NOTICE

NASA Contractor Report 152364

A STUDY OF THE APPLICATION OF ADVANCED TECHNOLOGIES TO SMALL, SHORT-HAUL TRANSPORT AIRCRAFT

FINAL REPORT

Prepared under Contract NAS2-10267 by
GENERAL DYNAMICS CONVAIR DIVISION
San Diego, California

for

AMES RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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By Cliff Adcock, Carl Coverston and Bill Knapton

September 1980

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1.0 SUMMARY

General Dynamics Convair division has conducted a study of the application of advanced technologies to small, short-haul transport aircraft under Contract NAS2-10267 for the Ames Research Center of the National Aeronautics and Space Administration.

The results show significant benefit of advanced technologies to this class of aircraft optimized to minimum DOC for 185 km (100 n.mi.) stage lengths. The technologies selected for evaluation and considered for recommended future research to validate these benefits are shown in Figure 1-1 on a sketch of the Advanced Technology, 30 passenger (AT 3-30) design.

Three abreast, 30 passenger designs were selected for comparison. The major characteristics of the 3-30 Baseline design utilizing current technology are compared with the AT 3-30 Advanced Technology design in Table 1-1. Performance is compared in Table 1-2.

The key improvements in the AT 3-30 Advanced Technology Aircraft compared to the 3-30 Baseline are shown to be as follows:

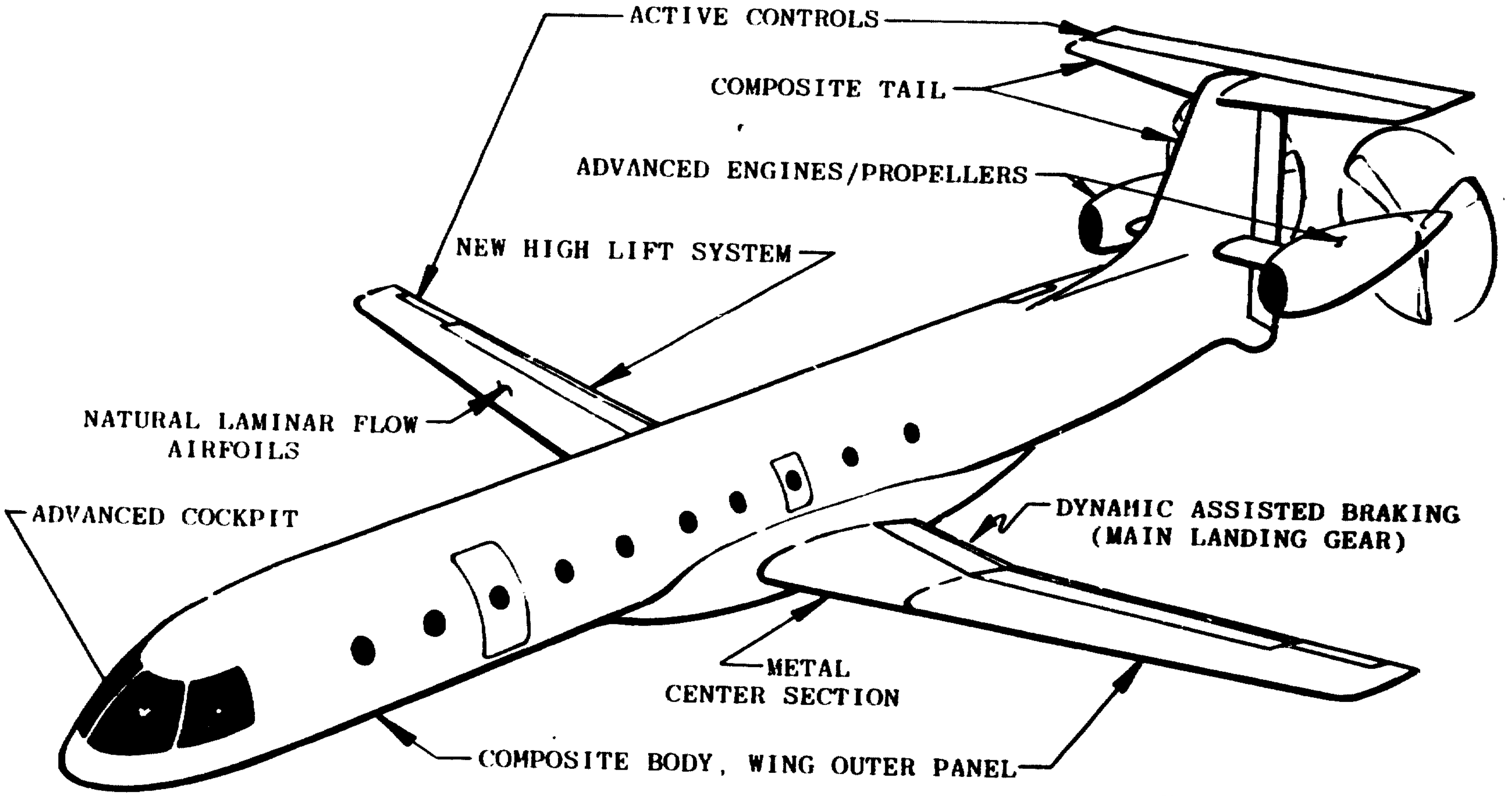
Engine Power is 37% less
Takeoff Weight is 22% less
Empty Weight is 27% less
Wing area is 51% less.

The higher wing loading of 402.8 kg/m^2 (82.5 lb/sq ft) compared to 253.9 kg/m^2 (52.0 lb/sq ft) and the benefits of the active flight control and gust alleviation system will result in improved ride quality.

Since the AT 3-30 Advanced Technology Aircraft is designed to the same guidelines as the 3-30 Baseline, the performance differences are at a minimum. The most important difference is the reduction in unit flyaway cost (19% less), DOC (24% less) and fuel consumption (31% less). In addition the AT 3-30 has a 1035 lb payload plus fuel capability into a 3000 ft runway compared to zero for the 3-30. Passenger capacity into a 7000 ft runway at 6000 ft altitude is essentially the same at 13 for a 185 km (100 n.mi.) trip.

Evaluation of the AT 3-30 Advanced Technology Aircraft shows that it saves about 15% in Direct Operating Cost versus selected existing aircraft or 24% versus the requirements 3-30 Baseline. An airplane of this configuration also has significant benefits in forms of reliability and operability which should enable it to sell a total of about 450 units through 1990, of which 80% are for airline use. The maximum U.S. market share is forecast to be 40%.

AT 3-30 ADVANCED TECHNOLOGY AIRCRAFT



For 100 n.mi

31% Fuel Savings

24% DOC Savings ($1.00/gal)

Figure 1-1. AT 3-30 Advanced Technology Aircraft

Table 1-1. AT 3-30 Characteristics Comparison

	3-30 Baseline	AT 3-30 Advanced Technology
Abreast	3	3
Passengers	30	30
Type	Low Wing, Twin Turboprop	Low Wing, Twin Pusher Turboprop
Engines/Props	Free Turbine/Three Blades	Free Turbine/Three Blades Pusher
Rated Power/Engine	1747 KW (2343 ESHP)	1095 KW (1469 ESHP)
Prop. Dia.	3.5 m (11.47 ft)	3.05 m (10.0 ft)
Max. T.O. Wt	13426 kg (29,600 lb)	10478 kg (23,100 lb)
Max. Landing Wt	12791 kg (28,200 lb)	9979 kg (22,000 lb)
Max. Zero Fuel Wt	12110 kg (26,700 lb)	9616 kg (21,200 lb)
Operating Wt Empty	8896 kg (19,610 lb)	6497 kg (14,324 lb)
Fuel Capacity	3523 kg (7,800 lb)	2173 kg (4,790 lb)
Wing Span	25.19 m (82.65 ft)	19.74 m (64.77 ft)
Area	52.86 sq m (569 sq ft)	26.01 sq m (280 sq ft)
Aspect Ratio	12.0	15.0
Sweepback C/4	5.0 deg	7.5 deg
Airfoil	NASA 63 Series	Advanced NASA Natural Laminar Flow
Flap	Single Slotted Fowler	Advanced Low Drag Fowler
Loading	253.9 kg/m^2 (52.0 lb/sq ft)	402.8 kg/m^2 (82.5 lb/sq ft)

Table 1-2. AT 3-30 Performance Comparison

	3-30 Baseline		AT 3-30 Advanced Technology	
Range with Full Design Payload	1111 km	(600 n mi)	1111 km	(600 n mi)
Corresponding Cruise Speed (TAS)	459 km/hr	(248 kt)	491 km/hr	(265 kt)
Corresponding Cruise Altitude	7071 m	(23,200 ft)	7224 m	(23,700 ft)
Runway Length (FAR 25) at S.L. 90F				
For Takeoff at Design T.O. Wt	1063 m	(3486 ft)	894 m	(2934 ft)
For Landing at Design Landing Wt	1219 m	(4000 ft)	1219 m	(4000 ft)
Corresponding Approach Speed	185 km/hr	(100 kt)	200 km/hr	(108 kt)
Corresponding Landing Stall Speed	143 km/hr	(77 kt)	154 km/hr	(83 kt)
Noise Levels (FAR 36, Amend 8, Stage III minus 8 EPNdB)				
Takeoff		83 EPNdB		83 EPNdB
Sideline		85 EPNdB		85 EPNdB
Approach		84 EPNdB		84 EPNdB
Maximum Cruise Speed at 10,000 ft (IAS)	463 km/hr	(250 kt)	463 km/hr	(250 kt)
Maximum Terminal Area Speed (IAS)	>333 km/hr	(180 kt)	333 km/hr	(180 kt)
Maximum Allowable Weight				
Into a 3000 ft Runway at S.L. 90F	<8891 kg	(19,600 lb)	6967 kg	(15,359 lb)
Into a 7000 ft Runway at 6000 ft Alt	10796 kg	(23,800 lb)	8286 kg	(18,268 lb)
100 n mi Trip Cruise Speed (TAS)	539 km/hr	(291 kt)	528 km/hr	(285 kt)
Corresponding Cruise Altitude	5181 m	(17,000 ft)	5181 m	(17,000 ft)
Corresponding Trip Fuel	261 kg	(576 lb)	176 kg	(389 lb)
DOC	1.69 $/km	(3.13 $/n mi)	1.29 $/km	(2.38 $/n mi)
Unit Flyaway Cost		3.16 $M		2.57 $M

Recommended future research based on this study of the application of advanced technology to small transport aircraft found that 1) Some technologies currently in research and development for other segments of the aircraft industry are applicable to this small, short-haul segment, 2) Other technologies currently in research and development require additional or redirected emphasis to be applicable to this type of aircraft and 3) Three new technologies were identified which are not currently in research and development.

2.0 TECHNICAL APPROACH

This study of the application of advanced technology to small, short-haul transport aircraft consists of four tasks. A flow diagram of these tasks is shown in Figure 2-1. Each task is summarized in the following paragraphs. The NASA Design Guidelines used are listed in Table 2-1.

Table 2-1. NASA Design Guidelines

Passenger Related	Performance Related
o 6 ft, 18 in. aisle	o 4000 ft FAR Part 25 field length
o 18 in. seat width, 32 in. pitch	o 600 n.mi. max payload range
o 0.8 in. garment space/passenger	o 250 KIAS cruise speed
o 20 × 20 × 11 in. for carry-on bag	o Stall speed ≤ 93 KIAS
o 5 cu ft preloaded baggage	o 200 lb per passenger
o Interior noise: 85 OASPL, 65 SIL	o $1.00 per gal fuel
o 5 psi cabin pressurization	o Community Noise: FAR Part 36 minus 8 EPNdB

Task I. Baseline Designs. Since no current aircraft can meet the mission requirements, baseline aircraft were designed using technology in short haul airline service in 1979 but meeting all of the mission requirements. Thirty and 50 passenger versions were designed covering (by shrinking and stretching) the 15 to 80 passenger range. They are shown to have similar design limitations and sensitivities. See Section 3.0.

Task II. Application of Advanced Technology. The 30 passenger baseline design was selected for application of advanced technology by specialty.

Aerodynamic, Structure, System, Propulsion and Configuration Specialty versions of the baseline were defined. In each case only the specialty technologies were applied. All other technologies remained as on the baseline. A final Advanced Technology Aircraft was designed incorporating the most promising of the specialty technologies to determine the synergistic effects. See Section 4.0 and 5.0.

Task III. Evaluation. The final Advanced Technology Aircraft was compared to the baseline and three current competing aircraft in Direct Operating Cost (DOC). A market assessment was made and the impact of current new designs was considered. The adaptability of the AT 3-30 was evaluated and the total market was considered. See Section 6.0.

Task IV. Recommendations for Future Research. Research has been recommended in three categories, namely, 1) Directly applicable technologies, 2) Technologies needing additional emphasis and 3) New technologies. See Section 7.0.

TECHNICAL APPROACH

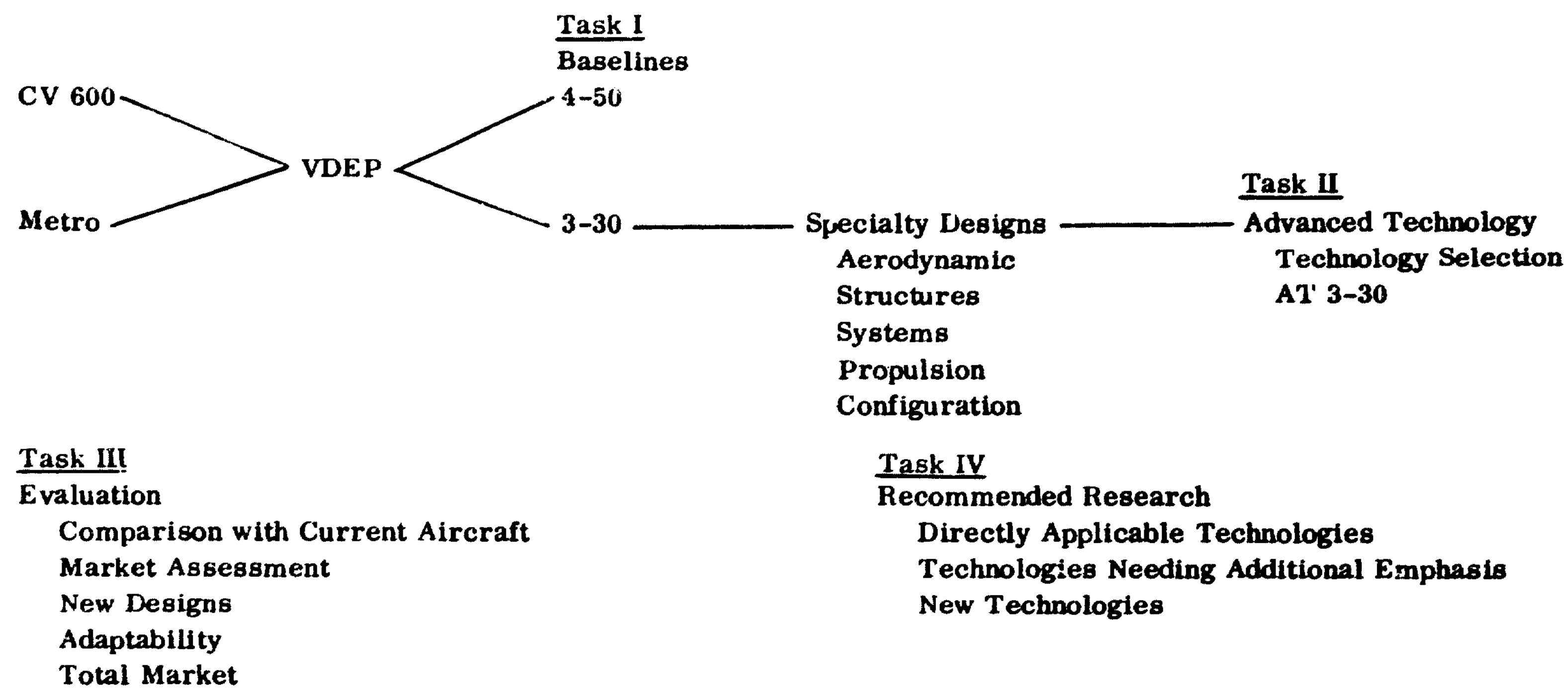


Figure 2-1. Technical Approach

As shown in Figure 2-1 a computer program (VDEP) is the focal point for sizing the aircraft designs in this study. VDEP has been modified, calibrated and validated to best represent small transport aircraft. These changes and results are discussed in Section 2.1.

2.1 VDEP MODIFICATION, CALIBRATION AND VALIDATION FOR SMALL TRANSPORT AIRCRAFT

SUMMARY. VDEP (Vehicle Design Evaluation Program) is a computer program for weight sizing, economic, performance and mission analysis of fuel-conservative aircraft, multi-bodied aircraft and large cargo aircraft using both JP and alternative fuels. It has been modified to better estimate the aerodynamics, performance and operating costs of small transport aircraft. The resulting program has been calibrated (by modifying coefficients) to reproduce the known group weight statement of the Convair CV600 40 passenger, twin turboprop transport of current technology with conventional structure having a demonstrated life of over 30,000 hours/60,000 landings. And, finally, the modified/calibrated program has been validated by estimating the weight and performance of the low wing Swearingen Metro II and the lift/drag characteristics of the high wing NORD 262 within acceptable accuracy. Thus, it is believed that the current STAT version of VDEP will adequately size current technology small transports to meet given mission requirements while assuring a life of over 30,000 hours/60,000 landings and will estimate their direct operating cost, DOC by the desired method.

The basic weight sizing, aerodynamic and DOC routines of VDEP have the capability to accurately reflect the effect of advanced technology by judicious modification of the coefficients in the various equations. This modification must be accomplished and justified outside of VDEP.

DISCUSSION. At the beginning of the study, VDEP, a Convair developed advanced design evaluation program, was selected as the most versatile computer program for synthesizing aircraft and determining the effect of advanced technology. This selection was based, in part, on the available modules and on the ability of their equations to accept the new coefficients presumed to be needed to reflect advanced technology. Its deficiencies appeared to be its low usage and its questionable ability to simulate propeller driven transport aircraft and their operations. Since the STAT study called for turboprop aircraft to be designed to meet a specified speed and runway requirements, the following modifications to VDEP were deemed necessary.

MODIFICATIONS

1. An optional module was added to better estimate the clean, power-on aerodynamic lift and drag characteristics of small, high or low wing, propeller-driven transport aircraft.

2. An optional module was added to simplify the estimation of the takeoff and landing runway requirements.

3. An optional module was added to calculate airplane, engine and propeller purchase prices by a method suggest by the NASA technical monitor.

4. The climb module was modified to restrict the climb altitude so that the horizontal distance travelled in climb is not greater than 25%* of the trip distance. This assures that no less than half of a given trip is flown at cruise altitude.

5. The cruise module was modified to allow cruise at maximum speed at the altitude for best range.

6. The direct operating cost module was modified to calculate DOC in the manner specified by the NASA technical monitor.

CALIBRATION

The modified VDEP weight sizing was calibrated to match the CV600 group weight statement by inputting the CV600 geometry and adjusting the coefficients in the weights equations to achieve the CV600 group weight statement within a few pounds per group. The calibration also inputs the body and contents weights since that is the operating mode for the STAT study, where the fuselage is designed outside of VDEP to meet the specified comfort and capacity requirements. Table 2-2 compares the VDEP calculated CV600 group weight statement with the hand lettered actual. NOTE: The CV600 landing gear weight is believed to be nearer 1800 lb than the 1589 listed on the weight statement. Table 2-3 lists the VDEP calibration input needed to generate the CV600 weights shown, and indicates the input items needed for any other airplane of the CV600 class.

VALIDATION OF WEIGHTS

The calibrated/modified VDEP program was run with Swearingen METRO II geometry, design conditions and body and contents weights as input. The resulting group weight statement is compared with the actual in Table 2-4. It shows a total weight empty discrepancy of about 100 lb (1.3%) after adjustment for the known METRO structure design differences from the CV600, i.e., double slotted flaps, reduced section wing carry through and added dorsal/vented tails. This correlation is very good.

Larger discrepancies in specific groups appear to be caused by accounting procedures. Consider for example, the groups mounted on the wing structure.

*May be varied by input

Table 2-2. VDEP Calculated Group Weight Statement (CV600)

COMMERCIAL AIRCRAFT STUDY
600 CLASS
BASELINE 600

06/15/79

GROUP WEIGHT STATEMENT				CV600 ACTUAL	GROUP C.G. STATEMENT STATION LOCATION WING	BODY
STRUCTURE				13057.5 LB (12830)		
WING			4061.2 (4067.8)		382.737	
BASIC STRUCTURE		3485.6				
BOX STR	2611.3				376.562	
RIB+LE+TE	874.2				376.562	
PENALTIES	0.0				0.000	
SECONDARY STRUCTURE		174.3			376.562	
FLAPS		401.3			435.612	
LEADING EDGE DEVICE		0.0			0.000	
SPOILERS		0.0			0.000	
WING FOLD		0.0			0.000	
HORIZONTAL TAIL			619.9 (623.5)		674.717	
VERTICAL TAIL			472.0 (474.1)		859.063	
BODY			4023.0 (4023.2)			360.539
LANDING GEAR			1812.2 (1589.7)		349.720	
SURFACE CONTROLS			595.5 (596.0)			387.308
NACELLE			1473.7 (1455.9)		216.896	0.000
PROPULSION				5910.6 (5953.6)		
ENGINES			3194.0 (3194.0)		207.160	0.000
PROPELLORS			1353.3 (1339.0)		75.180	0.000
PROPULSION SYSTEMS			1097.2 (1137.2)			
THRUST REVERSERS		0.0			0.000	0.000
INLETS		11.1 (9.8)			80.460	0.000
EXHAUST		550.1 (692.1)			564.848	0.000
COOLING		20.7 (19.8)			322.073	0.000
LUBRICATION		254.4 (255.5)			175.421	0.000
STARTING		56.9 (55.6)			175.421	0.000
ENGINE CONTROLS		104.0 (104.4)				278.112
FUEL SYSTEM			266.4 (242.5)			390.354
PLUMBING		151.8				
TANKAGE		114.6				
FOAM	0.0					
SEALING	114.6					
CELLS	0.0					
SYSTEMS AND EQUIPMENT				7043.6 (7045.3)		
AUXILIARY POWER UNIT			0.0			0.000
INSTRUMENTS			172.0 (172.3)			110.765
HYDRAULIC AND PNEU			346.9 (344.7)			260.666
ELECTRICAL			1289.1 (1292.2)			294.634
AVIONICS			577.5 (572.6)			369.462
ARMAMENT			0.0			0.000
FURNISHINGS			3599.0 (3599.1)			427.552
AIR COND / ANTI ICE			1059.0 (1059.4)			427.552
AUXILIARY GEAR			0.0			0.000
WEIGHT EMPTY				26011.7 (25820)	352.025	
BASIC OPERATING ITEMS				2249.6		
BASIC OPERATING WEIGHT				28261.2	355.[illegible]	

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ELECTRICAL		[illegible]		[illegible]			[illegible]
AVIONICS		577.6		(577.6)			
ARMAMENT		0.0					0.000
FURNISHINGS		3599.0		(3599.1)			427.552
AIR COND / ANTI ICE		1059.0		(1059.4)			427.552
AUXILIARY GEAR		0.0					0.000
WEIGHT EMPTY			26011.7	(25828)		352.025	
BASIC OPERATING ITEMS			2249.6				
BASIC OPERATING WEIGHT			28261.2			355.991	
PAYLOAD			8000.0				
ZERO FUEL WEIGHT			36261.2			362.962	
FUEL			6120.9			368.626	
WING		6120.9			368.626		
FUSELAGE		0.0					0.000
EXTERNAL TANK		0.0					0.000
MISSION RAMP WEIGHT	LB		42382.1			363.797	
MISSION LANDING WEIGHT	LB		37331.4				
DESIGN RAMP WEIGHT	LB		46200.0	(46200.)			
DESIGN TAKE OFF WEIGHT	LB		46200.0	(46200.)			
DESIGN LANDING WEIGHT	LB		44000.0	(44000.)			
DESIGN ZERO FUEL WEIGHT	LB		39500.0	(39500.)			
FUEL CAPACITY	LB		10385.0	(10385.)			

GROUP C.G. STATEMENT SUMMARY

WEIGHT EMPTY	
STA LOC AIRPLANE C.G.	352.025
C.G. IN PCT WING MAC	17.676
BASIC OPERATING WT	
STA LOC AIRPLANE C.G.	355.991
C.G. IN PCT WING MAC	21.103
ZERO FUEL WEIGHT	
STA LOC AIRPLANE C.G.	362.982
C.G. IN PCT WING MAC	27.142
TAKEOFF WEIGHT	
STA LOC AIRPLANE C.G.	363.797
C.G. IN PCT WING MAC	27.846

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Table 2-3. VDEP Weights Calibration Input (CV600)

General coefficients applicable to all aircraft of this class

AKN	2.04	DENOTES SINGLE SUBSONIC TURBOPROP NACELLE WITH MLG	
CE	3.94	COEFFICIENT	- ELECTRICAL
CG	0.0113	"	- LANDING GEAR
CH	0.98	"	- HORIZONTAL TAIL
CPCOOL	0.004	"	- PROPULSION COOLING
CPDST1	0.24	"	- PROPULSION DISTRIBUTION (FIRST)
CPDST2	0.40	"	- PROPULSION DISTRIBUTION (SECOND)
CPEXH	3.68	"	- EXHAUST SYSTEM WEIGHT
CPINLT	0.05	"	- PROPULSION INLETS
CPLUB	0.47	"	- PROPULSION LUBRICATION SYSTEM
CPPMP1	1.75	"	- PROPULSION PUMPS (FIRST)
CPPMP2	0.266	"	- PROPULSION PUMPS (SECOND)
CPREFL	2.	"	- PROPULSION REFUEL SYSTEM
CPSEAL	0.39	"	- PROPULSION SEALING
CPSTRT	0.5	"	- PROPULSION ENGINE STARTING
CPVENT	0.23	"	- PROPULSION VENT SYSTEM
CQ	0.72	"	- HYDRAULIC/PNEUMATIC SYSTEMS
CSA	0.379	"	- SURFACE CONTROLS
CUOIL	13.901	"	- ENGINE OIL WEIGHT
CUPL	200.	"	- PAYLOAD WEIGHT PER PASSENGER
CUUF	0.0059	RATIO	- UNUSABLE FUEL TO TOTAL FUEL WEIGHT
CV	0.92	CONSTANT	- VERTICAL TAIL
CWBOX	1.25	COEFFICIENT	- WING BOX
CWC1	0.053	"	- WING
CWFLAP	648.67	"	- WING FLAP, SINGLE SLOTTED
END	2.	DETERMINES AIRPLANE TAKEOFF GROSS WEIGHT FOR A GIVEN FUEL CAPACITY	

Body and contents weights input (for CV600)

CBFIX	4023	BODY STRUCTURE WEIGHT
COFIX	265.	FIXED WEIGHT OF AIR COND/ANTI ICE SYSTEMS
CPECFX	104.	FIXED WEIGHT OF ENGINE CONTROLS
CPEXFX	405.7	FIXED WEIGHT OF EXHAUST SYSTEM
QFPPR	4.	NUMBER OF PASSENGER SEATS PER ROW
QUPASS	40.	NUMBER OF PASSENGERS
WE FIX	1200.	FIXED WEIGHT OF ELECTRICAL SYSTEM
WFF	3599.	FURNISHINGS WEIGHT
WIFIX	172.	FIXED WEIGHT OF INSTRUMENTS
WL	577.6	FIXED WEIGHT OF AVIONICS
WOACFX	794.	FIXED WEIGHT OF AIR CONDITIONING
WPENG1	3194.	ENGINES WEIGHT
WUCREW	470.	CREW WEIGHT
WUMIS	1605.	MISCELLANEOUS USEFUL LOAD

Table 2-4. VDEP Calculated Group Weight Statement (METRO II)

COMMERCIAL AIRCRAFT STUDY
600 CLASS
METRO II

06/20/79

GROUP WEIGHT STATEMENT				ACTUAL METRO II	GROUP C.G. STATEMENT STATION LOCATION WING	BODY	METRO STRUCTURE DESIGN CHANGES
STRUCTURE			3755.7 LB.	(4357.8)	315.622 ← TO 4012.9		INCLUDING FOLLOWING CHANGES
WING		952.2		(1365.7)	315.622 ← TO 10TBS		DUE TO REDUCED SECTION WING CARRY THROUGH AND DOUBLE SLOTTED FLAPS
BASIC STRUCTURE	842.0						
BOX STR 617.0					312.819		
RIB+LE+TE 225.0					312.619		
PENALTIES 0.0					0.000		
SECONDARY STRUCTURE	42.1				312.819		
FLAPS	68.2				350.057		
LEADING EDGE DEVICE	0.0				0.000		
SPOILERS	0.0				0.000		
WING FOLD	0.0				0.000		
HORIZONTAL TAIL		177.7		(372.6)	642.243 ← TO 371		DUE TO ADDED DORSAL AND VENTRAL TAIL
VERTICAL TAIL		144.0			609.168		
BODY		1444.0		(1444.)		289.296	
LANDING GEAR		430.1		(623.4)	282.053		
SURFACE CONTROLS		276.1		(142.9)		289.296	
NACELLE		321.6		(402.2)	241.677	0.000	
PROPULSION			1538.1	(1334.8)			
ENGINES		716.1		(716.1)	236.137	0.000	
PROPELLORS		374.6		(303.5)	189.337	0.000	
PROPULSION SYSTEMS		271.0		(258.3)			
THRUST REVERSERS	0.0				0.000	0.000	
INLETS	4.1				193.897	0.000	
EXHAUST	112.3				321.937	0.000	
COOLING	10.5				212.737	0.000	
LUBRICATION	79.2				217.370	0.000	
STARTING	21.5				217.370	0.000	
ENGINE CONTROLS	43.3					213.526	
FUEL SYSTEM		176.4		(58.9)		309.960	
PLUMBING	116.6						
TANKAGE	59.6						
FOAM 0.0							
SEALING 59.6							
CELLS 0.0							
SYSTEMS AND EQUIPMENT			2063.5	(2022.5)			
AUXILIARY POWER UNIT		0.0				0.000	
INSTRUMENTS		42.0		(42.0)		130.872	
HYDRAULIC AND PNEU		135.9		(100.1)		220.416	
ELECTRICAL		482.8		(498.0)		220.416	
AVIONICS		243.0		(243.0)		276.002	
ARMAMENT		0.0				0.000	
FURNISHINGS		864.0		(863.6)		316.848	
AIR COND / ANTI ICE		295.8		(293.8)		282.408	
AUXILIARY GEAR		0.0				0.000	
WEIGHT EMPTY			7357.3	(7715.1)	289.965 ← TO 7614.5		DUE TO ABOVE CHANGES
BASIC OPERATING ITEMS			562.4				
BASIC OPERATING WEIGHT			7919.7		283.321		
PAYLOAD			3000.0				

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STARTING		21.5				
ENGINE CONTROLS		43.3				213.526
FUEL SYSTEM			176.4	(58.9)		309.960
PLUMBING		116.6				
TANKAGE		59.6				
FOAM	0.0					
SEALING	59.6					
CELLS	0.0					
SYSTEMS AND EQUIPMENT			2063.5	(2022.5)		
AUXILIARY POWER UNIT		0.0				0.000
INSTRUMENTS		42.0		(42.0)		130.872
HYDRAULIC AND PNEU		135.9		(100.1)		220.416
ELECTRICAL		482.8		(498.0)		220.416
AVIONICS		243.0		(243.0)		276.002
ARMAMENT		0.0				0.000
FURNISHINGS		864.0		(863.6)		316.848
AIR COND / ANTI ICE		295.8		(293.8)		282.408
AUXILIARY GEAR		0.0				0.000
WEIGHT EMPTY			7357.3	(7715.1)	289.965 ← to 7614.5 DUE TO ABOVE CHANGES	
BASIC OPERATING ITEMS			562.4			
BASIC OPERATING WEIGHT			7919.7		283.321	
PAYLOAD			3800.0			
ZERO FUEL WEIGHT			11719.7		296.425	
FUEL			4342.0		312.396	
WING		4140.4			312.396	
FUSELAGE		201.6				0.000
EXTERNAL TANK		0.0				0.000
MISSION RAMP WEIGHT LB			16061.7		300.742	
MISSION LANDING WEIGHT LB			15734.0			
DESIGN RAMP WEIGHT LB			12600.0			
DESIGN TAKE OFF WEIGHT LB			12500.0			
DESIGN LANDING WEIGHT LB			12500.0			
DESIGN ZERO FUEL WEIGHT LB			12500.0			
FUEL CAPACITY LB			4342.0			

GROUP C.G. STATEMENT SUMMARY

WEIGHT EMPTY	
STA LOC AIRPLANE C.G.	289.965
C.G. IN PCT WING MAC	16.708
BASIC OPERATING WT	
STA LOC AIRPLANE C.G.	283.321
C.G. IN PCT WING MAC	8.011
ZERO FUEL WEIGHT	
STA LOC AIRPLANE C.G.	296.425
C.G. IN PCT WING MAC	25.164
TAKEOFF WEIGHT	
STA LOC AIRPLANE C.G.	300.742
C.G. IN PCT WING MAC	30.815

FOLDOUT FRAME 2

Group Name	Weight (Lbs)	
	VDEP	ACTUAL
80% of landing gear	350	499.0
50% of surface controls	139	71.5
Nacelle structure	321.6	409.2
Fuel System	176.4	58.9
Hydraulic/pneumatic	135.9	100.1
	1122.9	1138.7

Although, the percentage error is large in any one group, the total error is less than 1.4%.

The wing structure group weight also shows a large discrepancy (more than 21%) even after adjustment for reduced section wing carry through and double slotted flaps. The causes of this discrepancy are not known, however, our calculation method is sufficiently detailed to adequately account for input changes. We believe, therefore, that unknown structural differences are responsible for the discrepancy. We also believe that our detailed method adequately represents the wing design changes to be considered in this study.

VALIDATION OF LIFT/DRAG POLAR

The modified VDEP program was run successively with CV600, Swearingen METRO II and NORD 262 geometry as input. The "TAERO" routine calculated the lift/drag polars by summation of the individual components lift and drag at several angles of attack, then interpolating the curve fitted lift and drag polars to output data at specified lift coefficients. The resulting lift/drag polars are compared with known data in Figure 2-2, 2-3 and 2-4, respectively.

Figure 2-3 shows the TAERO calculated lift/drag polar of the Swearingen METRO II compared with data points calculated from performance quoted in "Janes All the Worlds Aircraft" using engine data incorporating the sample installation losses from the engine performance calculation manual and propeller performance from the Hamilton Standard "Red Book". The TAERO method seems to provide a good fairing of the data.

Figure 2-4 shows the TAERO calculated lift/drag polar of the high wing NORD 262 compared with data points calculated from performance quoted in "Janes All the World Aircraft" using engine data incorporating 5% horsepower loss due to installation and propeller performance from the Hamilton Standard "Red Book". Again the TAERO method seems to provide a reasonable fairing of the available data and validates the VDEP method.

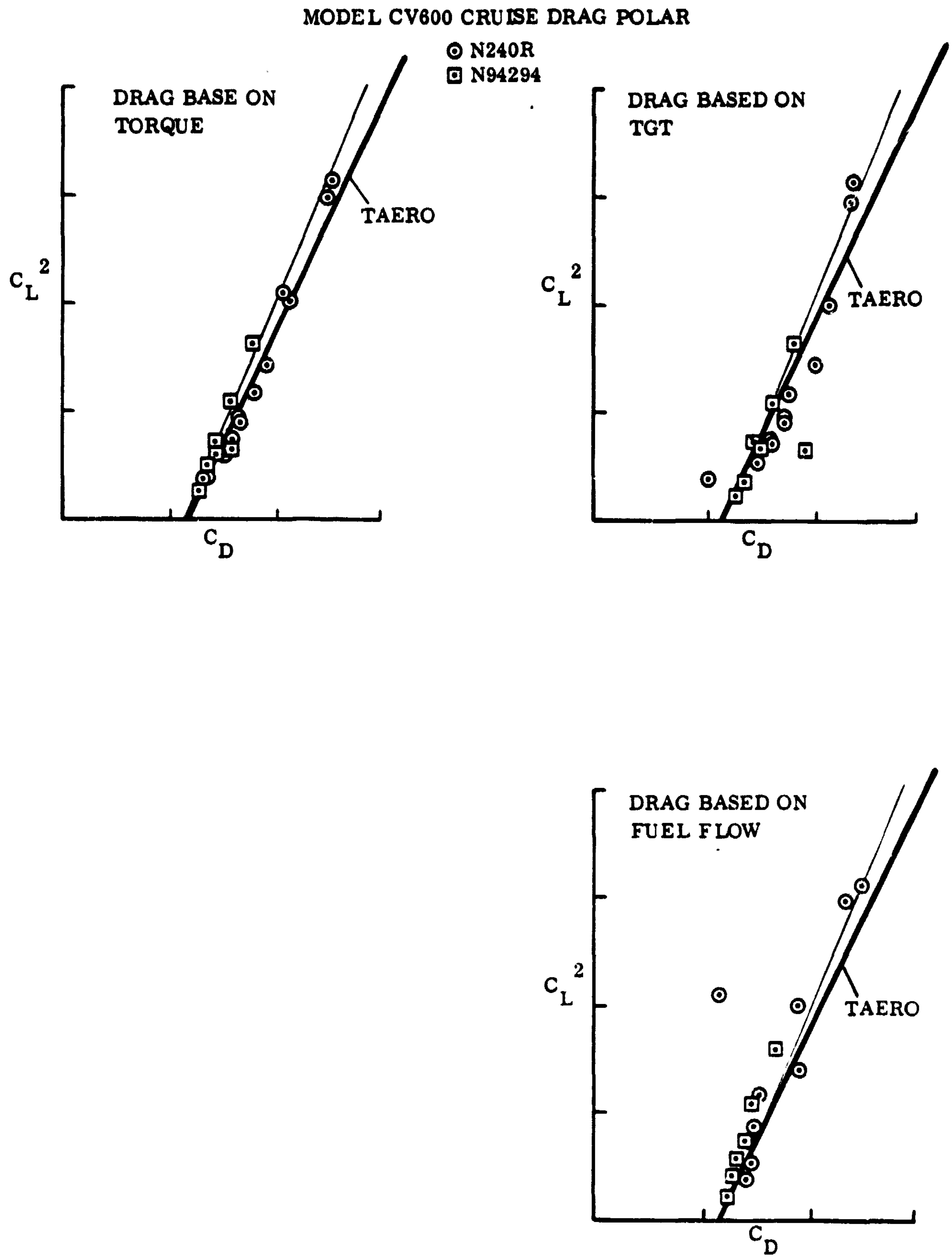


Figure 2-2. Model CV600 Cruise Drag Polar

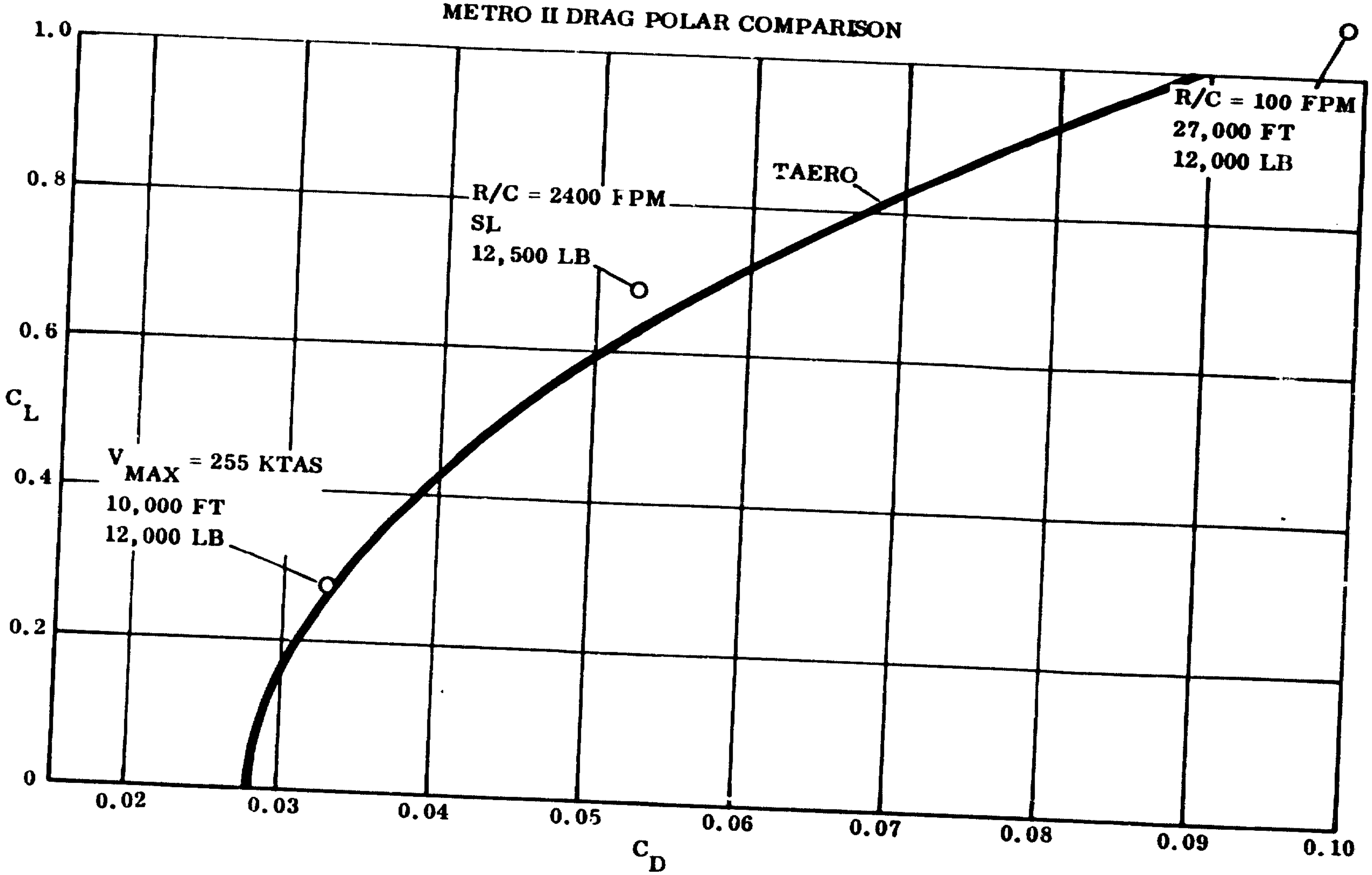


Figure 2-3. Metro II Drag Polar Comparison

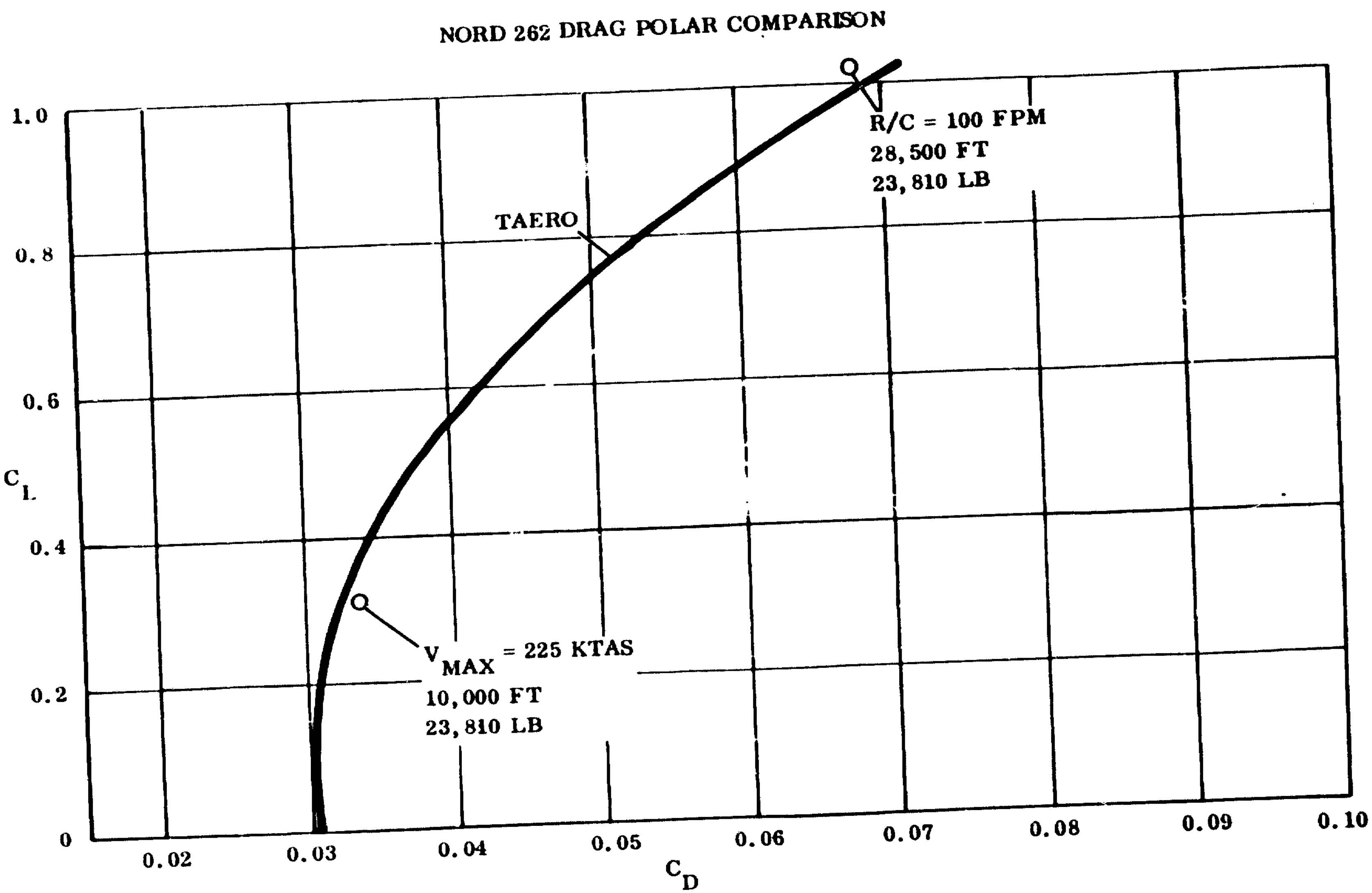


Figure 2-4. Nord 262 Drag Polar Comparison

3.0 CURRENT TECHNOLOGY BASELINES

A series of early fuselage studies covering the ranges from 2 to 5 abreast seating and fuselage fineness ratios from 6 to 12 was used to select a 3 abreast, 30 passenger (3-30) baseline fuselage which was stretchable from 15 to 50 passengers and a 4 abreast, 50 passenger (4-50) baseline fuselage which was stretchable from 20 to 88 passengers. Only the 30 and 50 passenger baseline fuselages were developed into complete aircraft designs.

The CV 600, a twin turboprop version of the CV 240, was used as the baseline technology level because of Convair's experience and expertise in this design. This 4 abreast, 40 passenger airliner exceeded many of the passenger comfort requirements of this study. See Table 3-1. Sufficient data was available to Convair to justify the design sizing methods used in this study. The aerodynamic and structures technologies used in this design are equivalent to current production aircraft in the small, short-haul transport class. Propulsion, interior and exterior noise and system have been updated to current technology.

Table 3-1. Comparison of CV 600 with Study Requirements

	CV 600	Study
Seat Width in.	18	18
Aisle Width in.	18	18
Aisle Height in.	79	72
Seat Pitch in.	38	32

This section presents Design Factors, Propulsion Analysis, Acoustic Analysis, Wing Design Considerations and Drawings and Characteristics of the two baselines sized for mission and performance requirements of the study optimized for min DOC at 100 n mi.

DOC for various stage lengths and fuel costs as well as DOC sensitivities to various physical and cost parameters are also presented for the two baselines.

3.1 DESIGN FACTORS

The study of the application of advanced technology to small, short haul transport aircraft requires the selection of baseline aircraft to which the advanced technology is applied. To keep the study as meaningful as possible, the baseline aircraft should 1) be of current technology, and 2) meet the study design ground rules. No current aircraft meets the design ground rules, especially, the cruise speed and cabin noise level requirements. Thus, the baseline aircraft are "paper designs".

Current technology is considered to be that which is in use by Commuter or Local Service airlines in mid 1979. Thus, two types of turboprop engines are considered to be current technology, i.e., those with 1) fixed or 2) free shaft power turbines. Free shaft engines have been chosen for this study to allow greater freedom in adjusting engine speed to reduce propeller noise. Turboprop powerplant scaling to hold propeller noise is discussed in the following paragraphs

ENGINE SELECTION

The Pratt and Whitney Aircraft of Canada PT6A-45 is selected to represent the small engine and the effect of flight speed and altitude on the thrust and fuel flow. The General Electric CT64-thermodynamic* limit is selected to represent a midsized engine and the large sized engine. The latter is obtained by doubling the CT64 SHP and F_N. Engine characteristics at SL, 90F, Takeoff Power Setting follow.

	Small	Mid	Large
SHP (HP)	927	3373	6746
F_N (LB)	70	247	494
W_F (LB/HR)	588	1636	Not Avail.

PROPELLER SELECTION

The propeller blade characteristics and number are selected for the small and mid-sized engines as representative of current design practice, and for the large engine as follows:

Engine	Small	Mid	Large
SHP	927	3373	6746
No. of Blades	3	4	6
Activity Factor/Blade	100	135	100
Design Lift Coefficient	0.4	0.4	0.4

These engine and propeller characteristics are used in the SAE AIR 1407 propeller noise calculation method and in a propeller thrust calculation method derived from the H.S. "Red Book" to generate the propeller efficiency versus diameter curves of Figure 3-1 (solid lines). The "sideline" noise is held constant at 88 EPNdB by selecting a gear ratio for the required propeller tip speed and RPM for each selected

*Disregarding the torque limited gear box of the CT64-820

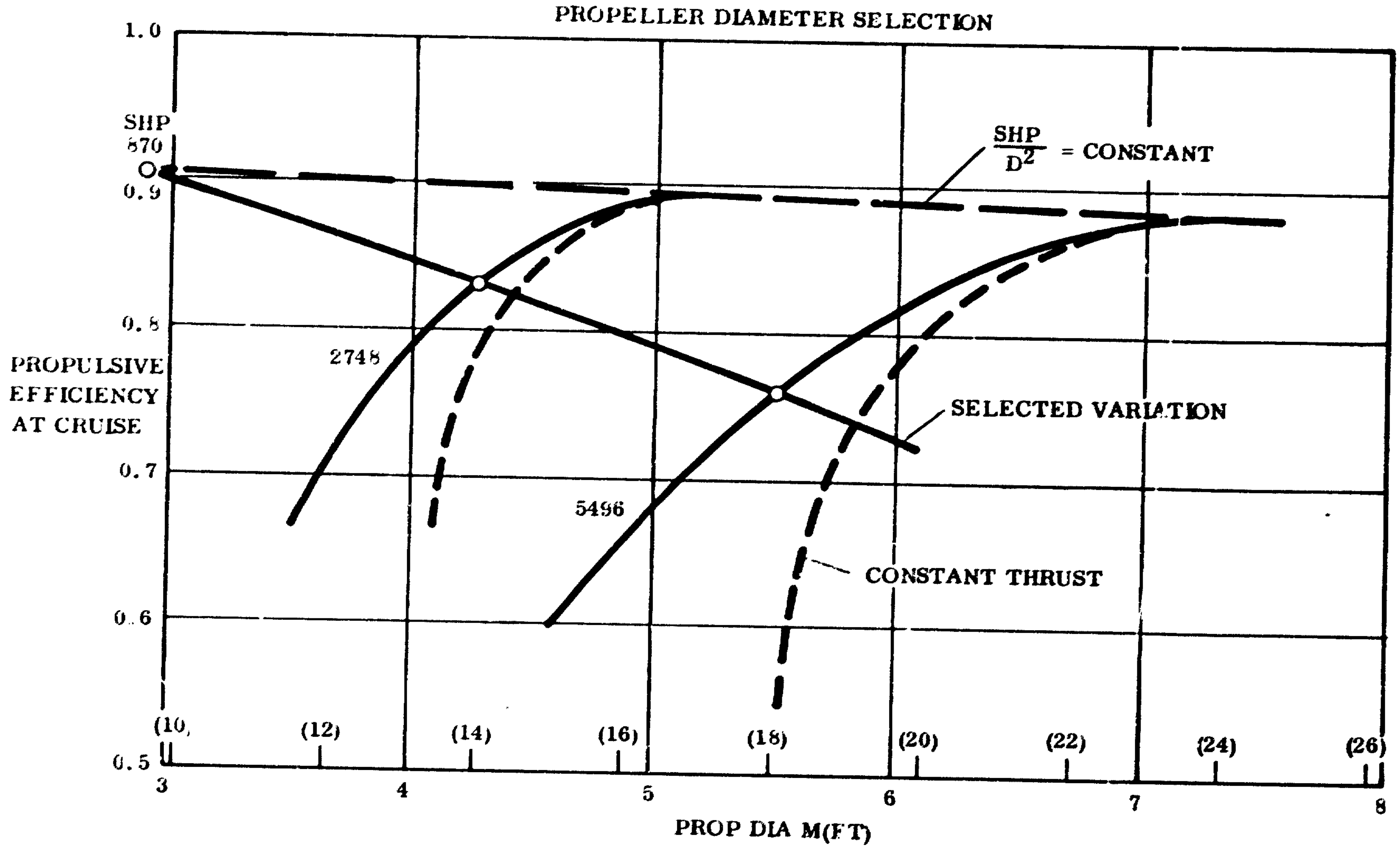


Figure 3-1. Propeller Diameter Selection

diameter. Then, the "cruise" noise is held constant by using 80% of the takeoff RPM for cruise (as for the CT64) and adjusting the propeller tip clearance to maintain the OASPL propeller noise at the side of the body (133.5 dB) achieved with a 4 ft clearance on the small propeller. See Table 3-2 for the detailed calculations.

Since the engine size is determined by the cruise speed capability, a loss in cruise efficiency results in an increased engine power output e.g., larger engine. The dotted curves on Figure 3-1 show the approximate variation of efficiency with diameter when the propulsive thrust is held constant. These curves show the range of propeller diameters from that which gives the maximum thrust to be the minimum diameter which will give the same thrust. Thus, for the largest engine, for example, the allowable propeller diameters run from a minimum of about 18 ft to a maximum of 24 ft (where the maximum thrust is achieved).

The final choice of propeller diameter is a compromise between the desire for a small diameter, to ease installation problems, (particularly for the large engine) and the desire for a small engine (maximum efficiency). The propeller diameter to be used in this study is approximately 5% greater than the minimum diameter. It results in the following propeller diameters and gear ratios:

Engine	Small	Mid	Large
Propeller Diameter (ft)	9.5	14	18
Maximum Prop. RPM	1700	1130	865
Gear Ratio	17.58 to 1	15 to 1	Not Avail.
Cruise Prop RPM	1360	905	692

SCALING FACTORS

The foregoing powerplant design process results in three discrete engine/propeller combinations which just meet the required external noise levels of FAR36 Stage 3 - 8 EPNdB with current technology. The overall sound pressure level (OASPL) at cruise is also the same on each. Since the baseline engines are assumed to be sized by cruise thrust, the engine scale factor (E.S.F.) corresponding to these engines is the ratio of their cruise thrust to that of the engine input for the PT6A-45. Thus, the midsized engine is 2970/1023 = 2.9 E.S.F. and the large engine is 5410/1023 = 5.3 E.S.F.

Figure 3-2 shows the required VDEP propulsion sensitive variables versus engine scale factor. Definition of parameters shown on Figure 3-2 are as follows:

Table 3-2. Engine/Propeller/Gear Box Calculation Holding Noise Constant

		SMALL (3 WAY / 300 TAF)	MID (4 WAY - 340 TAF) →				← LARGE (6 WAY - 600 TAF) →				
	D_p	9.3	16.0	16	15	14	26.0	22	20	18	16
	Takeoff Conditions S.L. 90°F M = .16 V_{TK} = 100 σ = .942										
	SHP	927	3373	3373	3373	3373	6746	6746	6746	6746	6746
	N_p	1700	1012	1040	1083	1130	775	778	860	865	900
	C_p	.129	.124	.152	.186	.230	.099	147	.204	.292	.400
	J	.60	.645	.665	.680	.700	.596	.646	.674	.790	.763
	$J/C_p^{1/3}$	1.307	1.296	1.248	1.193	1.143	1.298	1.22	1.146	1.202	.987
	C_p/x	.130	.1180	.1486	.177	.220	.0938	.130	.193	.278	.438
	ηx	.740	.725	.690	.630	.566	.741	.663	.596	.580	.382
	η	.745	.710	.662	.613	.548	.706	.647	.542	.513	.344
	FPI	2100				5757				10794	
	F	2030	7130	6670	6170	5510	14130	13000	11290	10300	6900
	V_{tip}	850	895	872	850	826	940	906	872	826	770
	RM_{tip}	.74	.780	.780	.74	.72	.82	.79	.76	.72	.67
	HM_{tip}	.787	.797	.777	.787	.736	.830	.800	.777	.736	.686
	PL 1	91.5	102.0	101.3	100.5	99.6	106.5	107.3	105.9	104.3	102.5
	PL 2	4.0	-4.0	-3.5	-2.9	-2.2	-10.0	-9.1	-8.1	-7.3	-6.2
	PL 3	-9.3	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5
NC=3	PNL	2.0	.5	.7	.9	1.1	0	.3	.8	1.8	2.2
-4	ΣPNdB	88.0	88.0	88.0	88.0	88.0	88.0	88.6	88.0	88.0	88.0
	Cruise Conditions 10,000 ft 23.3°F (ISA) M = .484 V_{TK} = 291 σ = .7384 N_{CR} = .8 N_{TO}										
	SHP	470	2748	2748	2748	2748	5496	5496	5496	5496	5496
	N_p	1360	811	833	866	906	620	622	687	692	720
	C	.308	.283	.307	.374	.468	.200	.301	.410	.595	.830
	J	1.96	1.96	1.90	1.86	2.00	1.72	1.36	1.93	2.03	2.18
	F_n	1.023	1.082	1.083	1.083	1.084	1.019	1.082	1.083	1.035	1.027
	$J/C_p^{1/3}$	2.92	2.935	2.92	2.71	2.58	2.92	2.78	2.50	2.41	2.23
	C_p/x	.309	.262	.284	.358	.445	.180	.280	.380	.604	.901
	η_x	.886	.896	.880	.864	.831	.903	.884	.848	.770	.683
	η	.904	.890	.888	.865	.831	.882	.864	.828	.758	.662
	F_N	1023	3208	3168	3096	2970	6300	6170	5820	5410	4730
	RM_{tip}	.635	.676	.657	.640	.636	.730	.673	.647	.613	.571
	HM_{tip}	.78	.796	.778	.788	.736	.800	.794	.763	.723	.673
	NL1	136.5	134.0	135.0	136.0	137.0	133.0	134.0	135.5	137.5	139.5
	ΔC	3.5	0	0	0	0	-3.5	-3.5	-3.5	-3.5	-3.5
	Y	4.	4.3	4.55	4.65	4.75	3.94	3.64	3.70	3.97	4.16
	Y/D	.421	.268	.285	.310	.340	.166	.165	.185	.215	.260
	NL_q	-9.5	-4.5	-5.5	-6.5	-7.5	0	-1.	-2.5	-4.5	-6.8
	XC	0	0	0	0	0	0	0	0	0	0
	RC	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	OASPL	133.5	133.5	133.5	133.5	133.5	133.5	133.5	133.5	133.5	133.5

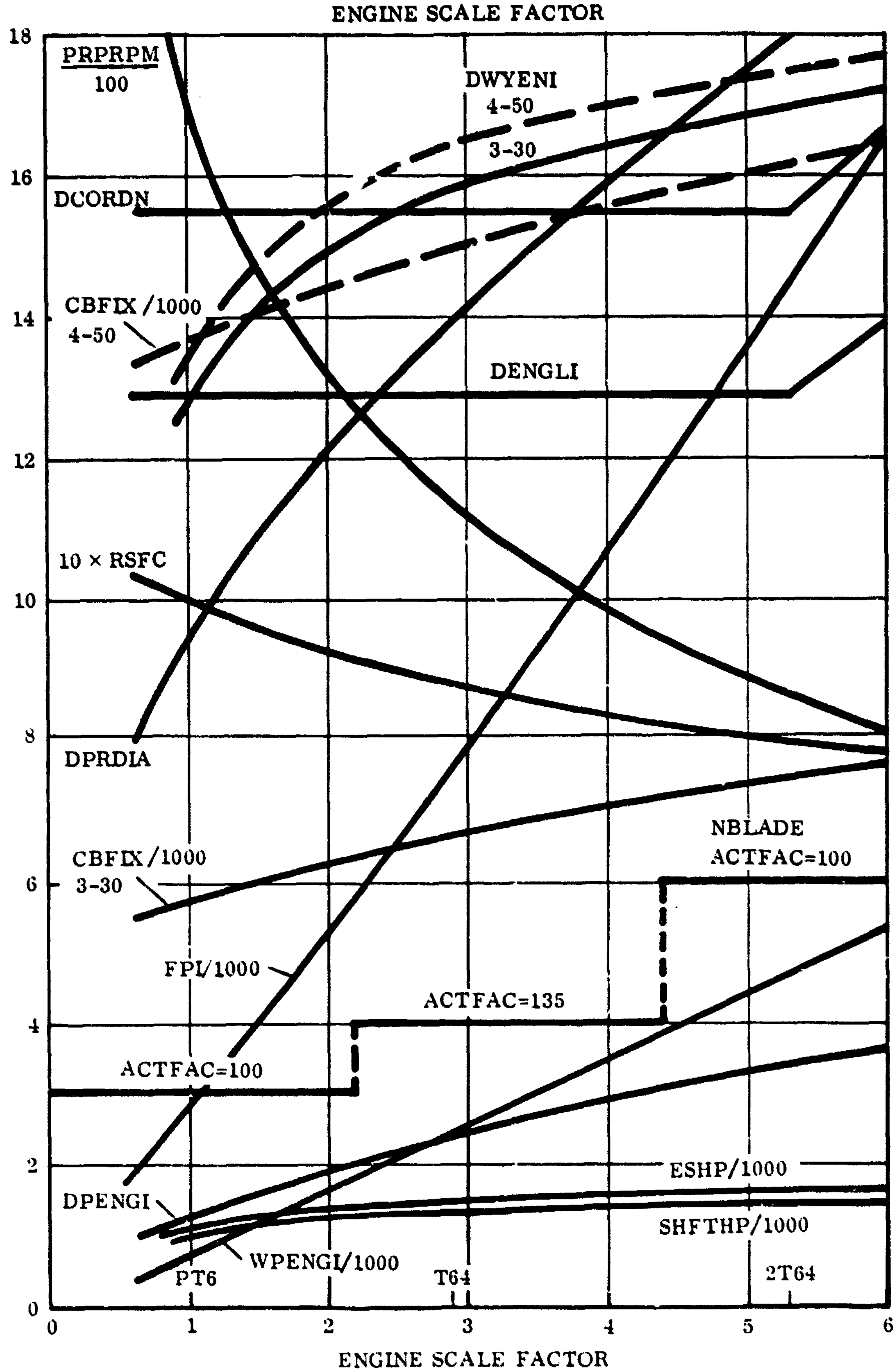


Figure 3-2. Engine Scale Factor

DPRDIA	- propeller diameter is faired through the available data
PRPRDM	- propeller design RPM is selected to provide a smooth variation of ND with ESF.
RSFC	- ratio of specific fuel consumption to input SFC is taken from General Electric curve at constant technology.
ESHP	- Equivalent Shaft Horsepower rating divided by ESF.
SHFTHP	- Shaft horsepower rating divided by ESF.
DPENGI	- Engine diameter is assumed to vary as $(SHP)^{.5}$ *
WPENGI	- Engine weight is assumed to vary as $(SHP)^{.93}$ *
DENGLI	- Engine length is assumed to vary as $(SHP)^{.4}$ * Since it is used only to determine the nacelle length (which is assumed to be 120% of the engine length), it is no shorter than the minimum nacelle length (required to position the propeller appropriately) divided by 1.2.
DCORDN	- Engine Nacelle length (see DENGLI)
DWYENI	- Engine spanwise location is varied to provide the required tip clearance to the side of body, and is, therefore different for each body width.
FPI	- total thrust per nacelle under sea level standard day, static conditions.
NBLADE / ACTFAC	number of propeller blades and activity factor per blade
CBFIX	- Body and contents, weight including acoustic penalty which varies with propeller diameter.

