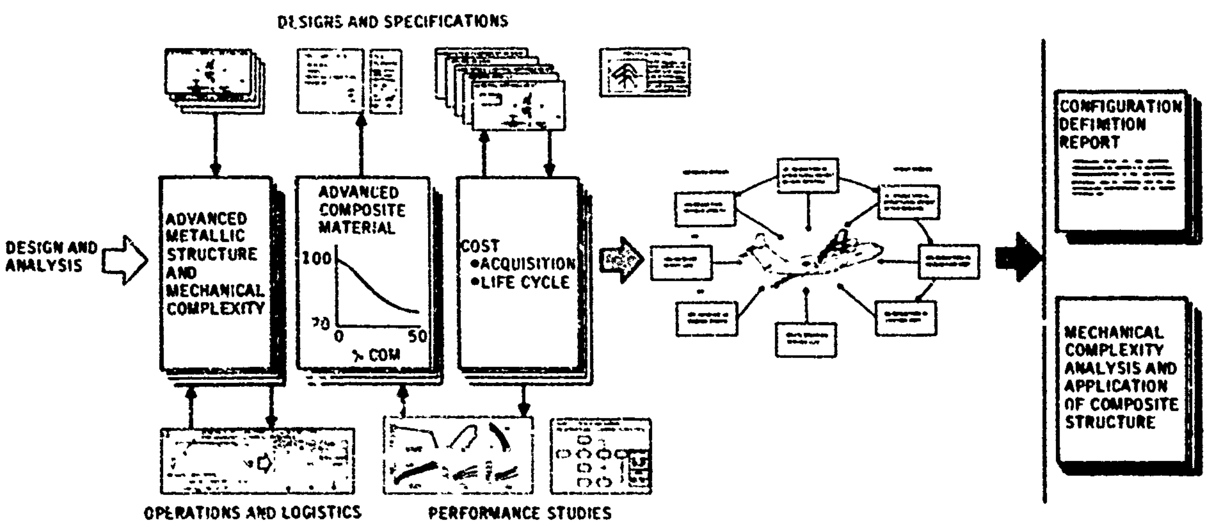


Figure 7-6. Design and Analysis Technology Programs

The resulting dimensions of improvement of the Phase II program are given in Table 7-1.

Table 7-1. Dimensions of Improvement

Low Speed Aerodynamics	Improve high-lift system i.e., cost, mechanical complexity, reliability
Supercritical Aerodynamics	Improve cruise mach number or wing volumetric efficiency
Advanced Structural Concepts	Reduce structural weight
Composite Materials	Reduce structural weight
Control System	Reduce mechanical complexity, improve engine out capability, incorporate fly-by-wire, optimize canard design
Advanced Technology Engine	Lower specific fuel consumption and higher thrust/weight
Landing Gear System	Crosswind capability, rough field operation, lower cruise drag

SECTION 8

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