* As indicated by Garret Airesearch engine scaling factors.

3.2 PROPULSION ANALYSIS

The small baseline powerplant to be scaled for use in the 30 passenger baseline aircraft is selected as:

PT6A-45 engine with standard gearbox (1700 prop RPM)

9.5 ft diameter 3 blade 100 AF per blade 0.4 $C_{\ell i}$	Propeller

This powerplant delivers a cruise thrust that is within 1% of the maximum achievable with this technology while meeting the traded noise limits allowed by FAR 36 XYZ (NPRM-75-35C) minus 8 EPNdB. It is truly representative of current technology while meeting the requirements of the STAT study.

DISCUSSION

The design conditions to be used for determining the baseline powerplants are as follows:

Condition	Altitude (ft)	Temp. (°F)	Mach.	Power Setting (% Max. T.O.)	EPNdB	Dist. to Mike (ft)
Takeoff	1,000	90	0.178	37	81	1,000
Sideline	0	90	0.160	100	86	1,476
Approach	394	90	0.155	8 (idle)	90	394
Cruise	10,000	23.4	0.456	Max cruise	No requirement	

The engine installation losses typical of current PT6 installations are taken to be:

10	Lb/min bleed air extraction
15	HP power extraction
0.5%	Intake loss (scoop inlet)
0%	Exhaust loss (P and WC spec duct)

Applying these to the CPWA deck P 1508 for the design conditions results in the following installed engine performance at optimum engine speed.

Condition	SHP	Fn(LB)	W_f (LB/HR)
Takeoff	335.3	22.6	337.9
Sideline	927.2	69.9	588.4
Approach	71.9	6.42	234.3
Cruise	870.3	4.83	480.3

Current technology propellers are assumed to have the following typical characteristics:

3	Blades
0.4	Design lift coefficient $C_{\ell i}$
100	Activity factor (AF) per blade

This engine performance is combined with parametric propeller diameters and speeds (RPMs) in a computer program called PROPPN which determines the propeller noise at the microphone location by use of the method of SAE AIR 1407 and the net thrust of the installed powerplant by the method of H-S PDB6101 "Red Book."

The propeller noise is plotted in Figure 3-3 for the takeoff, sideline and approach condition respectively. The traded limits shown allow 2 EPNdB additional noise at takeoff and 2 EPNdB less noise at approach from that of FAR 36XYZ (NPRM 75-35C) minus 8 EPNdB.

The takeoff and cruise thrust are also shown in Figure 3-3. Since, for this class of aircraft, the engine is expected to be sized by the cruise speed requirement of 250 KIAS at 10,000 ft, the propeller diameter/RPM is selected to maximize cruise thrust while just meeting the noise limits. This selected diameter/RPM (9.5 ft @ 1700 RPM) is within 1% of the maximum achievable with this technology.

The powerplant selected for the 50 baseline aircraft is defined below:

GECT64-820 engine with a nonstandard gearbox

Standard gearbox reduction ratio 13.44:1

Nonstandard gearbox reduction ratio = 11.00:1

Propeller:
- 12.35 ft diameter
- 4 blades
- 135 activity factor per blade
- 0.40 $C_{\ell i}$

The propeller selected meets all respective noise limits while supplying acceptable cruise and takeoff thrust.

A parametric analysis of propeller diameter and rotational speed was performed using engine characteristics at design condition. The results of this analysis are plotted in Figures 3-4 through 3-8 following, with tradeoff limits indicated.

The design conditions to be used for determining the baseline powerplants are the same as for the 30 passenger baseline.

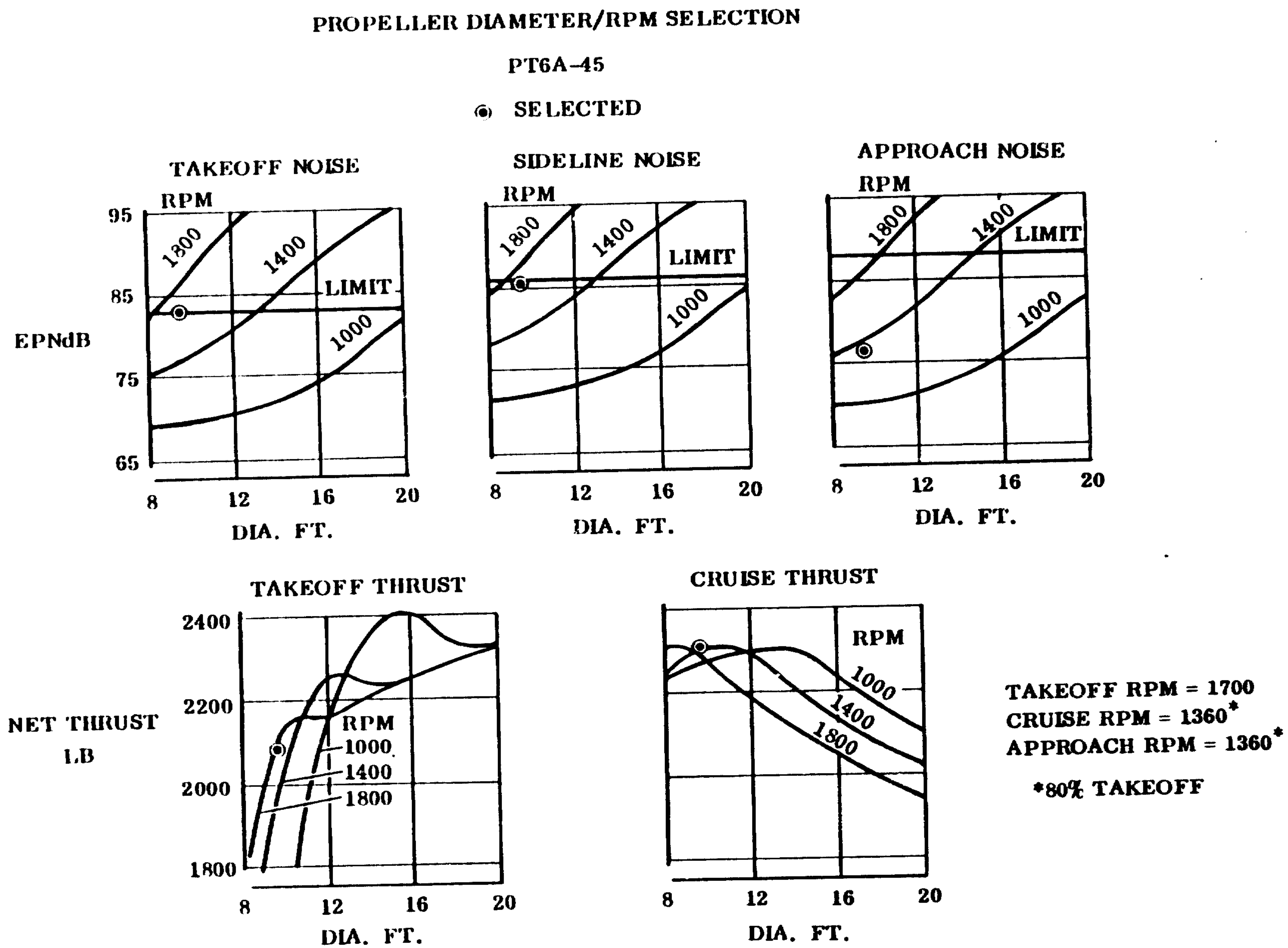


Figure 3-3. Propeller Diameter/RPM Selection

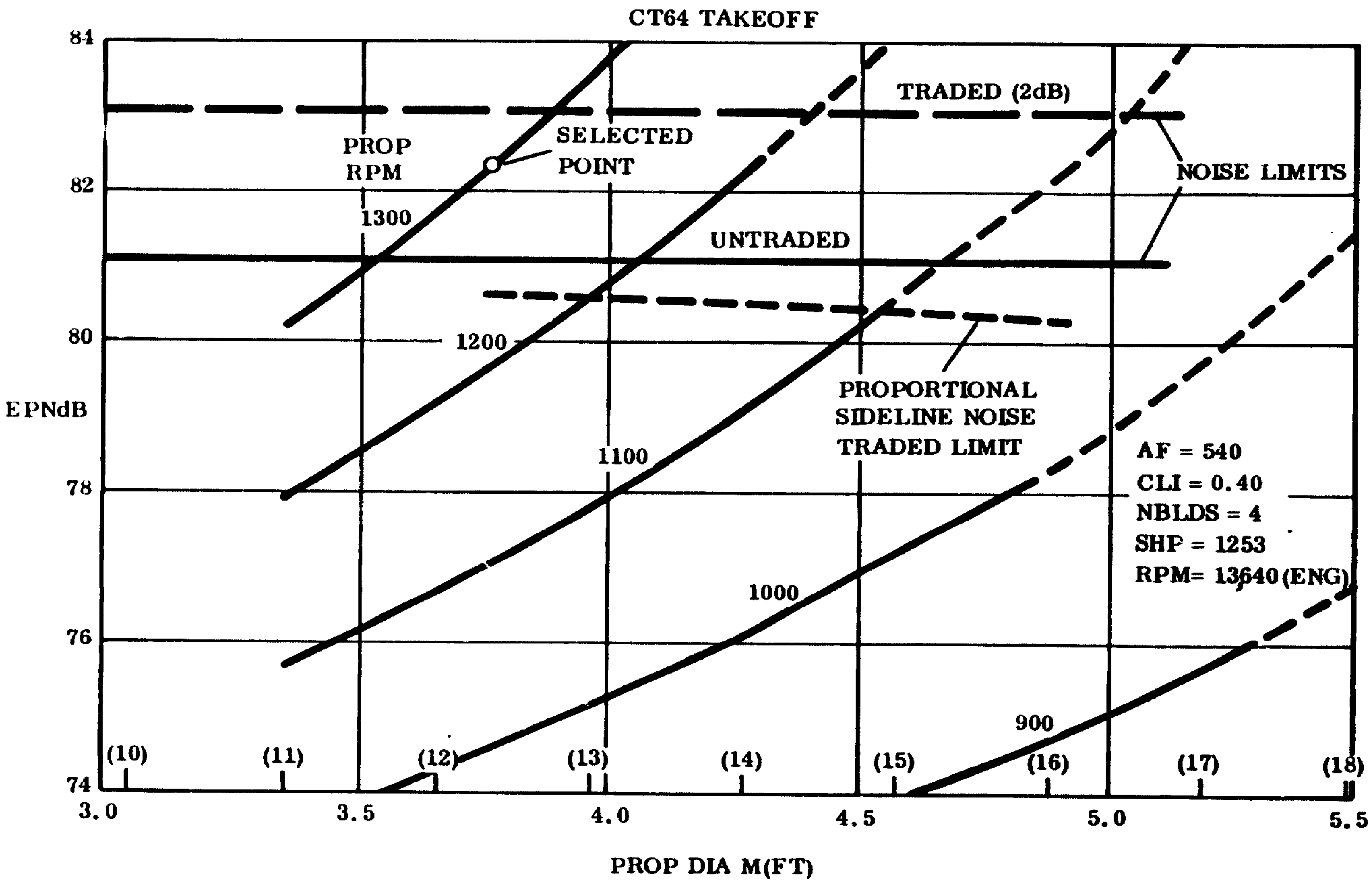


Figure 3-4. CT64 Takeoff

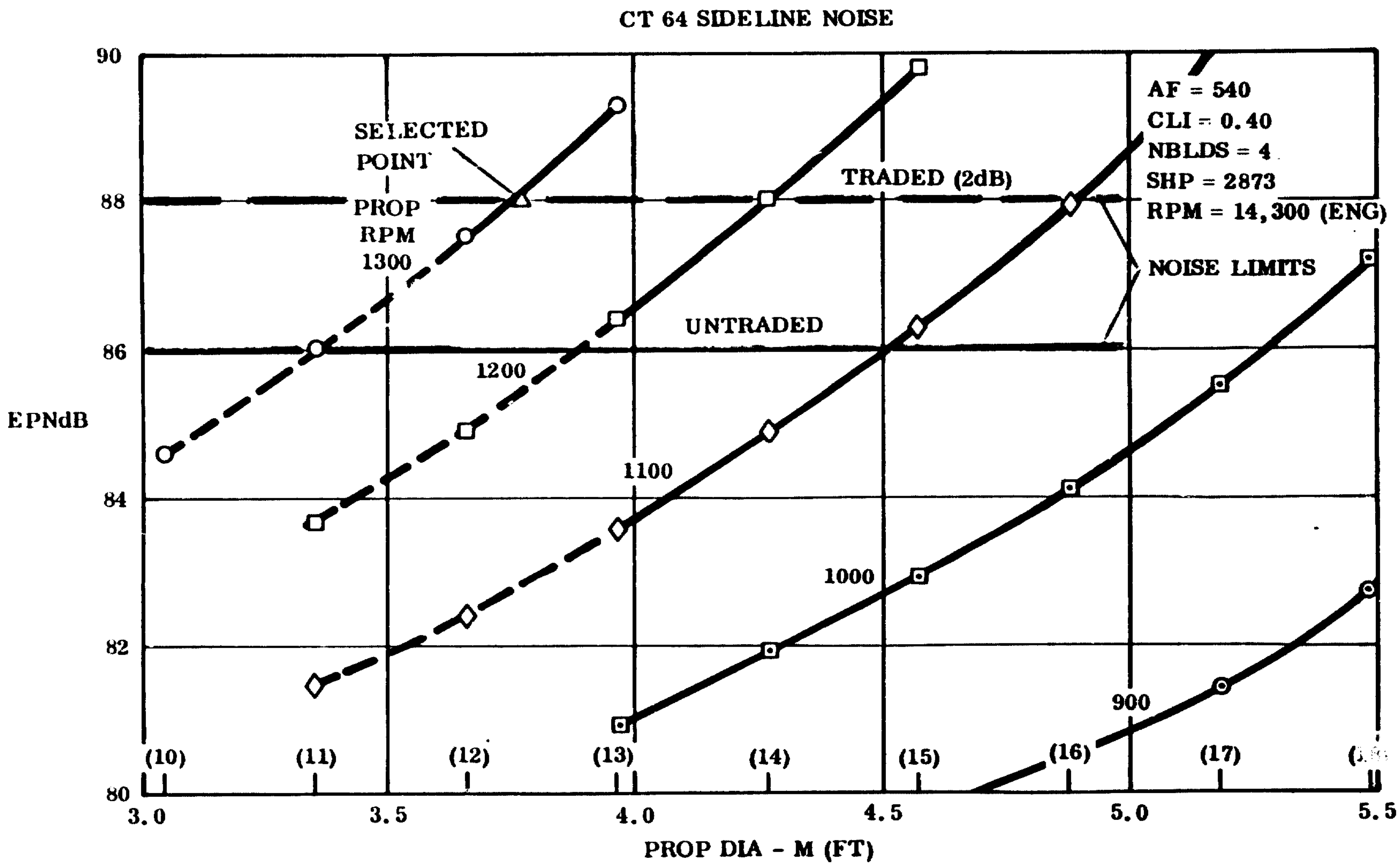


Figure 3-5. CT64 Sideline Noise

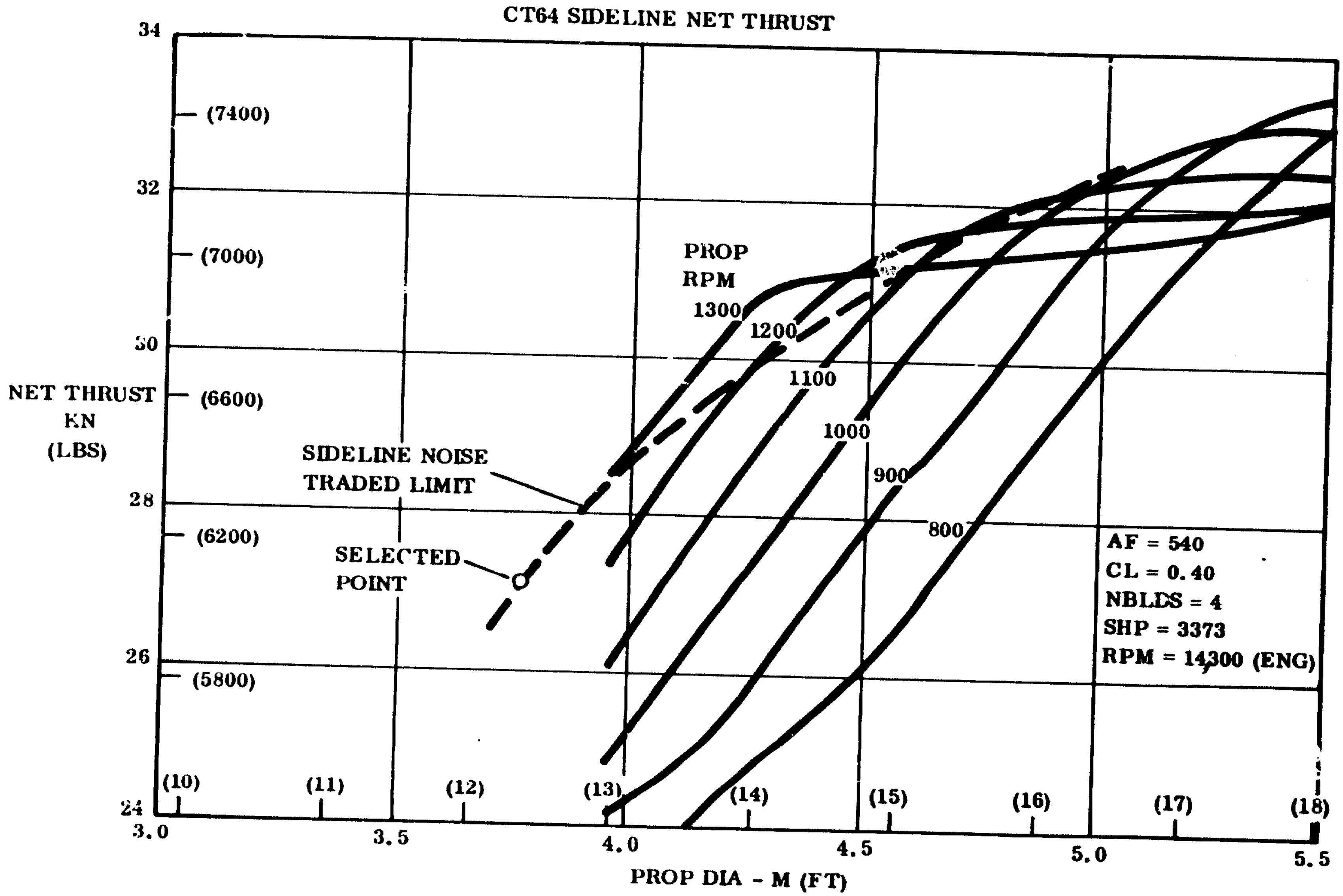


Figure 3-6. CT64 Sideline Net Thrust

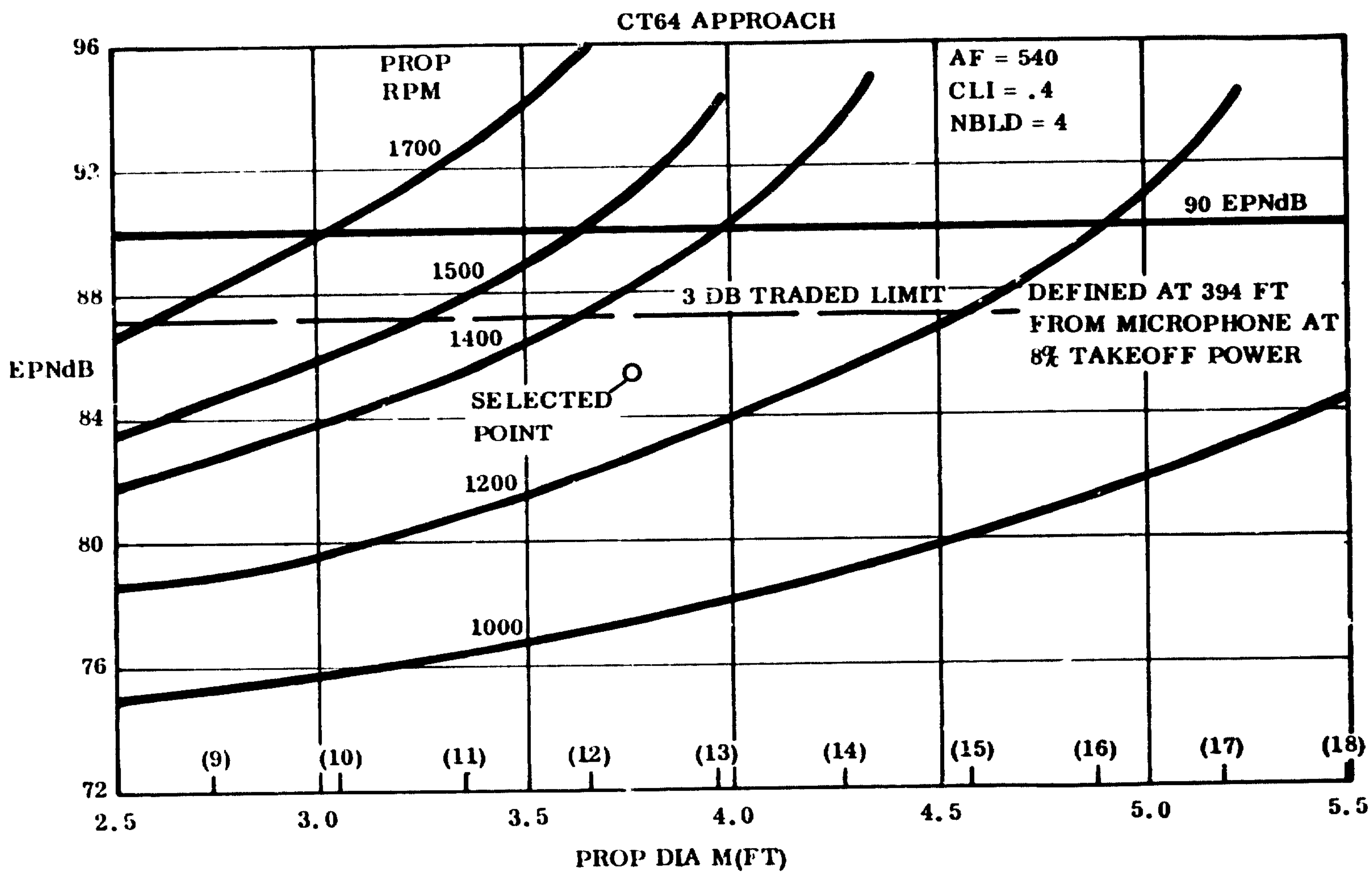


Figure 3-7. CT64 Approach

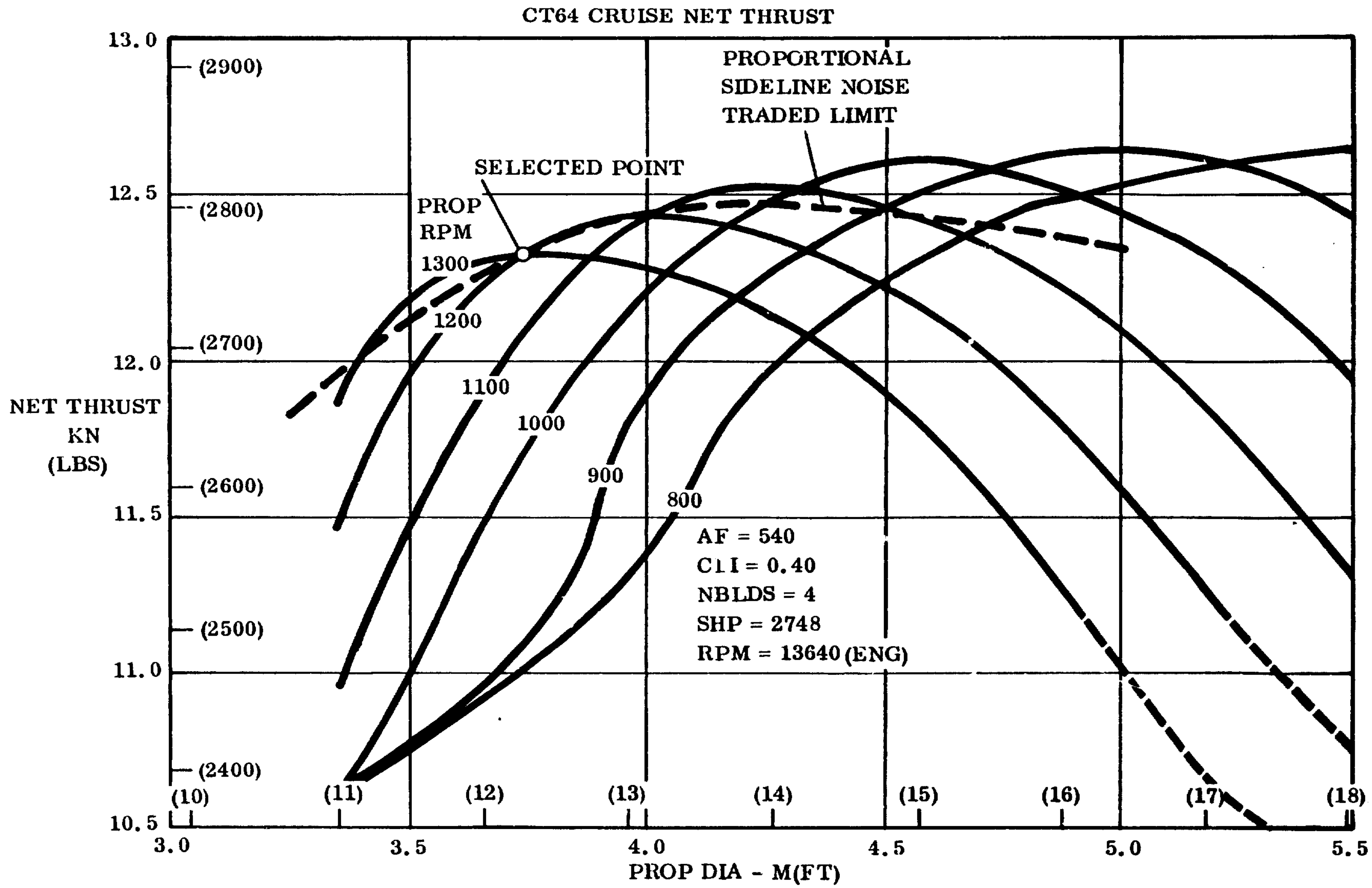


Figure 3-8. CT64 Cruise Net Thrust

A lower reduction ratio was used in conjunction with a lower takeoff power setting (sideline condition) to reduce noise. This decreased takeoff power and cruise thrust. The higher takeoff power was more than adequate (since the engine is sized by the cruise thrust requirement), so a loss here was not critical. A 1% cruise thrust reduction was accepted to decrease propeller diameter by more than 10%, providing a more manageable size.

3.3 ACOUSTIC ANALYSIS

The following parameters were assumed for calculation of the noise reduction (NR) properties of the cabin structure and interior volume.

Frame Spacing	=	16.0 ins.
Stringer Spacing	=	8.0 ins.
Frame Depth	=	3.0 ins.
Al. Skin Thickness (nom)	=	.040 in.
Avg. Structural Surface Density	=	1.15 lbs/ft^2
Window Structural Surface Density	=	5.5 lbs/ft^2

Note: Structural configuration and interior trim is approximately equivalent to that of the CV600 aircraft.

Two propellers were studied initially. The pertinent propeller parameters are given below. All propeller parameters are given for a cruise altitude of 10,000 feet and a true airspeed of 291 KTAS.

Prop Diameter	9.5 ft	12.25 ft
SHP	870	870
RPM	1700	1050
$M_{HELICAL}$	0.908	0.774
Blade Loading (SHP/D^2)	9.64	5.8

The 9.5 ft propeller was selected for further study as a baseline because it just met the far field noise requirements.

In estimating cabin noise levels the following effects were taken into consideration:

(a) The noise reduction (NR) of the cabin was increased by +3 dB to account for sea level cabin pressure at 10,000 ft altitude, i.e.,

$$dB = 20 \log_{10}\left(\frac{\rho C_{(10,000)}}{\rho_o C_{o(S.L.)}}\right), \text{ where } \rho = \text{air density}, \; C = \text{speed of sound}$$

(b) The noise radiation of the propeller was reduced by -3 dB at 10,000 ft alt by the same ratio as in (a), since SAE AIR 1407 predicts noise only at sea level.

(c) Beneficial effects due to forward flight of the propellers, as described in SAE AIR 1407, were enhanced further by data obtained by NASA/LRC and Ham. Std., published in ASME document 77-GT-70 Figure 1; "Some Measured and Calculated Effects of Forward Velocity on Propeller Noise."

The comparative results of 9.5 and 12.25 ft dia propellers are shown below.

Prop. Dia	9.5	12.25
Exterior OASPL-dB (prop. plane) (prop. harmonics only)	129 dB	123.5 dB
Interior OASPL-dB (prop. plane) (prop. harmonics only)	111[(a)]	111

(a) The cabin has a diametrical acoustic resonance (cross-mode) at about 80 Hz. Fundamental prop. blade passage frequency (3 × P) is 85 Hz at 1700 rpm cruise. Thus, the 111 dB OASPL level results from generation of an acoustic standing wave inside the cabin. This phenomenon essentially short circuits the acoustic transmission loss (TL) of the structure.

If both propellers are considered to be in the plane of a major bulkhead (area of high structural rigidity) with the first seat row about 3 feet aft of the bulkhead, then for 4 ft tip clearance the 9.5 ft prop. SPL (at the first seat row) is reduced to 106 dB and for the 12.25 ft prop. to 99.5 dB as shown below.

Prop. Dia	9.5 ft	12.25
Basic OASPL (interior) (with Sync-Ph) 2 ft tip cl	111 dB	106 dB
Incr. Tip Cl. to 4 ft	107 dB	101.5 dB
First Row 3 ft Aft of Bulkhead 4 ft Tip Cl.	106 dB	99.5 dB
Delta dB to 85 dB	21 dB	14.5 dB
Max total surface density of cabin for above delta	15 lbs/ft^2	8 lbs/ft^2
@ D/2, Taper to	6.6 lbs/ft^2	3 lbs/ft^2
@ D Taper to	3 lbs/ft^2	3 lbs/ft^2

Note: 3 lbs/ft^2 is considered minimum for aero noise vis-a-vis SIL requirements of 65 dB.

Surface densities required to meet 85 dB OASPL and 65 dB SIL are shown above and are used in the following paragraphs to develop the VDEP baseline acoustic weight penalties.

Weight and center of gravity analysis is summarized in Table 3-3 for the baseline 30 passenger, 3 abreast fuselage configuration for fuselage and contents with and without acoustic treatment.

Table 3-3. 30 Passenger Fuselage Weight

Condition	With Acoustic Treatment		Without Acoustic Treatment	
	Weight	*Fus. Sta.	Weight	*Fus. Sta.
Empty Weight	11399	383.1	8350	395.7
Operating Empty Weight	12471	390.1	9422	403.5
Zero Fuel Weight	18471	415.4	15422	428.6

*Fuselage Station 100 is Nose of Aircraft.

A 15.0 ft diameter propeller results in a 3049 lb acoustic weight penalty. See Table 3-4. The final 30 passenger baseline acoustic penalty is 2324 lb for a 11.47 ft propeller.

Table 3-4. 30 Passenger Baseline Acoustic Penalty

Baseline 15.0 Ft Dia/Propeller @ Station 280

Fuselage Station	Area Ft^2	Density Required	Existing Density	Density Penalty	Weight Penalty	Sta. $\bar{X}$
150 to 190	48.3	3.0	>3.0	0	0	-
190 to 370	149.7	15.0	2.4	12.6	1886.0	280.0
370 to 460	96.3	10.8	2.8	8.0	770.0	415.0
460 to 640	192.5	4.8	3.1	1.7	327.0	550.0
640 to 740	106.9	3.0	2.8	.2	21.0	690.0
200 to 735 *	222.9	3.0	2.8	.2	45.0	467.5
				Baseline Total	3049.0	348.6

*Upper quadrant

Weight and center of gravity analysis is summarized in Table 3-5 for the baseline 50 passenger, 4 abreast fuselage configuration for fuselage and contents with and without acoustic treatment.

Table 3-5. 50 Passenger Fuselage Weight

Condition	With Acoustic Treatment		Without Acoustic Treatment	
	Weight	*Fus. Sta.	Weight	*Fus. Sta.
Empty Weight	15291	443.6	10920	454.8
Operating Empty Weight	16652	442.1	12281	451.5
Zero Fuel Weight	26652	476.6	22281	488.6

*Fuselage Station 100 is Nose of Aircraft.

A 15.0 ft diameter propeller results in a 4370 lb acoustic weight penalty. See Table 3-6. The final 50 passenger baseline acoustic penalty is 3831 lb for a 13.15 ft propeller.

Table 3-6. 50 Passenger Baseline Acoustic Penalty

Baseline 15.0 Dia/Propeller @ Station 348

Fuselage Station	Area Ft^2	Density Required	Existing Density	Density Penalty	Weight Penalty	Sta. $\bar{X}$
165 to 258	100.8	3.0	2.95	.05	5.0	211.5
258 to 438	221.6	15.0	2.59	12.41	2750.1	348.0
438 to 528	110.8	10.8	2.58	8.22	910.8	483.0
528 to 708	221.6	4.8	2.20	2.6	576.2	618.0
708 to 810	114.8	3.0	3.51	0	0	759.0
165 to 810 *	328.8	3.0	2.61	.39	128.2	487.5
BASELINE TOTAL:					4370.3	415.7

*Upper quadrant

3.4 WING DESIGN CONSIDERATION

Baseline trade studies of aspect ratio (AR) and wing loading (W/S) have shown reduced DOC by increasing these parameters above AR = 12 and W/S = 70. Accepting the baseline high lift system, a study was conducted to increase AR from 12 to 15 at W/S = 70. The flutter limit for the baseline at AR = 12 is arbitrary and a survey of existing transports and bombers was made using b'/t (structural span/root thickness) as a traditional criteria for flutter potential. Structural span is measured along the c/2 line and is the sum of both wings. Since actual root thickness is often increased to lower b'/t by expanding the root chord and root thickness ratio on the inboard part of the wing, this thickness is used in Table 3-7. The value of b'/t is 50.5 on the Grumman Gulfstream I (G-159) twin turboprop as compared with the CV440 (the same as on the 340, 640, 580 versions) value of 39.0. Other high values of 57.6 for the B66B and 66.7 for the B47B cover the range. Many others are in the 40 to 46 range. The values for the baseline aircraft using the same thickness ratio at the root are shown in Table 3-8 for AR = 12, 13, 14, 15. With a value b'/t = 48.7 at AR = 15, it was felt that this was a useful range to investigate the potential reduction in DOC with AR on the 3-30 baseline.

Table 3-7. Existing Transports and Bombers Structural Span/Root Thickness Survey

		G-159	440	C118A	C130A	880	CL44	990	C135A	C133A	C141A	B66B	B47B	B36H	B52B
AR	-	10.1	12.0	9.4	10.1	7.2	9.8	6.4	7.0	12.1	8.0	6.7	9.4	11.1	8.6
Wing Area	ft^2	614	920	1463	1746	2000	2075	2250	2433	2673	3228	780	1428	4772	4000
Sweep C/2	deg	-0.5	2.1	-1.5	-3.5	32.3	4.1	32.5	32.1	-2.5	23.5	33.0	33.3	9.1	33.0
Design LF	g	3.75	3.75	3.75	4.5	3.75	3.75	3.75	3.75	3.75	3.75	4.8	3.0	3.0	3.0
b'	ft	78.8	105.4	117.5	132.8	142.0	142.7	142.3	154.5	179.8	175.3	86.5	138.8	232.9	220.7
c	ft	11.2	13.5	19.1	16.0	35.7	22.6	35.2	28.2	25.0	33.1	20.0	17.3	35.3	30.9
t	ft	1.56	2.70	3.05	2.88	3.28	3.84	3.28	4.70	3.85	4.33	1.50	2.08	7.33	4.98
t/c	-	0.14	0.20	0.16	0.18	0.09	0.17	0.09	0.17	0.17	0.14	0.08	0.12	0.22	0.16
b'/t	-	50.5	39.0	38.5	46.1	43.3	37.3	43.3	32.8	46.7	40.4	57.6	66.7	31.7	44.3

Table 3-8. Variation of 3-30 Baseline b'/t with Aspect Ratio

AR		12	13	14	15
Wing Area	sq ft	569	569	569	569
b'	ft	82.65	86.0	89.3	92.4
c	ft	10.60	10.21	9.84	9.51
t = 0.20 c	ft	2.12	2.04	1.97	1.90
b'/t	-	39.0	42.2	45.4	48.7

3.5 30 PASSENGER BASELINE AIRCRAFT

3.5.1 3-30 Baseline Design Selection

SUMMARY. A 3 abreast, 30 passenger low wing turboprop aircraft design is selected as a candidate to be a baseline for application of advanced technology. It meets both the cockpit and passenger cabin design requirements corresponding to current operator recommendations and the preferred aircraft mission performance requirements with current technology. It has the following characteristics. See Table 3-9 and 3-10.

Table 3-9. 3-30 Baseline Characteristics

Crew	2 pilots + 1 cabin attendant
Passengers	30
abreast	3
seat width between arm rests	45.72 cm (18 in.)
seat pitch	81.28 cm (32 in.)
aisle height	182.88 cm (72 in.)
aisle width	45.72 cm (18 in.)
weight allowance (including baggage)	90.72 kg (200 lb.)/passenger
Baggage, storage, carry-on	50.8 cm × 50.8 cm × 27.9 cm (2) underseat (20 in. × 20 in. × 11 in.) (1) overhead
garment	2.03 cm (0.8 in.)/passenger
preloaded (containerized)	0.142 cu. m (5 cu. ft.)/passenger
Cabin operating pressure	3.45 N/sq. cm (5 psi)
Maximum cabin interior noise level	85 dB OASPL/65 dBSIL
Fuselage length	2011.68 cm (792 in.)
Space and allowable weight provisions for a lavatory & a beverage bar	
Powerplants: (2) scaled PT6 engines driving 3 bladed propellers	
Rated Power	1747 kw (2343 ESHP)
Propeller Diameter	3.5 m (11.47 ft.)
Design* Weights	
Ramp	13426 kg (29,600 lb.)
Takeoff	13426 kg (29,600 lb.)
Landing	12791 kg (28,200 lb.)
Zero Fuel	12110 kg (26,700 lb.)
Basic Operating Weight**	8896 kg (19,611 lb.)
Fuel Capacity	3523 kg (7,767 lb.)

* Airframe design life 30,000 hours/60,000 cycles or more.

** Including 1054 kg (2324 lb.) of acoustic penalty in fuselage.

Table 3-10. 3-30 Baseline Performance

Wing, span	25.19 m (82.65 ft.)	
area	52.86 sq. m. (569 sq. ft.)	
aspect ratio	12.0	
sweepback of quarterchord	0.087 rad. (5.0 deg.)	
location on body	low	
single slotted flap area	8.99 sq. m. (96.77 sq. ft.)	
airfoil type	NACA 63 series	
Performance (standard day unless rated)		
Range with full design payload with I.F.R. reserves	1111 km (600 n. mi.)	
Corresponding cruise speed	459 km/hr (248 kt.) TAS	
Corresponding cruise altitude	7071 m (23,200 ft.)	
Runway length required (FAR 25) at S. L., 32°C (90°F)		
For takeoff at Design T.O. wt	1063 m (3486 ft.)	
For landing at intended destination at Design Landing wt.	1219 m (4000 ft.)	
Corresponding approach speed	185 km/hr (100 kt.) IAS	
Noise Levels (FAR 36, Amendment 8, Stage III minus 8 EPN dB)		
Takeoff	83 EPNdB (83 allowed after trading)	
Sideline	85 EPNdB (86 allowed, untraded)	
Approach	84 EPNdB (88 allowed after trading)	
Maximum cruise speed at 3048 m (10,000 ft.)	463 km/hr (250 kt.) IAS	
Maximum terminal area speed	>333 km/hr (180 kt.) IAS	
Landing stall speed at design landing weight	143 km/hr (77 kt.) IAS	
Aircraft Price (based on 250 A/C breakeven)	$M 3.159	
Direct Operating Cost at fuel price/gal. (on avg. stages of)	$0.75	$1.00
93 km (50 n. mi.) $/km ($/n. mi.)	2.34 (4.33)	2.54 (4.70)
185 km (100 n. mi.)	1.53 (2.83)	1.69 (3.13)
278 km (150 n. mi.)	1.26 (2.34)	1.37 (2.54)
370 km (200 n. mi.)	1.11 (2.06)	1.20 (2.23)
741 km (400 n. mi.)	0.95 (1.76)	1.04 (1.92)
1111 km (600 n. mi.)	0.90 (1.66)	0.98 (1.81)
Maximum allowable weight, 32°C (90°F)		
Into a 914 m (3000 ft) runway at S. L.	< 8891 kg (19,600 lb)*	
From a 2134 m (7000 ft) runway at 1829 m (6000 ft) altitude	10796 kg (23,800 lb)**	

* The maximum landing weight allowable into a 913 m (3000 ft) runway at S. L., 32°C (90°F) is less than weight of the aircraft without any payload or fuel and indicates the inability of the aircraft to operate from this runway at any altitude.

** The maximum allowable takeoff weight at 1829M (6000 ft) 32°C (90°F) is limited to 10796 kg (23800 lb) by the runway length of 2134 m (7000 ft.). This allows 13 passengers to be carried over a 185 km (100 n. mi.) range and indicates the degree of flexibility of this design.

A three view drawing is shown in Figure 3-9 (SD 79-48024) to provide a basis for computerized analysis and design studies for final airplane sizing. An inboard profile is shown in Figure 3-10 (SD 79-48017).

The airplane performance capability is summarized in Figure 3-11.

DISCUSSION: The 3 abreast, 30 passenger low wing turboprop aircraft has been designed to meet all the preferred cockpit, passenger cabin and performance requirements with current technology. It is a candidate to be a baseline for application of advanced technology.

The design procedure which assures compliance with all the requirements consists of the following steps.

STEP 1. Select a fuselage cross section having space for three 45.7 cm (18 in.) wide seats (between arm rests). Two of these are on the RH side of the airplane and one is on the LH side separated by an 45.7 cm wide × 182.9 cm high aisle (18 in. × 72 in.) It has space for a 50.8 cm × 50.8 cm × 27.9 cm (20 in. × 20 in. × 11 in.) bag to be stowed under each aisle seat with room for the same sized bag overhead on the RH side. It also has room for controls and ducts under the floor and for lights and air vents overhead. The 8.26 cm (3.25 in.) cabin wall is thick enough to accommodate structure having a life of at least 30,000 hrs and 60,000 cycles at an operating pressure of 3.45 N/sq. cm. (5.0 psi.) It will also accommodate acoustic material to assure a maximum cabin interior noise level of 85 dBOASPL and a speech interference level of 65 dB as well as typical decorative lining and trim. The selected cross section is circular 248.9 cm (98 in.) in diameter. It is shown on Figure 3-12 (SD 79-48014).

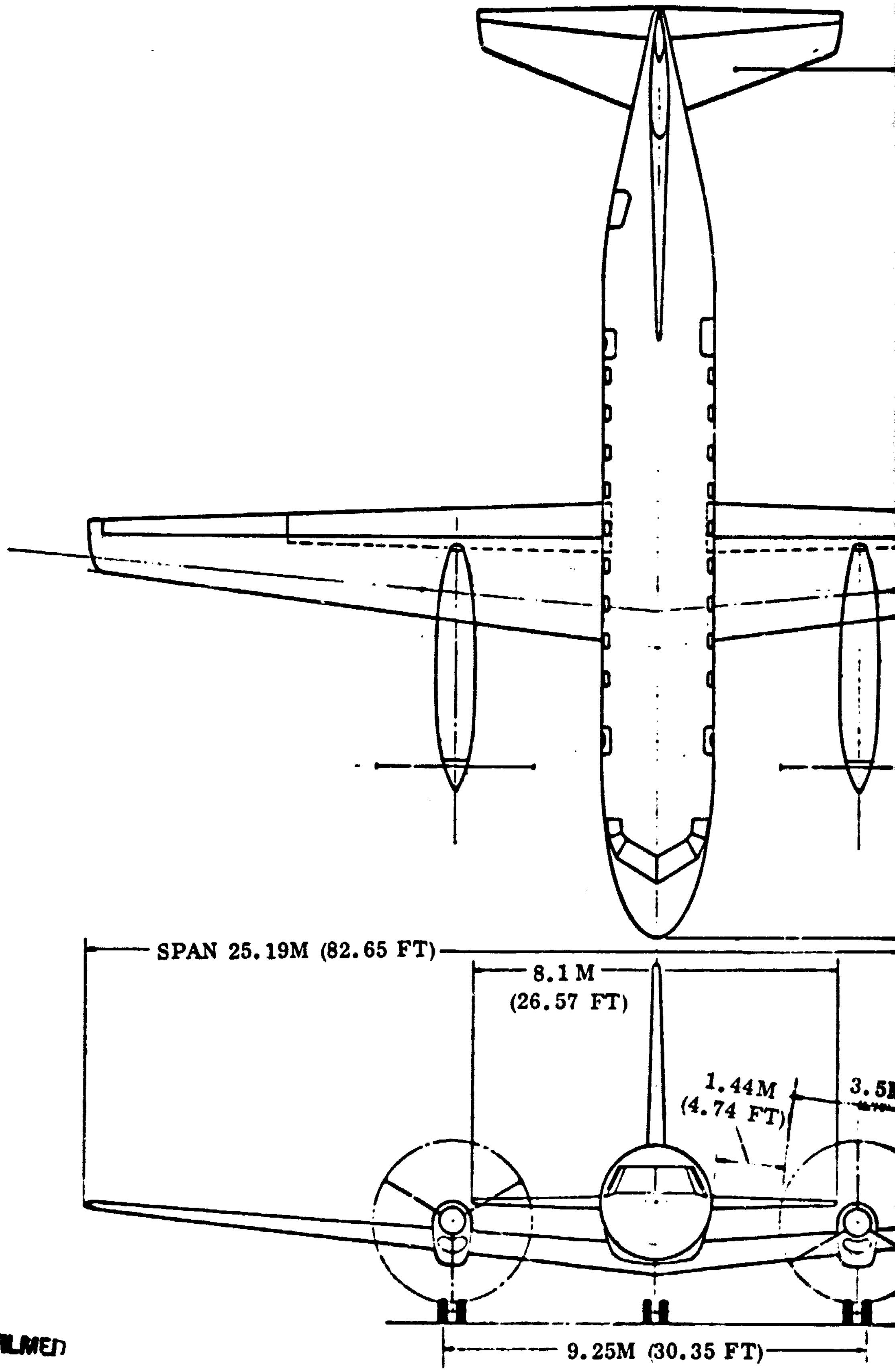
STEP 2. Select a fuselage length (utilizing the selected cross section) which includes a cockpit section, a passenger cabin and a tailcone.

The cockpit section is sized to provide space for a two man crew plus an observers seat, typical instruments and controls and a nose gear retraction well. See Figure 3-2.

The passenger cabin contains 30 seats on 81.3 cm (32 in.) pitch, a cabin attendant and seat, space for a lavatory and beverage bar, a garment stowage area having 2.0 cm (0.8 in.) of hanger bar per passenger, a 76.2 cm × 177.8 cm (30 in. × 70 in.) main entry door/stair, a 30.5 cm × 45.7 cm (12 in. × 18 in.) window for each seat, and three 61 cm × 127 cm (24 in. × 50 in.) Type I emergency exits. The main door constitutes the other emergency exit required by FAR 25.

The tail cone length is chosen at 2.5 diameters to minimize aerodynamic drag. It contains a baggage compartment with two containers capable of holding 0.14 cu. m (5 cu. ft.) of baggage per passenger, and easily loaded without interfering with passenger loading. It also contains the airconditioning/pressurization unit.

15 14 13 12 11



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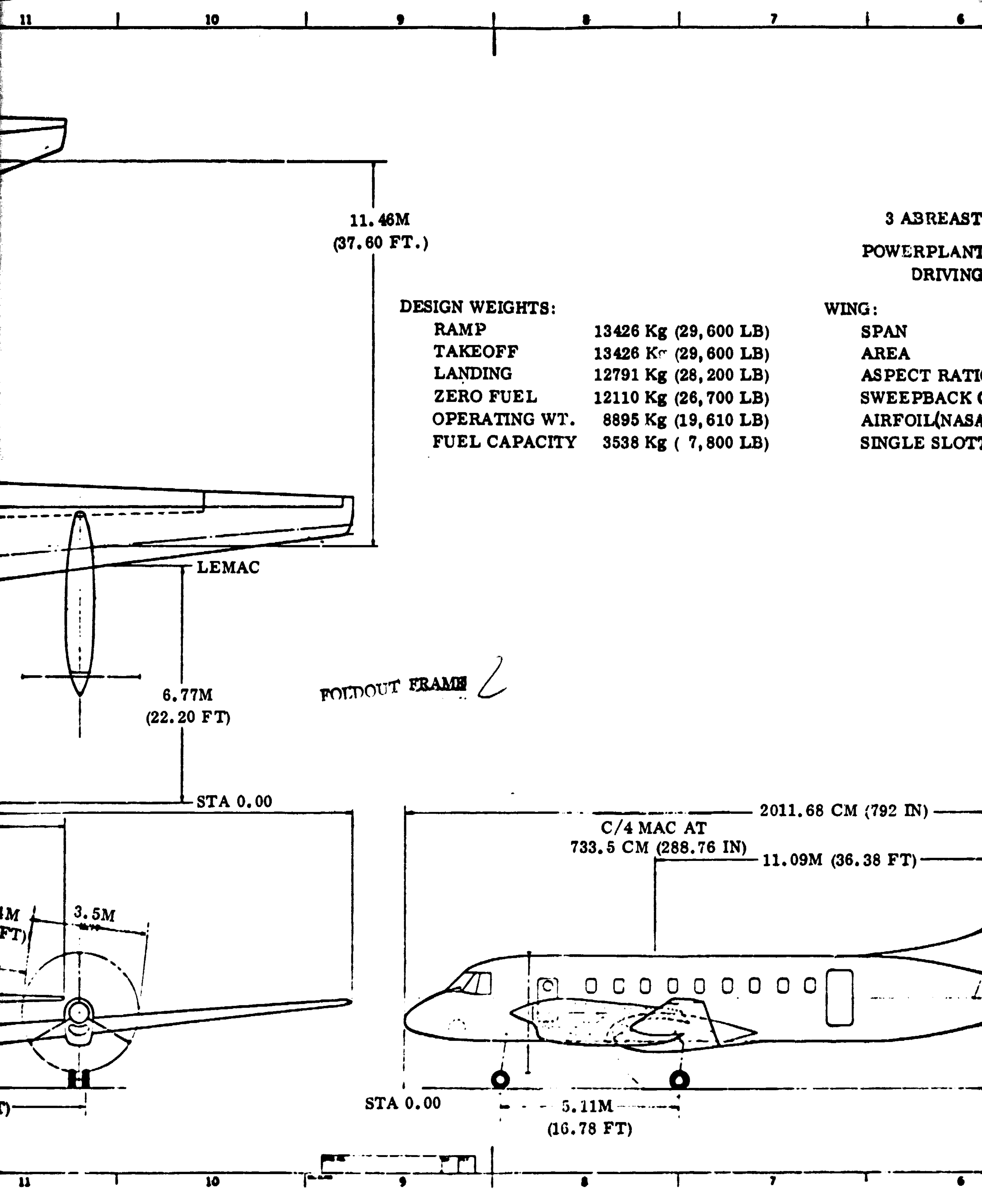

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3-30 BASELINE CHARACTERISTICS

3 ABREAST, 30 PASSENGER, LOW WING TURBO PROP TRANSPORT

POWERPLANT (2) FREE TURBINE ENGINES OF 1747 KW(2343 ESHP) EACH
DRIVING 3.5M(11.47 FT) DIAMETER 3 BLADED PROPELLERS

WING:

SPAN	25.19M (82.65 FT)
AREA	52.86 SQ. M (569 SQ. FT.)
ASPECT RATIO	12.0
SWEEPBACK C/4	.087R (5.0 DEG.)
AIRFOIL (NASA 63 SERIES)	
SINGLE SLOTTED FOWLER FLAP	

HORIZONTAL TAIL:

VOLUME COEFFICIENT	1.25
AREA	13.11 SQ. M

VERTICAL TAIL:

VOLUME COEFFICIENT	0.09
AREA	10.78 SQ. M

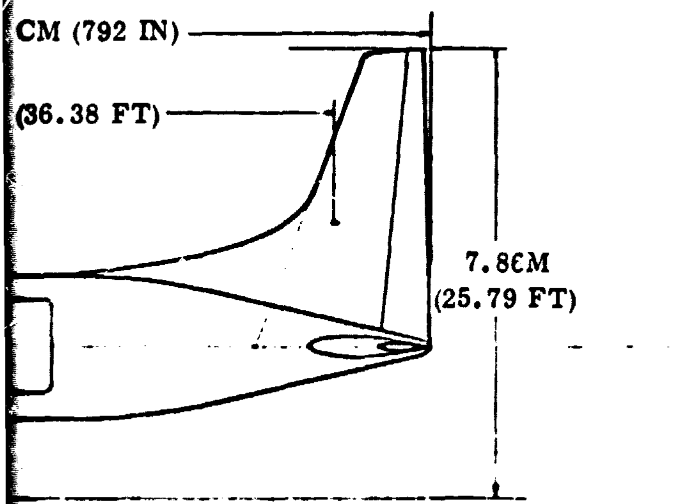

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Figure 5-

H

IZONTAL TAIL:

VOLUME COEFFICIENT	1.25
AREA	13.11 SQ. M (141 SQ. FT.)

TICAL TAIL:

VOLUME COEFFICIENT	0.09
AREA	10.78 SQ. M (116 SQ. FT.)

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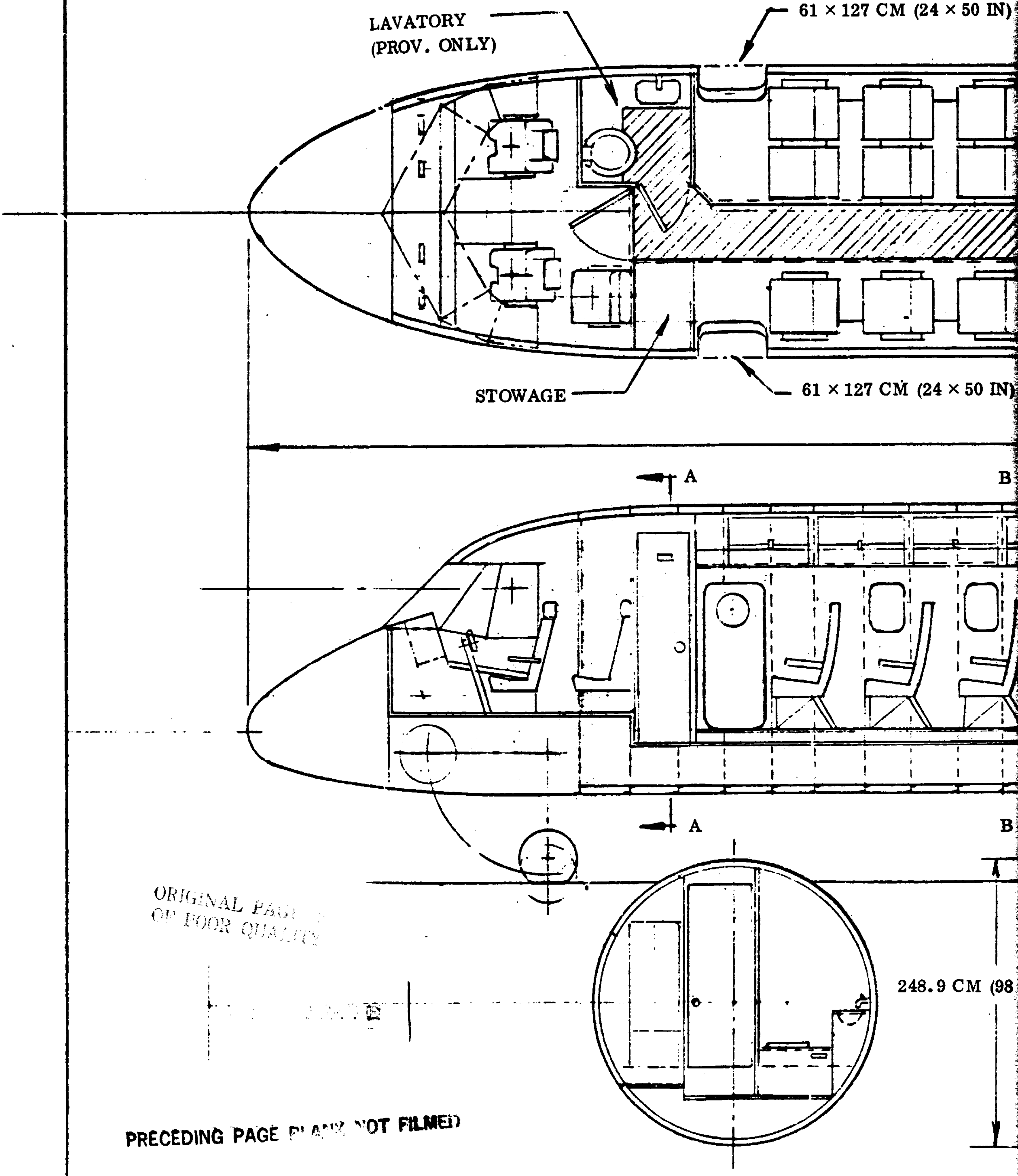
Figure 3-

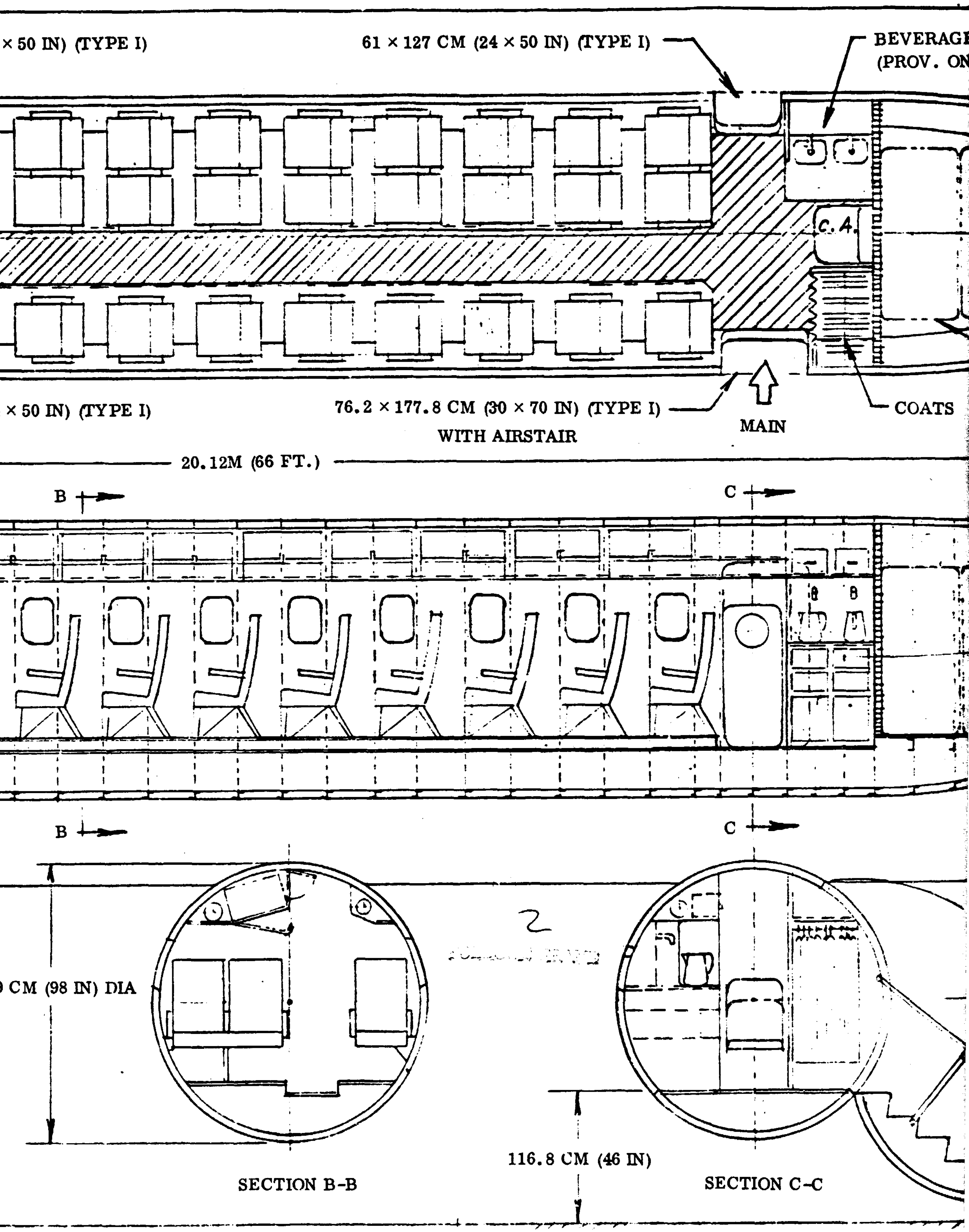
GENERAL DYNAMICS
CONVAIR DIVISION

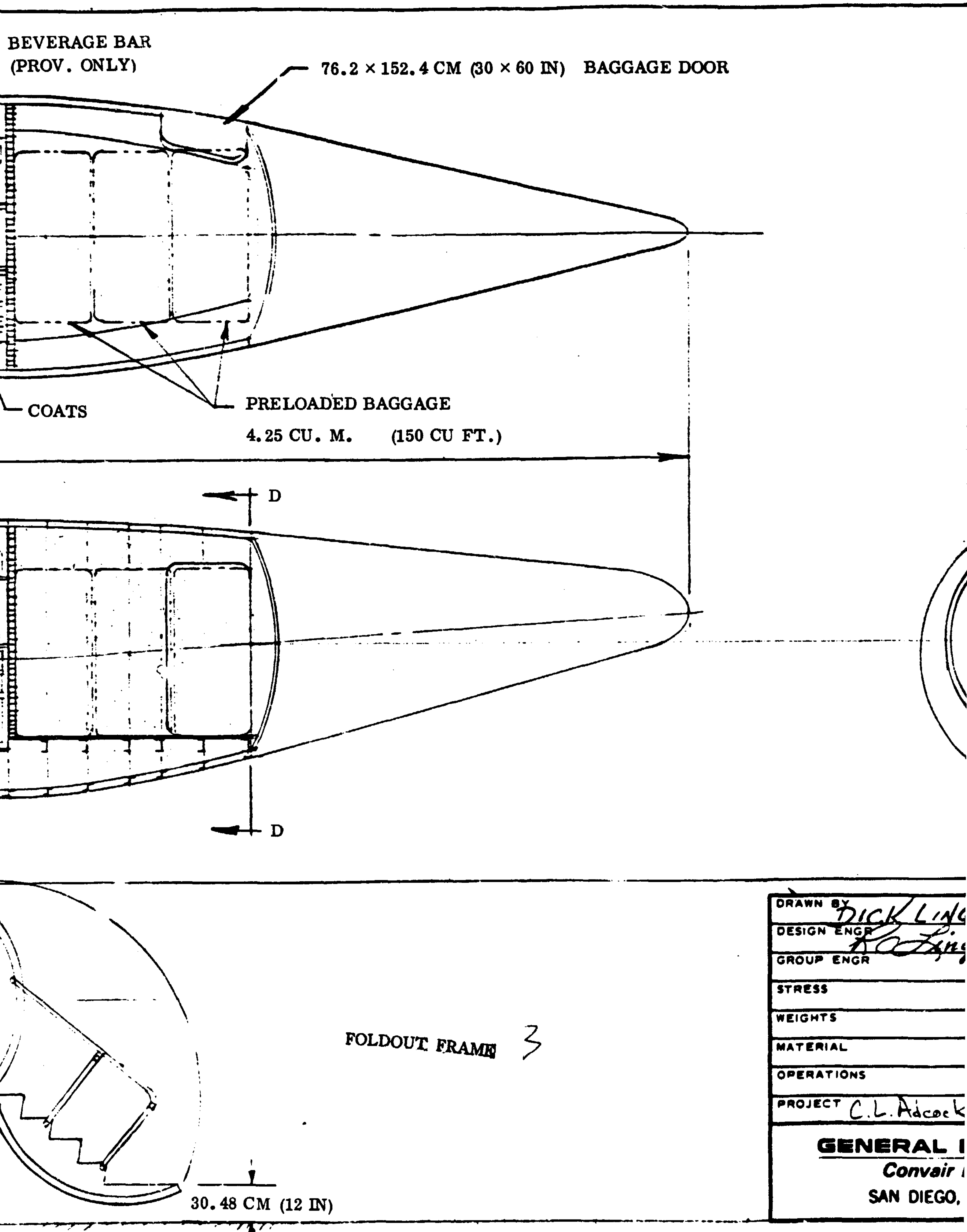
3-30 BASELINE
GENERAL ARRANGEMENT

J 14170 SD 79-


LAVATORY
(PROV. ONLY)
61 × 127 CM (24 × 50 IN)
STOWAGE
61 × 127 CM (24 × 50 IN)
A
B
A
B
248.9 CM (98

SECTION A-A


× 50 IN) (TYPE I)
61 × 127 CM (24 × 50 IN) (TYPE I)
BEVERAGE
(PROV. ON
C.A.
× 50 IN) (TYPE I)
76.2 × 177.8 CM (30 × 70 IN) (TYPE I)
WITH AIRSTAIR
MAIN
COATS
20.12M (66 FT.)
B
C
B
C
CM (98 IN) DIA
2
116.8 CM (46 IN)
SECTION B-B
SECTION C-C



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FOLDOUT FRAME 4

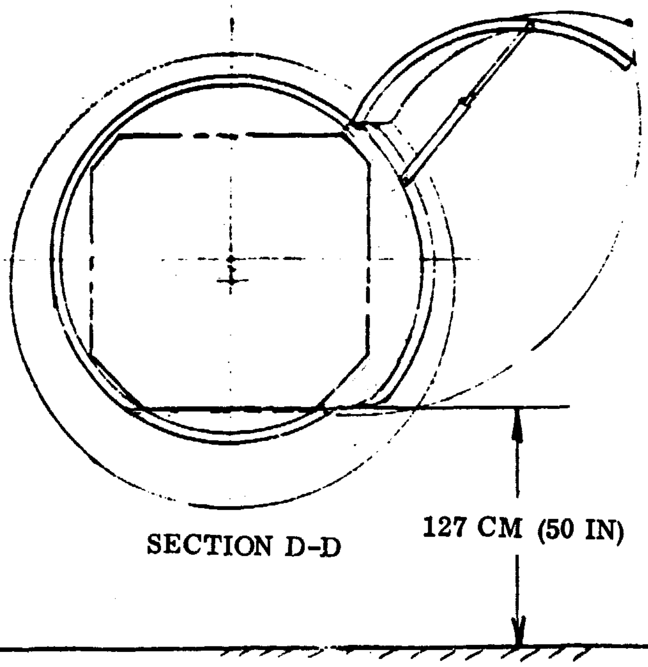

Figure 3-10

30 SEATS

DRAWN BY Dick Lingley	2-6-79	**PRELIMINARY DESIGN DRAWING**	
DESIGN ENGR R. Lingley	2-6-79	FUSELAGE LAYOUT 3-ABREAST BASELINE AFT ENTRANCE – 98-IN. DIA.	
GROUP ENGR			
STRESS			
WEIGHTS			
MATERIAL			
OPERATIONS			
PROJECT C.L. Adcock	2-8-79		
GENERAL DYNAMICS *Convair Division* SAN DIEGO, CALIFORNIA		CODE IDENT. 1417C	DRAWING NO. SD 79-48017
		SCALE 1/40	SHEET 1 OF 1

3-30 PERFORMANCE

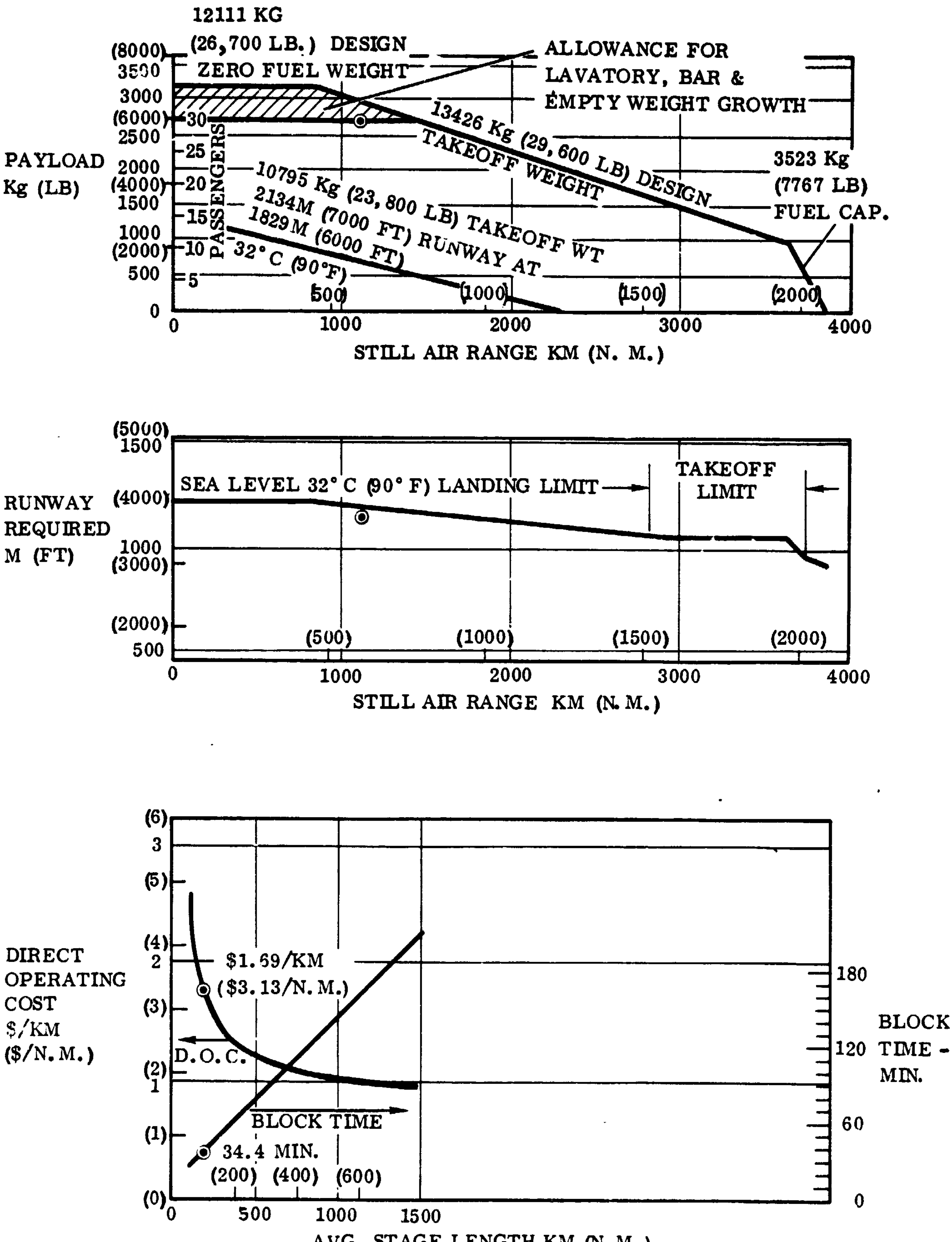

Figure 3-11. 3-30 Performance

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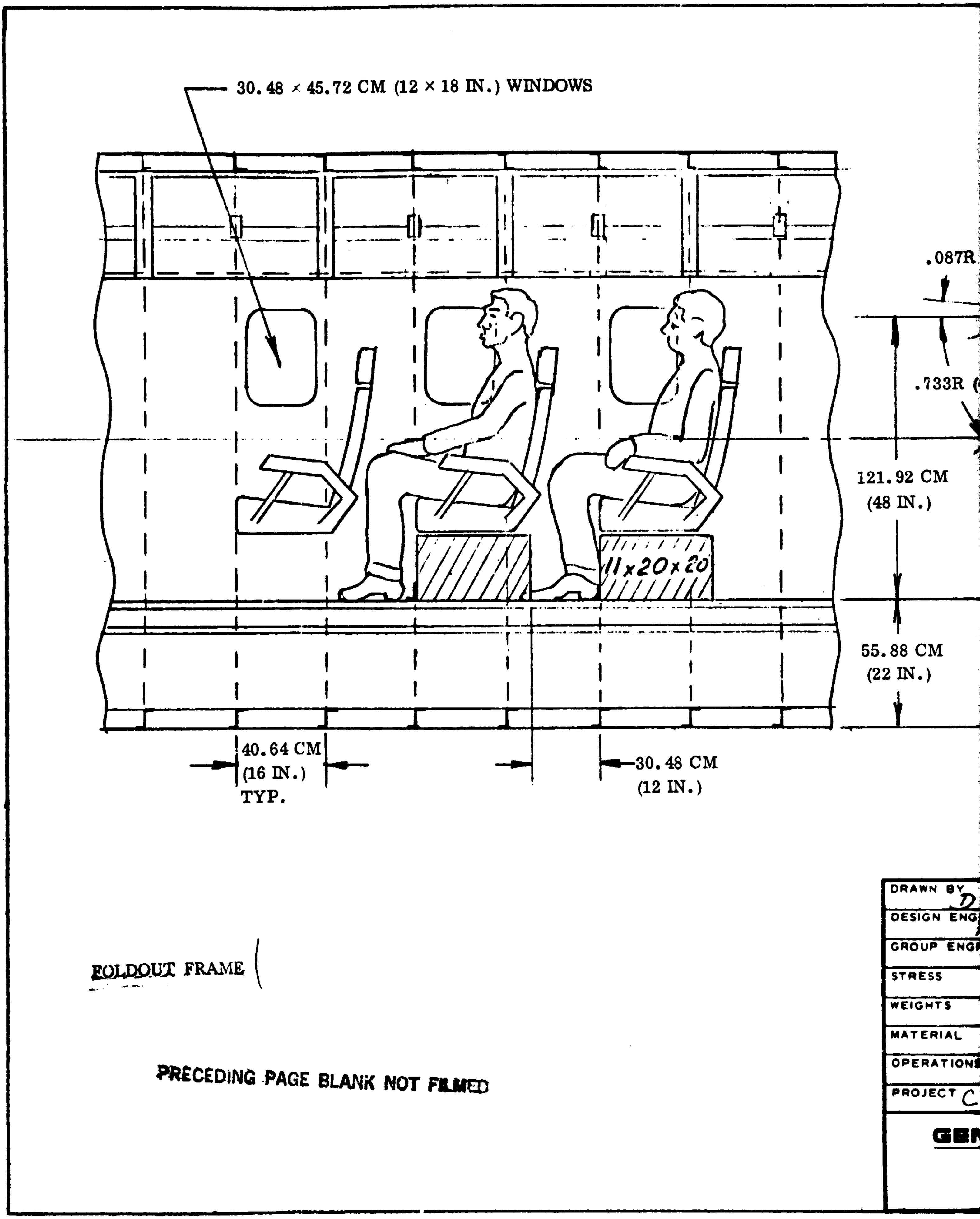

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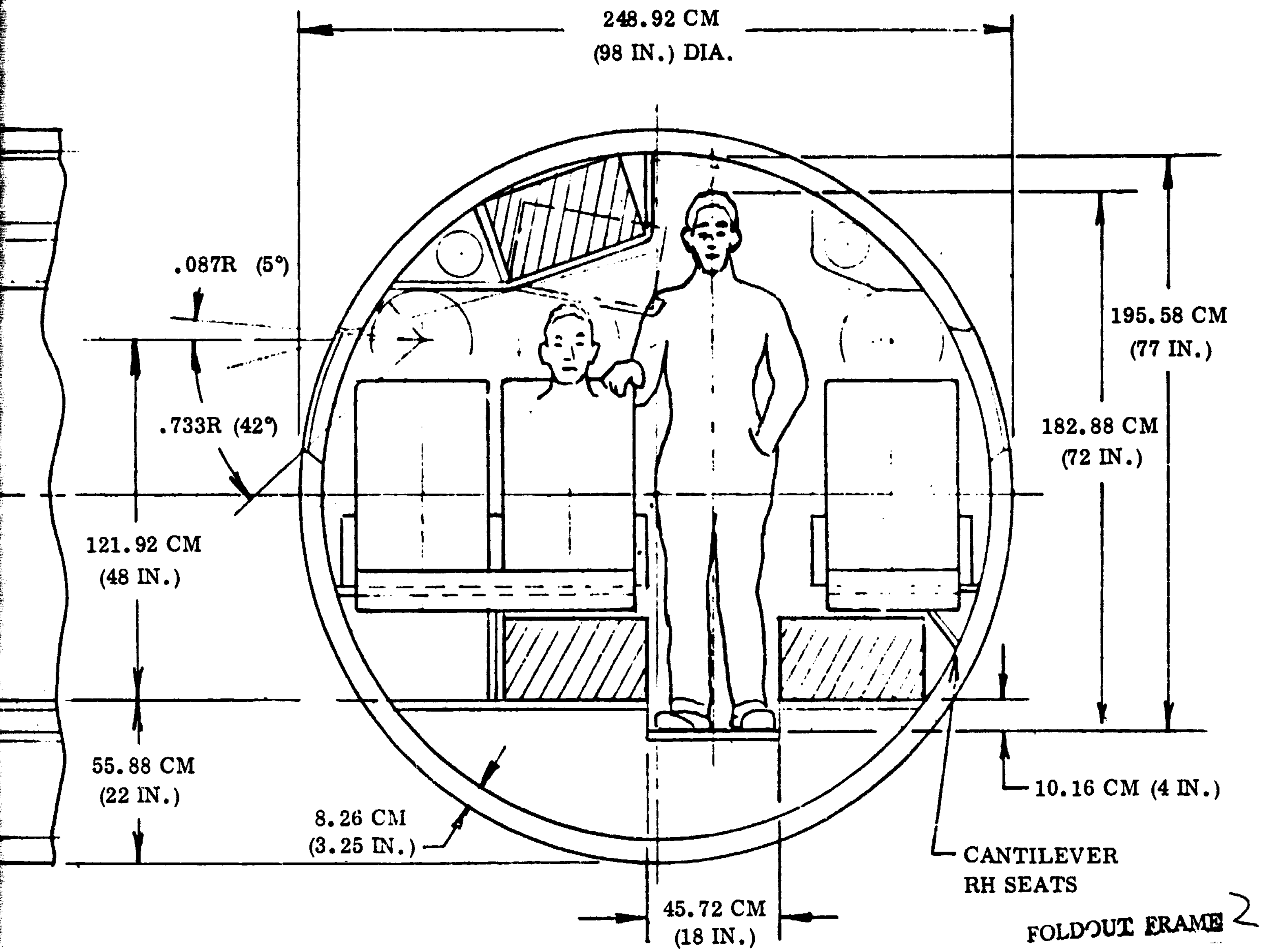

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VIEW LOOKING AFT
PERIMETER: 782.32 CM (308 IN.)

Figure 3-12

DRAWN BY DICK LINGLEY	1-31-79	**PRELIMINARY DESIGN DRAWING**
DESIGN ENGR R C Lingley	1-31-79	FUSELAGE CROSS SECTION STUDY OVER/UNDER CARRY ON BAGGAGE 3 ABREAST 98 IN. DIA. 248.92 CM (98 IN.) DIAMETER
GROUP ENGR		
STRESS		
WEIGHTS		
MATERIAL		
OPERATIONS		
PROJECT C. L. Adcock	2-8-79	

GENERAL DYNAMICS *Convair Division* SAN DIEGO, CALIFORNIA	CODE IDENT. 14170	DRAWING NO. SD79-48014
	SCALE 1/20	SHEET 1 OF 1

The selected fuselage is 2011.7 cm (792 in.) long. It is shown in Figure 3-10 (SD 79-48017).

STEP 3. Select a baseline turboprop engine of current technology suitable to be scaled. The free turbine P&W(C) PT6A-45 engine is selected for the 30-passenger aircraft.

STEP 4. Select a propeller and gearbox for the PT6A-45 engine which will meet the noise limits allowed by FAR amendment 8, Stage III minus 8 EPNdB.

Since there are innumerable combinations of propellers and gear boxes which will meet the desired noise limits, we have selected a 3 blade, 100 activity factor per blade, 0.4 design lift coefficient propeller as representative of typical current propeller design for the PT6. We have also selected the standard PT6A-45 gear box. Finally, we have initially selected a propeller diameter that maximizes cruise thrust since the final engine size (scale) is expected to be determined by the thrust required to meet the 463 km/hr (250 kt) IAS cruise speed at 3048 m (10,000 ft) and the resulting propeller diameter of 2.90 m (9.5 ft) is reasonable for a PT6A-45 size engine. Propeller diameter is scaled with engine size and noise in VDEP.

STEP 5. Determine fuselage weight and balance with acoustic treatment to meet the internal overall sound pressure level (OASPL) of 85 db. Initial estimates of aircraft weight and size resulted in the selection of a 4.57 m (15 ft.) diameter propeller for determining the basic fuselage weight with acoustic treatment weighs 5171 kg (11399 lb) and has an acoustic weight penalty of 1383 kg (3049 lb). The acoustic penalty is proportional to propeller diameter. This fuselage weight includes typical current technology systems, instruments, avionics and furnishings. No lavatory or beverage bar is included. The final fuselage and acoustic weight is determined by VDEP.

The optional lavatory, beverage bar and contents would weigh an additional 209 kg (461 lbs.) To accommodate this additional weight, the design zero fuel weight, design landing weight, design takeoff weight and design ramp weight have been increased 209 kg (461 lbs.)

STEP 6. Determine powerplant scaling factors which allow increasing the engine thrust as necessary to meet the mission requirements and determining the corresponding geometric, weight and cost parameters while meeting the required FAR noise levels and maintaining the required cabin noise level.

This was done by selecting the GE CT64 engine as a larger engine of similar technology to the PT6A-45. A propeller RPM and diameter were selected to meet the traded noise levels of FAR 36, Amendment 8, Stage III minus 8 EPNdB while maintaining the required cabin noise level. Since there is no "large" turboprop engine of this technology available, a "double sized" CT64 was used. Again a propeller diameter and RPM were selected to meet the traded noise levels of FAR 36, Amendment 8, Stage III minus 8 EPNdB and the required cabin noise level.

The primary design parameters (required for VDEP) are smoothly varied between these three discrete engine/propeller combinations. The engine growth factor are from Garrett data, the specific fuel consumption variation with engine size is from General Electric data and the remaining factors are smoothly, but arbitrarily faired between the calculated points. See Figure 3-2.

Since the engines are sized by cruise thrust, engine scale factor, (ESF), is based on cruise thrust rather than rated power, static thrust, or other parameter. The thrust and fuel consumption variations with speed, altitude and partial power setting are assumed to be those of the PT6A-45 with 2.90 m (9.5 ft) propeller. Known differences from these variations are adjusted by equivalent shaft horsepower (ESHP), shaft horsepower (SHFTHP) and takeoff thrust (FPI) by varying these items independently from ESF. For convenience, all engine scale factors are referred to the PT6A-45 with 2.90 m (9.5 ft) propeller. The propeller plane is maintained at the body station of the lavatory/buffet. Nacelles were assumed to have a maximum diameter 2.54 cm (1 in.) larger than the engine and to extend to 75% of the wing chord.

STEP 7. Using VDEP calculate the aircraft weight and geometry required to fly the 1111 km (600 n. mi.) design mission with a full passenger/baggage load at optimum cruise speed/altitude having reserve fuel remaining for an additional 185 km (100 n. mi.) flight to alternate and hold for 45 minutes, for parametric combinations of wing loading, aspect ratio and engine scale factor. Also calculate, for each of these combinations, the maximum cruise speed at 3048 m (10,000 ft) at start of cruise weight and the takeoff (and landing) runway required at sea level, 32°C (90°F) at design takeoff (and landing) weight. Also, calculate the direct operating cost at 185 km (100 n. mi.) average stage length.

STEP 8. Determine the minimum engine scale factor, ESF, to meet both a 463 km/hr (250 kt) IAS cruise speed at 3048 m (10,000 ft) altitude and 1219 m (4000 ft) runway at sea level by cross-plot, see Figure 3-13, and using VDEP calculate all of the STEP 7 data for the minimum ESF for each wing loading and aspect ratio.

STEP 9. Calculate the approach flap setting required to meet the approach speed of 185 km/hr (100 kt) IAS corresponding to a 1219 m (4000 ft) runway at sea level 32°C (90°F), using the current technology flap system performance shown in Figure 3-14. Using that flap setting, determine the thrust required to meet the 2.7%* approach climb gradient with one engine inoperative. This thrust requirement and the corresponding thrust available are calculated and plotted on Figure 3-15. Thrust is per propulsion unit.

*This value was used inadvertently instead of 2.1% specified in FAR 25.121(a). A check of this effect showed it to be less than 2% on ESF and W/S.

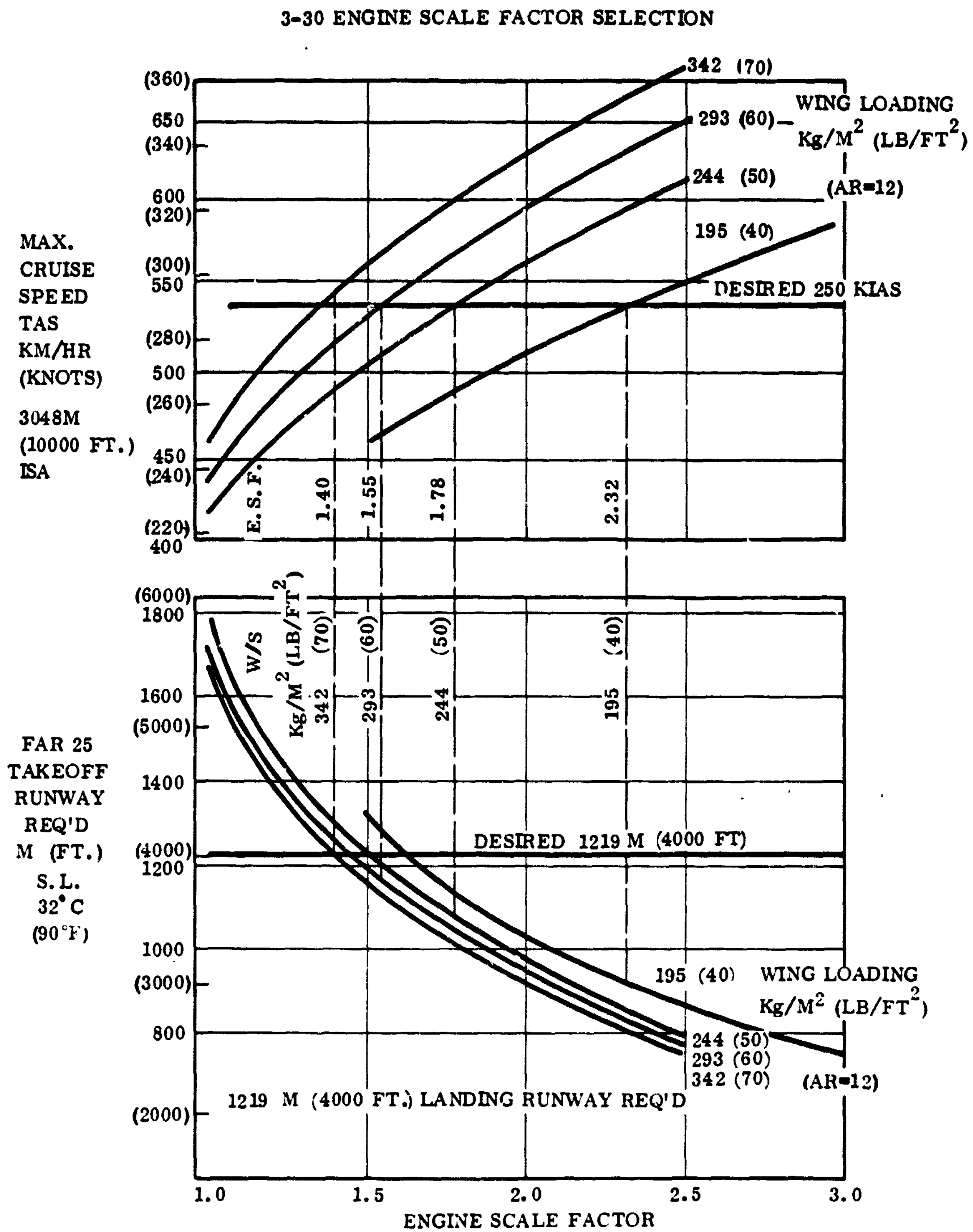


Figure 3-13. 3-30 Engine Scale Factor Selection

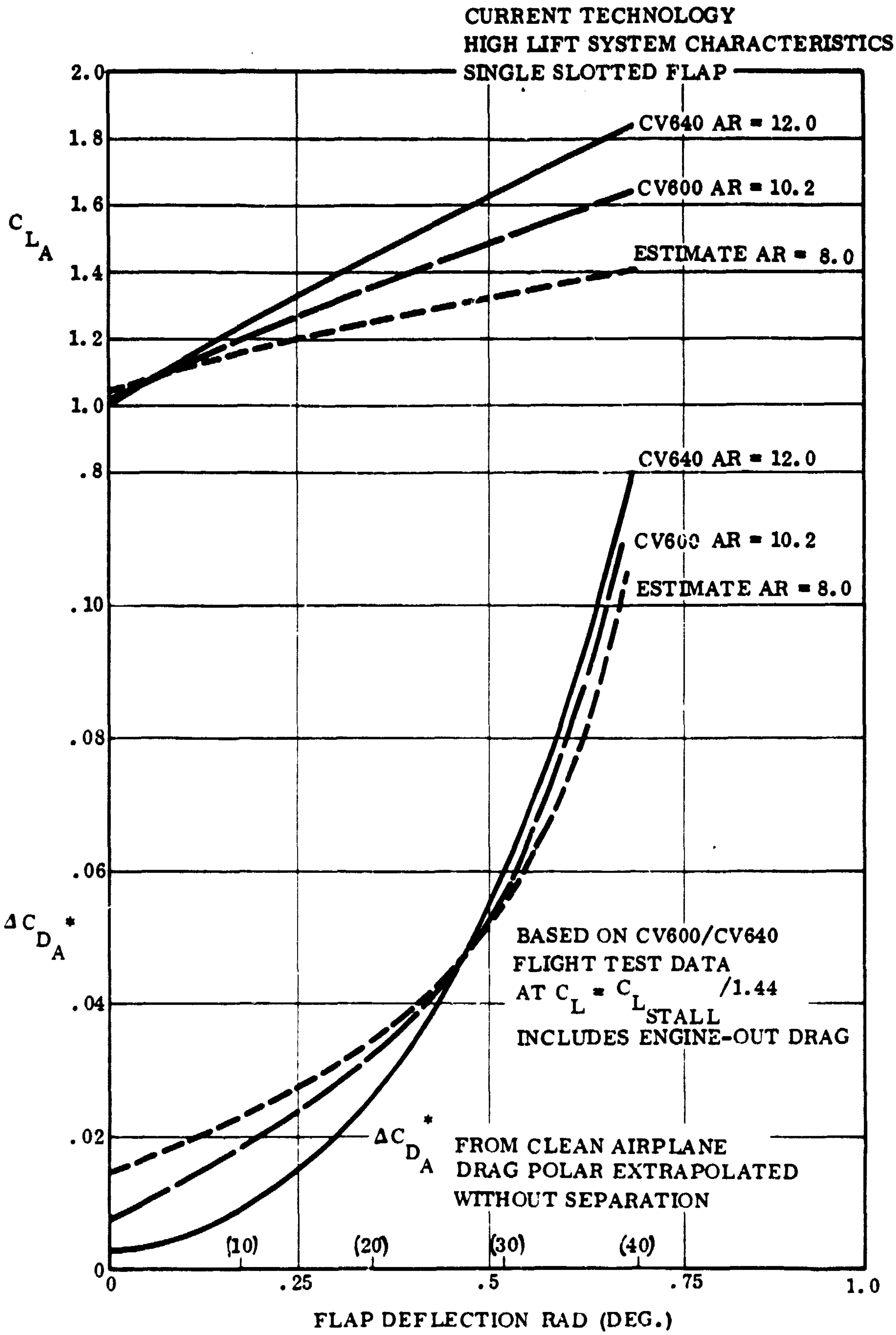


Figure 3-14. 3-30 High Lift Characteristics

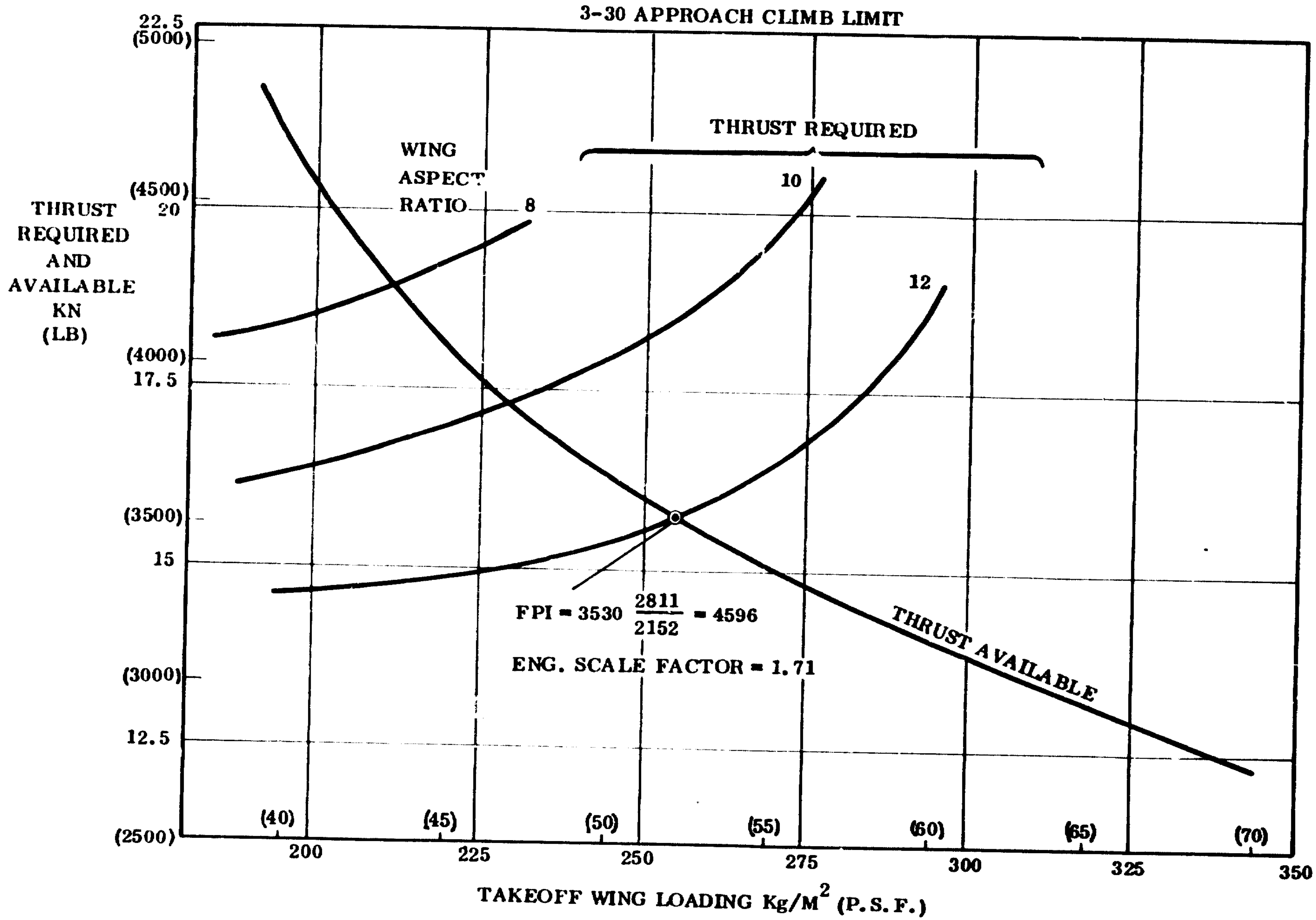


Figure 3-15. 3-30 Approach Climb Limit

STEP 10. Select the wing loading and aspect ratio of the airplane having the minimum DOC by cross plotting as shown in Figure 3-16.

The basic plot shows the DOC versus wing loading and aspect ratio with the aspect ratio 12 assumed to be representative of the maximum allowable by flutter using current technology.

Superimposed on the basic plot are wing loading limits for each aspect ratio which can meet the approach climb performance.

Thus the "optimum" design has an aspect ratio of 12, a takeoff wing loading of 52 and an engine scale factor of 1.71.

STEP 11. Using VDEP calculate the performance capabilities of the selected design and the DOC. This data is summarized early in this Section and covered in more detail in Section 3.5.2.

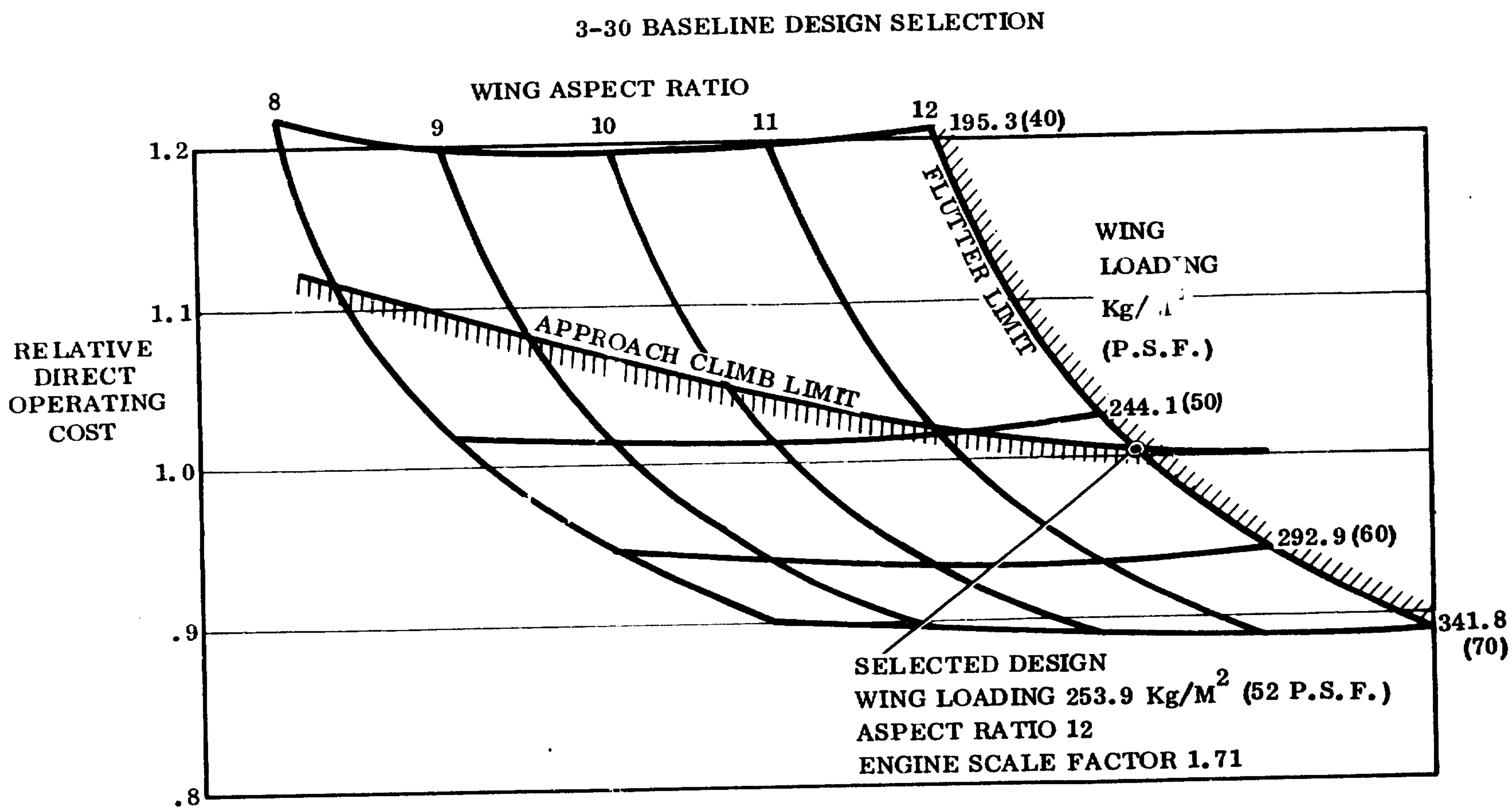


Figure 3-16. 3-30 Baseline Design Selection

3.5.2 3-30 Characteristics and Sensitivities

The characteristics and sensitivities of the 3 abreast, 30 passenger baseline design are presented as follows to assist in the application of advanced technology to this type, and size, of small, short haul, transport aircraft.

This data supplements 3-30 Baseline Design Selection, Section 3.1.1, with additional details of the

- o geometry, Table 3-11.
- o weights, Table 3-12.
- o aerodynamics, Figure 3-17.
- o cost, Table 3-13, 3-14 and 3-15.

It includes both the actual numbers and their percentage of the appropriate total. DOC sensitivities shown in Table 3-15 are from an earlier analysis which gave slightly higher values of DOC. The data is useful for order of magnitude comparisons. For each change the aircraft was resized at constant W/S and ESF holding mission requirements.

Table 3-11. 3-30 Baseline Geometric Data

		% of Total Wetted Area
Body:		
Length	2011.68 cm (792 in.)	
Maximum diameter	248.92 cm (98 in.)	
Wetted area	125.88 sq. m (1355 sq. ft)	44.0
Wing:		
Span	25.19 m (82.65 ft)	
Root chord	3.15 m (10.33 ft)	
Mean Aerodynamic Chord	2.27 m (7.46 ft)	
Tip chord	1.05 m (3.44 ft)	
Area	52.86 sq. m (569 sq. ft)	
Exposed area	45.34 sq. m (488 sq. ft)	
Root thickness	0.631 m (2.07 ft)	
Tip thickness	0.158 m (0.52 ft)	
Wetted area	94.39 sq. m (1016 sq. ft)	33.0
Quarter chord sweep	0.087 rad. (5.0 deg)	
Fuel volume	4387 liters (1159 gal)	
Flap area	8.99 sq. m (96.77 sq. ft)	
Horizontal Tail:		
Arm	11.46 m (37.6 ft)	
Area	13.10 sq. m (141 sq. ft)	
Exposed area	10.22 sq. m (110 sq. ft)	
Wetted area	21.09 sq. m (227 sq. ft)	7.4
Vertical Tail:		
Arm	11.09 m (36.38 ft)	
Area	10.78 sq. m (116 sq. ft)	
Exposed area	10.78 sq. m (116 sq. ft)	
Wetted area	22.30 sq. m (240 sq. ft)	7.8
Power Plants:		
Butt line	4.42 m (14.50 ft)	
Power/Engine	1747 kw (2343 ESHP)	
Propeller, Diameter	3.5 m (11.47 ft)	
Number of blades	3	
Activity factor per blade	100	
Wetted area	22.48 sq. m (242 sq. ft)	7.8
Total Wetted Area	286.14 sq. m (3080 sq. ft)	100.0

Table 3-12. 3-30 Baseline Weight Data

Design Weights	Kilograms	(Pounds)	% of Des. T.O. Wt.
Ramp	13426	(29,600)	100.00
Takeoff	13426	(29,600)	100.00
Landing	12791	(28,200)	95.27
Zero Fuel	12110	(26,700)	90.20
Fuel Capacity	3523	(7,767)	26.24
V_C/M_C	472 km/hr (255 kt) CAS/0.525		
Group Weights			
Body Structure*	2790	(6,150)	20.78
Wing: Box Structure	881	(1,943)	6.56
LE/TE Structure	253	(558)	1.89
Secondary Structure	57	(125)	0.42
Flaps	103	(226)	0.76
Horizontal Tail	135	(297)	1.00
Vertical Tail	136	(299)	1.01
Surface Controls	178	(393)	1.33
Landing Gear	517	(1,139)	3.85
Nacelle Structure	185	(407)	1.38
Total Structure	5234	(11,538)	38.98
Engines	644	(1,420)	4.80
Propellers	197	(435)	1.47
Propulsion Systems	205	(452)	1.53
Fuel System	108	(237)	0.80
Instruments	83	(183)	0.62
Hydraulic & Pneumatic	123	(271)	0.92
Electrical	177	(391)	1.32
Avionics	352	(777)	2.63
Furnishings	960	(2,117)	7.15
Air Conditioning/Anti Ice	318	(702)	2.37
Weight Empty	8401	(18,521)	62.57
Basic Operating Items	494	(1,090)	3.68
Basic Operating Weight	8896	(19,611)	66.25
Full Passengers/Baggage	2722	(6,000)	20.27
Full Pass. Zero Fuel Wt.	11617	(25,611)	86.52
Reserve Fuel (100 NM + 45 Min)	470	(1,036)	3.50
Design Mission Landing Wt	12087	(26,647)	90.02
Fuel Burned on 600 NM Trip	1070	(2,358)	7.97
Design Mission Ramp Wt.	13157	(29,005)	97.99

*Includes 1054 kg (2324 lb.) acoustics penalty

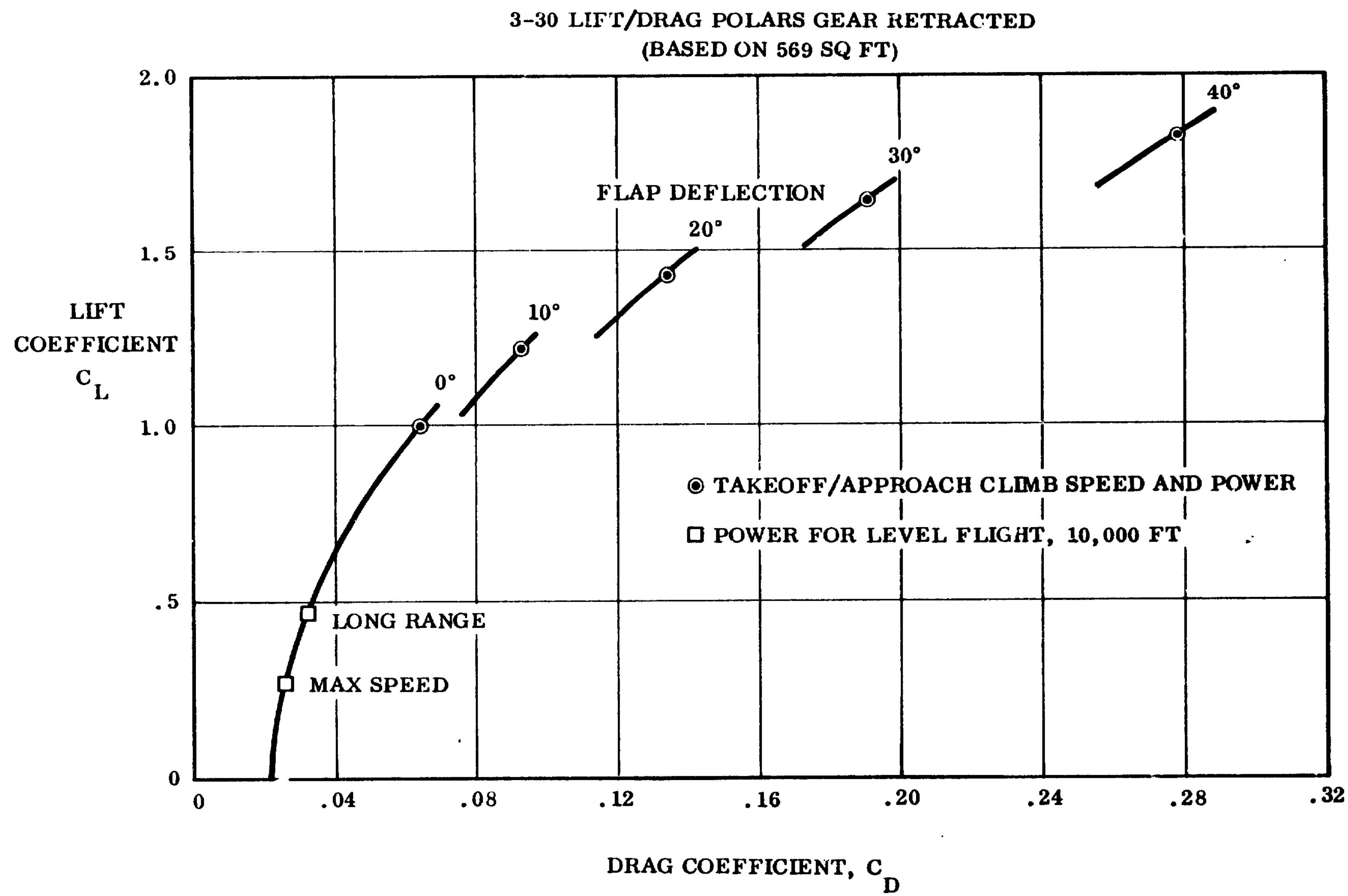


Figure 3-17. 3-30 Lift/Drag Polars

Table 3-13. 3-30 Baseline Cost Data

Aircraft Price

	1979 $M	% of Total Aircraft Price
Unit Price (250 Breakeven)	3.159	100.00
Airframe	1.980	62.69
Avionics	0.324	10.26
Engines	0.752	23.80
Propellers	0.103	3.25

Operating Conditions - 185 km (100 n. mi.) Trip

See Table 3-6.

Direct Operating Cost - 185 km (100 n. mi.) Trip	1979 $/km ($/n. mi.)	% of Total D.O.C.
Crew (1)	0.2334 (0.4322)	13.79
Fuel & Oil ($1.00/gal.)	0.5543 (1.0265)	32.75
Maintenance	0.5739 (1.0629)	33.91
Material, Engine	0.1224 (0.2267)	7.23
Airframe & other	0.0570 (0.1056)	3.37
Direct Labor, Engine (2)	0.0394 (0.0731)	2.33
Airframe & Other (2)	0.1798 (0.3329)	10.62
Burden (3)	0.1753 (0.3247)	10.36
Insurance (4)	0.0543 (0.1005)	3.21
Depreciation (5)	0.2767 (0.5124)	16.35
Total Direct Operating Cost	1.6920 (3.1345)	100.00
Total Direct Seat-Mile Cost	5.64¢/Skm (10.45¢/Sn. mi.)	100.00

(1) $/block hr. = 2.5 × seats

(2) $10 per man-hour

(3) 80% of direct labor

(4) 1.5% of total aircraft price per year

(5) Aircraft and spares depreciated over 12 years to 15% residual. Spares are (0.2 × seats + 2.0) % of total aircraft price.

Table 3-14. 3-30 Operating Conditions - 185 km (100 n. mi.) Trip

At End of	Altitude m (ft.)	Time* Min.	Speed-TAS km/hr (kt)	Distance* km (n. mi.)	Spec. Range km/kg (n. mi./lb)	Fuel Burned* kg (lb)
Takeoff	0 (0)	0.5	191 (103)	0 (0)	-	7 (16)
Climb	5182 (17,000)	8.5	333 (180)	43 (23)	0.416 (0.102)	109 (241)
Cruise	5182 (17,000)	24.4	539 (291)	185 (100)	0.939 (0.230)	261 (576)
Maneuver	0 (0)	34.4	0 (0)	185 (100)	-	306 (675)

An average of 2800 block hours per year utilization is equivalent to 904465 km (488,372 n. mi.) per year per aircraft.

*Time, distance and fuel burned are cumulative at the end of each stage.

Table 3-15. 3-30 Baseline D.O.C. Sensitivities

	Either		Or	
Item	Change	% D.O.C. Change	Change	% D.O.C. Change
Airframe & Other Cost	-$100,000	-.66	-1%	-.21
Engine Cost/Engine	-$10,000	-.64	-1%	-.24
Airplane Empty Weights	-454 kg (-1,000 lb)	-.25	-1%	-.05
Number in Crew	-1 Copilot	-13.11	-50%	-13.11
Block Fuel used 185 km (100 nm) Trip	-4.54 kg (-10 lb)	-.42	-1%	-.27
Fuel Price	-6.6¢/ltr (-25¢/gal)	-6.81	-1%	-.27
Fuel Heating Value	+232500 joule/kg (+100 Btu/lb)	-.11	+1%	-.20
Drag Area	-0.093 sq m (-1.0 sq ft)	-1.50	-1%	-.19
Span Efficiency	-		-1%	-.03
Increase Thrust	-		+1%	-.25
Reduced Horiz. Tail Size	-0.929 sq m (-10 sq ft)	-.13	-1%	-.02
Reduced Vert. Tail Size	-0.929 sq m (-10 sq ft)	-.18	-1%	-.02

3.6 50 PASSENGER BASELINE AIRCRAFT

3.6.1 4-50 Baseline Design Selection

SUMMARY. A 4-abreast, 50 passenger low-wing turboprop aircraft design is selected as a candidate to be a baseline for application of advanced technology. It meets both the cockpit and passenger cabin design requirements corresponding to current operator recommendations and the preferred aircraft mission performance requirements with current technology. It has the following characteristics. See Table 3-16 and 3-17.

Table 3-16. 4-50 Baseline Characteristics

Crew	2 pilots + 1 cabin attendant
Passengers	50
abreast	4
seat width between armrests	45.72 cm (18 in.)
seat pitch	81.28 cm (32 in.)
aisle height	194.31 cm (76.5 in.)
aisle width	45.72 cm (18 in.)
weight allowance (including baggage)	90.72 kg (200 lb.)/passenger
Baggage storage, carry-on	50.8 cm × 50.8 cm × 27.9 cm (2) underseat (20 in. × 20 in. × 11 in.) (2) overhead
garment	2.03 cm (0.8 in.)/passenger
preloaded (containerized)	0.142 cu. m (5 cu. ft.)/passenger
Cabin operating pressure	3.45 N/sq. cm (5 psi)
Maximum cabin interior noise level	85 dB OASPL/65 dBSIL
Fuselage length	2286 cm (900 in.)
Space and allowable weight provisions for a lavatory & a beverage bar	
Powerplants: (2) scaled free turbine engines driving 4-bladed propellers	
Rated Power	2394 kw (3211 ESHP)
Propeller Diameter	4.01 m (13.15 ft.)
Design* Weights	
Ramp	20412 kg (45,000 lb.)
Takeoff	20412 kg (45,000 lb.)
Landing	19459 kg (42,900 lb.)
Zero Fuel	18507 kg (40,800 lb.)
Basic Operating Weight**	13290 kg (29,299 lb.)
Fuel Capacity	7003 kg (15,441 lb.)

* Airframe design life 30,000 hours/60,000 cycles or more.

** Includes 1738 kg (3831 lb) of additional fuselage structure to meet the cabin noise level requirements.

Table 3-17. 4-50 Baseline Performance

Wing, span	31.67 m (103.92 ft.)	
area	83.61 sq. m. (900 sq. ft.)	
aspect ratio	12.0	
sweepback of quarterchord	0.087 rad. (5.0 deg.)	
location on body	low	
single slotted flap area	14.21 sq. m. (153 sq. ft.)	
airfoil type	NACA 63 series	
Performance (standard day unless rated)		
Range with full design payload with I.F.R. reserves	1111 km (600 n. mi.)	
Corresponding cruise speed	459 km/hr (248 kt.) TAS	
Corresponding cruise altitude	7193 m (23,600 ft.)	
Runway length required (FAR 25) at S.L., 32°C (90°F)		
For takeoff at Design T.O. wt.	1116 m (3669 ft.)	
For landing at intended destination at Design Landing wt.	1219 m (4000 ft.)	
Corresponding approach speed	185 km/hr (100 kt.) IAS	
Noise Levels (FAR 36, Amendment 8, Stage III minus 8 EPN dB)		
Takeoff	83 EPNdB (83 allowed after trading)	
Sideline	85 EPNdB (86 allowed, untraded)	
Approach	84 EPNdB (88 allowed after trading)	
Maximum cruise speed at 10,000 ft	463 km/hr (250 kt.) IAS	
Maximum terminal area speed	>333 km/hr(180 kt.) IAS	
Landing stall speed at design landing weight	143 km/hr (77 kt.) IAS	
Aircraft Price (based on 250 A/C breakeven)	$M 4.475	
Direct Operating Cost at fuel price/gal (on avg. stages of)	$0.75	$1.00
93 km (50 n. mi.) $/km ($/n. mi.)	3.49 (6.47)	3.78 (7.00)
185 km (100 n. mi.)	2.29 (4.25)	2.49 (4.61)
278 km (150 n. mi.)	1.84 (3.40)	1.99 (3.68)
370 km (200 n. mi.)	1.61 (2.98)	1.74 (3.22)
741 km (400 n. mi.)	1.37 (2.53)	1.49 (2.76)
1111 km (600 n. mi.)	1.29 (2.39)	1.40 (2.60)
Maximum allowable weight, 32°C (90°F)		
Into a 914 m (3000 ft) runway at S.L.	<13299 kg (27,299 lb.)*	
From a 2134 m (7000 ft) runway at 1829 m(6000 ft)altitude	16193 kg (35,700 lb.)**	

* The maximum landing weight allowable into a 914 m (3000 ft) runway at S.L., 32°C (90°F) is less than the weight of the aircraft without any payload or fuel and indicates the inability of the aircraft to operate from a 914 m (3000 ft) runway at any altitude.

** The maximum allowable takeoff weight from a 2134 m (7000 ft) runway at 1829 m (6000 ft) altitude at 32°C (90°F),16193 kg (35700 lb), is sufficient to carry 22 passengers over a 185 km (100 n. mi.) range.

A three view drawing is shown in Figure 3-18 (SD 79-48026) to provide a basis for computerized analysis and design studies for final airplane sizing. An inboard profile is shown in Figure 3-19 (SD 79-48025).

The airplane performance capability is summarized in Figure 3-20.

DISCUSSION: The 4-abreast, 50-passenger low-wing turboprop aircraft has been designed to meet all of the preferred cockpit, passenger cabin and performance requirements with current technology. It is a candidate to be a baseline for application of advanced technology.

The design procedure which assures compliance with all of the requirements consists of the following steps.

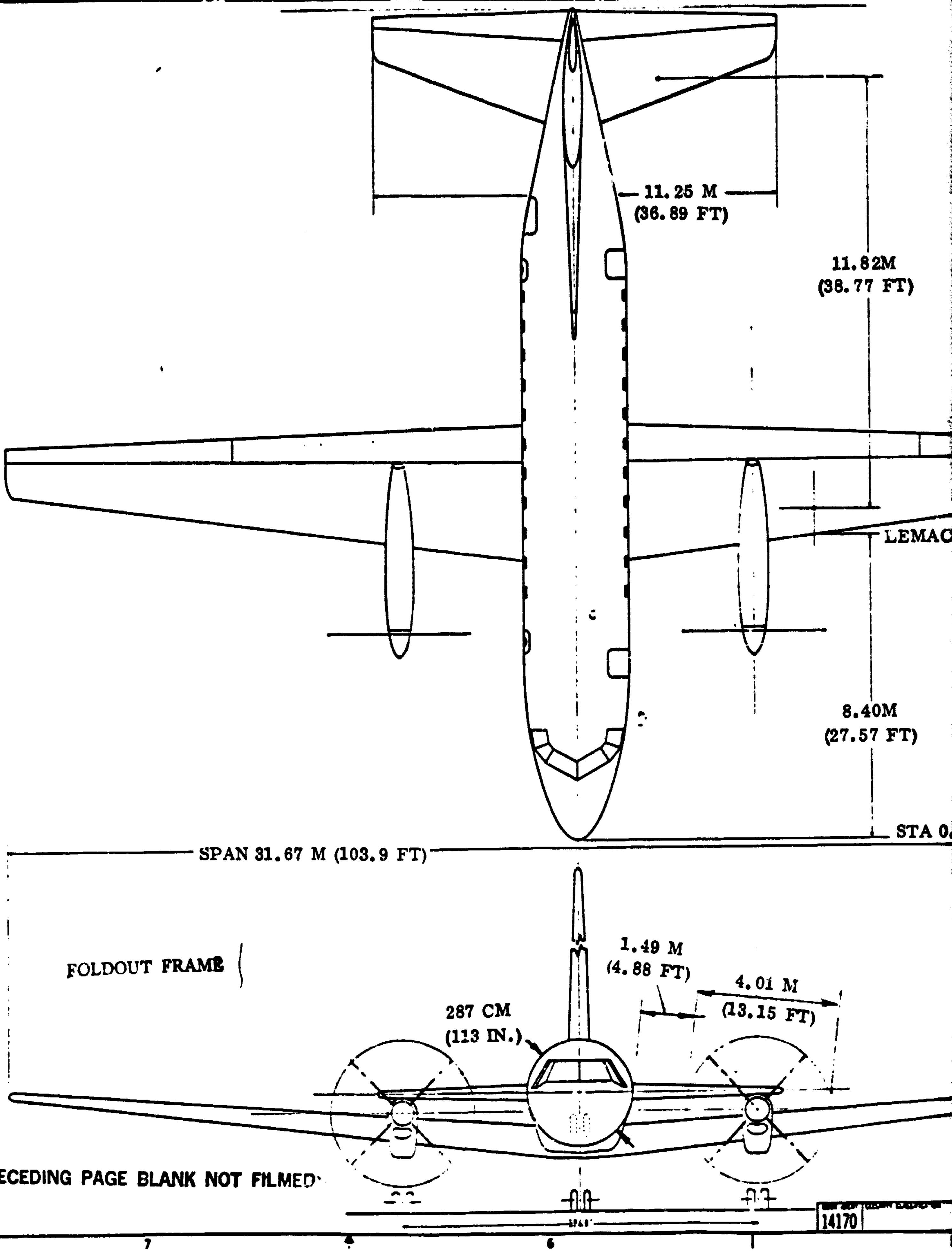
STEP 1. Select a fuselage cross section having space for four 45.7 cm (18 in.) wide seats (between armrests). Two of these are on each side of the airplane separated by a 45.7 cm wide × 194.3 cm high aisle (18 in. × 76.5 in.). It has space for a 50.8 cm ×50.8 cm × 27.9 cm (20 in. × 20 in. × 11 in.) bag to be stowed under each aisle seat with room for the same sized bag overhead on each side. It also has room for controls and ducts under the floor and for lights and air vents overhead. The 8.26 cm (3.5 in.) cabin wall is thick enough to accommodate structure having a life of at least 30,000 hrs and 60,000 cycles at an operating pressure of 3.45 N/sq cm (5.0 psi). It will also accommodate acoustic material to assure a maximum cabin interior noise level of 85 dB OASPL and a speech interference level of 65 dB as well as typical decorative lining and trim. The selected cross section is circular, 287 cm (113 in.) diameter. It is shown on Figure 3-21 (SD 79-48012).

STEP 2. Select a fuselage length (utilizing the selected cross section) which includes a cockpit section, a passenger cabin and a tailcone.

The cockpit section is sized to provide space for a two-man crew plus an observer's seat, typical instruments and controls and a nose gear and retraction well. See Figure 3-11.

The passenger cabin contains 50 seats on 81.3 cm (32 in.) pitch, a cabin attendant and seat, space for a lavatory and beverage bar, a garment stowage area having 2.0 cm (0.8 in.) of hanger bar per passenger, 76.2 cm × 177.8 cm (30 in. × 70 in.) main entry doors/stairs, 30.5 cm × 45.7 cm (12 in. × 18 in.) window for each seat, and two 61 cm × 127 cm (24 in. × 50 in.) Type I emergency exits.

The tailcone length is chosen at 2.5 diameters to minimize aerodynamic drag. It contains a baggage compartment with two containers capable of holding 0.14 cu m (5 cu ft) of baggage per passenger, and easily loaded without interfering with passenger loading. It also contains the airconditioning, pressurization unit.



FOLDOUT FRAME

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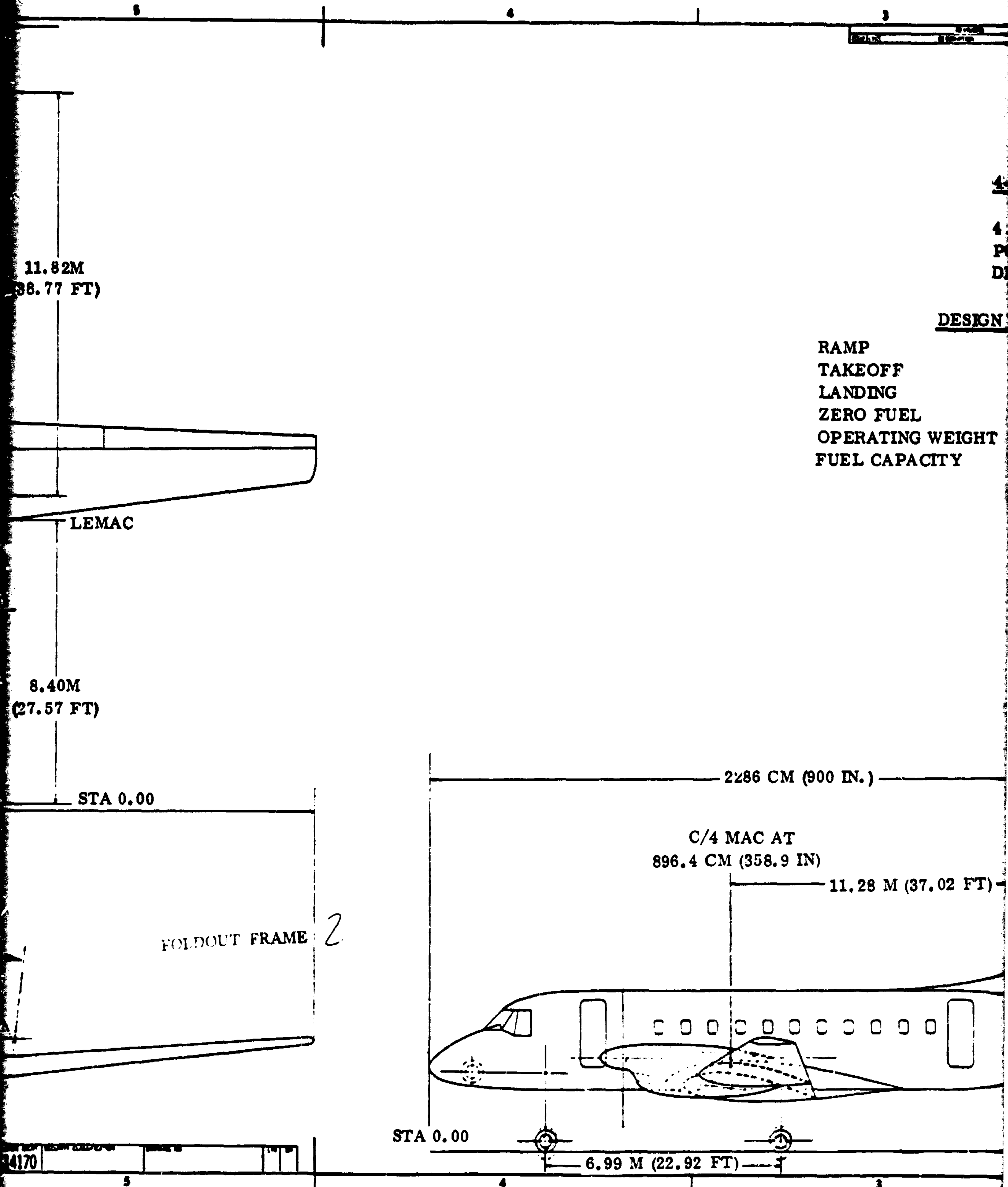
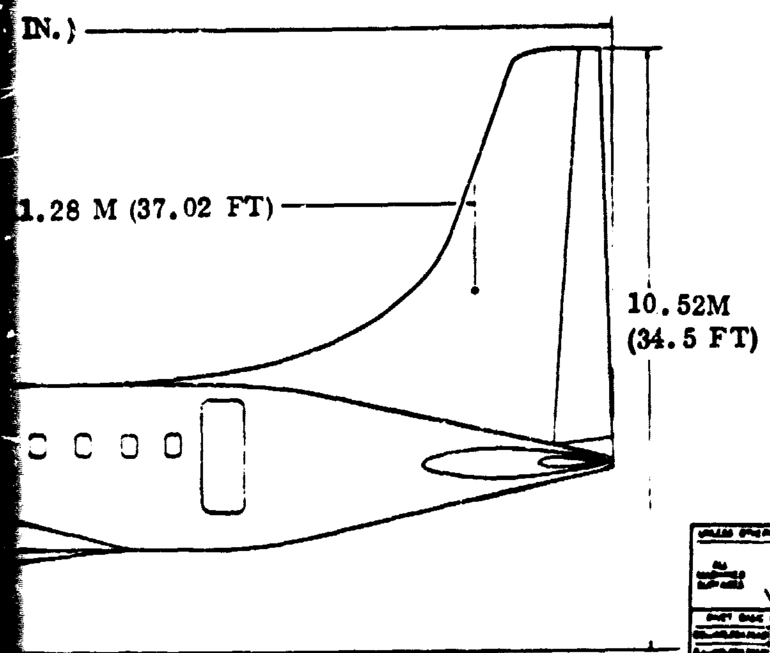


FOLDOUT FRAME 2

4-50 BASELINE CHARACTERISTICS

4 ABREAST, 50 PASSENGER, LOW WING, TURBOPROP TRANSPORT
POWERPLANT: (2) FREE TURBINE ENGINES OF 3211 ESHP EACH
DRIVING 4.008 M (13.15 FT) DIAMETER, 4 BLADED PROPELLERS

DESIGN WEIGHTS		WING	HORIZONTAL TAIL
AMP	20412 Kg (45,000 LB)	SPAN 31.669M (103.9 FT.)	VOLUME COEFFICIENT 1.25
AKEOFF	20412 Kg (45,000 LB)	AREA 83.613 SQ M (900 SQ. FT.)	AREA 25.27M^2 (272 SQ. FT.)
ANDING	19459 Kg (42,900 LB)	ASPECT RATIO 12	
ERO FUEL	18507 Kg (40,800 LB)	SWEEPBACK C/4 .087R (5 DEG)	**VERTICAL TAIL**
PERATING WEIGHT	13290 Kg (29,300 LB)	AIRFOIL NASA 63 SERIES	VOLUME COEFFICIENT 0.09
EL CAPACITY	7003 Kg (15,440 LB)	SINGLE SLOTTED FOWLER FLAP	AREA 21.09M^2 (227 SQ FT.)



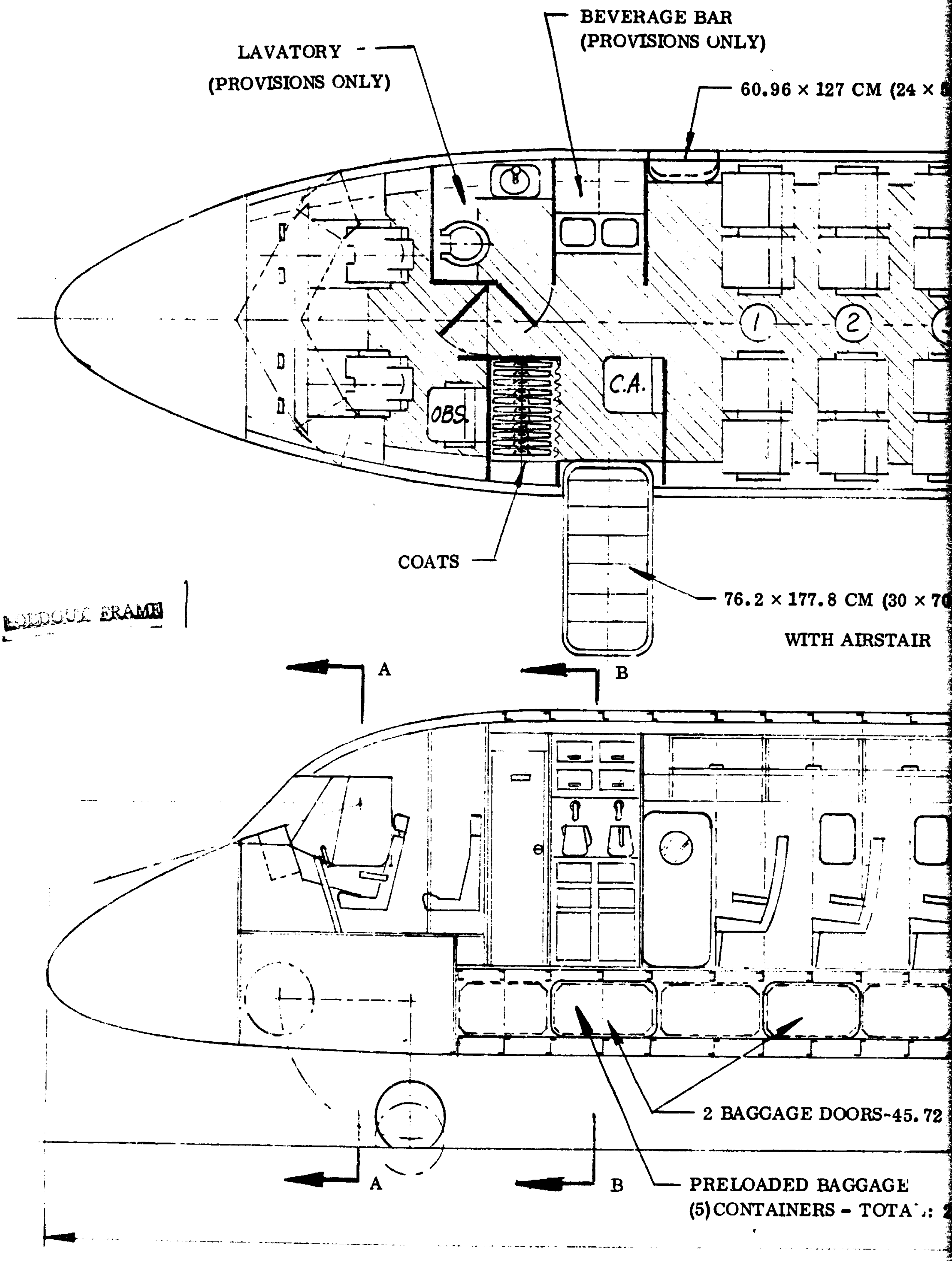
FOLDOUT FRAME 3

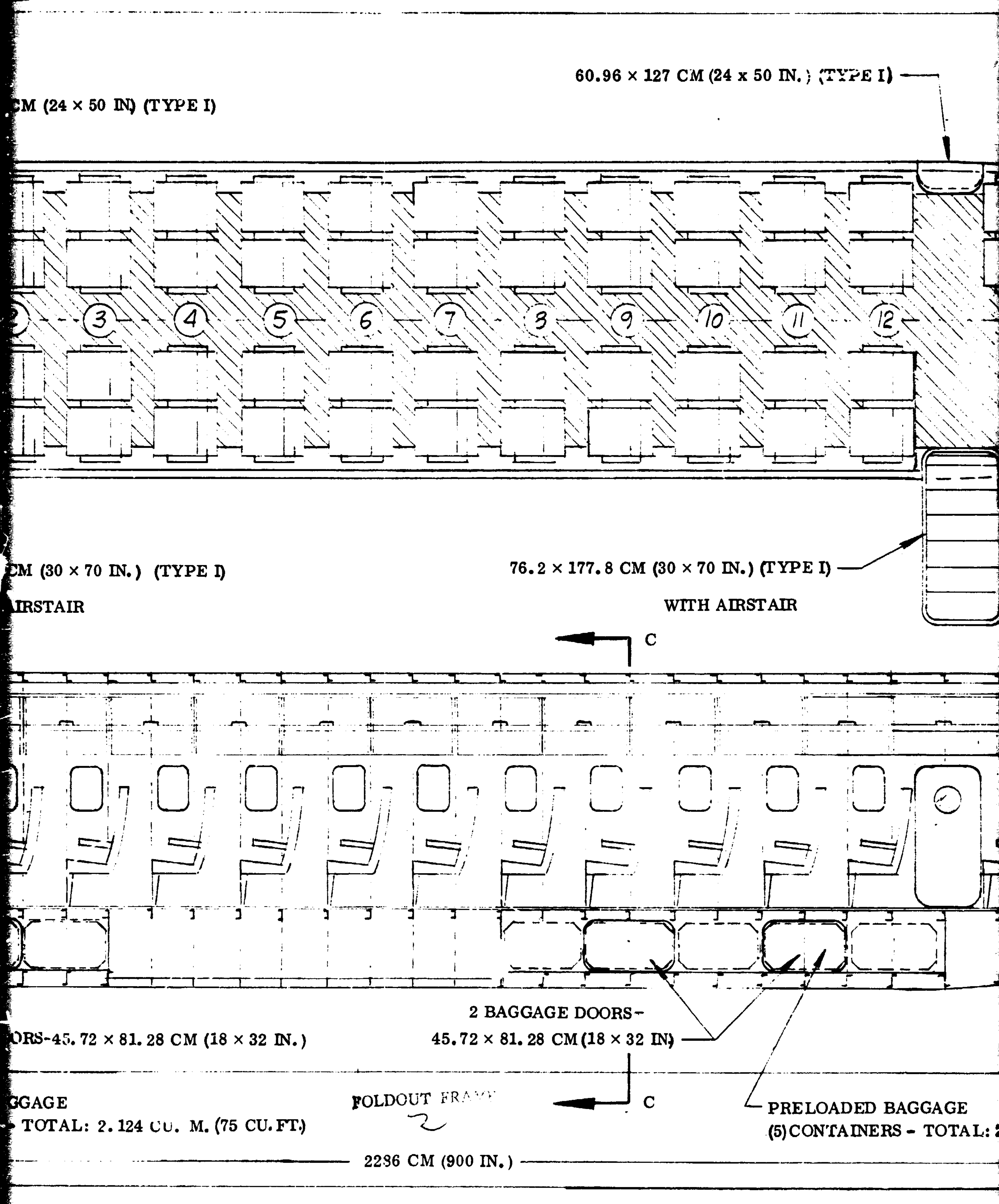
Figure 3-1

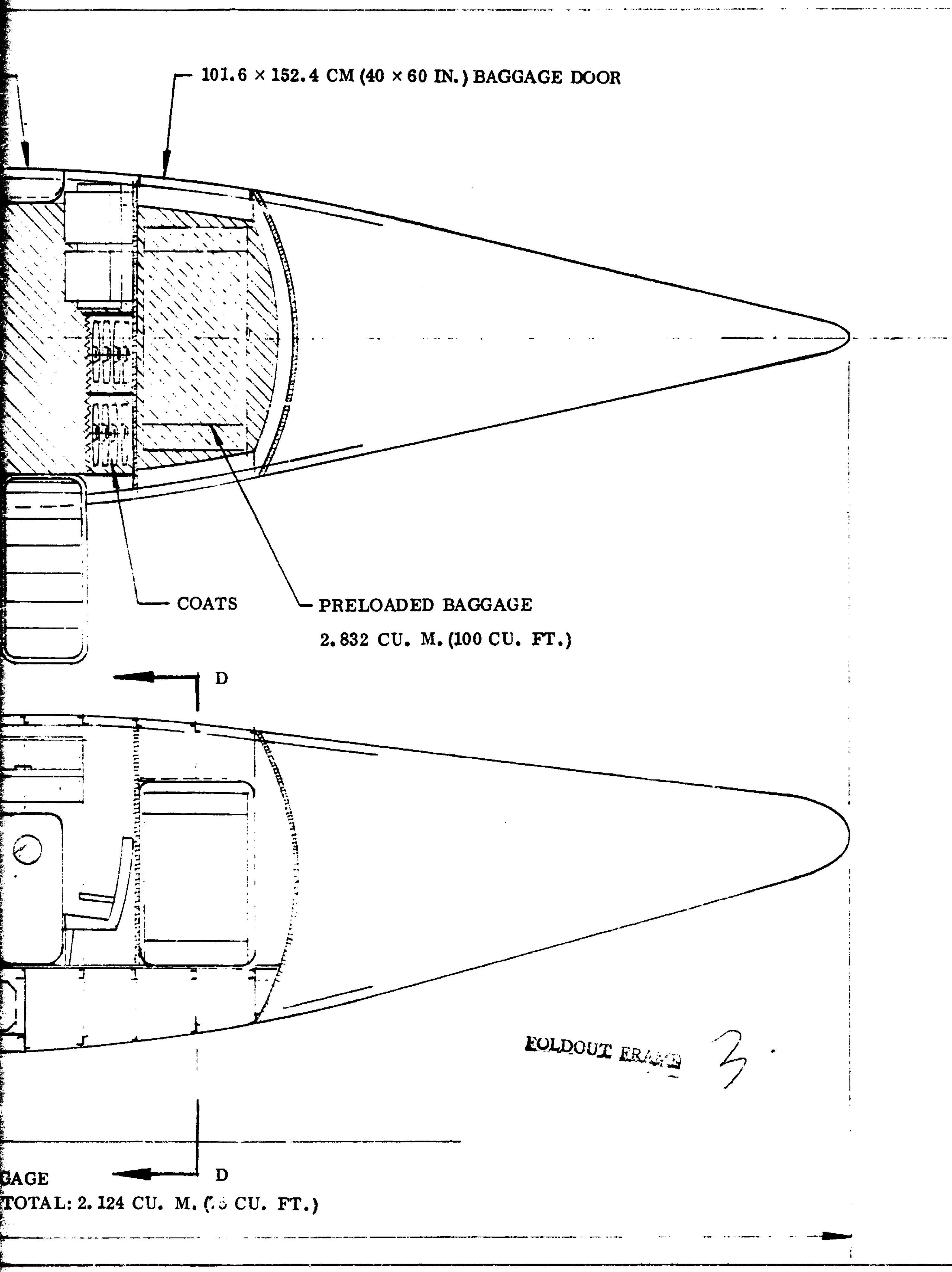
CONVAIR DIVISION OF GENERAL DYNAMICS SAN DIEGO CALIFORNIA

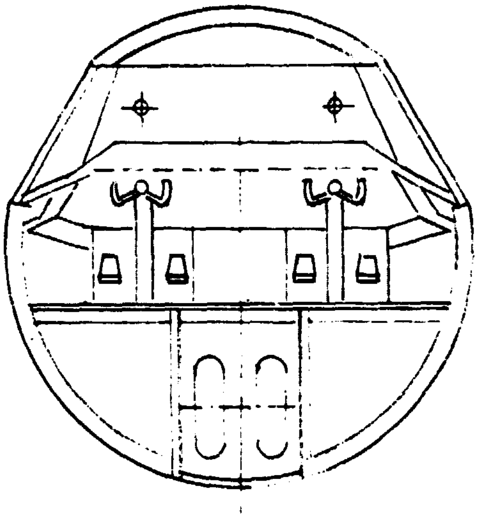
GENERAL ARRANGEMENT 4-50 BASELINE

J 14170 SD79-48026

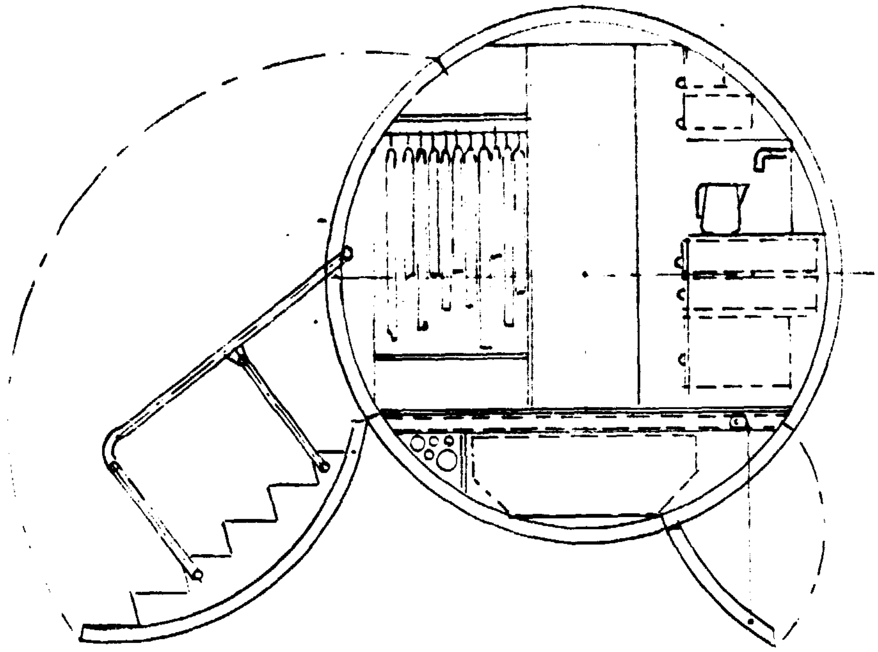

LAVATORY
(PROVISIONS ONLY)
BEVERAGE BAR
(PROVISIONS ONLY)
60.96 × 127 CM (24 ×
C.A.
OBS.
1
2
COATS
76.2 × 177.8 CM (30 × 7
WITH AIRSTAIR
A
B
A
B
2 BAGGAGE DOORS-45.72
PRELOADED BAGGAGE
(5)CONTAINERS - TOTA


60.96 × 127 CM (24 x 50 IN.) (TYPE I)
CM (24 × 50 IN) (TYPE I)
3
4
5
6
7
8
9
10
11
12
CM (30 × 70 IN.) (TYPE I)
AIRSTAIR
76.2 × 177.8 CM (30 × 70 IN.) (TYPE I)
WITH AIRSTAIR
C
2 BAGGAGE DOORS-
ORS-45.72 × 81.28 CM (18 × 32 IN.)
45.72 × 81.28 CM (18 × 32 IN)
GGAGE
TOTAL: 2.124 CU. M. (75 CU. FT.)
FOLDOUT FRAME
2
C
PRELOADED BAGGAGE
(5) CONTAINERS - TOTAL:
2286 CM (900 IN.)

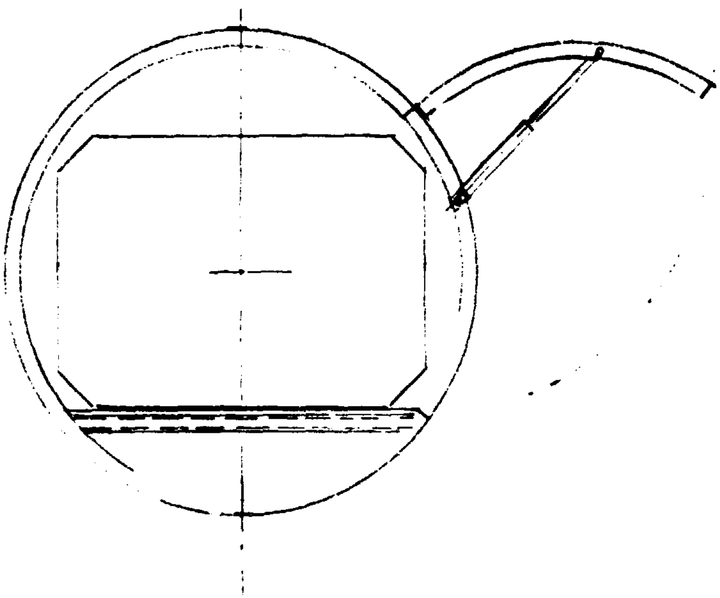

101.6 × 152.4 CM (40 × 60 IN.) BAGGAGE DOOR
COATS
PRELOADED BAGGAGE
2. 832 CU. M. (100 CU. FT.)
D
D
GAGE
TOTAL: 2. 124 CU. M. (CU. FT.)
FOLDOUT



SECTION A-A



SECTION B-B



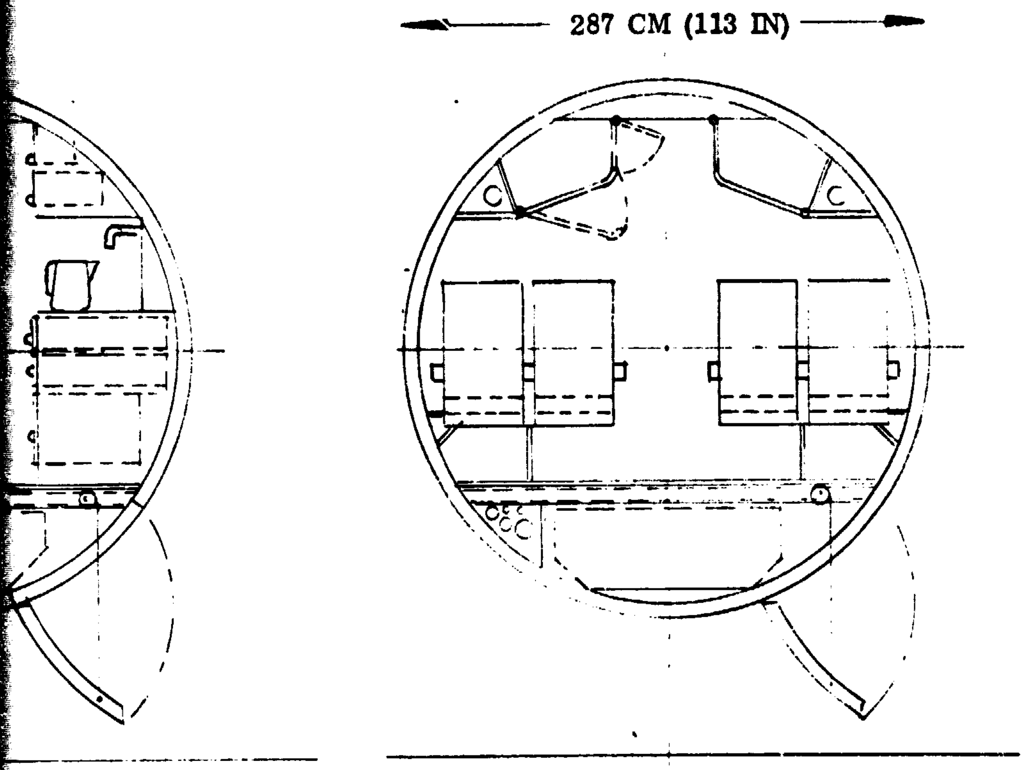
SECTION D-D

FOLDOUT FRAME 4

DRAWN BY	L.Pazmany	6-22-79
DESIGN ENGR	L.Pazmany	6-22-79
GROUP ENGR		
STRESS		
WEIGHTS		
MATERIAL		
OPERATIONS		
PROJECT	C.L.Adcock	6-22-79

FUS
4 A
2 E

GENERAL DYNAMICS
Convair Division
SAN DIEGO, CALIFORNIA



-B

SECTION C-C

4

5

Figure 3-19

6-22-79	**PRELIMINARY DESIGN DRAWING**
6-22-79	FUSELAGE LAYOUT 4 ABREAST - 50 SEATS - BASELINE 2 ENTRANCE - 13 IN. DIA.
6-22-79	

YNAMICS ivision ALIFORNIA	CODE IDENT. 14170	DRAWING NO. SD 79-48025
	SCALE 1:40	SHEET 1 OF 1

4-50 PERFORMANCE

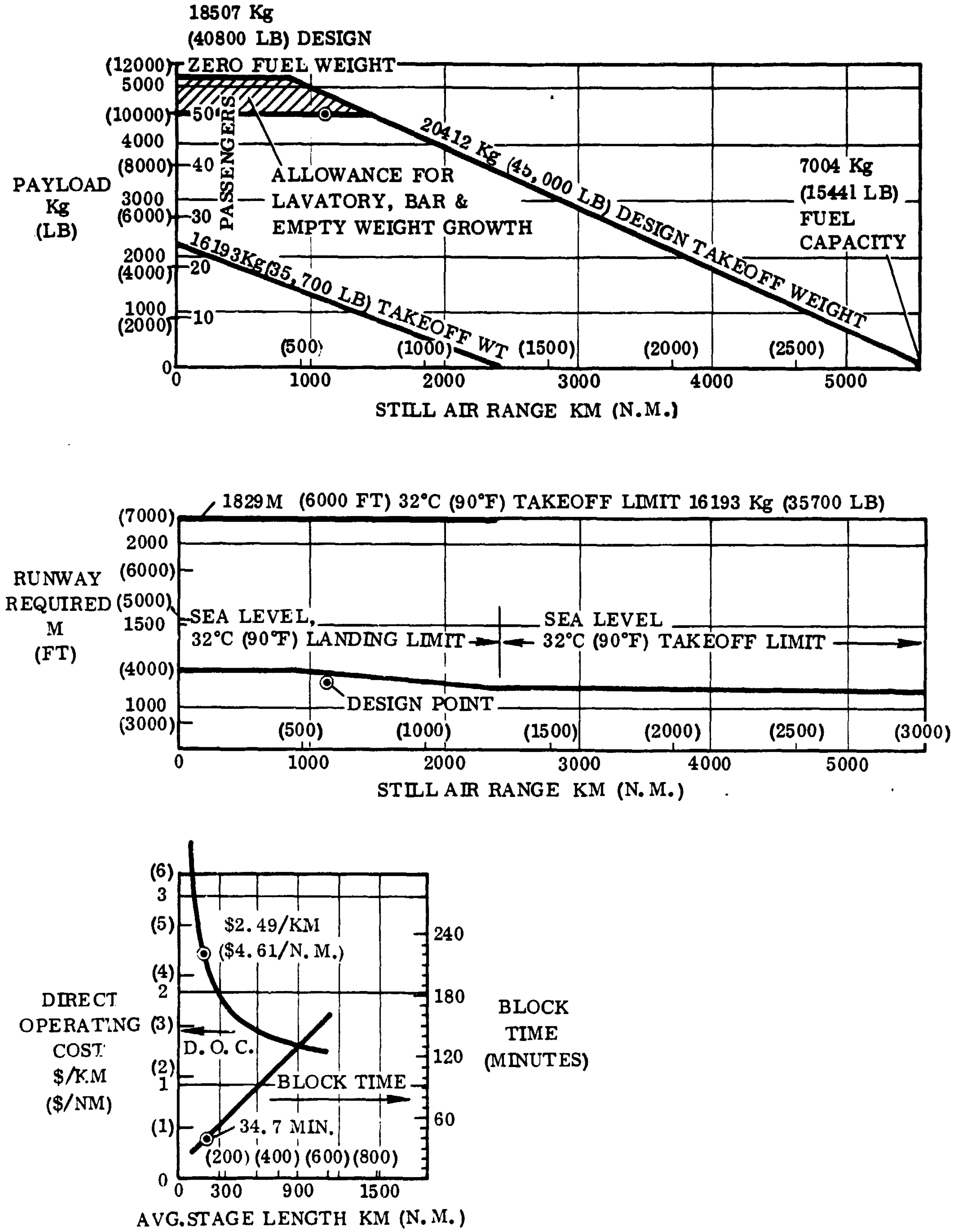
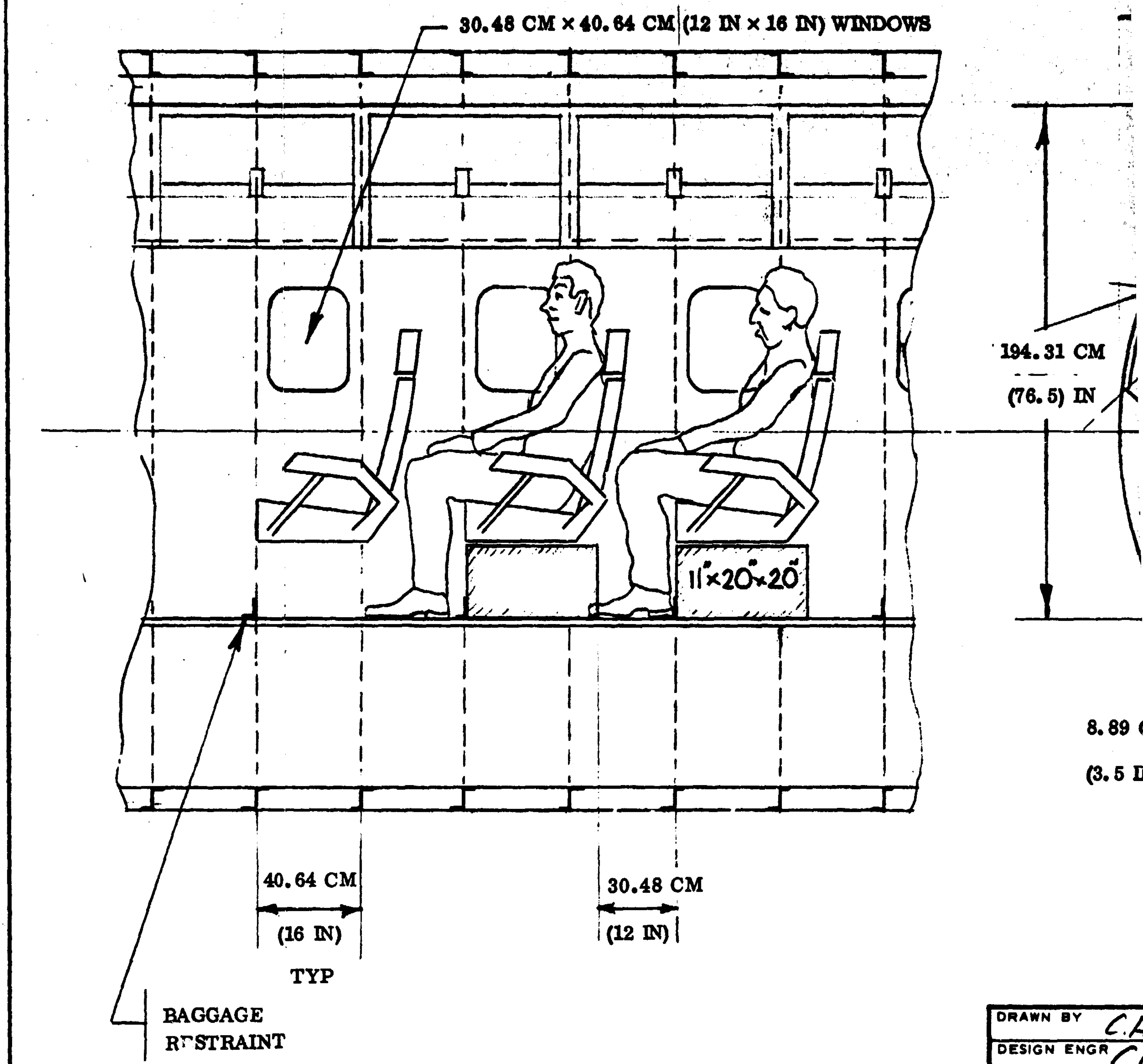


Figure 3-20. 4-50 Performance



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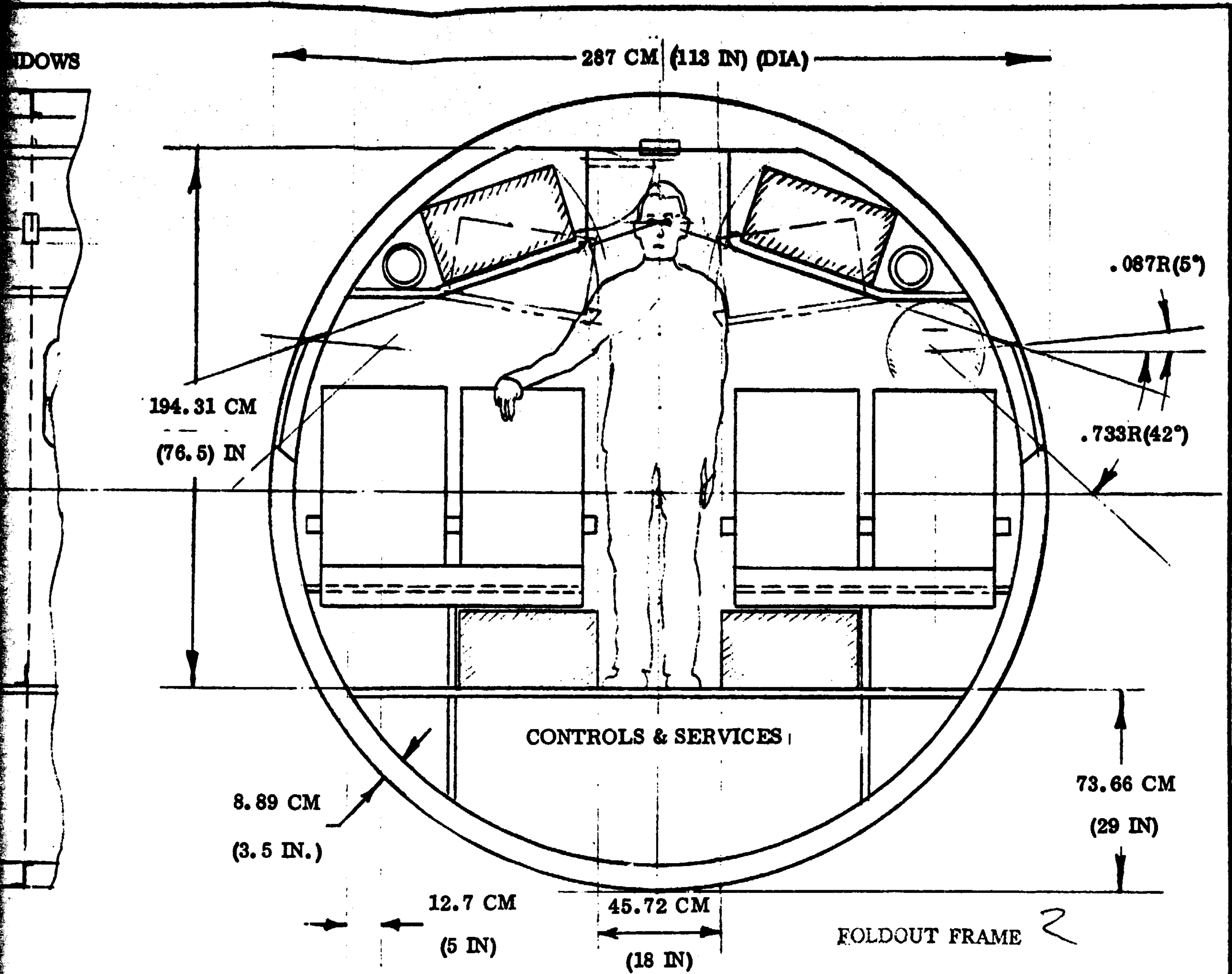
DRAWN BY	C.L.
DESIGN ENGR	C
GROUP ENGR	
STRESS	
WEIGHTS	
MATERIAL	
OPERATIONS	
PROJECT	C.L.

GENER

Co

SAN



VIEW LOOKING AFT

PERIMETER: 850.9 CM (335 IN.)

Figure 3-21

DRAWN BY C.A WRIGHT	1/26/79	PRELIMINARY DESIGN DRAWING	
DESIGN ENGR C A WRIGHT	1/26/79	FUSELAGE CROSS SECTION STUDY OVER/UNDER CARRY ON BAGGAGE 4 ABREAST 113 IN DIA	
GROUP ENGR			
STRESS			
WEIGHTS			
MATERIAL			
OPERATIONS			
PROJECT C.L. Adcock	2-8-79		
GENERAL DYNAMICS Convair Division SAN DIEGO, CALIFORNIA		CODE IDENT. 14170	DRAWING NO. SD 79-48012
		SCALE 1/20	SHEET 1 OF 1

The selected fuselage is 2286 cm (900 in.) long. It is shown in Figure 3-11 (SD 79-48025).

STEP 3. Select a baseline turboprop engine of current technology suitable to be scaled. The free turbine P&W (C) PT6A-45 engine is selected for the small aircraft.

STEP 4. Select a propeller and gearbox for the PT6A-45 engine which will meet the noise limits allowed by FAR amendment 8, Stage III minus 8 EPNdB.

Since there are innumerable combinations of propellers and gear boxes which will meet the desired noise limits, we have selected a 3 blade, 100 activity factor per blade, 0.4 design lift coefficient propeller as representative of typical current propeller design for the PT6. We have also selected the standard PT6A-45 gear box. Finally, we have initially selected a propeller diameter that maximizes cruise thrust since the final engine size (scale) is expected to be determined by the thrust required to meet the 463 km/hr (250 kt) IAS cruise speed at 3048 m (10,000 ft) and the resulting propeller diameter of 2.90 m (9.5 ft) is reasonable for a PT6A-45 size engine. Propeller diameter is scaled with engine size and noise in VDEP.

STEP 5. Determine fuselage weight and balance with acoustic treatment to meet the internal overall sound pressure level (OASPL) of 85 db. Initial estimates of aircraft weight and size resulted in the selection of a 4.57 m (15 ft) diameter propeller for determining the basic fuselage weight with acoustic treatment weighs 6936 kg (15,291 lb) and has an acoustic weight penalty of 1982 kg (4370 lb). The acoustic penalty is proportional to propeller diameter. This fuselage weight includes typical current technology systems, instruments, avionics and furnishings. No lavatory or beverage bar is included. The final fuselage and acoustic weight is determined by VDEP.

The optional lavatory, beverage bar and contents would weigh an additional 209 kg (461 lbs). To accommodate this additional weight, the design zero fuel weight, design landing weight, design takeoff weight and design ramp weight have been increased 209 kg (461 lbs).

STEP 6. Determine powerplant scaling factors which allow increasing the engine thrust as necessary to meet the mission requirements and determining the corresponding geometric, weight and cost parameters while meeting the required FAR noise levels and maintaining the required cabin noise level.

This was done by selecting the GE CT64 engine as a larger engine of similar technology to the PT6A-45. A propeller RPM and diameter were selected to meet the traded noise levels of FAR 36, Amendment 8, Stage III minus 8 EPNdB while maintaining the required cabin noise level. Since there is no "large" turboprop engine of this technology available, a "double sized" CT64 was used. Again a propeller diameter and RPM were selected to meet the traded noise levels of FAR 36, Amendment 8, Stage III minus 8 EPNdB and the required cabin noise level.

The primary design parameters (required for VDEP) are smoothly varied between these three discrete engine/propeller combinations. The engine growth factor are from Garrett data, the specific fuel consumption variation with engine size is from General Electric data and the remaining factors are smoothly, but arbitrarily faired between the calculated points. See Figure 3-2.

Since the engines are sized by cruise thrust, engine scale factor, (ESF), is based on cruise thrust rather than rated power, static thrust, or other parameter. The thrust and fuel consumption variations with speed, altitude and partial power setting are assumed to be those of the PT6A-45 with 2.90 m (9.5 ft) propeller. Known differences from these variations are adjusted by equivalent shaft horsepower (ESHP), shaft horsepower (SHFTHP) and takeoff thrust (FPI) by varying these items independently from ESF. For convenience, all engine scale factors are referred to the PT6A-45 with 2.90 m (9.5 ft) propeller. The propeller plane is maintained at the body station of the lavatory/buffet. Nacelles were assumed to have a maximum diameter 2.54 cm (1 in.) larger than the engine and to extend to 75% of the wing chord.

STEP 7. Using VDEP calculate the aircraft weight and geometry required to fly the 1111 km (600 n. mi.) design mission with a full passenger/baggage load at optimum cruise speed/altitude having reserve fuel remaining for an additional 185 km (100 n. mi.) flight to alternate and hold for 45 minutes, for parametric combinations of wing loading, aspect ratio and engine scale factor. Also calculate, for each of these combinations, the maximum cruise speed at 3048 m (10,000 ft) at start of cruise weight and the takeoff (and landing) runway required at sea level, 32°C (90°F) at design takeoff (and landing) weight. Also, calculate the direct operating cost at 185 km (100 n. mi.) average stage length.

STEP 8. Determine the minimum engine scale factor, ESF, to meet both a 463 km/hr (250 kt) IAS cruise speed at 3048 m (10,000 ft) altitude and 1219 m (4000 ft) runway at sea level by cross-plot, see Figure 3-22, and using VDEP calculate all of the STEP 7 data for the minimum ESF for each wing loading and aspect ratio.

STEP 9. Calculate the approach flap setting required to meet the approach speed of 185 km/hr (100 kt) IAS corresponding to a 1219 m (4000 ft) runway at sea level 32°C (90°F), using the current technology flap system performance shown in Figure 3-23. Using that flap setting, determine the thrust required to meet the 2.7%* approach climb gradient with one engine inoperative. This thrust requirement and the corresponding thrust available are calculated and plotted on Figure 3-24. Thrust is per propulsion unit.

STEP 10. Select the wing loading and aspect ratio of the airplane having the minimum DOC by cross plotting as shown in Figure 3-25.

*See Step 9, Section 3.5.1

The basic plot shows the DOC versus wing loading and aspect ratio with the aspect ratio 12 assumed to be representative of the maximum allowable by flutter using current technology.

Superimposed on the basic plot are wing loading limits for each aspect ratio which can meet the approach climb performance.

Thus the "optimum" design has an aspect ratio of 12, a takeoff wing loading of 50 and an engine scale factor of 2.47.

STEP 11. Using VDEP calculate the performance capabilities of the selected design and the DOC. This data is summarized early in this section and covered in more detail in Section 3.6.2.

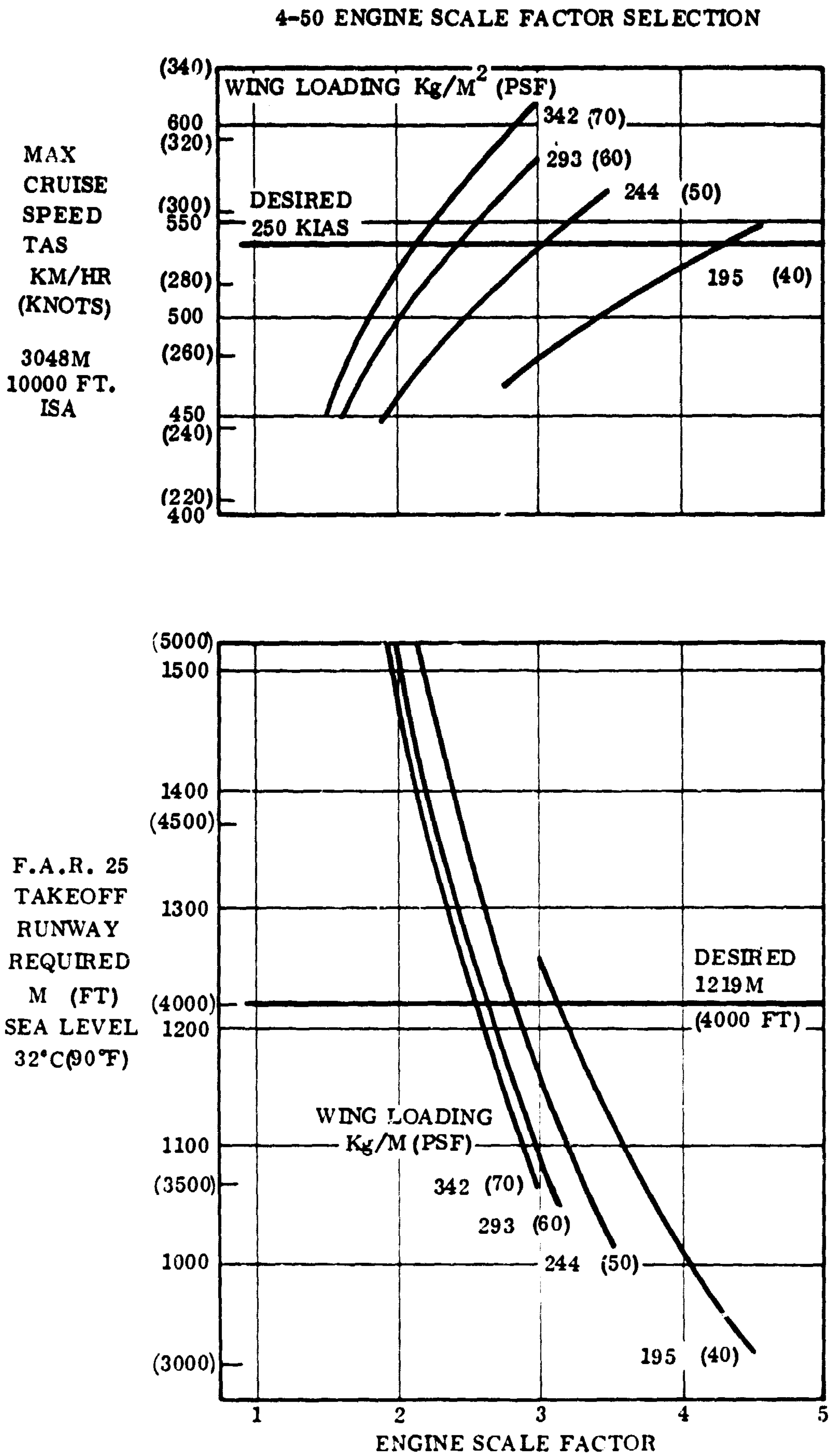


Figure 3-22. 4-50 Engine Scale Factor Selection

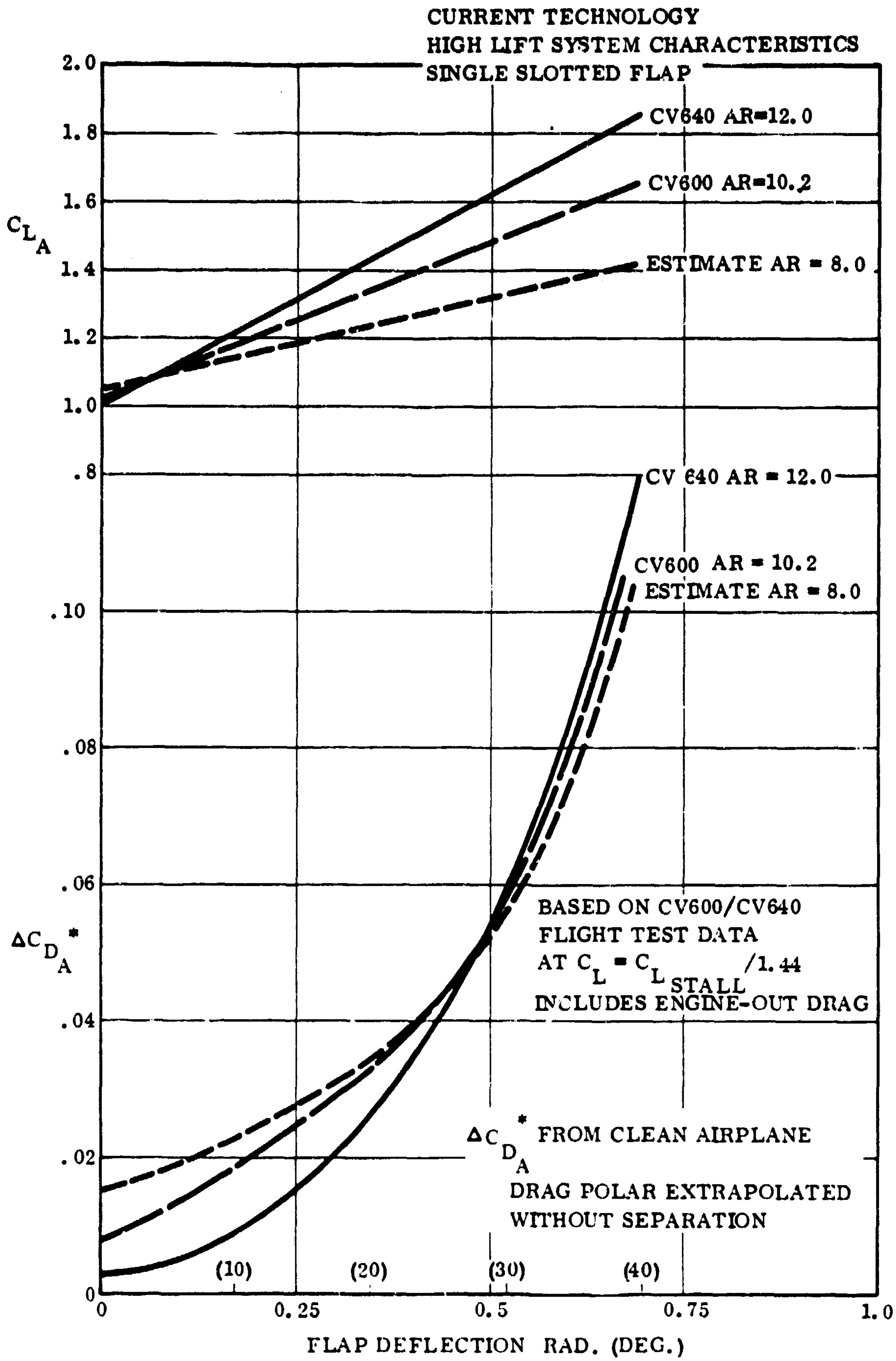


Figure 3-23. 4-50 High Lift Characteristics

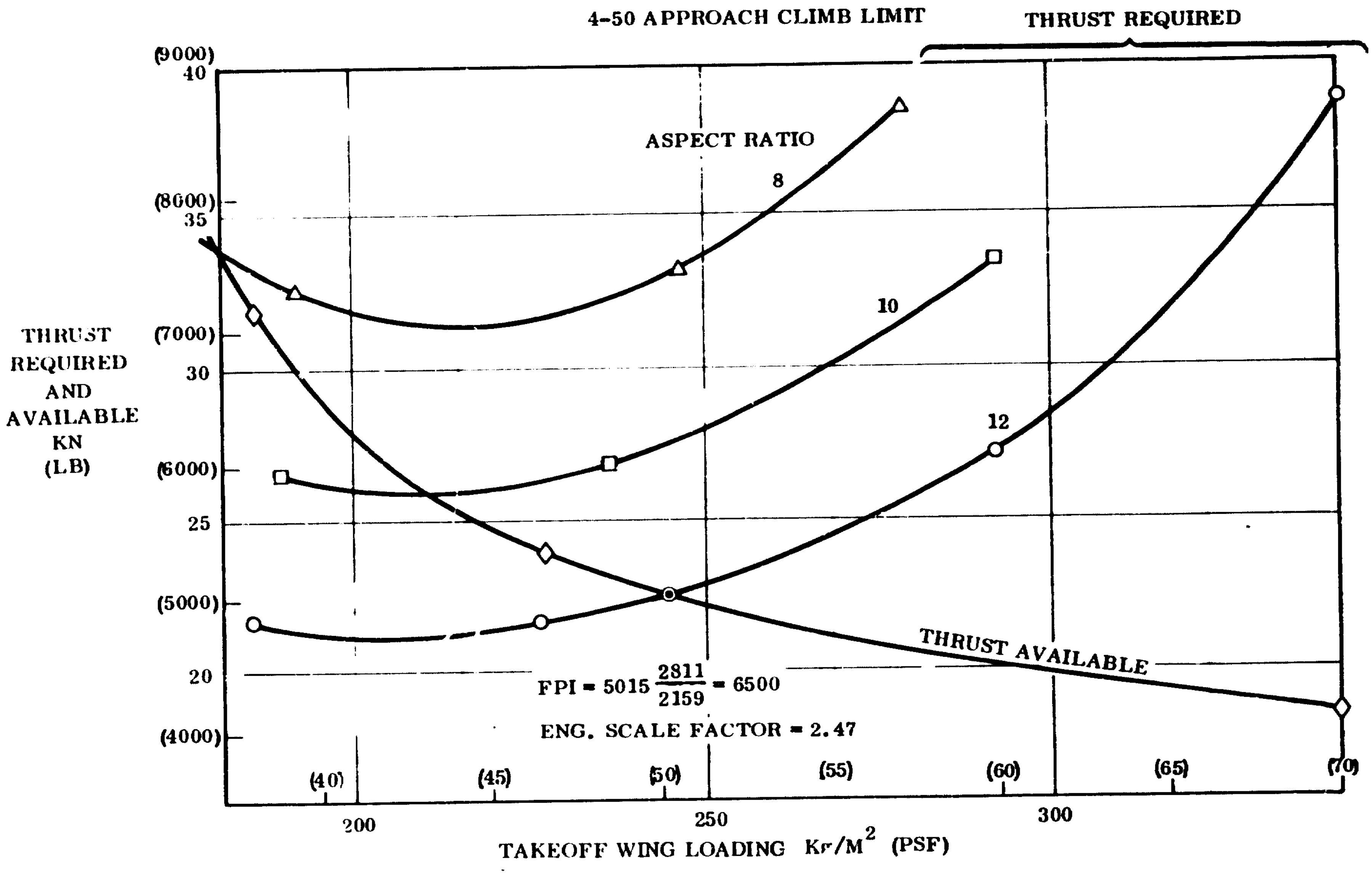


Figure 3-24. 4-50 Approach Climb Limit

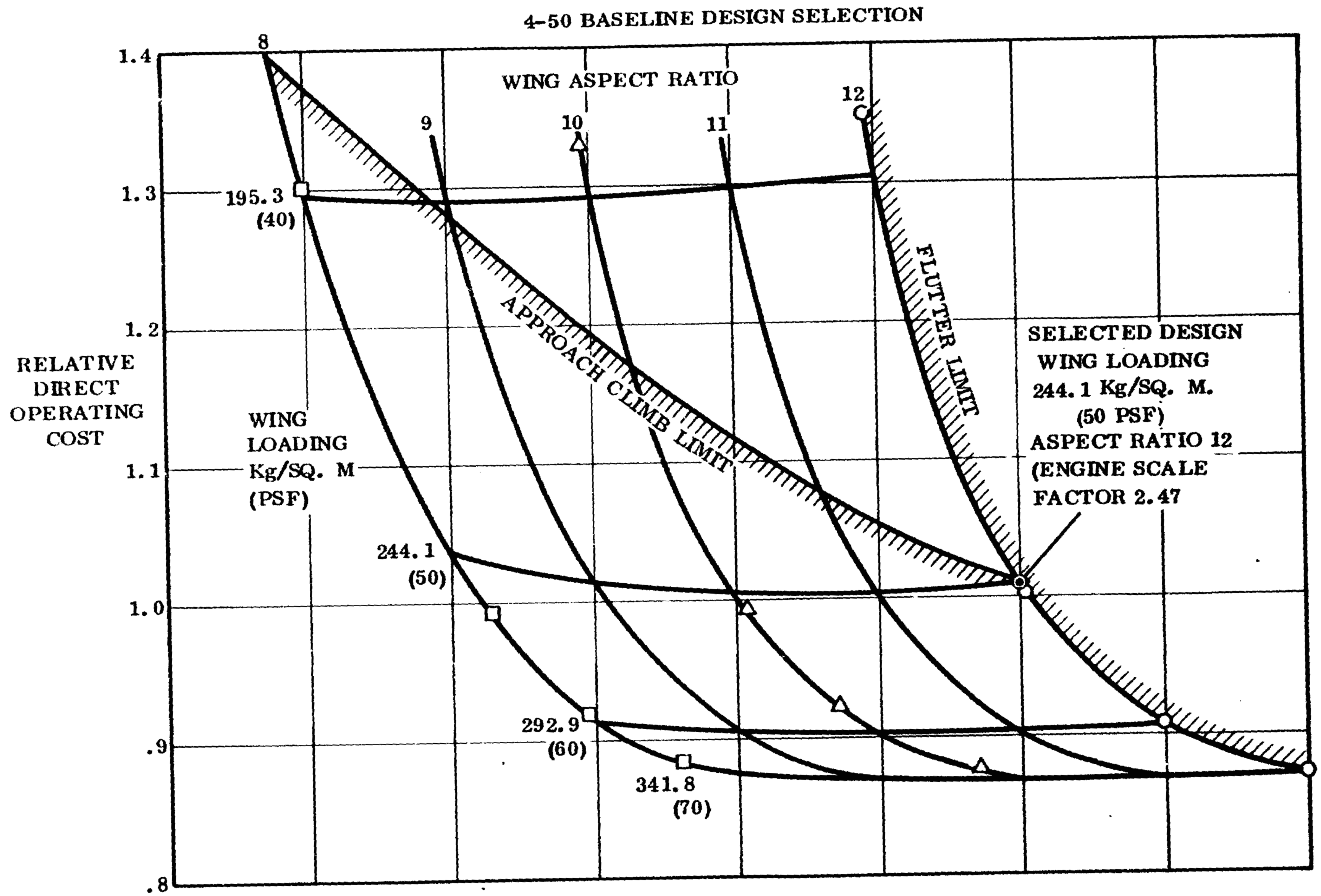


Figure 3-25. 4-50 Baseline Design Selection

C-2

3.6.2. 4-50 Characteristics and Sensitivities

The characteristics and sensitivities of the 4 abreast, 50 passenger baseline design are presented in this memorandum to assist in the application of advanced technology to this type, and size, of small, short haul, transport aircraft.

This data supplements 4-50 Baseline Design Selection, Section 3.6.1, with additional details of the

- o geometry, Table 3-18.
- o weights, Table 3-19.
- o aerodynamics, Figure 3-26.
- o cost, Table 3-20, 3-21 and 3-22.

It includes both the actual numbers and their percentage of the appropriate total.

DOC sensitivities shown in Table 3-22 are from an earlier analysis which gave slightly higher values of DOC. The data is useful for order of magnitude comparisons. For each change the aircraft was resized at constant W/S and ESF holding mission requirements.

Table 3-18. 4-50 Baseline Geometric Data

		% of Total Wetted Area
Body:		
Length	2286 cm (900 in.)	
Maximum diameter	287 cm (113 in.)	
Wetted area	164.9 sq. in. (1775 sq. ft)	38.5
Wing:		
Span	36.67 m (103.92 ft)	
Root chord	3.96 m (12.99 ft)	
Mean Aerodynamic Chord	2.85 m (9.38 ft)	
Tip chord	1.32 m (4.33 ft)	
Area	83.61 sq. m (900 sq. ft)	
Exposed area	72.56 sq. m (781 sq. ft)	
Root thickness	0.79 m (2.60 ft)	
Tip thickness	0.198 m (0.65 ft)	
Wetted area	15.12 sq. m (162.8 sq. ft)	35.3
Quarter chord sweep	0.087 rad (5.0 deg)	
Fuel volume	8721 liters (2304 gal)	
Flap area	14.21 sq. m (153.0 sq. ft)	
Horizontal Tail:		
Arm	11.83 m (38.8 ft)	
Area	25.27 sq. m (272 sq. ft)	
Exposed area	20.62 sq. m (222 sq. ft)	
Wetted area	42.54 sq. m (458 sq. ft)	9.9
Vertical Tail:		
Arm	11.28 m (37.0 ft)	
Area	21.09 sq. m (227 sq. ft)	
Exposed area	21.09 sq. m (227 sq. ft)	
Wetted area	43.48 sq. m (468 sq. ft)	10.2
Power Plants:		
Butt line	4.91 m (16.12 ft)	
Power/engine	2394 kw (3211 ESHP)	
Propeller, Diameter	4.01 m (13.15 ft)	
Number of blades	4	
Activity factor per blade	135	
Wetted area	26.2 sq. m (282 sq. ft)	6.1
Total wetted area	428.28 sq. m (4610 sq. ft)	100.0

Table 3-19. 4-50 Baseline Weights Data

Design Weights	Kilograms	(Pounds)	% of Des. T.O. Wt.
Ramp	20412	(45,000)	100.00
Takeoff	20412	(45,000)	100.00
Landing	19459	(42,900)	95.33
Zero Fuel	18507	(40,800)	90.67
Fuel Capacity	7003	(15,441)	34.31
V_c/M_c	472 km/hr (255 kt) CAS/0.525		
Group Weights			
Body Structure*	4026	(8,875)	19.72
Wing: Box Structure	1598	(3,522)	7.83
LE/TE Structure	442	(974)	2.16
Secondary Structure	102	(225)	.50
Flaps	149	(328)	.73
Horizontal Tail	235	(519)	1.15
Vertical Tail	249	(549)	1.22
Surface Controls	270	(596)	1.32
Landing Gear	840	(1,851)	4.11
Nacelle Structure	255	(562)	1.25
Total Structure	8165	(18,001)	40.00
Engines	962	(2,120)	4.71
Propellers	404	(891)	1.98
Propulsion Systems	265	(584)	1.30
Fuel System	145	(320)	.71
Instruments	87	(192)	.43
Hydraulic & Pneumatic	208	(458)	1.02
Electrical	191	(420)	.93
Avionics	352	(777)	1.73
Furnishings	1335	(2,943)	6.54
Air Conditioning/Anti Ice	455	(1,002)	2.23
Weight Empty	12568	(27,707)	61.57
Basic Operating Items	722	(1,592)	3.54
Basic Operating Weight	13290	(29,299)	65.11
Full Passengers/Baggage	4536	(10,000)	22.22
Full Pas. Zero Fuel Wt.	17826	(39,299)	87.33
Reserve Fuel (100 NM + 45 Min.)	653	(1,439)	3.20
Design Mission Landing Wt.	18479	(40,738)	90.53
Fuel Burned on 600 NM Trip	1532	(3,378)	7.51
Design Mission Ramp Wt.	20011	(44,116)	98.04

*Includes 1738 kg (3831 lb) acoustics penalty

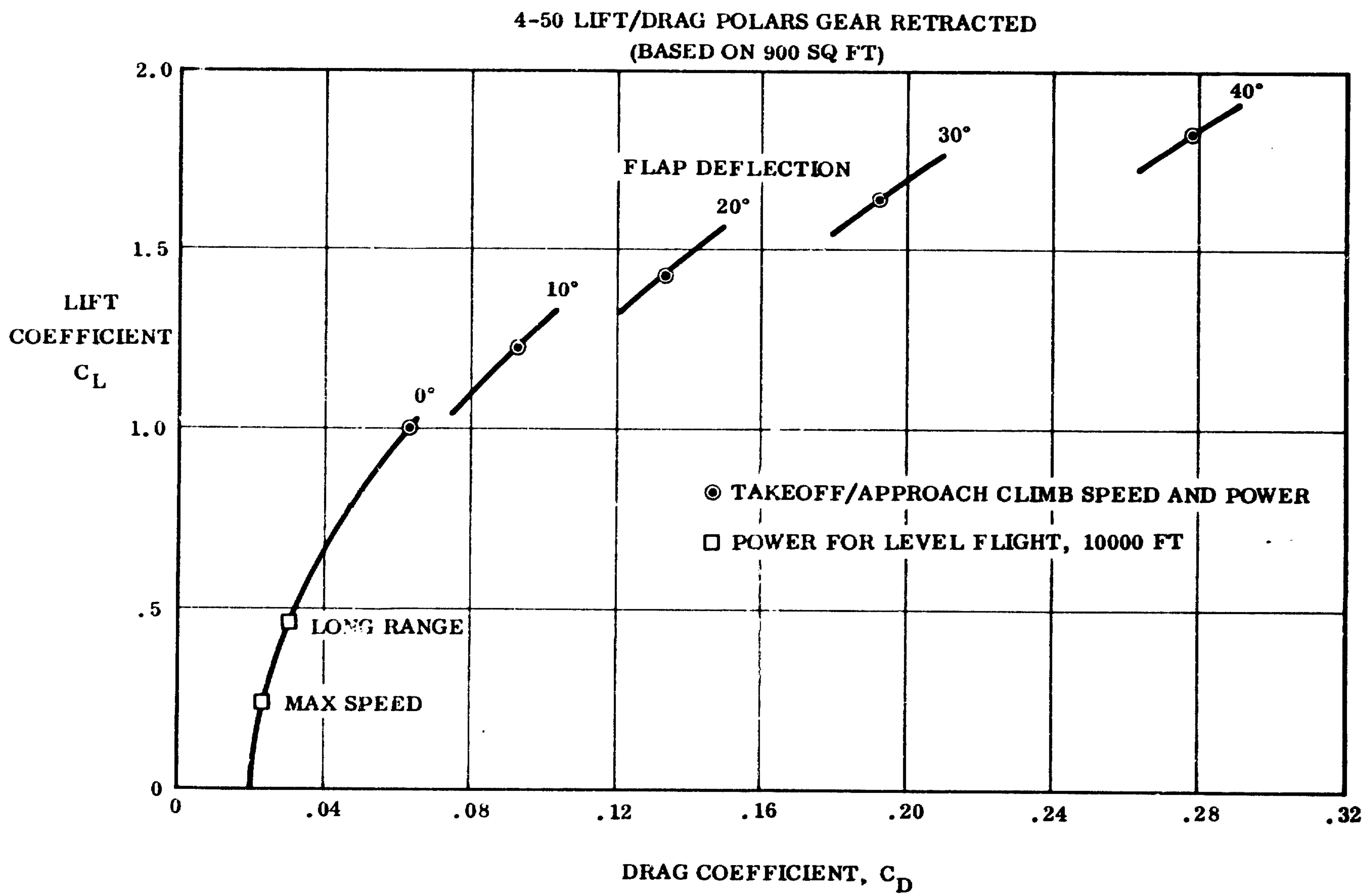


Figure 3-26. 4-50 Litt/Drag Polars

Table 3-20. 4-50 Baseline Cost Data

Aircraft Price

	1979 $M	% of Total Aircraft Price
Unit Price (250 Breakeven)	4.475	100.00
Airframe	2.732	61.05
Avionics	0.324	7.24
Engines	1.242	27.75
Propellers	0.176	3.93

Operating Conditions - 185 km (100 n. mi.) Trip

See Table 3-13.

Direct Operating Cost - 185 km (100 n. mi.) Trip	1979 $/km ($/n. mi.)	% of Total D.O.C.
Crew (1)	0.3938 (0.7275)	15.79
Fuel & Oil ($1.00/gal.)	0.7807 (1.4459)	31.39
Maintenance	0.8450 (1.5635)	33.94
Material, Engine	0.2033 (0.3765)	8.17
Airframe & Other	0.0761 (0.1410)	3.06
Direct Labor, Engine(2)	0.0441 (0.0817)	1.77
Airframe & Other(2)	0.2697 (0.4994)	10.84
Burden(3)	0.2510 (0.4649)	10.09
Insurance(4)	0.0770 (0.1426)	3.09
Depreciation(5)	0.3926 (0.7271)	15.78
Total Direct Operating Cost	2.4874 (4.6068)	100.00
Total Direct Seat-Mile Cost	4.97 ¢/Skm (9.21 ¢/Sn. mi.)	100.00

(1) $/block hr. = 2.5 × seats

(2) $10 per man-hour

(3) 80% of direct labor

(4) 1.5% of total aircraft price per year

(5) Aircraft and spares depreciated over 12 years to 15% residual.
Spares are (0.2 × seats + 2.0) % of total aircraft price.

Table 3-21. 4-50 Operating Conditions - 185 km (100 n. mi.) Trip

At End of	Altitude m (ft.)	Time* Min.	Speed-TAS km/hr (kt)	Distance* km (n. mi.)	Spec. Range km/kg (n. mi./lb)	Fuel Burned kg (lb.)
Takeoff	0 (0)	0.5	191 (103)	0 (0)	-	10 (21)
Climb	5182 (17,000)	9.0	333 (180)	44 (24)	0.298 (0.073)	160 (352)
Cruise	5182 (17,000)	24.7	535 (289)	185 (100)	0.559 (0.137)	367 (808)
Maneuver	0 (0)	34.7	0 (0)	185 (100)	-	1036 (2383)

An average of 2800 block hours per year utilization is equivalent to 896646 km (484,150 n. mi.) per year per aircraft.

*Time, distance and fuel burned are cumulative at the end of each stage.

Table 3-22. 4-50 Baseline D.O.C. Sensitivities

Item	Either: Change	Either: % D.O.C. Change	Or: Change	Or: % D.O.C. Change
Airframe & Other Cost	-$100,000	-.52	-1%	-.16
Engine Cost/Engine	-$10,000	-.24	-1%	-.15
Airplane Empty Weight	-454 kg (-1,000 lb)	-.19	-1%	-.05
Number in Crew	-1 Copilot	-3.27	-50%	-3.27
Block Fuel used 185 km (100 nm) Trip	-4.54 kg (-10 lb)	-.32	-1%	-.29
Fuel Price	-6.6¢/ltr (-25¢/gal)	-7.27	-1%	-.22
Fuel Heating Value	+232500 joule/kg (+100 Btu/lb)	-.12	+1%	-.19
Drag Area	-0.093 sq m (-1.0 sq ft)	-1.50	-1%	-.19
Induced Drag	-		-1%	-.04
Increase Thrust	-		+1%	-.26
Reduced Horiz. Tail Size	-0.929 sq m (-10 sq ft)	-.09	-1%	-.03
Reduced Vert. Tail Size	-0.929 sq m (-10 sq ft)	-.12	-1%	-.03

4.0 APPLICATION OF ADVANCE TECHNOLOGY

The approach to investigating the application of advanced technology taken in this study was to identify five major Advanced Technology Specialty Aircraft. These major design areas were as follows:

Aerodynamic Specialty Aircraft
Structures Specialty Aircraft
Systems Specialty Aircraft
Propulsion Specialty Aircraft
Configuration Specialty Aircraft (High Wing)

In each area the engineers were tasked to recommend technology application in their area of expertise. The remaining technology in each design was held constant. The description of the changes recommended and the results obtained are summarized in Table 4-1. In all cases significant improvements were found with the exception of the Configuration Specialty Aircraft (High Wing). These aircraft technologies are discussed in the following sections. Operating cost increments and ROI are compared in Table 4-2.

4.1 AERODYNAMIC TECHNOLOGY

SUMMARY. An "Aerodynamic Specialty" airplane design is selected to illustrate the potential benefits of applying advanced aerodynamic technology to the 3-30 baseline design while maintaining current technology in all non-aerodynamic areas. This design meets all of the design requirements of the baseline design with 23% smaller engines, 35% less wing area, 7-8% less weight, 21% less fuel, 13% higher cruise speed and has 10% less direct operating cost. Figure 4-1 shows a three view comparison of this "aerodynamic specialty" airplane with the baseline design.

Figure 4-1 also indicates the aerodynamic technologies being incorporated:

- o New high lift/low drag flaps having a large (35%) chord extension without open slots in the 10° takeoff and approach position. This applied on new technology airfoils results in a significant lift increase with little or no drag increase.
- o New natural laminar flow (NLF) airfoils for wing and tail incorporating NLF contours, surface coatings and a water methanol spray system to assure low cruise drag.
- o "VEE" tail to reduce drag without loss of stability or control.

Table 4-1. Comparison of Advance Tec

	3-30 Current Technology Baseline	3-30 Adv		
		Aerodynamic	Structures	
Description	30 Passengers, 81.28 cm (32 in.) Seat Pitch 4.26 cu m (150 cu ft) Preloaded Baggage 3.45 N/sq cm (5 psi) Cabin Pressure Current Tech Str Current Tech Sys Twin Tractor Free Turbine Engines 3 Blade Propeller Low Wing (AR = 12)	Baseline Plus: High L/D Flaps Natural Laminar Flow Wing System Vee Tail Faired Windshield Reduced Misc. Drag Wing AR = 15	Baseline Plus: Graphite/Kevlar Epoxy Structure Except Wing Center Section Box and Aluminum Honeycomb Lower Fuselage Crash Resistant Floor	Ba A A E Ac S Dy
Rated Power/Engine kw (ESHP)	1747 (2343)	1327 (1780) (-24%)	1309 (1755) (-25%)	138
Propeller Diameter m (ft)	3.50 (11.47)	3.24 (10.62)	3.23 (10.60)	3.2
Wing Span m (ft)	25.19 (82.65)	22.71 (74.53)	22.90 (75.14)	23.
Wing Area sq m (sq ft)	52.86 (569)	34.37 (370) (-35%)	43.66 (470) (-17%)	44.
Max Gross Wt kg (lb)	13426 (29,600)	12429 (27,400) (-7%)	11204 (24,700) (-17%)	114
Basic Operating Wt kg (lb)	8896 (19,611)	8247 (18,182) (-7%)	6991 (15,413) (-21%)	726
185 km (100 n mi) Trip				
Cruise Altitude m (ft)	5182 (17,000)	4572 (15,000)	5182 (17,000)	518
Flight Time min	24.4	23.3	24.7	24.5
Flight Fuel kg (lb)	261 (576)	207 (456) (-21%)	218 (480) (-17%)	224
Range-30 passengers km (n mi)	1445 (780)	1537 (830)	1556 (840)	155
Runway-SL 32°C (90°F) m (ft)	1219 (4000)	1219 (4000)	1219 (4000)	1219
Max Cruise Speed km/hr (kt)	539 (291)	539 (291)	539 (291)	539
Unit Flyaway Cost $M	3.16	2.73 (-14%)	2.49 (-21%)	2.74
DOC (100 n mi Trip) $/km ($/n mi)	1.69 (3.13)	1.42 (2.63) (-16%)	1.44 (2.66) (-15%)	1.45

(xx%) Change from Baseline

of Advance Technology 3-30 Characteristics

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3-30 Advanced Technology Specialty Designs				AT3-30 Advanced Technology Aircraft
s	Systems	Propulsion	3-30A Configuration	
s vlar ucture ing ction luminum b Lower Crash Floor	Baseline Plus: Automated Flight Advanced Cockpit Electric Active Controls Active Noise Suppression Dynamic Braking	Baseline Plus: Advanced Engines Advanced Quiet Propellers	High Wing Baseline	High L/D Flaps Natural Laminar Flow Wing (AR = 15) Faired Windshield Advanced Composite Structure Automated Flight Advanced Cockpit Electric Active Controls Dynamic Braking Advanced Engines Advanced Pusher Propellers
25%) 17%)	1387 (1860) (-21%) 3.28 (10.76) 23.03 (75.54) 44.22 (476) (-16%)	1544 (2070) (-12%) 4.63 (15.20) 24.13 (79.17) 48.40 (521) (-8%)	2650 (3553) (+52%) 4.00 (13.11) 25.98 (85.22) 56.21 (605) (+6%)	1095 (1469) (-37%) 3.05 (10.00) 19.74 (64.77) 26.01 (280) (-51%)
) (-17%) (-21%)	11476 (25,300) (-15%) 7261 (16,008) (-18%)	12338 (27,200) (-8%) 8110 (17,880) (-9%)	14787 (32,600) (+10%) 9930 (21,891) (+12%)	10478 (23,100) (-22%) 6497 (14,324) (-27%)
  %)	5182 (17,000) 24.5 224 (493) (-14%)	5791 (19,000) 25.5 205 (453) (-21%)	7010 (23,000) 25.0 315 (694) (+20%)	5182 (17,000) 25.0 176 (389) (-32%)
	1556 (840) 1219 (4000) 539 (291)	1482 (800) 1219 (4000) 539 (291)	1482 (800) 1219 (4000) 539 (291)	1482 (800) 1219 (4000) 528 (285)
 15%)	2.74 (-13%) 1.45 (2.69) (-14%)	2.75 (-13%) 1.45 (2.69) (-14%)	3.52 (+11%) 2.01 (3.72)(+18%)	2.57 (-19%) 1.29 (2.38)(-24%)

Table 4-2. Direct Opera

	3-30 Current Technology Baseline	3-30 Advanced Technolo	
		Aerodynamic	Structures
Unit Flyaway Cost $M	3.16	2.73	2.49
Direct Operating Cost Breakdown $/km ($/n. mi.)			
Crew	0.233 (0.432)	0.217 (0.401)	0.235 (0.435)
Fuel and Oil	0.554 (1.027)	0.440 (0.815)	0.460 (0.851)
Maintenance	0.574 (1.063)	0.498 (0.922)	0.478 (0.885)
Engine Material	0.122 (0.227)	0.086 (0.159)	0.087 (0.162)
Airframe Material	0.057 (0.106)	0.050 (.093)	0.046 (0.086)
Engine Labor	0.039 (0.073)	0.036 (0.067)	0.038 (0.070)
Airframe Labor	0.180 (0.333)	0.165 (0.305)	0.153 (0.284)
Burden	0.175 (0.325)	0.161 (0.298)	0.153 (0.283)
Insurance	0.054 (0.101)	0.044 (0.081)	0.043 (0.080)
Depreciation	0.277 (0.512)	0.222 (0.412)	0.219 (0.406)
Total DOC	1.692 (3.135)	1.420 (2.630)	1.435 (2.657)
¢/Skm (¢/S n. mi.)	5.64 (10.45)	4.74 (8.77)	4.78 (8.86)
Ref. to Baseline %	100.0	83.9	84.9
R.O.I %	8.2	16.3	15.4

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-2. Direct Operating Cost Comparison

dvanced Technology Specialty Designs				AT 3-30 Advanced Technology Aircraft
uctures	Systems	Propulsion	3-30A Config. (high wing)	
2.49	2.74	2.75	3.52	2.57
(0.435)	0.234 (0.433)	0.241 (0.446)	0.286 (0.529)	0.237 (0.440)
(0.851)	0.473 (0.876)	0.446 (0.826)	0.556 (1.030)	0.381 (0.705)
(0.885)	0.460 (0.851)	0.470 (0.871)	0.724 (1.340)	0.403 (0.746)
(0.162)	0.093 (0.173)	0.065 (0.120)	0.213 (0.395)	0.056 (0.104)
(0.086)	0.053 (0.099)	0.052 (0.096)	0.057 (0.106)	0.053 (0.097)
(0.070)	0.038 (0.070)	0.030 (0.055)	0.048 (0.088)	0.028 (0.052)
(0.284)	0.136 (0.251)	0.167 (0.309)	0.205 (0.379)	0.136 (0.251)
(0.283)	0.139 (0.257)	0.157 (0.291)	0.201 (0.373)	0.131 (0.245)
(0.080)	0.047 (0.087)	0.049 (0.090)	0.073 (0.135)	0.044 (0.081)
(0.406)	0.239 (0.442)	0.246 (0.456)	0.373 (0.690)	0.222 (0.411)
(2.657)	1.452 (2.689)	1.452 (2.689)	2.011 (3.724)	1.287 (2.383)
(8.86)	4.84 (8.96)	4.84 (8.96)	6.70 (12.41)	4.29 (7.94)
84.9	85.8	85.8	118.8	76.0
15.4	13.9	13.5	3.3	17.8

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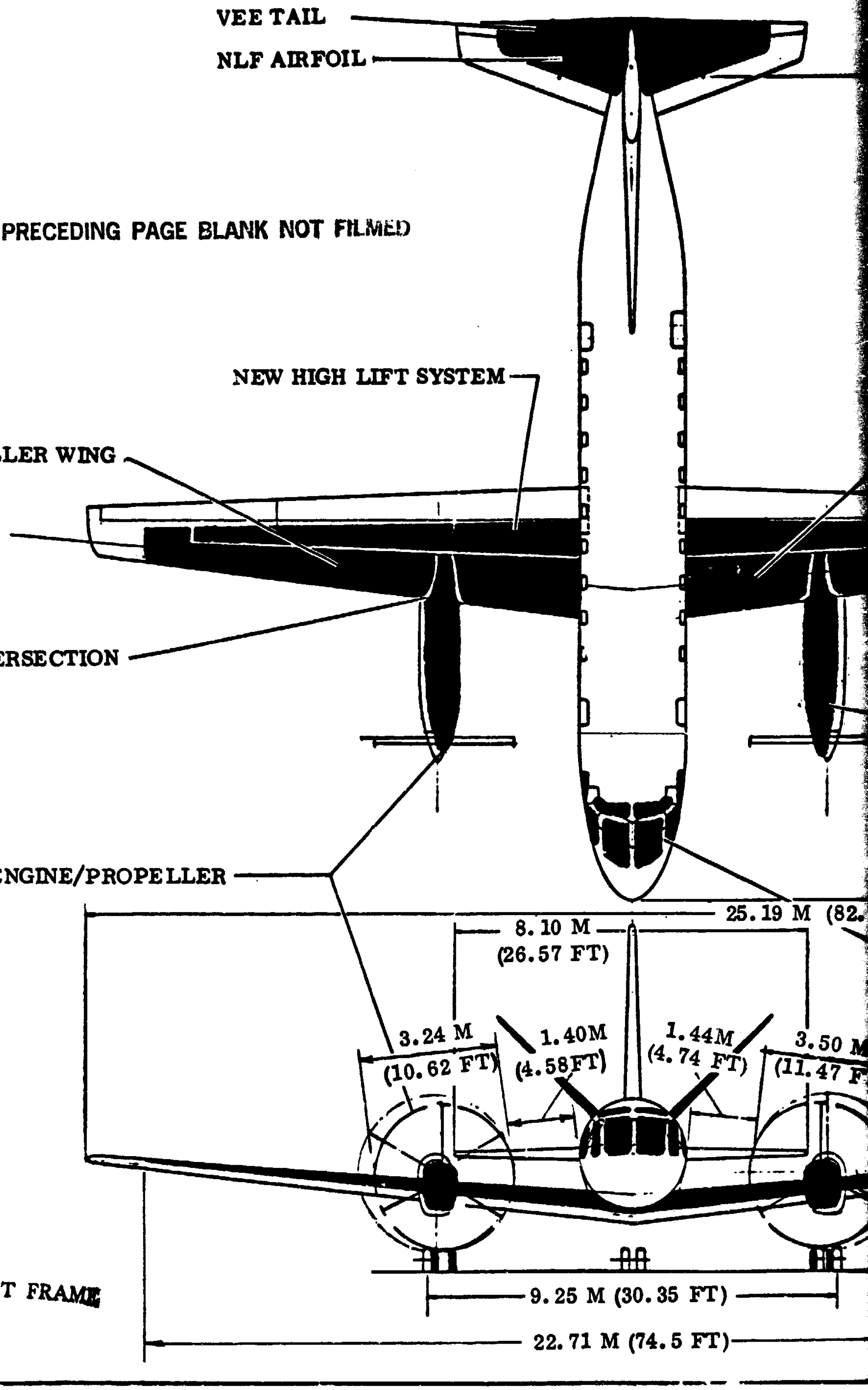

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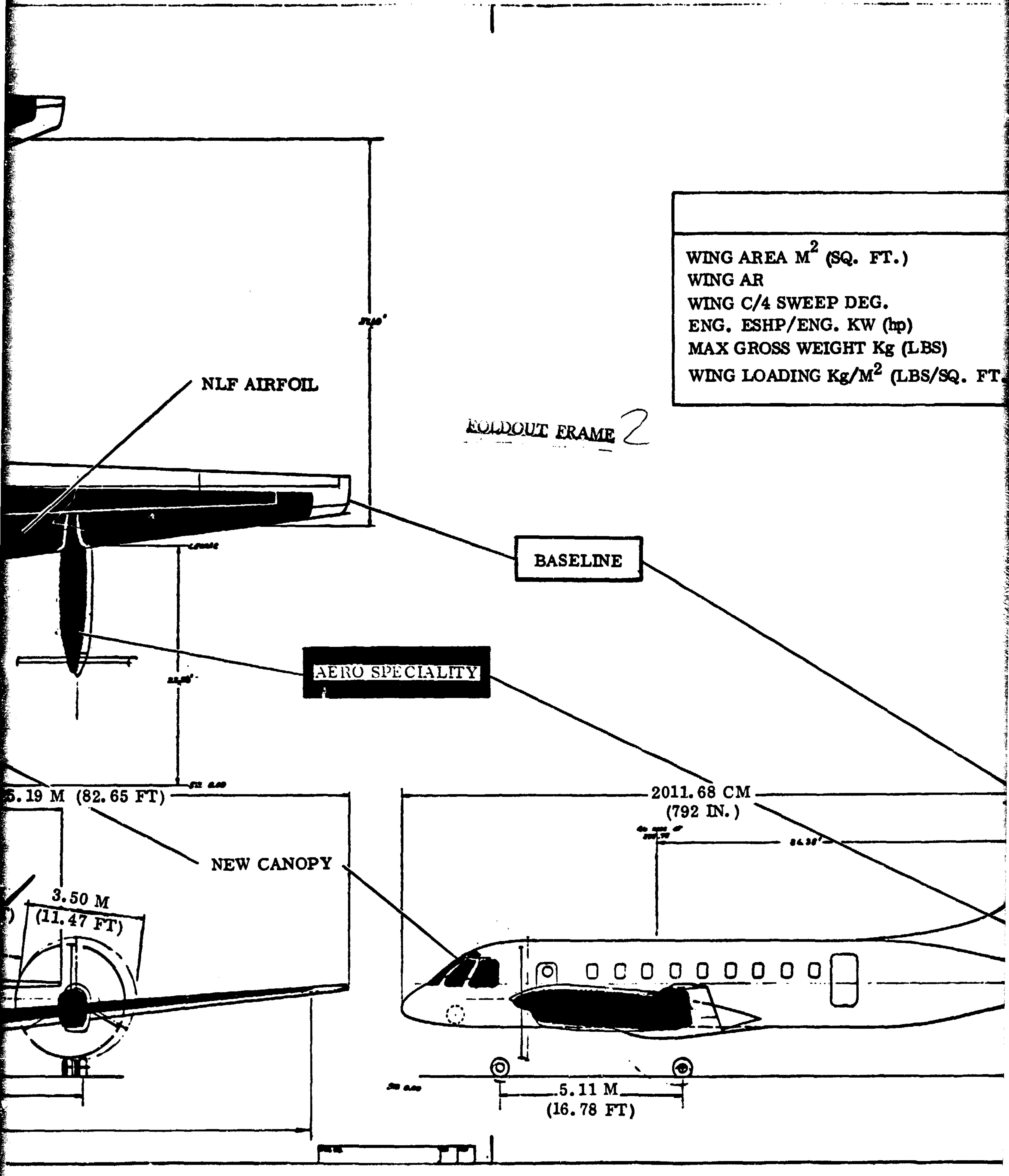

WING AREA M^2 (SQ. FT.)	
WING AR	
WING C/4 SWEEP DEG.	
ENG. ESHP/ENG. KW (hp)	
MAX GROSS WEIGHT Kg (LBS)	
WING LOADING Kg/M^2 (LBS/SQ. FT.	

	BASELINE	AERODYNAMIC SPECIALTY
	52.86 (569)	34.37 (370)
	12	15
	5.0	5.0
	1,747 (2,343)	1,327 (1,780)
	13,426 (29,600)	12,428 (27,400)
FT.)	253.9 (52.0)	361.3 (74.0)

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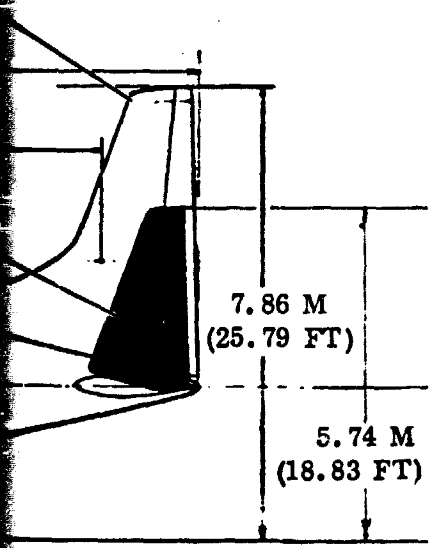


Figure 4-1

PRELIMINARY DESIGN DRAWING			
3-30 AERODYNAMIC SPECIALTY AIRCRAFT - COMPARISON W/BASELINE GENERAL ARRANGEMENT			
BY C.L. ADCOCK	APPROVED G. F. Adcock	SCALE -	DATE 3-24-
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS SAN DIEGO, CALIFORNIA		DRAWING NO. SD80-4800	

6549 (9-71)

- o Improved cockpit canopy contours using curved glass panels to minimize the drag penalty.
- o Reduced miscellaneous drag.

These technologies and their effects on the airplane are discussed in further detail in the discussion section below.

DISCUSSION. Several advanced aerodynamic technologies were considered for application to the 3-30 baseline design. The following of these are included in this "Aerodynamic Specialty" airplane design.

NEW HIGH LIFT/LOW DRAG FLAPS. Inspection of the design limitation of the 3-30 baseline disclosed that the approach climb requirement was limiting the allowable wing loading and D.O.C. even though the engine was sized by cruise speed rather than takeoff distance. The baseline circular arc flaps provided too little lift and too much drag. Subsequent investigation, showed that a trailing edge flap system having a large chord extension for takeoff and approach generated significantly more lift with a minimum drag increase. Reasoning that such a chord extension without a large deflection and with only one flap segment and no slots would be an improvement, GD/CV designed a new trailing edge flap system.

During flap extension the new flap moves directly aft on internal tracks through 35% chord in the first 10 degrees of deflection. The upper and lower surfaces remain in contact with the wing upper and lower surfaces throughout this portion of the flap travel. This is the takeoff and approach flap position. Further motion of the actuating mechanism causes the flap to rotate without further aft movement of the landing flap.

The estimated aerodynamic effects of this high lift system applied from the side of the body to the 90% semispan station and applied to a new NLF modification of a GA(W) airfoil are shown in Figure 4-2. Maximum lift is increased by 37% at 35° deflection with flap drag reduction of 15%.

NEW NATURAL LAMINAR FLOW AIRFOILS. The perennial hope for practical laminar flow currently rests in promising research in airfoil contours, surface coatings and anti contaminate sprays.

The most desirable wing contours for small, short haul transports must have high lift and low profile drag at high lift as well as laminar flow. The NASA GA(W) airfoils have the high lift and low profile drag at high lift required. Hopefully, they can be modified to provide natural laminar flow on the upper surface while retaining these other characteristics. We have assumed that the resulting airfoil shape will be derived from the GA(W), but will have an upper surface shape similar to the NASA 66_3-418 and will have the potential for laminar flow over 70% of the upper surface and 18% of the lower surface. Wing friction drag is reduced 20%.

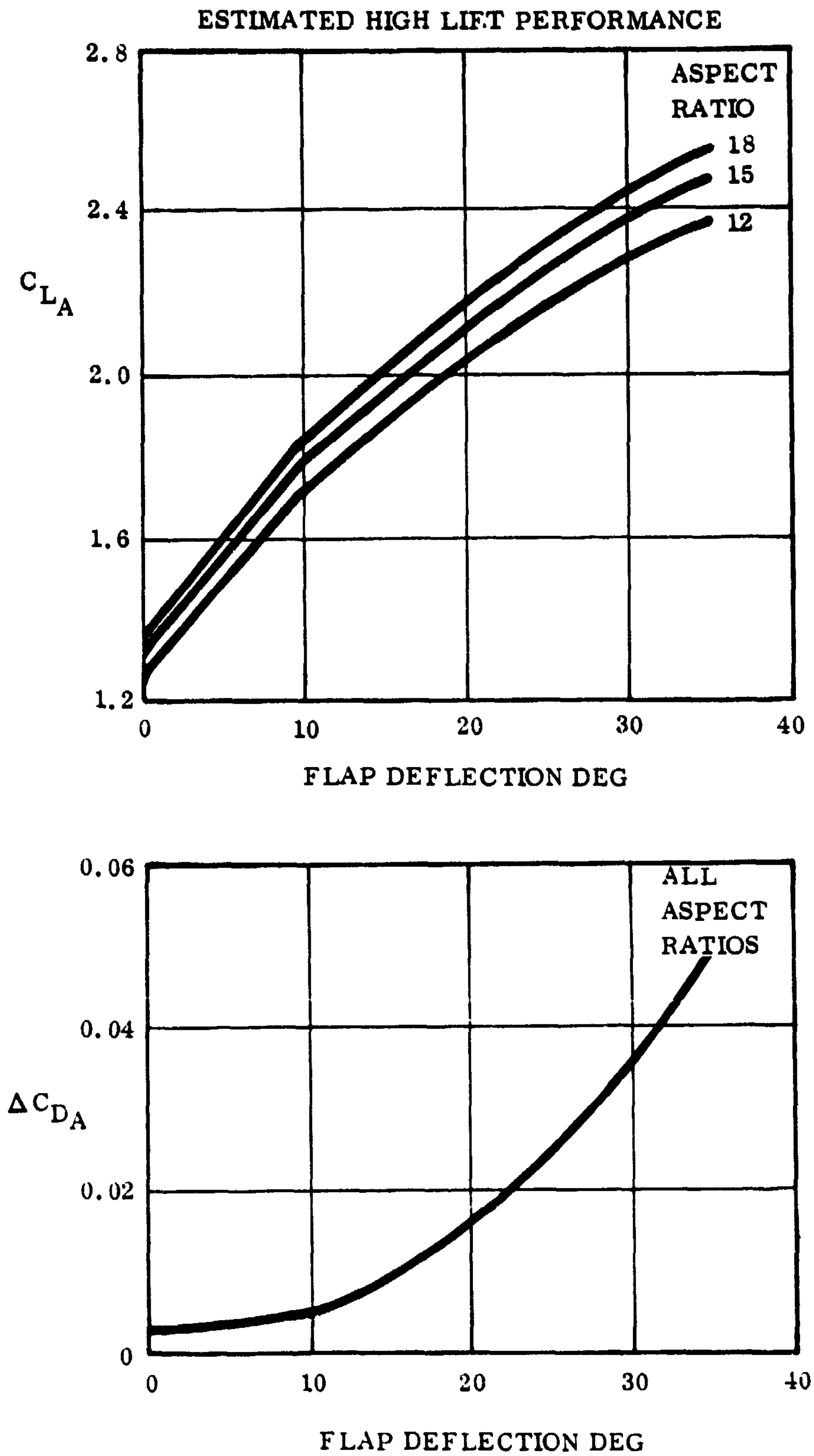


Figure 4-2. Estimated High Lift Performance

Construction and maintenance procedures must be established which will assure a smooth surface throughout the life of the airplane. We have assumed that current construction procedures can form the upper surface from the leading edge (stagnation point) to the 90% chord line, and the lower leading-edge-access-door surface from the stagnation point to the front spar.

A second assumption of this study is that surface coatings will be available and maintain the surface to the required smoothness without excessive maintenance.

A third assumption of this study is that a continuous water-methanol spray from ports at the wing and tail leading edge (stagnation point) will prevent insect contamination over the protected areas of the wing and tail. The propeller slipstream is assumed to be turbulent and to prevent laminar flow. The turbulence is assumed to expand laterally 7° from the leading edge. The system is assumed to discharge water-methanol at a rate of 12 lb/min/sq ft* of frontal area from a 100 gallon fuselage tank continuously for five minutes per flight during takeoff and climb to 10000 ft. No water is provided for letdown and landing since it is assumed that the wing and tail leading edges will be washed and the tank refilled after each flight in "bug country." The water-methanol is assumed to cost 30¢/gallon and to be used for 1/3 of the annual flights for an average cost of $9/flight. The maintenance/servicing cost is estimated at an average of $6.10 per flight for labor plus 15 gallons of cleaning solution at 60¢ per gallon.

"VEE" TAIL. The twin surface "VEE" tail maintains the desired stability and control while reducing the wetted area, weight, cost and maintenance by 25%.

IMPROVED COCKPIT CANOPY. A redesign of the cockpit canopy, using curved glass panels can reduce the cockpit drag and noise by minimizing peak pressures and separation. This results in a drag reduction of 0.3 sq ft. The added glass area adds 210 lb, but reduces noise saving 32 lb of acoustic material. VDEP estimates the initial cost and maintenance cost with sufficient accuracy.

REDUCED MISCELLANEOUS DRAG. Meticulous attention to construction practice; aerodynamic cleanliness; wing-fuselage, wing-nacelle and fuselage tail juncture; and skin smoothness including the use of surface coatings where advantageous. It is estimated that a reduction of 0.45 sq ft of drag area (75% of VDEP markup) is possible. The coatings are estimated to increase the airplane purchase price by $5000.

4.2 STRUCTURAL TECHNOLOGY

SUMMARY. A "Structures Specialty" airplane design is selected to illustrate the potential benefits of applying advanced structures technology to the 3-30 baseline

*Based on NASA tests (Dryden)

design while maintaining current technology in all non-structural areas. This design meets all of the design requirements of baseline design with 25% smaller engine, 17% less wing area, 16-21% less weight, 17% less fuel and has 15% less direct operating cost. Figure 4-3 shows the three view comparison of this "Structures Specialty" airplane with the baseline design.

Figure 4-3 also indicates the structures technologies being incorporated:

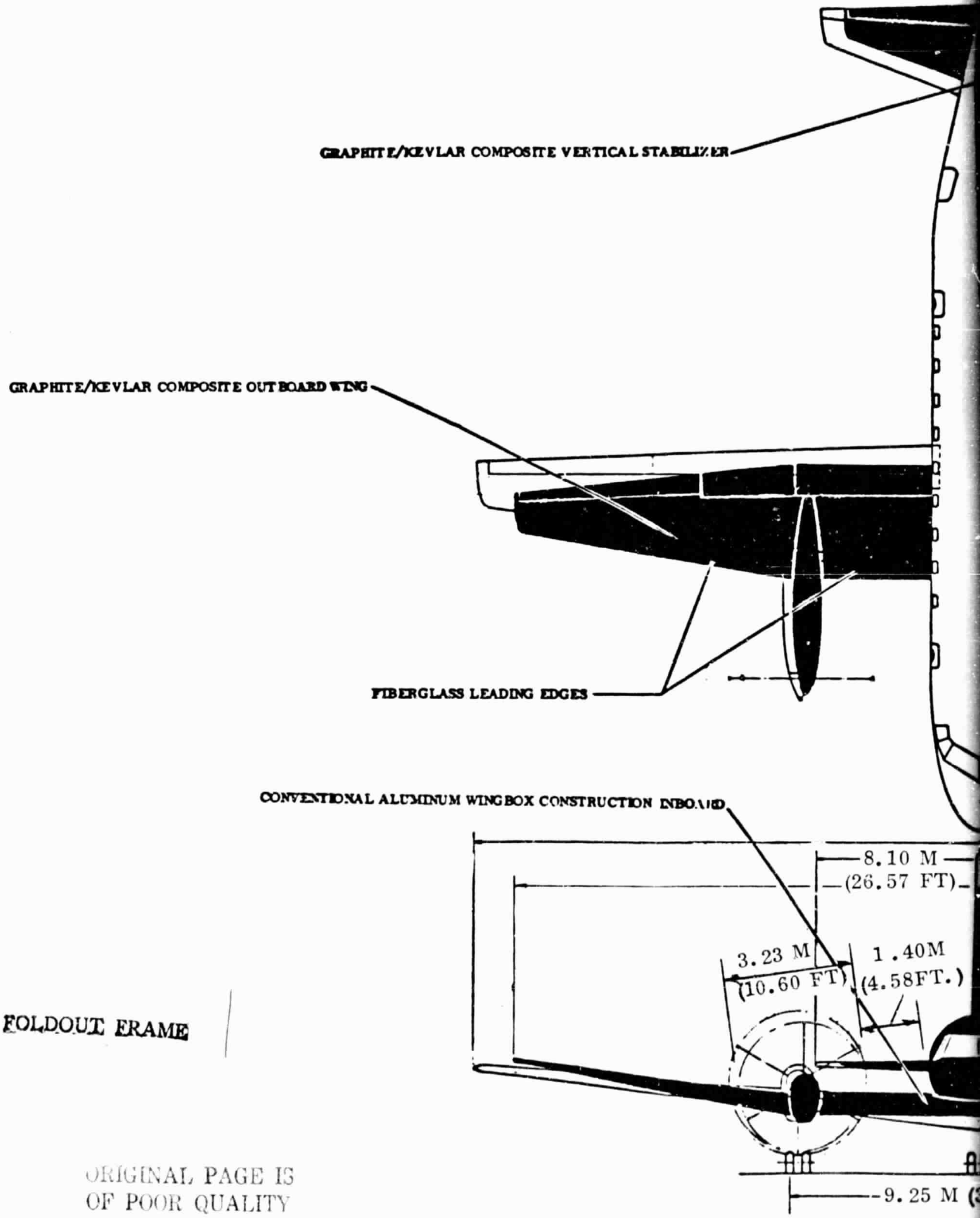
- o Graphite/kevlar composite fuselage with aluminum crushable honeycomb crash protection below the floor and conventional metal nose wheel support and wing box center section.
- o Outer panel wing box and all tail surfaces are of graphite/kevlar composite.
- o Wing leading edges are of fiberglass and the trailing edge flaps are made of graphite/kevlar/epoxy full depth honeycomb.

These technologies and their effects are discussed in further detail in the discussion section below.

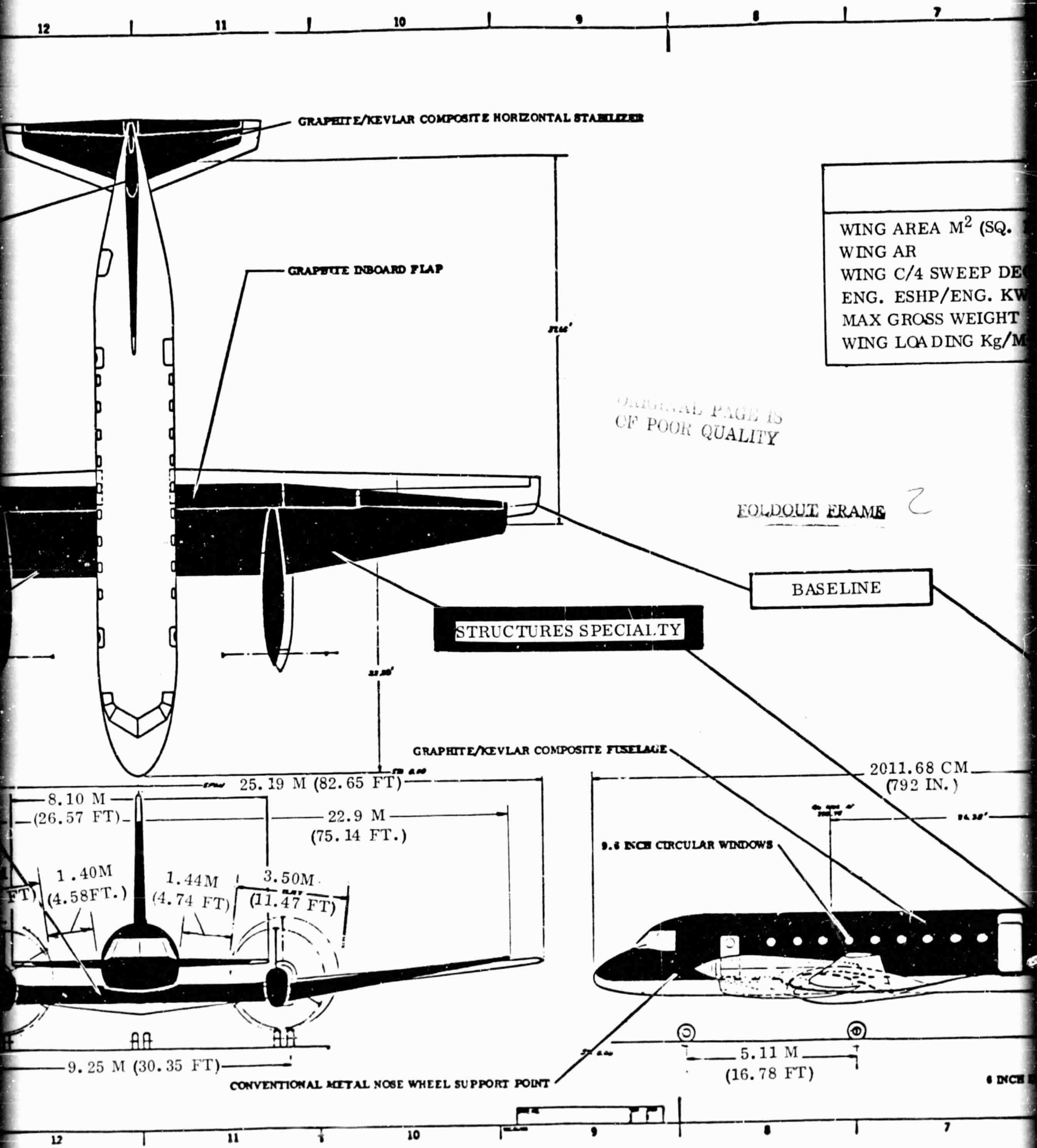
DISCUSSION. The advanced structural design features utilized in the Structures Specialty Aircraft are illustrated in detailed structural cross sections in Figure 4-4. The key features are discussed in the following paragraphs.

ADVANCED FUSELAGE STRUCTURE. In the advanced fuselage design, the cross sectional portion below the floor is substantially reduced for a number of reasons. The volume below the floor is, like on most small transports, unsuitable for luggage storage. Moreover, in going to composite fuselage shell design it is recognized that these materials lack in energy absorption capability due to their basically elastic behavior - a drawback under crash conditions. It is for these reasons that full depth, crushable aluminum honeycomb was used under the entire cabin floor. A center member in the floor permits the attachment of a solid material skid for a wheels-up runway landing. This skid extends from under the wing to the aft portion of the cabin. In the design the centroids of upper and lower fuselage skins intersect centroid of the floor cover sheet. Pressurization is transferred through the honeycomb to the lower fuselage skin. The hoop tension components of upper and lower skin result in compression into the honeycomb stabilized floor cover sheet. Bending deflections due to pressurization are small. While the use of honeycomb entails a modest weight penalty, it will provide, together with the skids, a substantial improvement of crash-worthiness.

Large cabin windows of the conventional aircraft design have been replaced by circular, much smaller windows with double pane design for acoustic reasons. Even with double panes, a substantial weight saving is achieved.



FOLDOUT FRAME


GRAPHITE/KEVLAR COMPOSITE HORIZONTAL STABILIZER
GRAPHITE INBOARD FLAP
WING AREA M² (SQ.
WING AR
WING C/4 SWEEP DE
ENG. ESHP/ENG. KW
MAX GROSS WEIGHT
WING LOADING Kg/M
BASELINE
STRUCTURES SPECIALTY
GRAPHITE/KEVLAR COMPOSITE FUSELAGE
25.19 M (82.65 FT)
2011.68 CM
(792 IN.)
8.10 M
(26.57 FT)
22.9 M
(75.14 FT.)
9.6 INCH CIRCULAR WINDOWS
1.40M
(4.58FT.)
1.44M
(4.74 FT)
3.50M
(11.47 FT)
9.25 M (30.35 FT)
5.11 M
(16.78 FT)
CONVENTIONAL METAL NOSE WHEEL SUPPORT POINT
6 INCH

	BASELINE	STRUCTURES SPECIALTY
REA M^2 (SQ. FT.)	52.86 (569)	43.66 (470)
R	12	12
/4 SWEEP DEG.	5.0	5.0
HP/ENG. KW (hp)	1,747 (2,343)	1,309 (1,755)
OSS WEIGHT Kg (LBS)	13,426 (29,600)	11,204 (24,700)
ADING Kg/M^2 (LBS/SQ. FT.)	253.9 (52.0)	256.3 (52.5)

FOLDOUT FRAME 3

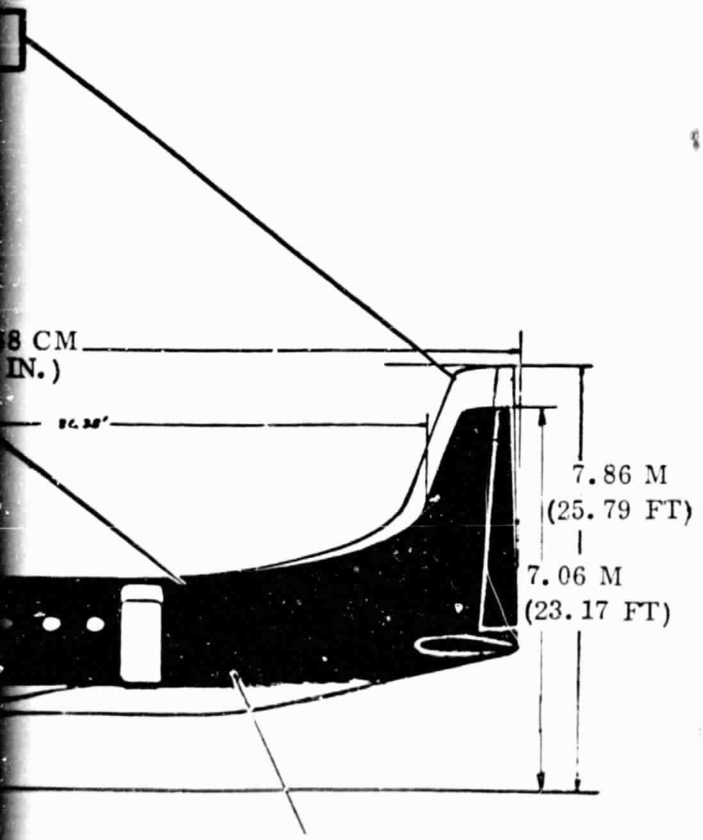


Figure 4-3

PRELIMINARY DESIGN DRAWING

3-30 STRUCTURES SPECIAL
AIRCRAFT - COMPARISON W/BA
GENERAL ARRANGEMENT

BY C.L. ADCOCK | APPROVED C.L. Adcock | SCALE –

CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

DRAWING SD8

6549 (9-71)

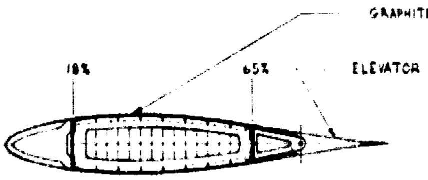
FOLDOUT FRAME 4

Figure 4-3

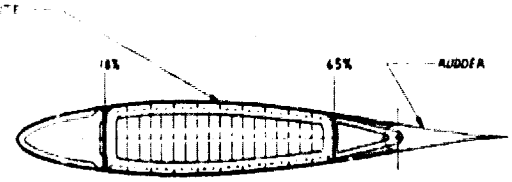
MINARY DESIGN DRAWING

JCTURES SPECIALTY
COMPARISON W/BASELINE
ARRANGEMENT

PROVED G. L. Adcock	SCALE -	DATE 3-24-80
VISION OF GENERAL DYNAMICS EGO, CALIFORNIA	DRAWING NO. SD80-48003	



CROSS-SECTION HORIZONTAL STABILIZER - TYPICAL



CROSS-SECTION VERTICAL STABILIZER - TYPICAL

CROSS

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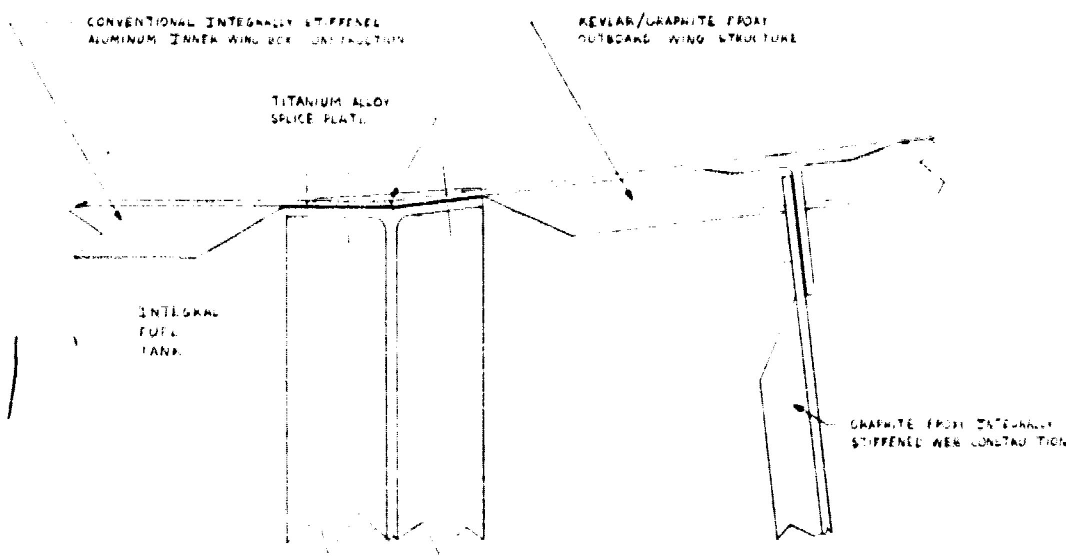
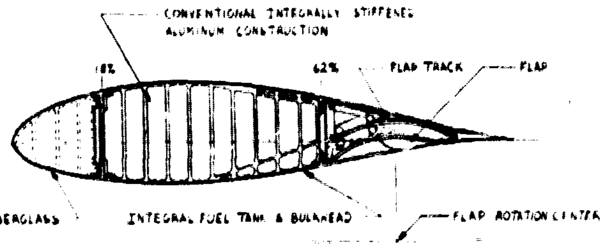
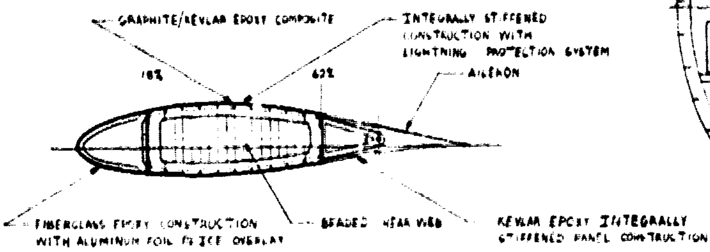


CROSS-SECTION AT WING SPLICE OUTBOARD TO INNER WING

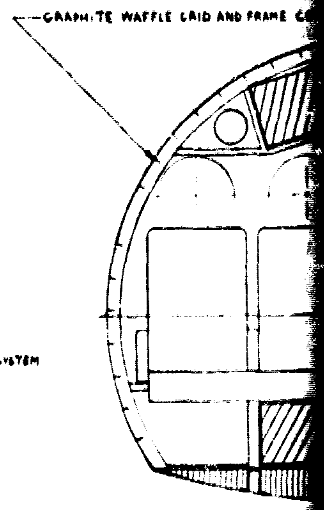
FULL SCALE



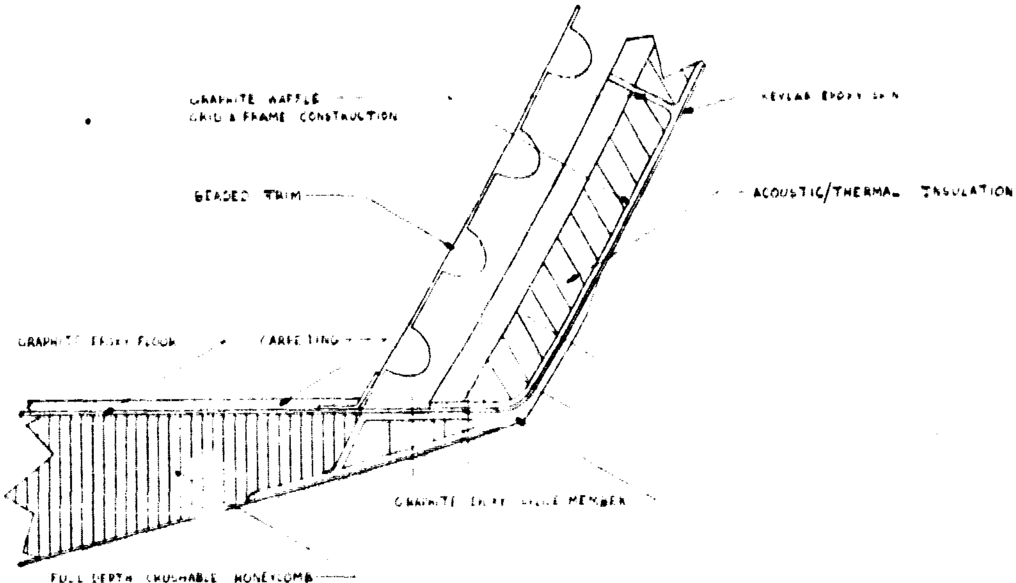
CROSS-SECTION INBOARD WING AT BREAK POINT



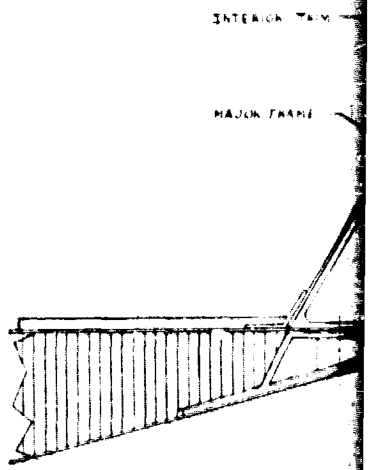
CROSS-SECTION OUTBOARD WING - TYPICAL



FUSELAGE CROSS-S



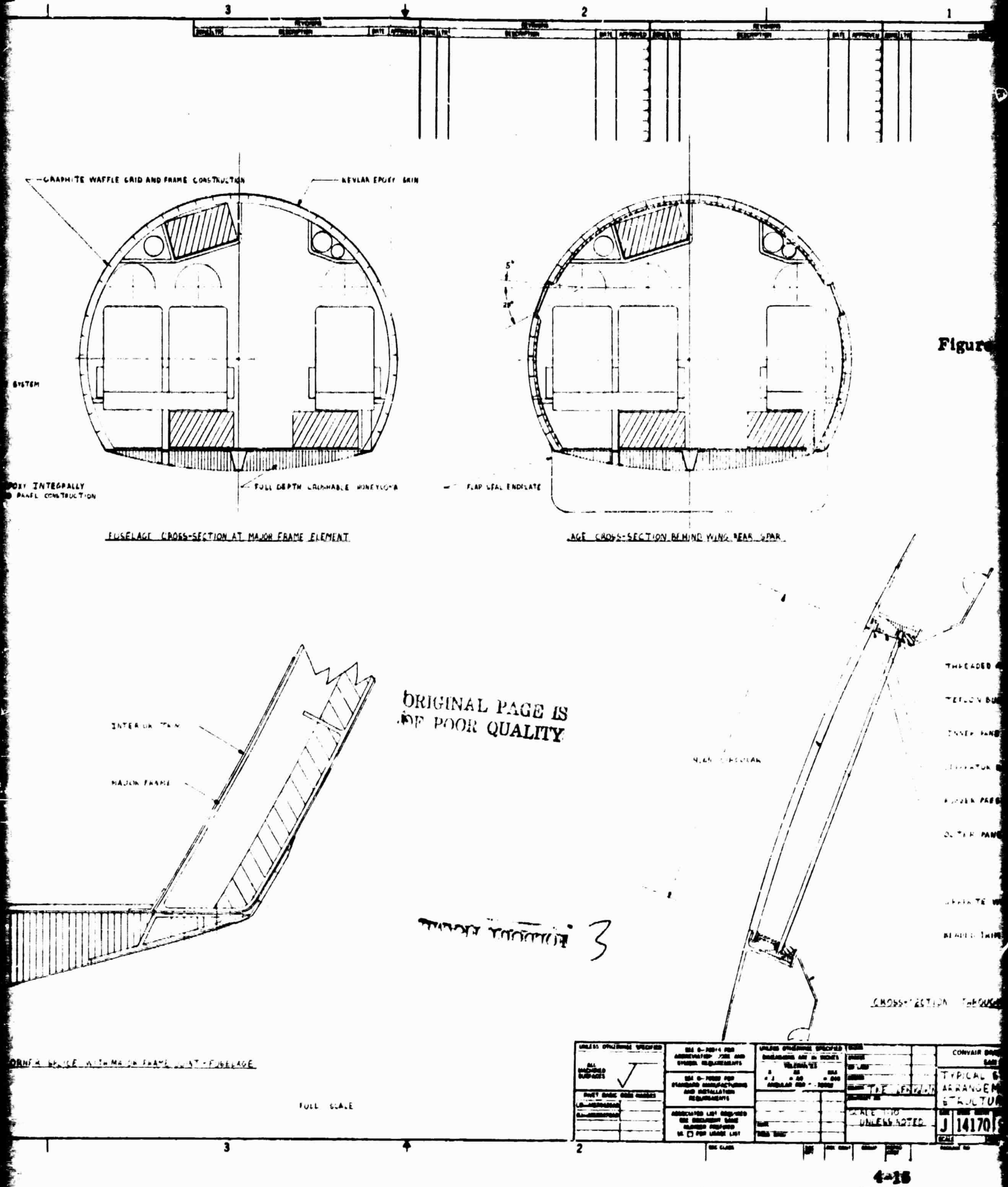
CORNER SPLICE - FUSELAGE



CORNER SPLICE WITH MAJOR FRAME JO

FOLDOUT FRAME 2

14170



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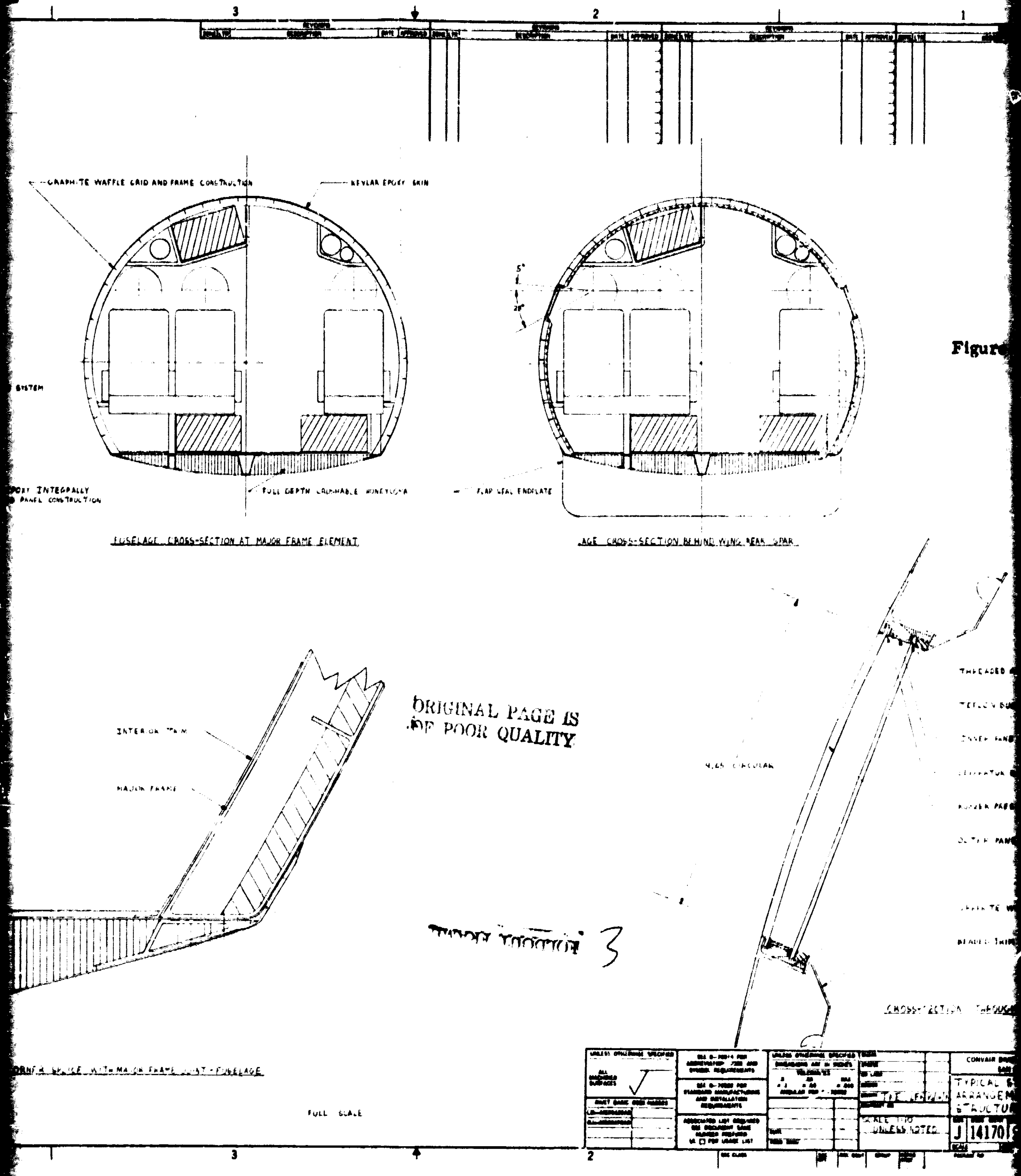
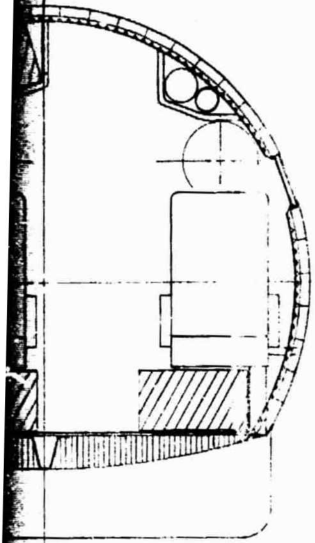
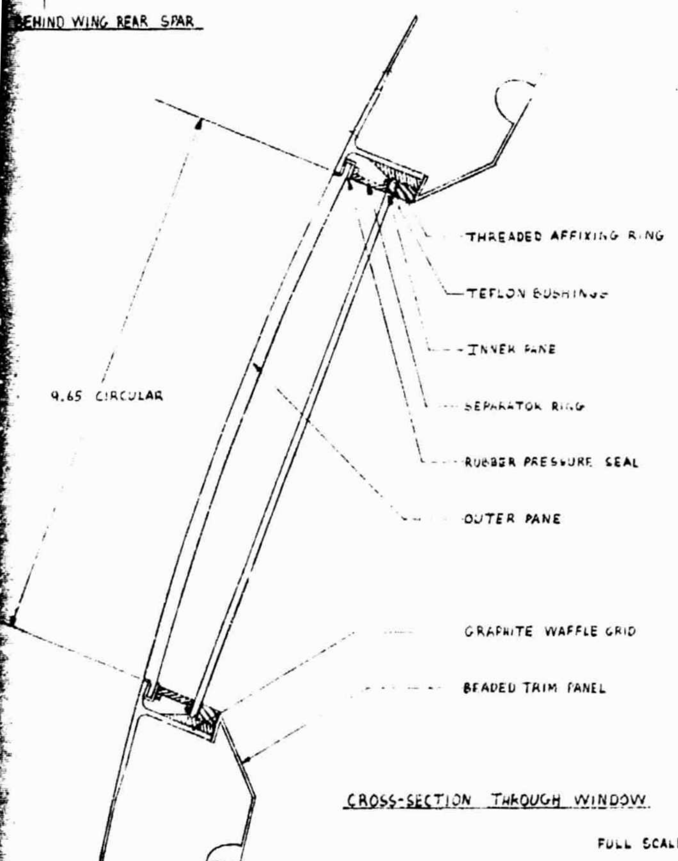

GRAPHITE WAFFLE GRID AND FRAME CONSTRUCTION
KEVLAR EPOXY SKIN
FULL DEPTH CRUSHABLE HONEYCOMB
FLAP SEAL ENDPLATE
FUSELAGE CROSS-SECTION AT MAJOR FRAME ELEMENT
AGE CROSS-SECTION BEHIND WING REAR SPAR
INTERIOR TRIM
MAJOR FRAME
FULL SCALE
SCALE TWO
UNLESS NOTED
J 14170

Figure 4-4





CROSS-SECTION THROUGH WINDOW

FULL SCALE

4 FOLDOUT FRAME

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

TYPICAL STRUCTURES ARRANGEMENTS — 3-30 STRUCTURES AIRCRAFT

SCALE 1:10 UNLESS NOTED

J | 14170 | SD 79-48032

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DRAWN T. KESSLEN

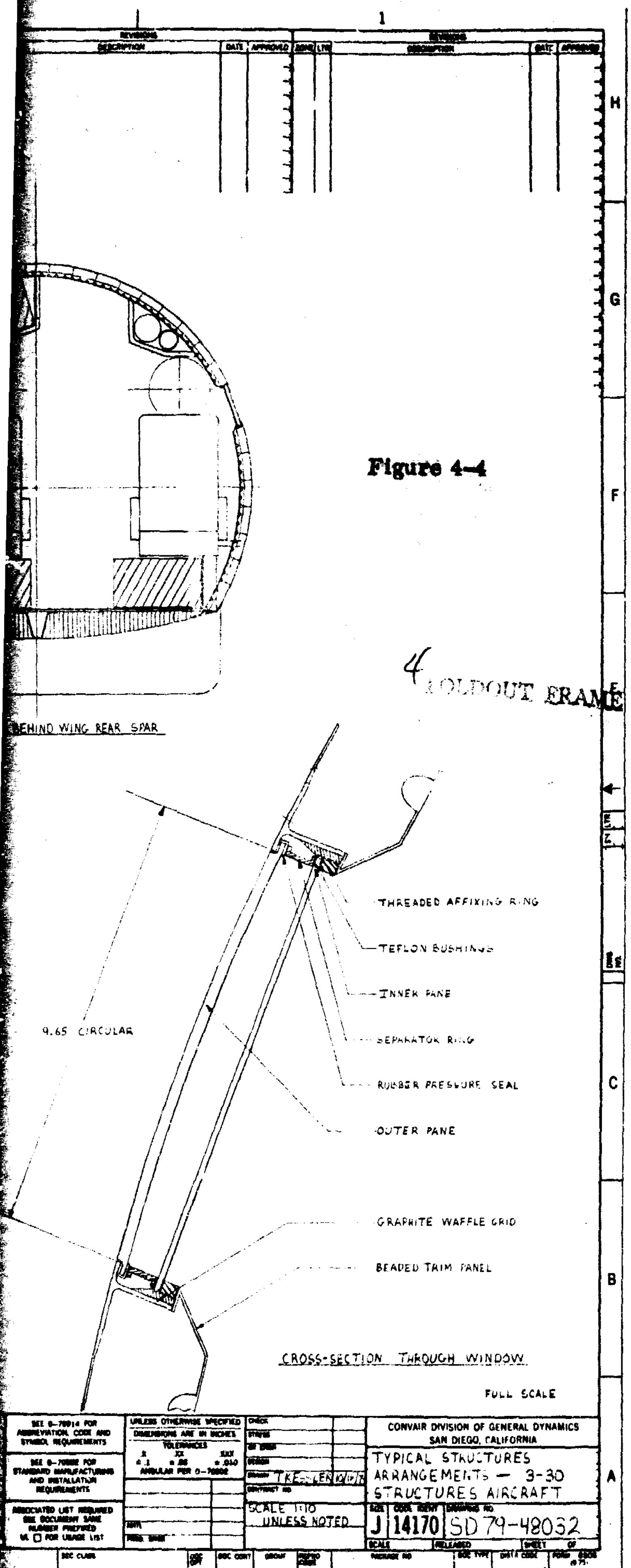


Figure 4-4

4 FOLDOUT FRAME

The upper shell construction is of integral molded design with a mechanical fastener joint at the top centerline. Thus, the shell has three components, two upper panels and the lower floor panel. Stringers, major frames and intermediate stiffeners are principally of graphite/epoxy material. The outer shell is kevlar/epoxy material. Close stiffener grid spacing is intended to contain any flaw growth, though particularly kevlar has little tendency to this failure mode. The overall body structural weight is 14% less than for the baseline conventional aluminum design. In assembly, the upper fuselage portion is lowered onto the bottom portion. The skin is continuously fastener attached and bonded at the joint. Frames are bolted to the lower side cap members. Condensation water run-off is collected at this point and discharged through vent holes.

Routing area for controls and electrical harnesses is provided in the floor and in the upper fuselage.

ADVANCED WING AND EMPENNAGE STRUCTURE. To further the objective of both cost and weight savings, the center wing arrangement was changed to a straight-through, constant, untwisted section. This design eliminates the highly loaded and costly center wing splice, permits interchangeable main landing gears, left and right hand flaps and engine nacelles. Inboard wing box construction is changed from built-up stiffened to integral blade stiffened construction. The center box contains the integral fuel tank. A sump tank is provided in the fairing behind the wing under the fuselage to avoid a large amount of unusable fuel. Aluminum alloy construction for the center wing box is retained for the following reasons.

a. Ductile yet strong aluminum alloys permit superior introduction of concentrated landing gear, flap track, wing fuselage attachment loads.

b. Aluminum construction provides more safety in case of engine fire, or crash landing.

c. Avoidance of dissimilar materials combinations of graphite and metals of wing box and fuel systems (lines, pumps, etc) with a high potential for galvanic corrosion.

The one-piece tank, broken up by slosh baffles, provides for single point refueling without large diameter interconnect fuel lines required for this feature on the conventional design. It is reasoned that load relief by outboard wing tanks is transitional as the tanks are flown empty. Principal benefit of the arrangement is in a milder wing bending fatigue spectrum. Weight penalties due to arrangement selection for the advanced wing are small and outweighed by advantages. The outboard wing box is of integral blade stiffened graphite/kevlar/epoxy construction weighing 34% less than aluminum design. Reusable silicone rubber thermal expansion tooling is employed for one-piece construction of upper and of lower wing surfaces. Spars of open truss designs for fastener assembly of surface panels to ribs and for access to the wing splice. Fastener penetration of outer cover surfaces are fully avoided, except at the splice. The splice employs a single row of one-quarter inch bolts in double shear. The tapered outer splice strip is of titanium alloy to reduce stresses caused by thermal expansion and contraction of the one-piece integrally stiffened aluminum alloy splice bulkhead.

The leading edge is of integrally stiffened fiberglass/epoxy construction manufactured with thermal expansion tooling. De-icing is provided by resistance heated aluminum alloy foil overlay, a design proven on C141 and C5A empennages. Wing tips are also foil covered to provide a dielectric film cover of the wing box for lightning protection. Flaps and ailerons are of graphite/kevlar/epoxy full depth honeycomb construction. Access into the outboard wing box and leading edge interior is provided from the trailing edge through the rear spar only. All controls and electrical harnesses are routed along the rear spar. Costly door access in the outboard composite wing is thus avoided.

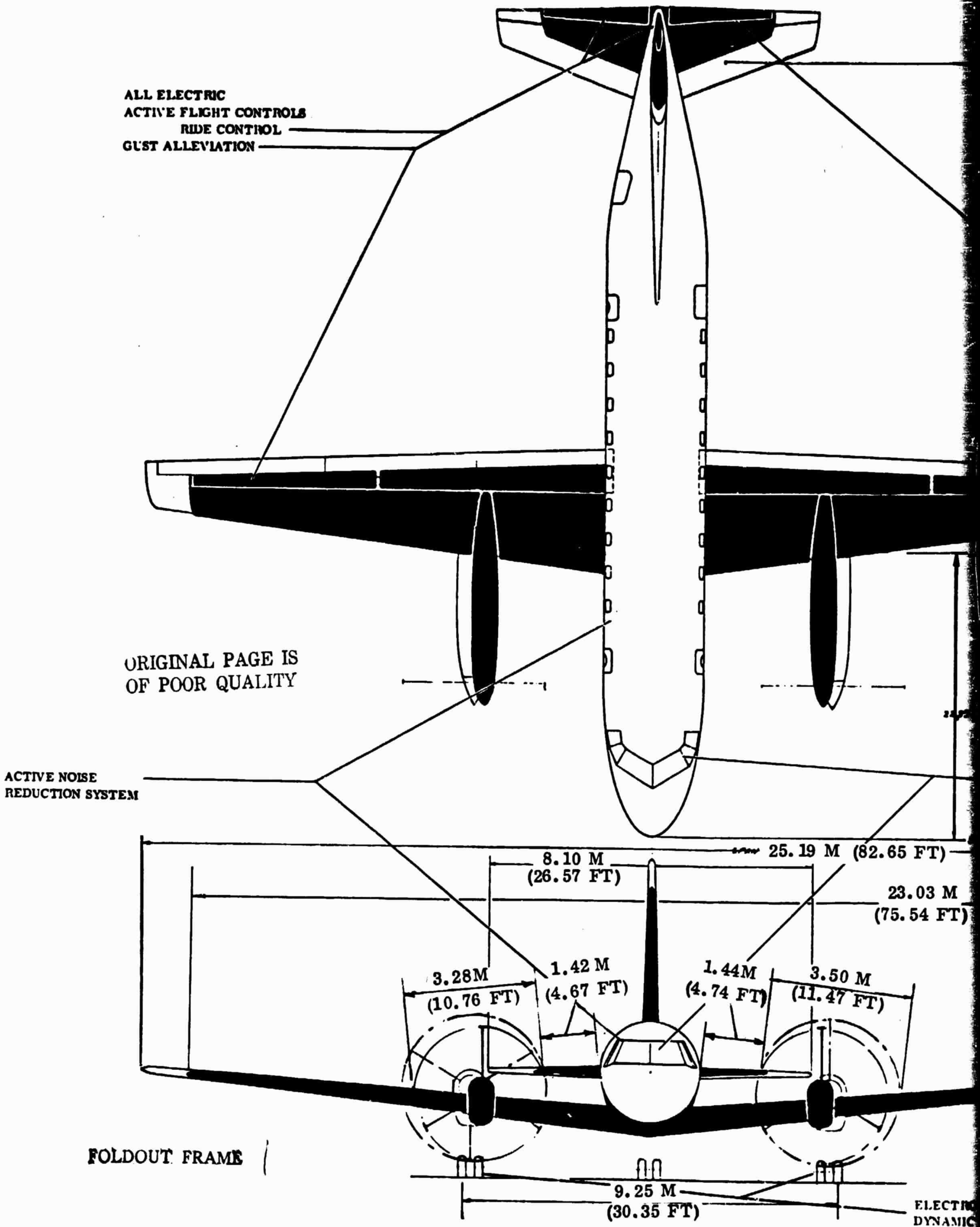
Horizontal and vertical stabilizer in advanced construction is identical in construction to the outboard wing. The same de-icing and lightning protection systems are employed. In difference to the outboard wing center box, a decreased proportion of graphite fiber tapes is used in the graphite/kevlar/epoxy composite combination due to lower load intensities. This construction replaces conventional z-stiffened aluminum alloy construction of the baseline aircraft. The net saving in empennage structural weight is 7.8%.

For the mix of composite materials used in this study, and for the post 1985 time period, we believe the potential exists for the average cost of composite structure to be no more than 2 1/2% greater than its builtup aluminum equivalent. In this study, we have assumed 10% higher airframe labor costs to account for the increased inspection of moisture and impact damage and repair.

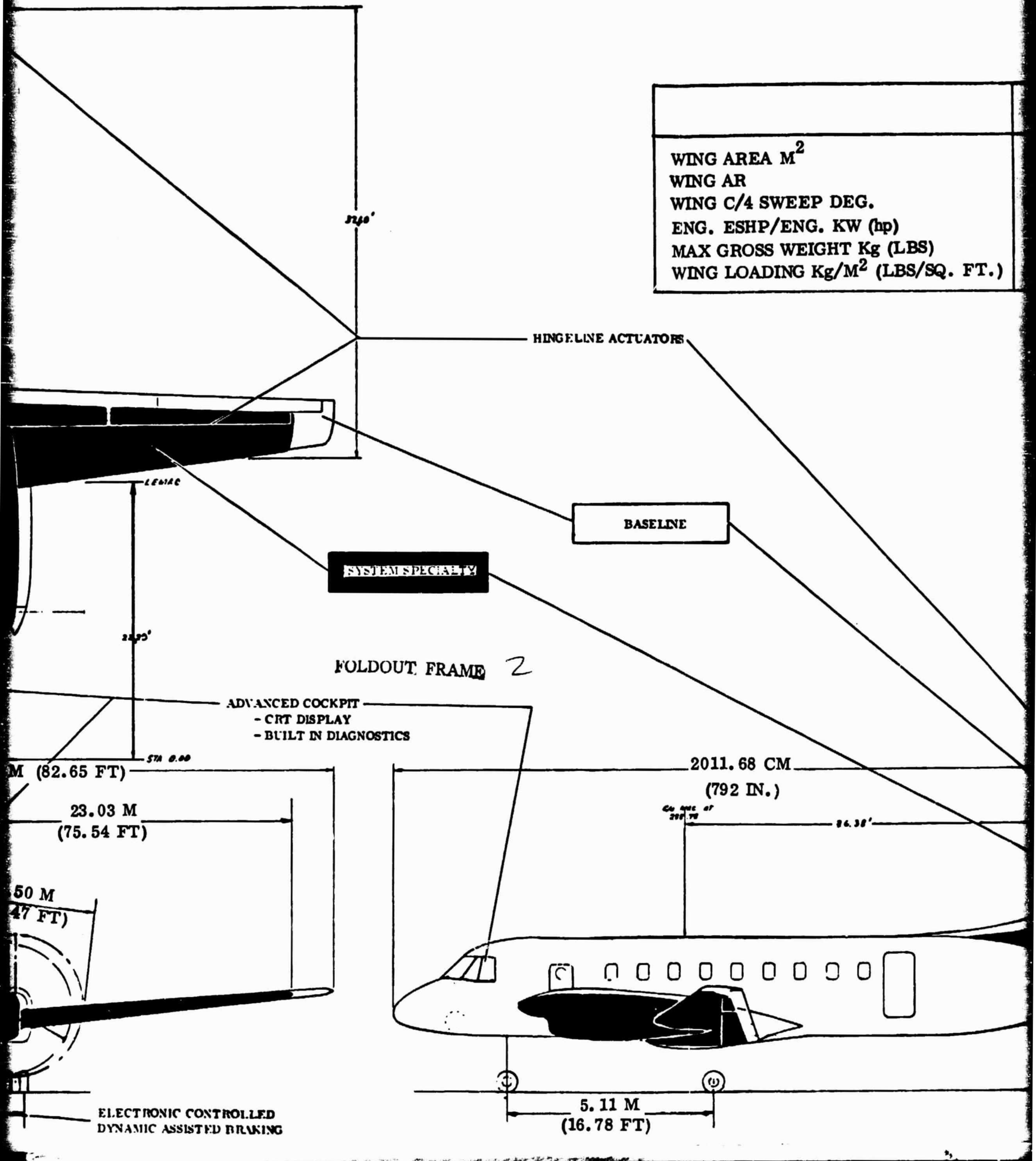
4.3 SYSTEMS TECHNOLOGY

SUMMARY. A "Systems Specialty" airplane design is selected to illustrate the potential benefits of applying advanced systems technology to the 3-30 baseline design while maintaining current technology in the basic airframe and propulsion design. This design meets all of the design requirements of the baseline design with 21% smaller engines, 16% less wing area, 15-18% less weight, 24% less fuel and has 14% less direct operating cost. Figure 4-5 shows a three view comparison of this "Systems Specialty" airplane with the baseline design.

Figure 4-5 also indicates the principal systems technologies being incorporated:



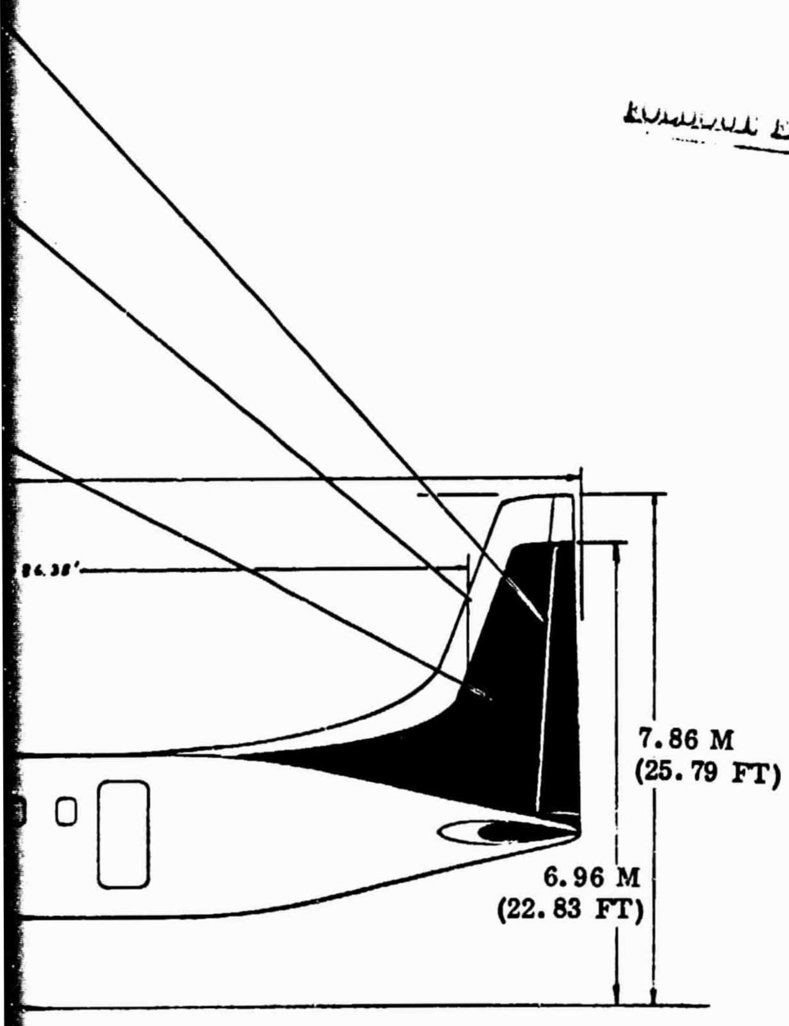
ALL ELECTRIC
ACTIVE FLIGHT CONTROLS
RIDE CONTROL
GUST ALLEVIATION
ORIGINAL PAGE IS
OF POOR QUALITY
ACTIVE NOISE
REDUCTION SYSTEM
25.19 M (82.65 FT)
8.10 M
(26.57 FT)
23.03 M
(75.54 FT)
3.28M
(10.76 FT)
1.42 M
(4.67 FT)
1.44M
(4.74 FT)
3.50 M
(11.47 FT)
9.25 M
(30.35 FT)
FOLDOUT FRAME



FOLDOUT FRAME 2

	BASELINE	SYSTEMS SPECIALTY
	52.86 (569)	44.22 (476)
	12.	12.
DEG.	5.0	5.0
KW (hp)	1,747 (2,343)	1,387 (1860)
HT Kg (LBS)	13,426 (29,600)	11,476 (25,300)
/M² (LBS/SQ. FT.)	253.9 (52.0)	259.7 (53.2)

FOLDOUT FRAME 3



Figure

PRELIMINARY DESIGN

3-30 SYSTEMS SPECI
AIRCRAFT-COMPARISO
GENERAL ARRANGE

BY C.L. ADCOCK | APPROVED G. L. Adcock

CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMI
SAN DIEGO, CALIFORNIA

6549 (9-71)

FOLDOUT FRAME 4

3

Figure 4-5

PRELIMINARY DESIGN DRAWING			
3-30 SYSTEMS SPECIALTY AIRCRAFT-COMPARISON W/BASELINE GENERAL ARRANGEMENT			
BY C.L. ADCOCK	APPROVED G. L. Adcock	SCALE –	DATE 3-24-80
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS SAN DIEGO, CALIFORNIA			DRAWING NO. SD80-48004

6549 (9-71)

CUT HERE GUARANTEED 8-71

- o All electric active flight controls with hingeline actuators, providing ride control, 40% gust alleviation and relaxed static stability.

- o Advanced cockpit incorporating CRT displays and builtin diagnostics.

- o Active cabin noise suppression.

- o Electronic controlled dynamic assisted braking.

These technologies and their effects are discussed in further detail in the discussion section below.

DISCUSSION. Many advanced systems technologies were considered in application to the baseline design in light of 3-30 design limitations. For instance, the 3-30 wing structure is designed by gust loadings. "Active" ailerons have been shown (in current NASA research) to reduce these gust loads by up to 40% thereby improving the ride quality, reducing the wing structure required and saving wing weight. Similarly "active" elevators and rudder reduce tail gust loads, improve ride quality and save fuselage and tail structure and weight. The necessary automated control and actuation systems needed to effectively operate these "active" surfaces are also being studied in current NASA research. As an indication of the potential improvement achievable by active controls, we have selected redundant, electric hingeline actuation (see Figure 4-6) with digital microprocessor control. We have also chosen to incorporate a full time, quadraplex channel, fly-by-wire autopilot eliminating much of the weight of conventional mechanical controls. This allows safe flight with reduced (or even negative) static stability minimizing the need for elevator deflection to trim and its associated drag. It also allows the horizontal tail size to be determined by its lift (control) requirements only, saving tail structure size and weight.

To this highly productive, fly-by-wire, active control system we have added an advanced cockpit (see Figure 4-7) featuring side stick controls CRT display/printer, extensive computer memory and digital processing capability, flight management keyboard input, advanced avionics and suitable season and switching. The resulting airplane has the potential for virtually automatic flight as follows:

- o Automated, computer guided, preflight checkout of all systems and controls including automatic check against the minimum equipment list. Faulty units are identified on the CRT and a hard copy record made on the printer.

- o Automated, computer guided, interactive weight and balance analysis and loading manifest on CRT with hard copy record from printer. Actual loading to be automatically verified by landing gear load sensors just prior to leaving the gate.

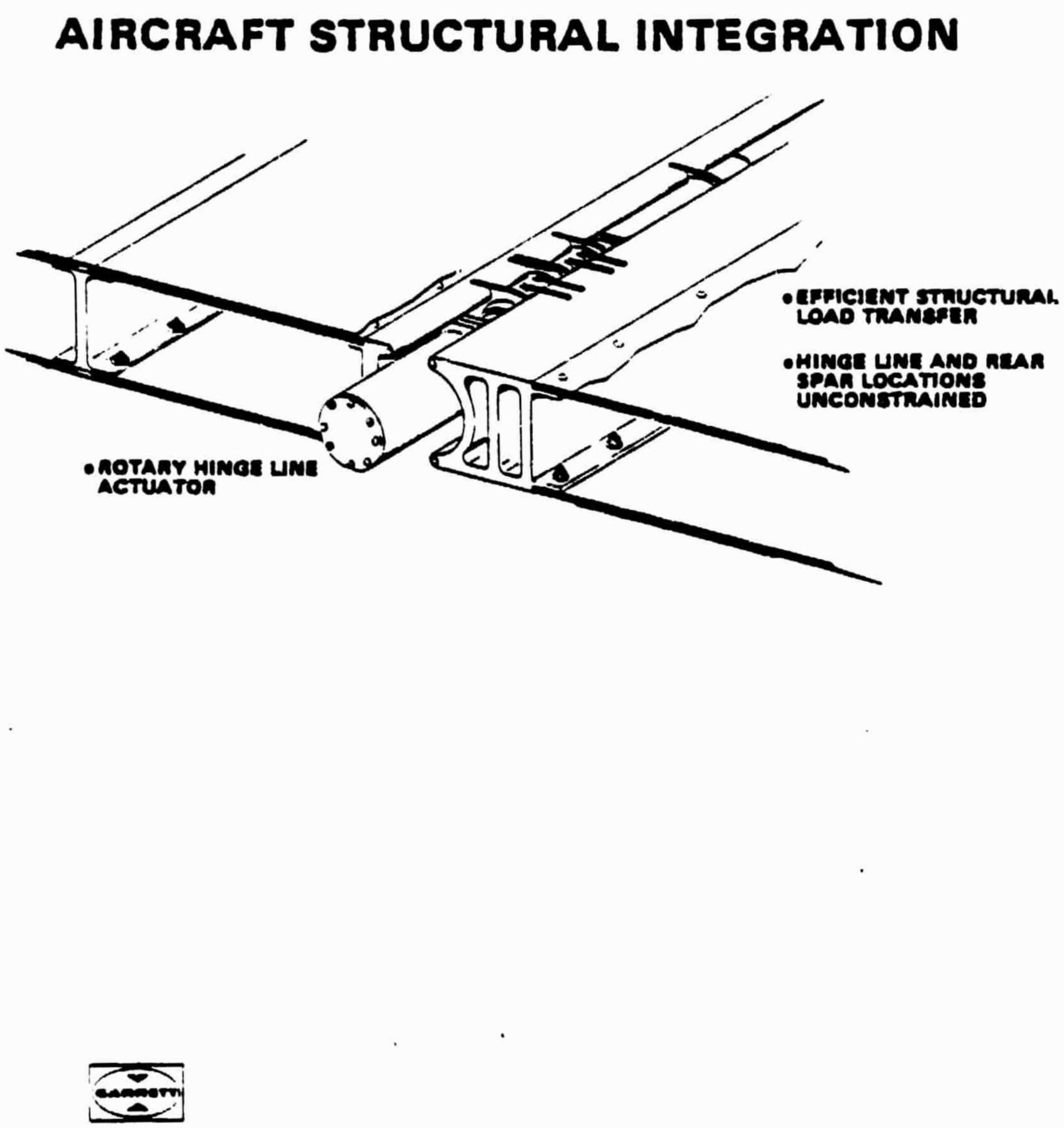


Figure 4-6. Aircraft Structural Integration

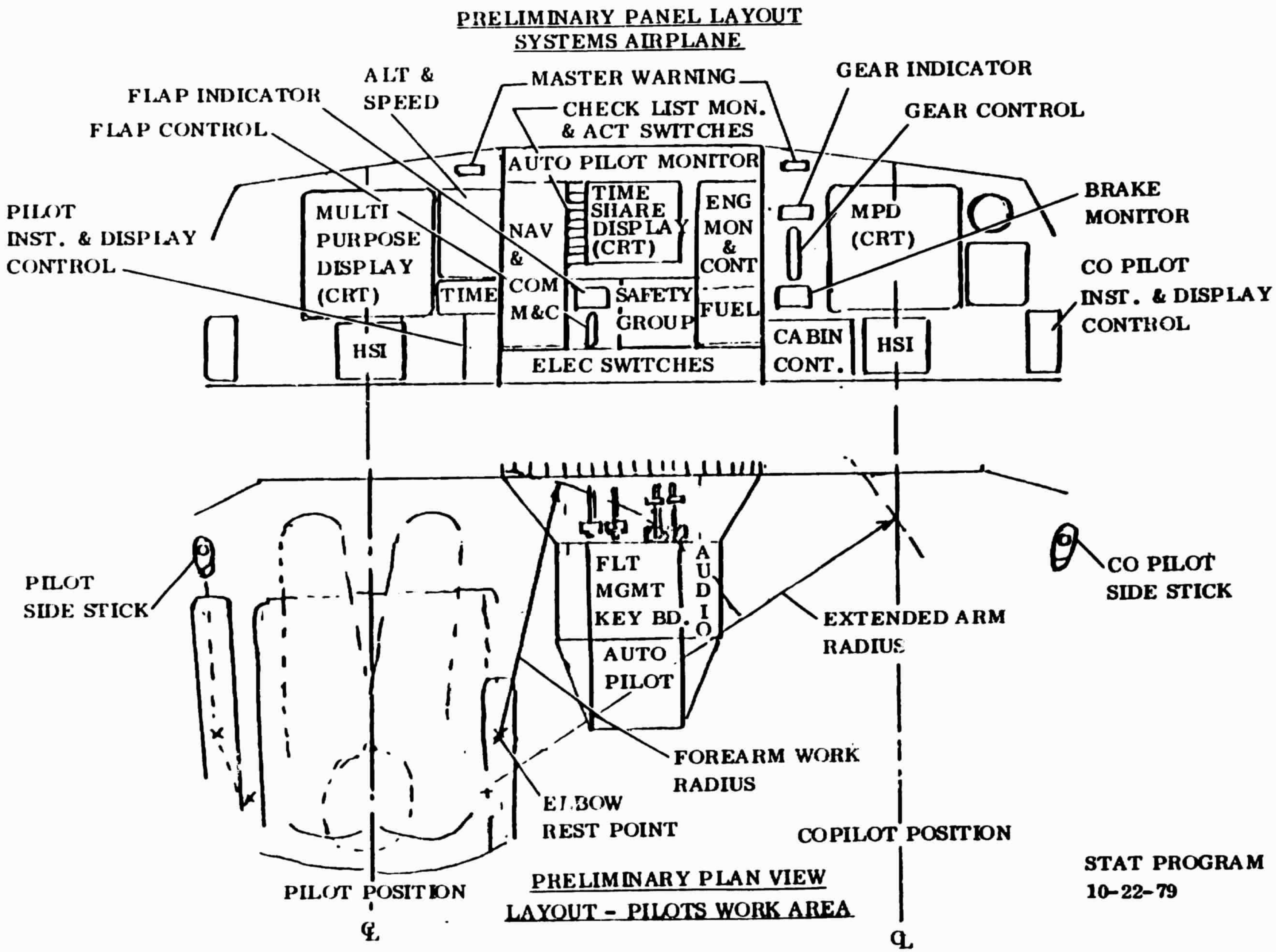


Figure 4-7. Panel Layout

- Automated preflight takeoff weight, flap/trim setting and speeds determination and "bug" settings for the specific runway conditions prevailing. Airplane and runway characteristics from the Airplane Flight Manual are stored in the computer memory and updated (daily, if necessary).

- Automated radio frequency selection from ATC/AGC commands by digital data link with CRT display to allow crew monitoring.

- Automated takeoff monitoring against computer memory standard with visual and audio cues to substandard performance and in case of equipment failure automatically displaying and, possibly, implementing the correct emergency procedures.

- Automated optimum cleanup and climbout configuration changes, speeds and power settings to minimize community noise (where applicable) or to minimize fuel consumption (or other selected parameter) while maintaining current ATC altitude and heading requirements acquired by digital data link.

- Automated optimum cruise power settings in accordance with company fuel and schedule policy while maintaining ATC required speeds, altitudes and headings.

- Automated area navigation by VOR (or other system) with automatic RF and heading settings input to radio, autopilot and CRT monitor from computer memory.

- Automated optimum let down and terminal area approach altitudes, speeds and flap settings while maintaining current ATC requirements and desired arrival times as acquired by digital data link.

- Automated landing CAT III or better.

- Automated display (and implementation, if desired) of correct emergency procedures at any point during the flight.

- Continuous CRT display of computer activity in terms of radio frequency and altimeter settings, altitude and airspeed selections, configuration and special ATC/AGC requirements.

- Frequent CRT display of active system fault testing and isolation status including CRT/hard copy faulty past identification for transmission to next available maintenance facility to minimize the down time needed for module replacement or repair.

The resulting airplane has a considerably reduced crew workload and fatigue factor especially in progressively developing emergency situations. Electric flight control maintenance manhours have been reduced 25% compared to hydraulic.

The airplane retains the hydraulic system for

- o Retracting and extending the landing gear
- o Nose wheel steering, and,
- o Primary braking forces.

The brakes are assisted at high speed by 1) the propellers in flat pitch (idle power) and 2) an electronically controlled electro-magnetic device* acting on the brake discs. These devices minimize the need (and use) of the brakes at high speed and minimize brake lining/disk wear. Deceleration is improved 16.6%.

The "systems" airplane also incorporates another new technology device suggested by the 3-30 design limitations, active cabin noise suppression*. This device projects sound waves inside the cabin of magnitude, frequency and timing to partially cancel the sound waves transmitted through the cabin wall from the propeller blade passage.

4.4 PROPULSION TECHNOLOGY

SUMMARY. A "Propulsion Specialty" airplane design is selected to illustrate the potential benefits of applying advanced propulsion technology to the 3-30 baseline design while maintaining current technology in all other areas. This design meets all of the design requirements of the baseline design with nearly 12% smaller engines, 8.5% less wing area, 7.9% less weight, 30% less fuel, 10% less total aircraft cost and 14.5% less direct operating cost. Figure 4-8 shows a three view comparison of the "Propulsion Specialty" airplane with the baseline design.

Figure 4-8 also indicates the propulsive technologies being incorporated:

- o New advanced engines having less weight per horsepower, lower SFC, reduced purchase price per horsepower and lower maintenance cost per engine hour.
- o Gear boxes especially designed to minimize propeller noise.
- o New advanced propellers having fiberglass blades with steel shanks utilizing new airfoils and planforms.

These technologies and their effects on the airplane are discussed in more detail in the discussion section below.

*Patent disclosure filed.

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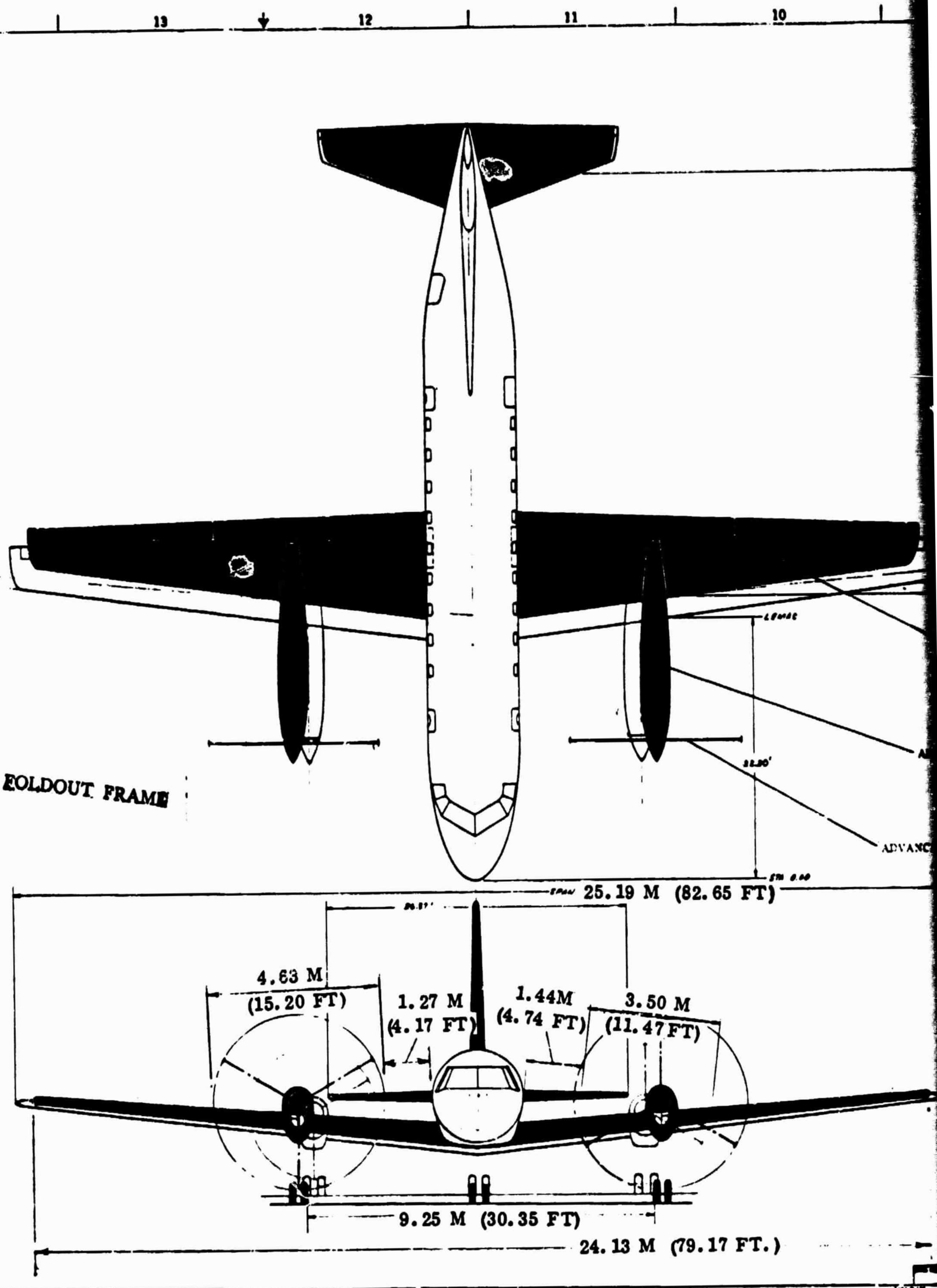
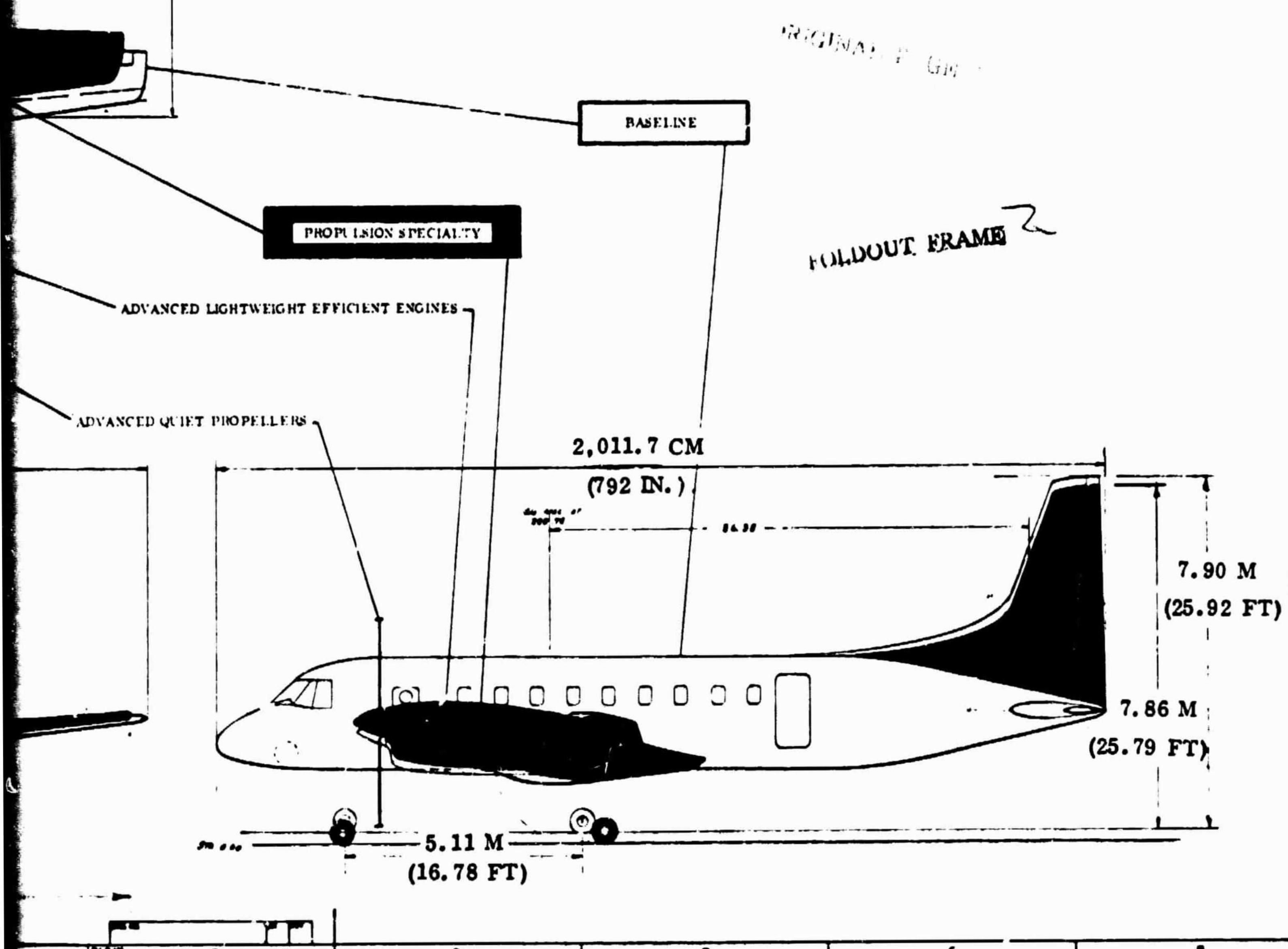


	BASELINE
WING AREA M^2 (SQ. FT.)	52.86 (569)
WING AR	12
WING C/4 SWEEP DEG.	5
ENG. ESHP/ENG. KW (hp)	1,747 (2,343)
MAX GROSS WEIGHT Kg (LBS)	13,426 (29,600)
WING LOADING Kg/M^2 (LBS/SQ. FT.)	253.9 (52.0)



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BASELINE	PROPULSION SPECIALTY
52.86 (569)	48.40 (521)
12	12
5	5
1,747 (2,343)	1,544 (2,070)
13,426 (29,600)	12,338 (27,200)
253.9 (52.0)	254.9 (52.2)

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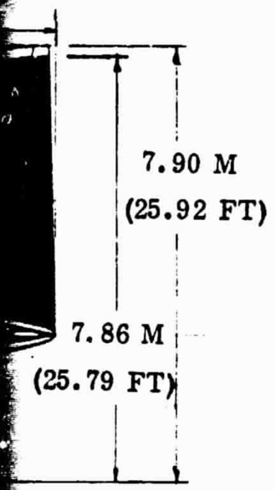
Figure 4-8



PRELIMINARY DESIGN DRAWING

3-30 PROPULSION SPECIALTY AIRCRAFT - COMPARISON W/BASELINE GENERAL ARRANGEMENT

BY C.L. ADCOCK	APPROVED C.L. Adcock	SCALE –	DATE 3-24-80

CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

DRAWING NO. SD80-48005

6549 (9-71)

DISCUSSION. In lieu of the results of the NASA (Lewis) contracted engine and propulsor studies, the "Propulsion Specialty" design is selected from currently available propulsor data from Hamilton Standard and advanced engine data supplied by General Electric, Avco Lycoming, Pratt and Whitney (Canada) and Garrett Airesearch. The selection process considers the typical performance characteristics of several propulsors compared with the aircraft requirements derived from the 3-30 baseline design limitations. It results in the selection of a quiet, open, propeller as being nearly optimum for this application.

Baseline Design Limits. The 3-30 Baseline design is significantly affected by three design limits:

- Cabin noise level. The design carries 2324 lb of acoustic penalty to meet the specified cabin noise level.
- Cruise speed. The powerplants sized by the cruise speed requirements have more than enough takeoff thrust to meet the required takeoff runway.
- Landing runway. The takeoff (waveoff) thrust is very nearly sufficient to allow the use of the maximum landing approach flap setting while meeting the approach climb gradient with the baseline single slotted flap system.

Thus, improvements in the baseline design can be made by a) reducing the propeller noise, b) increasing the cruise propulsive efficiency, and c) increasing the takeoff thrust while improving the high lift or braking systems.

Other Propulsors. One obvious way to reduce propeller noise is to surround the propeller with an acoustically treated shroud or cowl. This results in a "shrouded propeller," "Qfan" or "turbofan" type of powerplant. This method has the disadvantage of adding the weight and drag of the shroud/cowl which reduces both the cruise propulsive efficiency and the takeoff thrust. See Figure 4-9. The reduced cruise thrust of the shrouded/cowled propulsor also means that a given airplane requires larger, heavier, more expensive engines to meet the required cruise speed.

Another way to reduce propeller noise is to reduce the propeller tip speed. Figure 4-10, shows the tradeoffs. Increasing propeller diameter and reducing propeller RPM along the "line of peak cruise efficiency" reduces noise while maintaining cruise thrust. An alternate "quiet" propeller selection is shown at the largest diameter which maintains cruise thrust while reducing external noise about 9 EPNdB. This method has the advantage of simultaneously increasing takeoff thrust as shown in Figure 4-10, allowing higher wing loadings (with improved high lift systems) or increased takeoff weight from short, high or hot runways (with the current high lift system).

TYPICAL PROPULSION LAPSE RATE

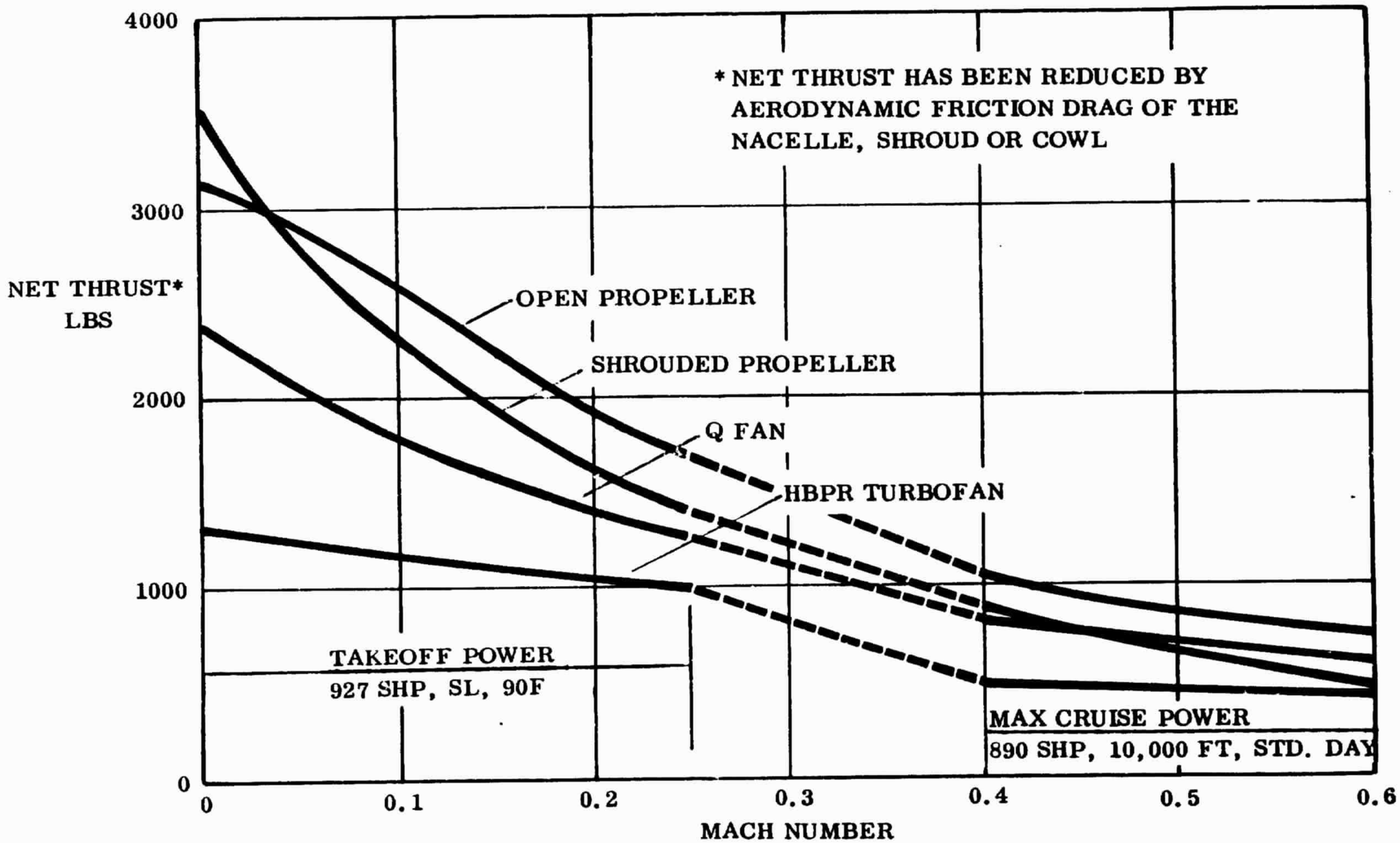


Figure 4-9 . Typical Propulsion Lapse Rate

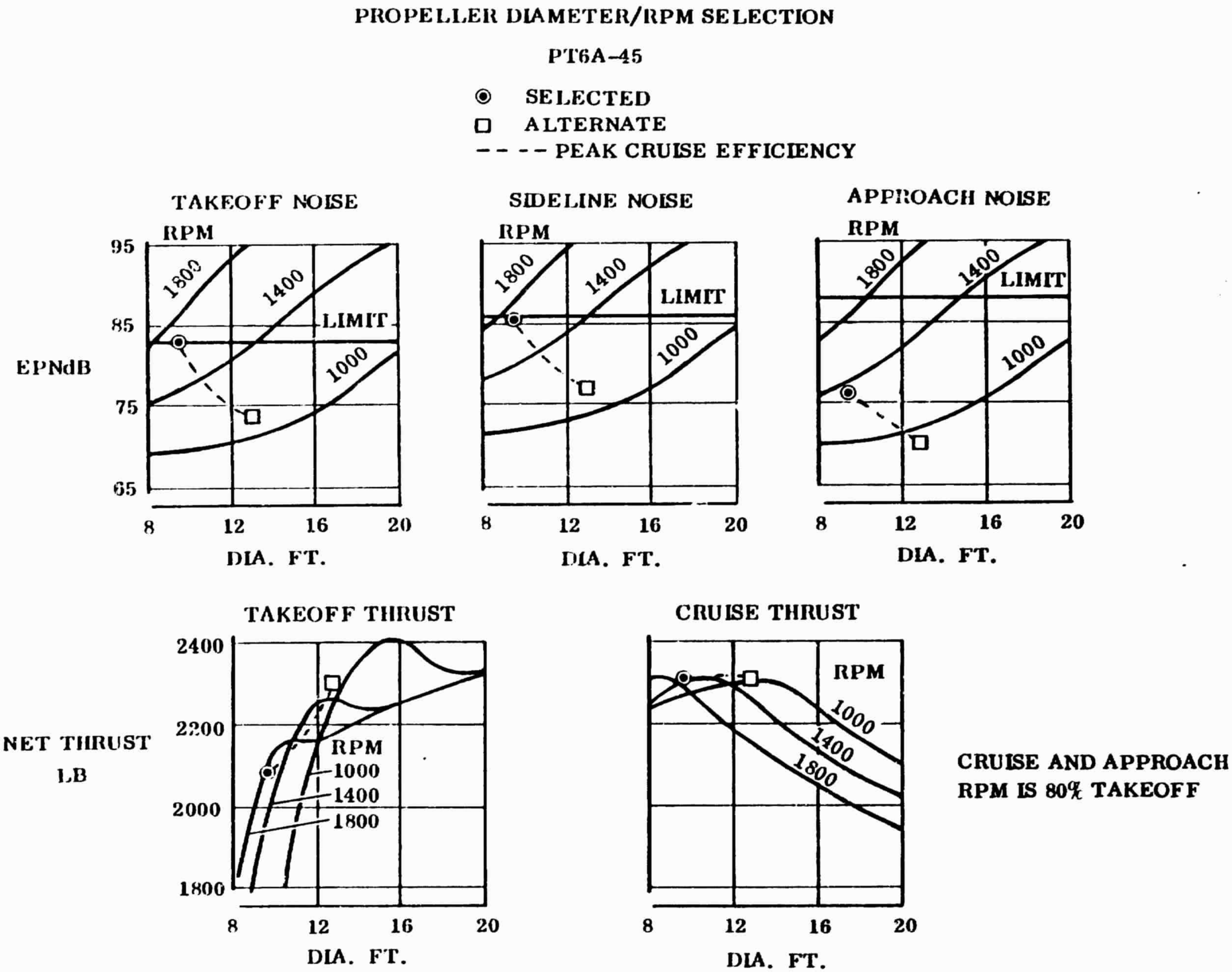


Figure 4-10. Quiet Propeller Alternate

The reduced tip speed of the "quiet" propeller also reduces the cabin acoustic penalty, as indicated in Table 4-3, where a 47.6% reduction in acoustic penalty is indicated for a "quiet" prop of the same diameter as the baseline propeller. Part of this saving is lost due to the increased diameter but the saving is still substantial.

Manpower limitations prevented completion of studies to quantify selection of a "quiet" propeller as the optimum propulsor for the 3-30 baseline transport, however, such a selection is believed to be near optimum. The selection of a 13 foot diameter, 1100 RPM "quiet" propeller for this study is arbitrary and intended as a point on the curve. It does not reflect any improvement in propulsive efficiency over the "H-S Red Book" nor any reduction in noise generation from the SAE AIR 1407 method although it is likely that new airfoils and planforms can improve both.

The advanced technology in the propellers is in their structure.* The blades are assumed to be of fiberglass construction with a steel spar with a total propeller weight saving of 23.7% and with corresponding reductions of 21.6% in initial cost and 0.6% in maintenance costs.

Advanced Engines. Very significant improvements in gas turbine engines are being made by using new materials, new aerodynamics and new design philosophies. Figure 4-11 shows that the SFC for 1980 technology engines is 13% less than for the 1960-70 technology engine of the same size. Similarly, Figure 4-12 shows that the 1980 technology engines will weigh 33% less than their equivalent sized current counterparts.

Engine Cost. The basic VDEP engine costing formula, used on all versions to date, is that of SAWE Paper 1224 adjusted to 1979 dollars. It relates engine cost to the 1.165 power of the rated shaft horsepower. This reflects the increasing sophistication of the newer large engines of the data base versus the older, less sophisticated small engines. Data from General Electric indicates that constant technology engine costs vary more nearly with the 0.5 power of the rated shaft horsepower. This latter relationship is used to estimate the cost of the advanced technology engines used in this "propulsion specialty" study.

Maintenance Cost. General Electric has analyzed their new family of engines versus their T58 and T64 models. Design simplifications, reduced parts count and modularity of their advanced technology engines are expected to result in a 30% savings in maintenance cost. This reduction is used in this "propulsion specialty" study.

Advanced Powerplant Performance. The baseline "quiet" propulsor performance is obtained by use of the engine scale factor corrections shown in Figure 4-13.

*No performance improvement is assumed.

Table 4-3. Acoustic Penalty Estimate for Quiet Prop

Reference	AP-STAT-79-17	Revised 5 June 1979	
Propeller	Baseline	Alt. Baseline	"Quiet"
Diameter (ft)	9.5	12.25	13.0
Shaft Horsepower	870	870	870
RPM	1700	1050	1100
TIP Speed (Rot.) (fps)	845	670	745
Corresponding Mach	.785	.621	.691
Helical Tip Speed* (fps)	975	835	890
Corresponding Mach	.905	.775	.825
NL1 (dB)	136.5	131.0	130.5
Y/D (4 ft clearance)	.421	.326	.307
NL2 (dB)	-5.2	-7.5	-5.2
NL1 + NL2 (dB)	131.3	123.5	125.3
Relative OASPL (dB)	0	-7.8	-6.0
Req'd Acoustic Penalty (lb)			
Sta 190-370	1886	835	1015
Sta 370-460	770	260	375
Sta 460-640	327	0	0
Sta 640-735	66	66	66
Total	3049 (10.0%)	1161 (38.1%)	1451 (47.6%)

*291 KTAS @ 10,000 ft

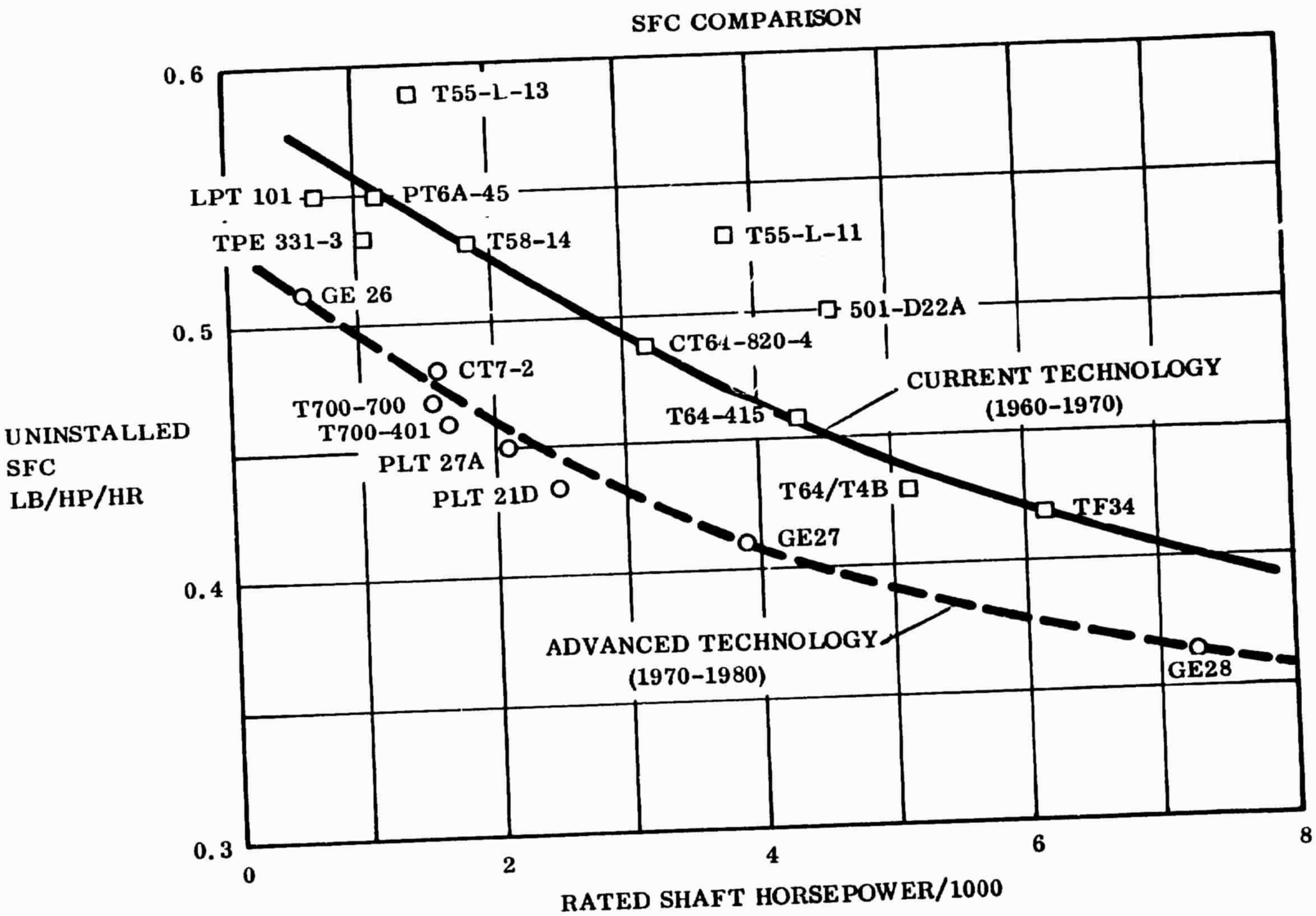


Figure 4-11. SFC Comparison

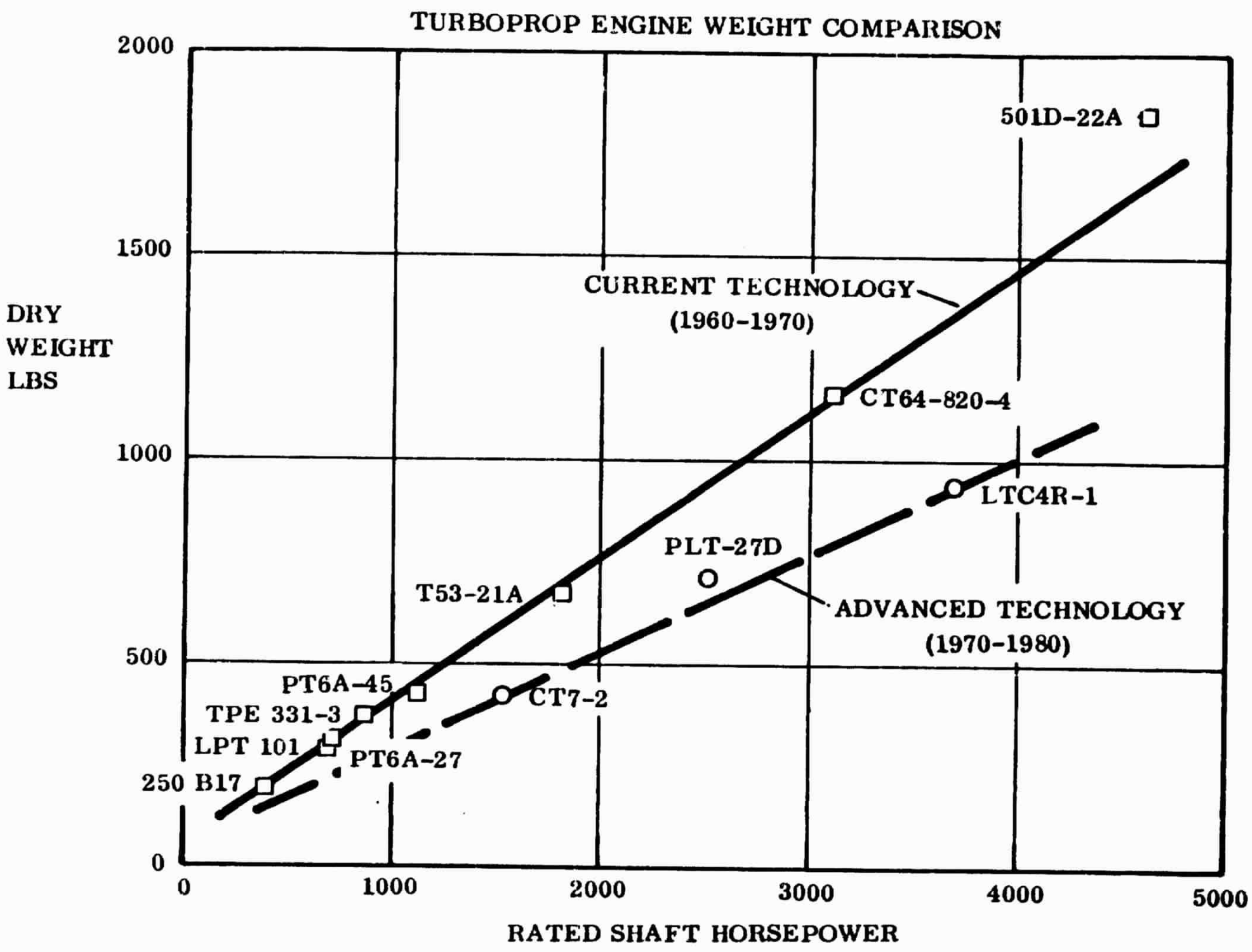


Figure 4-12 . Turboprop Engine Weight Comparison

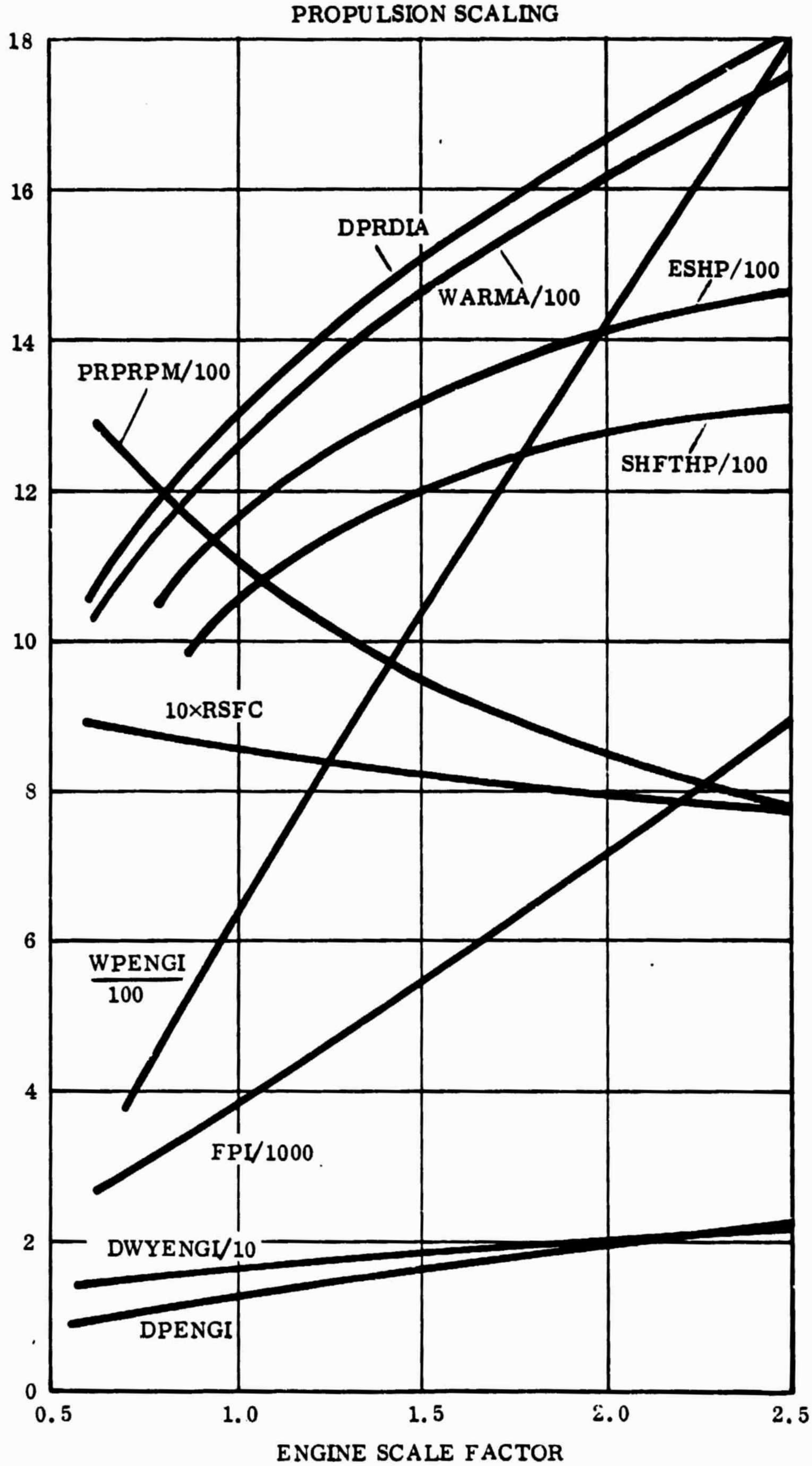


Figure 4-13 . Propulsion Scaling

4.5 CONFIGURATION TECHNOLOGY

A fifth discipline considered was "configuration." Figure 4-14 shows some of the configurations studied qualitatively. Each version had advantages and disadvantages but the two most powerful configuration ideas seemed to be 1) aft mounted, pusher propellers, which eliminate most of the cabin noise and vibration aspects of open propellers, while increasing static stability and improving balance, and 2) "canard" horizontal trim and maneuver surfaces, which add to the lift rather than detract from it. Item 1) above was incorporated in the AT 3-30 Advanced Technology Aircraft described in Section 5.0. The "canard" configurations were not studied.

VDEP has been calibrated to reproduce the performance of the METRO II low wing and the NORD 262 high wing as shown in Section 2.0. The influence of the high wing aerodynamics of the NORD 262 calibration on the overall configuration was used to size an alternate high wing configuration. Figure 4-15 shows a three view comparison of the 3-30A Configuration Specialty Aircraft with the 3-30 Baseline Aircraft. Characteristics are shown in Table 4-1 and 4-2.

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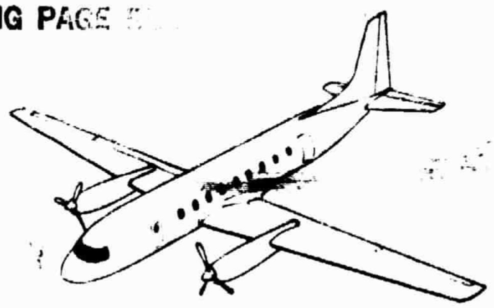

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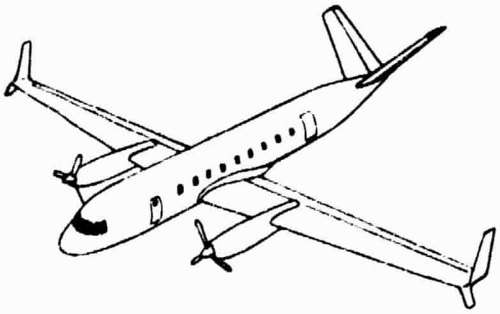

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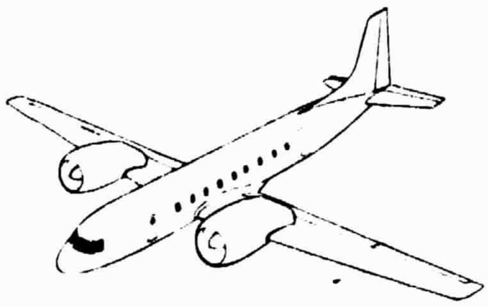

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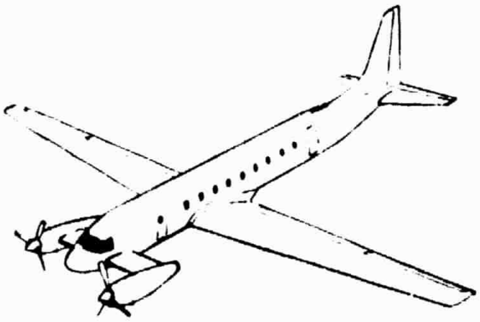

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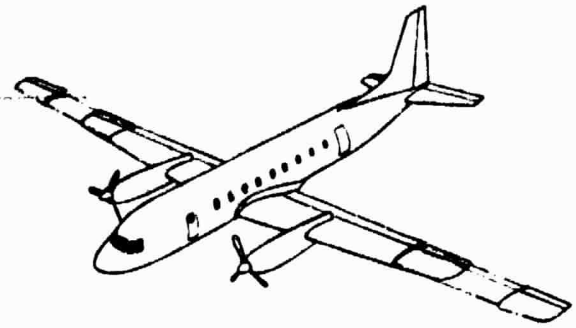

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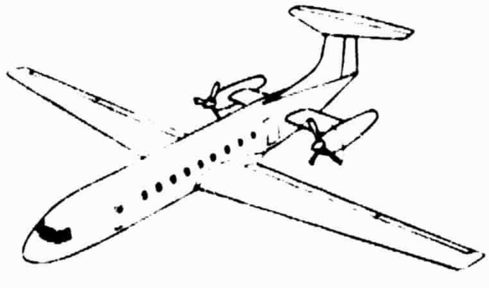

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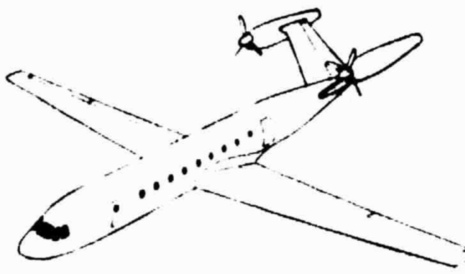

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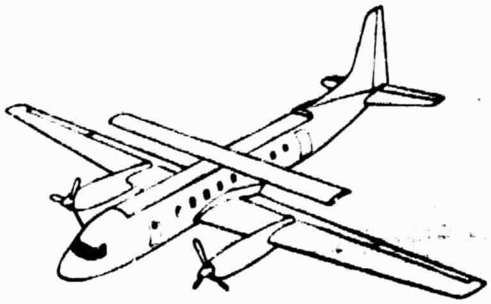

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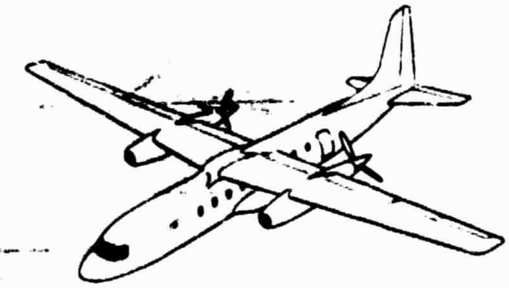

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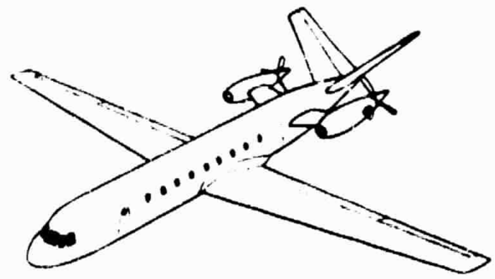

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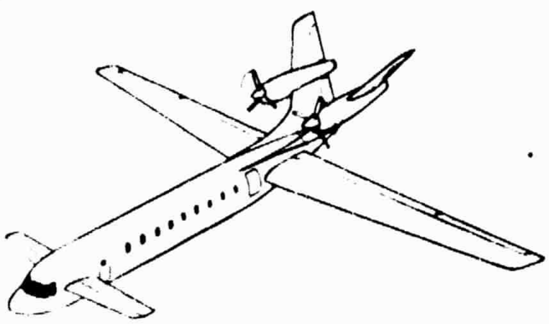

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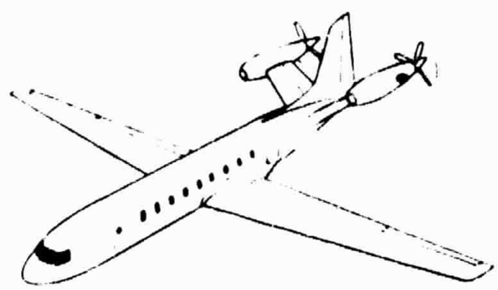

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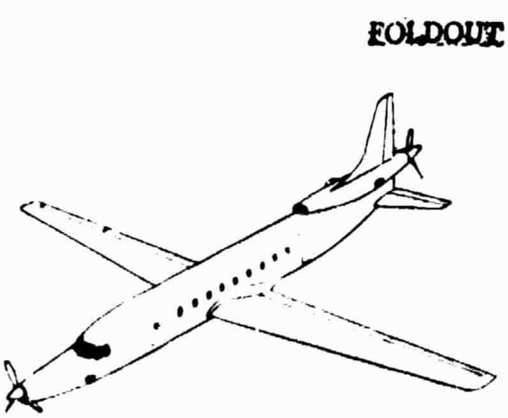

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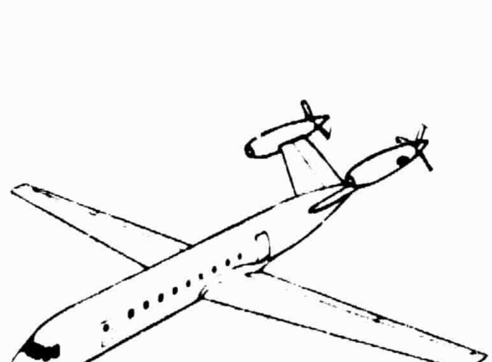

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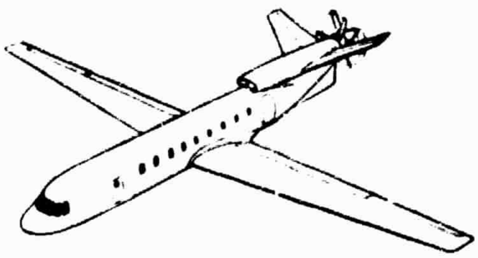

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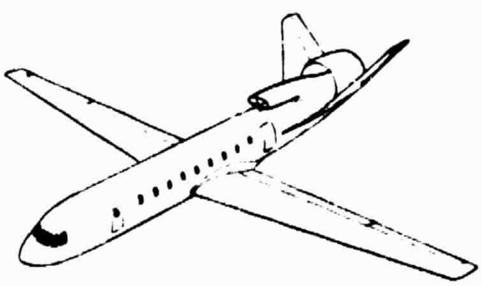

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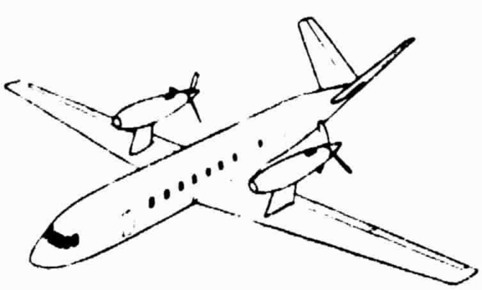

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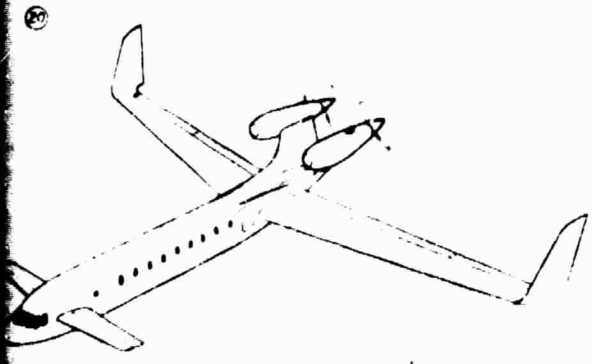

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Figura 4-14

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CONVAIR DIVISION OF GENERAL DYNAMICS SAN DIEGO CALIFORNIA

CONFIGURATION SPECIALTY AIRCRAFT MATRIX

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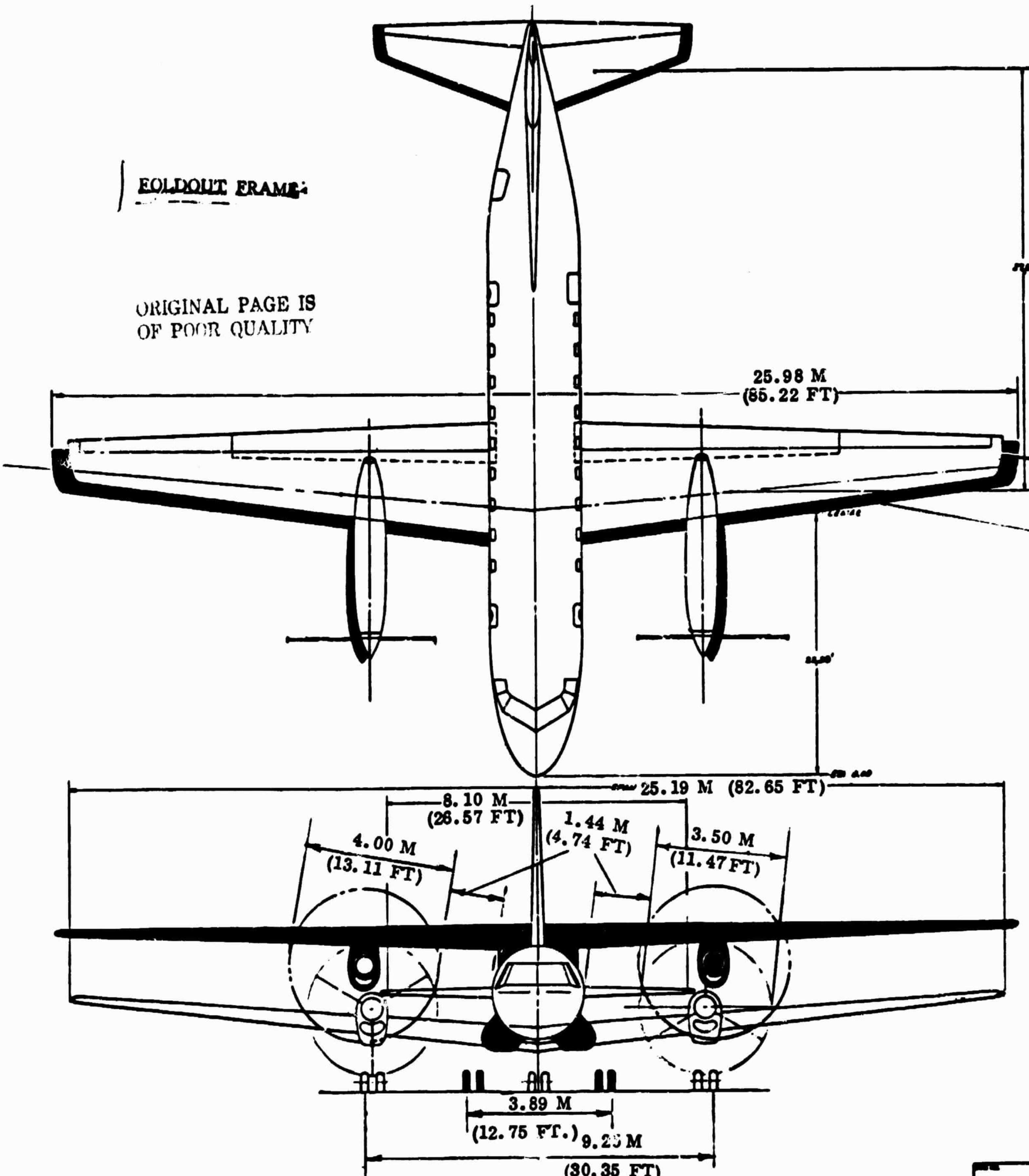
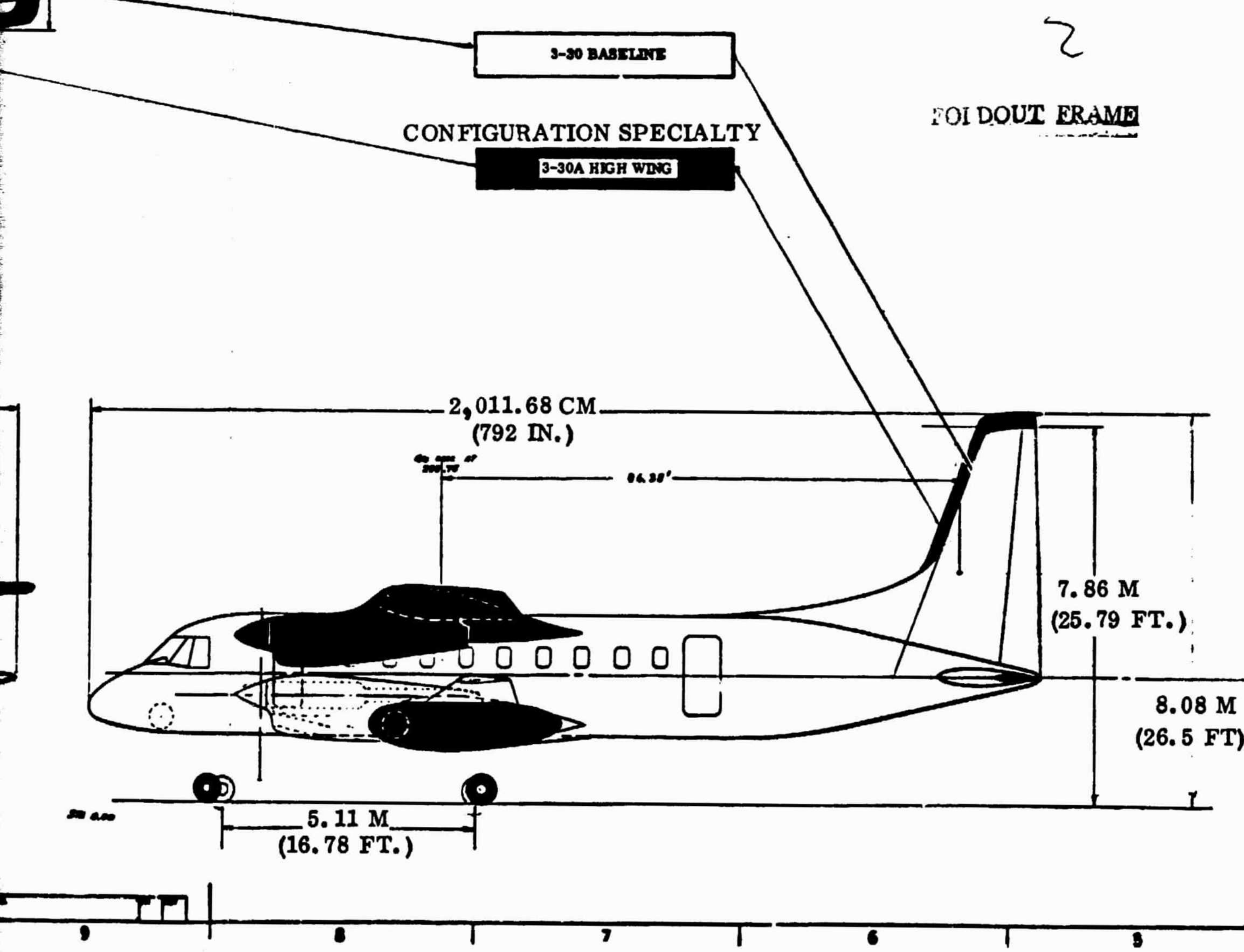


	BASELINE	HIGH WING
WING AREA M^2 (SQ. FT.)	52.86 (569)	56.21 (605)
WING AR	12	12
WING C/4 SWEEP DEG.	5.0	5.0
ENG. ESHP/ENG KW (HP)	1,747 (2,343)	2,650 (3,553)
MAX GROSS WEIGHT Kg (LBS)	13,426 (29,600)	14,787 (32,600)
WING LOADING Kg/M^2 (LBS/SQ. FT.)	253.9 (52.0)	263.2 (53.9)



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6549 (9-71

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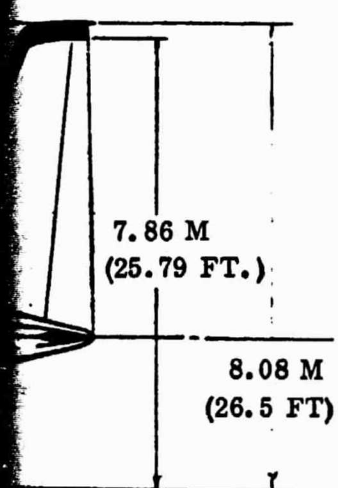

Figure 4-15

PRELIMINARY DESIGN DRAWING

3-30 CONFIGURATION SPECIALTY AIRCRAFT - COMPARISON W/BASELINE GENERAL ARRANGEMENT

BY C.L. ADCOCK	APPROVED C. L. Adcock	SCALE —	DATE 3-24-80

CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

DRAWING NO. SD80-48006

6549 (9-71)

5.0 SELECTED ADVANCED TECHNOLOGY DESIGN

SUMMARY: An Advanced Technology airplane design is selected for comparison with a current technology baseline design to determine the potential benefits of applying advanced technology to small, short haul transports. Both designs meet all of the comfort, safety, airframe life and performance requirements recommended to NASA by current short haul operators. They are both quiet, twin turboprop engined transports capable of carrying 30 passengers (3 abreast) with optional lavatory and buffet over a 1111 km (600 n. mi.) range from 1219 m (4000 ft) runways. The general arrangements are compared in Figure 5-1.

5.1 AT3-30 ADVANCED TECHNOLOGY AIRCRAFT SELECTION

The advanced technologies* included in the AT3-30 Advanced Technology design are:

1. Light weight, fuel efficient, low maintenance turboprop engines
2. Low wing, pusher configuration providing a quiet, vibration free cabin without an acoustic weight/cost penalty
3. Light weight, low cost, smooth surface composite structure
4. Natural laminar flow airfoil shapes
5. High aspect ratio wings with new high lift, low drag flaps
6. Low drag, high visibility cockpit with side stick controls and CRT display
7. Full time automated active controls with gust alleviation
8. Redundant fault testing and isolation systems
9. New dynamic assisted brakes

The Advanced Technology design shows significant improvements over the current technology baseline in:

1. Purchase price (18% less)
2. Engine power (37% less)
3. Wing area (51% less)
4. Empty weight (27% less)
5. Takeoff weight (22% less)

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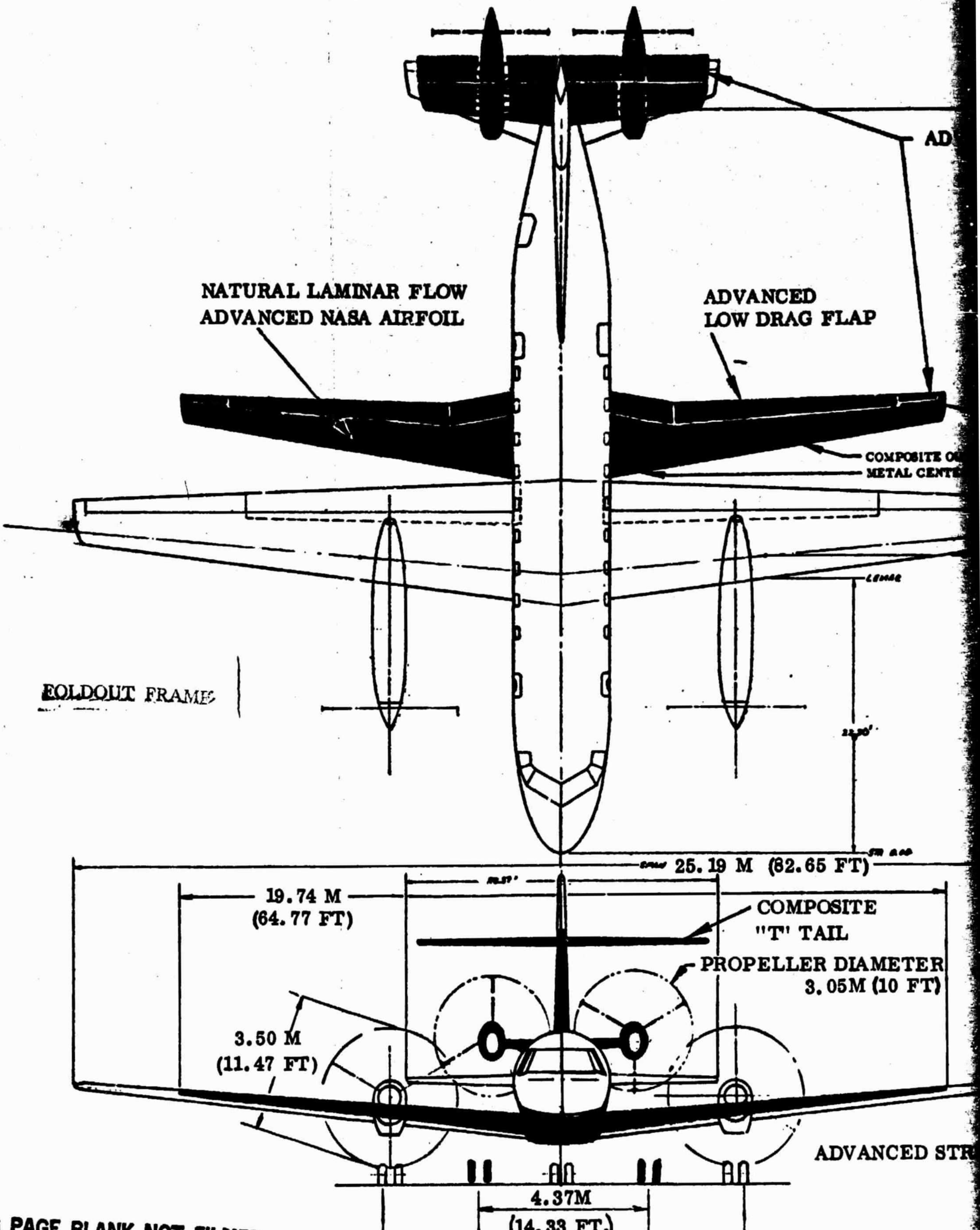
* The improvements in the operational efficiencies of the propulsion units and the airframe and in weight, initial cost and maintenance are discussed in Section 4.0 for the technologies used.



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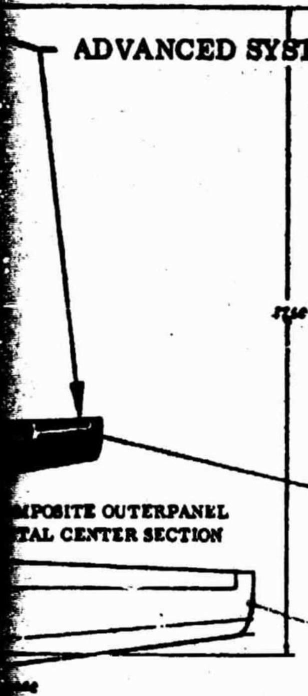
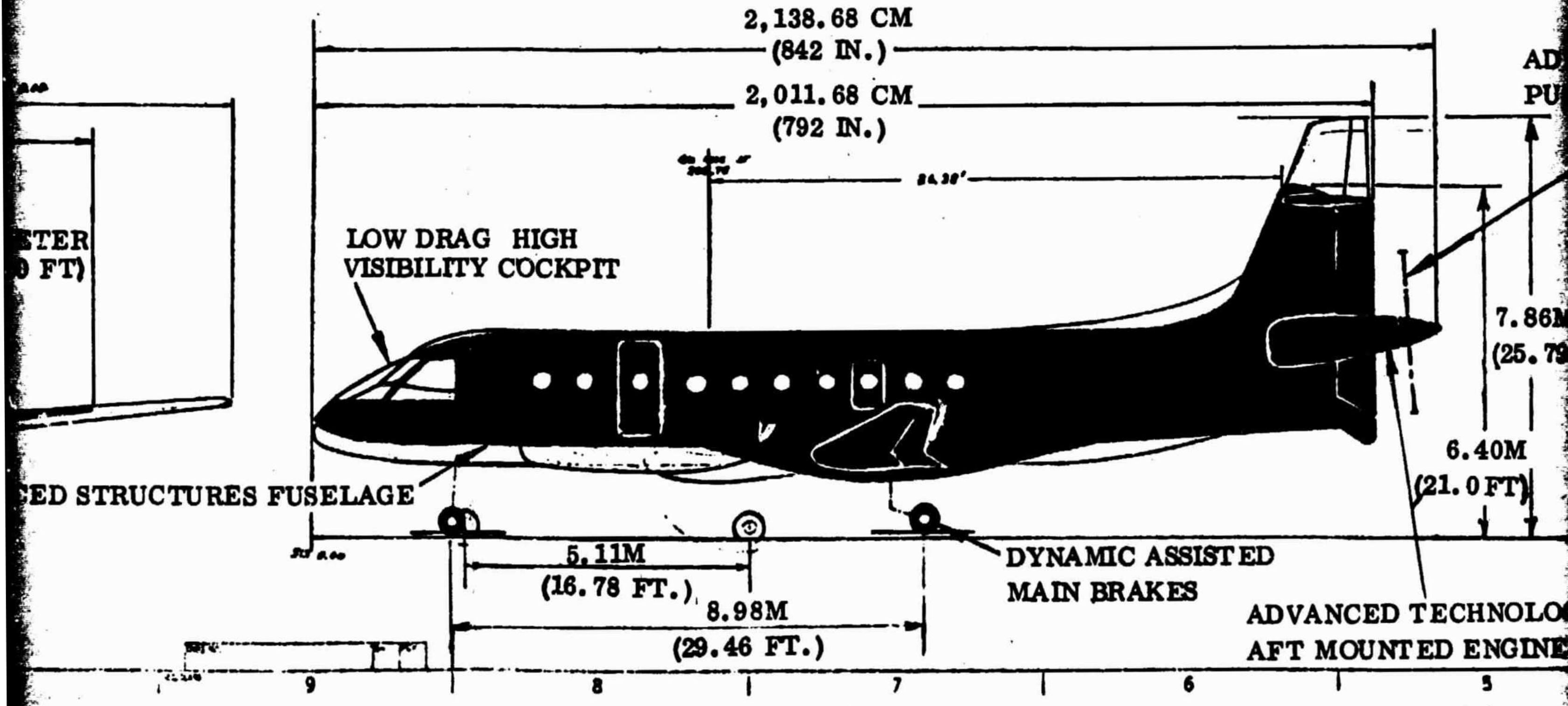


	BASELINE	ADVANCE TECHNOLO
WING AREA M^2 (SQ. FT.)	52.86 (569)	26.01 (280)
WING AR	12	15
WING C/4 SWEEP DEG.	5	7.5
ENG. ESHP/ENG KW (hp)	1,747 (2,343)	1,095 (1,469)
MAX GROSS WEIGHT Kg (LBS)	13,426 (29,600)	10,478 (23,1
WING LOADING Kg/M^2 (LBS/FT^2)	253.9 (52.0)	402.8(82.5

AT3-30 ADVANCED TECHNOLOGY AIRCRAFT

3-30 BASELINE AIRCRAFT



	ADVANCED TECHNOLOGY
	26.01 (280)
	15
	7.5
	1,095 (1,469)
)	10,478 (23,100)
	402.8(82.5)

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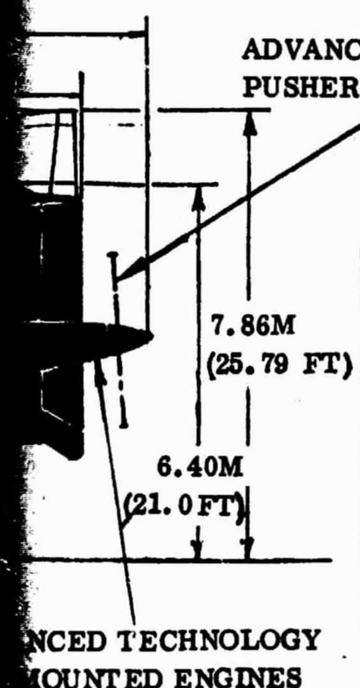


Figure 5-1

PRELIMINARY DESIGN DRAWING

AT3-30 ADVANCED TECHNOLOGY AIRCRAFT - COMPARISON W/BASELINE GENERAL ARRANGEMENT

BY C.L. ADCOCK	APPROVED G. L. Adcock	SCALE -	DATE 3-24-80

CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

DRAWING NO. SD80-48007

6549 (9-71)

6. Fuel consumption (31% less)
7. Maintenance cost (31% less)
8. Direct operating cost (24% less)
9. Ride comfort
10. Crashworthiness
11. Service and loading access
12. Turnaround time
13. Pilot workload/safety

DISCUSSION: The selection of this Advanced Technology design completes the airplane design phase of a study to determine the potential benefit of applying advanced technology to small, short haul transport aircraft. The Advanced Technology design and its characteristics are presented in comparison with the current technology baseline design and its characteristics. The evaluation of the improvements shown is presented in Section 6.0.

Both the current technology baseline and the Advanced Technology designs meet all of the NASA determined study ground rules for comfort, airframe life, safety and performance corresponding to current operator recommendations. Since no small, short haul aircraft currently in airline service can meet all of these ground rules and since it is imperative that all aircraft in the comparison be capable of doing so, a 30 passenger baseline was designed to meet all of the ground rules. The design methods and the resulting baseline design, using only that technology which was in short haul airline service in early 1979, are discussed in detail in Section 3.5.1. An "Advanced Technology" design using the same design methods and ground rules of the baseline design but utilizing the potential effects of selected advanced technology is discussed below.

CANDIDATE ADVANCED TECHNOLOGIES. The list of candidate advanced technologies came from lists of likely technologies currently in research and development by NASA, DoD and FAA for general aviation (GA), large, long haul transports (ACEE), short take off and landing (STOL, AMST) or conventional take off and landing (CTOL) augmented by suggestions from GDC design experts considering the baseline design limitation and sensitivities.

Since the tools were not available to determine the effect of each of these technologies individually within the available time and budget, the candidate technologies were segregated into four disciplines; aerodynamics, structures, systems and propulsion as shown in Table 5-1. These, in turn, were given to GDC experts in each discipline to create four "Speciality" designs by the study methods and meeting the study ground rules but incorporating the most promising advanced technologies in their discipline. These designs are compared to the baseline 3-30 and the advanced technology AT3-30 in Section 4.0.

Those technologies applicable to two or more disciplines were arbitrarily assigned to only one of the "speciality" designs. Thus active controls, which reduce trim drag by relaxed static stability and which reduce wing/tail loads and weight by gust alleviation are included on the "system" design rather than on the "aerodynamics" or "structures" designs.

Some technologies currently in research and development do not appear to be appropriate for small, short haul transports and are not included on any of the Speciality designs. In this category are winglets, whose principal benefit of reduced wing span does not appear to be useful to small aircraft, and active laminar flow control, whose complicated equipment does not appear to be warranted for such short flights.

Some technologies are new and have little, or no data base from which potential benefit can be estimated, but which are already being considered for future research. Proplets are in this category, having a significant potential to reduce propeller diameters while maintaining, or possibly increasing thrust and possibly reducing propeller noise. These are included in the STAT propeller study contracted to Hamilton Standard by NASA (Lewis) for completion in 1980.

Table 5-1 . Candidate T

AERODYNAMICS:

General Aviation Drag Reduction

Airfoil Development

Surface Coatings

Laminar Flow Control

Natural Laminar Flow

High Lift Concepts

High Aspect Ratio Super-Critical Wing

Double Curvature Cockpit Glass

Vee Tail

Prop Swirl Interference

*New Low Drag Flap

Self-Adaptive High Lift

STRUCTURES:

Composite Secondary Structures

Materials & Structures R&T

Composite Med. Primary Structure

Composite Primary Structure

Improved Crash Worthiness

Flt. Service Eval. Composite Structures

Vulnerability to Lightning of Composite Structures

Low Cost Automated Fabrication of Composite

Graphite/Kevlar Fuselage

Graphite/Kevlar Primary Structure

Aluminum Honeycomb Floor Structure

Low Cost Manufacture

Sizing & Analysis of Composite Structure

SYSTEMS:

Integrated Avionics

Low Cost Avionics

Integrated Control Systems

Digital Fly by Wire

Art Displays & Hardcopy Printer

Frequent Display or Fault Testing & Isolation Status

Automated Pre Flight Checkout

SYST

Term

Digit

All E

Activ

Gust

Moni

Adv.

Quiet

Integ

Max.

PROP

Engin

Prop

Broa

Optin

GA P

Quiet

Quiet

Adva

Envir

*Pate

FOLDOUT FRAME

SYSTEMS: (Cont)

- Terminal Area Operations
- Digital Operations
- All Electric Airplane
- Active Flight Controls
- Gust Alleviation
- Monitor & Warning Systems
- Adv. Flight Operations and Safety
- Quiet Approach Procedures
- Integrated Energy Management
- Max. Benefit of Active Controls
- Automated Takeoff Monitoring
- Computer Coupled Digital Data Link
- Automated Area Navigation by VDR
- Automated RF & Heading Input to Radio, Autopilot and CRT Monitor
- Automated Cat. III Landing
- Automated CRT display of Correct Emergency Procedures
- *Electronically Controlled Dynamic Assisted Brakes
- *Active Cabin Noise Suppression
- Landing Gear Configuration Braking

PROPULSION:

- Engine Component Improvement
- Prop Fan Technology
- Broad Spec Fuels
- Optimized Propellers
- GA Propeller Noise Reduction
- Quiet Clean GD Turbofan
- Quiet Short Haul Experimental Engine
- Advanced Turboprop Aircraft
- Environmental Impact
- Lightweight, Quiet, Efficient Propellers
- Pusher Propeller
- Lightweight High Ratio Gear Boxes
- Small Diameter Propellers/Proplets

FOLDOUT FRAME 2

*Patent disclosure filed

Finally, some technologies are new but are not known to be under consideration for future research. Three of these were identified in this study and patent disclosures have been filed for them. Preliminary first cut estimates have been made for their potential effects and they have been included in their particular Speciality design. They are noted on Table 5-1 by an asterisk.

A fifth discipline considered was "configuration". Figure 4-14 shows some of the configurations studied qualitatively. Each version had advantages and disadvantages but the two most powerful configuration ideas seemed to be 1) aft mounted, pusher propellers, which eliminate most of the cabin noise and vibration aspects of open propellers, while increasing static stability and improving balance, and 2) "canard" horizontal trim and maneuver surfaces, which add to the lift rather than detract from it.

SELECTED ADVANCED TECHNOLOGIES. Inspection of the characteristics of the "Speciality" designs and of their improvements over the baseline identified those technologies most likely to benefit the small, short haul transport. These technologies are listed in Table 5-2. Several of these are compatible and are included in this Advanced Technology design to illustrate the potential benefit of combining advanced technologies from several disciplines into one design. They were selected as follows:

1. New lightweight engines and propellers permit locating the propellers behind the fuselage. This eliminates the cabin acoustic weight/cost penalty and minimizes propeller induced vibration. It allows the propellers to be designed for optimum performance limited only by the less restrictive FAR36 noise regulations and opens the way for a new propeller development, proplets, which while not used in this design has the potential for reducing noise and diameter while maintaining high efficiency. It allows the fuselage structure to be optimized for loads and utility essentially eliminating consideration of noise and vibration. The aft propellers provide much of the desired static stability and allow the tail surfaces to be made as small

Table 5-2. Selected Advanced Technologies

AERODYNAMICS	**	Low Drag High Lift System
	**	Natural Laminar Flow Airfoils (no onboard cleaning)
	*	Double Curved Cockpit Glass
STRUCTURES	**	Graphite/Kevlar Composite Fuselage with crushable aluminum honeycomb below floor
	**	Graphite/Kevlar Wing Outer Panel Box and tail surfaces Fiberglass Leading Edges Graphite/Kevlar Honeycomb Trailing Edge Flaps
SYSTEMS	**	All Electric Active Flight Controls with hingeline actuators
	**	Advanced Cockpit Automated (pilot monitored) flight and builtin diagnostics
	*	Electronic Controlled Dynamic Assisted Braking
	*	Active Noise Suppression
PROPULSION	**	Advanced Engines - Efficient Modular Design
	**	Quiet Pusher Propellers with Fiberglass Blades, New Airfoils and Planforms.
CONFIGURATION	*	Pusher Propellers Mounted Aft of the Fuselage/Tail
	*	Canard Pitch Trim and Maneuver Surfaces

* New Technologies Needing Funding

** Current Technologies Needing Additional Funding for STAT as the control requirements will allow. The high remote propeller location allows the engines to be idled safety at the terminal eliminating the need for an auxiliary power unit, APU, or for an airconditioning/power ground cart while increasing engine life by reducing the number of cooling down periods and restarts.

2. Redundant, full time, automated active controls with gust alleviation. These reduce wing and tail gust loads and hence, weight, and combined with the stabilizing aft propellers allow the airplane to be balanced near mid-chord with adequate static stability, minimum trim drag and with a good ride, minimum pilot fatigue and maximum safety. The mid chord center of gravity location and the low wing position allowing the trailing arm landing gear to be mounted aft of the wing rear spar sufficiently outboard to provide stable cross wind handling on the ground and still be retracted under the fuselage in the wing/fuselage fillet area. This area of heavy structure beneath the passengers along with the energy absorbing fuselage and the pylon mounted aft engines combine to provide maximum safety for the passengers, crew and cargo in the event of an emergency (wheels up) landing on land or water.

3. An advanced cockpit featuring high visibility-low drag-double curved glass, side stick controls, CRT display/printer, extensive computer memory and digital processing capability, flight management keyboard input, advanced avionics-sensing and switching. This provides virtually automatic flight, minimizing the crew workload and fatigue and maximizing flight safety, especially in progressively worsening emergency situations. It provides optimum flight profiles and navigation saving time and fuel. With its fault testing and isolation systems it provides diagnostics information to minimize maintenance time, skill and cost and maximize dispatch reliability.

4. Advanced composite materials using graphite, kevlar and other high strength, high stiffness and low density fibers embedded in organic matrix

materials. These can be more readily tailored to structures loads and stiffness requirements than aluminum, particularly in the lightly loaded structures of small, short haul transports. The molded construction permits precision manufacture of large, one piece, integrally stiffened shell components with a minimum of skilled labor thereby minimizing the unit cost of large production runs while maintaining smooth, low drag exterior surfaces. The repair of composite structures is also easier than that of builtup or bonded metal. The center section wing box remains in builtup, ductile, aluminum construction to take advantage of its superior acceptance of concentrated landing gear, wing flap and wing-fuselage attachment loads.

5. Using natural laminar flow airfoils with smooth, composite skins and eliminating the propeller slipstream from the wing and tail maximizes the likelihood of achieving laminar flow with its saving in drag and fuel consumption.* The engine/propeller is mounted on pylons, rather than on the tail surfaces to minimize the effect of propeller pressure pulses on the tail surfaces and to minimize the effect of control movement on the inflow into the propeller in the hope that minimizing these effects will offset the added weight and drag of the pylons.

6. The low drag-high lift wing flap system on the high aspect ratio wing allows the use of a small wing that is highly efficient in all flight regimes from high altitude, high speed to low altitude, low speed. Further study may show that a flutter mode control system incorporated in the active control system may allow thinner wing sections and sufficiently reduced drag and fuel consumption to pay for its increased cost and maintenance.

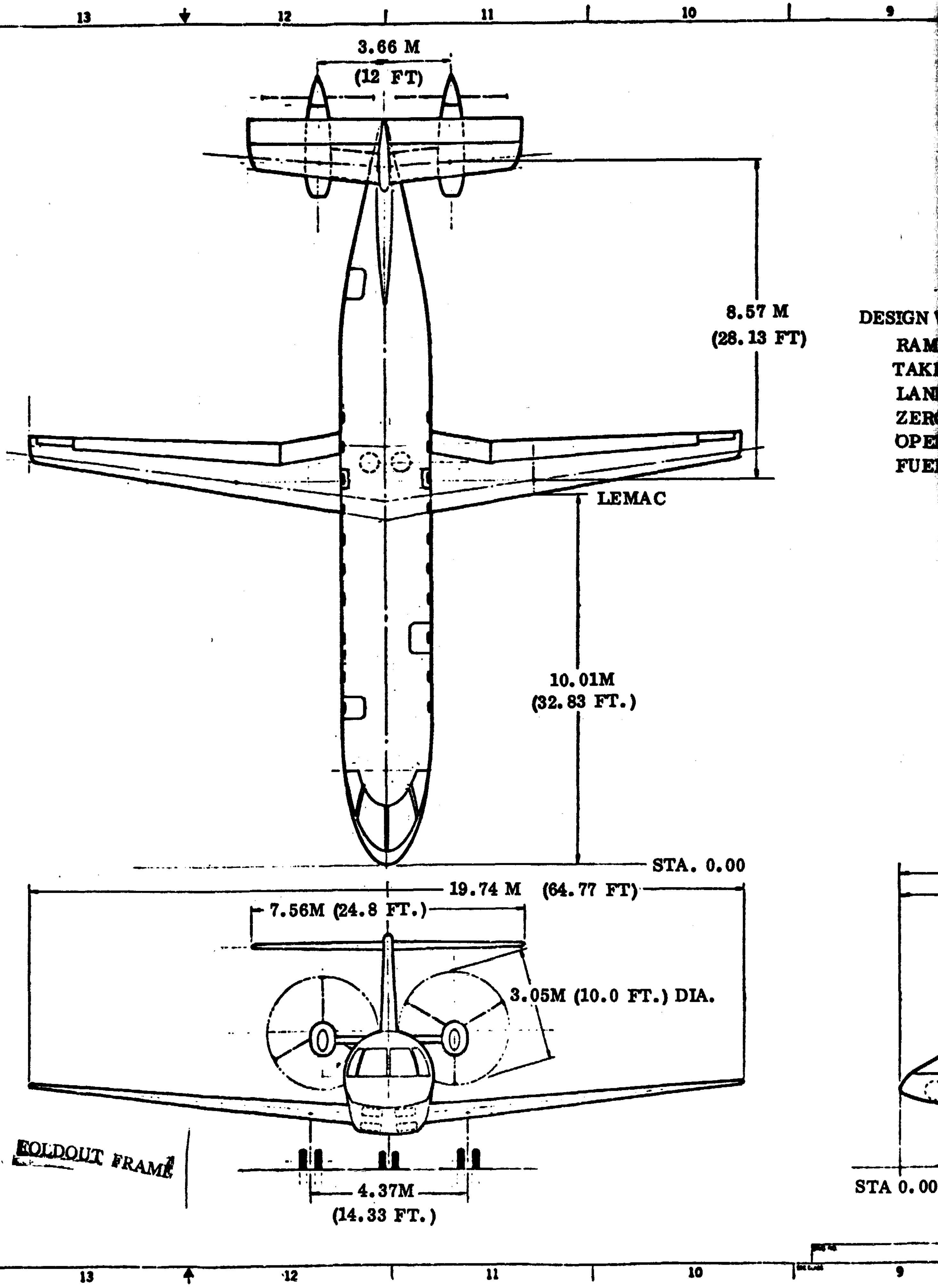
7. Dynamic assisted brakes allow further reductions in wing area while assuring the ability to stop in the 4000 ft runway. Thus, they further reduce fuel consumption while increasing brake life and reducing maintenance costs.

*No benefit for laminar flow is included in this design.

AT 3-30 ADVANCED TECHNOLOGY DESIGN. The selected technologies are combined in the Advanced Technology design shown in Figure 5-2. It meets all of the cockpit and passenger design requirements corresponding to current operator requirements and the preferred aircraft mission performance requirements. The cockpit and cabin interior have been rearranged from the baseline as shown in Figure 5-3 to provide significantly improved crew visibility, cabin interior traffic flow and to minimize exterior congestion during servicing. It still provides room for the following. (Table 5-3).

Table 5-3. AT 3-30 Interior Provisions

Passengers	30
abreast	3
seat width between arms	45.72 cm (18 in.)
seat pitch	81.28 cm (32 in.)
aisle height	182.88 cm (72 in.)
aisle width	45.72 cm (18 in.)
weight allowance (incl baggage)	90.72 kg (200 lb.)/passenger
Baggage, stowage, carry on	50.8 cm × 50.8 cm × 27.9 cm (20 in. × 20 in. × 11 in.)
	2 underseat, 1 overhead
garment	2.03 cm (0.8 in.)/passenger
preloaded (containerized)	0.142 cu. m (5 cu ft)/passenger
cabin operating pressure	3.45 N/sq cm (5 psi)
max cabin interior noise level	85 dB OASPL/65 dB SIL
space and allowable weight provisions for a lavatory & beverage bar	


13
12
11
10
9
3.66 M
(12 FT)
8.57 M
(28.13 FT)
DESIGN
LEMAC
10.01M
(32.83 FT.)
STA. 0.00
19.74 M (64.77 FT)
7.56M (24.8 FT.)
3.05M (10.0 FT.) DIA.
4.37M
(14.33 FT.)
STA 0.00

AT3-30 ADVANCED TECHNOLOGY AIRCRAFT CHARACTERI

3 ABREAST, 30 PASSENGER, LOW WING TURBOPROP TRANS

POWERPLANT (2) ADVANCED FREE TURBINE ENGINES OF 1095 KW (

DRIVING 3.05M (10.0 FT.) DIAMETER 3 BLADED PUSHER PROP

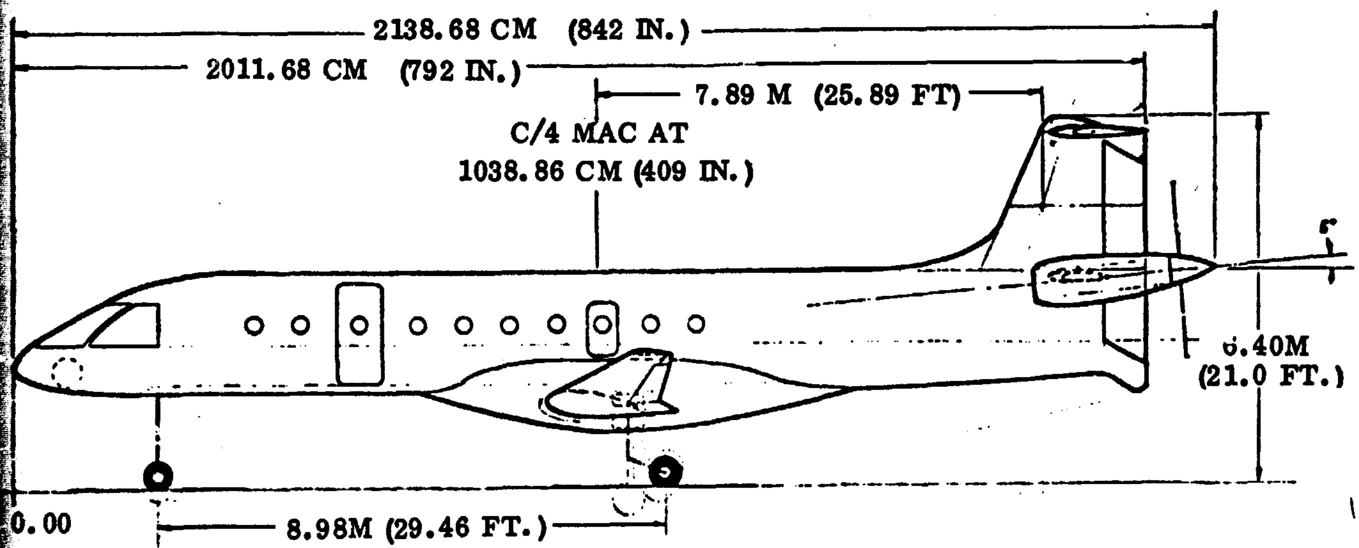
IGN WEIGHTS

RAMP	10478 Kg (23,100 LB)
TAKEOFF	10478 Kg (23,100 LB)
LANDING	9979 Kg (22,000 LB)
ZERO FUEL	9616 Kg (21,200 LB)
OPERATING WT.	6497 Kg (14,324 LB)
FUEL CAPACITY	2173 Kg (4,790 LB)

WING

SPAN	19.74 M (64.77 FT.)
AREA	26.01 SQ. M (280 SQ. FT.)
ASPECT RATIO	15.0
SWEEPBACK C/4	.131 R (7.5 DEG.)
AIRFOIL (ADVANCED NASA)	
ADVANCED LOW DRAG FLAP	

FOLDOUT FRAME 2



LOGY AIRCRAFT CHARACTERISTICS

LOW WING TURBOPROP TRANSPORT

TURBINE ENGINES OF 1095 KW (1469 ESHP) EACH

IETER 3 BLADED PUSHER PROPELLERS

19.74 M (64.77 FT.)	HORIZONTAL TAIL		
26.01 SQ. M (280 SQ. FT.)		VOLUME COEFFICIENT	1.32
15.0		AREA	11.43 SQ. M (123 SQ. FT.)
.131 R (7.5 DEG.)	VERTICAL TAIL		
		VOLUME COEFFICIENT	0.088
		AREA	5.72 SQ. M (61.53 SQ. FT.)

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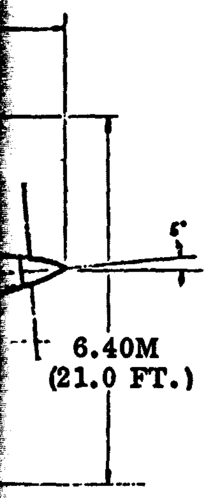
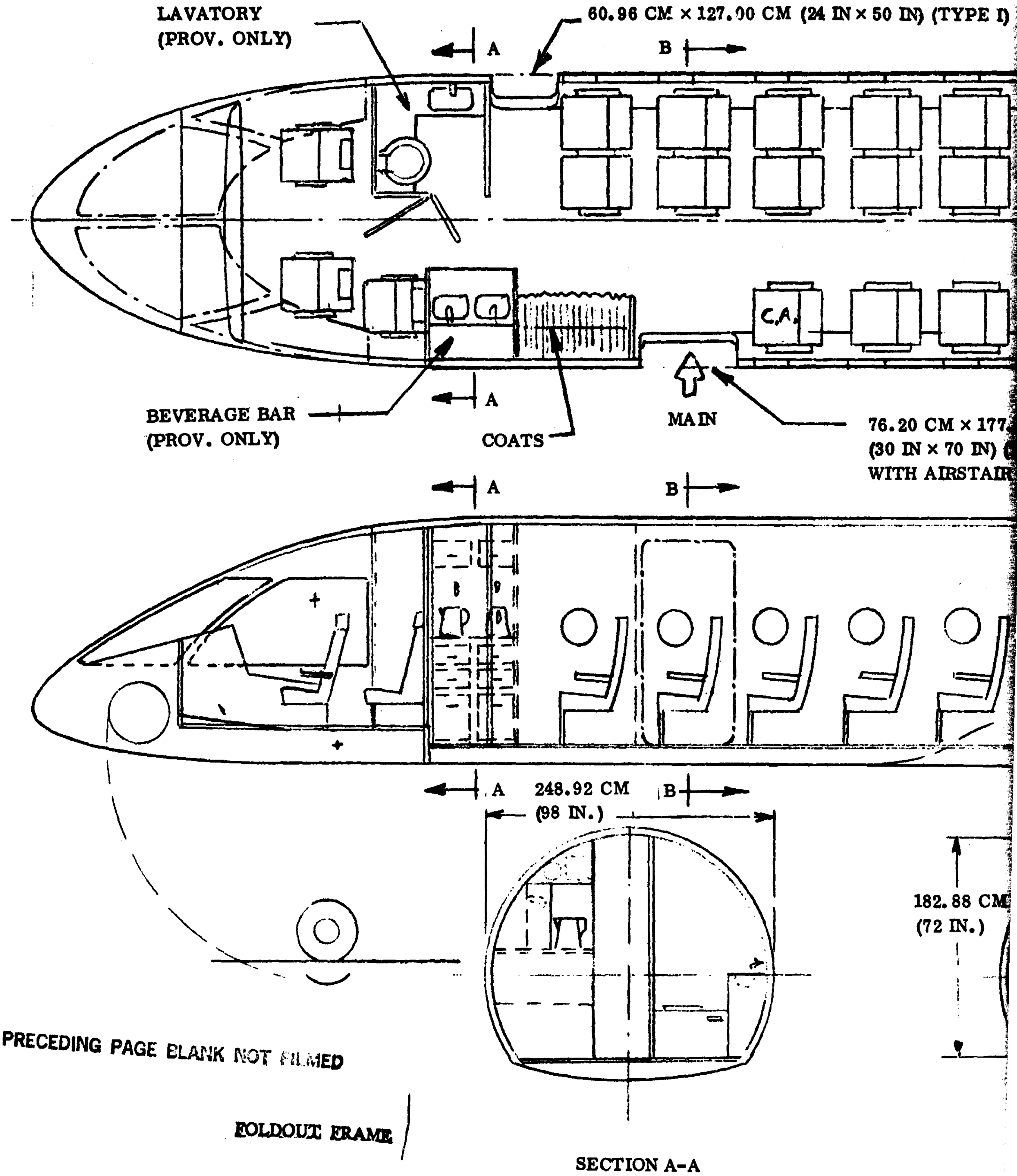


Figure 5-2

GENERAL DYNAMICS
CONVAIR DIVISION

AT3-30 COMBINED ADVANCED TECHNOLOGIES AIRCRAFT GENERAL ARRANGEMENT

14170 SD 79-48036



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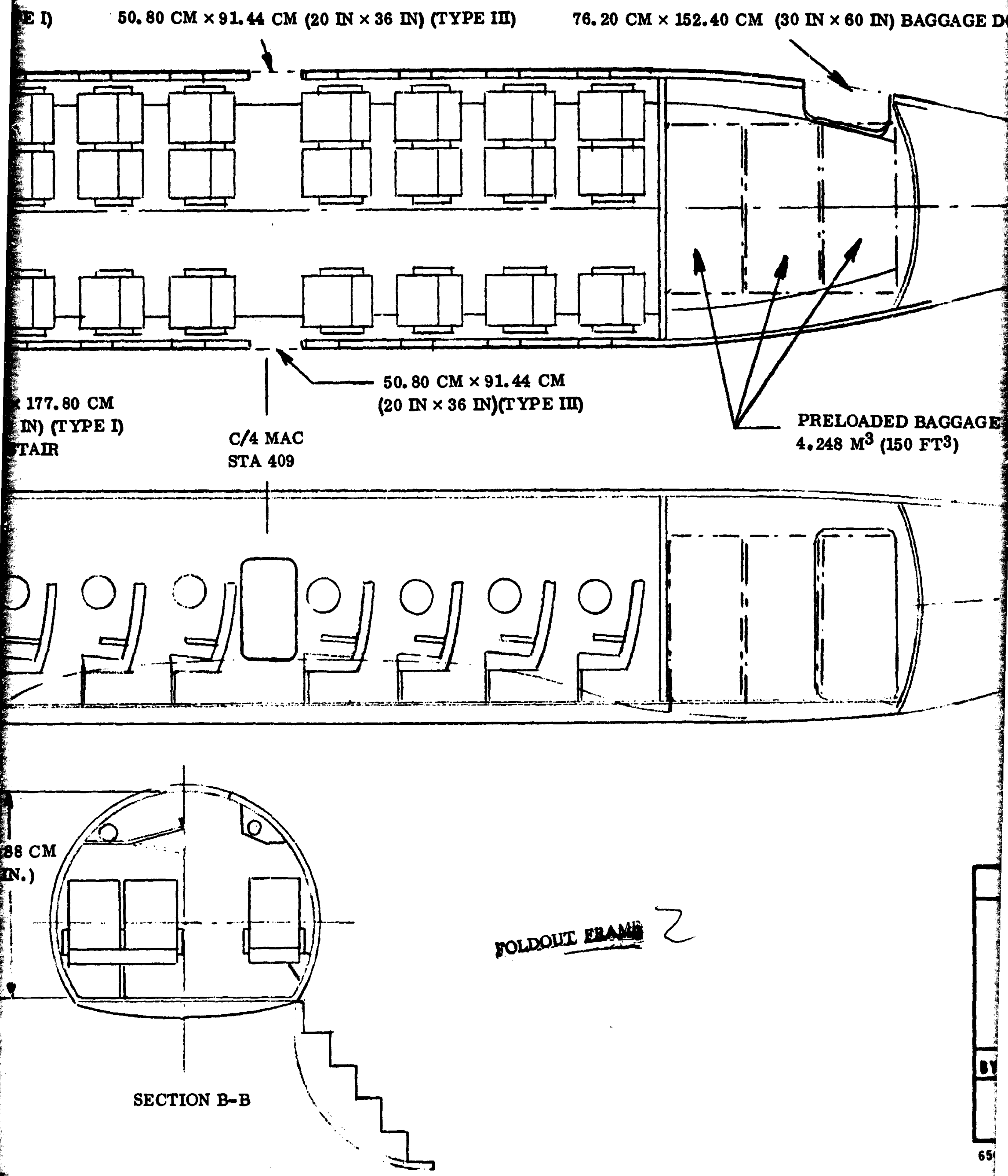
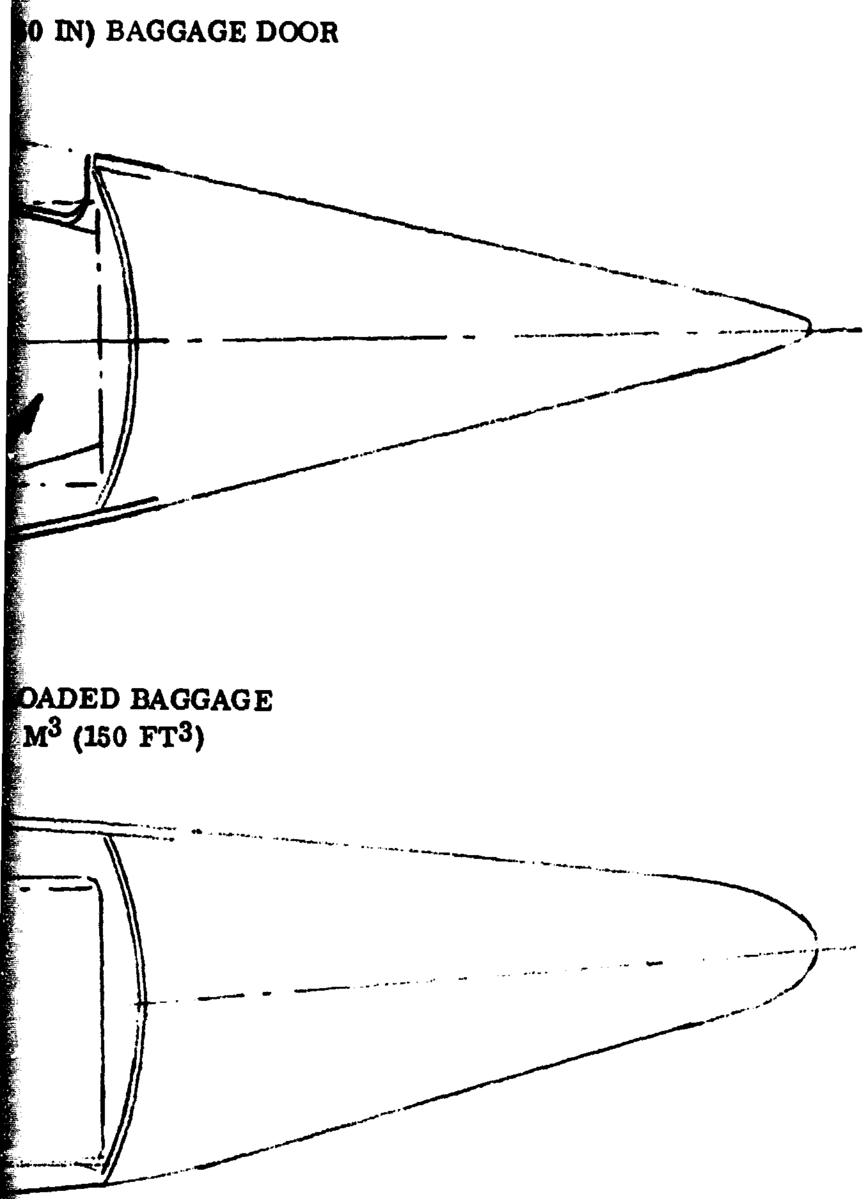


E I)
50.80 CM × 91.44 CM (20 IN × 36 IN) (TYPE III)
76.20 CM × 152.40 CM (30 IN × 60 IN) BAGGAGE D
177.80 CM
IN) (TYPE I)
TAIR
C/4 MAC
STA 409
50.80 CM × 91.44 CM
(20 IN × 36 IN)(TYPE III)
PRELOADED BAGGAGE
4.248 M3 (150 FT3)
88 CM
IN.)
SECTION B-B
FOLDOUT FRAME 2



FOLDOUT FRAME 3

Figure 5-3

PRELIMINARY DESIGN DRAWING

INTERIOR ARRANGEMENT AT3-30

BY C. Coverston	APPROVED G. L. Adcock	SCALE 1:40	DATE 1-22-80
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS SAN DIEGO, CALIFORNIA		DRAWING NO. SD80-48001	

6549 (9-71)

CUT HERE GUARANTEED 9-71

The advanced cockpit shown in Figure 4-7 features side stick controls, CRT display/ printer, extensive computer memory and digital processing capability, flight management keyboard, advanced avionics and suitable sensing and switching controlling a full-time quadruplex channel, fly-by-wire autopilot which in turn controls the redundant, electric hingeline actuators and active control surfaces to provide gust load alleviation (wing and tail), ride control and, if necessary, flutter mode control. This provides an aircraft capable of virtually automated flight from preflight checkout, through flight and navigation monitoring, automated display (and implementation if desired) of correct emergency procedures at any point during the flight and frequency display (and hard copy, if desired) of active system fault testing and isolation status. The resulting crew workload and fatigue factor are considerably reduced especially in the progressively developing emergency situations most likely to end in accidents. This should significantly improve crew response and overall safety.

The structure consists of graphite/kevlar composite in the fuselage, wing outer panel box, flaps and tail surfaces; aluminum honeycomb crash protection below the cabin floor; fiberglass wing and tail leading edges; and a conventional aluminum nose wheel support and wing center section box structure (to efficiently withstand landing impact loads) over a aife of 30,000 hours and 60,000 cycles. The landing gear retraction system, nose wheel steering and main wheel brakes are hydraulically actuated for fast efficient operation. The main wheel brakes are assisted at high speed by 1) the propellers in flat pitch (idle power) and 2) an electronically controlled electromagnetic device* acting on the brake discs. These devices minimize the need for and use of brakes at high speed part of the landing run and reduce brake lining/disc wear. These dynamic-assisted brakes combine with the improved low drag-high lift system* to allow operation into 4000 ft runways at intended destination with a considerably smaller wing than was required for the baseline thereby saving weight, cost and fuel.

The powerplants are (2) advanced technology turboprop engines such as the General Electric CT7 or Avco Lycoming PLT27 scaled to 1095 kw (1469 ESHP) each, driving

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*patent disclosure filed

3.05 m (10 ft) diameter advanced technology pusher propellers such as Hamilton Standard steel shank, fiberglass blade designs utilizing advanced airfoils and planforms.

AIRPLANE SIZING. The sizing technique is the same as that used for the baseline design except that the wing aspect ratio of 15 was determined from a separate study to minimize direct operating cost using the available active controls to control the flutter mode, if necessary. It consists of using the VDEP (Vehicle Design Evaluation Program) to calculate the aircraft geometry and weight required to fly the 1111 km (600 n. mi.) design mission with a full passenger/baggage load at optimum cruise speed/altitude having sufficient fuel in reserve for an additional 185 km (100 n. mi.) diversion to alternate and hold for 45 minutes for parametric combinations of wing loading and engine scale factor. The maximum cruise speed at 3048 m (10,000 ft) at start of cruise weight and the takeoff (and landing) runway required at sea level 32°C (90°F) at design takeoff (and landing) weight and the direct operating cost at 185 km (100 n. mi.) average stage length was also calculated.

The minimum engine size is found to be 1095 kw (1469 ESHP) which just meets the 463 km/hr (250 kt) IAS cruise speed requirement. Using this engine size, we then determined the maximum wing loading to meet the 2.7%* approach climb gradient with one engine inoperative to be 402.8 kg/m^2 (82.5 psf) with an 0.314 rad (18°) approach flap, 0.611 rad (35°) landing flap setting.

The AT 3-30 Advanced Technology design is compared to the baseline 3-30 design in a series of tables and figures.

- Table 5-4 compares the geometry. As shown there is a 20% reduction in wetted area in the new design.

- Table 5-5 compares the weights. As shown the new design is 42% lighter structurally, 27% lighter in basic operating weight and has a 22% lower takeoff weight to meet the same design mission as the baseline.

*See Step 9, Section 3.5.1

Table 5-4. Geometry Comparison

	Baseline*	Advanced Technology
Body, length	2011.68 cm (792 in.)	2011.68 cm (792 in.)
Maximum Width	248.92 cm (98 in.)	248.92 cm (98 in.)
Maximum height	248.92 cm (98 in.)	205.13 cm (80.76 in.)
Wetted area	125.88 sq. m (1355 sq. ft.)	121.33 sq. m (1306 sq. ft.)
Wing, span	25.19 m (82.65 ft.)	19.74 m (64.77 ft.)
Rcot chord	3.15 m (10.33 ft.)	3.28 m (8.61 ft.)
Mean aerodynamic chord	2.27 m (7.46 ft.)	1.43 m (4.68 ft.)
Tip chord	1.05 m (3.44 ft.)	0.658 m (2.16 ft.)
Area	52.86 sq. m (569 sq. ft.)	26.01 sq. m (280 sq. ft.)
Root thickness	0.631 m (2.07 ft.)	0.524 m (1.72 ft.)
Tip thickness	0.158 m (0.52 ft.)	0.079 m (0.26 ft.)
Wetted area	94.39 sq. m (1016 sq. ft.)	47.29 sq. m (509 sq. ft.)
Quarter chord sweep	0.087 rad (5.0 deg)	0.131 rad (7.5 deg)
Flap area	8.99 sq. m (96.77 sq. ft.)	7.06 sq. m (76.0 sq. ft.)
Airfoil section	NACA 63 series	Advanced NASA
Horizontal Tail, Arm	11.46 m (37.6 ft.)	8.57 m (28.1 ft.)
Area	13.10 sq. m (141 sq. ft.)	11.43 sq. m (123 sq. ft.)
Wetted Area	21.09 sq. m (227 sq. ft.)	22.30 sq. m (240 sq. ft.)
Vertical Tail, Arm	11.09 m (36.4 ft.)	7.89 m (25.9 ft.)
Area	10.78 sq. m (116 sq. ft.)	5.72 sq. m (62 sq. ft.)
Wetted Area	22.30 sq. m (240 sq. ft.)	11.80 sq m (127 sq. ft.)
Total Wetted Area	286.14 sq. m (3080 sq. ft.)	230.49 sq. m. (2481 sq. ft.)

*Current technology

Table 5-5. Weight Comparison

Design Weights	Baseline * Kilograms	(Pounds)	Advanced Technology Kilograms	(Pounds)	
Max Ramp	13426	(29,600)	10478	(23,100)	
Max Takeoff	13426	(29,600)	10478	(23,100)	(22% less)
Max Landing	12791	(28,200)	9979	(22,000)	
Max Zero Fuel	12110	(26,700)	9616	(21,200)	
Basic Operating Weight	8896	(19,611)	6497	(14,324)	
Fuel Capacity	3523	(7,767)	2173	(4,790)	
Group Weight Comparison					
Body Structure	2790**	(6,150)**	1498	(3,302)	
Wing Box Structure	881	(1,943)	518	(1,142)	
LE/TE Structure	253	(558)	109	(240)	
Secondary Structure	57	(125)	31	(69)	
Flaps	103	(226)	142	(313)	
Horizontail Tail	135	(297)	113	(250)	
Vertical Tail	136	(299)	76	(167)	
Surface Controls	178	(393)	89	(197)	
Landing Gear	517	(1,139)	389	(857)	
Nacelle Structure	185	(407)	78	(173)	
TOTAL STRUCTURE	5234	(11,538)	3043	(6,708)	(42% less)
Engines	644	(1,420)	390	(860)	
Propellers	197	(435)	335	(738)	
Propulsion Systems	205	(452)	164	(361)	
Fuel System	108	(237)	95	(210)	
Instruments	83	(183)	80	(176)	
Hydraulics & Pneumatic	123	(271)	73	(162)	
Electrical	177	(391)	266	(586)	
Avionics	352	(777)	292	(644)	
Furnishings	960	(2,117)	960	(2,117)	
Air Conditioning/Anti Ice	318	(702)	318	(702)	
WEIGHT EMPTY	8401	(18,521)	6014	(13,263)	(28% less)
Basic Operating Items	494	(1,090)	481	(1,061)	
BASIC OPERATING WEIGHT	8896	(19,611)	6497	(14,324)	(27% less)

* Current technology

** Includes 1054 kg (2324 lb) acoustic penalty

- Figure 5-4 compares the aerodynamics. As shown the Advanced Technology has a lower drag area at low lift. It has lower lift capability because it is lighter and does not need more.
- Table 5-6 and Figure 5-5 compare the performance of these designs. As shown, they have similar performance capabilities but the Advanced Technology design requires 24% less direct operating cost.
- Table 5-7 compares the aircraft manufacturing and direct operating cost details. The Advanced Technology Design costs 18% less to manufacture than the current technology baseline.

AERODYNAMIC COMPARISON

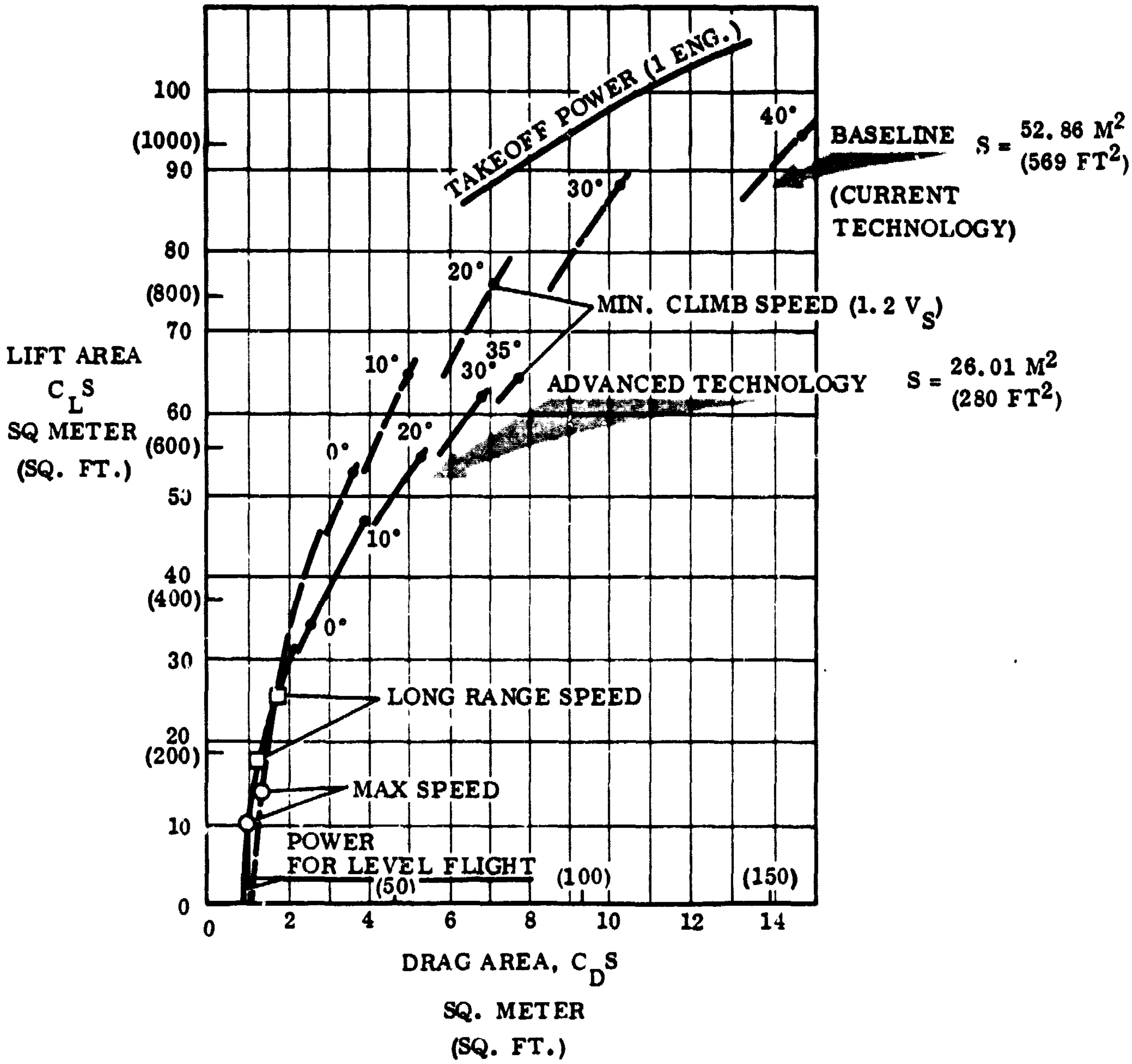

Figure 5-4. Aerodynamic Comparison

Table 5-6. Performance Comparison

	Baseline	Advanced Technology
• Range with full design payload with IFR reserves	1111 km (600 n. mi)	1111 km (600 n. mi)
Corresponding cruise speed (TAS)	459 km/hr (248 kt)	491 km/hr (265 kt)
Corresponding cruise altitude	7071 m (23,200 ft.)	7224 m (23,700 ft.)
• Runway length (FAR25) at S. L. 32°C (90°F)		
For takeoff at design takeoff wt	1063 m (3486 ft.)	894 m (2934 ft.)
For landing at design landing wt*	1219 m (4000 ft.)	1219 m (4000 ft.)
Corresponding approach speed	185 km/hr (100 kt)	200 km/hr (108 kt)
Corresponding landing stall speed	143 km/hr (77 kt)	154 km/hr (83 kt)
• Noise levels (FAR36, Amend 8, Stage III Minus 8 EPNdB)		
Takeoff (EPNdB)	83	83
Sideline (EPNdB)	85	85
Approach (EPNdB)	84	84
• Maximum Cruise Speed at 3048 m 10,000 (IAS)	463 km/hr (250 kt)	463 km/hr (250 kt)
• Maximum Terminal Area Speed (IAS)	>333 km/hr (180 kt)	>333 km/hr (180 kt)
• Maximum allowable weight		
Into a 914m (3000 ft) runway at S. L. 32°C (90°F)	<8891 kg (19,600 lb)	6967 kg (15,359 lb)
From a 2134 m (7000 ft) runway, 1829 m (6000 ft) altitude	10796 kg (23,800 lb)	8286 kg (18,268 lb)
• 100 NM Trip cruise speed (TAS)	539 km/hr (291 kt)	528 km/hr (285 kt)
Corresponding altitude	5181 m (17,000 ft)	5181 m (17,000 ft)

*at intended destination

PERFORMANCE COMPARISON

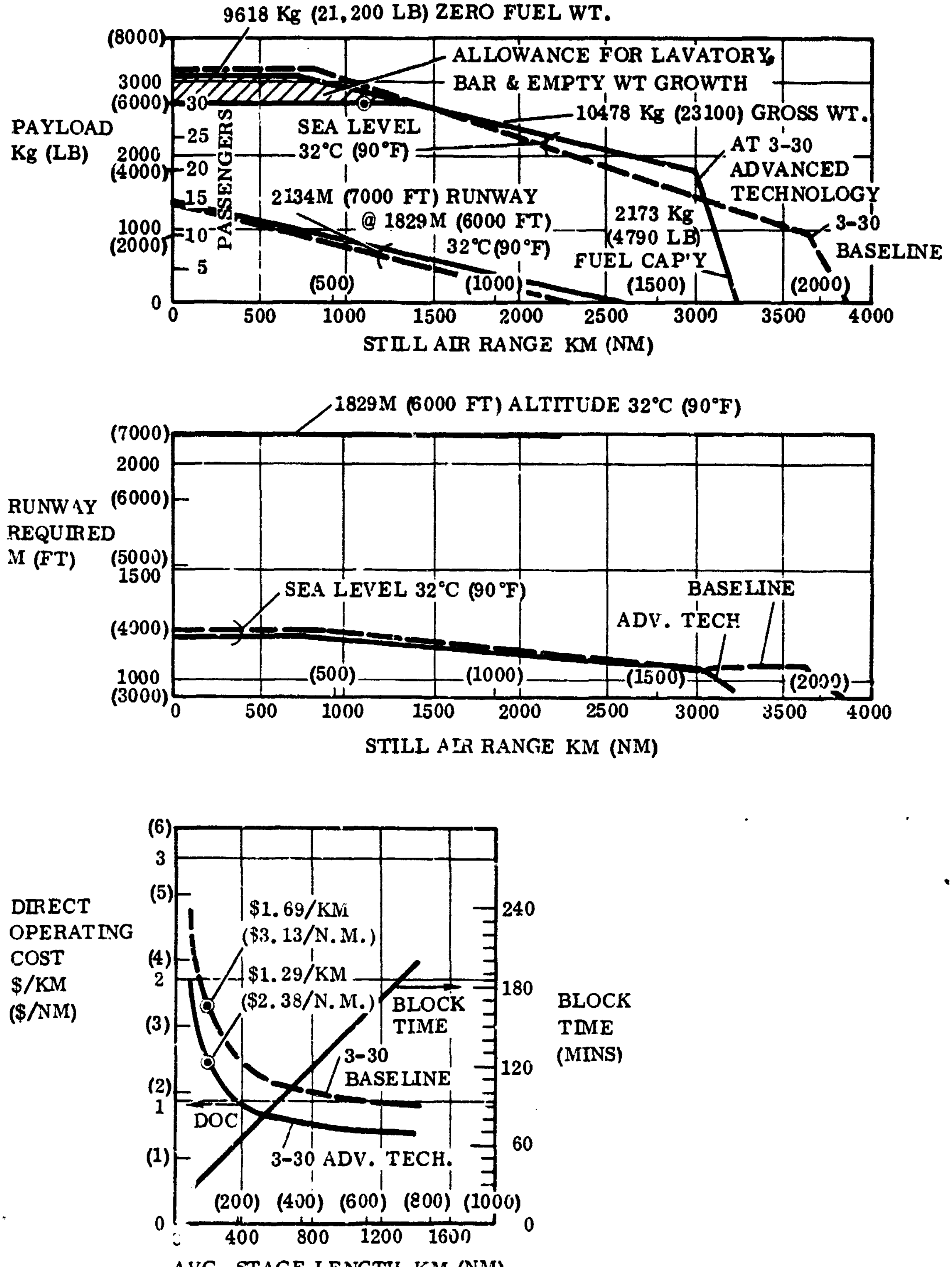

Figure 5-5. Performance Comparison

Table 5-7. Cost Comparison

	Baseline	Advanced Technology
Average Unit Price (250 Aircraft) (1979 $ M)	3.159	2.572
Airframe	1.980	1.467
Avionics	0.324	0.465
Engines	0.752	0.487
Propellers	0.103	0.153

	Baseline		Advanced Technology	
Direct Operating Cost at fuel price gallon	$0.75	$1.00	$0.75	$1.00
On 93 km (50 n. mi.) average stage length	2.34 (4.33)	2.54 (4.70)	1.78 (3.30	1.92 (3.55)
$/km ($/n. mi.)				
185 km (100 n. mi.)	1.53 (2.83)	1.69 (3.13)	1.19 (2.21)	1.29 (2.38)
278 km (150 n. mi.)	1.26 (2.34)	1.37 (2.54)	0.97 (1.80)	1.05 (1.94)
370 km (200 n. mi.)	1.11 (2.06)	1.20 (2.23)	0.86 (1.59)	0.92 (1.70)
741 km (400 n. mi.)	0.95 (1.76)	1.09 (1.92)	0.73 (1.36)	0.79 (1.47)
1111 km (600 n. mi.)	0.90 (1.66)	0.97 (1.81)	0.69 (1.28)	0.75 (1.39)

	Baseline 1979 $/km ($/n. mi.)	Advanced Technology 1979 $/km ($/n. mi.)
Direct Operating Cost on 185 km (100 n. mi.) Trip		
Crew	0.2334 (0.4322)	0.2374 (0.4397)
Fuel & Oil ($1.00 gal)	0.5543 (1.0265)	0.3809 (0.7054)
Maintenance	0.5739 (1.0629)	0.4030 (0.7464)
Material, Engine	0.1224 (0.2267)	0.0559 (0.1036)
Airframe & Other	0.0570 (0.1056)	0.0525 (0.0972)
Direct Labor, Engine	0.0394 (0.0731)	0.0281 (0.0521)
Airframe & Other	0.1798 (0.3329)	0.1355 (0.2510)
Burden	0.1753 (0.3247)	0.1309 (0.2425)
Insurance	0.0543 (0.1005)	0.0435 (0.0806)
Depreciation	0.2767 (0.5124)	0.2210 (0.4110)
Total Direct Operating Cost	1.6920 (3.1345)	1.2870 (2.3830)
Total Direct Seat-Mile Cost	5.64 ¢/Skm (10.45 ¢/Sn. mi.)	4.29 ¢/Skm (7.94 ¢/Sn. mi.)

6.0 EVALUATION

SUMMARY: The AT 3-30 Advanced Technology configuration saves about 15% in Direct Operating Cost versus existing competitors or 24% versus the requirements 3-30 Baseline. An airplane of this configuration also has significant benefits in forms of reliability and operability which should enable it to sell a total of about 450 units through 1990, of which 80% are for airline use. Maximum market share is forecast to be 40% in the U.S. Table 6-1 summarizes the technology benefits.

6.1 COMPARISON WITH COMPETING AIRCRAFT

For the primary comparison we have chosen 1) the Swearingen Metro as the current best selling commuter-type aircraft with 42 deliveries in 1979 and 80 expected in 1980, 2) the Shorts 330 (15 delivered in 1979, 20 forecast for 1980) as the only production 30 passenger turboprop and 3) the deHavilland Dash 7 with 73 firm orders at 12/31/79, which represents a strong selling aircraft of recent design in the 50 passenger class. Performance used is given in Section 6.6.

From the flyaway cost comparison, the Metro, the requirements baseline and the Dash 7 fall on a straight line when cost is plotted versus weight empty (Figure 6-1). This is consistent with the desirability of increasing performance demands as size increases so that cost per pound is increasing. The Shorts 330 is a relatively simple aircraft, without pressurization or retractable gear, and as would be expected, it falls considerably below the line of increasing sophistication. The advanced technology configuration is much smaller than the requirements baseline, but by virtue of it new technology cost per pound is about as far above the line as the Shorts 330 is below it.

In terms of Direct Operating Costs, (Table 6-2) the requirements baseline, the Metro, the Shorts 330 and the Dash 7 are all roughly comparable but there are significant differences in the cost elements induced by speed, relative cost and maintenance cost. The requirements baseline is 17% higher than the D.O.C. of the Shorts 330, saves significantly in crew cost, but trades this savings for maintenance (much larger engines) and ownership costs. Moving to the advanced technology airplane, we see major cost savings versus any of the competitors, primarily in the areas of fuel per seat mile versus all competitors and crew cost versus the slower Shorts 330. These savings versus the Shorts 330 are partially offset by the higher ownership costs of the advanced technology configuration.

6.2 MARKET ASSESSMENT VERSUS EXISTING COMPETITORS

METRO. The Metro will continue to dominate the market until new competitors such as the Beech 1900 begin taking a significant market share. A primary market for a new technology airplane will be to replace Metros as the traffic grows beyond their optimal capability.

Table 6-1. Technology Benefits

	Increment for Advanced Technology Aircraft
Reliability & Flexibility	Built-in Test Reduces False Alarms On-board Balance System Speeds Dispatch High Engines Eliminate Separate APU
Productivity & Utilization	Built-in Test Saves Diagnostic Time Advanced Avionics Hold Down Air Maneuvering Time
Maintenance Costs	Total Airplane Saves 25.4% Labor, 41.8% Parts Built-in Test, Smaller Airplane, Adv. Technology Engine, Electrical vs Hydraulic Controls
Through Stop Time	Keeping Engines Idling Eliminates Start & Stop Cycle
Required Ground Equipment	High Engines Kept Idling Eliminate Ground Power Units, but add Taller Engine Work Stands
Ground Servicing Labor	Configuration is Self Contained, Easy to Clean & Re-stock and Easy to Fuel. Electrical Actuators Reduce Need to Check for Hydraulic Leaks.

FLYAWAY COST COMPARISON

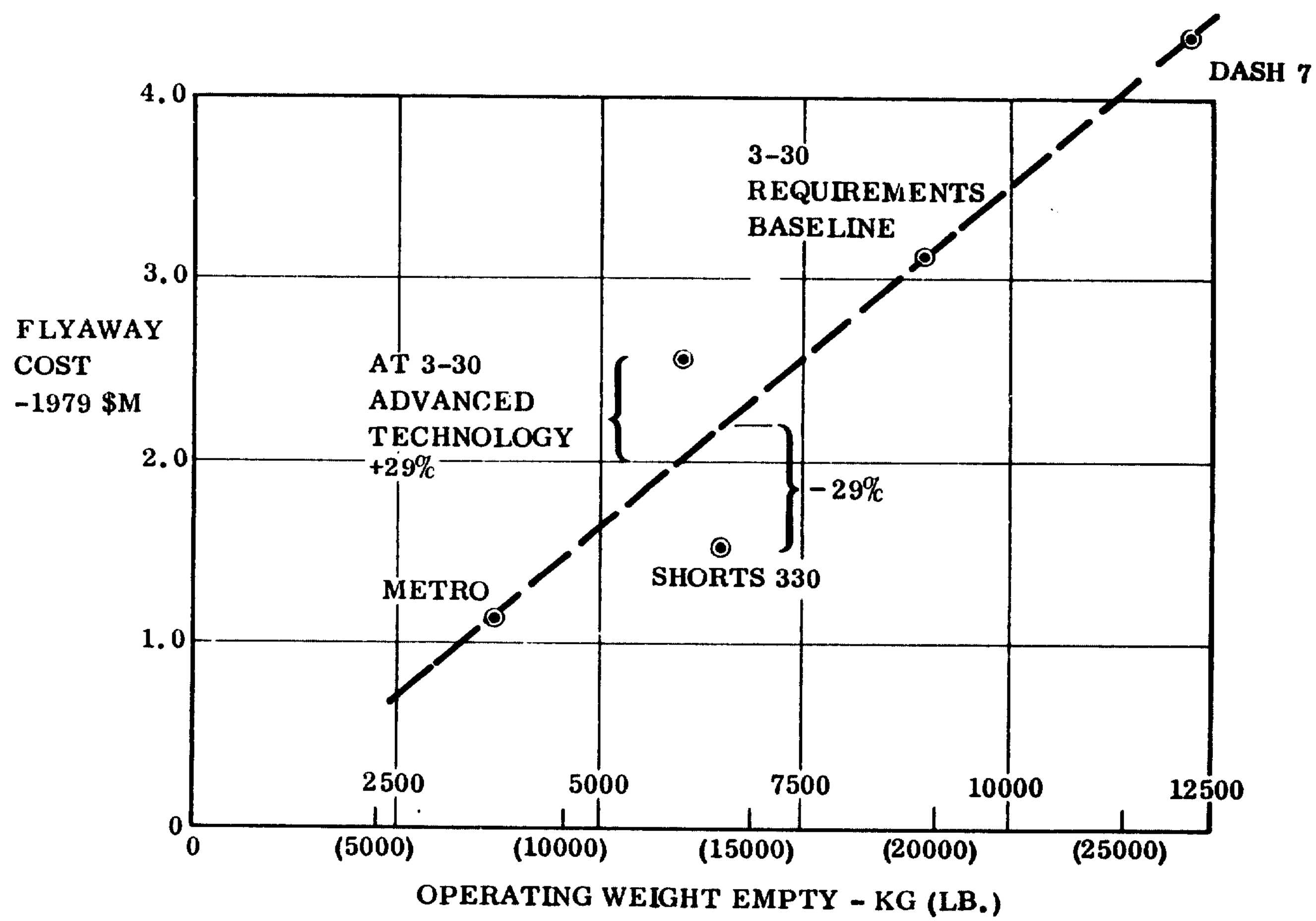

Figure 6-1. Flyaway Cost Comparison

Table 6-2. Direct Operating Cost Comparison

185 km (100 N. Mi.) Trip

	AT 3-30 Advanced Technology Aircraft	3-30 Requirements Baseline	Swearingen Metro	Shorts 330	deHavilland Dash 7
Direct Operating Cost Breakdown $/km ($/n. mi.)					
Crew	0.237 (0.440)	0.233 (0.432)	0.125 (0.231)	0.288 (0.534	0.435 (0.806)
Fuel & Oil @ $1.00/gal	0.381 (0.705)	0.554 (1.027)	0.290 (0.537)	0.524 (0.970)	0.747 (1.383)
Insurance	0.044 (0.081)	0.054 (0.101)	0.021 (0.038)	0.319 (0.059)	0.080 (0.149)
Maintenance	0.403 (0.746)	0.574 (1.063)	0.241 (0.446)	0.390 (0.723)	0.767 (1.421)
Airframe Labor	0.136 (0.251)	0.180 (0.333)	0.081 (0.150)	0.147 (0.272)	0.266 (0.493)
Airframe Material	0.053 (0.097)	0.057 (0.106)	0.022 (0.040)	0.029 (0.053)	0.095 (0.176)
Engine Labor	0.028 (0.052)	0.039 (0.073)	0.018 (0.033)	0.023 (0.042)	0.045 (0.083)
Engine Material	0.056 (0.104)	0.122 (0.227)	0.042 (0.077)	0.056 (0.104)	0.112 (0.208)
Burden	0.131 (0.243)	0.175 (0.325)	0.079 (0.146)	0.136 (0.252)	0.249 (0.461)
Depreciation	0.222 (0.411)	0.277 (0.512)	0.104 (0.192)	0.163 (0.301)	0.427 (0.791)
Total DOC	1.287 (2.383)	1.692 (3.135)	0.780 (1.444)	1.397 (2.587)	2.457 (4.550)
Seats	30	30	15*	29*	50
¢/Seat km (¢/Seat n. mi.)	4.29 (7.94)	5.64 (10.45)	5.20 (9.63)	4.82 (8.92)	4.91 (9.10)

*Weight Limited Payload to Common Mission Rules

SHORTS 330. This configuration will continue to sell well where 30 seat size is needed until new models such as the deHavilland Dash 8, the Embraer Brasilia and the Fairchild-SAAB 30 seat designs are available. At that time, the Shorts 330 market share will drop and will be purchased primarily as additions to existing fleets.

DASH 7. Where a fifty seat aircraft can be filled, the Dash 7 will continue to sell well. It offers the unique capability of operating into short runways and thus has the potential of being able to operate outside the congested approaches at such locations as Washington-National and New York-Kennedy. Until an advanced technology design of similar size is available, it has a secure niche in the marketplace. Table 6-3 is a qualitative comparison with existing competitors.

6.3 NEW DESIGNS

New 30 passenger designs are being offered by deHavilland, Embraer, Fairchild-SAAB and others on a lower key. These all appear to be fairly conventional designs and should approximate the performance and economics of the requirements baseline. Thus they will offer improved speed and comfort versus the Shorts 330, but no significant improvement in economics. When the advanced technology design faces these competitors the real issue will become: Should an airline replace its fleet for a 15% savings in D.O.C.? While this sounds attractive, relatively simple changes to the proposed 30 passenger designs such as incorporating newer engines could also achieve much of this savings. Accordingly, the market for advanced technology will be to augment the proposed designs and replace the older, smaller airplanes.

6.4 ADAPTABILITY TO OTHER USES

The unique features of this airplane in terms of a long range, high altitude or stable low altitude platform opens up interesting possibilities for non-airline use. Table 6-4 summarizes these applications and benefits. The deHavilland Twin Otters are used approximately 60% by airlines and 40% by other users. Similarly, total Swearingen production is about 60% Metros for airline use and 40% Merlins for business and utility applications. When an independent estimate of advanced technology aircraft use was made, it is 18% of airline use, and in consideration of its cost in the range of two to three times the cost of a Swearingen or a Twin Otter, this appears reasonable.

6.5 TOTAL MARKET

Table 6-5 and 6-6 develop the total commuter market in the U.S. and establish bounds for world market share. Table 6-7 is a forecast of total sales of an advanced technology design through 1995 or about 10 years of production following technology acquisition and configuration development. The nearer-term market is U.S. commuters, other applications strengthen later. Initially, the new 30 passenger design would face

Table 6-3. Competitive Assessment

	Advantages	Disadvantages
Advanced Technology Configuration	Low D.O.C. Improved Comfort Improved Operability Low Noise-Community	Initial Cost Differs from Stereotyped Airplanes
Metro	Low Purchase Price Appearance	Lacks Maintainability of Newer Aircraft Cramped Interior Interior Noise
Shorts 330	Low Purchase Price Simplicity Unique Size	Low Speed Lack of Pressurization Appearance Interior Noise
deHavilland Dash 7	Unique Size Airport Flexibility	4 Engines to Maintain Initial Cost

Table 6-4. Advanced Technology Airplane Adaptability

I Stretching for Transport Mission
- Good Potential for Stretching - 3 Rows to 39 Seats

II Business Applications
- Vs Merlin, King-Air - Unlikely, too Expensive
- Vs Convair-Liner, Fairchild - A Few Highly Specialized Uses

III Military & Quasi-Military Applications
- Light Transport (non-tactical) - Unlikely vs King Air & DC-9
- Coastal Surveillance/Fisheries Protection
  - Excellent Platform for Carrying Sensors - Can be Made into Long Duration, Comfortable Aircraft.

IV "Utility" Applications
- Geographic Survey - Photo / - Magnetic / - IR/UV etc. } Excellent Sensor Carrier with Advanced Flight Controls
- High Altitude & Duration (with limited payload)
- Can be Flown Low in Rough Air with Advanced Flight Control

Table 6-5. Total U.S. Commuter Market 1985 - 1995

Passengers in 1979 = 10.52M

Passenger Growth to 1985 @ 12%/Yr = 20.76M Total

Passengers to 1990 @ 10%/Yr = 33.42M Total

Passengers to 1995 @ 8%/Yr = 49.09M Total

Between 1985 and 1995 add 49.09M Pass.

\- 20.76M Pass.

28.33M Pass.

Average Annual Requirement 1985 - 1995 = 2.83M Pass.

Advanced Technology Aircraft @ 185 km (100 n. mi.). Carries 74,000 Passengers Per Year at 60% Load Factor.

Annual Addition ≈ 40 Advanced Technology Equivalents

Table 6-6. Deliveries of Commuter Type Aircraft

	1979	1980 Forecast	1981 Forecast
deHavilland Twin-Otter*	40	42	42
-Dash 7	8	19	36
Embraer Bandierante	40	48	48
Swearingen Metro	42	80	80
Shorts 330	15	20	24
	145	209	230

Typical Production Rate ≈ 3.5/Month

High Market Share ≈ 35%

*Estimated Airline Deliveries @ 61% of Total Production

Table 6-7. Market Assessment Advanced Technology Design

Deliveries 1985 through 1995

	Units	Basis
U.S. Commuters	114	Replace 30% of 15/20 Seat A/C
	160	40% of 40 Units Added Per Year
U.S. Business Applications	20	2 Per Year
U.S. Military/Fisheries	0	Not During This Time Period
U.S. "Utility" Applications	20	Average 2 Each to 10 Companies
Foreign Commuters	25	Replace 5% of 15/20 Seat A/C
	75	5% of 150 Units Per Year Added
Foreign Military/Fisheries	10	Allowance
Foreign "Utility" Application	30	150% of U.S.
	454	

Average Production Rate ≈ 3.8 Units/Month

5/6 Commuters, ≈1/6 "Other"

head-on competition from U.S., Canadian, Brazilian, Swedish, French and Italian offerings so foreign sales would be slow. Based on current transport production history, technological lifetimes are long and increasing. Accordingly, total lifetime production could reach 1,000 units, making this a very attractive design to aircraft manufacturers.

Figure 6-2 shows the place in the U.S. commuter fleet of advanced technology designs. A major portion of the added traffic is handled by the improved speed and utilization of the advanced technology designs such that each new technology seat added carries approximately three times the passengers of a typical seat in an existing airplane.

6.6 COMPETITIVE AIRCRAFT PERFORMANCE DATA

Performance data is presented for three current, small short-haul transport aircraft for comparison with the STAT baseline and advanced technology 30 passenger designs to assist in evaluating the impact of advanced technology on this class of aircraft.

The selected competitive aircraft are:

- Swearingen Metro II (20 passenger)
- Shorts 330 (30 passenger)
- deHavilland (Canada) DHC-7 (50 passenger)

For consistency the performance of all aircraft is calculated by the methods used in the STAT. The results closely match available data on these aircraft. Table 6-8 compares the principle aircraft physical characteristics and performance of these aircraft. Figure 6-3 compares the payload range of these aircraft with the STAT 3-30 baseline.

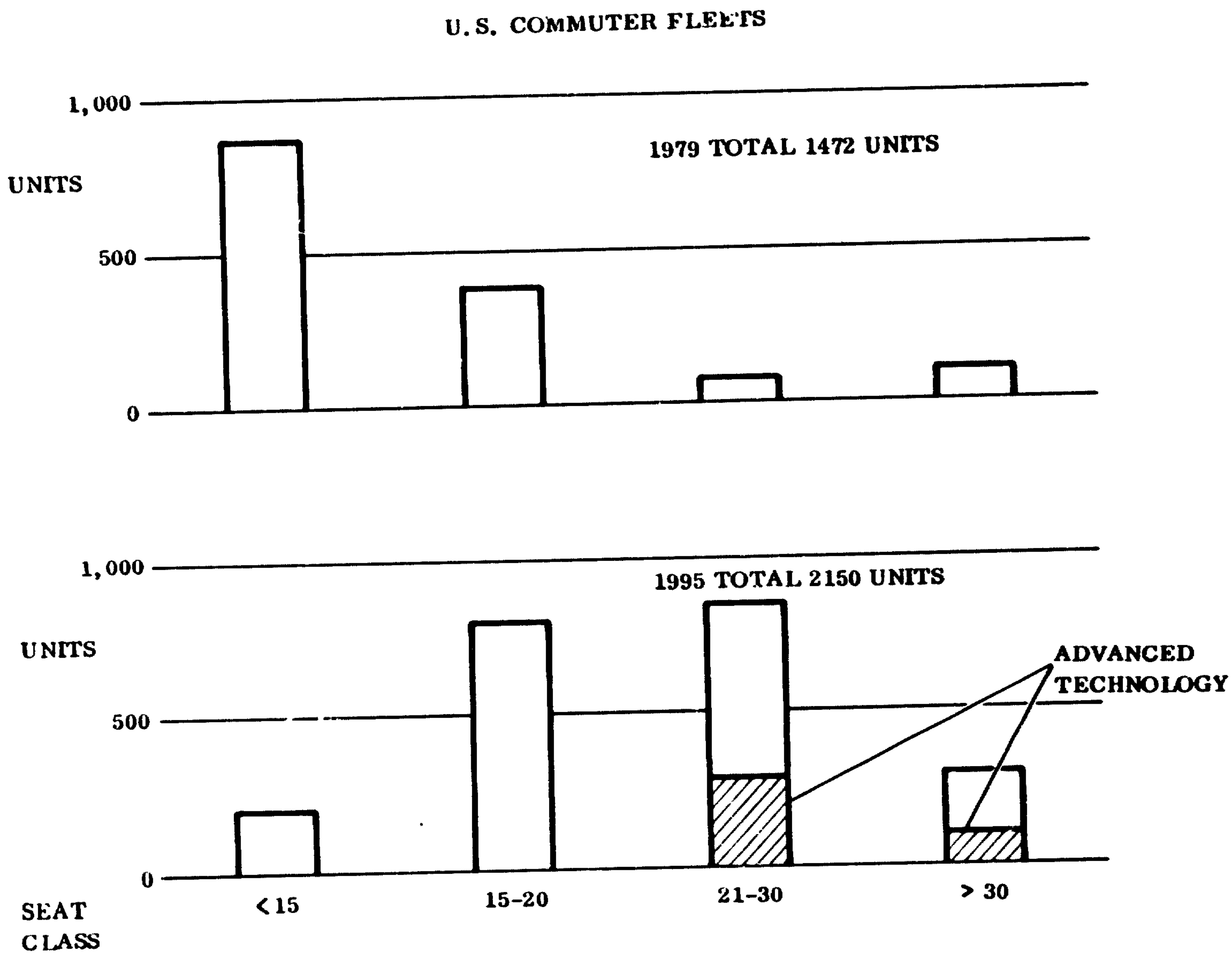

Figure 6-2. U.S. Commuter Fleets

Table 6-8. Principal Aircraft Characteristics and Performance

Aircraft		Metro II	Shorts 330	DHC-7	3-30	AT3-30
Engines		(2) GA TPE 331	(2) PWC PT6A-45	(4) PWC PT6A-50	(2) Turboprops	(2) Adv. Turboprops
Rated Power/Engine	kw (ESHP)	624 (840)	862 (1156)	835 (1120)	174-7 (2343)	1095 (1469
Wing Span	m (ft)	14.1 (46.25)	22.8 (74.67)	28.3 (93.0)	25.2 (82.7)	19.7 (64.8)
Max. Gross Wt	kg (lb)	5693 (12,550)	10161 (22,400)	19731 (43,500)	13426 (29,600)	10478 (23,100)
Oper. Empty Wt	kg (lb)	3708 (8,175)	6536 (14,410)	12179 (26,850)	8836 (19,611)	6497 (14,324)
185 km (100 n mi) Trip	kg (lb)	1402 (3,090)	2654 (5,850)	4536 (10,000)	2722 (6000)	2722 (6000)
Block Fuel	kg (lb)	163 (360)	274 (605)	358 (790)	306 (675)	211 (462)
Block Time	hr	0.615	0.713	0.645	0.573	0.583
Max. Range (Max. Pass	km (n. mi.)	185 (100)*	319 (172)**	1883 (1017)	1445 (780)	1482 (800)
Passengers		15*	29**	50	30	30
Block Fuel	kg (lb)	163 (360)*	420 (925)**	2359 (5200)	1345 (2965)	959 (2115)
Block Time	hr	0.615*	1.065**	4.932	3.22	3.16

*Maximum Passenger Load at 185 km (100 n. mi.) limited by maximum takeoff weight with STAT reserves

**Maximum Passenger Load and range limited by maximum zero fuel weight with STAT reserves

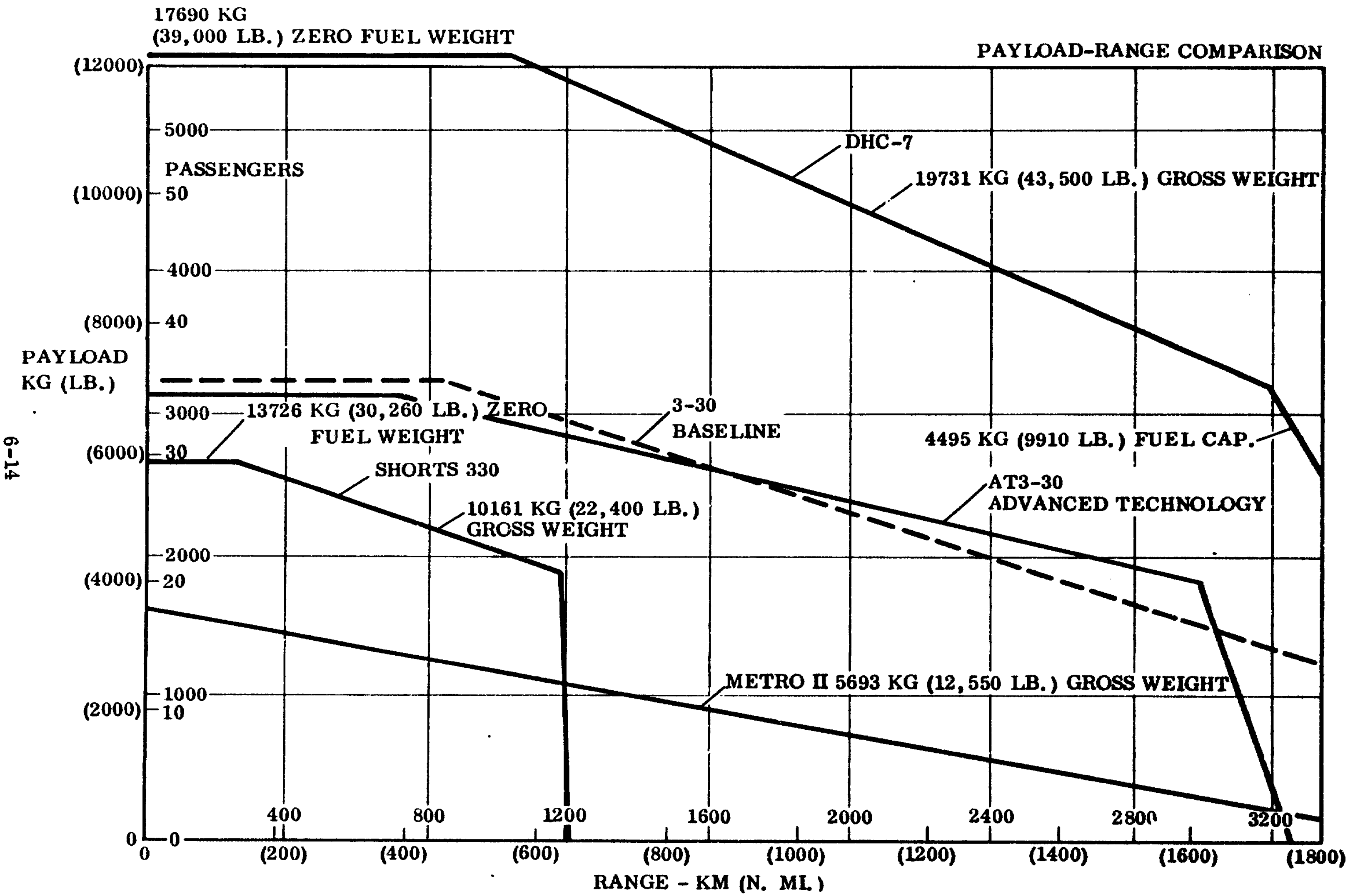

Figure 6-3. Payload Range Comparison

7.0 RECOMMENDATIONS FOR FUTURE RESEARCH

SUMMARY: A study of the application of advanced technology to small transport aircraft found that 1) Some technologies currently in research and development for other segments of the aircraft industry are applicable to this small, short-haul segment, 2) Other technologies currently in research and development require additional or redirected emphasis to be applicable to this type of aircraft and 3) Two new technologies were identified which are not currently in research and development.

7.1 APPLICABLE TECHNOLOGIES

1) Some current advanced engine concepts and component development from ACEE and QCQAT programs are applicable with added emphasis on components unique to small turbines (i.e. centrifugal compressors).

2) All electric active flight control concept and component development from the ACEE program also provides data that is applicable accounting for the requirements of the different size aircraft.

3) Finally composite structures concepts and component development from ACEE program also provides data applicable with additional emphasis on stiffeners required by the lightly loaded small transport structures allowing the use of minimum thickness skins and webs.

7.2 TECHNOLOGIES NEEDED ADDITIONAL EMPHASIS

1) Current propeller research and development should also be extended to give added emphasis to reducing propeller noise while maintaining high efficiency in the low Mach, high power waveoff condition and in the Mach 0.3 to 0.5 climb and cruise condition.

2) Current wing high lift system research and development should be extended to test new concepts to increase the maximum lift capability while improving lift/drag ratio at waveoff (75% of maximum lift).

7.3 NEW TECHNOLOGIES

1) Propeller research and development should give added emphasis to small diameter pusher installations minimizing the structural vibrations and cyclic propeller stresses due to installation while maintaining high efficiency.

2) Dynamically assisted braking should be developed to increase landing and rejected takeoff safety and reduce brake maintenance.

3) Active cabin noise suppression should be developed to reduce the passenger discomfort and improve the passenger acceptance of small transport aircraft.

7.4 MOST PROMISING TECHNOLOGIES

DISCUSSION: The most promising technologies affecting DOC are selected from Table 7-1 which shows the change in DOC from the baseline for that parameter in percent of total DOC. The DOC parameters showing the most reduction in DOC and the responsible technologies* are listed below in order of importance in terms of percent of total DOC.

-6.76% Fuel burned by Aerodynamic Aircraft. Primarily due to improved high lift system and reduced skin friction drag.

-6.76% Maintenance on Systems Aircraft. Primarily due to reduced labor (and burden) due to electric vs hydraulic systems.

-6.41% Fuel burned by Propulsion Aircraft. Primarily due to improved SFC, quieter propellers and light weight engines and propellers.

-6.12% Maintenance on Propulsion Aircraft. Direct reflection of modular, low parts count design.

-5.68% Maintenance on Structures Aircraft. Primarily due to smaller, light weight structure and smaller engine. Airframe labor hours/lb was increased 10%.

-5.61% Fuel burned by Structures Aircraft. Direct reflection of reduced weight in structure and acoustic penalty.

-4.82% Fuel burned by Systems Aircraft. Primarily due to a gust alleviation system reducing the weight of gust critical structure, a full time stability augmentation system reducing trim drag, dynamically assisted brakes and an active cabin noise suppression system** reducing acoustic penalty.

-4.50% Maintenance on Aerodynamic Aircraft. Primarily due to smaller engine. Airframe material and labor do not reflect the full impact of reduced weight due to high cost of cleaning** natural laminar flow wing and tail.

Combining those DOC improving technologies with those benefiting other operational factors from Section 6-0, Table 6-1, we find the most promising technologies to be:

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* Further discussion of these technologies as applied to the Advanced Technology Specialty Aircraft Designs can be found in Section 4.0. Improvements used in each technology are identified.

** Not incorporated in the AT3-30 Design, Section 5.0.

Table 7-1. DOC Changes from Baseline
(% Change from Baseline Total DOC)

DOC Cost Element	3-30 Advanced Technology Specialty Designs					AT3-30 Advanced Technology Aircraft
	Aerodynamic	Structures	Systems	Propulsion	3-30A High Wing	
Crew	-0.99	+0.10	+0.03	+0.45	+3.09	+0.24
Fuel & Oil	-6.76	-5.61	-4.82	-6.41	+0.10	-10.27
Insurance	-0.64	-0.67	-0.45	-0.35	+1.08	-0.64
Maintenance	-4.50	-5.68	-6.76	-6.12	+8.84	-10.11
Airframe Labor	-0.89	-1.56	-2.62	-0.77	+1.47	-2.62
Airframe Material	-0.41	-0.64	-0.22	-0.32	0	-0.29
Engine Labor	-0.19	-0.10	-0.10	-0.57	+0.48	-0.67
Engine Material	-2.17	-2.07	-1.72	-3.41	+5.36	-3.92
Burden	-0.86	-1.34	-2.17	-1.08	+1.53	-2.62
Depreciation	-3.19	-3.38	-2.23	-1.79	+5.68	-3.22
Total	-16.08	-15.24	-14.23	-14.22	+18.79	-24.00
Unit Flyaway Cost $M	2.73	2.49	2.74	2.75	3.52	2.57
Airframe	1.77	1.54	1.59	1.75	1.85	1.47
Avionics	0.32	0.32	0.49	0.32	0.32	0.46
Engines	0.55	0.54	0.57	0.56	1.22	0.49
Propellers	0.09	0.09	0.09	0.12	0.13	0.15

1. Full time automated active controls with redundant fault testing and isolation systems and providing gust alleviation and stability augmentation. They reduce labor and thereby reduce DOC and increase utilization and reliability (paramount considerations for the operator of a small fleet). They improve ride quality, dispatch reliability and reduce ticket cost (due to lower DOC) to the commuter passenger. Coupled with an advanced cockpit featuring high visibility, side stick controls, CRT display/printer, a coupled computer with extensive memory and digital processing capability, flight management keyboard input and avionics-sensing and switching they provide virtually automatic flight, minimizing the crew workload and maximizing flight safety, especially in progressively worsening emergency situations. Current research is directly applicable and less cost to demonstrate on a small transport aircraft.

2. Advanced turboprop engines utilizing modular, light weight, low parts count construction with high component efficiency and designed for maintainability. They reduce fuel consumption and engine maintenance cost and by their light weight reduce overall aircraft size and weight. Recent research is being applied in new engine designs such as the General Electric CT-7 and Lycoming PLT-27.

3. Low cost, load tailorable, composite primary structure such as graphite/Kevlar epoxy. They reduce weight, drag and engine size and can be tailored to reduce the acoustic weight penalty in the cabin. Recent research directly applicable can be demonstrated on small transport aircraft at lower cost.

4. Pusher propellers aft of the fuselage utilizing quiet, light weight propellers. They minimize the cabin noise without acoustic penalty. Their high location allows the engines to be idled at the terminal thereby eliminating a ground power cart or APU while improving engine life by reducing start/stop cycling. They provide considerable aerodynamic stability thereby allowing the tail sizes to be reduced to that required for control and reducing the center of gravity range by moving aft near the center of the cabin. Research is needed to determine a) the effect of nacelles, pylons, wings or control surface ahead of the propellers on the propellers stresses and efficiency, b) the effect of the cyclic propeller pulses on such adjacent structure and c) the means to minimize these effects.

5. Quiet propellers which also maintain high efficiency in the low Mach, high power waveoff condition and in the Mach 0.3 to 0.5 climb and cruise condition. Some form of endplate or proplet may prove more efficient than a plain blade when a low noise output is desired. Quiet propellers have considerable impact on the overall aircraft size and weight when a quiet cabin is required. Current propeller research should be extended to include quiet, small diameter propellers in the 1500 to 2500 ESHP range.

6. Low drag high lift system* reduce wing size, drag and weight improving the ride quality and reducing fuel consumption. Current airfoil and high lift system research should be directed specifically at increasing lift capability while maintaining a high lift/drag ratio at 75% of maximum lift (the approach climb waveoff condition). A new concept maintains a clean, unslotted wing to the maximum chordwise extension of the flap. Further deflection opens a single slot. Further research should be done.

7. Dynamically assisted braking* provides a secondary braking system that creates an electro-magnetic retardation proportional to wheel speed. It provides automatic, low cost, anti-skid and minimizes brake wear. It is a new concept on aircraft that improves the stopping capability and hence allows a higher approach speed and a smaller wing (for a given high lift system) with the consequent improvement in aircraft application. It is currently used in other applications.

8. Active cabin noise suppression* consists of several strategically located microphones and speakers in the cabin. Internal noise (pressure pulses) sensed by the microphones are automatically cancelled near the passengers head by accurately timed pulses from the speakers. This system reduces the large acoustic penalty required and hence reduces weight, size and fuel consumption. It needs research and development.

7.5 CONCLUSIONS

In this study of the application of advanced technology to small, short-haul transport aircraft the following conclusions have been reached.

1. Advanced technology will improve the productivity of small, short-haul transport aircraft.

2. This study has identified these technologies and quantified the potential improvement.

3. These technologies can significantly reduce DOC and unit flyaway cost even considering the higher cost of these technologies when compared to current technology aircraft designed to same requirements.

4. ROI is significantly increased.

5. Significantly, many of these technologies are currently being developed but still need verification for application to small, short-haul transport aircraft.

6. Some new technologies have been identified that have very high potential.

*Patent disclosure filed